MINISTRY OF EDUCATION
TECHNICAL TEACHERS
ASSOCIATION OF GHANA

Automotive and Metal Technology

(Applied Technology)

for Senior High Schools

Year 2

Tetteh Bruce
Philip Kwesi Incoom
Dr. Sherry Kwabla Amedorme

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FOREWORD

Ghana's new Senior High School Curriculum aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, knowledge, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, progress to further studies and enter the world of work. This is the first time that Ghana has developed a Senior High School Curriculum which focuses on national values, attempting to educate a generation of Ghanaian youth who are proud of our country and can contribute effectively to its development.

The Ministry of Education is proud to have overseen the production of these Learner Materials which can be used in class and for self-study and revision. These materials have been developed through a partnership between the Ghana Education Service, teacher unions (Ghana National Association of Teachers-GNAT, National Association of Graduate Teacher -NAGRAT and the Coalition of Concerned Teachers- CCT) and National Subject Associations. These materials are informative and of high quality because they have been written by teachers for teachers with the expert backing of each subject association.

I believe that, if used appropriately, these materials will go a long way to transforming our Senior High Schools and developing Ghana so that we become a proud, prosperous and values-driven nation where our people are our greatest national asset.

Haruna Iddrisu MP
Minister for Education

SECTION

1

ENGINE COOLING, HEAT TREATMENT AND MACHINES I

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AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

Internal combustion engines generate a lot of heat during operation, which can lead to severe damage if left unchecked. Engine cooling systems play an important role in maintaining proper engine temperatures, preventing overheating, and ensuring efficient performance.

This unit will explore the basic principles, components, and methods of engine cooling, including air-cooled and water-cooled systems. Understanding these concepts is essential for designing, maintaining, and improving engine performance in various applications. By the end of this unit, we will be able to explain engine cooling systems and describe the construction and operation of the air-cooling systems.

KEY IDEAS

- Air-cooled engines rely on fins, fans, and shrouds to remove heat, while water-cooled engines use radiators, thermostats, and water pumps.
- Each cooling system has its own advantages and disadvantages, including differences in design, weight, cost, and efficiency.
- Effective cooling is essential for maintaining engine performance, efficiency, and long life.
- Engine cooling systems are essential for preventing overheating and damage to internal combustion engines.
- The two primary cooling systems in use are air-cooled (using atmospheric air) and water-cooled (using liquid coolant).

INTRODUCTION TO THE ENGINE COOLING SYSTEM

The combustion process inside the internal combustion engine generates very high temperatures that can destroy the engine by melting the parts that are in direct contact with the burning gases. When operating at maximum power output, the engine can produce very high temperatures that can reach about 2500°C, which is high enough to melt any of the parts of the engine exposed to the direct heat of the combustion gases.

Some of the heat is released through the tailpipe in the form of exhaust gases, whilst the remaining heat is absorbed by the engine parts, which, if not controlled, can cause overheating of the engine. The cooling system is there to ensure that excess heat is removed from the engine for the following reasons:

1. The parts of the engine that come into direct contact with the hot gases, such as the piston crown, head gasket, valves, exhaust port and cylinder head, will expand and as a result, deform from their correct shape, causing gas leakage, loss of power, and melting of certain components.
2. The oil coating, needed for lubricating the piston and cylinder walls, will be burnt, causing excessive wear and even seizure of the piston.
3. The fresh air/fuel mixture entering the cylinder would be burnt, which would reduce the engine's power output.
4. The surface of the combustion chamber may become too hot and cause pre-ignition and knocking.
5. The temperature inside the passenger compartment will be too high, such that the driver and passengers would not feel comfortable in the car.

It is, however, advisable to control the heat rather than to eliminate it completely, as a good amount is needed to properly evaporate the compressed air/fuel mixture for proper combustion to take place. Unburnt fuel will remain on the cylinder walls and piston as deposits, come out as unburnt fuel with the exhaust gases, or leak past the piston into the sump and contaminate the lubricating oil.

Terminology in the Engine Cooling System

1. **Coolant:** A special liquid that helps keep the engine from getting too hot. It is usually a mix of water and an antifreeze agent.
2. **Radiator:** The radiator is the main component of the cooling system into which the coolant is poured and stored.
3. **Thermostat:** The thermostat functions as a valve that opens and closes automatically to allow the hot coolant to flow from the engine into the radiator.
4. **Antifreeze:** An antifreeze is a chemical agent added to the coolant to prevent it from freezing in cold weather. It also protects the metal parts of the cooling system from corrosion. Common antifreeze agents are ethylene glycol and propylene glycol.
5. **Core Plugs:** These are small disc-shaped metal plugs that seal holes in the engine block left after the casting process. If the coolant freezes, these plugs pop out to prevent the engine block from cracking. They may also be removed to have access to clean corrosive deposits in the water jackets.

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6. **Air Cooling:** This involves the use of atmospheric air or a fan to blow air on cooling fins to cool down the engine.
7. **Pressure Cap:** The pressure cap is a lid or cover that seals the radiator to a specific pressure and helps to raise the boiling point of the coolant.
8. **Water Pump:** The water pump is usually mounted on the front of the engine and turns on as soon as the engine starts. It is driven by the engine through a belt drive to circulate the coolant around the cylinders.
9. **Cooling Fan:** The cooling fan blows air over the engine or radiator.
10. **Viscous Coupling:** A special connection between the engine and the cooling fan. It only turns on the fan when needed.
11. **Drive Belt:** A belt driven by the crankshaft or the camshaft that powers the water pump.
12. **Heater:** Uses the excess heat from the coolant to warm up the car's interior.

Activity 1.1

Identifying a Cooling System

1. Your teacher will arrange a visit to the school auto workshop or a mechanic shop for you to observe different types of engine cooling systems.
2. Note down the differences and similarities you identified in the different types of engine cooling systems based on the following:
   a. parts
   b. size
   c. layout
   d. cooling medium
   e. application
3. Briefly explain how each of the cooling systems you observed works in an internal combustion engine.

Methods of Cooling

Engines use two primary cooling systems to release heat into the atmosphere. They are:

1. Air-cooled system: uses atmospheric air or fan-blown air to cool the engine.
2. Water-cooled system: uses a liquid medium, consisting of water and coolant, to extract excess heat from the engine.

ENGINE AIR COOLING SYSTEMS

An air-cooled engine (also called the direct method) uses direct air from the environment to remove heat generated by the engine, rather than relying on liquid coolant. In multi-cylinder air-cooled engines, the cylinders are mounted separately from the crankcase to allow for sufficient airflow to circulate directly around each cylinder. This design ensures maximum air exposure to each cylinder for effective cooling. The rate of heat removal depends upon the following factors:

1. total surface area from which heat is radiated;
2. thermal conductivity of the metal used for the engine;
3. cross-sectional area of the material;
4. rate of airflow around the heated surfaces; and
5. Difference in temperature between the engine and the surrounding air.

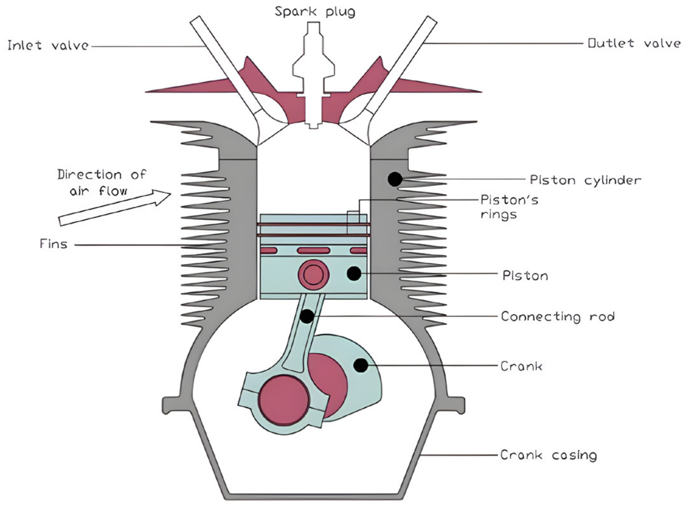

Figure 1.1: Features and components of an air-cooling engine

Key Features and Components of an Air-Cooled Engine

An air-cooled engine can easily be identified by its simplicity and light constructional features. Some basic features are:

1. **Fins:** Fins are thin metal plates, studs or extensions that are attached to cylinder blocks and heads to increase the surface area for improved heat removal
2. **Fan:** The fan blows air over and around the cylinders for constant cooling. It is generally required for all stationary air-cooled machines. Air-cooled engines used on moving machines like motorcycles and outboard motors do not require the use of a fan as their movement through the air draws in sufficient airflow over the engine for adequate cooling.

3. **Shrouds:** These are metal or plastic covers with tunnels that direct airflow from the fan or blower to the engine cylinder for efficient cooling.
4. **Materials:** Air-cooled engines require materials that conduct heat easily to enhance the cooling efficiency of the engine. Aluminium is commonly used for this purpose due to its improved heat-conducting property.
5. **Pistons:** This moves up and down in the cylinders to compress the air-fuel mixture.
6. **Crankshaft:** It converts the pistons' linear motion into rotational motion.
7. **Valves:** These control the flow of air-fuel mixture in and exhaust gases out.
8. **Rocker arms and Pushrods:** These operate the valves (in OHV engines).
9. **Spark Plugs:** It Ignites the air-fuel mixture in the combustion chamber.

Figure 1.2: Cooling fins on a typical air-cooling system

Working Principle of Air-Cooling System

In the air-cooling system, the heat generated by the engine is transferred to the outside air through the fins attached to the cylinders. As air flows over the engine, it absorbs heat and carries it away, helping to maintain a safe temperature. The fins ensure that the surface area of the hot engine cylinders is increased to allow more air to make contact with the engine. For more efficient cooling, and in non-motor applications, a fan is used to blow more air around the fins at a faster rate.

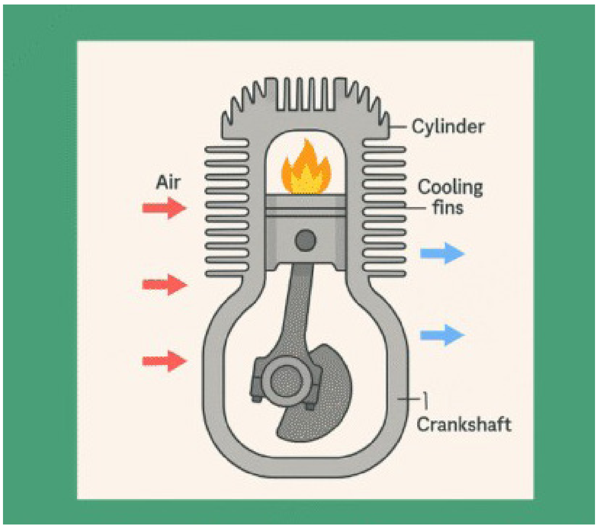

Figure 1.3: Principle of air-cooling system

Activity 1.2

Working Principle of Air-Cooled Engines

INSTRUCTIONS & CAUTION: Observe all workshop safety rules. Remember to wear your gloves before touching any hot surface.

1. Visit the school auto workshop or a mechanic shop in the community to examine different types of air-cooled internal combustion engines.
2. Select a particular vehicle and examine all the parts that are components of its cooling system.
3. Make a neat sketch of the selected engine, labelling clearly the main parts of the cooling system.
4. Describe how the parts work together to radiate heat from the engine.

Common Applications of Air Cooling

Air-cooled engines are commonly found in small machines and vehicles where simplicity and low weight are important.

Examples include:

1. Air compressors
2. Portable generators
3. Small automobiles (for e.g., old VW Beetle)
4. Small tractors
5. Motorcycles
6. Lawn mowers

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7. Small aircrafts
8. Computer components
9. Portable appliances
10. Refrigerators

Examples of air-cooled engine vehicles

Air-cooled engines are not commonly found in automobile applications today, but their history can still be traced to the earlier development of many of the car brands in use today. Classic car models that utilised air cooling include:

1. Volkswagen Beetle (1938)
2. Porsche 356 (1949)
3. BMW Isetta (1955)
4. Citroën 2CV (1948)
5. Volkswagen Type 2 Bus (1950)
6. Fiat 500 (original model)
7. Tatra T603 (1955)
8. Messerschmitt KR (1953)

Table 1.1: Advantages and disadvantages of the air-cooled system

Advantages	Disadvantages
They are simple in design and construction.	Their cooling follows a complex process.
They have fewer working parts, which makes it easy to service and maintain.	It relies solely on airflow, which can be less effective at low speeds.
They are generally lighter than water-cooled engines.	They are less efficient when used in large and heavy engines.
They are cheaper to manufacture and repair.	They may require more frequent checks and repairs if overheating occurs.
Their relatively smaller size makes them fit well in tight spaces.	They can overheat more easily in extreme conditions due to their location.
They do not require coolant or antifreeze.	The airflow used as a cooling medium cannot be effective at low speeds.
Air used as a cooling medium is readily available and easy to obtain at no cost.	A large amount of air is required to effectively cool the engine, which is difficult to achieve by the moving vehicle or fan.

Activity 1.3

Conducting an Interview on Air-cooled Engines

1. Conduct an interview with a professional auto mechanic or a workshop assistant to help you learn more about air-cooled engines using the interview guide below. **Note**: If you cannot access a professional auto mechanic or a workshop assistant, administer the interview guide using another peer.

Interview Guide: Understanding Air-cooled Engines

a. **Introduction:**

Thank you for taking the time to answer my questions. Your responses will help me gain a deeper insight into the study of air-cooled engines, which I am currently studying about in my second year as an Auto Mechanic student.

b. **Questionnaire**

- What is an air-cooled engine?
- Can you briefly explain how it differs from a water-cooled engine?
- Where are air-cooled engines commonly used?
- Why are they preferred in these applications?
- Can you describe the main parts of an air-cooled engine?
- What role does each part play in the cooling process?
- What is the purpose of the cooling fins on an air-cooled engine?
- How do they help with cooling?
- Why is a fan often used in air-cooled engines?
- How does the fan's position affect cooling?
- How does an air-cooled engine remove heat from the engine parts?
- What are some challenges in keeping an air-cooled engine from overheating?
- What are the main advantages of using an air-cooled engine over a water-cooled engine?
- What are some disadvantages of air-cooled engines?

c. **Conclusion:** Thank you for answering my questions. This information will really help me understand air-cooled engines better and complete my assignment.

2. After the interview, identify at least two areas in which you disagree with the respondent and give reasons why you disagree.
3. Compare your work with that of your colleague's and discuss with the whole class what you have learnt new from the interview.

UNIT 2

Metal Technology

Engineering Materials, Tools and Machines

Introduction

Heat treatment is a controlled process used to alter the physical and sometimes chemical properties of a material, typically metals and alloys. It involves heating and cooling the material to specific temperatures to enhance desired characteristics such as hardness, strength, toughness, and wear resistance. Understanding heat treatment is essential in industries like manufacturing, automotive, aerospace, and toolmaking, where material properties are crucial for performance and durability.

Furthermore, in learning about heat treatment processes, we will cover the main types: annealing, quenching, tempering, and case hardening, along with the science behind how these processes affect material structure at a microscopic level. This knowledge allows for better material selection and preparation, making selection and preparing, making it highly valuable for both practical and engineering applications.

KEY IDEAS

- Heat treatment of plain carbon steel involves controlled heating and cooling of processes to alter its physical and mechanical properties.
- The key ideas include phase transformation, annealing, normalising, hardening, tempering, critical temperature, quenching medium and carbon content.
- Understanding these principles helps control the mechanical properties of plain carbon steels for different applications.

HEAT TREATMENT OF PLAIN CARBON STEELS

Common types of heat treatment processes include annealing, quenching, tempering, normalising and case hardening as shown in the chart below.

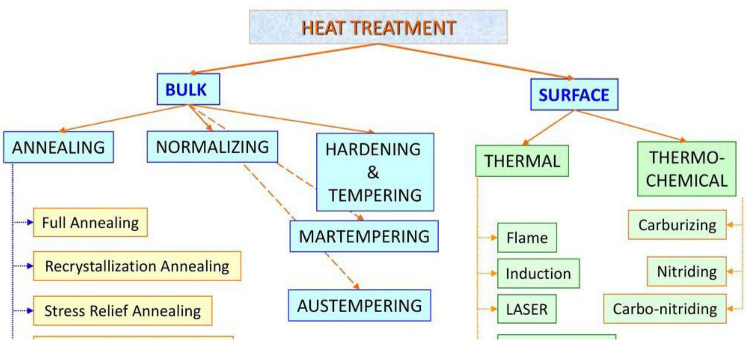

Figure 2.1: Flow chart of Heat Treatment Process.

Table 2.1: Common Heat Treatment Processes and Their Engineering Applications

S/N	Heat Treatment Process	Descriptions Of Heat Treatment Process	Engineering Applications Of Heat-Treated Steel
1	**Annealing**	Annealing involves heating the steel to a temperature above the critical point and then slowly cooling it in the furnace. This process eliminates internal stresses, refines the grain structure, and softens the steel.	Annealed steels are easier to machine, form and weld. They are used in applications where softness, machinability and forming are required, such as in automotive components, pipelines and sheet metal.
2	**Normalising**	Normalising involves heating the steel to a temperature above the critical point and then cooling it in still air. This process produces a fine-grained microstructure and uniform composition of metal. Normalised steels have improved mechanical properties	Often used in applications where higher strength and toughness are required, such as shafts, gears, and structural components.
3	**Hardening (Quenching)**	Quenching involves rapid cooling of the steel from a high temperature by immersion in a quenching medium such as water, oil, or brine or synthetic mediums such as a polymer solution. This rapid cooling traps carbon atoms within the crystal lattice, creating a hard, brittle structure called martensite.	It is used to increase the hardness and strength of metal, especially steel. Some practical applications include cutting tools, automotive parts, construction equipment, hand tools, industrial machinery, military and defence and medical tools.
4	**Tempering**	Tempering follows quenching and involves reheating the quenched steel to a temperature below the critical point and then cooling it at a controlled rate. This process reduces the hardness and brittleness induced by quenching while increasing toughness and ductility.	Tempered steels strike a balance between hardness and toughness, making them suitable for a wide range of applications including shafts, springs, and machine parts.
5	**Case Hardening**	Case hardening is a heat treatment process used to increase the surface hardness of a metal, typically low-carbon steel or iron, while retaining a ductile core.	It allows parts to have a hard, wear-resistant outer layer (the “case”) that can withstand abrasion and fatigue, while maintaining a tough and impact-resistant core.

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5a	**Carburising**	Carburising is a case hardening method that involves heating the steel in a carbon-rich atmosphere at high temperatures (between 870°C to 980°C or 1600°F to 1800°F) for an extended period. Carbon atoms diffuse into the surface of the steel creating a high-carbon layer. The surface layer becomes hardened through the formation of martensite or other hard phases upon quenching. The core remains unchanged in composition but retains its original properties.	Engineering Applications include gears, camshafts, and other components requiring wear resistance and high surface hardness benefit from carburising.
5b	**Nitriding**	Nitriding involves diffusing nitrogen into the surface of the steel at lower temperatures (500°C to 600°C or 930°F to 1110°F) in an ammonia-rich atmosphere. The process forms hard nitrides on the surface of the steel, improving wear resistance. The hardened layer consists of iron nitrides, which significantly increase surface hardness and wear resistance. The core remains relatively unaffected.	Components such as crankshafts, piston rods, and valves benefit from nitriding due to improved wear and fatigue resistance

Table 2.2: Descriptions of Quenching Mediums and their Engineering Applications.

Types of Quenching Medium	Description of Quenching Media	Engineering Applications of Quenching Media
Water	Water is commonly used as a quenching medium for many steels. It provides very rapid cooling rates, which can result in high hardness but may also induce bending or cracking in some materials due to the rapid thermal contraction.	Quenched steels are very hard but brittle. They are suitable for applications requiring high wear resistance and hardness, such as cutting tools, knives, and bearings.
Oil	Various types of oil, such as mineral oil and specially formulated quenching oils, are used, depending on the steel grade and desired properties. Oil quenching provides slower cooling rates compared to water, resulting in less bending and reduced risk of cracking. Oil is often used for alloying steels and tool steels.	

Brine (salt water):	Salt water or brine is a specific type of quenching medium used in heat treatment processes. It consists of water with dissolved salts, typically sodium chloride (table salt) or other salts like potassium chloride. The addition of salts to water alters its properties compared to plain water, making it a more effective quenching medium for specific engineering applications.	
Polymer Quenchants	Polymer solutions or synthetic quenching fluids offer even slower cooling rates than oil. They are used when minimal bending and high toughness are required, especially for parts with complex shapes.	
Molten Salt Baths:	Molten salts can be used as quenching media for specific applications where precise control over the cooling rate is needed. Salt baths can provide uniform heating and cooling, but they require specialised equipment and handling due to the high temperatures involved.	
Gas Quenching	Inert gases like nitrogen or helium can be used for quenching certain materials, particularly for components where surface oxidation must be avoided. Gas quenching allows for precise control of cooling rates and minimises bending.	
Air Cooling	Some materials can be cooled in still air after heating. This method provides the slowest cooling rate and is used for materials that require a soft, ductile structure without significant changes in mechanical properties.	

Table 2.3: Key Factors in Heat Treatment

S/N	Key Factor	Description of Key Factor
1	**Temperature**	Precise control of temperature is crucial for achieving the desired microstructural changes.
2	**Time**	The duration the metal is held at a particular temperature affects the diffusion processes and final properties.
3	**Cooling Rate**	The rate at which the metal is cooled can greatly influence the resulting microstructure and mechanical properties.
4	**Atmosphere**	The environment in which heat treatment is carried out (example, vacuum, inert gas) can affect surface chemistry and prevent oxidation.

1. Iron-Carbon Equilibrium Diagram

The Iron-Carbon Equilibrium Diagram, also known as the Iron-Carbon Phase Diagram, is a graphical representation of the phases and phase transformations in iron-carbon alloys as they cool or are heated. This diagram is basic in materials science and metallurgy because it helps in understanding the properties and

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behaviour of steels and cast irons, which are the most commonly used iron-carbon alloys.

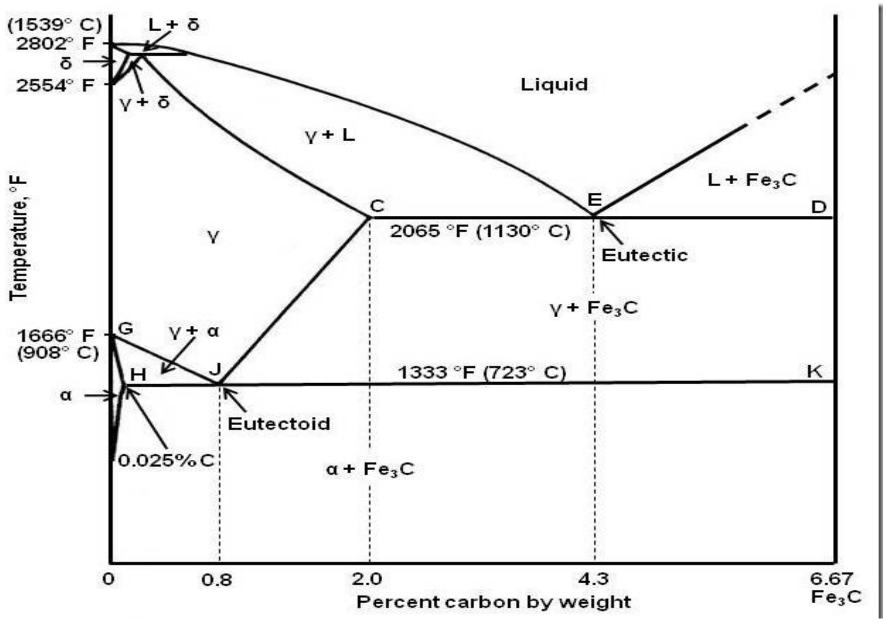

Figure 2.2: Iron-carbon equilibrium diagram.

Table 2.4: Key Features of the Iron-Carbon Equilibrium Diagram

Key Features (Phase 1)	Description of Key Features
Ferrite (α)	A solid solution of carbon in α-iron (body-centred cubic structure). It exists at low temperatures and low carbon concentrations (up to 0.022% carbon at 727°C).
Austenite (γ)	A solid solution of carbon in γ-iron (face-centred cubic structure). It exists at higher temperatures and higher carbon concentrations (up to 2.11% carbon at 1147°C).
Cementite (Fe_3C)	A compound of iron and carbon (iron carbide), with a fixed composition of 6.67% carbon. It is very hard and brittle.

2. **Phases as a Function of Temperature and Carbon Content**

- The diagram shows how the phases change with temperature for alloys with different carbon contents.
- At low temperatures, the stable phase is ferrite or pearlite (a mixture of ferrite and cementite).
- At higher temperatures, austenite is the stable phase, which can transform into pearlite upon cooling.

3. **Transformation Processes**

   a. **Eutectoid Reaction**: At 727°C, austenite transforms into a mixture of ferrite and cementite (pearlite) upon cooling.

b. **Eutectic Reaction**: At 1147°C, the γ phase transforms into a mixture of γ-phase and cementite (eutectic cementite) upon cooling.

4. **Microstructural Changes**

a. The diagram helps predict the microstructure (ferrite, pearlite, martensite, etc.) that will form in an iron-carbon alloy based on its cooling rate from a given temperature.

b. It guides heat treatment processes such as annealing, normalising, quenching, and tempering to achieve desired mechanical properties.

Table 2.5: Practical Applications of the Iron-Carbon Equilibrium Diagram

S/N	Practical Application	Detailed Explanation
1	**Material Selection**	Engineers use the iron-carbon equilibrium diagram to select appropriate materials based on desired mechanical properties and heat treatment capabilities.
2	**Heat Treatment**	It helps in designing heat treatment processes to achieve specific microstructures and mechanical properties in steels.
3	**Understanding Phase Transformations**	Provides insights into how phase transformations occur during heating and cooling, influencing material behaviour under different conditions.

Conclusion

This unit looked at heat treatment of plain carbon steels and the methods of heat treatment. These are essential for beginners learning crucial industrial processes used to alter the physical and mechanical properties of metals to enhance their performance, workability, and longevity. The main objectives of heat treatment are to increase hardness, strength, toughness and resistance to wear and corrosion, and to improve machinability and relieve internal stresses.

In conclusion, learning the heat treatment process is essential for understanding how to manipulate the properties of metals to meet specific performance requirements. This process involves controlled heating and cooling to alter the material's structure, improving hardness, ductility, toughness, and strength. By mastering techniques such as annealing, quenching, and tempering, one can enhance the durability and functionality of metal components across various industries. A solid grasp of heat treatment provides the foundation for producing materials that are resilient, reliable, and precisely suited for their applications.

Activity 2.1

Meaning of Heat Treatment

- In groups of not more than 5, brainstorm to come up with the meaning of heat treatment.

Note: *Use your ICT tools to facilitate your understanding*

Activity 2.2

Reasons for Heat Treatment

In groups of not more than five, discuss and record the reasons why metals should be heat-treated.

Note: *Use your ICT tools to facilitate your work*

Activity 2.3

Processes of Heat Treatment

In groups of not more than five (5), prepare charts explaining the topic "Processes of Heat Treatment of Metals."

Note

- Use your ICT tools (computers, tablets, or phones) to research and organise your work.
- Ensure your charts are clear, neat, and well-labelled.
- Each group should present their chart to the class.

Activity 2.4

Case Hardening Processes and Their Advantages

In groups of not more than five:

1. Prepare charts for learning the topic, ''the case hardening process''
2. Brainstorm the advantages of case-hardening metals.

Note: *Use ICT tools to facilitate your work.*

Activity 2.5

The difference between carburising and nitriding case hardening

In groups of not more than five, prepare charts to discuss the main difference between carburising and nitriding in case hardening.

Note: *Use ICT tools to facilitate your work.*

Activity 2.6

Heat Treatment Processes

In groups of not more than five learners,

1. Discuss the heat treatment of plain carbon steels.
2. Use a video to show the heat treatment processes (https://www.youtube.com/watch?v=lSoVtup4cdQ)

Note: *Respect each other's views during the discussions. Use ICT tools to facilitate your work.*

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UNIT 3

AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

Water-cooled engines play a crucial role in maintaining optimal temperature and performance in automotive engines. Unlike air-cooled systems, these engines use a combination of water and coolant that circulates through specialised channels, called water jackets, around the engine's cylinders. This system absorbs excess heat from the engine, transferring it to a radiator where the coolant cools down before recirculating. This system is favoured in modern engines due to its ability to cool more effectively and its suitability for both low-speed and high-performance vehicles.

In this unit, we will delve into each of the different methods of water cooling, including thermosiphon, forced or pump-assisted, pressurised, and closed cooling systems. We will also be able to draw comparisons between the thermosiphon and pump-assisted systems.

KEY IDEAS

- Efficient cooling reduces engine wear.
- Engine cooling systems combine temperature and pressure to produce an efficient outcome.
- Heat transfer is critical for engine efficiency.
- Managing the flow of coolant can largely prevent overheating of the engine.
- Pump-assisted cooling uses mechanical pumps for efficient heat transfer.
- Thermosiphon cooling uses natural convection to circulate coolant.

WATER COOLED ENGINES

In water-cooled engines, a liquid medium consisting of a mix of water and coolant circulates the cylinders of the engine. The water, which has a working temperature lower than the working temperature of the engine, flows through the water jackets of the cylinder block. The water absorbs heat from the engine and carries it to the radiator, where it cools down before flowing back to the cylinder block in a repeated cycle. Water-cooled engines have the following basic parts:

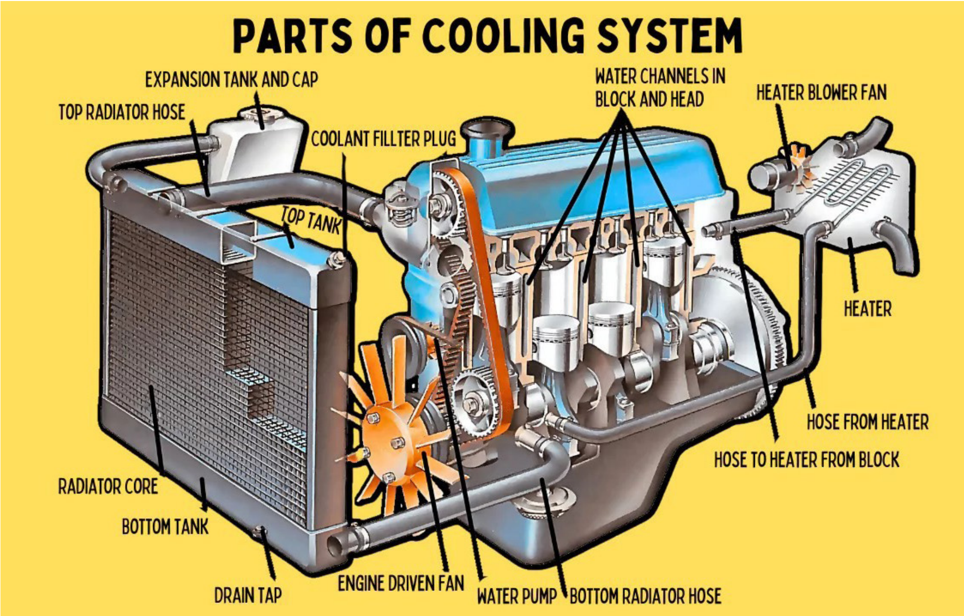

Figure 3.1: Parts of water-cooling system

1. **Water jacket**

   These are hollow spaces or passages created in the cylinder block and cylinder head to allow the liquid coolant to flow around the cylinder walls, combustion chambers and the valve ports. When assembled, a head gasket, sandwiched between the cylinder head and the cylinder block, ensures a gas-tight seal against leakage of coolant into the combustion chamber or of lubricating oil into the coolant.

2. **Water pump**

   The water pump (or cooling pump) is used to enhance the circulation of coolant to achieve uniform temperature distribution in the cylinder block. The coolant at the lower part of the cylinder block maintains a relatively lower temperature compared to the upper part and the cylinder head, which is in direct contact with the heat from the combustion chambers. The water pump is thereby needed to force the colder coolant through the galleries to the top of the engine, ensuring the water temperature is kept within operating levels.

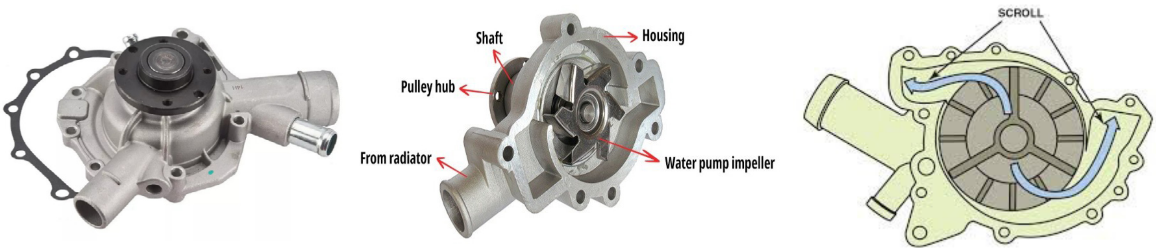

Figure 3.2: Water pump

3. Thermostat

The thermostat is simply a device that operates as a valve and controls the flow of coolant from the cylinder block to the radiator. When the coolant gets hot enough, the thermostat opens, allowing it to flow through the radiator to cool down. The thermostat will not open until the water temperature is very hot. During this period, the water bypasses the thermostat to circulate only through the cylinder block. This also ensures that the rising temperature of the coolant builds up for a faster warming up of the engine and to maintain a good working temperature.

Two common types of thermostats used in engine cooling systems are the wax-type and bellows-type.

Figure 3.3: Thermostat

4. Radiator

The radiator functions as a heat exchanger. Its purpose is to receive the heat that is carried by the hot coolant and release it into the surrounding air. Cooling fins, attached to the core, create a wider surface area for faster cooling of the radiator. The radiator mainly uses a convection process to dissipate heat from the coolant to the air moving around it.

The radiator connects to the cylinder block by means of hoses. A lower hose (outlet) sends the coolant from the radiator into the cylinder block, and an upper hose (inlet) returns the hot coolant into the radiator for cooling.

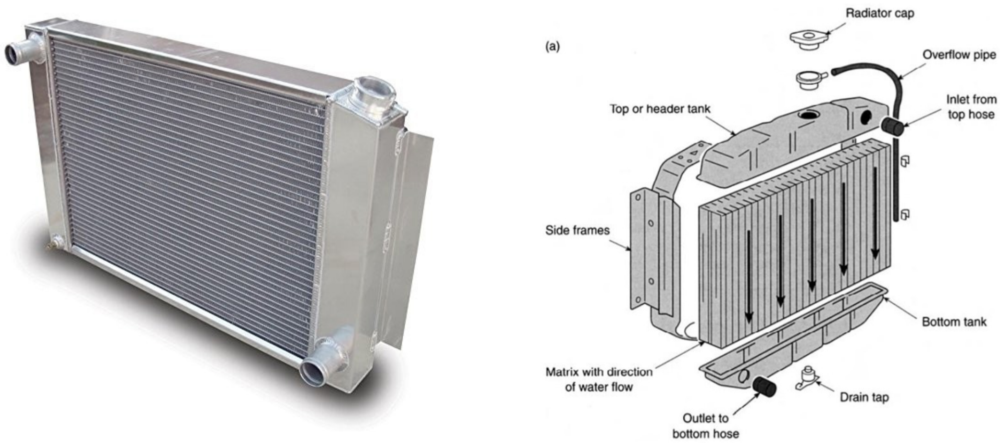

Figure 3.4: Radiator

5. **Cooling fan**

The airstream that cools the hot coolant in the radiator is supplied by a fan installed either behind or in front of the radiator. The fan becomes more useful when the vehicle moves slowly or stops with the engine still running. At high speeds, natural air is drawn through the front grille to cool the radiator, so the fan is disconnected from operating during this stage. A front-mounted fan is called a pusher fan, whilst a rear-mounted one is called a puller fan. Rear engines use roof scoops to direct natural airflow to the radiator at the rear of the vehicle.

In older vehicles, the fan was mounted on the water pump and was mechanically controlled by the engine. Modern vehicles use electric fans that are electronically controlled using sensors.

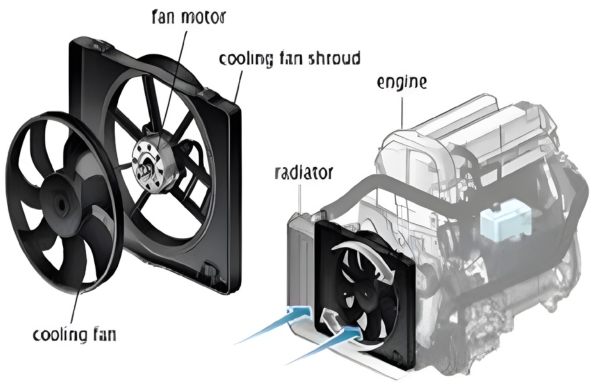

Figure 3.5: Radiator fan with labelled parts and fan fixed to an engine

Methods Used for Water Cooling

Engine water cooling can be designed using one of the following four methods:

1. Thermosiphon cooling
2. Forced or pump cooling
3. Cooling with a thermostatic regulator
4. Pressurised water cooling

Activity 3.1

Parts of the Water-cooling System

Materials needed

1. A car with a water-cooling system
2. Writing materials

CAUTION:

- Observe strictly all safety rules.

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- Do not loosen or tighten any component without the direction of an expert.

Activity Steps

1. Open the bonnet of the car.
2. Ask a friend to locate the following parts of the water-cooling system. Evaluate the responses they give.
   a. Pressure cap
   b. Radiator
   c. Cooling fan
   d. Expansion tank
6. Let your friend also evaluate you as you identify the following parts:
   a. Water pump
   b. Upper hose
   c. Lower hose
   d. Freeze plugs
   e. Thermostat
7. Discuss with your friend the purpose of each of the parts identified.

Thermosiphon Cooling

The thermosiphon cooling system operates on the principle of natural convection caused by variation in the density of water and hence does not rely on the assistance of a water pump to circulate the water through the engine. During engine operation, the heated water expands and becomes less dense. This makes it rise to the top of the engine and then to the top of the radiator, where it condenses or cools down and then drops back into the radiator for recirculation. This method uses all components of water-cooling systems except a pump.

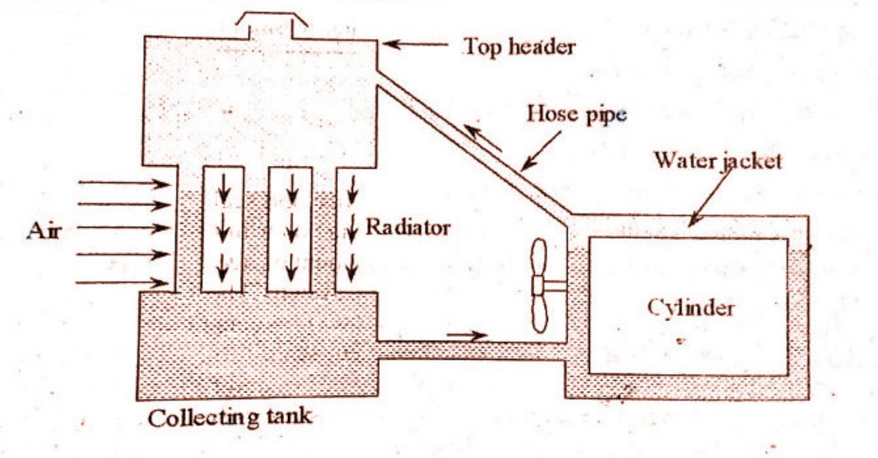

Figure 3.6: Thermosiphon water cooling system

Advantages of thermosiphon cooling systems

1. They are cheaper to purchase and maintain as no water pump is required.
2. They are reliable as there are no moving parts.
3. Circulation of coolant depends solely on the rise in engine temperature.
4. The flow of coolant is regulated by the temperature of the engine.
5. They operate quietly due to the absence of a water pump.

Activity 3.2

How the thermosiphon cooling system works

Materials needed

1. 2 metal containers
2. Pieces of tubing
3. Water
4. Pigment (or food colouring)
5. Heat source
6. Thermometer

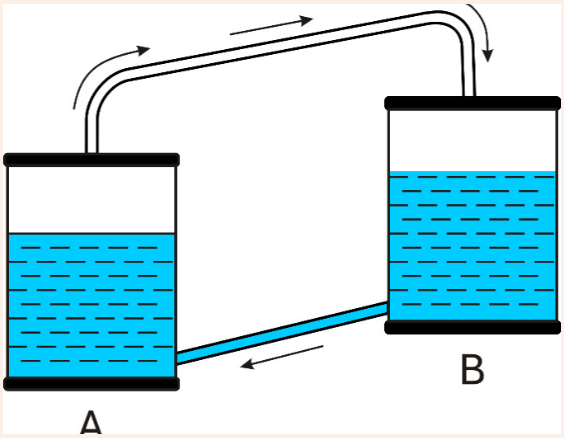

Figure 3.7: An experiment to illustrate thermosiphon water cooling

Activity Steps

1. Connect one piece of tubing to the tops of the two containers as shown in **Figure 3.7.**
2. Connect the second tubing to the two containers close to the bottom.
3. Secure the joints to ensure they are watertight.
4. Fill the containers with the same quantity of water.
5. Add a little pigment or food colouring to the water in **container A**.

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6. Place **container B** on a table a little higher than **container A**.
7. Heat the water in **container A** to a boil.
8. Observe the reaction of the water in the two containers.
9. After some time, use the thermometer to measure the temperature of water in **container B**. Record your result.
10. Measure the temperature of the water in **container A**. Record your result.
11. Record your observation from the experiment and describe in detail how the thermosiphon water cooling system works.
12. Share the outcome of your experiment with your friends in other groups.

Pump-Assisted Water-Cooled System

In this method, a mechanically operated pump driven by the crankshaft actively forces coolant through the engine's water jackets. The pump ensures that overheating is prevented at the hottest parts of the engine by directing coolant flow to high-temperature areas like exhaust valve seats and spark plug areas. By maintaining high coolant pressure, steam pockets are avoided, ensuring efficient heat transfer.

Pump-assisted cooling also allows for a smaller amount of coolant, which reduces the size and weight of the cooling system, especially the radiator and water jackets. Additionally, this system supports a smaller radiator, which helps with engine design and installation, especially in compact car layouts.

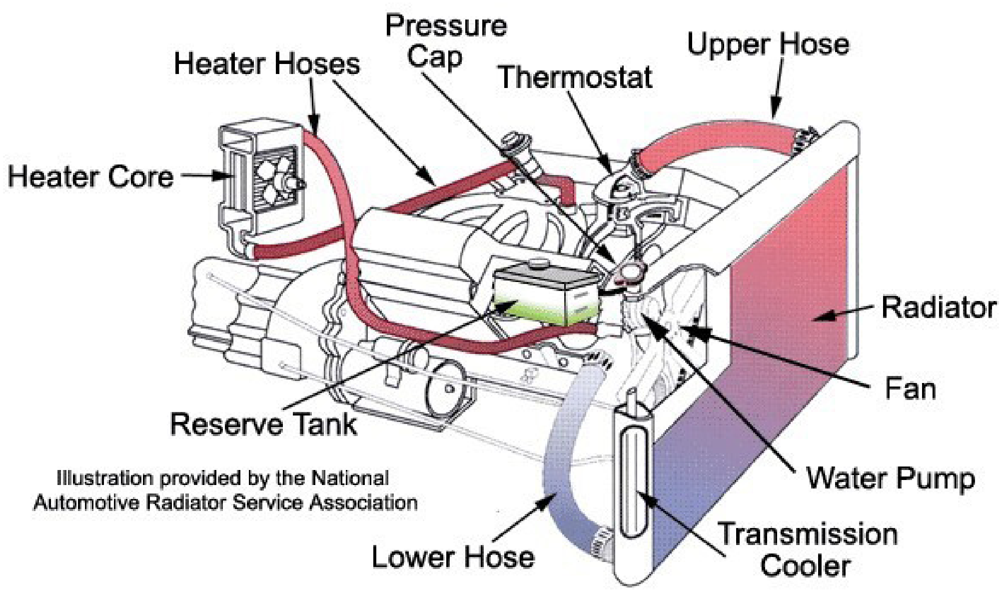

Figure 3.8: Pump-assisted water-cooling system

Advantages of a pump-assisted cooling system

1. It uses positive circulation, which ensures consistent and controlled movement of coolant through the engine and radiator.

2. It guarantees a quick warm-up of the engine since the thermostat prevents the rising hot coolant from flowing into the radiator to mix with the colder part.
3. It can operate efficiently even with smaller radiators and water jackets.
4. The radiator can be mounted lower than the engine, which reduces the height of the bonnet or hood.
5. The presence of the water pump reduces dependence on the fan, which ultimately reduces pressure on the engine.
6. The cooling effect of pump-assisted cooling prolongs the lifespan of engine components.

Drawbacks of the Pump-assisted cooling system

1. Pump-assisted cooling system requires more parts, such as the pump and tubing, making it a complex design.
2. The operation of the pump increases engine noise.
3. The need for a coolant means increased operational cost.
4. The pump adds extra load onto the engine.
5. The pump runs continuously with the engine even when cooling is not needed.
6. The high coolant speed can cause cavitation erosion in the system, that is., wearing out of surfaces because of a decrease in fluid pressure.
7. A fault in the driving mechanism of the pump will lead to inefficient cooling or the pump not working at all.

Activity 3.3

How pump-assisted water-cooling works

1. Search the internet for a video on the engine cooling system.
2. Watch the video.
3. Write down the title of the video and the address from which you obtained it.
4. Write down the names of all the parts of the cooling system identified in the video.
5. Describe how the pump-assisted water-cooling system works.
6. Discuss the operation of the pump-assisted cooling system with the larger class.

UNIT 4

METAL TECHNOLOGY

Engineering Materials, Tools and Machines

Introduction

Twist drilling and grinding are important machining processes used in many areas of manufacturing and mechanical engineering. They are essential for shaping, sizing, and finishing metal components that must meet accurate specifications. Understanding these processes helps students develop practical skills needed for workshop operations and future engineering tasks.

This lesson introduces the key ideas behind twist drilling, which involves creating cylindrical holes using a rotating drill bit, and grinding, which removes small amounts of material from a workpiece to produce smooth surfaces or precise dimensions. Students will learn about drill bit selection, cutting speeds and feeds, abrasive materials, grinding wheels, and the safety rules required when using these machines. By the end of this lesson, students should be able to perform basic drilling and grinding tasks with accuracy and confidence.

KEY IDEAS

- Learning these foundational elements will help you to develop efficient drilling techniques, leading to better quality holes and longer-lasting tools.
- These fundamentals will give you a solid foundation in understanding twist drills, drilling techniques, and grinding for maintenance.
- These key ideas will provide a foundation understanding of drilling and grinding operations and their significance in various industries.

TWIST DRILL, DRILLING AND GRINDING MACHINES

A drill is a tool used to drill a hole in a solid material. A helical groove known as a 'flute' is cut along the length of the drill.

Table 4.1: Different types of drill

S/N	TYPE OF DRILL	DESCRIPTION OF DRILL	SKETCH OF TOOL
1	**Straight fluted drill**	A straight flute drill has a long, narrow channel or flute that runs the length of the bit. The flute removes material as the bit penetrates the workpiece.	
2	**Centre drill**	The centre drills are straight shank, two fluted twist drills used when centre holes are drilled on the ends of a shaft. They are made in finer sizes.	
3	**Twist drill**	Twist drills are the type generally used in the workshop. They are made of high-speed steel (HSS) or high carbon steel. There are two types of twist drills namely. The diameter of the straight shank drill ranges from 2 to 16mm, that is a small size drill, being held in drill chuck. Taper shanks are provided on drills of larger diameter, that is medium to large size drills being fitted into the spindle nose directly or through taper sockets. Drills are made of high-speed steel. High speed steel is used for about 90 per cent of all twist drills. For metals more difficult to cut, HSS alloys of high cobalt series are used.	 a. Straight shank twist drill  b. Taper shank twist drill.

Principal Parts of The Twist Dill

A twist drill has three principal parts, namely:

1. Drill point or dead centre
2. Body
3. Shank

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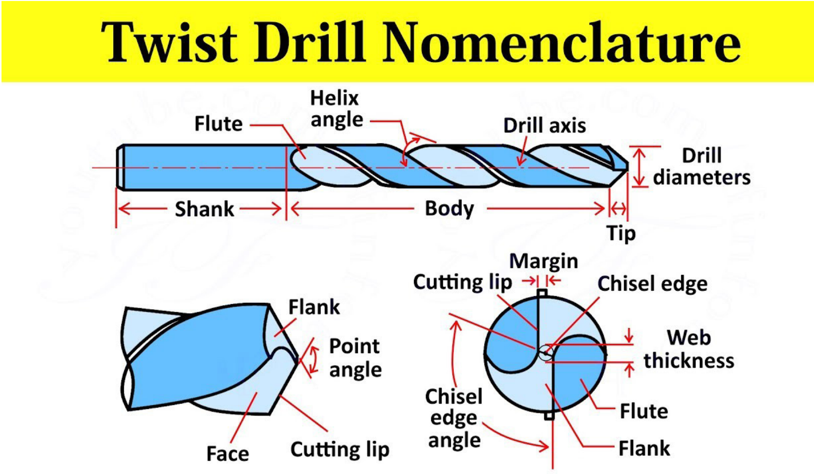


Figure 4.1: Parts of a twist drill.

Table 4.2: Nomenclatures/terminologies of a twist drill

S/N	NOMENCLATURE	DESCRIPTION OF NOMENCLATURE
1	**Axis**	It is the longitudinal centre line of the drill.
2	**Diameter**	Largest diameter measured across the top of the land behind the point.
3	**Back Taper**	The diameter reduces slightly toward the shank end of the drill; this is known as "back taper". Back taper provides clearance between the drill and workpiece, preventing friction and heat.
4	**Body**	It is the part of the drill from its extreme point to the commencement of the neck.
	Body Clearance	The part of the drill body that has been reduced to cut down friction between the drill and the wall of the hole.
5	**Neck**	The portion with reduced diameter between the body and the shank.
6	**Shank**	It is the part of the drill by which it is held and driven. The shank may be straight or tapered.
7	**Tang**	The flattened end of the taper shank is known as the tang.
8	**Point**	It is the conical, sharpened end of the drill. It consists of the following: • **Dead centre:** It is the sharp edge at the extreme tip of the drill. This should always be the exact centre of the drill. • **Lips:** These are the cutting edges of the drill. • **Heel:** It is the portion of the point back from the cutting edge.
9	**Flank**	The surface of the drill, which extends behind the lip to the flute.

10	**Flutes**	The grooves in the body of the drill are known as flutes.
11	**Flute Length**	The length of the flute measured from the drill point to the end of the flute runout. Flute length determines the maximum depth of drilling.
12	**Margins**	The cylindrical portion of the land that is not cut away to provide clearance.
13	**Helix Angle:**	The angle formed between a line drawn parallel to the axis of the drill and the edge of the land. (30° or 45°).
14	**Point angle**	This is the angle included between the two lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips. (118°).
15	**Chisel Edge**	It is the point where the two cutting lips meet at the extreme tip.
16	**Chisel Edge Angle**	The angle between the chisel edge and the cutting lip measured plane normal to the axis.

DRILLING MACHINE

Drilling is the operation of making a circular hole by removing a volume of material, usually metal, from the job by a cutting tool called a drill. The machine used for drilling is called a drilling machine. It is one of the most important and useful machine tools in a workshop. A drilling machine is also referred to as a Drill Press. The work piece is held stationary, that is clamped in position, and the drill rotates to make a hole. Besides drilling round holes, many other operations can also be performed on the drilling machine.

Operations Performed on Drilling Machine

A drilling machine is an extremely useful machine tool. Many operations can be performed on it, including:

Table 4.3: The Drilling Operations

S/N	OPERATION	DESCRIPTION OF OPERATION
1	**Drilling**	This is the operation of making a circular hole by removing a volume of metal from the job with a rotating cutting tool called a drill. Drilling removes solid metal from the job to produce a circular hole.
2	**Reaming**	This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called a reamer.
3	**Boring**	Boring is an operation used to enlarge a hole by means of an adjustable cutting tool with only one cutting edge.

4	**Counter boring**	It is the operation of enlarging the end of a hole cylindrically, as for the recess for a countersunk rivet. The tool used is known as a counterbore.
5	**Spot facing**	This is the operation of removing enough material to provide a flat surface around a hole to accommodate the head of a bolt or a nut. A spot-facing tool is very similar to the counterbore.
6	**Tapping**	This is the operation of cutting internal threads by using a tool called a tap. A tap is like a bolt with accurate threads cut on it.
7	**Lapping**	This is the operation of sizing and finishing a hole by removing very small amounts of material using an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, using a lapping tool.
8	**Trepanning**	A technique used for drilling larger hole diameters where machine power is limited, as it is not as power-consuming as conventional drilling, where the entire hole is converted into chips.

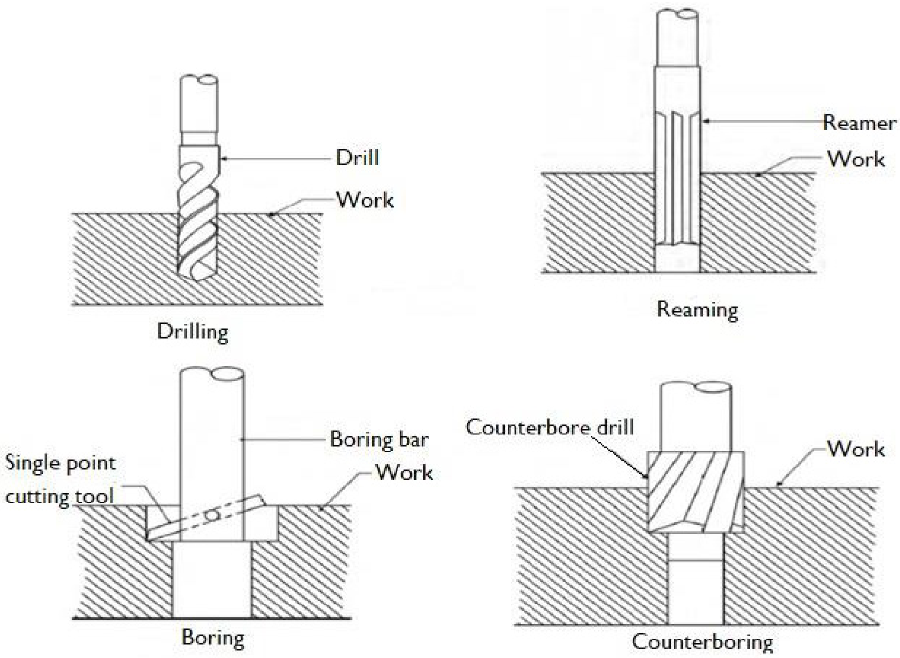


Figure 4.2: Applications of a twist drill

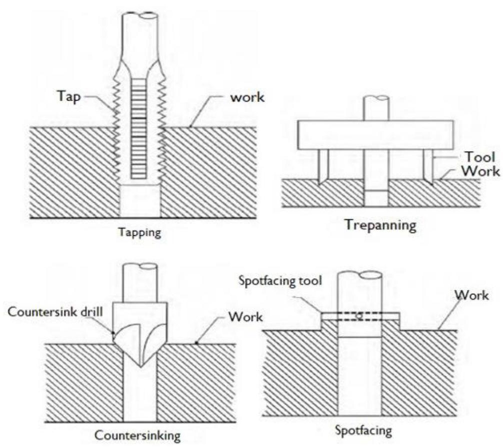


Figure 4.3: Applications of a twist drill

Figure 4.4: Applications of a twist drill

Construction and Parts of Drilling Machine

The drilling machine consists of the following parts:

1. Base
2. Pillar
3. Main drive
4. Drill spindle
5. Feed handle
6. Work table

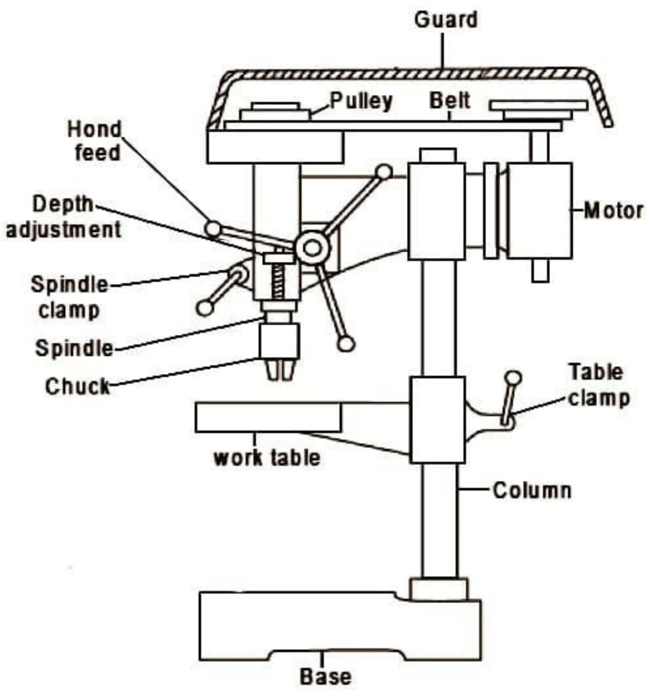


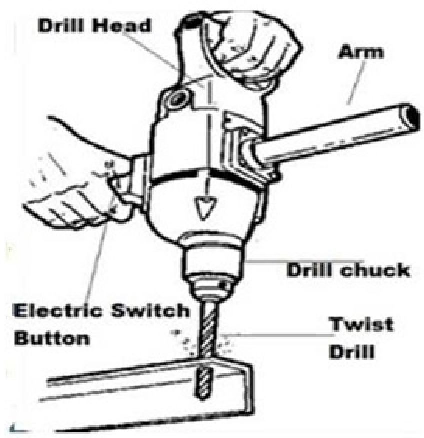
Figure 4.6: Parts of a drilling machine

Types of drilling machine

Drilling machines are classified based on their constructional features or the type of work they can handle. The various types of drilling machines are as follows:

1. Portable drilling machine
2. Bench/Sensitive drilling machine
3. Pillar/Upright drilling machine
4. Radial drilling machine
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Automatic drilling machine
8. Deep hole drilling machine

Table 4.4: Showing types of a drilling machine

S/N	Types of drilling machine	Description of the drilling machine	Sketch/Picture of drilling machine
1	**Portable Drilling Machine**	A portable drilling machine is a small, compact unit and used for drilling holes in workpieces in any position, which cannot be drilled in a standard drilling machine. It may be used for drilling small diameter holes in large castings or weldments at the place where they are lying. Portable drilling machines are fitted with small electric motors, which may be driven by both A.C. and D.C. power supply. These drilling machines operate at fairly high speeds and accommodate drills up to 12 mm in diameter. A portable drilling machine can be carried and used anywhere in the workshop	 

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<td>2</td>
<td>Sensitive Drilling Machine</td>
<td>
It is a small machine used for drilling small holes in light jobs.
In this drilling machine, the work piece is mounted on the table, and the drill is fed into the work by purely hand control.
High rotating speed of the drill and hand feed are the major features of a sensitive drilling machine.
As the operator senses the drilling action in the workpiece, at any instant, it is called a sensitive drilling machine.
A sensitive drilling machine consists of a horizontal table, a vertical column, a head supporting the motor and driving mechanism, and a vertical spindle.
Drills of diameter from 1.5 to 15.5 mm can be rotated in the spindle of a sensitive drilling machine.
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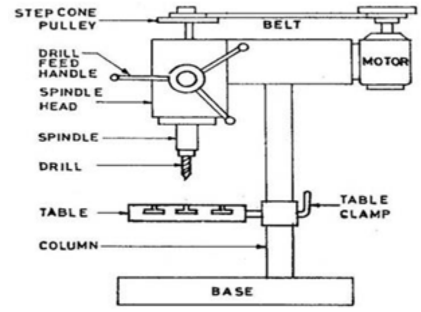

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<tr>
<td>3</td>
<td>Pillar or Upright Drilling Machine</td>
<td>
The upright drilling machine is larger and heavier than a sensitive drilling machine.
It is designed for handling medium-sized workpieces and is supplied with a power feed arrangement. In this machine, many spindle speeds and feeds may be available for drilling different types of work.
Upright drilling machines are available in various sizes and with various drilling capacities (ranging up to 75 mm diameter drills).
4. The table of the machine also has different types of adjustments.
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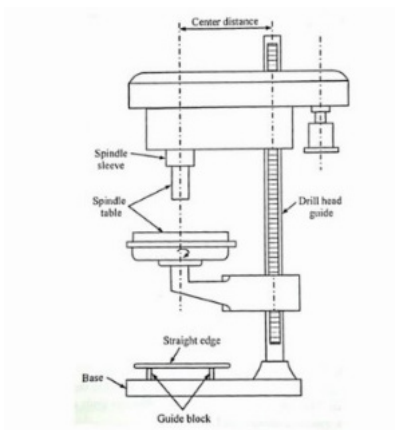

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4	**Radial Drilling Machine**	The radial drilling machine consists of a heavy, round vertical column supporting a horizontal arm that carries the drill head. The arm can be raised or lowered on the column and can also be swung around to any position over the work, and can be locked in any position. The drill head containing the mechanism for rotating and feeding the drill is mounted on a radial arm and can be moved horizontally on the guideways and clamped at any desired position.	

Work Holding Devices in Drilling Machines

The devices used for holding the work in a drilling machine are

1. Drill vice
2. 'T' - bolts and clamps
3. Step block
4. V - block
5. Angle plate
6. Drill jigs

- **Cutting speed**: The cutting speed in a drilling operation refers to the peripheral speed of a point on the surface of the drill in contact with the work. It is usually expressed in meters/min.

  The cutting speed (Cs) may be calculated as:

  $$Cs = ((22/7) \times D \times N)/1000$$

  Where, D is the diameter of the drill in mm and N is the rpm of the drill spindle.

- **Feed:** The feed of a drill is the distance the drill moves into the job at each revolution of the spindle. It is expressed in millimetres. The feed may also be expressed as feed per minute.

GRINDING

Grinding is a metal cutting operation, like any other process of machining and removes metal in a comparatively small volume. The cutting tool used is an abrasive wheel which has many numbers of cutting edges. The machine on which the grinding operation is performed is called a grinding machine. Grinding is done to obtain very high dimensional accuracy and better appearance. The accuracy of the grinding process is 0.000025mm. The amount of material removed from the work is much less than drilling.

Types of Grinding Machines

Types of grinding machines according to the accuracy of the work to be done on a grinding machine are classified as seen in **Table 4.5**.

Table 4.5: Classifications of grinding machines.

S/N	TYPE OF GRINDING MACHINE	DESCRIPTION OF TYPE OF GRINDING MACHINE	SKETCH OR PICTURE OF TYPE OF GRINDING MACHINE
1	**Rough grinding machines**	The rough grinding machines are used to remove stock with no reference to the accuracy of results. Excess metal present on the cast parts and welded joints are removed by rough grinders. The main types of rough grinders are:	
2	**Hand grinding machine/ Fixed hand-held grinder**	An angle grinder is a hand-held tool carried to the work, with the disc secured at an angle to the body of the grinding machines	
3	**Bench grinding machine**	A bench grinder is a benchtop type of grinding machine used to drive abrasive wheels.	

4	**Floor stands/ Pedestal grinding machine:**	An off-hand grinder, which may be fixed to a bench or a pedestal, is usually fitted with one or two abrasive discs revolving at right angles to the spindle turned by a motor.	

Other types of rough grinding machines are flexible shaft grinding machines, swing frame grinding machines and abrasive belt grinding machines.

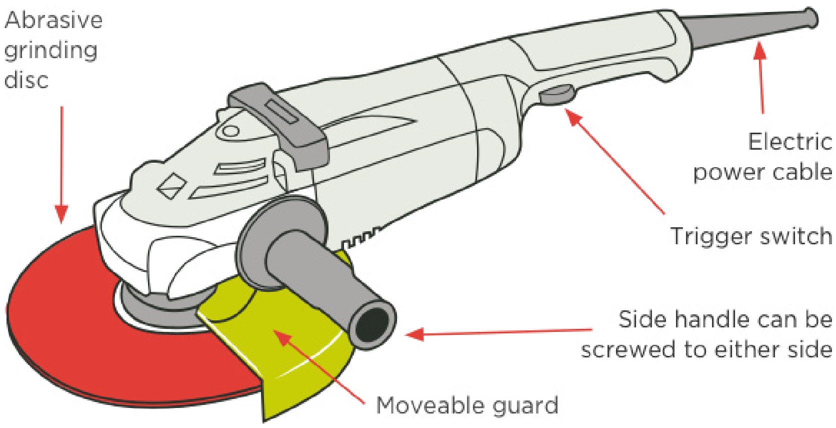

Figure 4.6: Parts of a drilling machine

Precision grinding machines

Precision grinders are used to finish parts to very accurate dimensions. The main types of precision grinders are:

1. Cylindrical grinding machines
2. Internal grinding machines
3. Surface grinding machines
4. Tool and cutter grinding machines
5. Special grinding machines

Grinding Machine Operations

The process of grinding is the operation of removing excess material from metal parts by a grinding wheel made of hard abrasives. The following operations are generally performed in a grinding machine.

1. Cylindrical grinding
2. Taper grinding

3. Gear grinding
4. Thread grinding

Table 4.6: Parameters of grinding operation

S/N	PARAMETER	DESCRIPTION OF PARAMETER
1	**Cutting Speed**	Cutting speed in a grinding wheel is the relative peripheral speed of the wheel with respect to the workpiece. It is expressed in metres per minute (mpm) or metres per second (mps).
2	**Feed Rate**	Feed rate is a significant parameter in the case of cylindrical grinding and surface grinding. Feed rate is defined as the longitudinal movement of the workpiece relative to the axis of the grinding wheel per revolution of the grinding wheel.
3	**Depth of Cut**	Depth of cut is the thickness of the layer of metal removed in one pass. It is measured in mm, and normally the depth of cut is kept ranging between 0.005 to 0.04 mm.

Various elements of a grinding wheel

1. **Abrasives:** Abrasives are used for grinding and polishing operations. They should have uniform physical properties of hardness, toughness and resistance to fracture. Abrasives may be classified into two principal groups.
   a. Natural abrasives
   b. Artificial abrasives
2. **Silicon carbide**: Silicon carbide is manufactured from 56 parts of silica, 34 parts of powdered coke, 2 parts of salt and 12 parts of sawdust in a long rectangular electric furnace of the resistance type that is built of loose brickwork. There are two types of silicon carbide abrasives: green grit and black grit.
3. **Aluminium oxide**: Aluminium oxide is manufactured by heating mineral bauxite, silica, iron oxide, titanium oxide, etc., mixed with ground coke and iron borings in arc type electric furnace.
4. **Bonds:** A bond is an adhesive substance that is employed to hold abrasive grains together in the form of grinding wheels. There are several types of bonds. Different grinding wheels are manufactured by mixing hard abrasives with suitable bonds.

Table 4.7: Grinding terms

S/N	Griding Term	Explanation of Term
1	**Grain size (Grit)**	The grinding wheel is made up of thousands of abrasive grains. The grain size or grit number indicates the size of the abrasive grains used in making a wheel, or the size of the cutting teeth. Grain size is shown by a number indicating the number of meshes per linear inch of the screen through which the grains pass when they are graded. There are four different groups of grain size namely coarse, medium, fine and very fine. If the grit number is large, the size of the abrasive is fine, and a small grit number indicates a large grain of abrasive.
2	**Grade**	The grade of a grinding wheel refers to the hardness with which the wheel holds the abrasive grains in place. It does not refer to the hardness of the abrasive grains. The grade is indicated by a letter of the English alphabet. The term ‘soft’ or ‘hard’ refers to the resistance a bond offers to disruption of the abrasives.
3	**Structure**	The relative spacing occupied by the abrasives and the bond is referred to as structure. It is shown by the number and size of void spaces between grains. It may be ‘dense’ or ‘open’. Open structured wheels are used to grind soft and ductile materials. Dense wheels are useful in grinding brittle materials.
4	**Glazing**	Glazing is the condition of the grinding wheel in which the cutting edges or the face of the wheel takes a glass-like appearance. Glazing takes place if the wheel is rotated at very high speeds and is made with harder bonds.
5	**Loading**	The wheel is loaded if the particles of the metal being ground adhere to the wheel. The openings or pores of the wheel face are filled up with metal chippings.

Dressing the Grinding Wheel

Grinding wheels are dressed to restore their cutting capacity and cutting properties.

1. **Importance of dressing a grinding wheel:**
   - **a.** removes metal or foreign matter which has lodged in and loaded (filled up) the pores of the wheel.
   - **b.** removes dull grains which did not break off. The dull-grained (or glazed) wheel will burn the work and cause fine heat cracks.
2. **Truing of grinding wheel:** Truing is the process of changing the shape of the grinding wheel as it becomes worn from its original shape, owing to the breaking away of the abrasive and bond. This is done to make the wheel true and concentric with the bore, or to change the face contour for form grinding

Grinding Fluids

Normally, grinding fluids remove heat from the grinding zone and wash the chips away. Generally, two types of grinding fluids are used:

1. Water-based fluids and
2. Oil-based fluids

Safety Measures to Be Observed When Using The Grinding Machines

Personal protective equipment (PPE);

1. Safety glasses must be worn at all times in work areas.
2. Long and loose hair must be contained.
3. Hearing protection must be used when using this machine.
4. Sturdy/strong footwear must be worn at all times in work areas.
5. Close-fitting/protective clothing must be worn.
6. Rings and jewellery must not be worn.

Table 4.8: Safety measures

PICTORIAL FORM OF PPE	TYPES AND FUNCTIONS OF PPE
	Safety glasses must be worn at all times in work areas
	Long and loose hair must be contained.
	Hearing protection must be used when using this machine.
	Strong footwear must be worn at all times in work areas.

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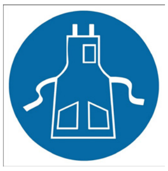	Close fitting/protective clothing must be worn.
	Rings and jewellery must not be worn.

Conclusion

This unit provided an in-depth description of the twist drill and the use of drilling and grinding machines. The unit looked at the types, parts and functions of the twist drill. The unit also highlighted the types of drilling machines, and the operations performed on the drilling machine. The types of grinding machines and their parts were also discussed, focusing on some grinding operations and terms used in grinding.

Both twist drilling and grinding operations are integral to manufacturing processes, and mastery of these techniques can lead to improved product quality, efficiency and innovation. Continuous learning and adaptation to new technologies and methods are essential for success in these fields

Activity 4.1

Functions of Parts of The Twist Drill

1. In groups of not more than five, prepare an image for identifying and explaining the functions of the parts of the twist drill.
2. Exhibit your image in class for appraisal
3. Modify your image based on recommendations from the appraisal

__Note__: Use ICT tools and the image below to facilitate your work.

Activity 4.2

Names and Parts of The Drilling Machine

Using images and in groups of not more than five, brainstorm to come up with the:

a. Parts of the drilling machine

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b. Names of types of drilling machines.

Note: *Use ICT tools and the images below to facilitate your understanding.*

Activity 4.3

Principles of operations on a drilling machine

In groups of not more than five, use the table below to discuss at least 6 p operations performed on a drilling machine.

Note: *Use ICT tools and the table below to facilitate your understanding.*

Operation name	Image	Description

Activity 4.4

Types of grinding machines and grinding wheels

Using the images and in groups of not more than five:

1. Identify types of grinding machines and grinding wheels.
2. Explain the types of grinding machines and grinding wheels.

Note: *Use ICT tools and the images below to facilitate your work.*



Activity 4.5

Operations of the twist drill and grinding machine

Using an image and in groups of not more than five.

1. Discuss the twist drill
2. Demonstrate/perform operations using drilling and grinding machines.

Note: *Use ICT tools and the image below to facilitate understanding.*

Activity 4.6

Descriptions, parts and functions of drilling and grinding machines

In groups of not more than five, prepare a table to;

1. Describe the twist drill
2. Identify the major parts of the drilling and grinding machines
3. Brainstorm the functions of drilling and grinding machines

Note: *Use ICT tools to facilitate your work.*

Twist drill	Description
Drilling machines	**Parts and functions**
Grinding machines	**Parts and functions**

Activity 4.7

Visiting a local workshop to identify, sketch, observe and demonstrate grinding and drilling operations.

Your teacher will organise a visit to a local workshop for you to:

1. Identify the twist drill, grinding and drilling machines in the workshop.
2. Sketch the twist drill, grinding and drilling machines in the workshop.
3. Observe and demonstrate the uses of the grinding and drilling machines with the help of your Applied Technology teacher or the workshop assistant.
4. Make sketches and take pictures of the machines, tools, equipment and the operations and display in the class for appraisal.
5. Write a visit report and discuss in class in groups.

Notes:

a. *Use ICT tools to facilitate your work and understanding.*

b. *Observe the basic safety precautions during the visit.*

EXTENDED READING

- **A Short Course on Cooling Systems:** https://www.carparts.com/blog/a-short-course-on-cooling-systems/?srsltid=AfmBOop7cfrUGmIMfmv6H0RnXQD_plwFdqtW-j-cWvARuYqbmgvKqVmV
- **Cooling Systems:** https://www.summaryplanet.com/engineering/Cooling-systems.html
- **Engine Cooling System in a Car Explained:** https://www.youtube.com/watch?v=yv-kx9EG1KQ&t=244s
- https://en.wikipedia.org/wiki/Heat_treating
- https://fractory.com/iron-carbon-phase-diagram/
- https://khkgears.net/new/gear_knowledge/abcs_of_gears-b/Gear_Materials_and_Heat_Treatments.html
- https://www.jswonemsme.com/blogs/blogs-articles/what-is-the-importance-of-proper-heat-treatment-in-steel-crankshaft
- https://www.metalsupermarkets.com/what-is-case-hardening/
- https://www.slideshare.net/slideshow/heat-treatment-79299404/79299404
- https://www.sst.net/metal-case-hardening/
- **Parts of drill machine**: https://i.ebayimg.com/images/g/tkgAAOSwdAtku~mn/s-l1600.webp
- **Portable Drilling Machine:** https://tiimg.tistatic.com/fp/1/008/270/light-weight-and-portable-electric-drill-machine-770.jpg
- **Radial Drilling Machine:** https://www.usitools.com/7118-medium_default/radial-drilling-machine--big-capacity-dr80.jpg
- **Sensitive drilling machine:** https://shikshartin.wordpress.com/wpcontent/uploads/2018/09/sensitive-drill.jpg
- **Water Cooling – Parts, Working, Diagram, Advantages and Disadvantages:** https://learnmech.com/water-cooling-systems-parts-advantages-and-disadvantage/

Review Questions

Questions 1.1

1. Explain with a simple layout the main components of an air-cooled engine
2. Explain how an air-cooled engine works and state two common applications for air-cooled engines.
3. Why are fins important in air-cooled engines?
4. What are the advantages and disadvantages of air-cooled engines over water-cooled engines?

Questions 1.2

1. Imagine you are working in a small workshop that creates agricultural metal tools. One day, you noticed that some of tools easily bend or break when using them. Your Applied Technology Teacher explains that to make the tools stronger and more durable, they need to go through a process called heat treatment. Explain the term heat treatment.
5. Imagine we have a metal workshop where we produce tools and equipment. In this workshop, we deal with various heat treatment processes to ensure our products are durable, strong, and can withstand different stress levels. There are several processes in heat treatment. Explain the following heat treatment processes:
   - Normalising
   - Tempering
   - Case hardening
   - Annealing
6. Imagine you are designing a high-strength bike lock to resist cutting and wear. The outer surface of the lock needs to be extremely hard to withstand scratches, abrasions, and potential cutting attempts from tools, but the inner metal core should stay tough and somewhat flexible to absorb impacts without breaking. Explain why a metal should be case hardened.
7. A company specialises in manufacturing high -performance automotive components, including gears, pistons, and crankshafts. The company needs each part to withstand high loads, resist wear, and maintain dimensional stability under high-temperature conditions. To achieve these requirements, the company decides to use specific heat treatment processes for each component.
   a. Explain which appropriate heat treatment process would be required to heat treat gears, pistons and crankshafts.

b. Explain how the heat treatment process above would be applied.

Questions 1.3

1. Make a neat sketch of the layout of a thermosiphon system for a water-cooled engine and describe its operation.
2. What safety measures must be observed when inspecting the water in the radiator?
3. Prepare a table showing symptoms of the water pump not functioning properly, causes and ways to resolve them.
4. Draw 5 comparisons between thermosiphon and pump-assisted water-cooling systems.

Questions 1.4

1. Imagine you are in a machine shop or a school workshop, working on a project that requires drilling holes into metal. You have been given a twist drill, a common tool for that purpose, and your task is to sketch it, label four parts, and understand how each part functions.
   a. Make a freehand pictorial sketch of the twist drill
   b. Label any four parts of the twist drill sketched above
   c. Explain any four parts of the twist drill.
8. You have been tasked by your Applied Technology to drill holes for dowels and screws of different parts of the wooden cabinet. Each area requires a different type of drilling machine based on precision, power, and location. Describe the differences between portable drilling, bench/sensitive drilling and pillar/upright drilling machines.
9. Imagine you are working on a DIY (Do It Yourself) project where you are creating a wooden shelving unit, and you need to prepare different types of holes in the wood for the various fasteners and fittings. Explain the following drilling operations:
   a. Reaming
   b. Boring
   c. Countersinking
   d. Counter boring
   e. Tapping
10. Imagine you are at a workshop, working with a standard drilling machine, and you need to replace a parallel shank drill bit with a taper shank drill bit. Describe the steps you would take to change parallel and taper shank drill bits on a drilling machine.

11. Imagine you are in a workshop, and ready to drill holes in a metal workpiece for a project. The machine in front of you is a pedestal drilling machine, with its main components exploded for sketching and labelling.

    a. Make a freehand pictorial sketch of the pedestal grinding machine.

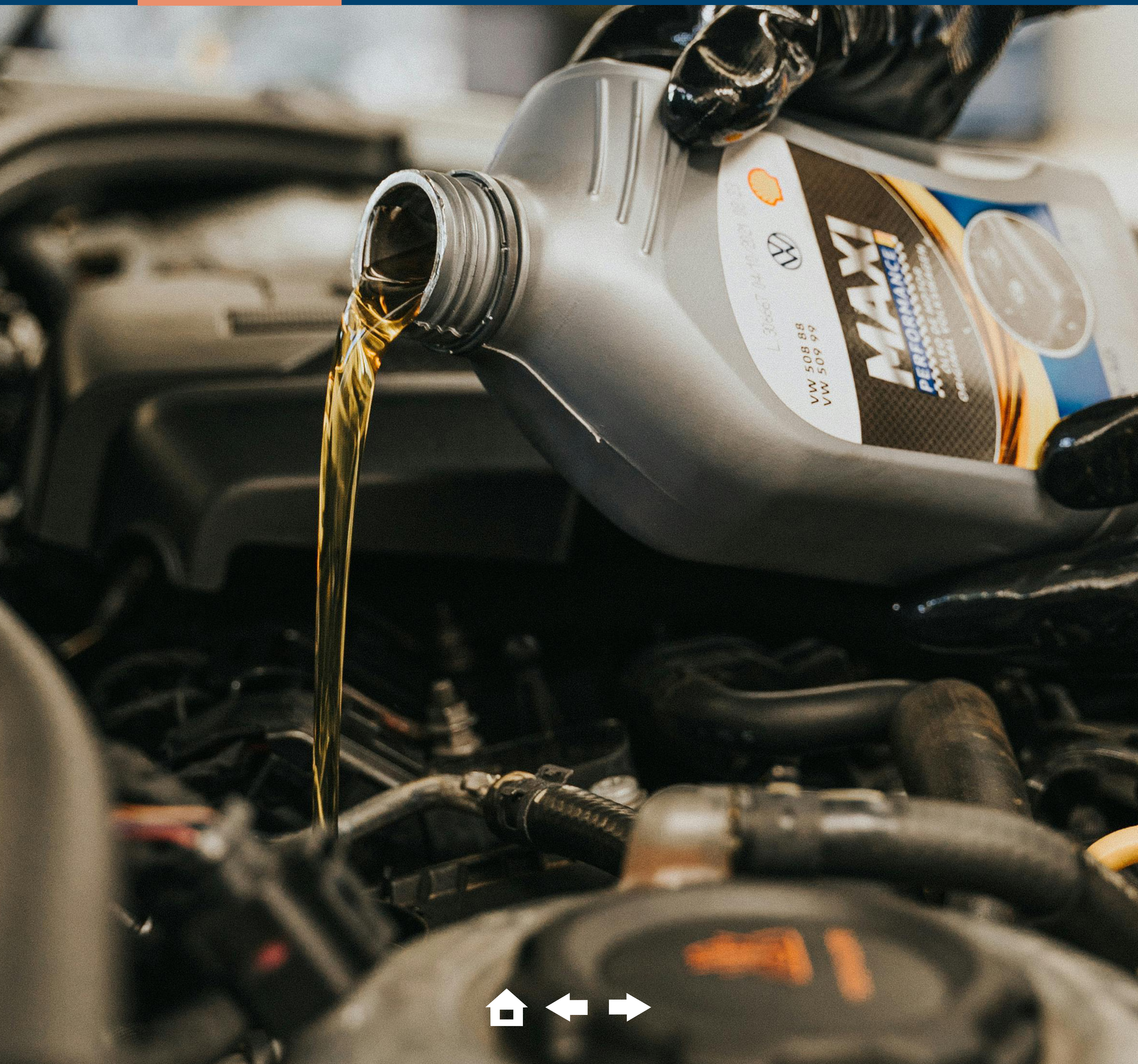
    b. Label any six parts of the pedestal grinding machine sketched (in a) above.

    c. Give an account of how to dress a glazed grinding wheel.

SECTION

2

ENGINE COOLING, LUBRICATION & MACHINES II



UNIT 5

AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

Keeping an engine at the right temperature is very important because it helps the engine run smoothly, safely, and for a long time. If an engine becomes too hot or too cold, it can cause damage or reduce performance, so understanding how engine cooling works is an important part of vehicle maintenance. In this lesson, we will learn about two main parts of the engine cooling system: the thermostat and the pressurised cooling system. We will see how the thermostat controls the flow of coolant and helps the engine warm up quickly, and how the pressurised cooling system raises the coolant's boiling point so the engine can handle higher temperatures.

We will also learn the role of the pressure cap in keeping the system sealed and preventing coolant loss. By the end of this lesson, We should be able to explain why stable engine temperature is important, describe how the thermostat works, explain how the pressurised cooling system controls heat, identify the functions of the pressure cap, and understand how these systems help protect the engine and make it last longer.

KEY IDEAS

- Air-cooled systems are simpler and lighter but less efficient, while water-cooled systems offer stable temperature control.
- Pressurised water-cooling systems maintain positive pressure to prevent coolant loss and enhance heat transfer.
- Proper cooling system design and maintenance are critical for preventing overheating, reducing maintenance costs, and ensuring optimal engine performance.
- Radiator pressure caps manage system pressure by raising the boiling point of coolant and minimising evaporation.
- Sealed cooling systems utilise expansion tanks for coolant expansion and contraction.
- Thermostats regulate engine temperature by controlling coolant flow to the radiator.

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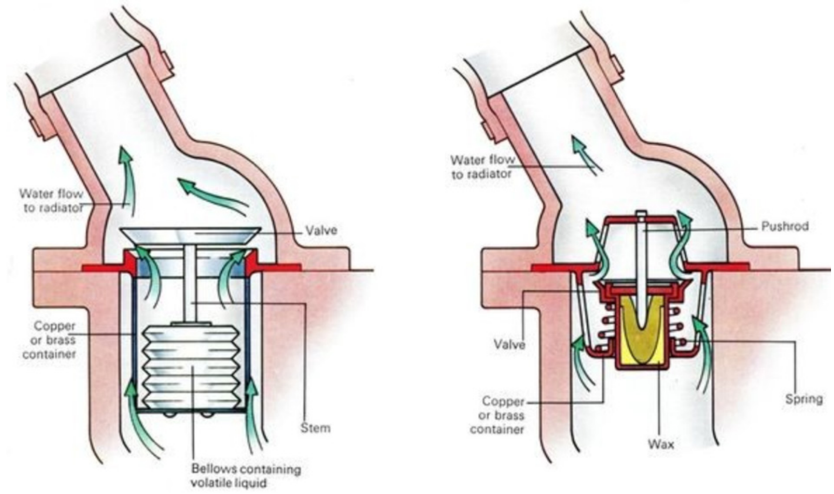
THERMOSTAT

The thermostat is simply a valve that controls temperature in an engine. It helps the coolant warm up quickly and then keeps it at a steady temperature. Since the total amount of coolant in an engine takes time to heat up, the thermostat keeps coolant from flowing to the radiator until the engine reaches a certain temperature. Once the thermostat reaches that temperature, it opens up, allowing coolant to flow fully through the radiator, which provides good cooling.

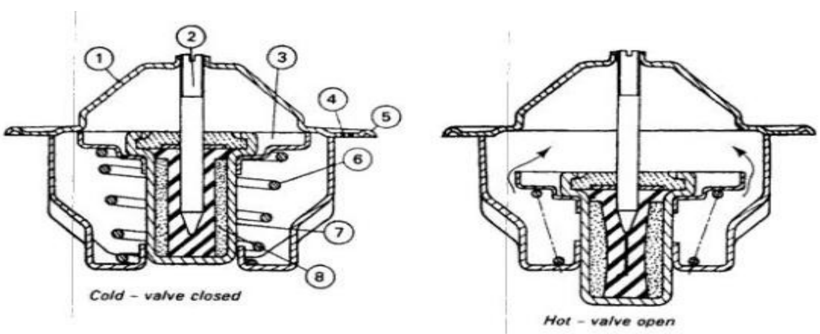


a) Bellows-type thermostat

b) Wax-type thermostat

Figure 5.1: Bellows-type and wax-type thermostats (Source: uk.pinterest.com)

The opening and closing of the thermostat keep the engine's temperature steady. The two popular thermostats are the "wax capsule" type and the "bellows" type (See ***Figure 5.1***). Electronically controlled thermostats, which provide precise temperature control, are emerging in newer vehicles.



1. Bridge
2. Thrust pin
3. Valve
4. Hole
5. Flange
6. Spring
7. Metal cylinder
8. Wax-filled rubber sleeve

Figure 5.2: A wax-type thermostat in closed and open positions

Parts of the wax-type thermostat

1. Bridge
2. Thrust pin
3. Valve
4. Hole
5. Flange
6. Spring
7. Metal cylinder
8. Wax-filled rubber sleeve

Pressurised Water Cooling

A pressurised water-cooling system is a sealed, closed-loop design that maintains a positive pressure to efficiently manage heat transfer and prevent coolant loss. This system uses a pressure cap to regulate pressure, which raises the coolant's boiling point and minimises evaporation. The pressurised system prevents air entry, reduces formation of air bubbles, and minimises sudden flow changes, ensuring stable fluid flow and efficient heat transfer.

Activity 5.1

How a thermostat works

1. Watch video 'Thermostat / how does it work? (3D animation)' at: https://www.youtube.com/watch?v=aOXz5hlKO9s
8. Write a short note describing the operation of a thermostat in the engine cooling system.
9. Join your class in a forum to discuss the advantages of a thermostat in the cooling system of a car.

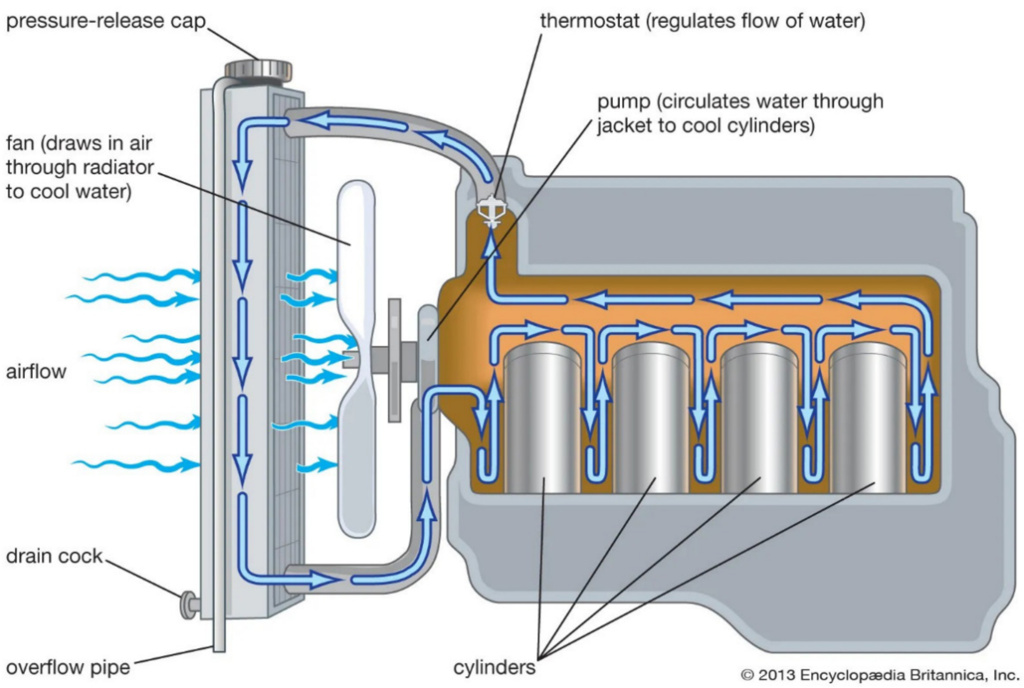


Figure 5.3: Pressurised water-cooling system

Key Features of A Pressurised Cooling System

1. It uses a sealed system, which prevents air entry and contamination of the coolant.
2. It operates under positive pressure, which means the pressure in the system is always higher than atmospheric pressure.
3. It uses a reservoir or expansion tank, which ensures expansion and contraction of the coolant.
4. The pressure cap is actively responsible for regulating the pressure in the system.
5. Closed-loop design: Coolant circulates continuously.

The advantages of using a pressurised system

1. It allows the coolant to circulate at a higher temperature without boiling.
2. It helps to prevent overheating in high-altitude areas, where lower air pressure would normally make the coolant boil at a lower temperature.
3. It allows for a smaller radiator size with narrower water jackets.
4. The increase in pressure at the coolant pump inlet reduces the possibility of cavitation damage.
5. Because the system has to be sealed to pressurise it, instead of simply being vented to the atmosphere, coolant losses through evaporation and surging are minimised.

6. Coolant losses through evaporation and backflow are minimised.

Activity 5.2

How a pressurised cooling system works

1. Search the internet for videos and images on a pressurised cooling system.
2. Based on the results of your research, describe the key features and working of the pressurised cooling system.
3. How does the pressurised cooling system differ from the closed or sealed type?

Radiator Pressure Cap

The radiator pressure cap increases the cooling system pressure, which increases the boiling point of the coolant and prevents coolant loss resulting from a boil over. The pressure cap, apart from providing a watertight seal for the cooling system, serves as a pressure control valve and a vacuum control valve.

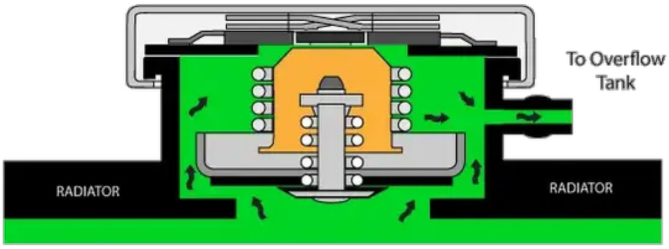


Figure 5.4: Radiator pressure cap (coolant expansion stage)

during engine operation, the hot coolant expands and builds pressure in the system, which pushes against a spring in the cap. The radiator cap allows the coolant to expand and contract without allowing air to enter the cooling system. After the engine warms and system pressure reaches the maximum operating pressure of the cap, the spring compresses and the coolant flows through a vent into the reservoir or expansion tank.

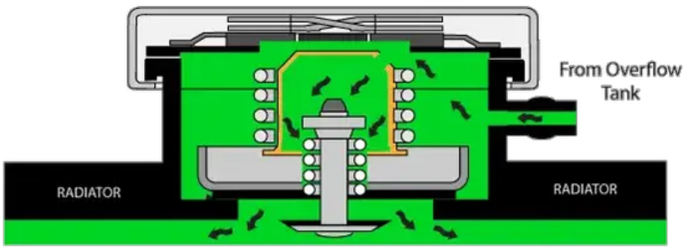
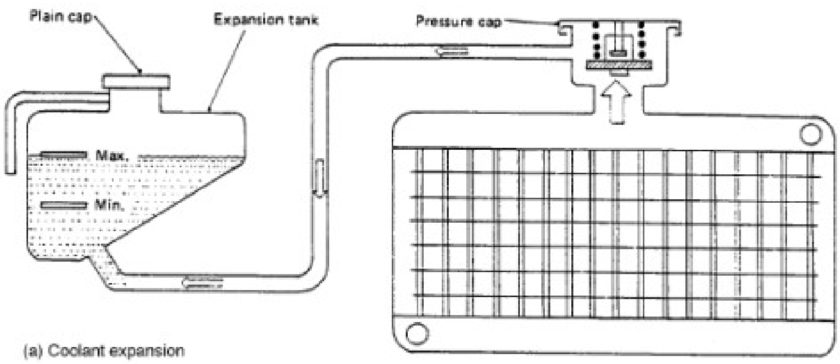


Figure 5.5: Radiator pressure cap (coolant contraction stage)

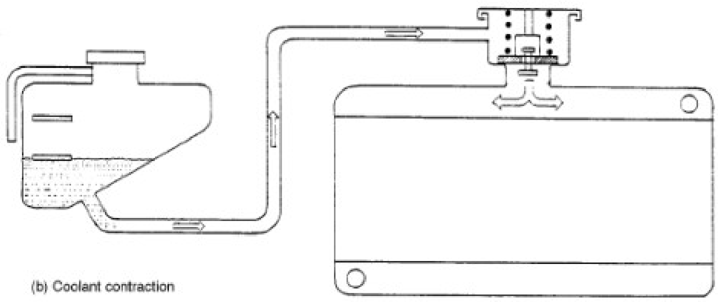
Sealed Cooling Systems

The sealed cooling system uses an expansion tank, which is part of the pressurised section of the cooling system. The expansion tank is designed such that it provides space for the coolant to expand and contract. A vent pipe, connecting from the filler neck of the radiator to the bottom of the expansion tank allows air to escape as coolant expands. Another vent pipe fitted to the top of the expansion tank allows air to enter as coolant contracts.

Some expansion tanks can also function as a fill point for the system because the pressure cap is located on it instead of the radiator. In a sealed cooling system, it is not necessary to inspect the coolant level as often as an open system because it is sealed. Figure 5.6 shows the coolant expansion and contraction stages.



a. Coolant expansion stage



b. Coolant contraction stage

Figure 5.6: Sealed cooling systems

Comparison of air- and water-cooled systems

Table 5.1: Comparison of air- and water-cooled systems

Air-cooled systems	Water-cooled systems
They are simple in design with fewer parts.	They are more complex in design, requiring a radiator, hoses, a pump, coolant, etc.
They have lower maintenance costs and fewer parts to service.	Their maintenance cost is high due to more parts.
Lighter, which can improve efficiency.	Heavier due to coolant and additional components.

They are less efficient and may overheat in extreme conditions.	They are more efficient and have stable temperature control.
There is no risk of coolant freezing, making them ideal for very cold conditions.	They require antifreeze to prevent freezing in cold climates.
They are generally cheaper to produce and maintain.	They have higher production and maintenance costs.
They are noisier in operation.	Water used as a cooling medium absorbs some of the engine noise.
They are suitable for small engines, such as motorcycles.	They are suitable for most modern high-performance vehicles.
Obstructed airflow can lead to overheating in certain parts.	Cooling is generally consistent throughout the entire system.

Activity 5.3

Debate on the importance of thermostats

Two cars with a common problem were presented to two mechanics to work on a car each. Both mechanics diagnosed their car and were convinced that the cooling system's thermostat was not functioning, and which resulted in frequent overheating of the engine.

Mechanic A decided to replace the thermostat with a new one, which ended up solving the problem. Mechanic B decided that the car did not require a thermostat and so removed it completely, and the problem stopped anyway, and so exclaimed: "After all, thermostats are not so important in the cooling system of a car!"

1. Which of the two mechanics did the right thing?
2. Write down your reasons for your choice of answer.
3. Based on your reasons, prepare some notes to speak for, or against, in a debate on the topic: "After all, thermostats are not so important in an engine's cooling system.'

Activity 5.4

Working Principles of The Thermostat and Water-Cooled Systems

Your teacher will arrange a visit for the class to the school workshop. You will observe and record how the thermostat, pressurised and sealed water-cooling systems work in practice. You should note down any problems that can occur and come up with your own ideas on how they can be overcome.

UNIT 6

METAL TECHNOLOGY

Engineering Materials, Tools and Machines.

Introduction

Machine tools such as the lathe and shaping machine are essential in workshops and manufacturing because they allow the creation of precise and accurately shaped parts. Mastering these machines is important for machinists and engineers, as they are widely used in mechanical engineering and production processes. This lesson will introduce the lathe machine and the shaping machine explaining their main components, functions, and typical operations. We will learn how the lathe is used to shape, cut, and finish cylindrical parts, and how the shaping machine is used to create flat or contoured surfaces on workpieces. The lesson will also highlight safety practices and the correct techniques for operating these machines efficiently. By the end of this lesson, students should be able to describe the main components and uses of the lathe and shaping machines as well as explain common operations performed on these machines.

KEY IDEAS

- Knowledge on the use of shaping machines provides engineers the needed skills used in various industries, including manufacturing, automotive, aerospace and metalworking to produce parts with precise flat surfaces, grooves, slots and other geometric features.
- Lathe machines are used in various industries, including automotive, aerospace and manufacturing to produce parts such as shafts, pulleys, bolts, bushings and other parts of machines.
- The setup, operation and safety practices associated with shaping machines are essential for machinists and engineers, enabling them to produce accurate and high-quality components efficiently.
- They are particularly useful for producing keyways, splines and flat surfaces on small to medium-sized workpieces.

THE LATHE MACHINE

A lathe is a machine which removes excess material in the form of chips by rotating the workpiece against a stationary cutting tool. The lathe is one of the most important machine tools in the metalworking industry. A lathe operates on the principle of a rotating workpiece and a fixed cutting tool. The cutting tool is fed into the workpiece, which rotates about its axis, causing the workpiece to be formed into the desired shape. A lathe machine is also known as the mother/father of the entire tool family. A lathe machine is also known as "Centre Lathe", because it has two centres between which the job can be held and rotated.

Main Parts of the Lathe Machine

1. Bed
2. Headstock
3. Spindle
4. Tailstock
5. Carriage: Saddle, Apron, Cross-slide, Compound rest, Compound slide and Tool post
6. Feed mechanism
7. Lead screw
8. Feed rod

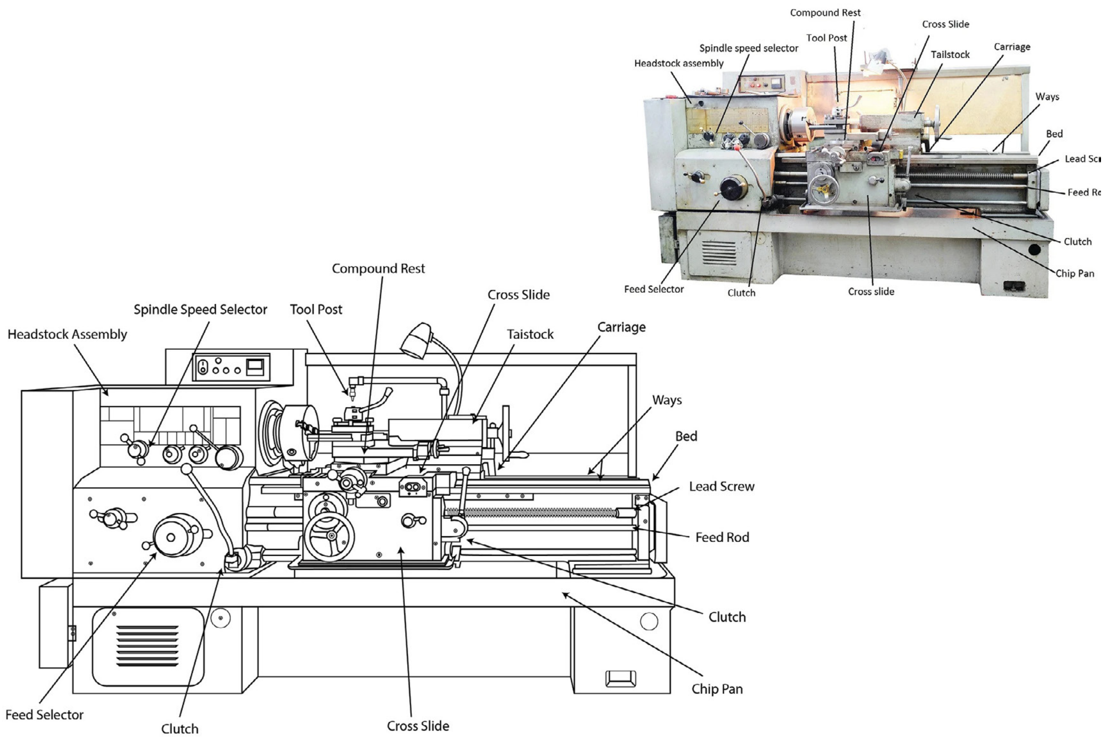


Figure 6.1: Main parts of the lathe machine

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Table 6.1: Functions of the main parts of the lathe machine

S/N	Part of The Lathe Machine	Function of Parts of The Lathe Machine
1	**Bed**	It supports all major components
2	**Headstock**	It holds the jaws for the work piece, supplies power to the jaws, and has various drive speeds
3	**Spindle**	The spindle rotates on two large bearings housed on the headstock casting
4	**Tailstock**	It supports the other end of the workpiece
5	**Carriage**	It is located between the headstock and tailstock on the lathe bed guide ways. It can be moved along the bed either towards or away from the headstock. It has several parts to support, move and control the cutting tool.
6	**The parts of the carriage**	Saddle, apron, cross-slide, compound rest, compound slide, tool post
7	**Feed Rod and Lead Screw:**	The feed rod is powered by a set of gears from the headstock

Types of Lathe Machines

The various designs and constructions of lathe machines have been developed to suit different machining conditions and usage. The following are the different types:

1. Engine Lathe or Centre Lathe

a. It is the most common type of lathe and is widely used in workshops.

b. The speed of the spindle can be widely varied as desired, which is not possible in a speed lathe.

2. Bench Lathe

a. Small lathe which can be mounted on the workbench.

b. It is used to make small, precision and light jobs.

3. Speed Lathe

a. It is named because of the very high speed of the headstock spindle.

b. It consists of a headstock, a tailstock and a tool post. It has no gearbox.

c. Applicable in wood turning, metal spinning and operations

4. Tool room lathe

a. It is like an engine lathe, designed for obtaining accuracy.

b. It is used for manufacturing precision components, dies, tools, jigs, etc., and hence it is called a tool room lathe.

5. Special-purpose lathes

a. Gap lathe

b. Instrument lathe

c. Facing lathe

d. Flow turning lathe

e. Heavy-duty lathe

6. Automatic Lathe

a. A lathe in which the work piece is automatically fed without the use of an operator.

b. It requires less attention after the setup has been made and the machine loaded.

7. Turret Lathe

a. A turret lathe is the adaptation of the engine lathe where the tailstock is replaced by a turret slide (cylindrical or hexagonal).

b. The tool post of the engine lathe is replaced by a cross slide, which can hold a number of tools.

8. Capstan Lathe

a. These are like turret lathes with the difference that the turret is not fixed but moves on an auxiliary slide.

b. These are used for the fast production of small parts.

Sizes of a lathe machine (Specifications of Lathe)

The size of a lathe is specified by the following point;

1. The length of the bed
2. Maximum distance between live and dead centres.
3. The height of centres from the bed
4. The swing diameter
5. The bore diameter of the spindle
6. The width of the bed
7. The type of the bed
8. Pitch value of the lead screw

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9. Horsepower of the motor
10. Number and range of spindle speeds
11. Number of feeds
12. Spindle nose diameter
13. Floor space required
14. The type of the machine

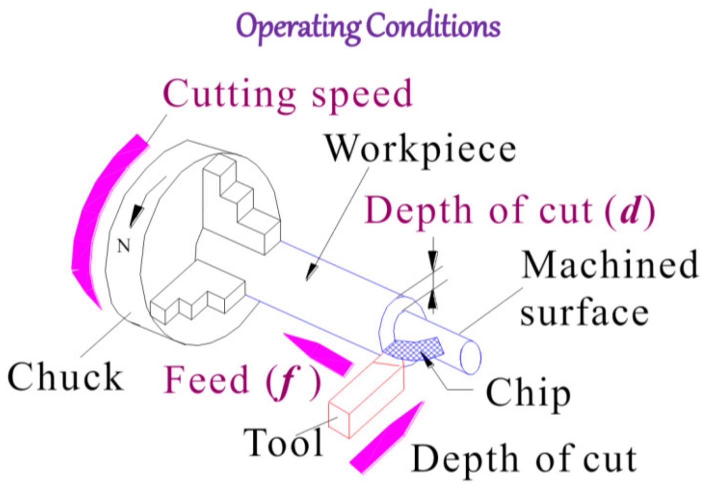

Figure 6.2: Parallel turning indicating operating conditions on the lathe machine

Cutting Speed of The Lathe Machine

The cutting speed for lathe work is defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting.

Table 6.2: Explanations of Operating Conditions of the Lathe Machine

S/N	OPERATING CONDITIONS	DESCRIPTIONS OF OPERATING CONDITIONS
1	**Feed**	Feed is defined as the distance that a tool advances into the work during one revolution of the headstock spindle. It is usually given as a linear movement per revolution of the spindle or job. Depth of cut refers to the distance the cutting tool penetrates the workpiece material during each pass.
2	**Machining time**	It is the time it takes to complete a particular cutting operation on a workpiece.

Lathe Operations

Operations, which can be performed in a lathe either by holding the workpiece between centres or by a chuck, include:

a. Straight turning
b. Shoulder turning
c. Taper turning
d. Chamfering
e. Eccentric turning
f. Thread cutting
g. Facing
h. Forming
i. Filing
j. Polishing
k. Grooving
l. Knurling
m. Spinning
n. Spring winding

Operations which are performed by holding the work by a chuck or a faceplate or an angle plate are:

a. Undercutting
b. Parting-off
c. Internal thread cutting
d. Drilling
e. Reaming
f. Boring
g. Counter boring
h. Taper boring

Operations which are performed by using special lathe attachments are:

a. Milling
b. Grinding

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Table 6.3: Some of the operations carried out on the lathe machine

S/N	TYPE OF OPERATION	DESCRIPTION OF OPERATION
1	**Turning**	To remove material from the outside diameter of a workpiece to obtain a finished surface.
2	**Facing**	To produce a flat surface at the end of the work piece or for making face grooves.
3	**Boring**	To enlarge a hole or cylindrical cavity made by a previous processor to produce circular internal grooves.
4	**Drilling**	To produce a hole in the work piece.
5	**Reaming**	To finish the drilled hole.
6	**Threading**	To produce external or internal threads on the work piece.
7	**Knurling**	To produce a regularly shaped roughness on the workpiece

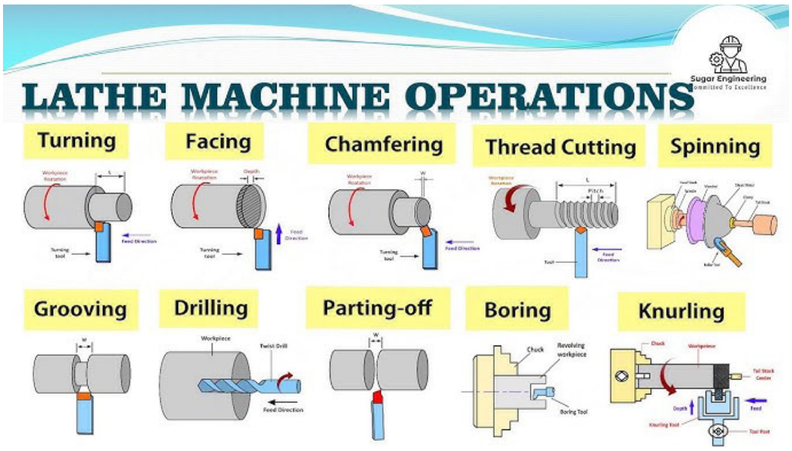


Figure 6.3: Lathe operations

Accessories and Attachments of The Lathe

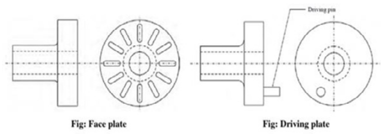
Lathes come with many accessories provided by the manufacturer to support different lathe operations. The main lathe accessories include centres, catch plates and carriers, chucks, collets, face plates, angle plates, mandrels, and rests. These accessories are used either to hold and support the workpiece or to hold the cutting tool. Attachments are additional pieces of equipment provided for specific tasks.

Common lathe attachments include stops, ball turning rests, thread chasing dials, milling attachments, grinding attachments, gear cutting attachments, turret attachments, crank pin turning attachments, and taper turning attachments. These attachments allow the lathe to perform special operations beyond the basic turning and shaping tasks.

Work holding devices

The work holding devices are used to hold and rotate the workpieces along with the spindle. Different work holding devices are used according to the shape, length, diameter and weight of the workpiece and the location of turning on the work. They include: Chucks, Face plate, driving plate, Catch plate, Carriers, Mandrels, Centres, Rests.

Table 6.4: Work holding devices

S/N	Device	Description of Device	Sketch/Picture of Device
1	Chucks	The chuck is one of the most important devices for holding and rotating a job in a lathe. It is attached to the headstock spindle of the lathe. The internal threads in the chuck fit onto the external threads on the spindle nose. Short, cylindrical, hollow objects or those of irregular shapes, which cannot be conveniently mounted between centres, are easily and rigidly held in a chuck. Jobs of short length and large diameter or of irregular shape, which cannot be conveniently mounted between centres, are also held quickly and rigidly in a chuck	
2	Face plates	Face plates are employed for holding jobs, which cannot be conveniently held between centres or by chucks. A face plate possesses the radial, plain and T slots for holding jobs or workpieces by bolts and clamps. Face plates consist of a circular disc bored out and threaded to fit the nose of the lathe spindle. They are heavily constructed and have strong thick ribs on the back. They have slots cut into them; therefore nuts, bolts, clamps and angles are used to hold the jobs on the face plate. They are accurately machined and ground. Angle plates are used in conjunction with a face plate when the holding surface of the job should be kept horizontal.	 
3	Driving plate	The driving plate is used to drive a workpiece when it is held between centres. It is a circular disc screwed to the nose of the lathe spindle. It is provided with small bolts or pins on its face. Workpieces fitted inside straight tail carriers are held and rotated by driving plates.	

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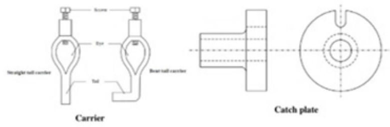
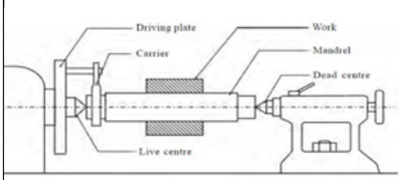
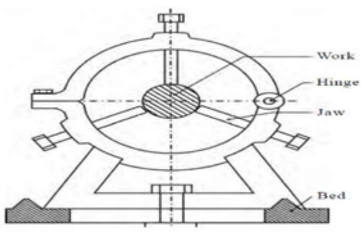
4	Catch plate	When a workpiece is held between centres, the catch plate is used to drive it. It is a circular disc bored and threaded at the centre. Catch plates are designed with 'U' – slots or elliptical slots to receive the bent tail of the carrier. Positive drive between the lathe spindle and the workpiece is affected when the workpiece fitted with the carrier fits into the slot of the catch plate.	 
5	Carrier	When a work piece is held and machined between centres, carriers are useful in transmitting the driving force of the spindle to the work by means of driving plates and catch plates. The work is held inside the eye of the carrier and tightened by a screw.	
6	Mandrels	A mandrel is a device used for holding and rotating a hollow job that has been previously drilled two centres. It is rotated by the lathe dog and the catch plate and it drives the work by friction.	
7	Holding work between centres	The most common method of holding the job in a lathe is between the two centres generally known as the live centre (headstock centre) and dead centre (tailstock centre). They are made of very hard materials to resist deflection and wear and they are used to hold and support the cylindrical jobs.	
8	The steady rest	A rest is a lathe device, which supports a long slender job, when it is turned between centres or by a chuck, at some intermediate point to prevent bending of the job due to its own weight and vibration set up due to the cutting force that acts on it. There are two different types of rests: Steady rest and Follower rest.	

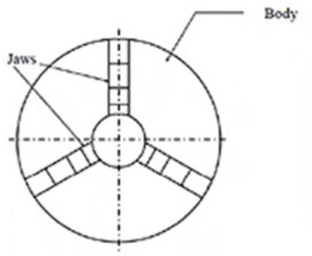
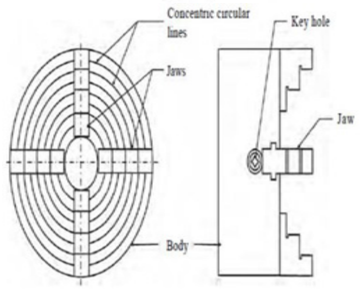
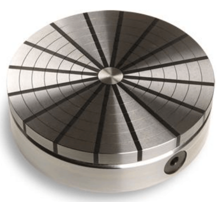
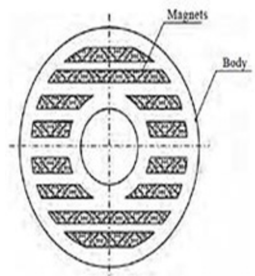
The most commonly used lathe chucks:

- **a.** Three-jaw universal
- **b.** Four-jaw independent
- **c.** Magnetic chuck
- **d.** Collet chuck

e. Air or hydraulic chuck operated chuck

f. Combination chuck.

g. Drill chuck.

Device	Description of Device	Sketch/Picture of Device
Three-jaw Universal Chuck	The three jaws fitted in the three slots may be made to slide at the same time by an equal amount by rotating any one of the three pinions by a chuck key. This type of chuck is suitable for holding and rotating regular-shaped workpieces like round or hexagonal rods about the axis of the lathe. Workpieces of irregular shapes cannot be held by this chuck. The work is held quickly and easily as the three jaws move at the same time.	 
Four-Jaw Independent Chuck:	There are four jaws in this chuck. Each jaw is moved independently by rotating a screw with the help of a chuck key. A particular jaw may be moved according to the shape of the work. Hence, this type of chuck can hold works of irregular shapes, but it requires more time to set the work up aligned with the lathe axis. Experienced turners can set the work about the axis quickly. Concentric circles are inscribed on the face of the chuck to enable quick centering of the workpiece	 
Magnetic Chuck	The holding power of this chuck is obtained by the magnetic flux radiating from the electromagnet placed inside the chuck. Magnets are adjusted inside the chuck to hold or release the work. Workpieces made of magnetic material only are held in this chuck. Very small, thin and light works which cannot be held in an ordinary chuck are held in this chuck.	 

Collet chuck	Collet chuck has a cylindrical bushing known as collet. It is made of spring steel and has slots cut lengthwise on its circumference, so it holds the work with more grips. Collet chucks are used in capstan lathes and automatic lathes for holding bar stock in production work.	

Safety precautions to be observed when operating the lathe machine

1. Always wear approved safety glasses.
2. Roll up sleeves, remove tie and tuck in loose clothing.
3. Never machine if the safety guards are removed.
4. Stop the lathe before measuring work or cleaning, oiling or adjusting the machine.
5. Always remove the chuck key after use.
6. Always remove chips with a brush.

SHAPING MACHINE

A shaper is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line. It is intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical or inclined. In general, the shaper can produce any surface composed of straight-line elements.

Working Principles of Shaper

The job is fixed rigidly in a suitable vice or directly clamped on the machine table. The tool is held in the tool post mounted on the ram of the machine. This ram reciprocates to and fro and in doing so makes the tool cut the material in the forward stroke. No cutting takes place during the return stroke of the ram. It is called the idle stroke. The job is given an intended feed in a direction normal to the line of action of the cutting tool.

Shaper machine operations

Generally, there are four types of operations performed on a shaper:

1. Vertical Cutting Operation
2. Horizontal Cutting Operation
3. Inclined Cutting and

4. Angular or Irregular Cutting Operation

Types of Shapers

1. According to the type of mechanism used for giving reciprocating motion to the ram:
   a. Crank type.
   b. Geared type.
   c. Hydraulic type.
2. According to the position and travel of the ram:
   a. Horizontal type
   b. Vertical type
   c. Travelling head type
3. According to the type of design of the table:
   a. Standard shaper
   b. Universal shaper
4. According to the type of cutting stroke:
   a. Push type
   b. Draw type

Shaper Machine Specification

The following are some specifications of a shaper:

1. Weight of the Machine:
2. Floor space required.
3. Maximum stroke of Ram
4. Drive types (Hydraulic, Gear and Crank type)
5. Input Power
6. Cutting to Return Stroke ratio
7. Angular Movement of the table and
8. Feed

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Principal Parts of a Shaper

Figure 6.4 below shows the parts of a standard shaper. The main parts are labelled:

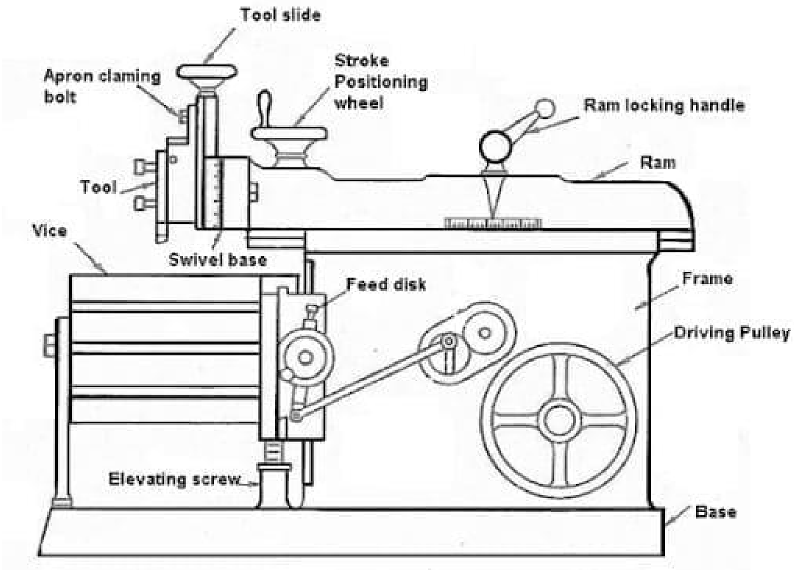

Figure 6.4: Principal parts of a shaper

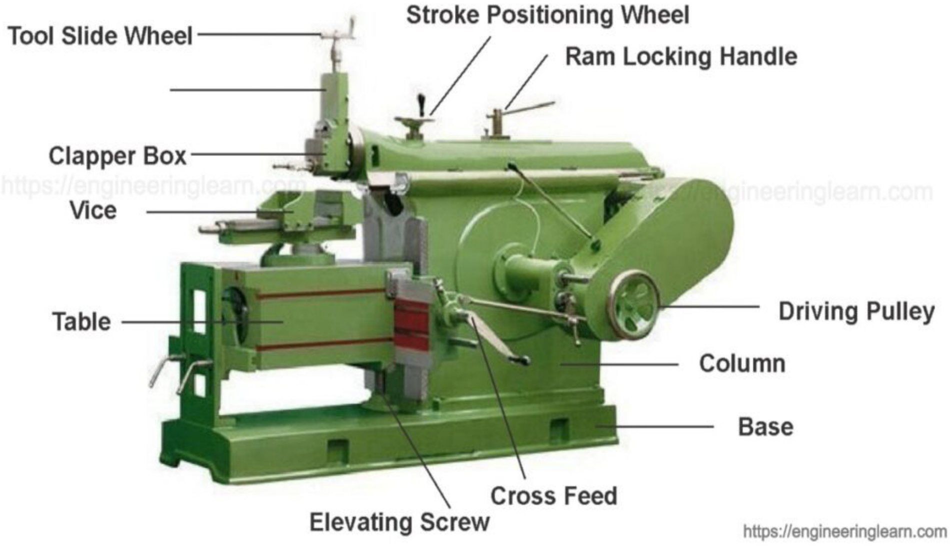

Figure 6.5: Standard Shaper

Table 6.5: Important parts of the sharper machine and their functions

S/N	Part	Description/functions of the part
1	**Base**	**Base:** It is a rigid and heavy cast iron body to resists vibration and takes up a high compressive load. It supports all other parts of the machine, which are mounted over it. The base may be rigidly bolted to the floor of the shop or to the bench according to the size of the machine. **Column:** The column is a box-shaped casting mounted upon the base. It houses the ram-driving mechanism. Two accurately machined guide ways are provided on the top of the column on which the ram reciprocates.

2	**Cross rail**	The shaper's cross rail has two parallel guide ways on its top in the vertical plane perpendicular to the rail axis. It is mounted on the front vertical guide ways of the column. It consists of mechanism for raising and lowering the table to accommodate different sizes of jobs by rotating an elevating screw which causes the cross rail to slide up and down on the vertical face of the cross rail.
3	**Column**	A horizontal cross feed screw is fitted within the cross rail and parallel to the top guide ways of the cross rail. This screw actuates the table to move in a crosswise direction.
4	**Saddle**	The saddle is on the cross rail and holds the table on top. Crosswise movement of the saddle by rotation the cross-feed screw by hand or power causes the table to move sideways.
5	**Table**	The table is a box-like casting having T-slots both on the top and sides for clamping the work. It is bolted to the saddle and receives crosswise and vertical movements from the saddle and cross rail.
6	**Ram**	It is the reciprocating part of the shaper, which reciprocates on the guideways provided above the column. The ram is connected to the reciprocating mechanism contained within the column.
7	**Tool head**	The tool head of a shaper performs the following functions: • It holds the tool rigidly, • It provides vertical and angular feed movement of the tool, and • It allows the tool to have an automatic relief during its return stroke.

Shaper mechanism

- The metal is removed in the forward cutting stroke, while in the return stroke, no metal is removed during this period. To reduce the total machining time, it is necessary to reduce the time taken by the return stroke. The shaper mechanism should be so designed that it can allow the ram holding the tool to move at a comparatively slower speed during the forward cutting stroke, and during the return stroke, the ram moves faster rate to reduce the idle return time. The mechanism is called the quick return mechanism.

Table 6.5: Advantages and disadvantages of the shaper machine

Advantages of the Shaper Machine	Disadvantages of the Shaper Machine
1. The tool (single-point cutting tool) speed is low. **2.** The workpiece can be held easily in this machine. **3.** It produces flat or angular surfaces. **4.** Setup of the shaper and tool changing is easy.	**1.** The cutting speed is not very high. **2.** Only one cutting tool can be fixed. There is no option for more than one cutting tool.

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The Applications of Shaper Machine

1. A shaping machine is used to make internal splines.
2. It generates straight and flat surfaces, either horizontal, vertical or angular planes.
3. It also makes gear teeth.
4. It makes keyways in pulleys or gears.
5. It is also used for producing contours of concave/convex or a combination of these.

Conclusion

This unit provided an in-depth description of the parts and the uses of the lathe and shaping machines. The unit delved into the types, parts and functions of the lathe machine. The unit also highlighted the shaper machine, its parts and functions. Operations performed on the shaping machine have also been discussed. This unit further provided activities and review questions with solutions to facilitate the understanding of learners.

Activity 6.1

Group Activities on The Lathe

1. In groups of not more than five, watch a video on the working principles of the centre lathe. Then, using a table, identify the main parts of the centre lathe.
2. Your teacher will arrange a visit to a nearby mechanic's shop for you. Identify and list the accessories of a centre lathe. Then, using neat sketches and a table, discuss the accessories of a centre lathe.
3. Using tables and pictures, discuss in your groups the principles of operations performed on a lathe machine.
4. Using a table list, discuss the working principles of the shaping machine. Now, prepare a table for identifying and brainstorming the main parts of the shaping machine.
5. Using tables and pictures, discuss the operations performed on the shaping machine.
6. Your teacher will arrange a visit to a local metal workshop for you to identify the major parts of the lathe and shaping machines. Now, do the following:
   a. Draw freehand pictorial sketches of the parts of the lathe and shaping machines.

b. Brainstorm and record on a table the functions of the lathe and shaping machines in the school workshop.

c. Observe and demonstrate the uses of the lathe and shaping machines.

Note: *Use ICT tools to watch videos on some operations performed on the lathe and shaping machines.*

UNIT 7

AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

The engine lubrication system plays a vital role in ensuring the longevity, performance, and efficiency of internal combustion engines. This complex system distributes oil to moving parts, reducing friction, overheating, and wear. Without proper lubrication, engines risk extreme overheating and seizure.

This unit provides an in-depth look at the engine lubrication system, covering its importance, main components, and the various methods it employs to keep engine parts lubricated. Additionally, it discusses the structure and function of key parts, including the oil sump, oil filter, oil pump, oil galleries, oil cooler, and oil pressure indicator. Overall, you will learn how each part contributes to a continuous oil flow, which is essential for maintaining a smooth and efficient operation of the engine.

KEY IDEAS

- Effective engine lubrication is crucial for preventing premature wear and tear.
- Engine design influences lubrication system configuration.
- Filtration plays a vital role in maintaining oil quality and engine longevity.
- Monitoring oil pressure is essential for detecting potential engine problems.
- Proper oil circulation ensures consistent engine performance and efficiency.

ENGINE LUBRICATION SYSTEM

The engine lubrication system is a vital component of modern internal combustion engines, which ensures maximum performance, efficiency, and longevity of the engine. This very essential system distributes oil to the moving parts in the engine to reduce friction between surfaces in close contact. The lubrication system also reduces overheating and wear on moving parts. The absence of a proper lubrication system can result in extreme overheating and engine seizure.

The engine lubrication system operates by continuously circulating oil throughout the engine to reduce friction, cool components, and clean away contaminants. The process begins in the oil pan or sump, located at the base of the engine, where oil is stored. An oil pump draws oil from the sump, pressurises it, and circulates through the engine.

The pressurised oil is directed through an oil filter, which removes contaminants, debris, and metal particles that could harm engine components. The clean, pressurised oil moves through small channels, known as oil galleries, to reach certain parts of the engine, such as bearings, pistons, and the camshaft, that require lubrication. The lubricating oil forms a thin coating or film between moving parts, reducing direct metal-to-metal contact and thus minimising wear and friction. As the oil moves through the engine, it absorbs heat generated during combustion, helping to regulate the engine's temperature.

Finally, the oil returns to the pan, completing the cycle. In the sump, it cools before it is drawn up by the pump to repeat the cycle. This continuous flow of oil keeps the engine running smoothly, prolonging its life and maintaining its efficiency. Figure 7.1 shows a Layout of the engine lubrication system.

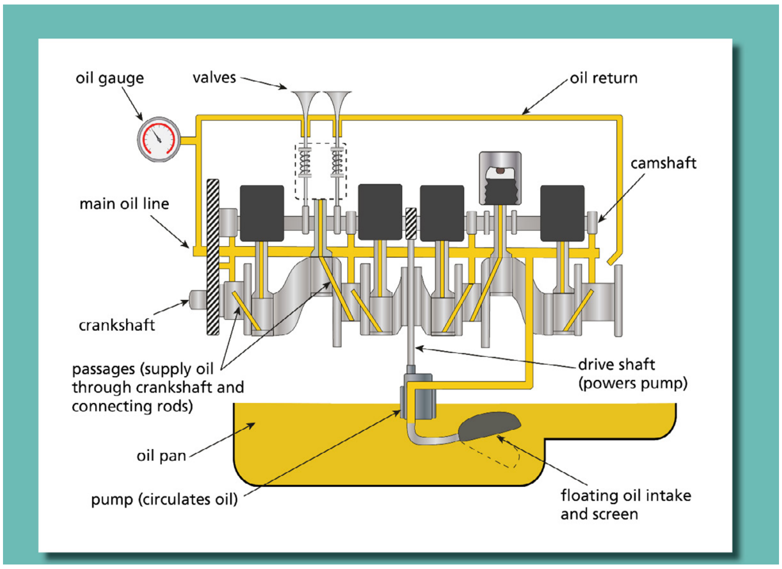

Figure 7.1: Layout of the engine lubrication system

Lubrication

Lubrication is the method of reducing friction between mating surfaces by the application of a lubricant. The engine oil is the basic form of lubricant for the engine.

Importance of lubrication

The lubrication system offers the following advantages:

1. Lubricates all moving parts to prevent wear.
2. Minimises friction between moving components.
3. Assists in cooling the engine.
4. Aids in sealing piston rings on the surface of the cylinder wall.
5. Reduces noise to ensure mating parts run quietly and smoothly.

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6. Cleans and suspends dirt within the oil until it can be drained from the engine.
7. Neutralises acids produced during the combustion process.
8. Protects against rust and corrosion.

The main components of the internal combustion engine to be lubricated

Various components of the engine require adequate lubrication to ensure efficient performance, minimise friction, and prevent premature wear. The following are the main components that require lubrication:

1. Crankshaft main bearings
2. Big end bearings
3. Piston pins and small end bushes
4. Cylinder walls
5. Piston rings
6. Timing Gears
7. Camshaft and bearings
8. Valves
9. Tappets and push-rods
10. Oil pump parts
11. Water pump bearings
12. In-line Fuel Injection Pump bearings
13. Turbocharger bearings (if fitted)
14. Vacuum pump bearings (if fitted)

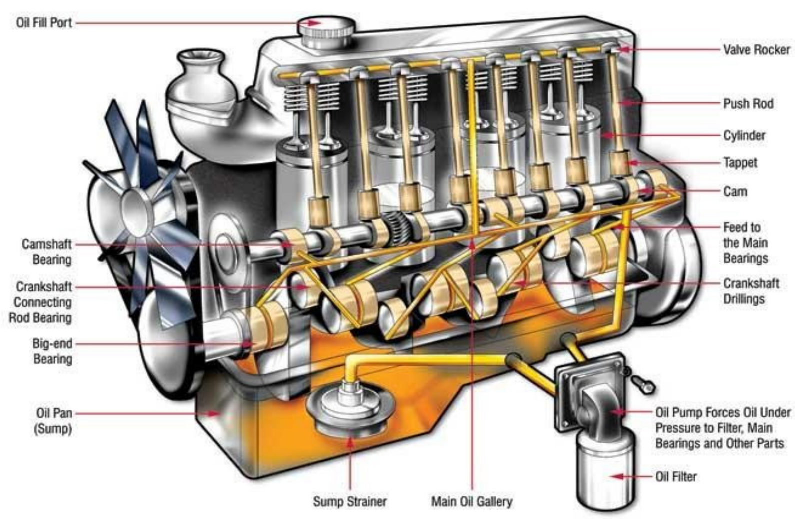

Figure 7.2: Oil distribution channels in the engine.

Main Parts of An Engine Lubrication System

Oil sump

The oil pan or sump is bolted to the bottom of the engine block and acts as a seal for the crankcase. There are two sump systems used in engine lubrication. They are wet sump and dry sump.

Wet sump

In this system, the sump serves as a reservoir for engine oil. It is designed to hold the oil needed to lubricate the engine during operation, along with an extra reserve. Additionally, the oil pan aids in cooling the oil as it comes into contact with outside air. The oil pump draws oil from the pan, pressurises it, and sends it to the main oil gallery, where it is distributed to bearing surfaces and the valve train. The oil then drains back into the pan, maintaining a continuous flow throughout the engine. Most wet sump engines use a dipstick to check the level of oil in the sump.

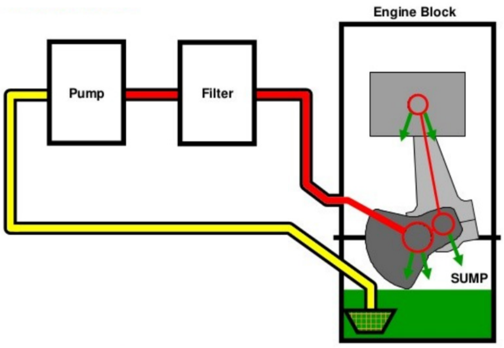

Figure 7.3: Wet sump lubrication system

Dry sump

In a dry sump system, the oil pan does not store oil. The oil is stored in a separate container (reservoir) which is mounted away from the engine. The oil pump sends oil directly to the crankshaft, valve train, and other parts that require lubrication. After lubricating, the oil drains into the sump. Some dry sumps use an additional pump (called a scavenging pump) to send the lubricating oil back into the reservoir where it is stored.

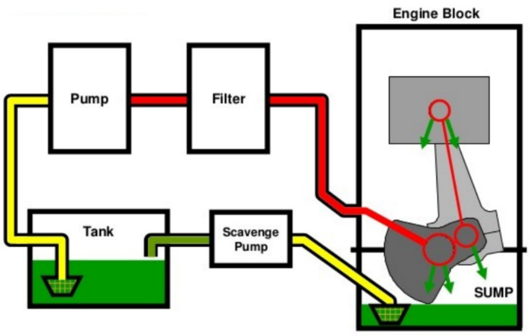

Figure 7.4: Dry sump lubrication system.

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Engine oil filter

All the oil from the pump first flows through the oil filter. The purpose of the oil filter is to trap dirt, carbon deposits and metal particles and prevent them from reaching the parts of the engine that need to be lubricated. If these metal particles are not removed, they can cause wear to the parts of the engine that move in close contact.

The oil filter consists of a metal container filled with a special filtering material made of paper or other materials. Most vehicles today use a full-flow filtration system, where all oil going to the engine bearings first passes through the filter. However, if the filter becomes clogged, a relief valve lets oil bypass the filter to keep the engine lubricated, even if the oil is not filtered. After all, dirty oil is better than no oil at all.

Figure 7.5: Oil filter

Oil pump

The oil pump serves as the heart of the lubrication system. Just as the human heart circulates blood through veins, the engine's oil pump circulates oil through the engine's oil galleries. The oil pump sucks oil from the sump through its pickup tube, which is an extension that connects the pump and the oil stored in the sump. The end of the pickup tube is covered with a strainer or a filter screen, which remains under in the oil to trap large particles before they can reach the pump.

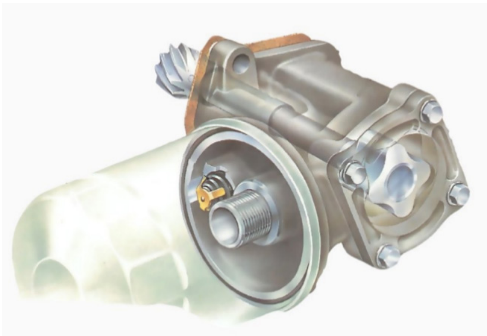

Figure 7.6: An oil pump assembly

The oil pump is designed with an oil pressure relief valve, which prevents excessive system pressure at higher engine speeds. When oil pressure rises above the recommended value set for the pump, the spring-loaded pressure relief valve opens to allow excess oil to bypass the system and return directly to the sump.

The most commonly used oil pumps are the rotor and gear types. Oil pumps may be driven by the camshaft, directly by the crankshaft or by a chain or gear mechanism.

Figure 7.7: Gear-type oil pump

Figure 7.8: Gear-type oil pump

The oil galleries

The oil galleries are interconnected channels or pathways drilled through the engine block during production. From the filter, the oil flows into the galleries, where it is directed to various engine parts. The crankshaft has its own passages, called oilways, which carry oil from the main bearings to the connecting rod bearings. Engines with features like a remote oil filter, an oil cooler, or a dry sump system use external oil lines to direct oil to specific areas.

Oil cooler

An oil cooler helps keep engine oil at the right working temperature. Many diesel, high-performance, and turbocharged engines use an external oil cooler, where oil flows from the pump, through the cooler, and then into the engine. The cooler looks like a small radiator and is usually mounted near the front of the engine or inside the main radiator. The coolant and air flowing through or around it help to remove heat from the oil.

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Figure 7.8: An oil cooler

The oil pressure indicator/light

The purpose of the oil pressure indicator is to signal or warn the driver of low oil pressure in the system. The oil gauge shows the actual pressure in the engine, while the warning light signals when the oil pressure is too low.

Figure 7.9: A mechanical oil pressure gauge

Activity 7.1

Principle of the engine lubrication system

1. Watch the video 'Engine Lubrication System' at: https://www.youtube.com/watch?v=9lse1SfDq7M&t=160s
2. Carefully follow the step-by-step process of the lubrication system.
3. Note down what things are different from what you have read in your learner material under the engine lubrication system.
4. Based on the video you watched, briefly explain the function of the engine lubrication system.
5. Seek the opinion of at least two colleagues and compare their answers with your answer.
6. Share your answer with them as well.

7. Join your friends to research, discuss and record the applications of lubrication in other areas.

Activity 7.2

Layout of the engine lubrication system

1. Search the internet or ask the teacher to arrange a visit to your school's auto workshop to examine a cutout model of an engine.
2. Sketch the layout of the lubrication system, showing clearly the major components.
3. Use arrows to indicate the directional flow of oil in the system.
4. In addition to your sketch, list the main components of the engine that require lubrication.
5. How do oil galleries differ from water jackets in the cylinder block?

Activity 7.3

Procedure for changing engine oil.

Tools and materials needed

1. Spanner
2. Oil filter wrench
3. Oil drain pan
4. Funnel
5. New oil filter
6. New oil (specified grade, correct quantity)

CAUTION: Wear your PPE (especially overcoat, gloves) and strictly observe all workshop safety rules at all times. This activity must be supervised by a qualified mechanic.

Activity Steps

1. Ensure that the vehicle is properly parked on a level surface.
2. Select the required tools.
3. Start the engine and run it for a few minutes to warm up the oil. Switch off the engine.
4. Place the drain pan under the oil drain plug, loosen the plug with a spanner, and allow the oil to fully drain.

5. Use an oil filter wrench to carefully unscrew the old filter.
6. Apply lubricant to the rubber gasket of the new filter and screw it on by hand until it feels very tight.
7. Replace the drain plug and tighten it securely.
8. Using a funnel, pour the recommended amount of new oil into the oil filler hole on top of the engine.
9. Use the dipstick to check the oil level to ensure the oil has reached the correct level.
10. Dispose of the old oil properly if it cannot be reused for other purposes apart from lubrication.
11. Start the engine and let it run briefly. Let it cool a little and check the oil level using the dipstick
12. Check for any leaks around the filter and drain plug.

UNIT 8

METAL TECHNOLOGY

Engineering Materials, Tools and Machines.

Introduction

The milling machine is an important and useful tool in manufacturing, used to shape, cut, and finish materials such as metals and plastics. It removes material from a workpiece using a rotating multi-tooth cutter, allowing precise shaping of parts with complex designs. Understanding milling operations is important because these machines are widely used in industries where accuracy and efficiency are essential, such as aerospace, automotive, and tooling. This lesson will cover the main concepts of milling operations and the role of cutting fluids. Students will learn how milling machines work, the purpose of cutting fluids in reducing friction, controlling heat, and removing chips, and how these factors improve surface finish, tool life, and machining efficiency.

KEY IDEAS

- Milling machine removes material from a workpiece using a rotating multi-tooth cutter.
- Milling machines allow the production of parts with complex shapes and accurate dimensions
- Cutting fluids cool and lubricate the cutting area, reducing friction and heat during milling operations.
- Proper use of cutting fluids extends the life of cutting tools and improves the surface quality of machined parts.
- Milling machines and cutting fluids are widely used in industries

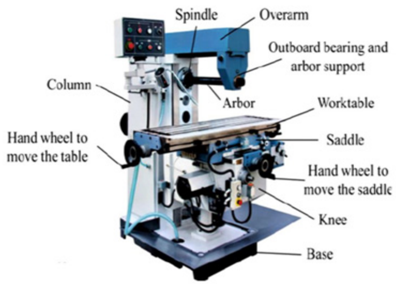
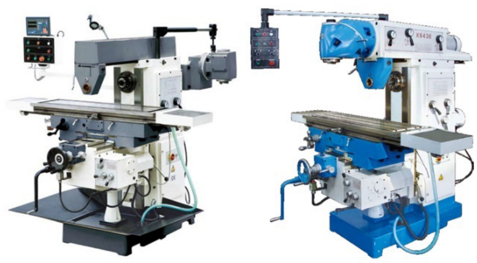
THE MILLING MACHINE

Milling is a process of removing metal by feeding the work against a rotating multipoint cutter. The machine tool intended for this purpose is known as milling machine. A milling machine is a versatile tool used in manufacturing and machining processes. It involves using rotating cutters to remove material from a workpiece to shape, size, or finish it. A milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads and helical surfaces of various cross-sections. The surface obtained by this machine tool is superior in quality and more accurate and precise.

Types of Milling Machine

There are two types of milling machine. They are the horizontal milling machine and the vertical milling machine.

Table 8.1: Showing Types, Description and Pictures of Milling Machines

S/N	Type of Milling Machine	Description	Sketch/Picture of Milling Machine
1	**a. Horizontal or knee milling machine**	The column of the horizontal or knee type milling machine is mounted vertically upon the base. It has an overhang called a knee which slides up and down the front of the machine and to which the cross-slide and the adjustable worktable are attached. The knee is designed to move up and down accurately on the guide ways of the column. The saddle and table are mounted on the knee. The horizontal machine has two types: the universal milling machine and the plain milling machine.	
	b. Universal milling machine	The table of a universal milling machine can be swivelled by 45º on either side allowing helical milling works to be performed. It is named so because it can be adapted for a very wide range of milling operations. Various milling attachments like an index head, vertical milling head, slot milling head and rotary table can be mounted. It can machine drills, reamers, gears, milling cutters with a very high degree of accuracy and so has an important place in a workshop.	

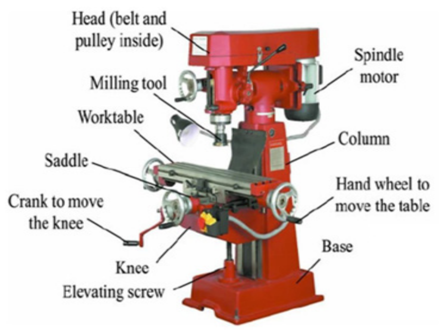
	c. Plain milling machine	It is rigid and sturdy. Heavy workpieces are mounted and machined on the machine. The work mounted on the table is moved vertically, longitudinally and crosswise against the rotating cutter. The table cannot be rotated. It is also called a horizontal milling machine because the cutter rotates in horizontal plane.	
2	**Vertical milling machine**	The vertical milling machine has its spindle positioned at right angles to the table. The cutter is moved vertically or at an angle by swivelling the vertical head of the machine. The machine is adapted for machining slots and flat surfaces by moving the table. By mounting end mills and face milling cutters on the spindle, vertical milling and internal milling operations are performed	

Table 8.2: Parts of the milling machine

S/N	PART	DESCRIPTION OF PART OF MILLING MACHINE
1	**Arbor**	It is between the column and the outer arbour yoke. The cutter is fitted on the arbour.
2	**Outer arbour yoke**	It is at the end of the overarm and used as a support for the arbour.
3	**Overarm**	Used for positioning the outer arbour yoke.
4	**Knee**	The overhang in front carries the worktable that slides up and down.
5	**Knee longitudinal adjustment handle**	Used to move the vertical feed of the table, but is automatically disengaged whenever the power is engaged.
6	**Table traverse lever**	Used to control the direction of movement of the table. It also controls longitudinal feed.
7	**Automatic feed lever**	Used to engage and disengage the automatic mechanism of the worktable.
8	**Main drive clutch**	Used for starting and stopping the arbour of the horizontal miller or the spindle arm of the vertical miller.

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9	**Feed selector lever**	Used for increasing or reducing the automatic-feed rate of the worktable.
10	**Speed selector lever**	Used for selecting a required speed of the arbour or spindle.
11	**Worktable**	Used for holding the work. It moves perpendicular to the arbour.
12	**Milling cutters**	Milling cutters are essential tools used in milling machines to perform various cutting operations. These cutters come in a wide range of shapes, sizes, and configurations, each designed for specific types of milling tasks.
13	**Saw tooth cutters**	They are produced in either straight or spiral form. Saw teeth are used for making metal-slitting cutters and smaller sizes of plain milling cutter. The cutting edge is backed off for about 5o to give clearance. The teeth may either be form-relived or profile-ground.
14	**Form tooth cutters**	A form cutter is made by leaving a land or relieving a land of a considerable width between the grooves and then backing off or relieving the land eccentrically. The formed cutter may be used with another cutter to make a gang. The main advantage of the formed cutter is that it can be sharpened many times without changing the shape of the cutting edge.
15	**Inserted tooth cutter**	The teeth made of high-speed steel are inserted and rigidly held in a mild steel or cast-iron blank. Worn or broken blades can be easily replaced by new blades.

Figure 8.1: Milling cutters

Milling operations

Milling operations refer to the different machining processes carried out using a milling machine to remove material from a workpiece. These operations involve a rotating multi-tooth cutter that removes small chips of material as it moves over the surface of the workpiece.

Table 8.3: Milling operations

S/N	TYPES OF MILLING OPERATION	DESCRIPTION OF OPERATION
1	**Peripheral milling**	The machining is performed by the cutting edges on the periphery of the milling cutter. It is classified under two headings:
2	**Up milling**	In this method, the workpiece mounted on the table is fed against the direction of rotation of the milling cutter. The cutting force is at minimum during the beginning of the cut and maximum at the end of cut. The thickness of chip is more at the end of the cut. As the cutting force is directed upwards, it tends to lift the workpiece from the fixtures. A difficulty is felt when pouring coolant on the cutting edge. Due to these reasons the quality of the surface obtained by this method is wavy. This machine being safer, is commonly used and sometimes called conventional milling.
3	**Down milling**	The workpiece mounted on the table is moved in the same direction as the milling cutter's rotation. The cutting force is maximum at the beginning and minimum at the end of cut. The chip thickness is more at the beginning of the cut. The workpiece is not disturbed because of the bite of the cutter on the work. The coolant directly reaches the cutting point and as a result the quality of surface finish obtained is high. Because of the backlash error between the feed screw of the table and the nut, vibration is setup on the workpiece
3	**Profiling**	Milling to a predetermined outline by means of a guide bar and template.
4	**Gang milling**	When two or more cutters are used together on one arbour.
5	**Routing**	Milling to an irregular outline while guiding the hand.
6	**Straddle milling**	When two side milling cutters are used and two sides of the work are milled at the same time.
7	**Milling Flutes**	The production of grooves or the cutting of flutes on drills, taps and reamers.
8	**Angular milling**	The production of flat surfaces at an inclination to the axis of the cutter.
9	**Face milling**	The production of flat surfaces at right angles to the axis of the cutter.

10	**Plain milling or slab milling**	The production flat surfaces are parallel to the axis of the cutter.
11	**Form milling**	The production of concave and convex surfaces.

The "up milling" and "down milling" operations

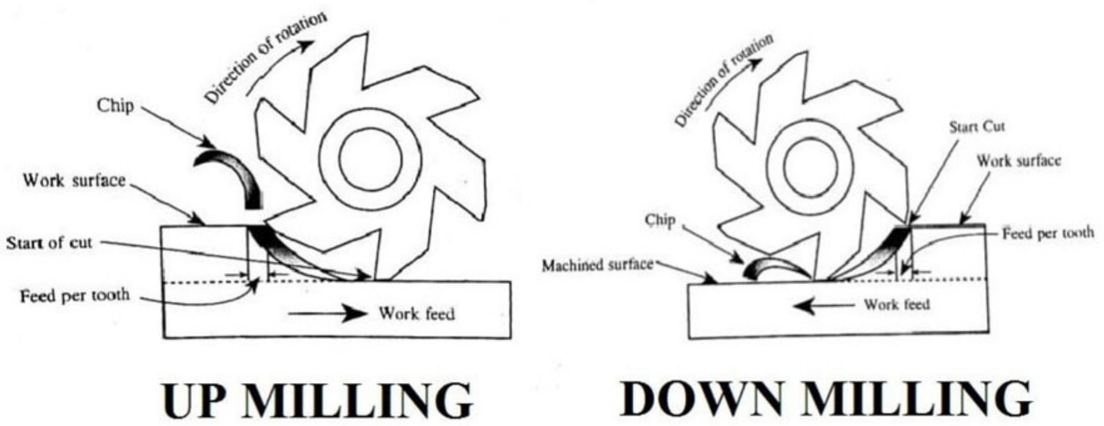

Figure 8.2: Up milling and down milling operations

CUTTING FLUIDS

Cutting fluids (metalworking fluid, coolant) are liquids used in metalworking operations for reducing friction between the work piece and the tool and for removal of the heat generated by the friction. Cutting fluids are designed specifically for metalworking processes such as machining and stamping. There are various kinds of cutting fluids which include oils, oils-water emulsions, pastes, gel, aerosols (mists) and air or other gases.

The Most Common Cutting Fluids

Straight oils are one of the most common oil types used in metalworking operations. They are also known as neat oils, mineral oils or petroleum-based oils. They consist primarily of mineral oil, derived from crude oil through the refining process.

1. **Spirit:** This is a soluble microemulsion lubricant for cutting equipment.
2. **Lactuca:** This is a soluble microemulsion lubricant for general machining equipment.
3. **Martol:** This is a soluble deformation oil for steel and aluminium cutting.
4. **Drosera:** This is a mineral multipurpose oil for high-speed cutting tools.

Table 8.4: Types of cutting fluid: Advantage and Disadvantages

Type of cutting fluid and description	Advantages	Disadvantages
Straight metalworking oils: These fluids are mineral oil based. They contain no water. Metalworking functionality of straight oils may be improved by various additives: fatty oils for better wettability; sulphur, chlorine or phosphorous for extra pressure conditions (EP) and better lubrication. Straight oils are used in low-speed applications, for metalworking stainless steels and other poorly machinable metals and in operations in which good lubrication is necessary (honing, deep drilling etc.).	• They have excellent lubrication. • They have good corrosion protection. • They have an easy maintenance effect.	• They have poor heat removal. • They are toxic. • They have high viscosity. • They are flammable (can catch fire easily
Emulsifiable metalworking oils: Emulsifiable oils are mineral oil based and contain emulsifiers and other additives. Emulsifiers reduce interfacial tension between oil droplets and water, providing a stable, finely dispersed oil emulsion in water. Emulsifiable oils are mixed with water in a concentration of 2-10%.	• They have good lubrication. • They have good cooling capability. • They have good corrosion protection effect. • They are less expensive. • They are non-flammable.	• They are toxic. • They are susceptible to hard water (may form insoluble precipitates).
Synthetic metalworking fluids: Synthetic metalworking fluids are water-based solutions (or emulsions) of synthetic lubricants (soaps and other wetting agents), corrosion inhibitors, water softeners, anti-bacteria additives (biocides), glycols and other additives. Synthetic fluids are supplied as concentrates, mixed with water before use. Synthetic fluids are used in a wide variety of metalworking operations including poorly machinable alloys, heavy duty grinding, high speed cutting.	• They have very good cooling capability. • They have good lubrication properties. • They are very stability in hard water. • They have very good corrosion protection properties. • They have low mist. • They can be easily handled. • They have a good cleaning and maintenance effect.	• They have some toxicity. • They can be easily contaminated by foreign oils. • They are relatively expensive

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Semi-synthetic metalworking fluids: Semi-synthetic fluids are water-based mixtures (solution and emulsion) of synthetic lubricants, additives, emulsifiers and some amount (2%-30%) of mineral oil. Semi-synthetic fluids combine advantages (and disadvantages to some extent) of mineral emulsions and synthetic fluids.	• They possess better corrosion protection. • They have better cooling and wetting capabilities, • They can be easily handled.	• They have a misting effect. • They are relatively unstable in hard water, • They can be contaminated by foreign oils, • They have some toxicity.

Functions of A Cutting Fluid

1. It helps in increasing the lifespan of drills and cutting equipment. The temperature of a tool cooled by a cutting fluid (coolant) does not exceed the critical value, beyond which the tool hardness drops and its wear rate increases.
2. It helps the machine to work under extreme amounts of pressure and torque.
3. It helps to improve machine performance by cooling the cutting tool.
4. It helps to improve the machine's finish of work, reducing tip welding and preventing pitting.
5. Cutting fluids remove the chips and fines formed in cutting (abrading) operations keeping the cutting zone clean and preventing surface damage.
6. Cutting fluids may contain corrosion inhibitors which form a protection film on the work piece surface, machine parts and chips.
7. Cutting fluids lubricate the workpiece-tool metal-to-metal contact zone preventing tool galling and seizure, which assures good surface finish.

Factors to consider when selecting metal working fluids

Cutting fluids are formulated to work with specific metals and under specific conditions. The following factors should be considered for a proper selection of a metal working fluid:

Table 8.5: Selection of appropriate cutting fluids

S/N	FACTOR	DESCRIPTION
1	Metalworking operation process	For example: fluids used for cutting aluminium alloys are not suitable for cold rolling the alloys.
2	Metal to be machined	Different cutting fluids (coolants) are used for working different metals.
3	Corrosion sensitivity of the metal	Rust protection is achieved by metalworking fluid containing mineral oil. Synthetic lubricants do not provide proper corrosion protection.

4	Hardness of the water	Special cutting fluids are used for mixing with hard water.

Conclusion

In conclusion, the milling machine is a versatile tool essential for creating precision parts with varying shapes, sizes, and tolerances. Its flexibility allows it to be used across various industries, from manufacturing to aerospace. The use of cutting fluids in milling operations enhances tool life, improves surface finish, and reduces the risk of overheating. Cutting fluids also help remove chips from the cutting area, reducing the likelihood of damage to both the tool and the workpiece. Proper use and maintenance of milling machines, along with selecting appropriate cutting fluids, can significantly boost efficiency, accuracy, and productivity in machining tasks

Activity 8.1

Meaning of Milling

In a group of not more than five l, brainstorm the term milling. When discussing you should think about and record the following aspects – what is it, why is it done, when is it done and how important an operation it is in engineering.

Note: *Use ICT tools to facilitate your discussions.*

Activity 8.2

Parts and functions of the milling machine

Using the table below and in groups of not more than five;

1. Describe the milling machine.
2. Identify the parts of the milling machine
3. Explain the functions of the milling machine.

Description	Parts	Functions

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Activity 8.3

The Milling Operations

Describe the milling operations performed on the milling machine.

Note: *Use ICT tools to facilitate your work.*

Activity 8.4

Types, Functions, Advantages and Disadvantages of Cutting Fluids

Using the table below, and in a group of not more than five;

1. Brainstorm the functions of cutting fluids.
2. Identify and list the types of cutting fluids.
3. Discuss the advantages and disadvantages of cutting fluids.

Note: *Use ICT tools and the table to facilitate your group work.*

Functions	Types	Advantages	Disadvantages

Activity 8.5

Conditions for Selecting A Particular Cutting for Machining Processes

In groups of not more than five i.e., discuss and write down the conditions under which a particular cutting would be selected for a machining process.

Note: *Use ICT tools to facilitate your group work.*

Activity 8.6

Identifying and Sketching Major Parts of The Milling Machine.

In a group of not more than five;

1. Identify and list the major parts of the milling machine in the school workshop.
2. Brainstorm the functions of the major parts of the milling machine in the school workshop.
3. Sketch the major parts of the milling machine

Activity 8.7

Sketching and Demonstrating the Uses of a Milling Machine.

Your teacher will arrange a visit to a local metal workshop for you to:

1. Identify the milling machine
2. Observe and demonstrate the uses of the milling machine.

Note:

- *Solicit the guidance or assistance from your Applied Technology Teacher or the Workshop Assistant.*
- *Observe the basic workshop safety precautions at all times during the visit.*

EXTENDED READING

- Engine thermostat: https://savree.com/en/encyclopedia/engine-thermostat
- Cooling systems: https://www.summaryplanet.com/engineering/Cooling-systems.html
- What Does a Thermostat Do in a Car?: https://auto.howstuffworks.com/how-does-the-thermostat-in-a-cars-cooling-system-work.htm
- Why does a cooling system need to be pressurised?: https://www.physicsforums.com/threads/why-does-a-cooling-system-need-to-be-pressurized.465289/
- Types of Lathe Machines & Their Uses [Complete Guide] PDF
- Parts of a Lathe Machine and How They Work [Full Guide]
- Lathe Machine: Definition, Parts, Types, Operation, Specification, Advantages, Application [Notes & PDF]
- Shaper Machine - Types, Parts, Working, Operations, Diagram
- Shaper Machine - Types, Parts, Working, Operations, Diagram
- Maintenance for Lathe Machine: A Complete Beginner's Guide
- Care and Maintenance of Shaping Machines | PDF | Machining | Machines
- Oil pump: https://www.howacarworks.com/oil-pump
- Around and Around - Where the Oil Goes in Your Engine: https://www.machinerylubrication.com/Read/532/around-around-where-oil-goes-in-your-engine
- What is Engine Lubrication System? - Types & Uses: https://www.theengineeringchoice.com/what-is-engine-lubrication-system/
- Wong, V. W. Lubrication and Friction
- Different Types of Milling Machine Explained [with PDF]
- Milling Machine: Definition, Parts, Operation, Working Principle, Application, Advantages [Notes & PDF]
- Cutting Fluid - Definition, Types, Purpose, Properties, & Applications - Mechanical Education
- Cutting Fluids: Definition, Types, Properties, Functions, Uses
- 10 Types of Milling Machines You Should Know - CNC Masters

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Review Questions

Questions 2.1

1. Compare four advantages and disadvantages of air cooled and water-cooled engines.
2. Search the internet for a step-by-step guide on how to replace the radiator in a car's cooling system.

Questions 2.2

1. In a school workshop, another group of students are learning about manufacturing processes. The instructor introduces the lathe machine and asks the students to shape a cylindrical piece of metal into a smooth shaft for a small engine. What is a lathe machine?
2. You are in a workshop class where your Applied Technology Teacher is giving a detailed explanation of the lathe machine. Using neat sketches, explain the following parts of the lathe machine
   a. Lathe Bed
   b. Carriage
   c. Headstock
   d. Tailstock
3. You are working in a workshop and need to turn a cylindrical work piece on a lathe machine. The workshop provides you with two different types of chucks: a three-jaw chuck and a four-jaw chuck. Explain the difference between a three-jaw chuck and a four-jaw chuck,
4. You are working in a workshop, where the instructor explains the operations of a lathe machine. To better understand how the lathe machine works, you are asked to use diagrams to visually represent each step of the processes. Describe the following operations on the lathe machine:
   a. Finish turning
   b. Rough turning
   c. Turning
   d. Drilling
   e. Knurling
5. You have been tasked with using a shaper machine to create a perfectly flat surface on a steel workpiece. Explain the functions of the main parts of the shaper machine

6. In a workshop setting, you have been asked to work on a metal block that needs a flat on one side, and the shaper machine is ideal for this task. Describe the working principles of the shaper machine.

Questions 2.3

1. Explain four key points that support the importance of the engine lubrication system.
2. Describe the main parts of the engine lubrication system.
3. Describe the function of the following parts of the engine lubrication system
   a. Oil sump
   b. Oil filter
   c. Oil pump
   d. Oil galleries
   e. Oil cooler
   f. Oil pressure indicator

Questions 2.4

1. Imagine that a manufacturing company needs custom metal parts for an engine. A technician sets up a milling machine with a specific cutting tool. They secure the metal block on the machine's bed, programming it to move thin precise directions. As the machine rotates the tool, it shaves off layers from the block, forming groves, slots, or contours until the parts match the blueprint specifications. Explain what is meant by the term milling.
2. In a manufacturing workshop where a technician is tasked with creating a complex, precision part for an automotive engine. The part requires precise grooves, slots, and pockets that can be achieved through milling. To accomplish this, the technician selects a milling machine, which operates on a simple but powerful principle: rotating a cutting tool against a stationary moving workpiece to remove material and shape it accurately. Describe the principles of operation of the milling machine.
3. In your community, there is a small custom metalworking shop that takes on various precision jobs. The shop has several types of milling operations available to create different shapes, surfaces, and features on metal parts based on client needs. Explain the following milling operations.
   a. Face milling
   b. Straddle milling
   c. Gang milling
   d. Form milling

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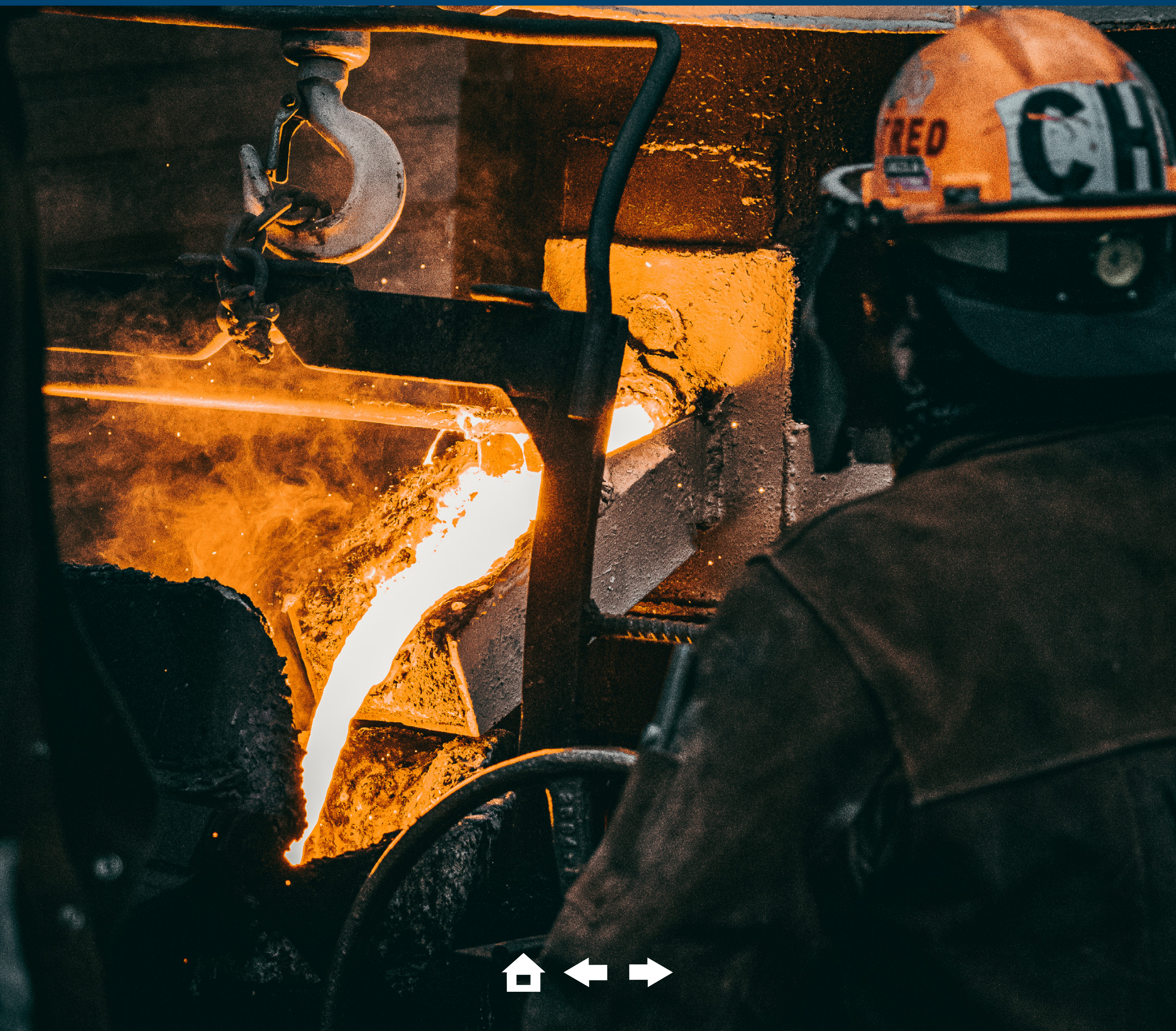
4. A metal worker is cutting a large piece of steel using a milling machine. As the cutter engages with the steel, heat, friction and metal chips are generated. To ensure a smooth and efficient cutting process, a cutting fluid is applied: Explain any four functions of cutting fluids.

SECTION

3

ENGINE LUBRICATION, SAND CASTING AND MACHINES III



UNIT 9

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AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

Effective engine lubrication is important for the longevity, performance, and efficiency of internal combustion engines. A well-designed lubrication system reduces friction, wear, and tear on moving parts, ensuring optimal engine operation. There are three primary types of engine lubrication systems: petroil or mist lubrication, wet sump lubrication, and dry sump lubrication. Each system has its advantages and disadvantages, and understanding these differences is essential for selecting the right lubrication method for various applications. Additionally, knowing the key components such as oil pumps, pressure relief valves, and oil filters is vital for maintaining and improving engine performance.

Now we will discover the principles, benefits, and limitations of each lubrication system, as well as the functions and characteristics of major lubrication components.

KEY IDEAS

- All internal combustion engines need a lubrication system to run smoothly and last long. Regular maintenance of the lubrication system is necessary for keeping the engine running smoothly. Choosing the right type of lubrication system depends on the engine's purpose and performance needs.
- Applying the principle of sand casting involves several key ideas that ensure effective, high-quality production. The steps below help ensure a successful sand-casting process and result in a high-quality finished product.
- As technology advances, machining processes are becoming far more accurate, and more cost-effective, supporting faster, more accurate and more cost-effective, supporting industries' demands for high-quality products and innovation.
- Each machining process plays a unique role in meeting industry requirements for part accuracy, surface finish and production volume.
- Studying the various machining processes in the manufacturing industry is essential for improved product quality, cost-effectiveness, versatility, efficiency, innovation and competitiveness, safety and maintenance.

ENGINE LUBRICATION TYPES

There are three main types of lubrication systems in common use on internal combustion engines:

1. Petroil or mist lubrication system
2. Wet sump lubrication system
3. Dry sump lubrication system

Petroil or Mist Lubrication System

The mist lubrication system is commonly used in two-stroke petrol engines where crankcase lubrication is not possible. This is because the charge is partially compressed in the crankcase before it is transferred to the combustion chamber.

In a mist lubrication system, a small amount of lubricating oil (around 2 to 5%) is mixed with the petrol (to form what is commonly referred to as 'pre-mix) before it is fed into the fuel tank. This fuel-oil mixture is then introduced through the carburettor into the cylinder. As the petrol vaporises, the oil, in mist form, enters the cylinder through the crankcase. Oil droplets settle on the crankcase, lubricating the main bearings, crankshaft and connecting rod bearings, while the remaining oil mist lubricates the piston, piston rings, and cylinder walls.

Advantages of a mist lubrication system

- **a.** It has a simplified design with fewer components.
- **b.** It requires less maintenance.
- **c.** It has efficient lubrication from the oil droplets.
- **d.** It is smaller in size due to the absence of oil.
- **e.** It is lightweight, making it suitable for portable applications.
- **f.** It has lower production and maintenance costs.
- **g.** The lubricating mist helps to cool the engine components.
- **h.** There is minimal oil exposure to dirt, dust, and debris from the environment.

Disadvantages of a mist lubrication system

- **a.** There is inadequate lubrication at low engine speeds.
- **b.** Incorrect oil-fuel ratio can lead to engine overheating or seizure.
- **c.** The combustion process can cause higher oil consumption.
- **d.** Burning of oil along with the fuel contributes to smoke and pollution.
- **e.** Insufficient lubrication can lead to premature wear and frequent maintenance.

f. The lubrication limitations can reduce engine lifespan.

g. Engine performance relies heavily on a proper oil-fuel mixture.

h. Lubricating mist may not provide sufficient lubrication during cold starts.

i. It has lower protection against corrosion and extreme temperatures.

j. It is not ideal for high-performance applications.

Wet Sump Lubrication System

Wet sump lubrication is a system where oil is stored in a sump at the bottom of the engine. From the sump, the oil is supplied to the various components to reduce friction and wear. This method ensures a consistent supply of lubricating oil and promotes efficient operation and cooling of the engine parts during use. Wet sump lubrication may be achieved through a splash method or a pressure method.

Splash lubrication

In an engine, special dippers or scoops on the connecting rods dip into the oil reservoir with every rotation, splashing oil onto the cylinders and pistons to keep them well-lubricated. This system is perfect for small engines, like those in motorcycles and lawnmowers.

However, splash lubrication has limitations. Too little oil in the sump can cause inadequate lubrication, while too much oil can cause problems like oil foaming. Air bubbles in the oil can even lead to bearing failure. To avoid these issues, many engines use a combination of splash lubrication and force-feed lubrication.

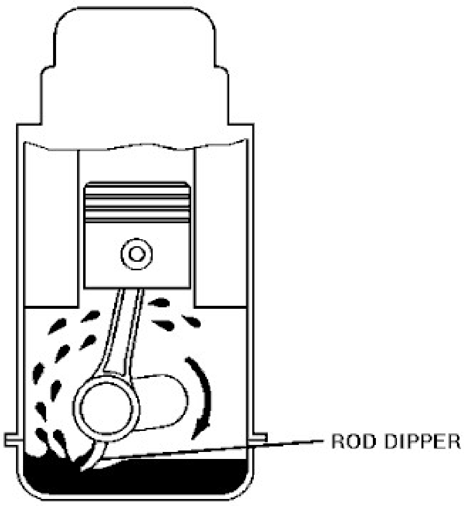

Figure 9.1: Splash lubrication system

Pressure Lubrication

This method of lubrication uses a pump that delivers pressurised oil to the moving parts of the engine. Pressure lubrication may take the form of a full-force lubrication or may combine splash and force-feed lubrications.

In a full force-feed lubrication system, oil is delivered under pressure to lubricate the main bearings, rod bearings, camshaft bearings, and the entire valve mechanism. This system also supplies pressurised oil to the pistons and piston pins through drilled passages in the connecting rods, which channel oil from the connecting rod bearing to the piston pin bearing. This setup not only lubricates the piston pin bearings but also helps lubricate the pistons and cylinder walls.

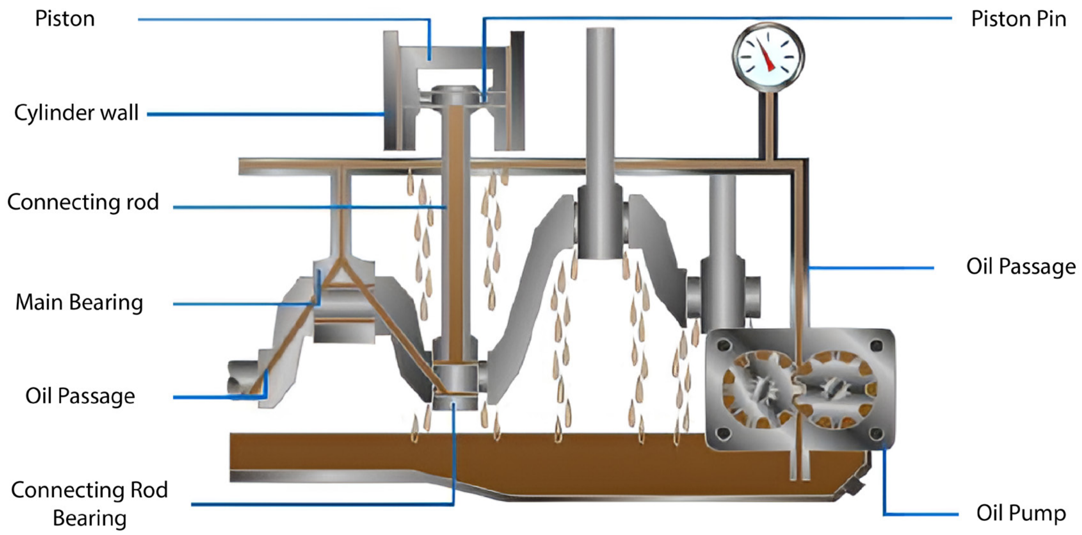

Figure 9.2: Pressure lubrication system

Dry Sump Lubrication System

A dry sump oil system lacks an oil reservoir in the sump beneath the crankcase. Instead, it uses two or more pumps: a scavenge pump and a pressure pump. The scavenge pump returns oil from the engine and sends it to an external reservoir, while the pressure pump draws oil from the reservoir and pumps it back into the engine under pressure.

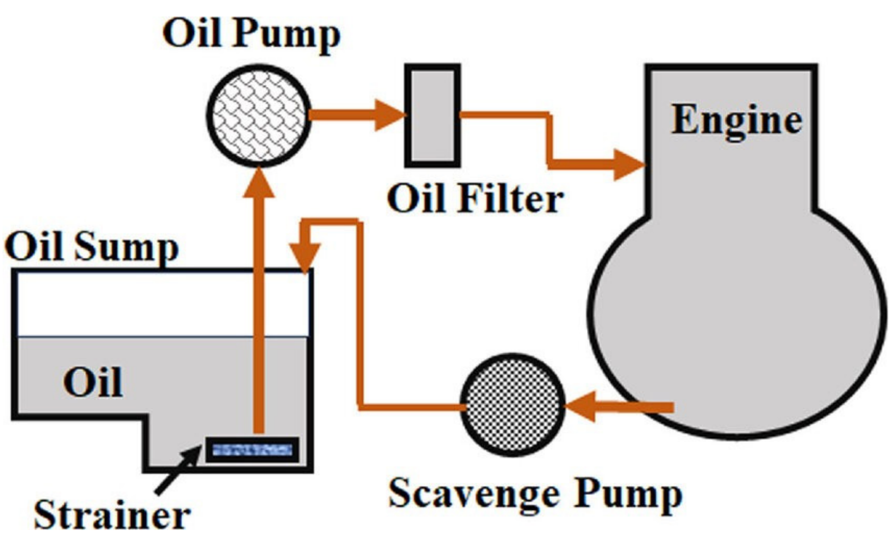

Figure 9.3: Dry sump lubrication system

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Advantages and disadvantages of wet sump lubrication and dry sump lubrication

Table 9.1: Advantages and disadvantages of wet sump and dry sump lubrication systems

Type of lubrication system	Advantages	Disadvantages
Wet sump	Simpler design and less expensive to manufacture.	Limited oil capacity, which may not be ideal for high-performance applications.
	Compact and easier to maintain, as it has fewer components.	Oil can slosh during sharp turns or inclines, leading to inconsistent lubrication.
	Requires less space since the oil is stored directly in the oil pan under the engine.	Less effective cooling compared to a dry sump, as the oil remains near hot engine components.
Dry sump	Greater oil capacity, supporting better lubrication and cooling in high-performance engines.	More complex system with multiple pumps and an external reservoir, making it costly and heavier.
	Reduced risk of oil starvation during high-speed cornering or steep inclines.	Requires additional space to accommodate the external oil reservoir and plumbing.
	Improved engine performance as the crankshaft doesn't dip into oil, reducing drag.	More challenging to install and maintain due to its complexity.

Activity 9.1

Types of Engine Lubrication Systems

1. Your teacher will arrange a visit to the school workshop to identify types of engine lubrication systems. During the visit, make notes about what you see.
2. When you are back in the classroom, form groups of no more than 5.
3. Discuss and answer the following questions:
   a. Explain the main types of engine lubrication systems.
   b. Describe how each system operates.
   c. Identify the engine parts lubricated by the splash and pressure feed lubrication system.
4. Staying in your groups, you will follow the steps below, using your notes to support your answers.
   a. Watch the video '*Types of Lubrication Systems*' at:

- https://www.youtube.com/watch?v=NrXakLBUYMA

b. After watching the video, prepare a hand-drawn chart comparing the different types of lubrication systems, highlighting key features, working, advantages, disadvantages, and typical applications. Use the table below as a guide.

Type of system	Key features	How it works	Advantages	Disadvantages	Applications

5. Discuss with your group members which lubrication system would be best for the following engines:

a. Motorcycle

b. Car

c. Race car

6. Write a justification note for your choices and present it to the rest of the class.

Oil Pump

An oil pump consists of a mechanism with parts that rotate to pull oil from the reservoir or sump and squeeze it under pressure to the various points of lubrication. A standard oil can deliver approximately 120 litres of oil at a vehicle speed of 100 km/h.

An oil pump has an inlet port and an outlet port. The oil enters the inlet port on the low-pressure side (LPS). The pickup tube and strainer are also located on the low-pressure side. The high-pressure side (HPS) is where the pump generates higher pressures to distribute oil throughout the engine.

The most common types of pumps used in motor vehicle engines are;

a. Gear-type,

b. Rotary-type

c. Vane-type.

a. **Gear pump:** A gear pump operates using two interlocking gears: a drive gear connected to an input shaft and a driven gear. As the gears rotate, oil is trapped between their teeth and the pump cavity wall. When the gear teeth unmesh, the oil is forced out, creating pressure.

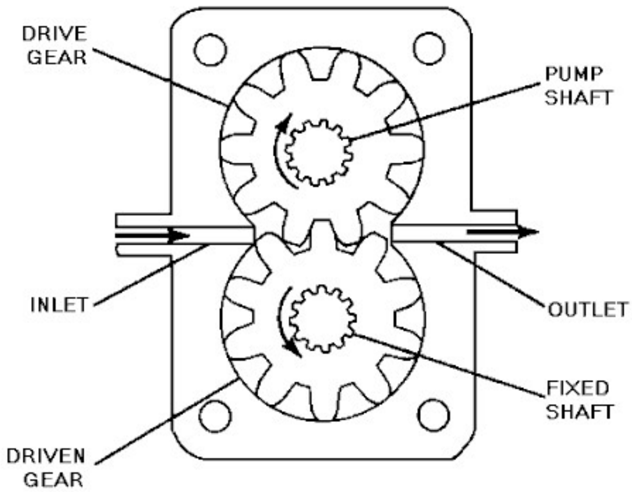

Figure 9.4: Gear-type oil pump

b. **Rotary pump:** A rotary pump features an inner rotor and an outer rotor with a number of lobes. The inner rotor is connected to the drive shaft and controls the outer rotor, which has one more lobe than the inner rotor. As the rotors turn, oil fills the space created by the unmeshing lobes. Continuing rotation traps the oil between the lobes, cover plate, and pump cavity. The meshing lobes then squeeze the oil out, directing it through the engine. Rotary pumps move more oil volume than gear pumps due to the larger space within the outer rotor's open lobe.

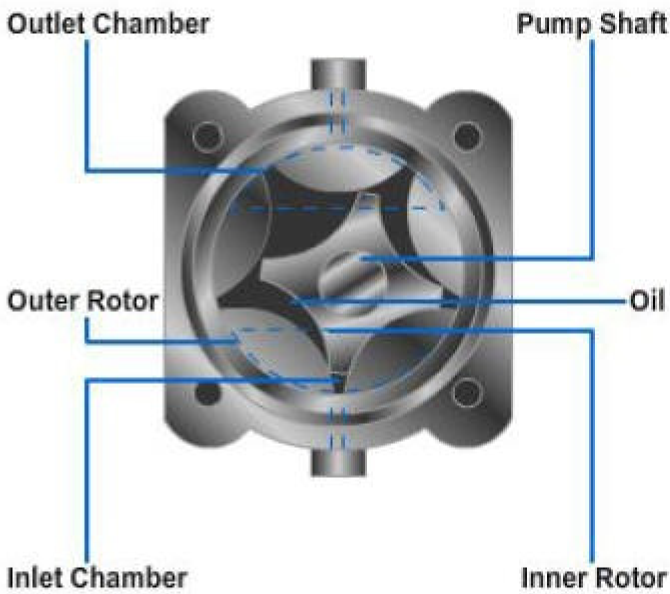

Figure 9.5: Rotor oil pump

c. **Vane pump:** A vane pump uses a rotating rotor with extending/retracting vanes to create sealed compartments, pressurising oil as the vanes move. This simple, efficient design provides smooth flow, high pressure capability, and minimal pressure fluctuations.

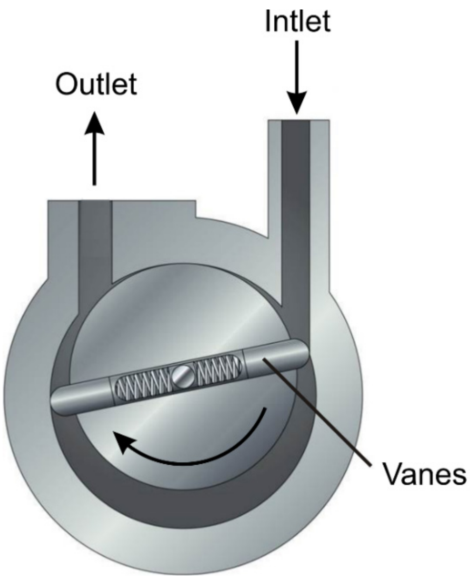

Figure 9.6: Vane-type oil pump

Pressure Relief Valve

Oil pumps can produce more pressure than is required, so a pressure relief valve is included in the lubrication system. At high engine speeds, an oil pump can generate pressures of between 100 and 800 psi (or 6.9-55.2 bar). A pressure relief valve limits the pressure of the oil in the lubrication system to between 36 and 58 psi (2.5-4 bar). This control mechanism is very important because the pump would produce excessive pressure at high speeds.

In operation, the pressure relief valve remains normally closed until oil pressure flowing through it reaches the desired set pressure. As the pressure increases, the valve, consisting of a spring-loaded ball or plunger, opens to allow the excess oil to return to the sump. When the flow pressure drops, the valve closes again to allow normal flow of oil to continue.

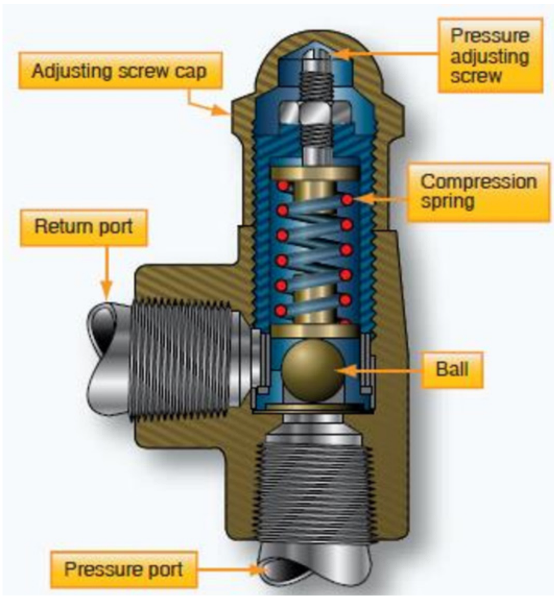

Figure 9.7: Pressure relief valve

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Activity 9.2

Components and Their Appropriate Lubrication Type

Your teacher will arrange a visit to the school workshop where the following activity will take place. In groups of no more than five, look at a lubrication system and its various parts. Make sketches as you observe.

Materials needed

1. Small internal combustion engine (such as a lawn mower or motorcycle engine)
2. Basic toolkit (wrenches, screwdrivers)
3. Oil
4. Diagram or chart of the engine lubrication system
5. Labels or markers
6. A mat or container
7. Notebook and pen for observations

CAUTION

- Wear your PPE, especially gloves and safety goggles.
- Observe workshop safety rules at all times.

Activity Steps

1. Carefully remove the oil pan or sump to expose internal components of the lubrication system and the engine.
2. label parts as they are removed and place them on the mat or in the container.
3. Identify the following parts:
   a. Crankshaft
   b. Camshaft
   c. Connecting rods
   d. Cylinder walls
   e. Bearings
4. Compare the parts with the diagram or chart to be certain about which parts are lubricated through splash or pressure methods.
5. Examine the path the oil takes to reach each component
6. Sketch the engine parts that are lubricated.
7. Identify splash-lubricated parts with the letter '**S**' and pressure-lubricated parts with the letter '**P**'.
8. Clean up and reassemble the engine.

9. In class, discuss why certain parts are lubricated by splash whilst other parts are lubricated by pressure feed methods.
10. In your groups, discuss and explore the advantages and disadvantages of each lubrication method.

Oil Filters

The manufacturing process leaves metal and sand particles in new engine blocks. Over time, engine components, such as piston rings, break down and release tiny metal pieces in the sump as well. Oil filtration is essential to trap these contaminants, to protect bearings and maintain free flow of lubricating oil. Apart from the strainer, which prevents larger particles from being drawn into the pump, an oil filter, containing a very fine filtering element, is used to trap very tiny particles from the oil.

The oil filter helps to clean the oil in the system. If the filter clogs, a valve opens and directs unfiltered oil to the engine. Most oil filters on diesel engines are larger than those on similar gasoline engines. Two types of oil filters are used. They are full-flow and bypass oil filters.

There are two basic oil-filtering systems – full-flow and bypass. The full-flow type filters all of the oil before delivering it to the engine. The bypass type only filters some of the oil.

Full-flow filter

Most engines use full-flow filtration, where oil from the pump passes through the oil filter before it travels to other parts of the engine. This system requires regular filter replacement since it the filter can get clogged because of the dirt it traps from the oil. However, when the filter gets clogged, a valve opens to allow oil to bypass the filter to allow dirty or unfiltered oil to flow through the system. This is a safety mechanism to prevent engine failure. After all, unfiltered oil is better than no oil at all.

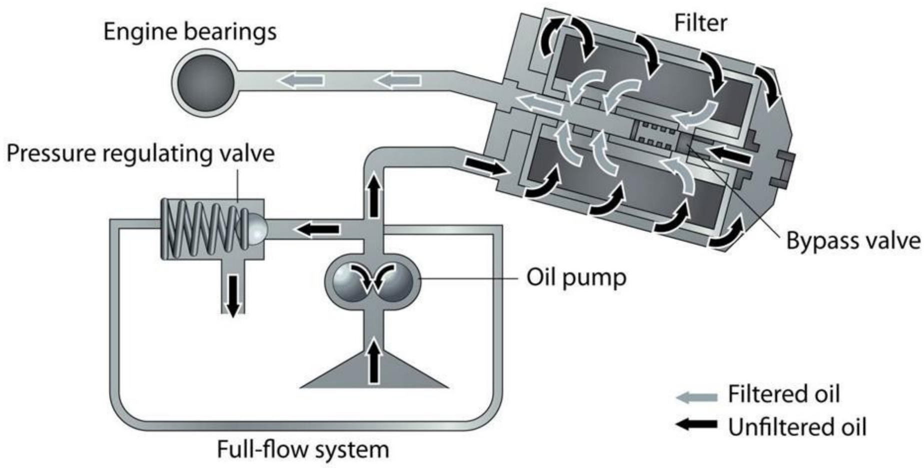

Figure 9.8: Full-flow filter system

Bypass filter

In a bypass system, the bypass element filters only some of the oil from the pump by tapping an oil line into an oil passage. It collects finer particles than a full-flow filter. After this oil is filtered, and it goes back to the sump.

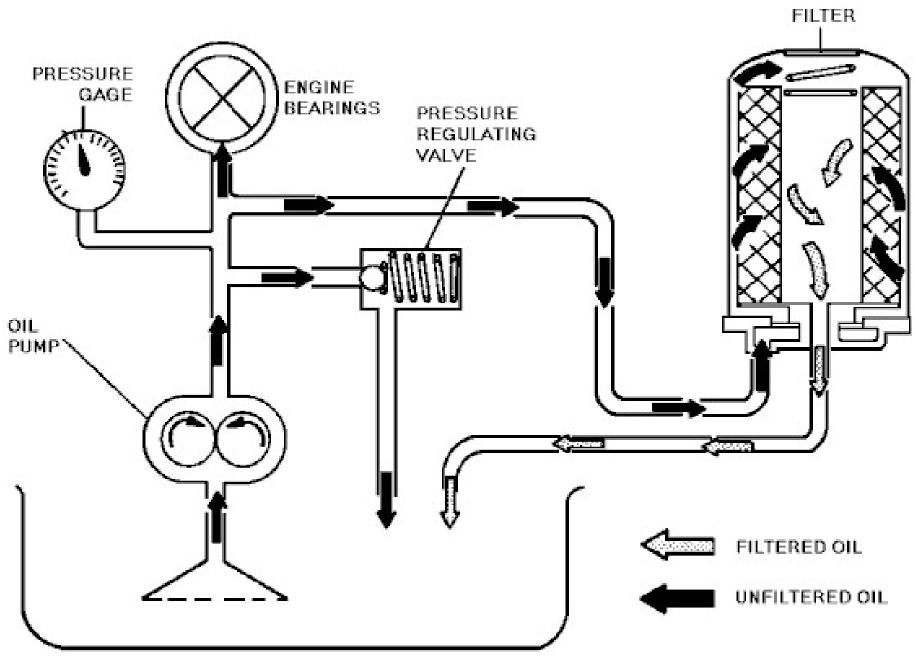

Figure 9.9: Bypass filter system

Activity 9.3

Description of Major Lubrication Components

1. Explore the internet for pictures or diagrams of the following lubrication components:
   - **a.** Gear-type oil pump
   - **b.** Rotor-type oil pump
   - **c.** Vane-type oil pump
   - **d.** Full-flow oil filter
   - **e.** Bypass oil filter
   - **f.** Pressure relief valve
2. With the aid of neatly labelled sketches, describe each of the components listed above.
3. Compare your answer with that of your peers, noting down similarities and differences in the responses.

UNIT 10

METAL TECHNOLOGY

Engineering Materials, Tools and Machines

Introduction

Machining processes are important methods used in workshops to shape and finish metal parts so they can be used in machines, vehicles, and many mechanical systems. These processes are essential because they help produce accurate, smooth, and strong components that fit and work properly in real applications. Without machining, many of the tools, engines, and equipment we use every day could not be made to the correct size or quality.

In this lesson, students will learn about the main machining processes used on machine tools. These include cutting, drilling, turning, milling, and shaping operations. Students will also be introduced to the basic working principles of machine tools, the processes that are performed on each machine tool and the correct process sequence in which the operations are to be carried out in order to complete the machining of a job as well as the importance of safety when carrying out the operations

KEY IDEAS

- As technology advances, machining processes are becoming far more accurate, and more cost-effective, supporting faster, more accurate and more cost-effective, supporting industries' demands for high-quality products and innovation.
- Each machining process plays a unique role in meeting industry requirements for part accuracy, surface finish and production volume.
- Studying the various machining processes in the manufacturing industry is essential for improved product quality, cost-effectiveness, versatility, efficiency, innovation and competitiveness, safety and maintenance.
- They are essential for producing everything from everyday consumer goods to specialised parts used in aerospace, medical and heavy industries.

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MACHINING PROCESSES IN MANUFACTURING INDUSTRY

Manufacturing Processes

Examples of manufacturing processes are casting, machining, joining and deformation processes.

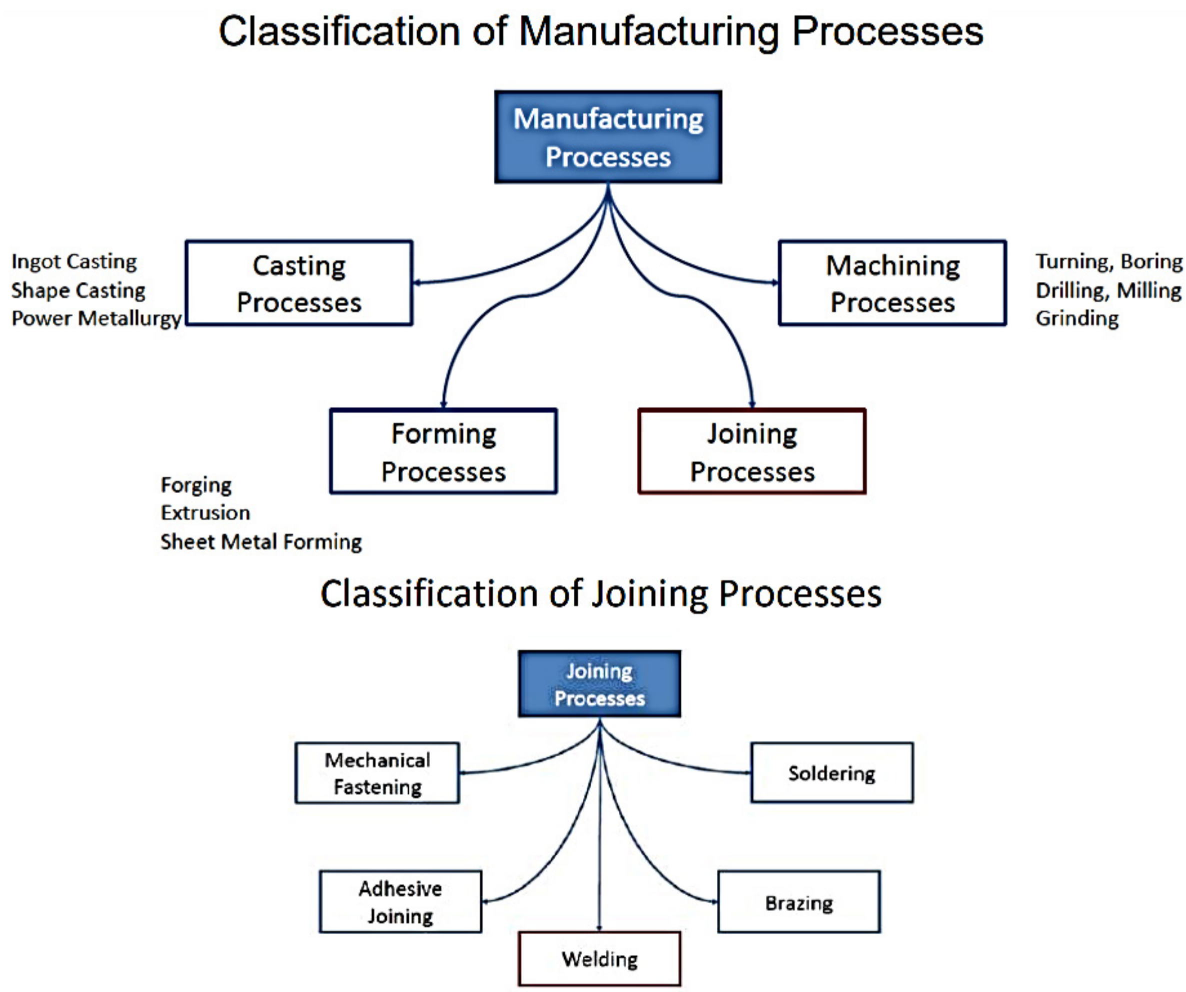


Figure 10.1: Manufacturing and Joining Processes

Machining Process

The machining process is a manufacturing method in which material is selectively removed from a workpiece to shape or finish it into a desired form. This is achieved using various cutting, grinding and abrasive tools. The process involves a combination of movement between the tool and the workpiece to create precise dimensions, intricate shapes and fine surface finishes.

Machining processes are integral to the production of components used in industries such as automotive, aerospace, electronics and construction. The processes are also essential in the manufacturing industry for producing precise and complex parts used in a variety of applications, from automotive and aerospace components to medical devices and consumer products. Some common machining processes are turning, facing, knurling, chamfering, thread cutting, grooving, etc.

Types of motions in Machining

Working motions in machine tools are generally of two types: ***rotary*** and ***translatory***.

Working motions of some important groups of machine tools are shown in the figure below.

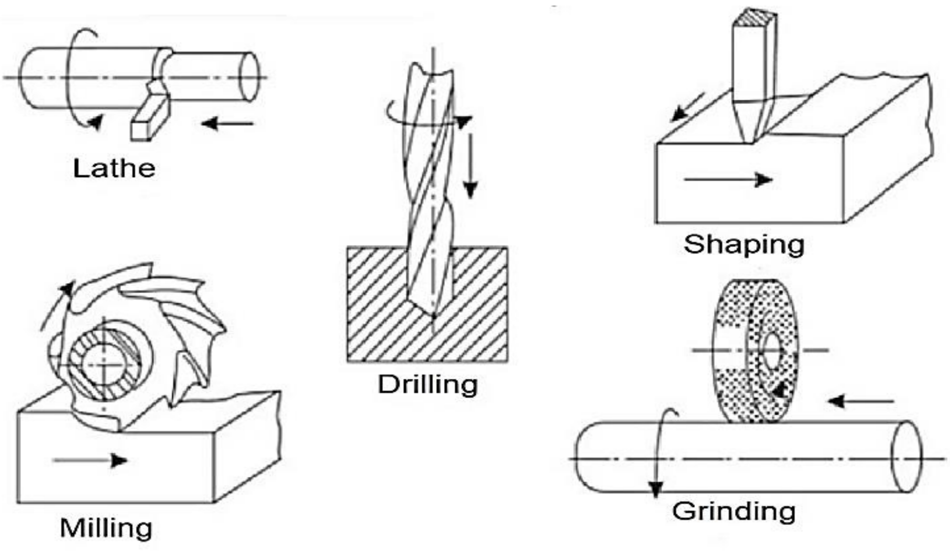


Figure 10.2: Various machining processes with the various relative motions

Table 10.1: Types of machines and their various relative motions

S/N	TYPE OF MACHINE	TYPE OF RELATIVE MOTION
1	**Lathe and boring machines**	Drive motion - Rotary motion of the workpiece. Feed motion – Translatory motion of the cutting tool in the axial or radial directions.
2	**Drilling machines**	Drive motion - Rotary motion of the drill. Feed motion - Translatory motion of the drill.
3	**Milling machines**	Drive motion – Rotary motion of the cutter. Feed motion – Translatory motion of the workpiece.
4	**Shaping, planing and slotting machines**	Drive motion – Reciprocating motion of the cutting tool. Feed motion – Intermittent translation motion of the workpiece.

5	**Grinding machines**	Drive motion – Rotary motion of the grinding wheel. Feed motion – Rotary as well as translatory motion of the workpiece.

Processes performed on the lathe machine

The processes that can be performed on a lathe machine are: Turning (plain, step, taper, etc.), facing, knurling, chamfering, Thread cutting, grooving, parting-off, drilling, reaming, boring, grinding and milling. The tools used for these operations are all different.

Some of the right-hand lathe tools are shown below:

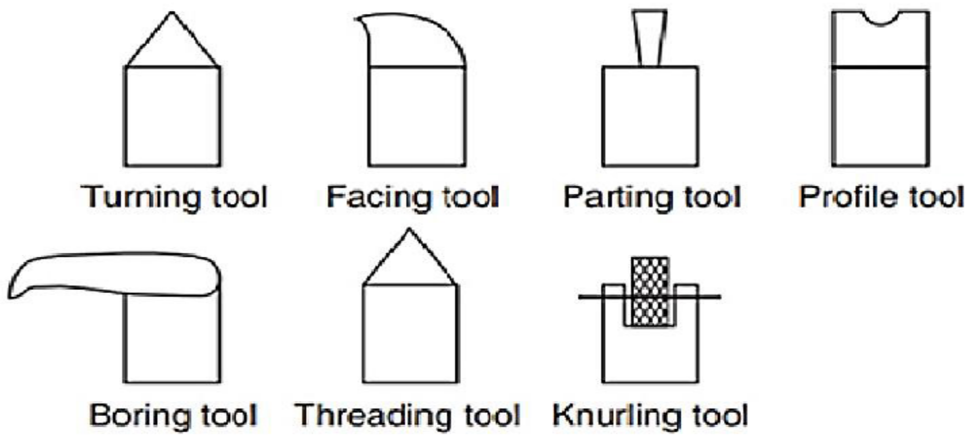
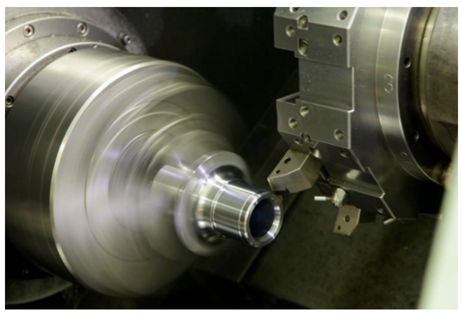


Figure 10.3: Right-hand lathe tools

What are Machine Processes?

Machine processes are operations performed by machines or equipment to shape, cut, form, or otherwise manipulate materials into desired forms. These processes are widely used in manufacturing and engineering to produce various products or components. Examples of machine processes are shown in the Table below:

Table 10.3: Major Machine Processes

S/N	PROCESS/ OPERATION	DESCRIPTION OF PROCESS/OPERATION	SKETCH/PICTURE OF PROCESS/OPERATION
1	**Parallel turning**	Parallel turning is the process of reducing the diameter of a shaft on the lathe using a turning tool. When the tool travels parallel to the lathe's axis, the operation is called parallel turning. In this case, the cutting tool, which is fixed in the tool post, travels by the carriage along the bed, reducing the diameter of the workpiece.	

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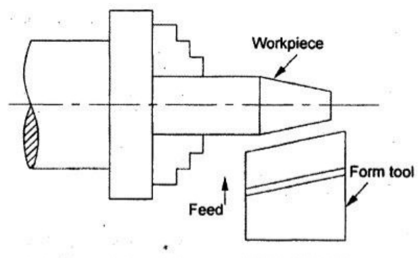
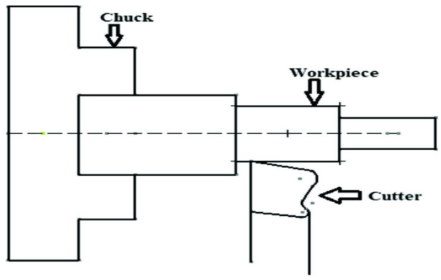
	Taper turning	Taper turning is the process of gradually reducing the diameter of the workpiece along its length, creating a conical or tapered shape. Unlike straight turning, where the workpiece diameter remains constant along its length, taper turning creates a change in diameter from one end to the other.	
	Step Turning	A step turning operation is performed using a step cutting tool, after the turning operation. The work is held in between the centres or with the chuck, the tool is held at a height equal to the axis of the work.	
2	**Knurling**	It is a machining process that creates a textured pattern on the surface of a workpiece to provide grip or enhance the aesthetic appearance of the part. It is commonly used on handles, knobs and other parts where a non-slip surface is desirable. The process involves pressing a hardened knurling tool against the workpiece, which is rotated on a lathe, to imprint a series of ridges or grooves. There are two types of knurling: diamond knurling and straight knurling.	 Diamond knurling  Straight knurling
3	**Facing**	Is the process of squaring the ends of the workpiece on the lathe machine. The cutting tool is traversed perpendicular to the axis of rotation of the workpiece using the cross-slide handwheel.	

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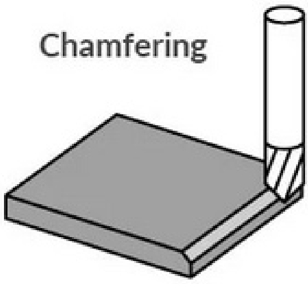
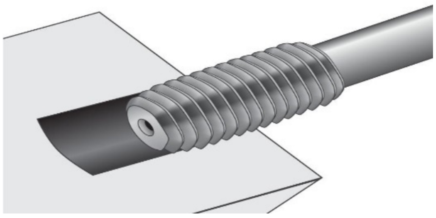
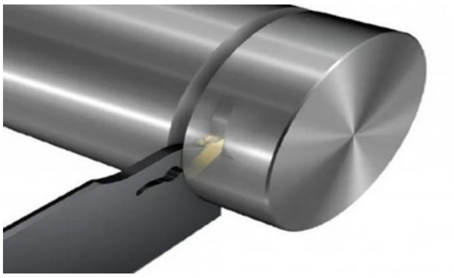
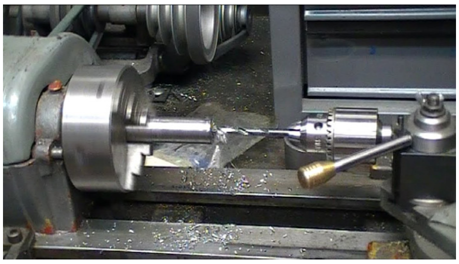
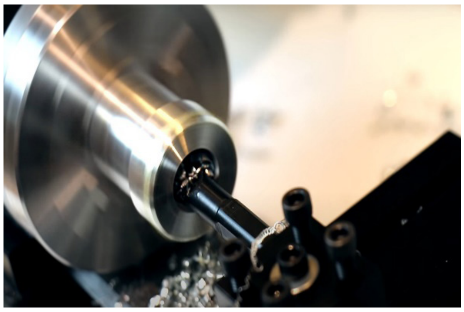
4	**Chamfering**	Is the operation of bevelling the sharp ends of a workpiece to avoid any injuries to the persons using the finished product. Chamfering is like form turning and is done with a chamfering tool that has its cutting edge at the desired chamfer angle, usually 45o.	
5	**Thread cutting**	Is the operation of producing a helical groove of specific shape on the inner or outer surfaces of a cylinder or bore.	
6	**Grooving or groove cutting**	Is the process of producing a narrow groove on the surface of a cylindrical job. The diameter of the workpiece is reduced slightly from the surface over a narrow width.	
7	**Parting-off**	Is the process of making a recess on a piece of work using a parting-off tool. A piece of work can also be cut off using this method. As the name itself indicates, parting is the operation of cutting a workpiece into two.	
8	**Drilling on the lathe machine**	This is the operation of making a circular hole by removing a volume of metal from the job by a rotating cutting tool called a drill. Drilling removes solid metal from the job to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angles and a centre punch is used to make an indentation for the drill point at the centre to help the drill in getting started.	

9	**Drilling using the drilling machine**	Drilling is a cutting process where a drill bit is spun to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multi-point. The bit is pressed against the work-piece and rotated at rates from hundreds to thousands of revolutions per minute.	
10	**Reaming**	This is the operation of sizing and finishing a hole already made by a drill. Reaming is performed by means of a cutting tool called reamer. Reaming operation serves to make the hole smooth, straight and accurate in diameter.	
11	**Boring**	In machining, boring is the process of enlarging a hole that has already been drilled (or cast) by means of a single-point cutting tool. Boring is used to achieve greater accuracy of the diameter of a hole and can be used to cut a tapered hole. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters. Boring operations may be carried out on various machine tools, such as lathe, milling or boring machine itself.	
12	**Grinding**	Is a material removal process in which abrasive particles are contained in a bonded grinding wheel that operates at very high surface speeds. The grinding wheel is usually disk shaped and is precisely balanced for high rotational speeds.	
13	**Milling**	Unlike a lathe, a milling cutter does not give a continuous cut but begins with a sliding motion between the cutter and the work. Then follows a crushing movement and then a cutting operation by which the chip is removed.	

Process Sequence

The process sequence implies the order in which the operations are to be carried out to complete the machining of a job. The sequence to be adopted depends upon the operations to be performed on the workpiece. Imagine that you are asked to produce the component shown below from the stock (raw material) of size 30 mm in diameter and 45 mm in length.

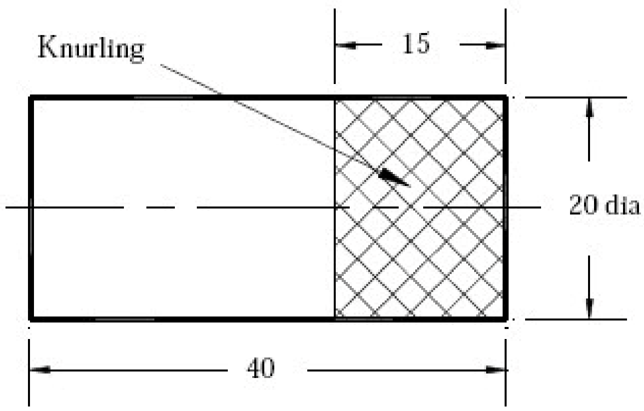


Figure 10.4: Component to be produced

To produce this component, you must carry out the following operations/ steps:

1. Turning to get the desired diameter of 20 mm (reduce from 30 mm to 20 mm).
2. Facing to reduce the length from 45 mm to 40 mm.
3. Knurling for the 15 mm length.

A possible process/sequence for the component could be turning, facing and knurling. It is also possible to produce the component by first facing, then turning and knurling. i.e. facing, turning and knurling. Another sequence is also possible, but the knurling cannot be done first. There is more than one possible sequence for producing the same component. *The general steps when turning external work parts held in a chuck should follow the next sequence;*

1. First, rough cuts are applied on all surfaces, starting with the cylindrical surfaces (largest diameters first) and then proceeding with all faces;
2. Special operations such as knurling and grooving (if any) are applied;
3. Diameters are finished first, then the faces.
4. External threads (if any) are cut.

Activity 10.1

Basic Manufacturing Processes

1. Organise yourselves into groups of no more than five for all of the following activities. For each activity, you can use visual aids and ICT tools to support your discussions and understanding.
2. Discuss and record the following various manufacturing processes you may come across in a modern workshop. You can create a picture or a table to document and display your findings.
   a. Common machining processes
   b. Parallel and taper turning machining processes
   c. Sequential processes for producing a threated machine part
   d. Machining process for producing gears

Activity 10.2

Observing the Various Machining Processes in the Manufacturing Industry Using Videos

In your group, watch the video (Machining processes - click here (https://www.youtube.com/watch?v=SwK5uWrbTEM) or, by using visual aids, observe the various machining processes in the manufacturing industry and discuss the processes. Discuss, identify and agree on which artefacts can be produced using the various machining processes.

Activity 10.3

Discuss Three Machining Processes (Turning, Milling and Drilling)

In your group, discuss any three machining processes and share your understanding of different techniques, such as turning, milling, or drilling, with your colleagues.

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Activity 10.4

Turning and Drilling Processes

In your group and by using pictures or visual aids, take turns to explain the turning and drilling processes. Use ICT tools to reinforce and clarify your understanding.

Activity 10.5

Visiting local workshops to observe modern machining processes

Your teacher will arrange for you to visit a manufacturing workshop to observe modern machining processes and to have hands-on practice on the machining processes.

This activity will require you to:

1. Undertake projects that require you to design, plan and manufacture a part or assembly.
2. Write a visit report and present it in class for discussions.
3. Make sketches and take pictures of manufacturing machines and processes
4. Prepare a sketch or photo album and present it in class for appraisal.

Note:

a. Observe the basic workshop safety precautions during the visit.
b. Wear your PPE at all times.
c. Use ICT tools to facilitate your work.

Conclusion

Understanding the various machining processes will allow you to optimise your work for quality, efficiency, and cost purposes. Selecting the appropriate process involves evaluating factors such as material type, desired tolerances, production volume, and complexity. Mastery of these processes equips engineers to innovate, reduce waste, and improve productivity. As the industry evolves, knowledge of both traditional and advanced machining technologies like CNC and automation enhances adaptability in a competitive market.

AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

Engine lubrication oils are the lifeblood of internal combustion engines, playing a vital role in ensuring smooth operation, optimal performance, and prolonged longevity. The effectiveness of an engine's lubrication system directly impacts fuel efficiency, power output, and overall engine health. We will now learn about the essential properties and characteristics of engine oils, additives, and ratings. Additionally, we will explore the critical function of crankcase ventilation systems, highlighting their importance in maintaining a clean and efficient engine environment. By understanding these key concepts, we can make informed decisions about engine maintenance and efficiency.

KEY IDEAS

- Additives improve or add new characteristics to oils, which enhance engine protection and performance.
- Crankcase ventilation systems control harmful gas build-up and prevent pollution.
- Engine oils are classified by viscosity and performance standards.
- Engine oils are essential for smooth operation, optimal performance, and extended engine life.
- Engine oils can be made from animal, vegetable, mineral, or synthetic sources.
- Important properties determine how effectively an oil can lubricate, flow, and perform in various temperatures and conditions.

PROPERTIES OF ENGINE LUBRICATION OIL

The lubrication system creates a protective layer between the surfaces of moving parts, reducing friction and helping to control heat generation. The ability of any lubrication system to achieve its optimum function largely depends on the lubricating oil used. Engine lubricating oils can be produced from animal oils, vegetable oils, mineral oils and synthetic formulations. ***Figure 11.1*** is an example of lubricating oil.

Figure 11.1: An engine oil

Animal oils are obtained from the processed fat of certain animals, including tallow and whale. Vegetable oils are obtained from the fat of plants, including rapeseed and corn. Both animal and vegetable oils can easily decompose and lose their lubricating properties.

Mineral oils are obtained from refined petroleum and have better lubricating properties than oils from animal and vegetable sources. Synthetic oils, however, have proven to possess more advanced properties and can retain their properties throughout their usage life. For this reason, they are the preferred oil type for today's high-performance vehicle engines.

Engine lubricating oils have several critical properties that ensure they effectively protect and enhance the performance of an engine.

1. **Viscosity:** This is defined as a measure of the resistance to flow of an oil, or the internal friction existing in the film of the oil. In simple terms, viscosity describes how thick or thin an oil is. A good lubricating oil must have a balanced thickness. It should be thick enough to provide a protective film between mating surfaces, but at the same time, thin enough to flow easily to be able to wash away dirt and particles from surfaces.
2. **Viscosity index (VI):** This is a measure of how much the oil's viscosity changes with temperature. A high viscosity index indicates that the oil maintains stable viscosity across changes in temperature, which means that its viscosity remains almost stable between very cold and very hot temperatures.
3. **Pour Point:** This refers to the lowest temperature at which oil will pour or flow. In other words, pour point indicates the temperature below which the oil becomes too thick and will no longer flow freely, which can potentially affect the performance of the engine. Oils with lower pour points can withstand cold temperatures while remaining fluid to circulate the engine.

4. **Flash Point:** This is the lowest temperature at which engine oil will briefly ignite when heated, without sustaining combustion. A higher flash point will ensure a reduction in the risk of fire hazards, which will ultimately ensure a safe working environment.
5. **Cloud point:** This is the temperature at which wax crystals begin to form, causing the oil to appear cloudy and solidify.
6. **Oiliness:** This refers to the ability of an oil to cling, coat or continue to remain when it encounters metal surfaces.
7. **Fire point:** This is the lowest temperature at which the oil sparks and gives off flame for some time.

Additives for Lubricants

Additives are chemical compounds that are added to engine oils to improve upon their properties or introduce a new characteristic effect.

1. **Detergents and Dispersants:** These additives neutralise and suspend deposit-forming materials, including sludge and carbon, in the oil, making it safe and easy to remove them during routine oil changes.
2. **Anti-Wear Additives:** These form protective films on engine components, reduce wear, prevent galling and seizing.
3. **Viscosity Index Improvers:** They reduce viscosity change with temperature, permit reduced fuel consumption, maintain low oil consumption and allow easy cold starting.
4. **Antioxidants:** These prevent oil degradation and oxidation, extending the life of the oil and protecting engine components from corrosion.
5. **Pour Point Depressants:** these lower the freezing point of oil to ensure the oil can flow freely at low temperatures.
6. **Anti-Foam:** This additive is introduced to reduce the formation of foam in the crankcase. It is important to note that the presence of air bubbles in the oil will reduce its lubricating property.
7. **Corrosion Inhibitors:** They provide additional protection, safeguarding metal components from rust and wear.
8. **Anti-rust:** This ensures that rust is prevented from forming on metal surfaces. It achieves this by forming protective surface films or by neutralising acids present in the oil.

Activity 11.1

Engine oils additive analysis

Organise yourselves into groups of no more than five for this activity.

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Materials needed

- Cardboard
- Marker
- Colour pencils/crayons

Activity Steps

1. Search the internet for a detailed list of additives used in engine oils.
2. Prepare a poster or chart and use it to describe the role of each additive and how it enhances engine performance.
3. Display your chart by hanging it on the wall.
4. Ask your group members to choose which of the additives they consider to be the most important.
5. Lead the class to discuss the importance of additives in engine oils.

Classification of Engine Oils Based On Rating

Engine oils are classified based on ratings that denote their viscosity characteristics and performance standards.

Engine oil ratings are standardised classifications that define an oil's performance, protection, and viscosity characteristics. These ratings ensure that vehicle users select the right oil for their vehicle's specific needs. The Society of Automotive Engineers (SAE) and the American Petroleum Institute (API) are two leading organisations that establish and certify these ratings. Both designations are displayed on the API Service Classification Symbol, also known as the API Donut found on oil containers.

1. **SAE rating:**

   The Society of Automotive Engineers (SAE) determines standards for oil viscosity grades. The SAE rating system uses a number to represent the viscosity or the flow of the oil in different temperature conditions. The higher the SAE number, the higher the viscosity.

   Single-grade oils are denoted by a number after SAE (for example, SAE 20, SAE 5W) whilst **multi-grade** oils are indicated by two numbers separated by 'W' (for example, SAE 5W-30, SAE 15W-40. For multi-grade oils, the number before the 'W' represents the flow rate of the oil in cold weather (winter) whilst the number after the 'W' represents the flow rate in hot weather. Remember, here, that the ratings help manufacturers and consumers to identify the viscosity characteristics of the oil.

2. **API Service rating:**

   The American Petroleum Institute (API) classification determines the oil's performance level and appropriate applications. An API certified oil has the

API Certification Mark and the API Service donut symbol printed on the packaging.

Figure 11.2: API certification mark

The API certification mark indicates the suitability of the oil for petrol engines, diesel engines, or both. The API Donut symbol, on the other hand, is divided into three sections and provides details about the oil's performance level, viscosity grade, and energy-saving characteristics. The top section indicates the **API Service Category, which specifies** the particular performance standards the oil must meet. The **Centre Section s**hows the **SAE viscosity**, which represents the oil's viscosity characteristics across different temperatures. The third section and bottom section indicate if the oil is **'Resource Conserving'**, meaning it has energy-saving properties and meets fuel economy standards.

Figure 11.3: API Donut Symbol

Activity 11.2

Engine oil ratings

Organise yourselves into groups of not more than five for this activity.

Materials needed

1. Writing materials
2. Camera/mobile phone

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3. Computer application for photo editing

Activity Steps

1. Your teacher will arrange for your group to visit a lubricant store close to you.
2. Ask the storekeeper if you can collect samples of engine oils.
3. Take photos of their SAE and API ratings.
4. Use a graphic design computer application to prepare a poster using the pictures collected.
5. Provide as the title: 'SAE and API Ratings of Engine Oils'.
6. Include the names of the group members.
7. Your teacher will arrange for you to visit and display your poster in the school auto workshop.
8. Take a tour of the workshop as you compare your poster with those of other groups, noting down differences and similarities.
9. As a whole class, discuss the significance of engine oil ratings to automobile manufacturers, users, and the entire nation.

Crankcase Ventilation

Crankcase ventilation is a system that is used to exit or expel harmful gases from the crankcase of an internal combustion engine in a controlled way. During engine operation, some of the combustion gases leak past the piston and cylinder walls, causing pressure to build up in the crankcase. The hot combustion gases condense and mix with the lubricating oil to form sludge. Sludge at the bottom of the sump contributes to corrosion and poses a resistance to oil flow. The crankcase ventilation system is therefore provided for two main reasons:

1. To prevent pressure build-up inside the engine crankcase because of combustion gases blowing past the pistons.
2. To prevent the emission of harmful gases from the engine.

In older vehicles, a breather was provided to allow clean air to enter the crankcase while a vent pipe led the harmful gases out of the crankcase. This method, though successful, released harmful gases into the atmosphere, thereby causing air pollution.

Positive Crankcase Ventilation (PCV)

The Positive Crankcase Ventilation (PCV) system was created to remove harmful gases from the engine and keep them from polluting the air. It works by using a vacuum to direct these gases from the crankcase into the intake manifold. From there, the gases mix with the air-fuel mixture flowing into the combustion chamber, where they are burned off. A PCV valve controls the flow of gases in the system. This valve helps both to ventilate the crankcase and to reduce pollution.

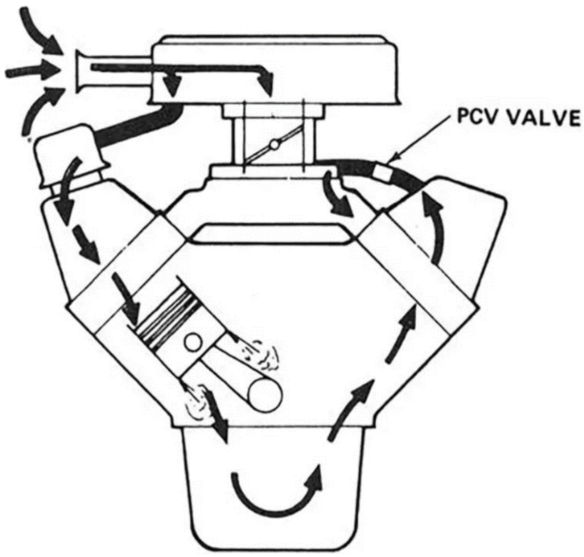

Figure 11.4: A positive crankcase ventilation

The PCV Valve

The flow control valve, commonly known as the PCV valve, is the most important part of the PCV system. Its purpose is to regulate the flow of vapour from the crankcase to the intake manifold. This regulation ensures that the crankcase is properly ventilated without disturbing the fuel/air mixture needed for combustion.

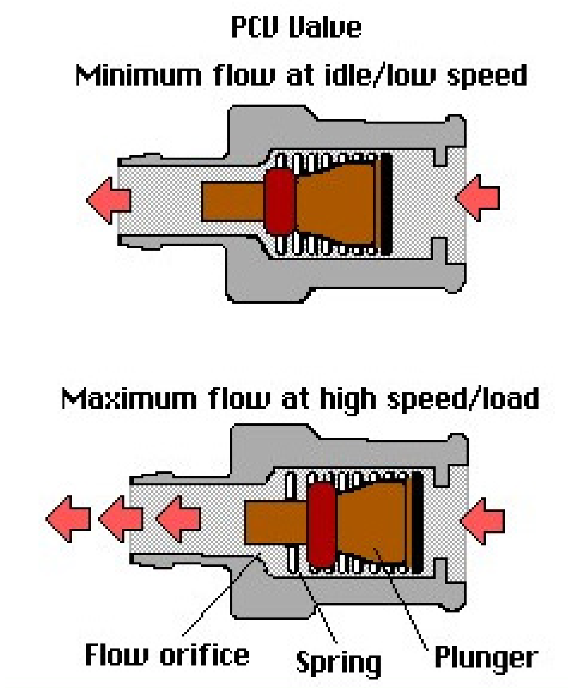

Figure. 3.11.5: A PCV valve

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Activity 11.3

Crankcase ventilation

Organise yourselves into groups of no more than five for this activity.

CAUTION: Observe workshop safety rules at all times and always wear your PPE.

Activity Steps

1. Your teacher will arrange for your group to visit the school auto workshop or a mechanic shop in your community.
2. In your group, inspect the different engine models you find.
3. Analyse the crankcase ventilation system used on each engine type.
4. Write down a brief description of the crankcase ventilation path used for one the engines.
5. Discuss in your group the consequences of inadequate ventilation and propose solutions to improve engine performance and service life.

UNIT 12

METAL TECHNOLOGY

Engineering Materials, Tools and Machines

Introduction

Sand casting is one of the oldest and most widely used methods of shaping metal because it is inexpensive, flexible, and suitable for making both small and large parts, and in this lesson students will learn what sand casting is and how it works, the materials used such as sand, metal, and patterns, the main steps in the process including making the mold, pouring the metal, cooling, and finishing, as well as the advantages and limitations of sand casting compared to other methods, and by the end of the lesson they should be able to explain the basic idea of sand casting and why it is useful, identify the main materials and tools involved, describe the step-by-step procedure of making a casting in sand, and recognize the benefits and challenges of using sand casting in manufacturing.

KEY IDEAS

Applying the principle of sand casting involves several key ideas that ensure effective, high-quality production. The steps below help ensure a successful sand-casting process and result in a high-quality finished product. Here are some fundamental concepts to keep in mind:

- Pattern Design and Material Development
- Sand and Mould Preparation
- Mould Design Considerations
- Melting and Pouring of Metal
- Finishing and Quality Control
- Inspection and Testing

PRINCIPLES OF SAND CASTING

Foundry

A foundry is a metal casting factory that creates metal objects by melting down metal, pouring molten metal into a mould and letting it cool to solidify. Foundries are equipped with equipment, machines, tools, protective gear and devices that all make this metal casting process possible.

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Main equipment used for foundry

The two main equipment used for foundry work are:

1. **A cupola or cupola furnace**: It is a melting device used in foundries that can be used to melt cast iron, bronze and other metals.
2. **Blast Furnace**: It is primarily used for producing pig iron from iron ore, which can then be refined into steel.

Metal Casting

Metal casting is the process of pouring liquid metal into a mould to achieve a desired shape. The term casting also applies to the part made in the process.

Figure 12.1: Typical metal cast parts

Classification of Casting Process

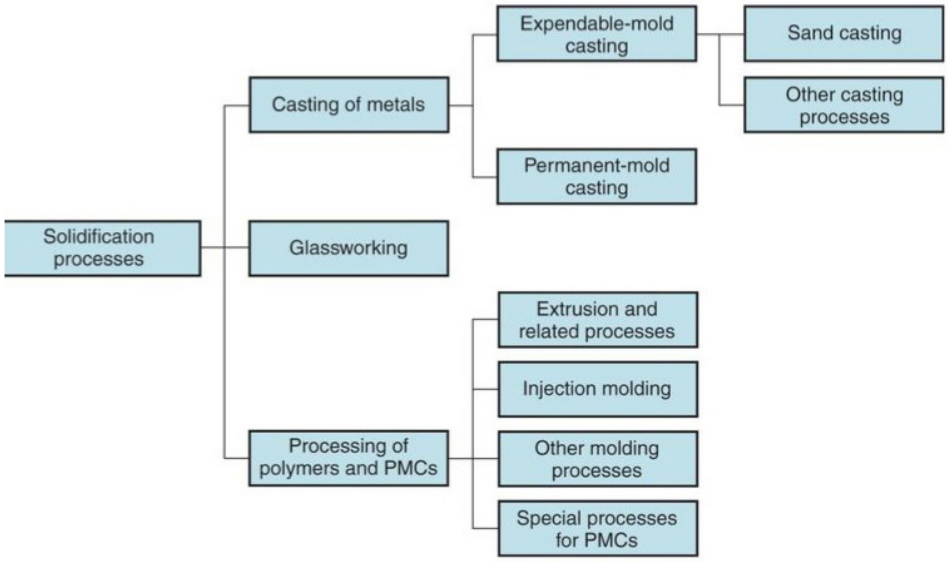


Figure 12.2: Flow chart of Classification of Casting Process

Types of mould process

There are two main types of mould processes and these are:

1. **Expendable mould processes (Temporary) mould** – uses an expendable mould which must be destroyed to remove casting. Mould materials used are sand, plaster and similar materials, plus binders.
2. **Non-expendable (Permanent) mould processes** – uses a permanent mould which can be reused to produce many castings. Made of metal (or, less commonly, a ceramic refractory material).

What is Sand Casting?

Sand casting is a metal forming process in which a mould is first formed from a three-dimensional pattern of sand and molten metal is poured into the mould cavity for solidification. The sand shell is subsequently removed after the metal components cool and form the required shape. Certain sand-casting components require a secondary machining process after casting.

Advantages of sand casting

1. It is very simple and inexpensive.
2. Any material such as ferrous or non-ferrous metals can be made.
3. Intricate shapes can be made.
4. Any size and weight can be made.
5. Certain metals and alloys can be made.

Applications of sand casting

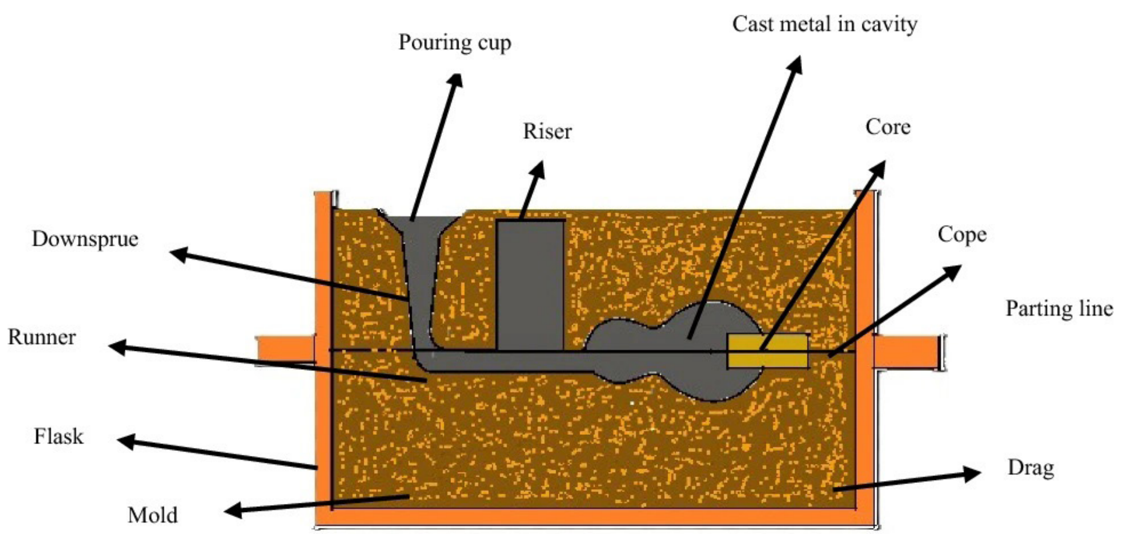
Sand casting is applied in the manufacture of cylinder blocks, liners, machine tool beds, pistons, piston rings, wheels, water supply pipes and bells.

Sand casting typically uses a type of sand called foundry sand, which has specific properties that make it ideal for forming moulds. The main types of sand used in sand casting are green sand, dry sand, resin-bonded sand, core sand and silica sand. Each type of sand is chosen based on the specific requirements of the casting, such as surface finish, dimensional accuracy, and the ability to handle temperature changes.

Table 12.1: Properties of moulding sand

S/N	PROPERTY	DESCRIPTION
1	**Porosity**	It is the property of sand which permits steam and other gases to pass through the sand mould. If the sand is too fine, the porosity will be low.
2	**Strength**	Measurement of strength can be done by using Universal Sand Strength Testing Machine.
3	**Flowability**	When rammed, sand will flow into all portions of a mould and take up the required shape.
4	**Refractoriness**	The sand must be capable of withstanding high temperature of the molten metal without breaking.
5	**Adhesiveness**	It is the property of sand that makes it capable of adhering or sticking to the sides of the moulding box.
6	**Cohesiveness**	It is the property of sand due to which the sand grains stick together during ramming. It is defined as the strength of the moulding sand.
7	**Chemical Resistivity**	The moulding sand should not chemically react with the metallic mould.

A Cross-Section of Sand-Casting Mould



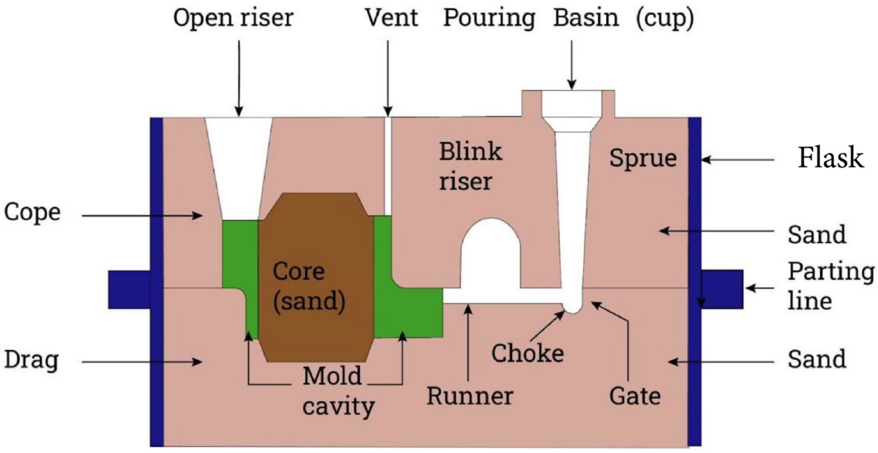


Figure 12.3: Parts of the sand-casting mould

Table 12.2: Terminologies of sand-casting mould

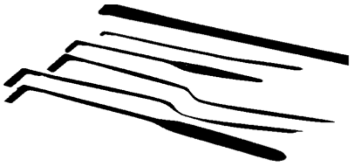
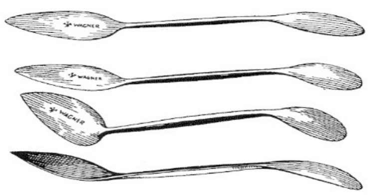
S/N	TERMINOLOGY	DESCRIPTION OF TERMINOLOGY
1	**Flask**	A metal or wood frame, without a fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names, such as **a. drag** – lower moulding flask, **b. cope** – upper moulding flask, **c. cheek** – intermediate moulding flask used in three-piece moulding.
2	**Pattern**	It is a replica of the final object to be made. The mould cavity is made with the help of the pattern.
3	**Parting line**	This is the dividing line between the two moulding flasks that make up the mould.
4	**Moulding sand**	Sand which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay and moisture in appropriate proportions.
5	**Facing sand**	The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings
6	**Core**	A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
7	**Pouring basin**	A small funnel shaped cavity at the top of the mould into which the molten metal is poured.
8	**Sprue**	The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of molten metal into the mould.
9	**Runner**	The channel through which the molten metal is carried from the sprue to the gate.

10	**Gate**	A channel through which the molten metal enters the mould cavity.
11	**Chaplets**	Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force.
12	**Riser**	A column of molten metal placed in the mould to reveal that the mould is full and to feed the castings as it shrinks and solidifies. It is also known as feed head.
13	**Vent**	Small openings in the mould to facilitate the escape of air and other gases from the mould.

Table 12.3: Tools and equipment used in sand casting

S/N	TOOL AND EQUIPMENT	DESCRIPTION TOOL/ EQUIPMENT	SKETCH/PHOTO OF TOOL/ EQUIPMENT
1	**Hand riddle**	It consists of a screen of standard circular wire mesh equipped with a circular wooden frame. It is generally used for cleaning the sand to remove foreign materials such as nails, shot metals, gravel, and splinters of wood from the sand.	
2	**Shovel**	It consists of a steel pan fitted with a long wooden handle. It is used in mixing, tampering and conditioning the foundry sand by hand. It is also used for moving and transferring the moulding sand to the container and moulding box or flask. It should always be kept clean.	
3	**Rammers**	They are required for stamping the moulding sand mass in the moulding box to pack or compact it uniformly all around the pattern. The common forms of rammers used in ramming are hand rammer, pein rammer, floor rammer and pneumatic rammer.	

4	**Sprue pin**	It is a tapered rod of wood or iron which is placed or pushed in the cope to join the mould cavity while the moulding sand in the cope is being rammed. Its withdrawal from the cope produces a vertical hole in the moulding sand called sprue through which the molten metal is poured into the mould using a gating system. It helps to make a passage for pouring molten metal into the mould through the gating system.	
5	**Strike off bar**	It is a flat bar made of wood or iron having straight edges. It is used to strike off or remove the excess sand from the top of a moulding box after completion of ramming thereby, making its surface plain and smooth. One of the edges is bevelled and the other end is kept perfectly smooth and plain.	
6	**Mallet**	A mallet is like a wooden hammer and is used in carpentry or sheet metal shops. In moulding shops, it is used for driving the draw spike into the pattern and then rapping it for separation from the mould surfaces so that the pattern can be withdrawn leaving the mould cavity without damaging the mould.	
7	**Draw spikes/ draw screw**	It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other. It may have screw threads on the end to engage metal pattern for its withdrawal from the mould. It is used for driving into the pattern which is embedded in the moulding sand and raps the pattern to get separated from the pattern and finally draws it out form the mould cavity.	 Draw spikes  Draw screw

8	**Vent rod**	The vent rod is typically a slender metal rod that is inserted into the sand mould to create small holes or vents to allow escape of gases from the mould when the molten metal is being poured. The vents should be strategically placed to ensure that gases can escape without compromising the structural integrity of the mould or the quality of the casting. Proper venting is essential to achieving a high-quality casting with minimal defects.	
9	**Lifters**	They are also known as cleaners or finishing tools made of thin sections of steel of various lengths and width with one end bent at a right angle. They are used for cleaning. Repairing and finishing the bottom and sides of deep and narrow openings in mould cavity after withdrawal of the pattern. They are also used for removing loose sand from the mould cavity.	
10	**Trowels**	They are used for finishing flat surfaces and joints and parting lines of the mould. They consist of metal blades made of iron and wooden handles. The common metal blade shapes of trowels may be rectangular oriented. The trowels are basically used for smoothing or slicking the surfaces of the moulds. They are also used to cut in-gates and repair the mould surfaces.	
11	**Slicks**	They are identified as small double ended mould finishing tools which are generally used for repairing and finishing the mould surfaces and their edges after withdrawal of the pattern. The most commonly used slicks are of the types of heart and leaf, square and heart, spoon and bead and heart and spoon.	

12	**Smoothers**	They are known as finishing tools which are commonly used for repairing and finishing flat and round surfaces, round or square corners and edges of moulds.	
13	**Swab**	It is a small hemp fibre brush used for moistening the edges of sand mould, which are in contact with the pattern surface before withdrawing the pattern. It is used for sweeping away the moulding sand from the mould surface and the pattern. It is also used for coating the liquid blacking on the mould faces in dry sand moulds.	
14	**Spirit level**	Is used to check whether the sand bed or the moulding box is horizontal or flat	
15	**Gate cutter**	Is a small shaped piece of sheet metal commonly used to cut runners and feeding gates for connecting the sprue hole with the mould cavity.	
16	**Gaggers**	They are pieces of wires or rods bent at one or both ends used for reinforcing The downward projecting sand mass in the cope.	
17	**Bellows**	It is a hand operated leather made device equipped with compressed air jet to blow or pump air when operated. It is used to blow away the loose or unwanted sand from the surfaces of the mould cavity.	
18	**Clamps, cotters and wedges:**	They are made of steel and are used for clamping the moulding boxes firmly together during pouring.	 Clamp  Cotter  Wedges

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Note: *Use the links below to watch videos on sand-casting tools, equipment and processes:*

- https://www.youtube.com/watch?v=cma92zgD5nM
- https://www.youtube.com/watch?v=v8uVwR-DJBg

Table 12.4: Basic steps for making sand castings

S/N	STAGE	DESCRIPTION OF STAGE
1	**Pattern making**	A pattern is the replica of the part to be cast and is used to prepare the mould cavity. It is the physical model of the casting used to make the mould and made of either wood or metal. The mould is made by packing some readily formed aggregate material, such as moulding sand, surrounding the pattern. When the pattern is withdrawn, its imprint provides the mould cavity. This cavity is filled with metal to become the casting. If the casting is to be hollow, additional patterns called 'cores', are used to form these cavities.
2	**Core making**	Cores are placed into a mould cavity to form the interior surfaces of castings. Thus, the void space is filled with molten metal and eventually becomes the casting.
3	**Moulding**	Moulding consists of the mould preparation activities for receiving molten metal. Moulding usually involves: (i) preparing the consolidated sand mould around a pattern held within a supporting metal frame, (ii) removing the pattern to leave the mould cavity with cores. The mould cavity is the primary cavity containing the liquid metal and it acts as a negative of the desired product. The mould also contains secondary cavities for pouring and directing the liquid material into the primary cavity and will act as a reservoir, if required.
4	**Melting and pouring**	The preparation of molten metal for casting is called melting. The molten metal is transferred to the pouring area where the moulds are filled.
5	**Cleaning**	Cleaning involves removal of sand, scale and excess metal from the casting. Burned-on sand and scales are removed to improve the surface appearance of the casting. Excess metal in the form of fins, wires, parting line fins and gates are removed.
6	**Inspection**	Inspection of the casting for defects and general quality is performed.

Steps for making a simple sand mould

1. Place a drag flask on the board.
2. Sprinkle dry facing sand over the board.
3. Locate drag half pattern on the mould board.
4. Pour moulding sand to cover the pattern with the fingers and then completely fill the drag.
5. Pack sand tightly in the drag by means of hand rammers.

6. Use pein hammers to first close drag pattern and butt hammer to surface ramming. The ramming must neither be too hard or soft.
7. Level/remove the excess sand with a straight bar called a strike off bar.
8. Make vent holes in the drag to the full depth of the flask using a vent rod to facilitate the escape of gases during pouring and solidification.
9. Turn the finished drag flask upside down, exposing the pattern.
10. Make a sprue passage located at some distance from the pattern edge using a sprue pin. Place the riser pin at an appropriate place.
11. Fill, ram and vent the cope in the same manner.
12. Remove the sprue and riser, and make a pouring basin at the top and pour the liquid metal.
13. Remove the pattern from the cope and drag.
14. Make runners and gates by cutting the parting surface with a gate cutter (a gate cutter is a piece of sheet metal bent to the desired radius).
15. The core for making a central hole is now placed into the mould cavity in the drag.
16. Assemble the mould ready for pouring molten metal.

Pattern

The pattern is used for forming an impression on the material. The pattern and the part to be made are not the same. They differ in the following aspects. A pattern is always made larger than the final part to be made. The excess dimension is known as pattern allowance.

Table 12.5: Materials Used for Making Sand Casting Pattern

S/N	Type of Material	Reasons for the Choice of Material
1	**Wood**	The most commonly used pattern material is wood, the main reason being the easy availability, low weight, easy shaping and low cost.
2	**Metal**	Metal patterns are extensively for casting, because of their strength, accuracy, good dimensional stability, durability and smooth surface finish. Many materials, such as Cast iron, brass, aluminium, and white metal, can be used as pattern materials. Aluminium and White metal are also commonly used; these materials are lightweight, corrosion-resistant and can be easily worked.
3	**Plastics**	Plastics are also used as pattern materials because of their low weight, easier formability, good dimensional stability, smooth surfaces and durability. E.g. Epoxy resin.
4	**Plasters**	It has high strength, can be easily formed into complex shapes and can be used only for small patterns. E.g. Gypsum cement

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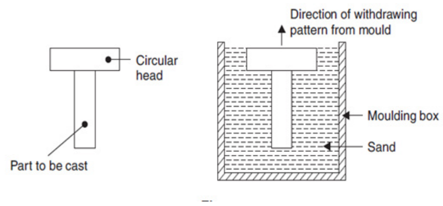
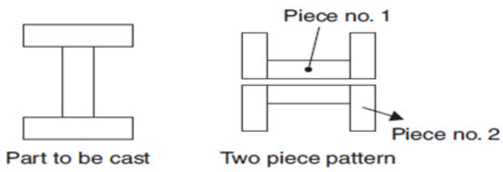
Types of patterns

Examples of patterns used for sand casting include:

1. Solid or single piece pattern,
2. Split pattern,
3. Loose piece pattern,
4. Match plate pattern,
5. Gated pattern.

Table 12.6: Patterns used for sand casting

S/N	Type of Pattern	Description of Pattern	Picture/Sketch of Cross-Section of Pattern
1	**Solid or single piece pattern**	Such patterns are made in one piece and are suitable only for very simple castings. There is no provision for runners and risers, etc.	
2	**Split pattern**	It is not practical to have one one-piece pattern for parts of complicated shapes, because it would not be possible to withdraw the pattern from the mould.	

Sand Casting using Split Patterns

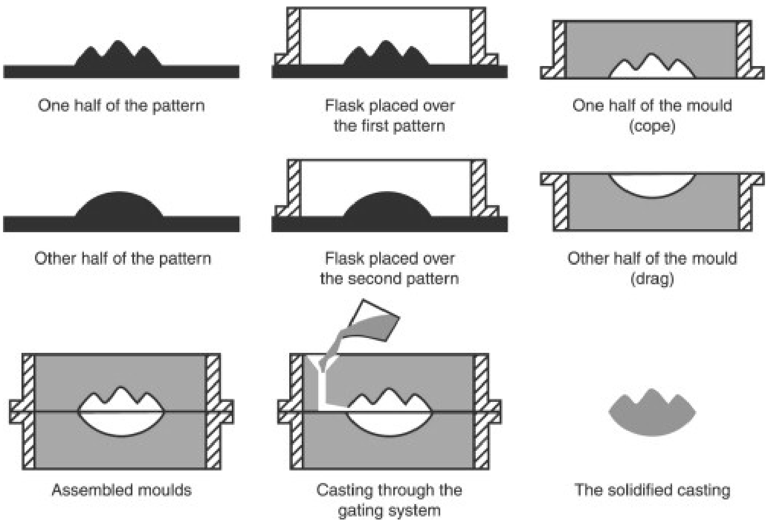


Figure 12.4: Sand casting using split patterns

What Is Die Casting?

A sand mould is usable for production of only one casting and cannot be used twice. A Die is essentially a metal mould and can be used again and again and is usually made in two portions. One portion is fixed and the other is movable. Together, they contain the mould cavity in all its details. After clamping or locking the two halves of the dies together, molten metal is introduced into the dies. If the molten metal is fed by gravity into the dies, the process is known as gravity die casting process. If the metal is forced into the dies under pressure, the process is called "***pressure die casting***".

Steps in die casting

1. Close and lock the two halves of a die after coating the mould cavity surfaces with a mould wash, if specified.
2. Inject the molten metal under pressure into the die.
3. Maintain the pressure until the metal solidifies.
4. Open die halves.
5. Eject the casting along with runner, riser, etc.
6. Repeat the above cycle.

Types of pressure die casting

There are two types of pressure die casting:

1. **Hot chamber process**: This uses pressures up to 35 MPa and is used for zinc, tin, lead, and their alloys. In this process, the chamber, in which molten metal is stored before being pressure injected into the die, is kept heated.
2. **Cold chamber process**: In this process, pressures as high as 150 MPa are used. The storing chamber is not heated. This process is used mainly for metals and alloys having relatively higher melting points, e.g., aluminium, magnesium and their alloys.

Table 12.7: Advantages and disadvantages of die casting

S/N	Advantages of Die Casting	Disadvantages of Die Casting
1	It is used for the mass production of castings of small and medium size. e.g., pistons of motorcycle and scooter engines, valve bodies, carburetor housings, etc.	The initial cost of manufacturing a die is very high
2	This process produces high quality, defect-free castings.	Large size castings cannot be produced by this process
3	The castings produced by this process are of good surface finish and have good dimensional control and may not require much machining. All castings produced are identical.	Castings with very complex shapes or with many cores are difficult to produce by die casting.

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4	In the case of mass production, castings can be produced cheaply.	
5	The process does not require the use of sand and requires much less space as compared to a conventional foundry using sand moulds.	

Defects in Sand Casting

In sand casting, defects refer to imperfections or irregularities in the final cast product that reduce its quality or functionality. These defects arise from issues in the casting process, including mould design, sand quality, pouring temperature, or cooling rates. Common defects in sand casting include those shown in **Table 12.8.**

Table 12.8: Some common defects in sand casting

S/N	Defect	Description of Defect
1	**Blow-holes**	They appear as small holes in the casting. They may be open to the surface or they may be below the surface of the casting. They are caused due to entrapped bubbles of gases. They may be caused by excessively hard ramming, improper venting, excessive moisture or lack of permeability in the sand.
2	**Shrinkage cavity**	Sometimes, due to the faulty design of casting consisting of very thick and thin sections, a shrinkage cavity may be caused at the junction of such sections. The shrinkage cavity is totally internal.
3	**Porosity**	Small holes or voids inside the cast, often caused by trapped gas or insufficient venting
5	**Cold shuts**	A cold shut is formed within a casting when molten metal from two different streams meets without complete fusion. Low pouring temperature may be the primary cause of this defect.
6	**Mismatch/ Mould shift**	Misalignment of the mould halves, leading to a mismatch in the final products This defect takes place when the mould impression in the cope and drag do not sit exactly on one another but are shifted a little bit. This happens due to mismatch of the split pattern (dowel pin may have become loose) or due to defective clamping of cope and drag boxes.
7	**Sand inclusions**	Particles of sand embedded in the casting, usually from mould erosion or poor mould strength.
8	**Drop**	This happens when a portion of the mould sand falls into the molten metal. Loose sand inadequately rammed, or a lack of binder may cause this defect.
9	**Scab**	This defect occurs when a portion of the face of a mould lifts or breaks down, and the recess is filled up by molten metal.

10	**Hot tears/ cracks**	These cracks are caused in thin, long sections of the casting. If the part of the casting cannot shrink freely on cooling due to intervening sand being too tightly packed, it offers resistance to such shrinking. The tear or crack usually takes place when the part is red hot and has not developed full strength, hence the defect is called "hot tear". The reason may be excessively tight ramming of sand.

Conclusion

In conclusion, applying the principles of sand casting to produce articles offers several advantages, particularly for manufacturing complex, custom-shaped, or large metal components. Sand casting provides versatility, allowing the use of various metals and alloys, and is cost-effective for low to medium production volumes. The process enables flexibility in design and quick adaptability to modifications, which is ideal for prototyping or producing intricate parts.

However, while sand casting is a reliable and efficient process, it does come with challenges, such as lower dimensional accuracy and surface finish compared to other casting methods. Careful control of the sand mould quality and meticulous preparation of the casting are essential to ensure a high-quality final product. By adhering to best practices in mould preparation, pouring techniques, and cooling rates, manufactures can effectively leverage sand casting to meet diverse industrial needs, balancing cost and complexity while maintaining quality.

Activity 12.1

Meaning of sand casting

Organise yourselves into groups of no more than five for the following activities. Using samples of sand-casting tools and equipment, identify and discuss their uses. Also, discuss the processes used in sand casting.

1. Your teacher will present you with a video or pictures on the sand casti process.
2. Appoint one group member to note down the major steps involved in the sand-casting process as you watch the video or examine the pictures.
3. Brainstorm with your group members what sand casting entails.
4. Share your answers with your peers in a class discussion.

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Activity 12.2

Functions of tools and equipment used for sand casting

1. Your teacher will display real tools or pictures of tools used for sand casting to the entire class.
2. In a class discussion, describe each tool and its function.
3. Break into your activity groups.
4. In your groups, write down the description and use of the particular tool you have been assigned.
5. Share your group's answer and discuss with the entire class.
6. Write down additional points that may be given by members from other groups throughout the discussion session.
7. Collate similar information from other tools presented by other groups and use it to prepare a comprehensive chart of sand-casting tools.

Activity 12.3

Sequential processes to follow to produce machine parts

1. Your teacher will guide you to watch a video on the sequential process to follow to produce a machine part using sand casting.
2. Participate in explaining each major step as the video is paused intermittently.
3. Your teacher will assign each group a specific step of the sand casting process. On a paper, include details about the step assigned to your group and don't forget to include a neat sketch of the step!
4. Let a member from your group display your chart with members from other groups, displaying the step-by-step procedure in sand casting following a sequential order.
5. As a whole class, discuss the sand-casting process.
6. Note down the complete procedure in your exercise book.

Activity 12.4

Common defects in sand casting

1. Prepare a chart for learning the topic "common casting defects".
2. Display your chart in class for appraisal
3. Modify your chart after the appraisal report.

Activity 12.5

Demonstrating the uses of sand-casting materials, tools and equipment.

1. Using samples of sand-casting materials, tools and equipment:
2. Identify sand-casting materials, tools and equipment.
3. Discuss the uses of sand-casting materials, tools and equipment.
4. Demonstrate the processes used in sand casting.

Activity 12.6

Designing and making sand casting articles

In your group, design and make articles using the sand-casting process.

CAUTION

- Always wear protective gear and follow safety instructions
- Use improvised tools where necessary.

Steps

1. Choose a simple object to make.
2. Draw a basic sketch of your design.
3. Use wood, plastic, or metal to make the shape of your design. Ensure all the surfaces are smooth.
4. Place the pattern in the moulding box.
5. Sift and mix sand with the binding agent.
6. Pack the sand tightly around the pattern.
7. Carefully remove the pattern to leave a hollow shape.
8. Pour the molten metal into the sand mould. Observe strictly safety precautions during this step.
9. Allow the metal to cool and harden.
10. Break open the mould to remove the article.
11. Clean and smooth the finished product.
12. Show your finished article to the class.
13. Share with the entire class the difficulty your group faced in preparing the article.
14. Discuss ways in which the various articles can be improved.

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Activity 12.7

Embarking on a visit to prepare photo or sketch albums

1.

a. Your teacher will arrange a visit to a local workshop to observe the sand-casting processes.

b. In groups, prepare a report based on your observations. In your report, be sure to include:

- Identifying and state the functions of each tool and equipment used in the sand-casting process.

c. present your report to the class for a discussion.

2. Make sketches and or use pictures you may have taken during your visit.

EXTENDED READING

- Fundamentals of Automotive systems: https://www.waybuilder.net/sweethaven/MechTech/Automotive01/AutomotiveSystems.asp?iNum=52
- What is pressure lubrication? https://addinol.de/en/service-en/expert-tip/pressure-lubrication/
- The Basics of Pressure Relief Valves: https://www.beswick.com/resources/the-basics-of-pressure-relief-valves/
- Gear Pump Explained: https://savree.com/en/encyclopedia/gear-pump
- Spring-loaded Pressure Relief Valves: https://www.leser.com/en-us/products/spring-loaded-pressure-relief-valves/
- How the Oil Filter Works: https://filkit.com.ua/en/smartblog/15/How-the-Oil-Filter-Works.html
- What are the Properties of Lubricants/Oils?: https://www.conro.com/Blog/what-are-the-properties-of-lubricants-oils/
- API Standard: https://oil2.ru/api/
- PCV Valve: What it Does, and Symptoms of a Bad One: https://comtiresco.com/blog/auto-repair-and-maintenance/pcv-valve-what-it-does-and-symptoms-of-a-bad-one/

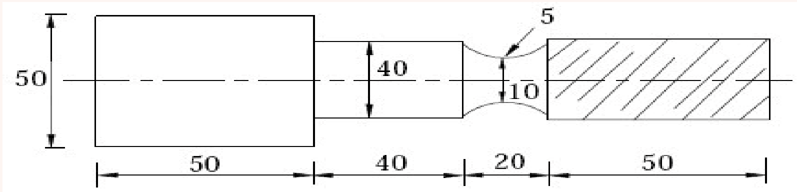
Review Questions

Questions 3.1

1. List four components of the engine that are lubricated by splash and pressure feed methods of lubrication.
2. Explain how a wet sump lubrication system operates and identify three key features of a Petroil (mist) lubrication system.
3. Describe the function of an oil pump, oil filter and pressure relief valve in an automotive lubrication system.
4. Compare three advantages and disadvantages between wet sump and dry sump lubrication systems.
5. Propose two improvements to an existing wet sump lubrication system to enhance its performance and reliability in modern automotive engines.

Questions 3.2

1. Imagine you have visited a metal workshop where several manufacturing processes take place. Identify four basic manufacturing processes you can carry out at the workshop
2. You have been assigned by your Applied Technology Teacher to design and manufacture metal parts for automotive engines. Explain at least three machining processes you will use in your school workshop.
3. You have been given a blueprint to produce a cylindrical metal part with a specific diameter and a flat surface with a key slot. You will use a lathe machine to shape the cylindrical part and a milling machine to create the flat surface and slot. Explain how to carry out the lathing and milling processes.
4. Imagine a manufacturing company needs to produce gears for new line of electric vehicles.
5. These gears must be high-precision and durable, as they'll be subject to high speeds and loads. The engineering team must identify the most suitable machine processes to achieve the desired accuracy, material quality, and production efficiency. Which machining processes will be appropriate when cutting gears? Explain why.
6. A machine shop has received an order to manufacture steel shafts with specific dimensions, requiring both parallel and tapered turning on a lathe. The final component will have a cylindrical body of a constant diameter with a tapered end for fitting into a larger assembly. The machinist needs to document the process sequence to ensure consistent quality and efficiency in production. Write the process sequence to be used for manufacturing the component shown below.



Component to be produced from a 175 mm length and 60 mm diameter metal piece

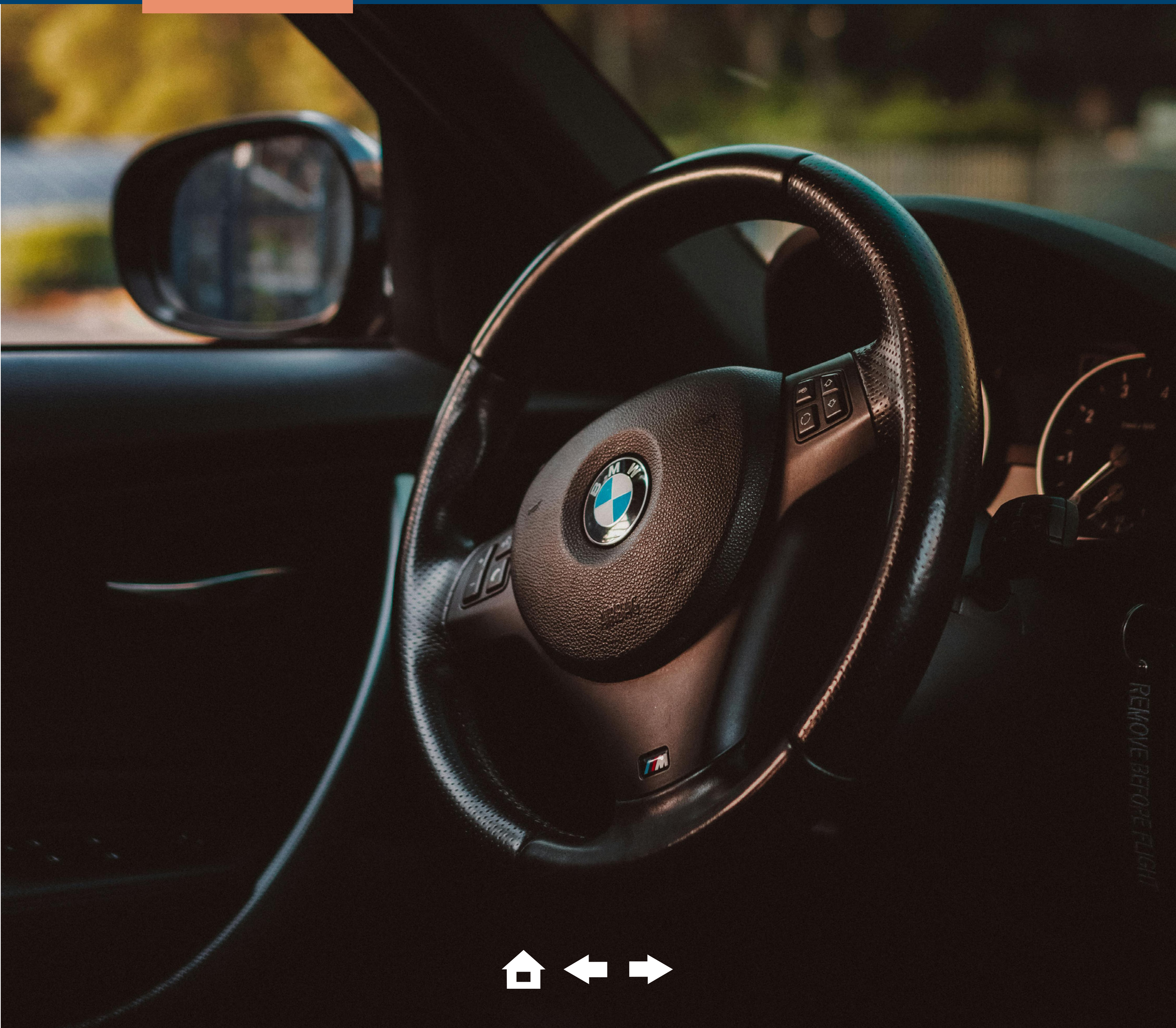
Questions 3.3

1. Imagine you are working in a foundry where you want to create metal part shaped like a small gear. You start with a pattern, which is a model of the gear made of wood, plastic, or metal. This pattern is pressed into sand inside a mould box, leaving a cavity that has the exact shape of the gear. Explain what is meant by sand casting
2. Imagine you are setting up a campsite and building a fire pit. Explain the functions of the following tools and equipment used in sand casting
    a. Bellow
    b. Slick and spoon
    c. Draw screw or gimlet
    d. Rammer
    e. Water can
3. Bells are basically made from bronze using the sand-casting processes. Describe how a bell can be produced using sand casting
4. The head of a ball-pein hammer can suitably be made using sand casting. How can you produce a ball pein hammer head using the process of sand casting?
5. A team is working on a new mobile banking application. During testing, they identified several issues that impact usability, performance, and security. Specify four common casting defects and explain the reasons which caused these defects.

SECTION

4

VEHICLE STEERING AND METAL FORMING PROCESSES I



UNIT 13

AUTOMOTIVE TECHNOLOGY

Introduction to Vehicle Technology

Introduction

In this unit, you will learn about the axle, a key component of the vehicle, that supports vehicle weight, connects and enables the rotation of wheels. Vehicles typically have two axles: front and rear, classified as dead or live. Dead axles only support weight, while live axles transmit power. The front axle supports the vehicle's weight, aids steering, absorbs road shocks, and can transmit torque in live axle configurations. Made from high-strength steel, its design ensures durability and ground clearance.

You will also explore stub axles connected to the front axle via kingpins, providing mounting points for the wheels and assisting steering. The importance of vehicle dimensions to the design and usage of vehicles will also be examined in this unit.

KEY IDEAS

- Axles are used to connect a pair of wheels on a vehicle.
- Axles support weight and enable wheel alignment and rotation.
- Stub axles attach wheels to the front axle and support steering.
- The design of live front axles and vehicle dimensions ensures stability, durability, and ease of manoeuvrability.
- The three primary types of axles are front, rear, and stub axles. Front and rear axles may be classified as live (transmitting power) or dead (only supporting weight).
- Vehicle key dimensions are critical for design, functionality, and compliance with regulations.

THE AXLE

The axle is a central rod or shaft that spans the width of the vehicle, connecting each pair of wheels and providing mounting points for the wheels. It is horizontally attached to the underside of the vehicle and is secured to the vehicle body or chassis by means of suspension mechanisms and bearings. Axles support the weight of the vehicle and enable the wheels to align and rotate. Every vehicle typically has at least two sets of axles: one for the front wheels and the other for the rear wheels.

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Types of Axles

Three different axles are typically involved in the suspension and steering of vehicles. They are the front axle, rear axle, and stub axle. Each of these three axles operates differently from the other. The front and rear axles may be described as dead or live, depending on the role they play. Live axles transmit power and rotate with the wheels, whilst dead axles only support the weight of the vehicle without transmitting motion or torque to the road wheels.

Front axle

The front axle of the vehicle connects the front wheels to the vehicle and supports the vehicle's weight at the front. Each wheel is mounted on a stub axle, which is pivoted to the end of the front axle using a kingpin or swivel pin. The two stub axles are connected by steering arms, which are joined together by a track rod and linked to a mechanism connected to the steering wheel.

Figure 13.1: A front axle

Functions of the front axle

The front axle of the vehicle plays numerous important roles:

1. It supports the weight of the vehicle at the front.
2. It provides mounting points for the front wheels. As the front wheels are usually the steered wheels, the front axle becomes an integral part of the steering as well as the suspension system.
3. Apart from the above roles, the front axle works with the suspension system to absorb road shocks transmitted by the front wheels and also absorbs braking forces to keep the vehicle stable on the road.
4. Front axles can also function as live axles to transmit torque from the engine or form part of the drive train to transmit power to the road wheels.

Front axle construction

The front axle is made from high-strength steel and has an upward bend at the middle to provide ground clearance. It is designed to absorb bending loads due to the weight of the vehicle, and also torque loads arising from the braking.

The axle beam usually has an 'I' or 'H' section, which offers a high strength-to-weight ratio, and are capable of withstanding the bending and twisting forces encountered during steering and load-bearing. The beam may also be solid, round or tubular in section, depending on vehicle weight and other design considerations.

The front axle assembly consists of the main beam, which is installed transversely underneath the vehicle frame, with stub axles, which are joined to the extreme ends of the beam by kingpins.

Types of front axles

Front axles may be classified as ***"dead" or "live"***, depending on the way they support the movement of the vehicle.

Dead Front Axle

Dead front axles are located at the front of the vehicle to provide support to the vehicle. Dead axles do not transmit engine power or drive to the road wheels. Even though they do not play active role in the transmission system, their ends are designed to allow the stub axles to be mounted on them.

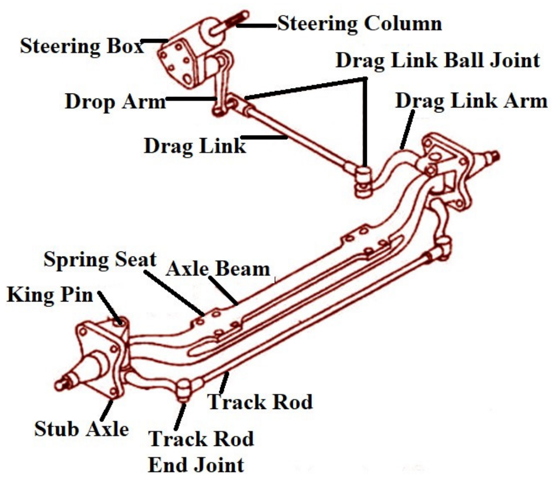

Figure 13.2: An 'I' section dead front axle

Front Live Axle

Front live axles transmit drive from the gearbox to the road wheels. They are generally used on four-wheel drive vehicles. The use of live axles provides improved strength and durability, which is important in an off-road vehicle subjected to harsh terrain. The front live axle construction is very similar to the rear live axle, with a differential-final drive unit linked via drive shafts to the road wheels.

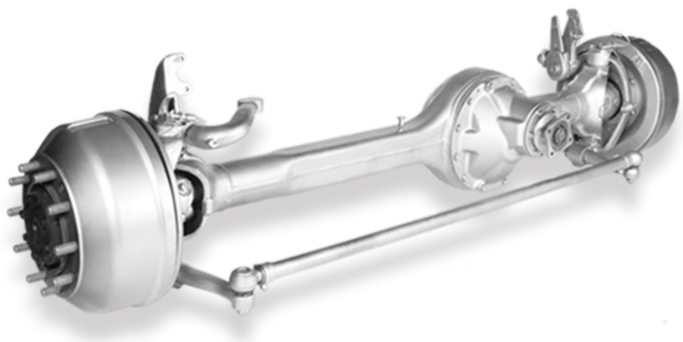

Figure 13.3: A front live axle

Stub axle

Stub axles provide a means of attachment or mounting points for the road wheels to the front axle. They also provide additional support to the main axle and the steered wheels. The stub axle and front axle or suspension mechanism are joined by a kingpin or swivel pin, which serves as a pivot point for the smooth turning of the stub axle during cornering or steering.

Figure 13.4: A stub axle

Types of stub axles

Stub axles are categorised based on their design and how they are attached to the axle beam or suspension system. Four main designs in use are Elliot, Reversed Elliot, Lemoine and Reversed lemoine.

- **Elliot Stub Axle**: This type has a yoke-shaped end that connects to the front axle using a kingpin, cotter, and bush.

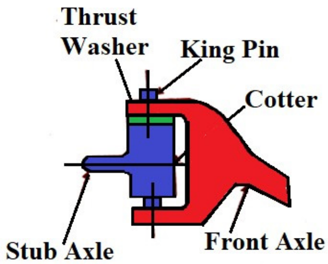

Figure 13.5: Elliot stub axle

- **Reversed Elliot Stub Axle**: This is similar to the Elliot type but has an inverted (reversed) yoke.

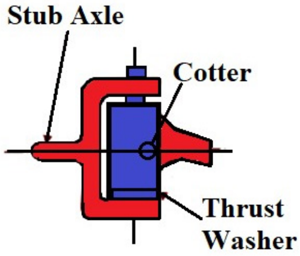

Figure 13.6: Reversed Elliot stub axle

- **Lemoine Stub Axle**: This type of stub axle has an L-shaped spindle, which makes the design more compact and lightweight.

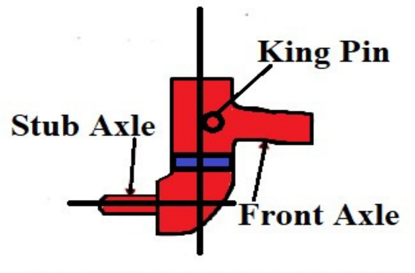

Figure 13.7: Lemoine stub axle

- **Reversed Lemoine Stub Axle**: This is a variation of the Lemoine stub axle with a reversed or inverted L-shaped spindle.

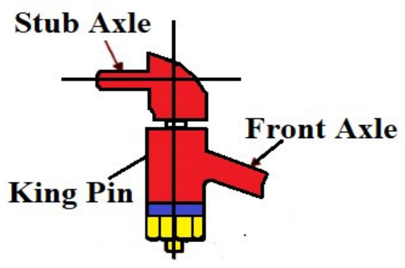

Figure 13.8: Reversed Lemoine stub axle

Activity 13.1

Identification and description of stub axles

Organise yourselves into groups of 5 and complete the following. Your teacher will organise a visit to the school car park or a local mechanic's shop.

Materials needed

- Sketchpad
- Pencil/pen
- Internet

Activity Steps

1. In your groups, identify on your school compound, or a mechanic shop in your school community, vehicles that use front axles.
2. Sketch the beam axle and stub axle connection.
3. Name the type of stub axle used in the assembly.
4. Write a descriptive note on the sketch you have made, describing the type of front axle and the stub axle you have illustrated.

5. In your groups, also discuss the following:
6. Various types of front axles
7. Different types of stub axles
8. Based on your group discussion, prepare a report and present that to the class for feedback and discussion.

Vehicle Dimensions

Vehicle dimensions are the measurable size specifications of a vehicle, which define its physical space, shape, and functionality. These measurements are very important for determining the vehicle's suitability for various requirements, including design, functionality, safety, parking, storage, transportation and compliance with road regulations. Typical vehicle dimensions include:

1. **Wheelbase:** The horizontal distance between the centres of the front and rear wheels.
2. **Front Overhang:** The distance from the front of the car to the centre of the front wheels. It affects how well the car can go over obstacles in front of it.
3. **Rear Overhang:** The distance from the back of the car to the centre of the rear wheels. It affects how well the car can manoeuvre over obstacles when going backward.
4. **Overall Length:** This specifies how long the car is from the very front to the very back, including the bumpers.
5. **Front Wheel Track:** The distance between the centres of the left and right front wheels.
6. **Rear Wheel Track:** The distance between the centres of the left and right wheels on the same axle.
7. **Overall Width:** How wide the car is at its widest point, without the mirrors. This shows if the car can fit through tight spaces.
8. **Overall Height:** This is the vertical distance from the ground to the highest point of the car. It matters for aerodynamics and fitting in low spaces.
9. **Ground Clearance:** The gap between the lowest part of the car and the ground. It is important for driving over rough surfaces without scraping the bottom.

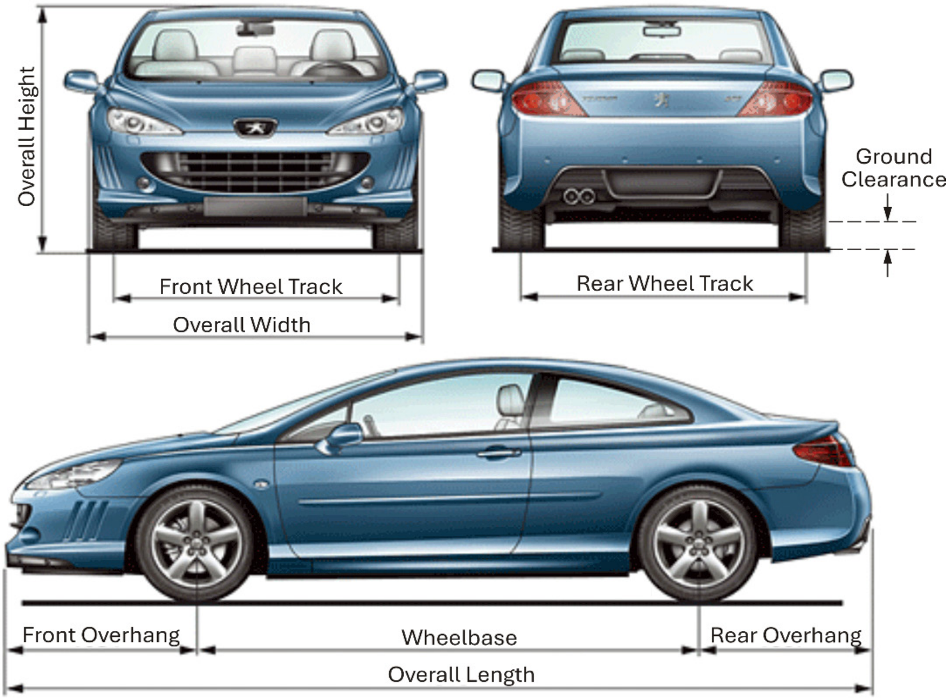

Figure 13.9: Vehicle dimensions

Activity 13.2

Taking Vehicle Dimensions

You will conduct this activity together with your group members.

Materials needed

- Tape measure
- Rule
- Chalk
- Note pad
- Pen/pencil

Activity Steps

1. Your teacher will organise an activity for you to identify five different types (models) of vehicles at your school car park or on the school compound. (Make sure they are stationary and the tyres are pointing in the straight-ahead position).
2. Measure each of the following dimensions and use the data to prepare a chart using the template below:

Table 13.1: Vehicle dimensions template

Vehicle type	Overall length	Wheel base	Overall width	Track	Overall height	Front clearance	Rear clearance	Ground clearance
1.								
2.								
3.								
4.								
5.								

3. Compare your group's data with those of other groups and discuss the significance of vehicle dimensions in the design and production of vehicles.

UNIT 14

METAL TECHNOLOGY

Welding Technology

Introduction

Metal forming is an important manufacturing process used to shape metal into useful products by applying force. It plays a key role in making many items we use every day, such as car parts, building materials, and machine components. This makes the topic relevant for students studying engineering and technical subjects. In this lesson, students will learn about the two main types of metal forming: bulk forming and sheet forming. Bulk forming processes, such as forging and rolling, are used to make strong and solid parts like shafts, rods, and gears. Sheet forming processes, including bending, shearing, and deep drawing, shape thin metal sheets into products like car body panels. The lesson will also introduce the concepts of cold working and hot working. Cold working is done at room temperature, which increases the strength of the metal but can make it harder to shape. Hot working is done at high temperatures, making the metal easier to form and reducing the chance of cracks.

KEY IDEAS

- Bulk forming involves shaping large pieces of metal, like rods or gears, through processes such as forging, rolling and extrusion.
- Cold working, where metal is shaped at room temperature, increases its strength but makes it harder to form.
- Forging process where metal is heated and then hammered or pressed into shape.
- Hot working where metal is heated to make it easier to shape, improving its properties and preventing cracks.
- Rolling process where metal is passed through rollers to reduce its thickness or shape it into sheets or strips.
- Sheet forming is used for shaping thin sheets of metal to include shearing, bending and deep drawing processes.

METAL FORMING PROCESSES WITH ENGINEERING APPLICATIONS

Metal forming is a very important manufacturing operation. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity and considerable material saving. Materials are converted into finished products through different manufacturing processes. Manufacturing processes are classified into shaping (casting), forming, joining, coating, dividing, machining and modifying material properties.

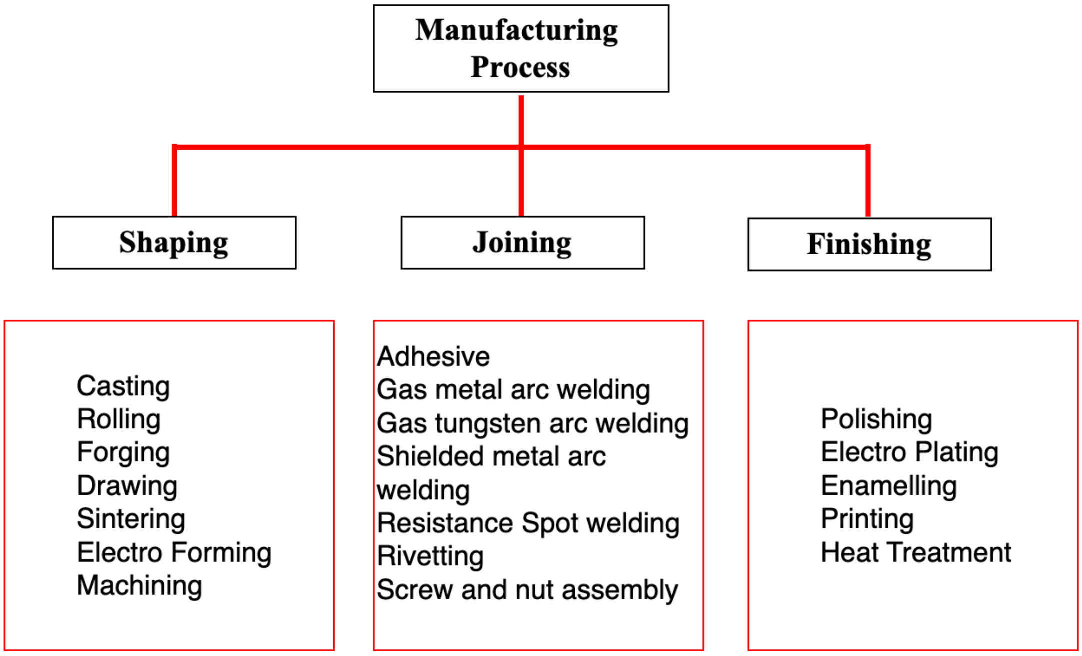

Figure 14.1: Various Manufacturing Operations on Materials

Of these manufacturing processes, forming is a widely used process which finds applications in automotive, aerospace, defence and other industries.

General Classification of Metal Forming Processes

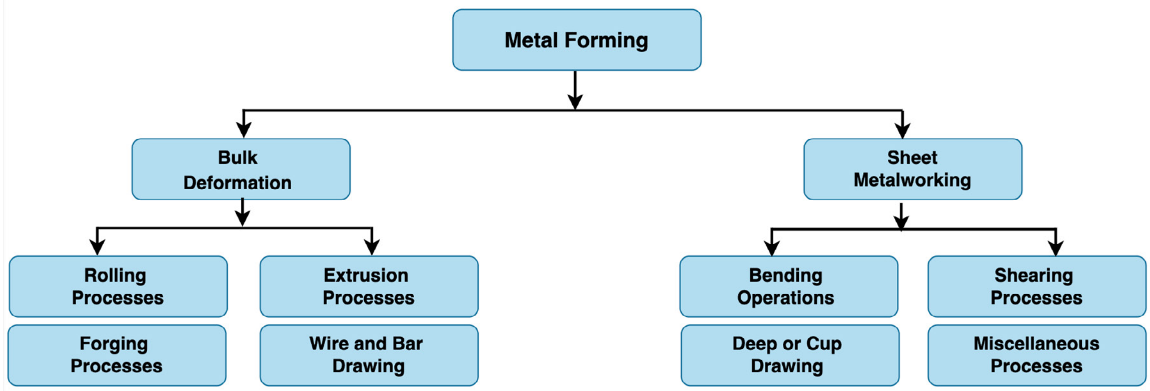

Figure 14.2: Metal forming process

What Is the Metal Forming Process?

Metal forming processes, also known as mechanical working processes, are primary shaping processes in which a mass of metal or alloy is subjected to mechanical forces. Under the action of such forces, the shape and size of the metal piece undergo a change.

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The tools used for such deformation are called a die, a punch, etc., depending on the type of process.

Classification of basic bulk forming processes

1. **Bulk forming:** It is a severe deformation process resulting in massive shape change. The surface area-to-volume of the work is relatively small. Bulk forming processes involve significant plastic deformation of the metal, where the volume of the material remains relatively constant but its shape changes significantly. It is mostly done in hot working conditions.

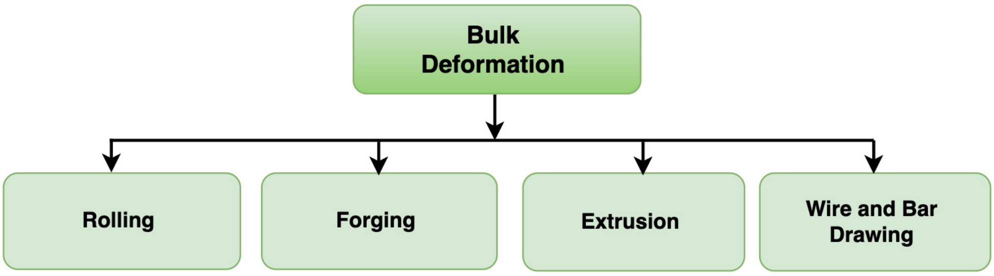

Figure 14.3: Bulk forming processes

2. **Rolling**: In this process, the work piece in the form of slab or plate is compressed between two rotating rolls in the thickness direction, so that the thickness is reduced. The rotating rolls draw the slab into the gap and compresses it. The final product is in the form of sheet.
3. **Forging**: The work piece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.
4. **Extrusion**: In this, the work piece is compressed or pushed into the die opening to take the shape of the die hole as its cross section.
5. **Wire or rod drawing**: Is similar to extrusion, except that the workpiece is pulled through the die opening to take the cross-section.

Classification of basic sheet forming processes

1. **Sheet forming**: Sheet metal forming involves forming and cutting operations performed on metal sheets, strips, and coils. The surface area-to-volume ratio of the starting metal is relatively high. Tools include punch, die that are used to deform the sheets.

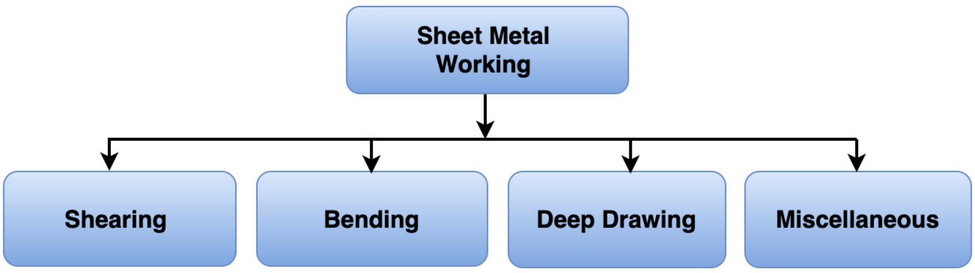

Figure 14.4: Sheet forming

2. **Bending**: In this, the sheet material is strained by a punch to give a bend shape (angle shape) usually in a straight axis.
3. **Deep (or cup) drawing**: In this operation, forming a flat metal sheet into a hollow or concave shape like a cup is performed by stretching the metal in some regions. A blank holder is used to clamp the blank on the die, while the punch pushes into the sheet metal. The sheet is drawn into the die hole, taking the shape of the cavity.
4. **Shearing**: This is the cutting of sheets by a shearing action. In other words, cutting the sheet metal along a straight line using a pair of shearing blades.

Cold and Hot Working of Metals

Cold working, also known as cold forming, is a process where metals are shaped at temperatures below their recrystallisation temperature, typically at or near room temperature. This process increases the strength and hardness of the material through strain hardening while maintaining or improving surface finish and dimensional accuracy.

Table 14.1: Types and Description of Cold Working Process

S/N	Type of Cold Working Process	Description of Cold Working Process
1	**Cold Rolling**	It reduces the thickness of metal sheets or strips by passing them through rollers and enhances surface finish and dimensional accuracy. It produces products like sheets, strips, and foils.
2	**Cold Forging**	It deforms metal using compressive forces without heating. That is shaping metal by hammering or pressing at low temperatures. It is used for making high-strength components such as bolts, nuts, and screws.
3	**Cold Drawing**	It pulls metal through a die to reduce the diameter or create specific shapes. It is used for making wire, rods, and tubes.
4	**Cold Bending**	It bends metal sheets or bars to form specific angles or curves. It is used for forming angles, channels, and other shapes.
5	**Cold Stamping**	It uses dies and presses to cut or shape metal sheets. It is used for producing automotive panels, appliances and enclosures.

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Table 14.2: Advantages and Disadvantages of Cold Working Process

S/N	Advantages of Cold-Working Metals	Disadvantages of Cold-Working Metals
1	It is widely applied as a forming process for steel.	The strength of the metal is high, so large forces are needed for deformation.
2	Cold working is done at room temperature, so no oxidation and scaling of the work naturally occurs.	Complex shapes cannot be formed.
3	Provides an excellent surface finish, which reduces the secondary machining process.	Tools must be specially designed, so tool costs are high.
4	High-dimensional accuracy.	Stress formation in the metal during cold working is higher, so this requires stress relieving.
5	Highly suitable for mass production and automation because of low working temperature.	Tool wear- Tools and equipment used in cold working experience higher wear and tear due to the increased forces and stresses involved.

APPLICATIONS OF COLD WORKING OF METALS

Cold working is used in various industries to produce parts that require high strength, precise dimensions, and good surface finish. Common applications include those shown in **Table 14.3** below.

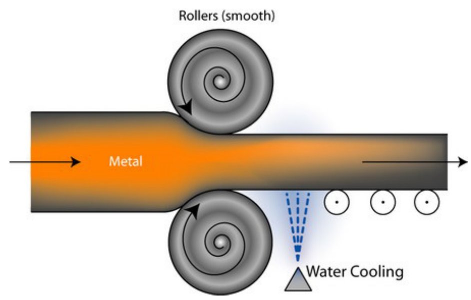
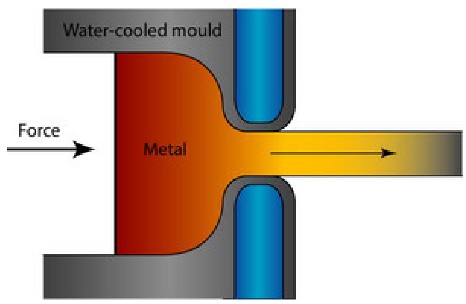
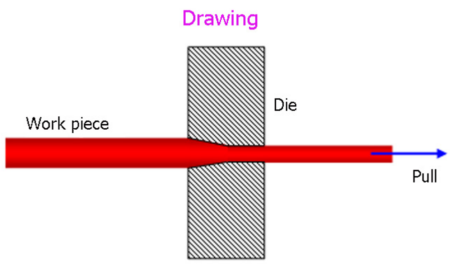
Table 14.3: Examples of Applications of Cold Working of Metals

S/N	Practical Applications of Cold Working of Metals	Examples of Practical Applications of Cold Working of Metals
1	Automotive Components	Fasteners, springs, and body panels.
2	Construction Materials	Steel beams and reinforcement bars.
3	Consumer Goods	Metal cans, kitchen utensils, and electronic device casings.
4	Aerospace Parts	Brackets, frames, and fittings.

Hot Forming of Metals

Hot working is a process where metals are shaped at temperatures above their recrystallisation temperature but below the melting point. Plastic deformation of metals and alloys happens under the condition of temperature and strain rate, and the recrystallisation temperature is 30 to 40% of the melting temperature. This high-temperature processing allows for significant deformation of the metal without the risk of fracturing, making it ideal for shaping large or complex parts.

Table 14.4: Types of Hot Working Process

S/N	Type of Hot Working Process	Description of the Type of Hot Working Process	Picture of the Type of Hot Working Process
1	**Hot Rolling**	Passing the metal through rollers to reduce thickness, improve uniformity, or create specific cross-sectional shapes. Used to produce sheets, plates, and structural shapes like I-beams and rails.	
2	**Hot Forging**	Shaping metal by compressive forces using a hammer or press, often resulting in more durable parts with a refined grain structure. It produces high-strength components like crankshafts, gears, and axles.	
3	**Hot Extrusion**	Forcing metal through a die to create long parts with uniform cross-sections, such as pipes or rods.	
4	**Hot Drawing**	Pulling the metal through a die to reduce diameter or change its cross-sectional shape. It is used for making wire, rods and tubing	

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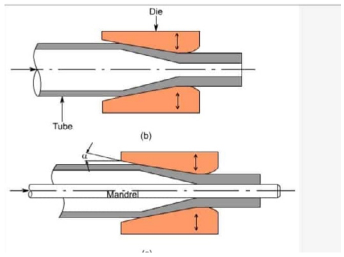
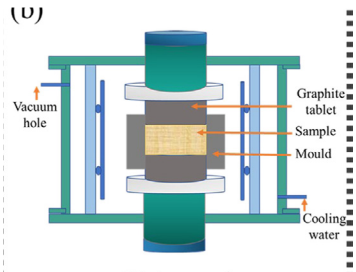
5	**Hot Swaging**	Reduces the diameter or shapes the metal by using a series of dies that hammer around the circumference of the workpiece. Typically used for tapering or reducing the ends of rods and tubes	
6	**Hot Spinning**	A rotating metal blank is pressed against a shaped mandrel to form axisymmetric parts. It is used for making items like gas cylinders, cones, and domes	
7	**Hot Pressing**	Applying pressure to metal within a mould to achieve the desired shape, often used for intricate or complex parts.	 Hot-pressing

Table 14.5: Advantages and Disadvantages of Hot Working of Metals

S/N	Advantages of Hot Working Process	Disadvantages of Hot Working Process
1	Lower working force is enough to give shape.	The process takes place at higher temperatures, that is, above 730 ^{0}C, so special protection of machines is necessary; otherwise, machine and tool life will be reduced.
2	A very dramatic shape change is possible.	Handling cost is high (energy and cost-intensive). Maintaining high temperatures requires substantial energy, leading to high operational costs.
3	Properties such as strength, ductility and toughness are improved.	If the die or the tool wears, the surface finish is affected (surface finish issues).
4	Density increases by removing voids.	While the object cools from its recrystallisation temperature, its dimensions may vary due to the shrinkage of the parts.
5	Desired shape can be easily obtained under plastic deformation.	Oxidation and scaling- at high temperatures, the surface of the metal reacts with oxygen, forming oxide layers or scales, which may require additional finishing processes.

6	The effect of impurities can be reduced.	Lower dimensional accuracy (the high temperatures can cause thermal expansion and warping, leading to less precise dimensions compared to cold working.
7	A good grain structure is obtained.	Reduced tool life- Tools and dies used in hot working are exposed to extreme heat, which accelerates wear and reduces their lifespan.
8	Atoms in the same direction lead to better strength.	Environmental: The energy-intensive nature of the process can contribute to environmental issues, such as increased greenhouse gas emissions.

Applications of Hot Working

Hot working is widely used in industries that require the shaping of large or complex metal components. Common applications are shown in Table 4.14.6 below.

Table 14.6: Applications of Hot Working of Metals

S/N	Types of Hot Working of Metal	Examples of Application
1	Structural Components	Beams, columns, and rails used in construction and infrastructure
2	Automotive Parts:	Including crankshafts, connecting rods, and gears
3	Aerospace Components:	Turbine blades, engine parts, and airframe components.
4	Heavy Machinery	Components like shafts, gears, and large machine frames.
5	Metal Stock Production	Creating billets, bars, and sheets for further processing.

Difference Between Hot Working and Cold Working Metals

The main difference between cold and hot working lies primarily in the temperature at which the metal is processed and the resulting mechanical properties and characteristics of the finished product. Below are some other differences between hot and cold working of Metals.

Table 14.7: Differences Between Hot Working and Cold Working of Metals

S/N	Hot Working	Cold Working
1	Working above the recrystallisation temperature.	Working below the recrystallisation temperature.
2	New crystals are formed.	No new crystals formed.
3	It hardens the metal.	No hardening occurs.

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4	Impurities are removed from the metal.	Impurities are not removed from the metal.
5	Elongation of metal takes place.	Elongation decreases.
6	Large-sized metals are deformed.	Limited to size.
7	Internal stress is not formed.	Internal stress is formed.

Conclusion

In this lesson, we have explored the fundamental metal forming processes such as forging, rolling, extrusion, and bending that serve as the backbone of modern manufacturing. These techniques enable the production of diverse products, ranging from complex automotive components to everyday household items. Learners have gained insight into the two general classifications of metal forming processes, with emphasis on both bulk metal forming and basic sheet metal forming. By reviewing hot and cold working methods and their engineering applications, the lesson highlights not only the usefulness of these processes but also their important role in shaping materials to meet industrial demands.

Activity 14.1

Metal forming processes

Organise yourselves into groups of 5 and complete the following activities:

1. In your groups, brainstorm and discuss the following.
2. What is meant by metal forming processes?
3. How is each basic metal forming process used in making articles?
4. Describe how two or more metal forming processes are used to produce articles.
5. What are the advantages of using metal forming processes to produce articles?
6. What are the differences between hot forming and cold forming processes for producing artefacts?

Activity 14.2

Differences between rolling, forging and extrusion

Discuss the differences between rolling, forging and extrusion and present the report to the class.

Activity 14.3

Preparation of charts to show the differences between cold working and hot working processes.

Prepare tables to show the differences between cold working and hot working processes and present your chart in class for appraisal.

Activity 14.4

Field visit

1. Your teacher will arrange an educational visit to a local workshop for you to observe the basic metal forming processes.
2. In your groups, identify and make sketches or take pictures of some tools and equipment used for the processes.
3. Prepare a presentation for your class and include pictures and descriptions for each tool from your visit. Present this to the class for discussion and feedback.

Note:

- **a.** Observe the basic safety precautions during the visit.
- **b.** Wear your PPE.

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AUTOMOTIVE TECHNOLOGY

Introduction to Vehicle Technology

Introduction

The steering system in automobiles enables the driver to control the vehicle's direction by converting the rotary motion of the steering wheel into angular motion of the front wheels. It enhances vehicle safety, manoeuvrability, and driving comfort while meeting requirements such as responsiveness, minimal effort, and vibration reduction. Power-assisted steering (PAS) systems, including electric and hydraulic types, amplify the driver's effort and improve handling, especially for heavier vehicles. Key components of steering systems include the steering wheel, column, shaft, gearbox, and linkages. Rack-and-pinion and recirculating ball mechanisms are commonly used, with the former favoured for its simplicity and the latter for heavy-duty applications. We will learn in this unit how these systems ensure smooth and precise control of the vehicle.

KEY IDEAS

- Electric power-assisted steering (EPAS) uses sensors and an electric motor to provide variable assistance.
- Hydraulic power-assisted steering (HPAS) uses a pump and hydraulic fluid to make steering easier.
- Power-assisted steering (PAS) reduces the driver's effort by amplifying steering input.
- The main components of the steering system include the steering wheel, column, shaft, gearbox, and linkages.
- The steering system allows the driver to control the vehicle's direction by turning the front wheels.

MAIN COMPONENTS OF THE STEERING SYSTEM

The Steering System

The purpose of the steering system is to allow the driver to direct the vehicle along the road and turn it in a desired direction. The system consists of a number of parts that are assembled together to achieve the prime purpose of helping the driver to control the vehicle in motion. The steering effect is achieved by converting the rotary movement of the steering wheel in the driver's hand into the angular turning of the front wheels on the road surface. The steering system, generally, provides improved vehicle safety, steering quality, and steering control.

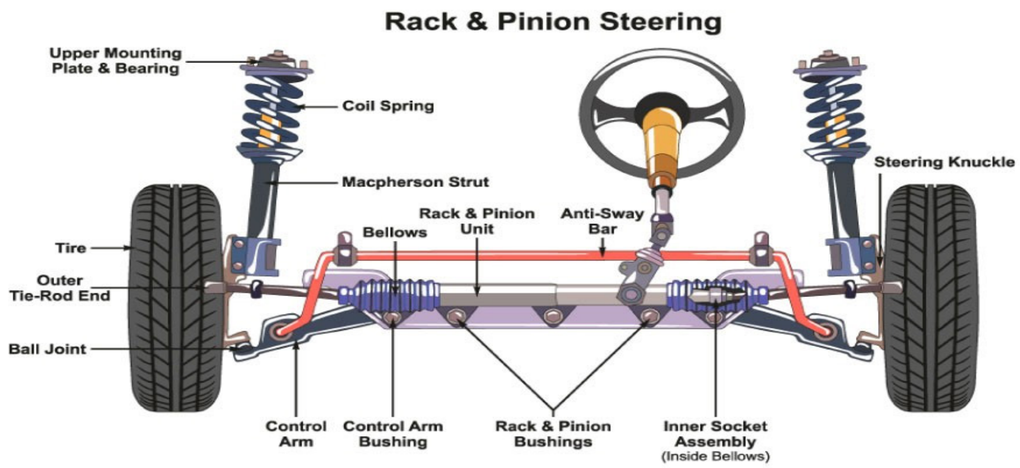

Figure 15.1: The automobile steering system (Source: thors.com)

Requirements Of The Steering System

The general requirements for a vehicle's steering system are as follows:

1. It should respond quickly to the driver's input without delay.
2. It must operate under minimal effort from the driver.
3. It should maintain control even on uneven or rough roads.
4. It must be self-centring and maintain its effectiveness under all driving conditions.
5. Its components must be strong and resistant to wear over a long time.
6. It should minimise vibrations and provide a smooth driving experience.
7. It should occupy minimal space without compromising functionality.
8. It should be capable of multiplying the little effort by the driver into a greater turning of the wheels on the road.
9. It must be light and easy to operate.
10. It must absorb road shocks and vibrations and not transmit them to the driver.
11. The connections must remain rigid at all times.

Power-assisted Steering (PAS)

Power-assisted steering (or PAS) is a steering system that relies on an additional device to increase the turning effect of the steering mechanism. Power-assisted steering significantly multiplies driver's effort by increasing the turning output of the steering wheel without stress to the driver. power-assisted steering offers the following advantages:

1. It offers easy steering while reducing driver fatigue.
2. It reduces the number of steering wheel turns from lock-to-lock.
3. It minimises the feedback of road shocks through the steering mechanism to the driver.
4. It enhances safety by improving the vehicle's resistance to sudden swerving due to uneven drag forces, such as when a tyre deflates.
5. It supports heavier loads on the steered wheels, which enables a more flexible vehicle design for better passenger or cargo space.

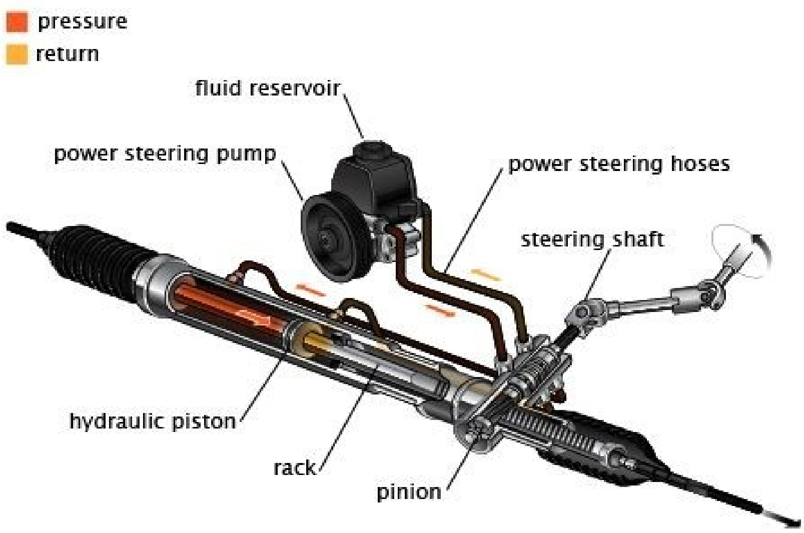

Figure 15.2: A power-assisted steering mechanism

Types of Power-Assisted Steering

The two types of power-assisted steering in use are *electronic* and *hydraulic* power-assisted steering systems.

Electric power-assisted steering (EPAS)

Electric power-assisted steering systems rely on an electric motor, an electronic control module and sensors to control the steering gear mechanism. EPAS is more fuel-efficient since it doesn't require a hydraulic pump, reducing engine load. It provides variable assistance, making steering easier at low speeds and more controlled at high speeds. However, it relies on the vehicle's electrical system, and any failure can lead to loss of steering assistance.

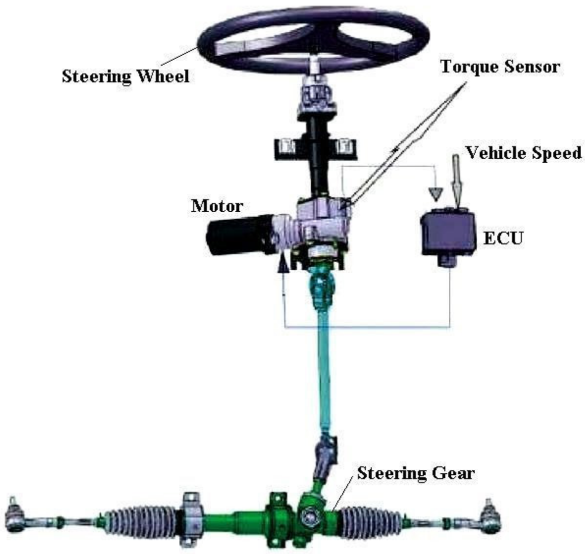

Figure 15.3: Electric power steering.

Hydraulic power-assisted steering (HPAS)

Hydraulic systems use an engine-driven pump, a fluid reservoir, hoses, lines, and a steering assist unit to boost the steering effort. The pump circulates fluid within a closed-loop servo mechanism, building up hydraulic pressure when necessary. As the driver turns the steering wheel, a hydraulic control valve is activated due to the resistance encountered from the steered wheels through the steering reduction gear. This valve then directs hydraulic pressure to a double-acting power cylinder or ram. Inside the cylinder, thrust is generated on one side or the other of a servo piston, which is connected to the steering mechanism. This action augments the driver's effort, making steering easier and more responsive.

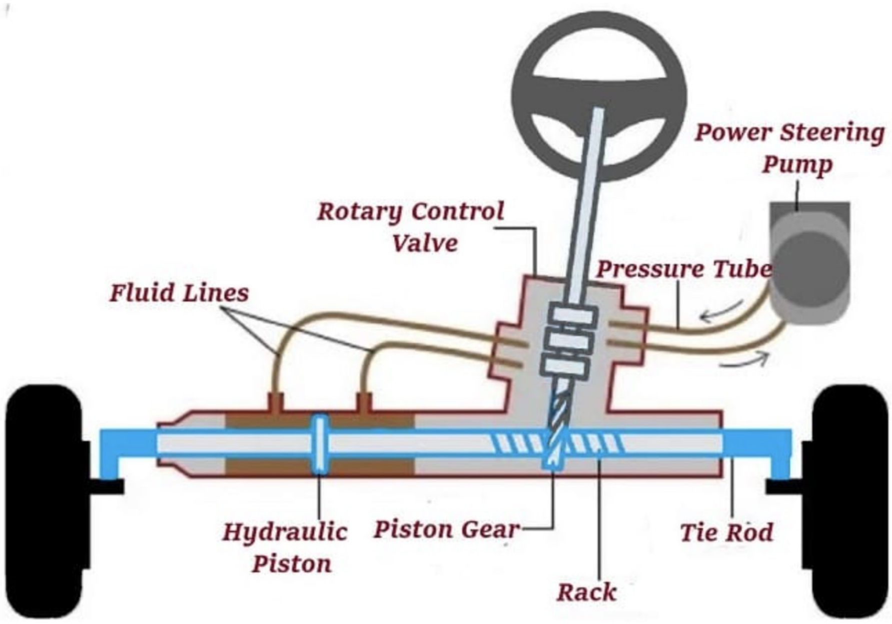

Figure 15.4: Hydraulic power-assisted steering

Main Components of Power-Assisted Steering System (Power Steering)

1. **Power Steering Pump:** The power steering pump pressurises the hydraulic fluid to provide the force needed to assist steering. The pump is driven by the engine through a belt mechanism.
2. **Hydraulic Lines:** The hydraulic lines consist of hoses and tubes that carry and distribute the pressurised hydraulic fluid between the pump, reservoir, and steering gearbox.
3. **Power Steering Fluid:** The steering fluid is a specialised oil that transmits pressure, lubricates the moving components, and reduces wear and tear.
4. **Steering Gearbox or Rack:** The steering gearbox or rack-and-pinion unit is a mechanism that translates the rotational movement of the steering wheel into linear motion to turn the wheels. It also contains the power-assist mechanism that works to reduce the effort required by the driver in operating the steering.
5. **Power Steering Control Module:** The power steering control module is an electronic unit found in electric power-assisted steering systems. It processes information from sensors, such as steering torque and speed, to determine how much assistance the electric motor should provide. This ensures optimal steering performance based on driving conditions.

Main components of the manual steering system

The major parts of the manual steering system include the following:

1. Steering wheel
2. Steering column
3. Steering shaft
4. Steering gearbox
5. Steering linkage.

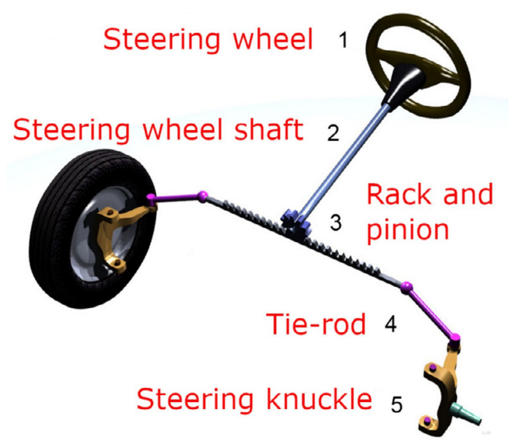

Figure 15.5: Components of the manual steering system

1. Steering wheel

The steering wheel is the part of the steering system that is controlled by the driver. It is circular and generally padded to offer a comfortable grip. Most steering wheels have two or three spokes or a large centre section that connects the wheel portion to the hub. The hub has internal splines which mesh with external splines on the steering shaft. The steering wheel contains other attachments like the horn switch and the Supplemental Restraint System (SRS) air bag.

2. Steering column

The steering column is a cylindrical tube component within which the steering shaft is installed. Some columns are designed with a collapsible mechanism, a safety feature which ensures the steering wheel collapses or retracts from the driver in the event of collision to reduce the risk of injury to the driver. It also provides comfort to the driver and allow for easy entering and exiting of the driver from the driver's seat. Others with a telescoping design allow the steering wheel to be adjusted closer to or farther from the seat.

The steering column, apart from protecting and supporting the steering shaft, serves as a mounting point for the ignition switch, provides a channel for the wiring and electrical connectors for the horns, air bag systems, cruise control and steering wheel mounted buttons or paddies.

3. Steering shaft

The steering shaft is a slender, often cylindrical, hexagonal or Double-D, hollow or solid rod that connects and transmits the rotational motion of the steering wheel to the steering gearbox. A universal joint or flexible coupling is used to attach the shaft to the steering gearbox. It is made from high-strength steel or other strong metal to withstand shocks and bending. It is installed within the steering column with bearings to offer protection and enhance smooth operation.

4. Steering linkages

Steering linkages connect the steering gear to the steering arms on the front wheels. The main steering linkages include the tie rods, drag link, idler arm, and pitman arm. The pitman arm transfers motion from the steering gearbox to the drag link, which connects to the idler arm and maintains alignment. The tie rods connect to the wheels and ensure they turn simultaneously. Together, these linkages transmit the driver's input from the steering wheel to the wheels, ensuring precise and synchronised movement.

5. The Steering Gearbox

The steering gearbox (or simply, steering box) is positioned between the steering shaft and the wheel axle. It contains a set of gears that multiply the minimum

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effort of the driver on the steering wheel into a greater turning force of the road wheels. The rotary motion of the steering wheel is converted to linear (side-to-side) motion of the track rod or drag link.

Types of steering gearboxes

Different types of steering gearboxes have been designed and used in automobile applications over the years. Each one has its own unique characteristics and advantages. They include:

1. Rack and pinion
2. Recirculating ball
3. Cam and roller
4. Cam and peg
5. Worm and sector
6. Screw and nut
7. Worm and roller

The two most common steering gearboxes are the *rack and pinion* and the *recirculating ball* types.

1. Rack and pinion steering gearbox

The rack and pinion mechanism is the simplest design of steering gearboxes and is the most widely used type on light vehicles. It uses a rack and pinion mechanism to convert rotational motion of the steering wheel into linear motion that creates a swivelling effect on the steered wheels. The rack, usually machined on a track rod, meshes with a pinion gear at the end of the steering shaft.

The rack-and-pinion gearbox is compact in construction, lightweight and offers a smoother operation.

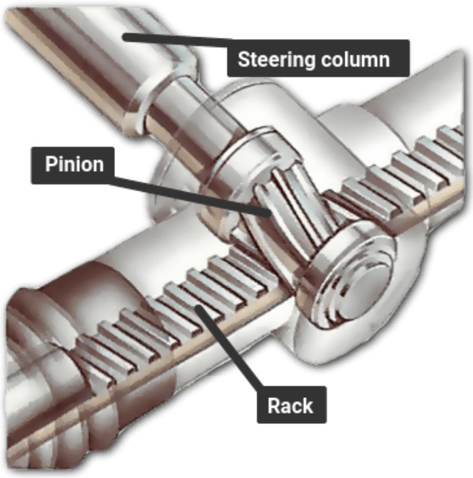

Figure 15.6: A rack and pinion steering mechanism

2. Recirculating ball steering gearbox

The recirculating ball gearbox is a type of steering gearbox that uses a worm and ball mechanism to transmit steering motion. The gearbox contains a ball nut that engages with the worm on the steering shaft, and recirculating balls that provide a smooth steering action. As the steering wheel is turned, the worm rotates, moving the ball nut and ultimately steering the vehicle.

The recirculating steering gearbox is often used in heavy-duty applications. It was also popular on older vehicles.

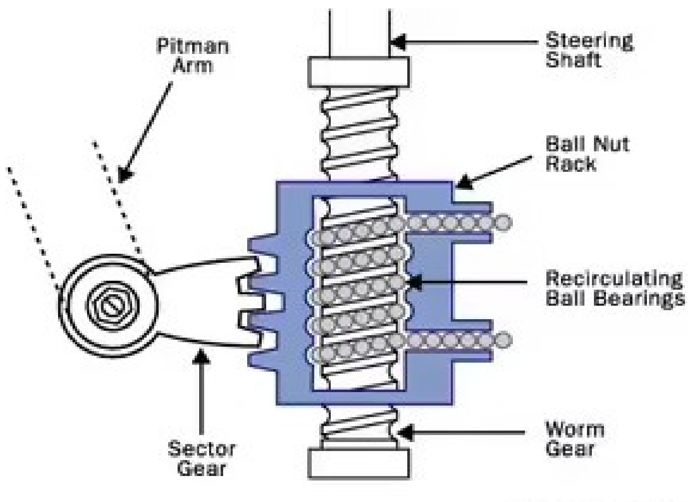

Figure 15.7: A recirculating ball gearbox mechanism

Activity 4.15.1

Description of the steering system main components

1. Organise yourselves into groups of 5 and watch a video on the main components of the steering system at the link below:
    - **Steering System Components.** Click on this link: https://www.youtube.com/watch?v=HFBwFV9tUZ0
2. Discuss and note down each of the parts identified in the video.
3. Research the steering system using other materials, including the internet, for an illustration of the manual steering system.
4. Prepare your own sketch of the manual steering system and label the major parts.
5. For each of the components, provide a description of the physical features and the function in the steering system.
6. Present your group's answer to the whole class and take part in a discussion on the components of the steering system.

STEERING GEOMETRY

Steering geometry refers to the arrangement and alignment of the steering components relative to the vehicle's body or frame and the road surface to ensure proper steering response, stability, and control.

1. **Caster angle**

   Caster angle is defined as the angle between the true vertical centreline of the tyre and an imaginary line that passes through the centre of the upper strut mount and the lower ball joint. A positive caster angle occurs when the caster line is tilted toward the back of the vehicle. Conversely, a negative caster angle is obtained when the caster line is tilted forward, toward the front of the vehicle. The caster angle helps to:

   a. Assist in maintaining the vehicle's directional stability;

   b. help the wheels naturally return to the straight-ahead position; and

   c. counteract the pull on the steering caused by the road's sloped surface.

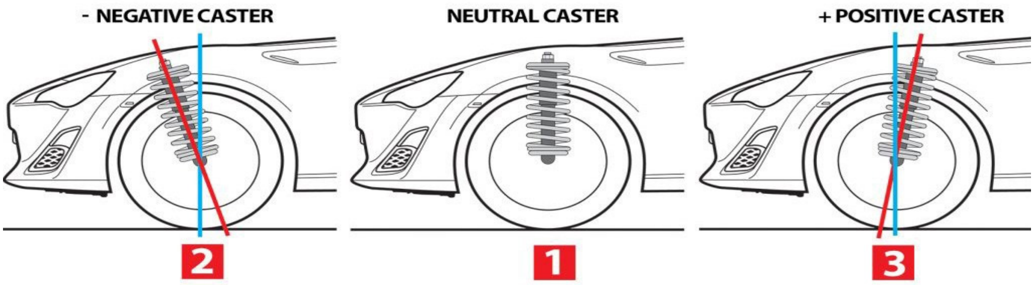

Figure 15.8: Castor angles

2. **Camber angle**

   Camber refers to the angle formed between the wheel's vertical axis or plane and a line perpendicular to the road surface, measured when the wheels are pointing straight ahead. When the top of the wheel is tilted outward, camber is considered positive. This setup reduces the scrub radius and affects the forces exerted on the wheel during cornering. Conversely, when the top of the wheel is tilted inward, camber is considered negative. This configuration enhances cornering force and allows for a lower vehicle centre of gravity.

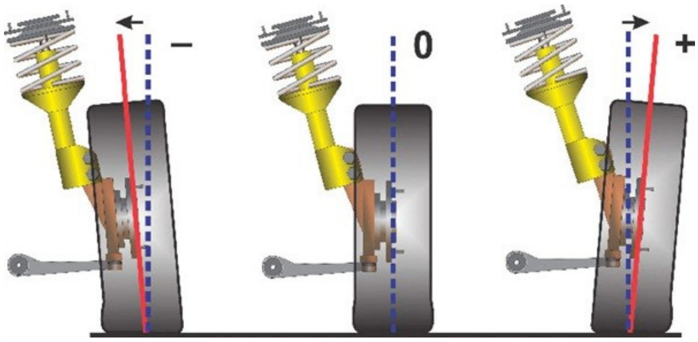

Figure 15.9: Camber angles

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3. Kingpin inclination (KPI)

The kingpin inclination is the angle formed between the steering axis and a vertical line perpendicular to the road surface, as viewed from the front or rear of the vehicle. When the kingpin is tilted outward at the bottom, it creates an angle between the kingpin's centreline and the vertical plane. This geometry can also be called steering axis inclination or swivel angle inclination (SAI), in the case of steering arrangements that use ball joints or MacPherson strut mechanism.

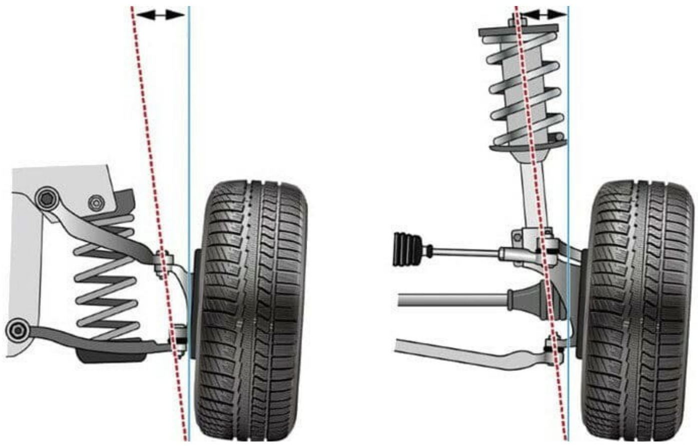

Figure 15.10: Steering axis inclination and kingpin inclination

4. Centre point steering

This is a steering geometry design where the steering axis meets the wheel axis in the wheel centre plane, with no offset at the road surface. This helps to achieve zero scrub. A zero-scrub radius improves steering precision and reduces the effort required to control the steering.

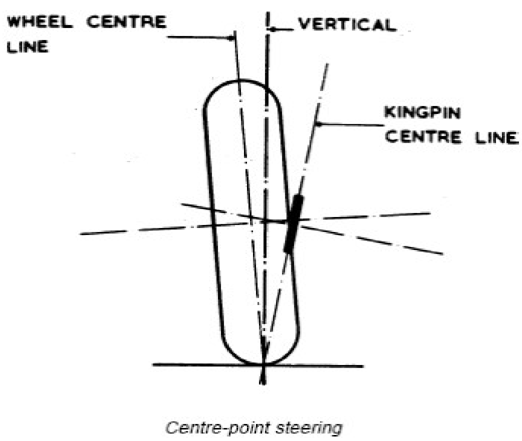

Figure 15.11: Centre point steering

5. Toe-in or toe-out

Toe refers to the difference in distance between the front and rear edges of the tyres. Toe-in occurs when the front edges of the wheels are closer together than the back edges, as seen from the direction of travel or viewed from above the vehicle. Toe-out, on the other hand, occurs when the front edges of the wheels are farther apart than the back edges. When the distance between the wheels is the same in front of and behind the axle, the vehicle is said to have zero toe. Proper toe alignment is necessary for achieving even tyre wear and improved handling and stability.

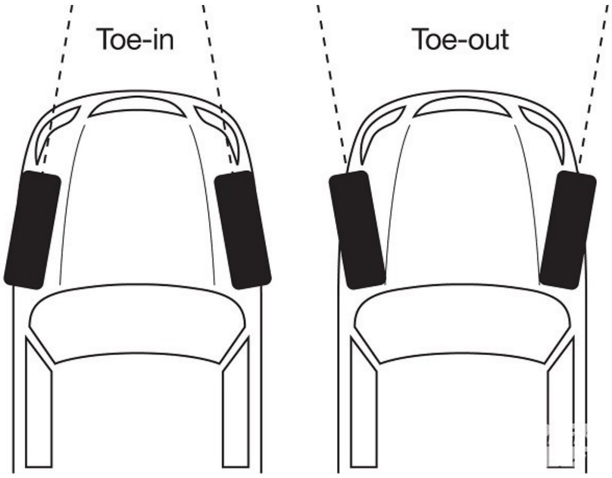

Figure 15.12: Toe-in and toe-out.

6. Steering Ratio

When steering, the driver applies a small amount of force to the steering wheel, which generates a significantly larger force at the front wheels. This increase in force is determined by the steering ratio, which represents the number of degrees the steering wheel must turn to pivot the front wheels by 1 degree. A higher steering ratio makes the vehicle easier to steer but requires more rotation of the steering wheel to achieve the desired turning angle.

7. Ackermann Steering Geometry

Ackermann steering geometry ensures that the inner and outer wheels follow different turning radii when cornering. This steering design prevents unwanted tyre scrubbing, which can lead to uneven tyre wear and reduced traction. Instead, the Ackermann principle enables all four wheels to roll smoothly and efficiently through the turn, resulting in improved manoeuvrability, enhanced stability, and a more responsive driving experience.

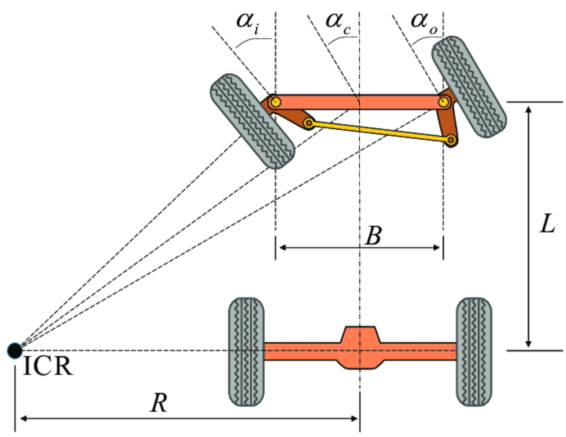

Figure 15.13: Ackermann steering geometry

8. Toe-out on turns

Toe-out on turns, also known as turning radius angle, is the amount the front wheels toe-out when turning corners. As the vehicle goes around a turn, the inside tyre must travel in a smaller radius circle than the outside tyre.

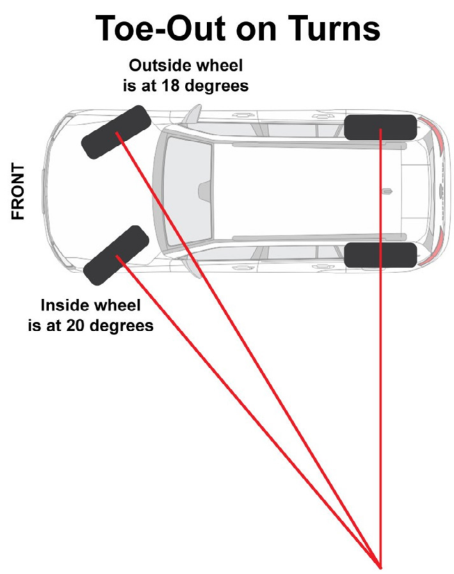

Figure 15.14: Toe-out on turns

9. Slip angle

Slip angle is the difference between the steering angle or direction the tyre is pointed and the actual direction the tyre is moving. It is caused by lateral forces acting on the tyre during cornering, causing the tyre to slip or scrub slightly off its steered path. This angle plays a critical role in vehicle handling and stability.

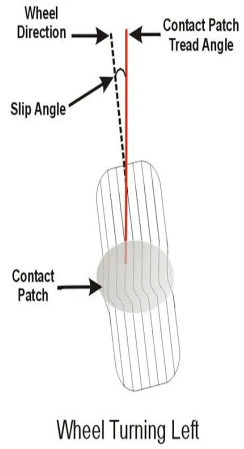

Figure 15.15: Slip angle

10. Understeer, oversteer and neutral steering

Oversteer occurs when the rear of the vehicle swings outward more than the front during cornering. This happens because the slip angle on the rear axle is much greater than that on the front axle, causing the vehicle to follow a tighter circle. If the steering angle is not reduced, the vehicle may lose control and spin out.

Understeer happens when the front of the vehicle swings outward more than the rear during cornering. In this case, the slip angle on the front axle is greater than that on the rear axle, making the vehicle follow a wider circle. To maintain the turn, a greater steering angle is required, and understeering vehicles may struggle to stay in the curve.

Neutral steering occurs when the vehicle's turning response matches the steering wheel input, regardless of the speed of the moving vehicle. This means the turning radius remains consistent and predictable as the speed changes.

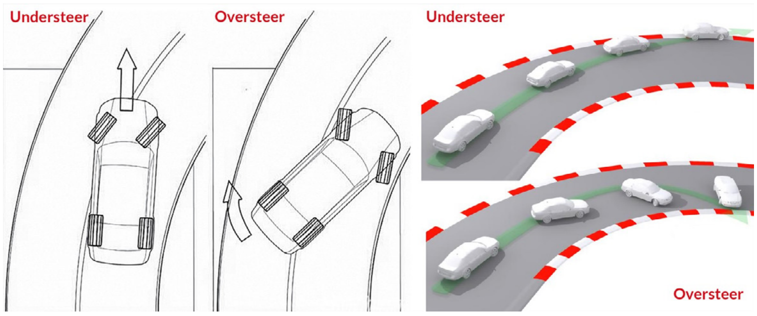

Figure 15.16: Understeer and oversteer.

Activity 15.2

Description of various steering angles

Materials needed

- Cardboard
- Markers (different colours)

Organise yourselves into groups of 5 and complete the following:

1. explore the internet for images and videos on steering geometry.
2. After watching the videos and studying the images, write down at least three different definitions for steering geometry.
3. Using different colours for distinction and clarity of parts, sketch each of the following steering geometry features:
   a. Positive camber and negative camber
   b. Positive caster and negative caster
   c. Kingpin or steering axis inclination
   d. Toe-in and toe-out
   e. Ackermann principle
4. In your notepads, describe how each of the steering geometry angles contributes to the safety and stability of the vehicle on the road.
5. Read out the descriptive notes while displaying the table on the board.

6. Discuss with the entire class the benefits of the various steering geometry angles to driving.

Activity 15.3

Field Trip

1. Organise yourselves into small groups. Your teacher will make arrangements for you to visit a school workshop or local repair workshop to observe and identify the main components of the steering system.
2. During the visit, you will note down the various parts of the steering system and any differences between different types. You will also observe and record the process of wheel alignment.
3. As a group, present your findings to the rest of the class for discussion.

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UNIT 16

METAL TECHNOLOGY

Welding Technology

Introduction

Metal forming is an important part of manufacturing because it shapes metal into useful parts for cars, buildings, machines, and many everyday products, making it highly relevant in engineering. This lesson introduces three main metal forming processes: forging, rolling, and extrusion. Forging uses force to shape metal into strong and reliable parts, rolling reduces metal thickness using rollers for smooth and efficient mass production, and extrusion pushes metal through a die to form long and complex shapes. After studying this lesson, students should be able to explain the importance of metal forming, describe how forging, rolling, and extrusion work, identify their advantages and applications, and understand how these processes help produce high-quality components

KEY IDEAS

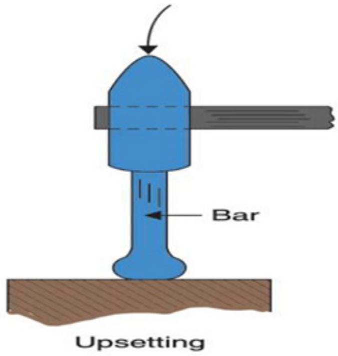
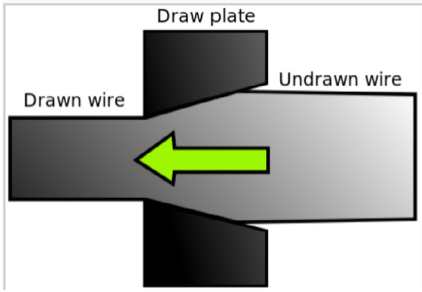
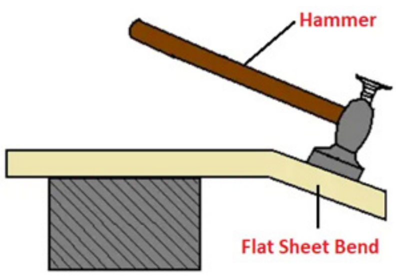
The key ideas behind forging, rolling, and extrusion operations in sheet metal processing are:

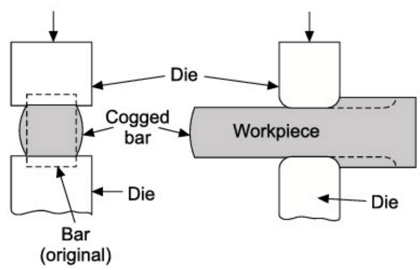
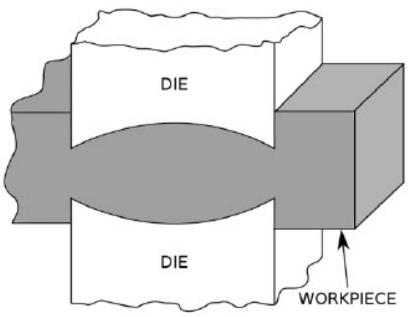
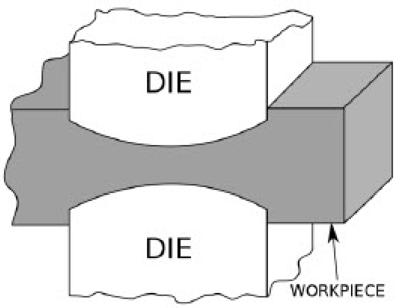
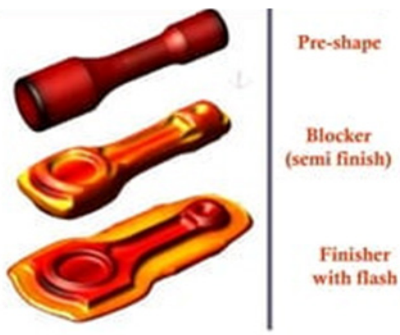
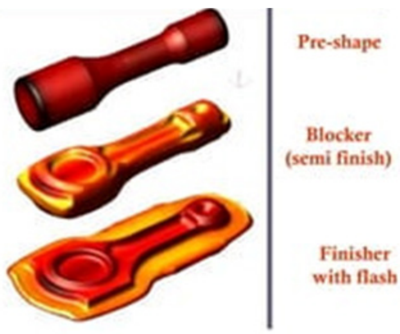
- Deforming metal using compressive forces to shape it
- Forcing metal through a die to produce long pieces with a uniform cross-sectional profile
- Reducing the thickness or altering the cross-section of metal sheets by passing them through rollers
- These processes modify the shape and properties of sheet metal, making it suitable for various industrial applications.

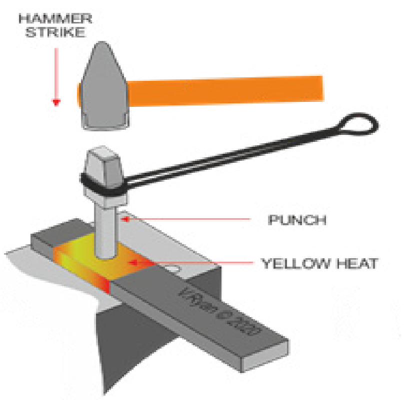
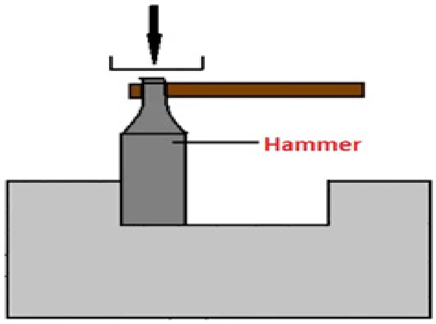
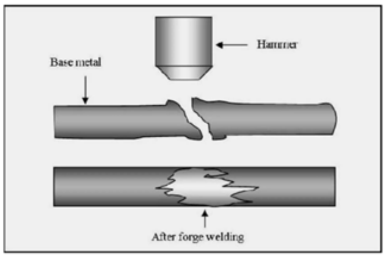
FORGING

Forging is a process where metals are shaped using compressive forces. This can be done using a hammer, press or other tools to deform the metal typically while it is hot (hot forging) but sometimes also at room temperature (cold forging). The goal is to shape the metal into desired forms or dimensions, improving its strength and structure through controlled deformation. Forging is used to create a wide range of metal components from small hand tools to large industrial parts and is valued for producing strong, durable and precisely shaped items.

Table 16.1: Forging Operations

S/N	Forging Operation	Description of Operation	Picture of Operation
1	**Upsetting**	It is the process of increasing the cross-section at the expense of the length of a workpiece. It is the simplest example of open die forging.	
2	**Drawing down**	It is the reverse of an upsetting process. In this process length is increased and the cross-sectional area is reduced.	
3	**Cutting**	This operation is done by means of hot chisels and consists of removing extra metal from the job before finishing it.	
4	**Bending**	The bending of bars, flats and other such material is often done by a blacksmith. For making a bend, first the portion at the bend location is heated and jumped (upset) on the outward surface. This provides extra material so that after bending, the cross-section at the bend does not reduce due to elongation.	

5	**Cogging (drawing out):**	Cogging is an open die forging operation in which the thickness of a bar (or workpiece) is reduced by successive hammer blows at specific intervals.	
6	**Edging**	Edging is the process of gathering material into a region using a concave shaped open die. The process is called edging because it is usually carried out on the ends of the workpiece.	
7	**Fullering**	Fullering is the process of reducing the cross-sectional area of a portion of the stock using a convex shaped die known as fullers. The metal flow is outward and away from the centre of the fuller.	
8	**Blocking**	Is the stage that makes the metal to approximately the final shape with generous corner and fillet radii.	
9	**Finisher**	Is where the die imparts final shape and size, after which the flash is trimmed from the part	

10	**Punching and drifting**	Punching is an operation in which a punch is forced through the work piece to produce a rough hole. Punching is usually followed by drifting i.e., forcing a drift in the punched hole through and through. This produces at better hole as regards its size and finish.	
11	**Setting down and finishing**	Setting down is the operation by which the rounding of a corner is removed to make it a square. It is done with the help of a set hammer. Finishing is the operation where the uneven surface of the forging is smoothened out with the use of a flatter or set hammer, and round stems are finished to size with the use of swages after the job has been roughly brought to the desired shape and size.	
12	**Forge welding**	Forge welding is a method for joining two pieces of metal together by heating them to a high temperature and then hammering them together to create a joint.	

Connecting Rod

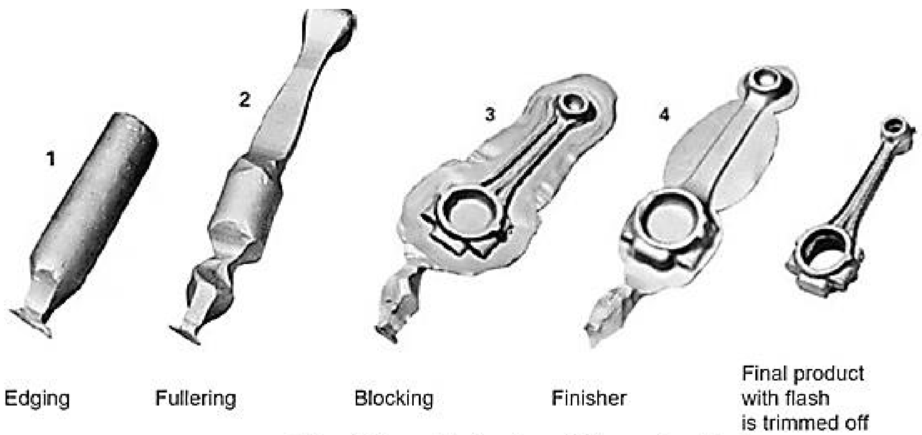


Figure 16.1: Steps to follow in forging of a Connecting Rod

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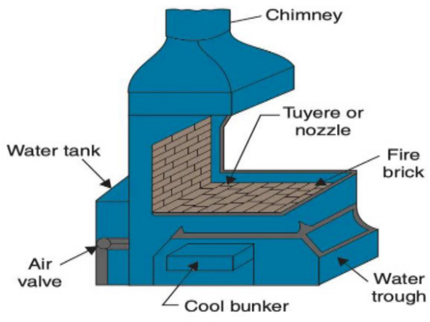
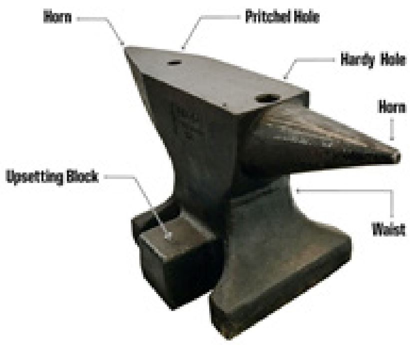
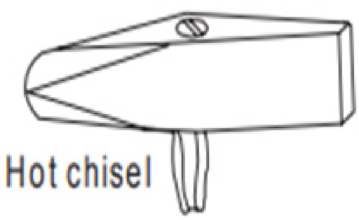
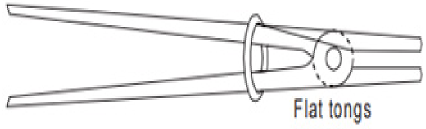
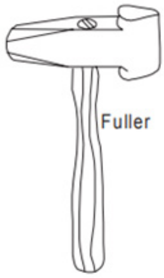
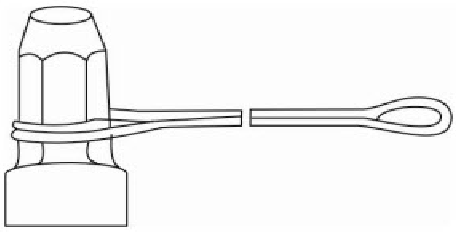
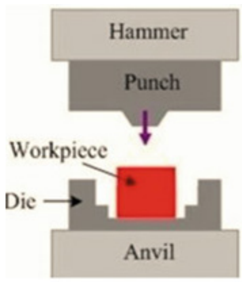
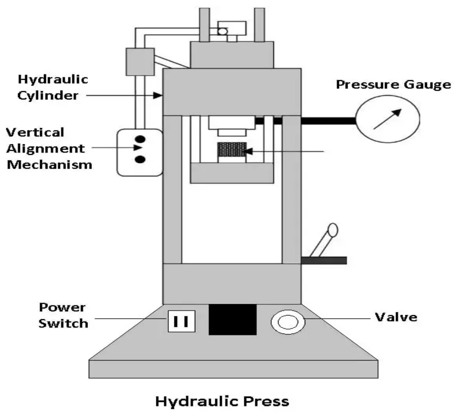
Forging Tools and Equipment

Below are different types of forging tools and their uses

Table 16.2: Description of Tools and Equipment Used for Forging

S/N	Name of Tool	Description	Picture
1	**Furnace or hearth**	These forging tools are used by blacksmiths for heating metal pieces. They usually consist of four legs, a cast iron or steel body, an iron bottom, a chimney, and a blower.	 Smith's forge
2	**Anvil**	Anvils are types of forging tools that serve as a workbench for blacksmiths. An anvil is a large slab of metal usually made of steel. It is used to perform different operations like flattening metal surfaces and obtaining shapes with the use of the hammer. Some anvils contain hardy holes and punches holes. The hardy hole serves as a square shank for the hardy and the punch hole provides clearance for the punching hole in the metal.	
3	**Chisel**	A chisel is used for cutting and chipping out metal. It is made of high petroleum steel with an octagonal cross-section with a tapered cutting edge on one end. A chisel used in forging is one of two types, hot and cold chisel. A hot chisel is used for hot forging and a cold chisel is used for cold forging.	

4	**Tongs**	These forging tools are used in transporting the heated metal to the anvil. Tongs are available in different types and designs to provide adequate gripping of different metal shapes and sizes. They are also used for holding and turning hot metals. These tongs are available in different types and sizes. They are classified based on the grip of the tongs.	 
5	**Fuller**	Fuller helps to create grooves or indentions in the forging process. It is also used to stretch metal. Fuller works in pairs, by placing one beneath the metal, and the other on top. This allows the indentation of both sides of the metal to occur simultaneously.	
6	**Set hammer**	Set hammer is a forging tool used for making surface planes, forming and making corners. This forging tool has similar shapes with flatter. It is made from tool steel. The workpiece must be placed on an anvil before a set hammer can be used.	
7	**Drop hammer**	A drop hammer is a heavy ram which falls onto the metal by gravity. It is used by the smith's hand power.	
8	**Power hammer**	The power source is from hydraulics, compressed air, or electricity in driving the hammer. It is used when a large quantity of jobs is needed. The power works by placing the workpiece on its anvil, and a lever is used to control the heavy ram falling on the workpiece.	

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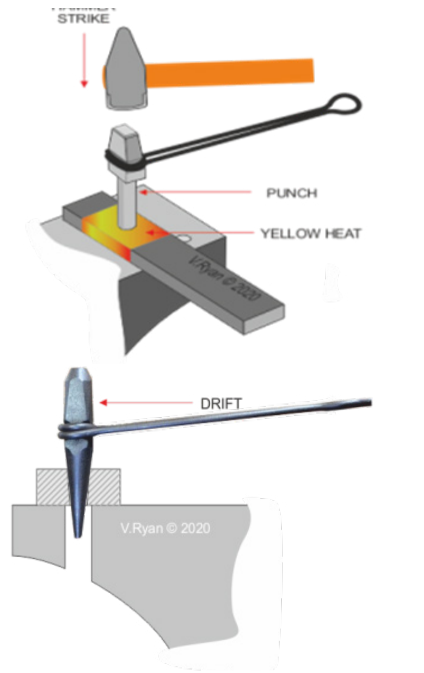
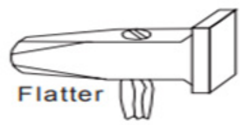
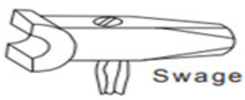
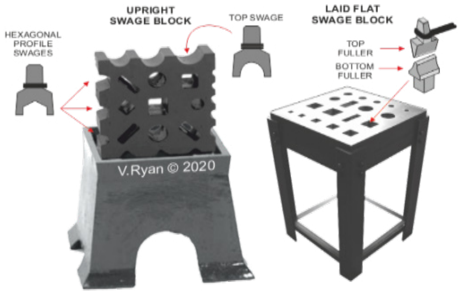
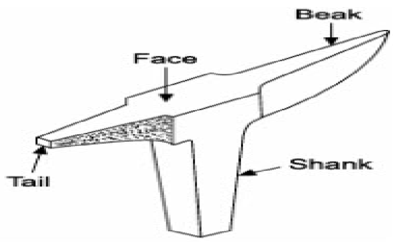
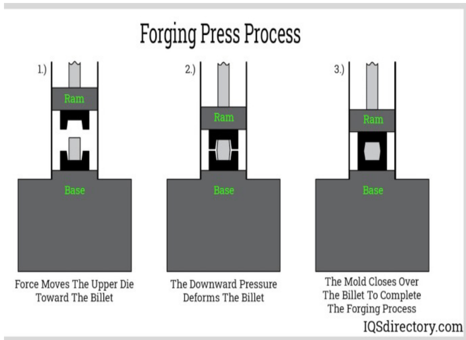
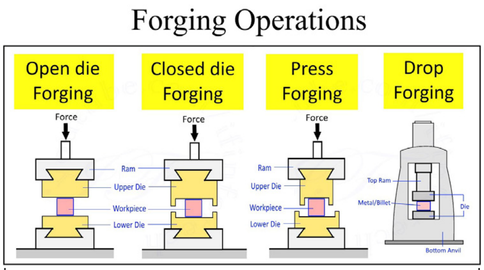
9	**Punch and drift**	These types of forging tools are made of high-carbon steel which helps in making hot holes on hot metal pieces. This forging tool is available in different sizes and has a common shape. Drift is a large size of punch used in enlarging holes.	
10	**Flatter**	This forging tool is used to flatten the surface of the workpiece. It consists of a plane face joined with a straight shank. Flatters materials are high-carbon steel.	
11	**Swage**	Swage is a forging tool type that gives various shapes to the workpiece. It is also made of high-carbon steel.	
12	**Swage block**	This forging equipment is made of cast iron or cast steel rectangular block, having several holes in it. The holes are made of different sizes and shapes.	
13	**Bick iron**	A bick iron is a type of small anvil specifically used for working on small jobs in just the same way as anvil. It is made of tool steel and has a tapered shank which is fitted into the hardie hole of the anvil during its use.	

14	**Press**	This forging equipment uses excessive pressure to fold metal into the desired shape. This forging equipment can forge the entire product at once. Presses are available in two types, mechanical and hydraulic press forging	
15	**Mechanical press forging**	This is a mechanical device, equipped with a motor, crank, flywheel, etc. which easily forces the ram against the metal. This forging equipment is not suitable for large or complex items, but it is useful when simple shaping effects are required.	
16	**Hydraulic press forging**	The operation is performed by high-pressure fluid propelled by hydraulic pumps to force ram against the metal. This forging equipment provides force while forging an item. It is used and preferred when a large or complex item is needed to be forged.	
17	**Forging dies**	This forging equipment is required to properly mould metal. It serves as a mould into which malleable metals are pressed. The dies are important in all forging projects; they are used for large production and complex jobs. Dies are available in two types: open die and closed die.	

Classification of Forging

Forging can be classified into two categories.

1. **Open die forging:** Open-die forging, also known as free forging or smith forging, is the process of striking a hammer to deform a piece of metal, typically placed on a stationary anvil. Another approach is to use compression to press the metal between simple dies.

These simple dies are typically flat, semi-round or V-shaped as shown below. Regardless of the die shape, the metal is never completely encased in the open-die forging process. The dies hammer or press the metal through a series of repetitions, altering the material until achieving the desired shape.

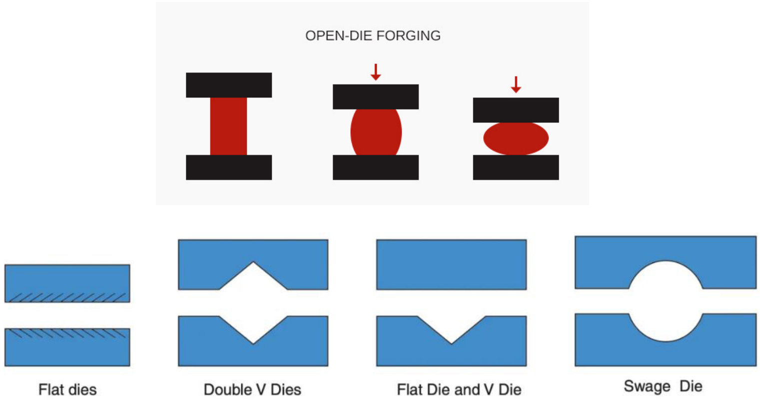


Figure 16.4: Open die forging

Table 16.3: Advantages and Disadvantages of Open Die Forging

S/N	Advantages of Open Die Forging	Disadvantages of Open Die Forging
1	Simple process.	Limited to simple shapes.
2	Dies are inexpensive	Close dimensional tolerances not possible.
3	Useful for small quantities.	Machining to final shape required if necessary.
4	Wide range of job sizes can be handled.	Low production rate.
5		High degree of skill required.

2. **Closed die forging**: Closed die forging is a forging process in which dies move towards each other and covers the workpiece in whole or in part. The heated raw material, about the shape or size of the final forged part, is placed in the bottom die. The shape of the forging is incorporated in the top or bottom die as a negative image. Coming from above, the impact of the top die on the raw material forms it into the required forged form.

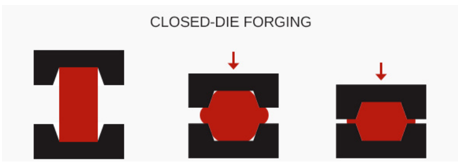


Figure 16.5: Closed die forging

Table 16.4: Advantages and Disadvantages of Closed Die Forging

S/N	Advantages of closed die forging	Disadvantages of closed die forging
1	Better surface finish and superior mechanical properties.	Not typically economical for short or small production runs due to the cost of die production due to high initial cost
2	Reduced or no machining.	Close dimensional tolerances are not possible.
3	Cost-effective for large production runs.	Machining to final shape is required if necessary.
4	Dimensions with tighter tolerances and various shapes can be achieved.	Low production rate.
5	More precise, consistent impressions.	High degree of skill required.
6	Ability to reproduce nearly any shape and/or size.	Higher setup cost due to costly machines and furnaces.

Types of forging processes based on method of application of force.

The different types of forging operations are hand forging, drop forging and press forging.

Table 16.5: Types of Forging Process

S/N	Forging Process	Description of Forging Process	Picture of Forging Process
1	**Hand Forging**	The hand forging process consists of forming the desired shape of a heated metal by applying repeated blows of a hand-held hammer. A flat die or an anvil is used. The desired shape of the metal piece is maintained by the smith during the forging process as the desired length and cross-section are adjusted manually by positioning and turning the part on the flat surface of the anvil. While hammering, tongs hold the red-hot metal and a well-rounded chisel shaped edge, called fuller, and is used to draw out the metal. Fuller is held on the metal by a helper while the smith strikes the metal with a hammer. The quality of the forging is wholly dependent on the skill of the smith.	

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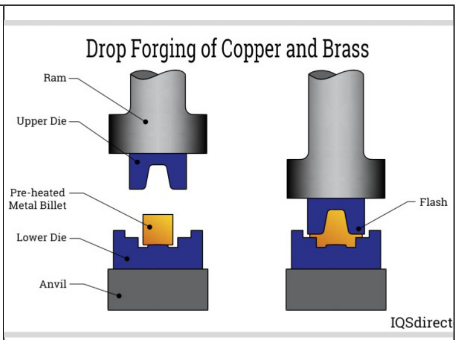
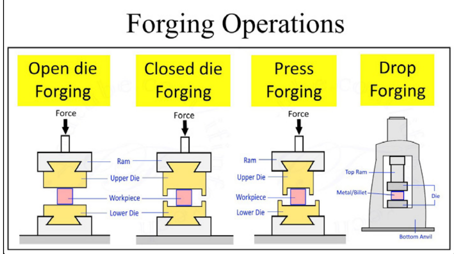
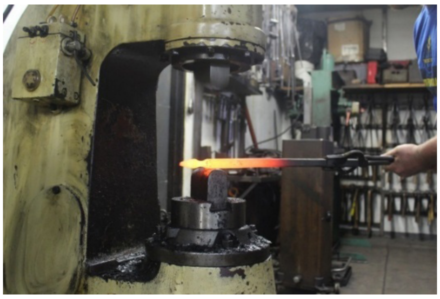
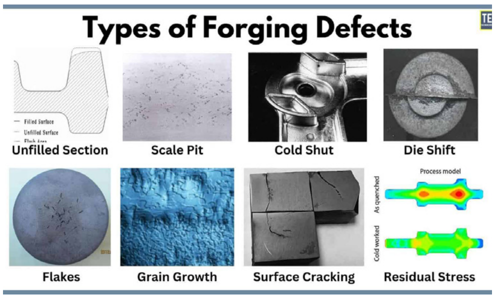
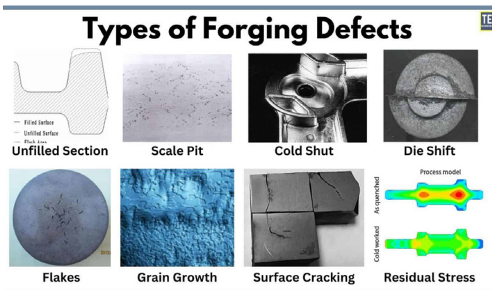
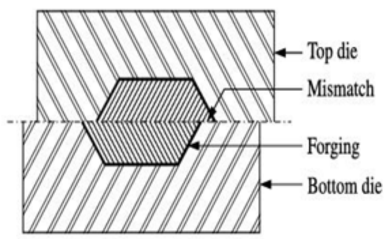
2	**Drop forging**	Drop forging is a mechanised form of the black smith's hammer. In drop forge a massive weight is raised and made to fall freely. Dies are made in sets or halves; one half of the die is attached to ram and the other to a stationary anvil. The drop hammer uses compressed air or steam to lift the ram and lets it fall by gravity. The image below shows open-die drop forging (with two dies) of an ingot to be further processed into a wheel.	
3	**Press Forging**	Press forging is done in presses rather than with hammers. In press forging a slow squeezing action is used to transfer a great amount of compressive force to the workpiece. Unlike die forging where multiple blows are required to transfer the required energy to the material being forged, the press forging process is more accurate as ram stick to the die impression more rigidly and transfers the force uniformly & gradually to the bulk of the material giving time for the metal to flow as it is pressed.	
4	**Forging with Power Hammering**	The use of hand forging is restricted to small forgings only. When a large forging is required, comparatively light blows from a hand hammer or a sledgehammer wielded by the striker will not be sufficient to cause significant plastic flow of the material. It is therefore necessary to use more powerful hammers. Various kinds of power hammers powered by electricity, steam and compressed air (i.e., pneumatic) are used for forging.	

5	**Machine forging**	For specific jobs like mass manufacture of bolts and nuts from bar stock, special forging machines have been developed. These machines work alongside a furnace in which one end of bar is heated for some length. The heated end of the bar is then fed into the machine. With the help of dies and a heading tool, the hexagonal head of the bolt is forged by "upsetting". These machines are horizontal mechanical presses which can be operated by a foot pedal. The die consists of two halves and a heading tool.	

Forging defects

The common forging defects can be traced to defects in raw material, improper heating of material, faulty design of dies and improper forging practice.

Table 16.6: Forging Defects

S/N	Defect	Description	Picture
1	**Laps and Cracks**	Laps and Cracks at corners or surfaces lap is caused due to following over of a layer of material over another surface. These defects are caused by improper forging and faulty die design.	
2	**Incomplete forging**	Either due to less material or inadequate or improper flow of material.	
3	**Mismatched forging**	Due to improperly aligned die halves.	

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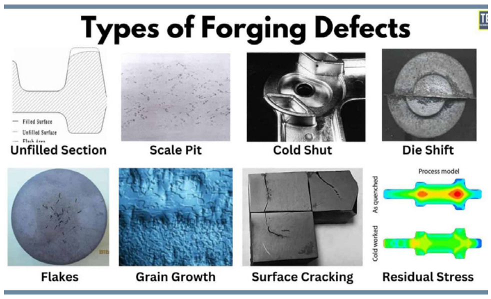
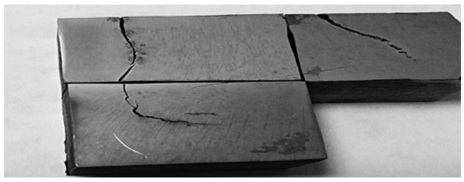
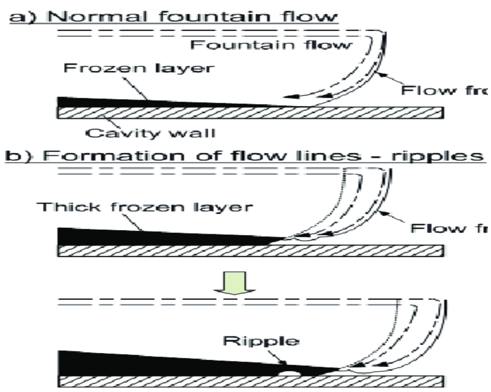
4	**Scale pits**	Due to the squeezing of scales into the metal surface during hammering action.	
5	**Burnt or overheated metal**	Due to improper heating.	
6	**Internal cracks**	Internal cracks in the forging which are caused by heavy hammer blows and improperly heated and soaked material.	
7	**Fibre flow lines disruption**	Due to very rapid plastic flow of metal.	

Heat Treatment of Forgings

The forged components may be subjected to severe stresses in service. To improve service life, to improve properties, to remove internal stresses and sometimes to improve the machinability, forgings may be given a suitable heat treatment after completing forging operations. The most common heat treatment given is normalising.

Cold forging: Cold forging is a process that takes place near room temperature, rather than at higher temperatures like warm and hot forging. It is done by placing the workpiece in-between two dies and pounding the dies until the metal assumes their shape.

Example 16.1: Explain the procedure of making the head of rivet by forging operation.

Solution: Step-by-step procedures to be followed in making the head of a rivet by forging operation are explained below:

1. Keep the blank in the die as shown in **Figure 16.6 (a)** below and position the knockout pin depending on the length of rivet required. The punch should have the negative shape of the rivet head as shown.
2. Apply force through the punch. At the end of the stroke, the head is formed as shown in **Figure 16.6 (b)**.
3. Now, remove the rivet by pushing the knockout pin.

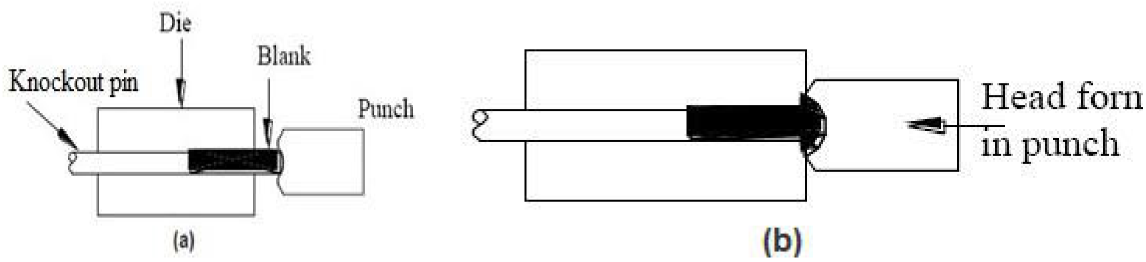


Figure 16.6: Rivet head formation.

ROLLING

Rolling is a deformation process in which the workpiece thickness is reduced by compressive forces exerted by two opposing rolls.

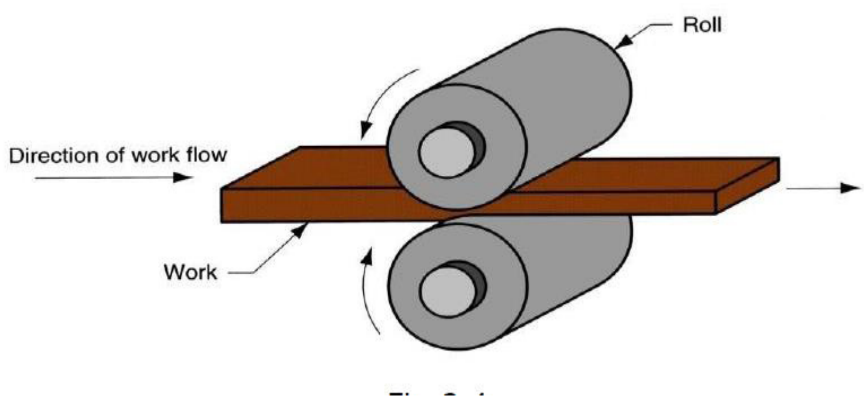


Figure 16.7: Rolling

The Functions of The Rotating Rolls

The rotating rolls perform two main functions:

1. Pull the work into the gap between them by friction between the work part and the rolls.
2. Simultaneously squeeze the work to reduce the cross-section.

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Types of rolling

By the geometry of work:

1. **Flat rolling**: used to reduce the thickness of a rectangular cross-section.
2. **Shape rolling:** a square cross-section is formed into a shape such as an I-beam.

By the temperature of work:

1. **Hot Rolling:** most common due to the large amount of deformation required.
2. **Cold rolling:** This produces finished sheet and plate stock.

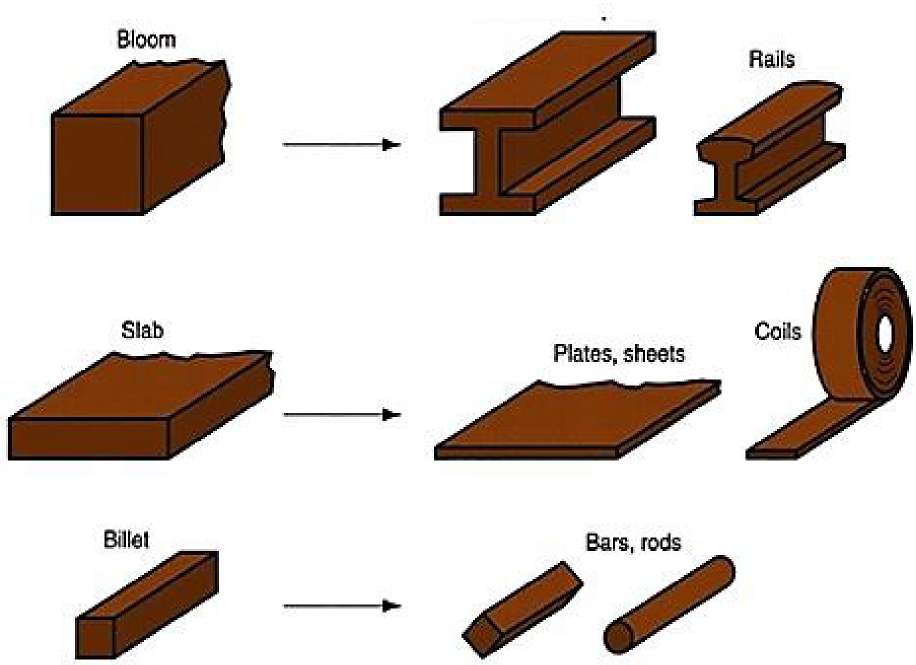
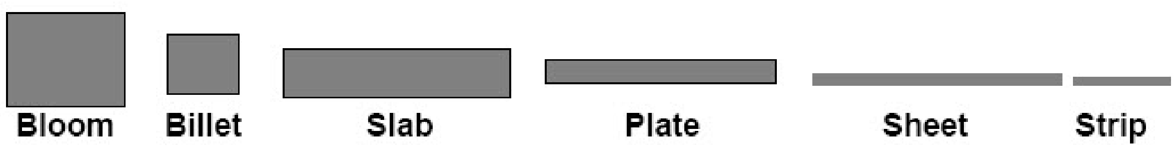


Figure 16.8: Some of the steel products made in a rolling mill.

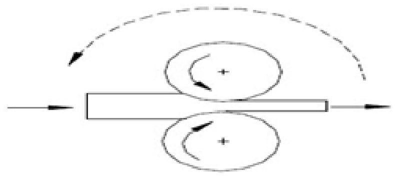
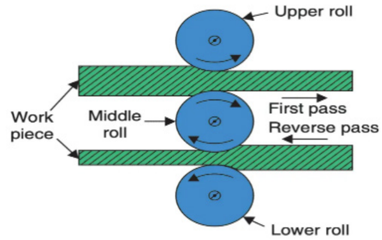
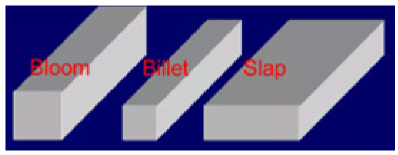
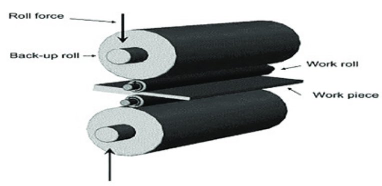
Flat rolling products at a glance

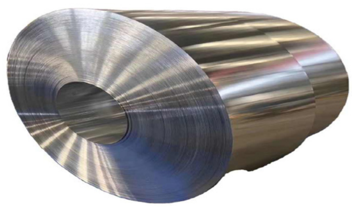
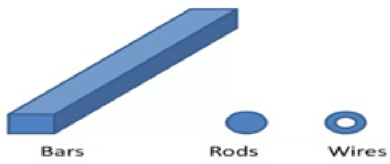
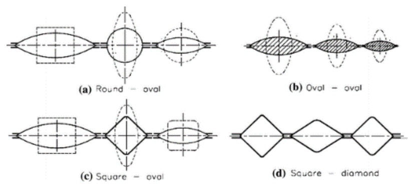
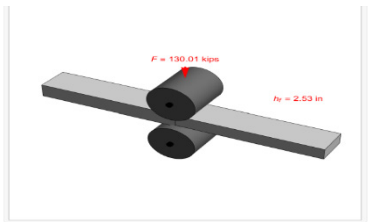


Nomenclature of Rolling and Rolled Products

Rolling operations involve several specific terms that describe the processes, equipment, and characteristics associated with rolling metal. Some of the key terms are described below:

Table 16.7: Nomenclature of rolling and rolled products

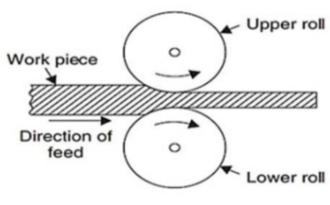
S/N	Nomenclature	Meaning of Nomenclature	Picture
1	**Rolling Mill**	The equipment used to roll metal into sheets, bars, or other shapes. It consists of rolls, bearings, a housing for containing the rolls, a drive (motor), and the associated equipment	
2	**Rolls**	Cylindrical tools that apply pressure to the metal as it passes between them, reducing its thickness and changing its shape.	
3	**Bloom**	A semi-finished product, larger than billets, usually having a square cross-section of more than 150 mm by 150 mm.	
4	**Billet**	A semi-finished metal product that has been cast and is used as raw material for rolling.	
5	**Slab**	A semi-finished steel product obtained by rolling ingots on a rolling mill or by continuous casting and having a rectangular cross-section.	
6	**Plate**	A flat, rolled metal product, thicker than sheet metal, typically more than 6 mm thick.	
7	**Sheet**	A thin, flat piece of metal rolled to a thickness between 0.2 mm and 6 mm.	
8	**Strip**	A long, narrow piece of rolled metal, thinner than a sheet, usually has thickness between 0.1 to 2.5mm	
9	**Flat**	Flats are available in various thickness and widths and are long strips of material of specified cross-section. It has thickness between 2.5mm to 6mm	

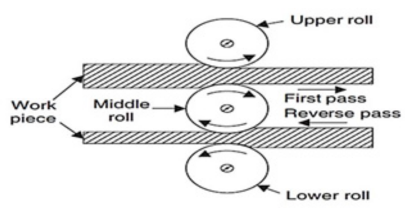
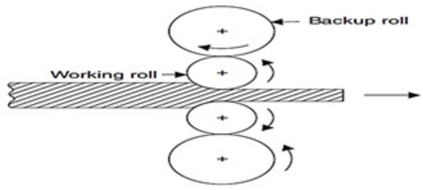
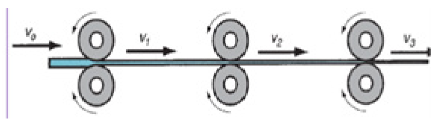
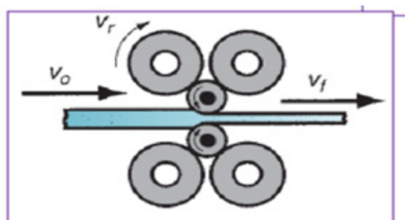
10	**Foil**	It is a very thin sheet. Maximum thickness of 1.5mm, maximum with 300mm	
11	**Bar**	Bars are usually of circular cross-section and of several metres length. They are common stock (raw material) for capstan and turret lathes.	
12	**Wire**	A wire is a length (usually in coil form) of a small round section, the diameter of which specifies the size of the wire.	
13	**Gauge**	The thickness of the metal sheet or strip, often measured in specific units depending on the material.	
14	**Pass**	Each time the metal passes through the rolls of a rolling mill, reducing its thickness and altering its shape.	
15	**Draft**	The difference in thickness between the incoming and outgoing metal in a single pass through the rolls.	

Classes of Rolling Mills

Rolling mills may be classified according to the number and arrangement of the rolls.

Table 16.8: Classification of Rolling Mills

S/N	Type of Rolling Mill	Description	Picture (Cross-Section)
1	**Two high rolling mills**	Comprises of two heavy rolls placed one over the other. The rolls are supported in bearings housed in sturdy upright frames (called stands) which are grouted to the rolling mill floor.	 (a) A two high mill

2	**Three high rolling mills**	A three high rolling mill arrangement is shown below. It consists of three rolls positioned directly over one another as shown	 (b) A three high rolling mill
3	**Four high rolling mills**	This mill consists of four horizontal rolls, two of small diameter and two much larger ones. The larger rolls are called backup rolls.	 Four high mill
4	**Tandem rolling mills**	A tandem rolling mill is a type of machine used to shape metal into thin sheets or strips. It has a series of rollers arranged in a straight line. The metal passes through each roller one after the other, becoming thinner with each step.	
5	**Cluster rolling mills**	Cluster rolling mills are used in industries to shape metals into thin sheets or foils. They consist of multiple rollers which help to reduce the thickness of materials like aluminium, copper, or steel.	 (d)

Cold Rolling

Cold rolling is performed at or near room temperature, below the recrystallisation temperature of the metal. The metal is passed through rollers multiple times to achieve the desired thickness and surface finish.

Table 16.9: Comparison between Hot Rolling and Cold Rolling

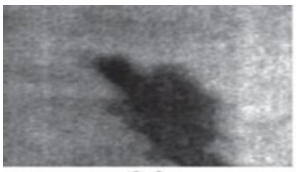
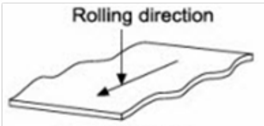
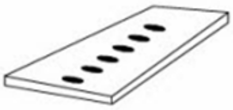
Feature	Hot Rolling	Cold Rolling
Temperature	Above the recrystallisation temperature	Room temperature
Surface Finish	Rough and scaly	Smooth and polished
Tolerance and Precision	Less precise	Highly precise
Mechanical Properties	Lower strength and hardness, higher ductility	Higher strength and hardness, lower ductility

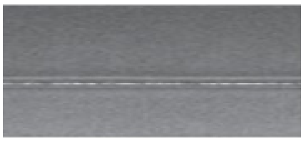
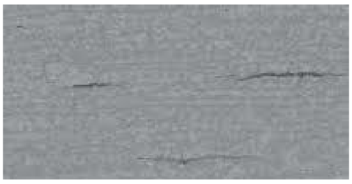
Grain Structure	Coarse and non-uniform	Fine and uniform
Common Applications	Large structural components	Precision products with high surface quality

Rolling Defects

Rolling defects refer to imperfections or flaws that occur during the rolling process in metalworking.

Table 16.10: Examples of Rolling Defects

S/N	Type of Rolling Defect	Description of Rolling Defect	Picture
1	**Surface defects**	Surface defects include rusting and scaling, surface scratches, surface cracks, pits left on the surface due to subsequent detachment or removal of scales, which may have been pressed into the surface.	
2	**Structural defects**	Structural defects are more important than rolling defects, some of which are difficult to remedy.	
2a	**Wavy edges**	The edges of the metal become uneven or wavy. This happens when the edges stretch more than the centre during rolling.	 (a) Wavy edges
2b	**Zipper cracks**	Long, straight cracks that appear along the edges or centre of the metal. These cracks are caused by too much stress or poor material quality.	 (b) Zipper cracks
2c	**Edge cracks**	Cracks that form along the edges of the metal usually due to uneven pressure during rolling.	 (c) Edge cracks
2d	**Centre split**	A crack that runs through the centre of the metal. This happens when the rolling force is too strong, causing the middle to tear.	

2e	**Alligatoring**	The metal splits into layers that look like an alligator's open mouth. This is caused by uneven forces inside the metal during rolling.	
2f	**Folds**	Layers of metal overlap creating weak spots. This happens when the metal is not fed properly into the rollers.	
2g	**Laminations**	Thin, unwanted layers or impurities trapped inside the metal. These often come from flaws in the original material.	

EXTRUSION

It is a manufacturing process in which a block of metal enclosed in a container is forced to flow through the opening of a die. The metal is subjected to plastic deformation and it undergoes reduction and elongation. The die is a little disk with an opening of a specific size and shape. When the material is put under pressure through the die, it will create a desired shape. Often the die is made of steel.

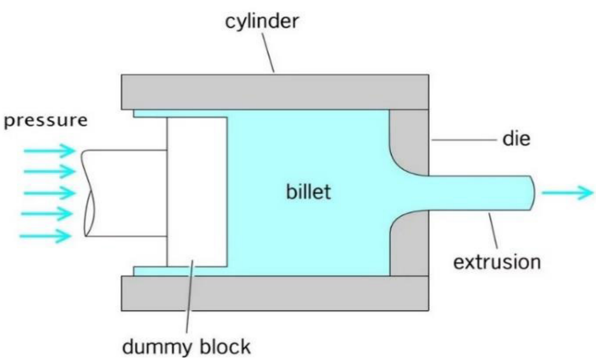


Figure. 4.16.9: Extrusion

Advantages of the Extrusion Process

1. The complexity and range of parts which can be produced by the extrusion process are very large. Dies are relatively simple and easy to make.
2. The extrusion process is complete in one pass only. This is not so in the case of rolling, where the amount of reduction in extrusion is very large indeed. Extrusion processes can be easily automated.
3. Large diameter, hollow products, thin-walled tubes, etc., are easily produced by the extrusion process.

4. Good surface finish and excellent dimensional and geometrical accuracy are the hallmarks of extruded products. These cannot be matched by rolling.

Classification of extrusion processes

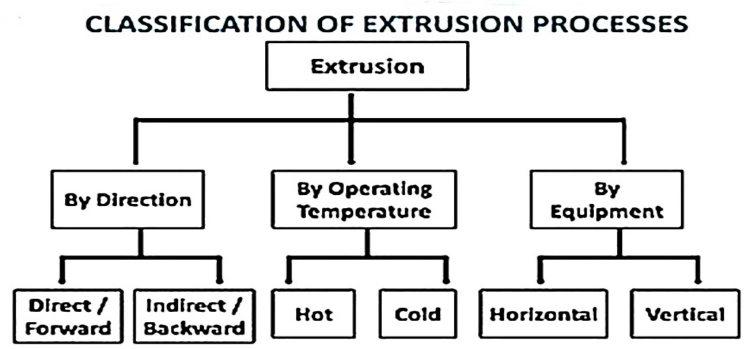
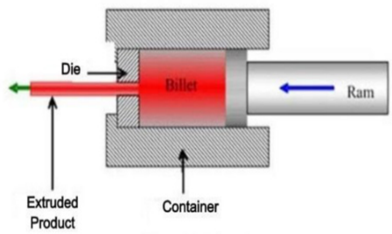
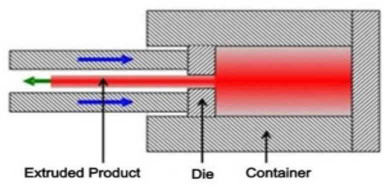
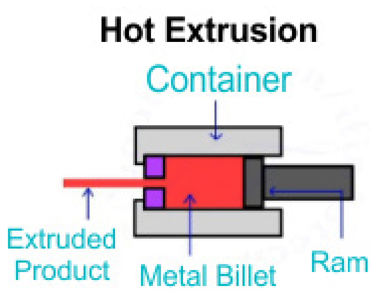


Figure 16.10: Flow chart of Classification of extrusion processes

Table 16.11: Types of Extrusion

S/N	Type of Extrusion	Description	Picture
1	**Direct extrusion**	It is a process in which the metal billet is placed in a container is forced by a ram to pass through a die. In this type, the direction of flow of metal is the same as the movement of the ram. The punch closely fits the die cavity to prevent backwards flow of material.	
2	**In-direct extrusion**	It is a process in which a hollow ram containing the die is forced into the container containing metal. A hollow ram limits the applied load. The movement of the metal is opposite to the direction of the ram motion.	
3	**Hot extrusion**	It is done at a fairly high temperature, approximately 50 to 75% of the melting point of the metal. The die life and components are affected due to the high temperatures and pressure, which makes lubrication necessary.	

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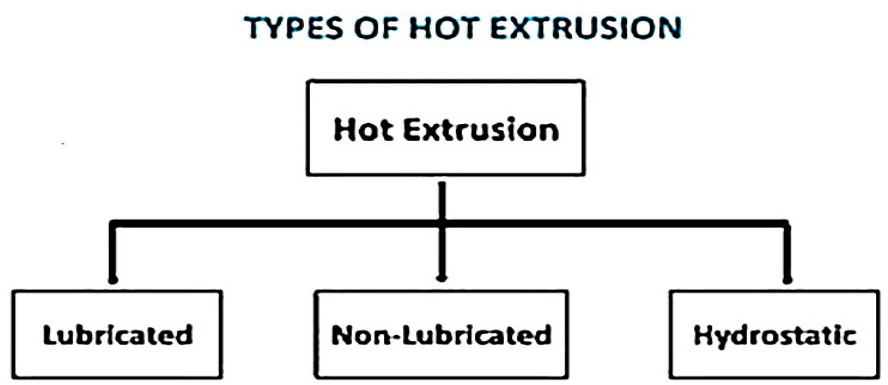
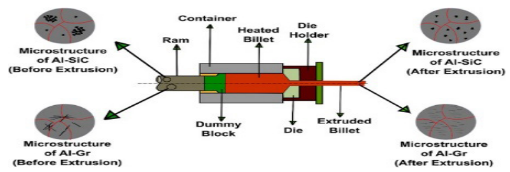
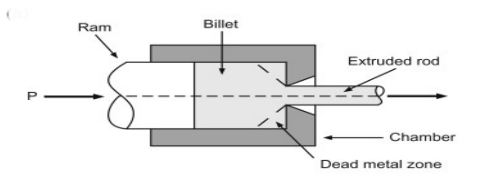
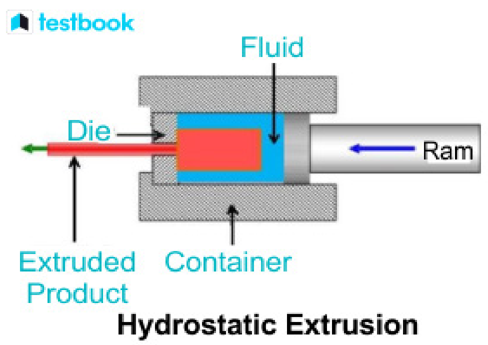


Figure 16.11: Flow Chart on Types of Hot Extrusion

Table 16.12: Types of Hot Extrusion

S/N	Type of Hot Extrusion	Description	Picture
1	**Lubrication hot extrusion:**	In this type before the billet (metal ingot) is inserted into the hot extrusion container, a suitably lubricating system is positioned immediately ahead of the die to reduce frictional stresses.	
2	**Non-Lubrication hot extraction**	In this type, no lubrication is used on the billet, container or die for reducing frictional stresses. It can produce very complex sections with excellent surface finishes.	
3	**Hydrostatic extrusion**	Hydrostatic extrusion is a manufacturing process used to form metals and other materials by forcing them through a die using a pressurized fluid as the driving force, where mechanical force is directly applied to material, hydrostatic extrusion relies on a fluid medium to evenly distribute pressure around the material.	

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Cold extrusion

Cold extrusion is the process carried out at room temperature or slightly elevated temperature. This process can be used for materials that can withstand the stresses created by extrusion.

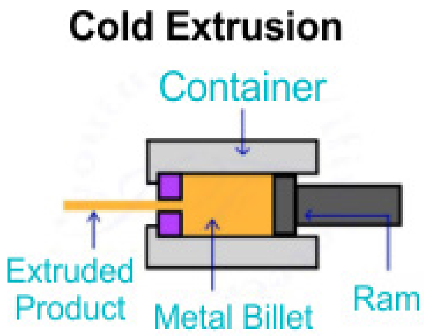

Figure 4.16.12: Cold Extrusion

Table 16.13: Comparison between Hot and Cold Extrusion

Cold extrusion	Hot extrusion
Better surface finish and lack of oxide layers.	The surface is coated with oxide layers. Surface finish not comparable with cold extrusion.
Good control of dimensional tolerance - no machining or very little machining required.	Dimensional control is not comparable with cold extrusion products.
High production rates at low cost. Fit for individual component production.	High production rates, but the process is fit for bulk material, not individual components.
Improved mechanical properties due to strain hardening.	Since processing is done hot, recrystallisation takes place.
Tooling subjected to high stresses.	Tooling is subjected to high stresses as well as high temperatures. Tooling stresses are lower than for cold extrusion
Lubrication is crucial.	Lubrication is crucial

Conclusion

Understanding forging, rolling, and extrusion processes is crucial in sheet metal work as these techniques transform raw materials into desired shapes and sizes, enhancing their mechanical properties. Forging improves strength and durability by shaping metal under high pressure, making it suitable for critical applications like automotive and aerospace components. Rolling ensures uniform thickness and surface finish, widely used in producing sheets and plates for construction and manufacturing. Extrusion enables the creation of suitable components like tubing, frames, and architectural profiles.

Activity 16.1

Forging, rolling and extrusion processes

Organise yourselves into groups of 5 to perform the activities that follow.

1. Prepare a table to identify and explain forging, rolling and extrusion processes in sheet metal work.
2. Using ICT tools, prepare a presentation or a report to demonstrate how forging, rolling and extrusion in sheet metal work are used in making articles. In your presentation, also describe the processes for using forging, rolling and extrusion to produce specific articles and how these processes can be combined to produce an article.

Activity 16.2

Discussion of differences

1. In your groups, discuss the differences between rolling, forging and extrusion processes
2. Also discuss the differences between cold rolling, hot rolling, cold extrusion and hot extrusion.
3. Compile your findings in a table and present it to the class for discussion and feedback.

Activity 16.3

Embarking on educational visit to observe forging, rolling and extrusion processes

1. Your teacher will organise an educational visit to a local workshop to observe the forging, rolling and extrusion processes.
2. Make sketches or take pictures of tools and equipment found at the workshop to prepare a sketch or photo album and display in class for appraisal.
3. Observe and discuss in your group the functions of the tools and equipment used in forging, rolling and extraction and present your report in class for discussions.

Note:

a. Observe the basic safety precautions during the visit.

b. Wear your PPE.

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EXTENDED READING

- **Types of Axles: Everything You Need to Know:** Types of axles.
    - https://www.caranddriver.com/research/a31547001/types-of-axle/
- **Types of Axles: Rear Axles, Front Axle and Stub Axle:**
    - https://www.theengineerspost.com/types-of-axles/
    - *Live Axle:* https://www.counterman.com/counter-view-live-axle/
- **Car Handling Basics, How-To & Design Tips**
    - https://www.buildyourownracecar.com/race-car-handling-basics-and-design/#google_vignette
- **Forging**
    - https://en.wikipedia.org/wiki/Forging
    - https://www.thecrucible.org/guides/blacksmithing/power-hammer/
    - https://www.youtube.com/watch?app=desktop&v=YuQFhbRaWD0&pp=ygURI29w-ZW5kaWVlcXVpcG1lbnQ%3D
- **Rolling**
    - https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson5.html
    - https://www.slideshare.net/rmrm64/rolling-processpdf
    - https://www.researchgate.net/publication/313896846_Classification_of_surface_defects_on_steel_sheet_using_convolutional_neural_networks/figures?lo=1
- **Extrusion**
    - https://testbook.com/mechanical-engineering/extrusion-process-and-types
    - https://leadrp.net/blog/a-complete-guide-to-aluminum-extrusion/
- **Direct extrusion**
    - https://engineeringlearn.com/types-of-extrusion-process-working-advantages-disadvantages/
- **Indirect extrusion**
    - https://engineeringlearn.com/types-of-extrusion-process-working-advantages-disadvantages/

Review Questions

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Questions 4.1

1. Describe the various types of front axles.
2. Write three functions of the front axle.
3. Explain the differences between a live and dead axle.

Questions 4.2

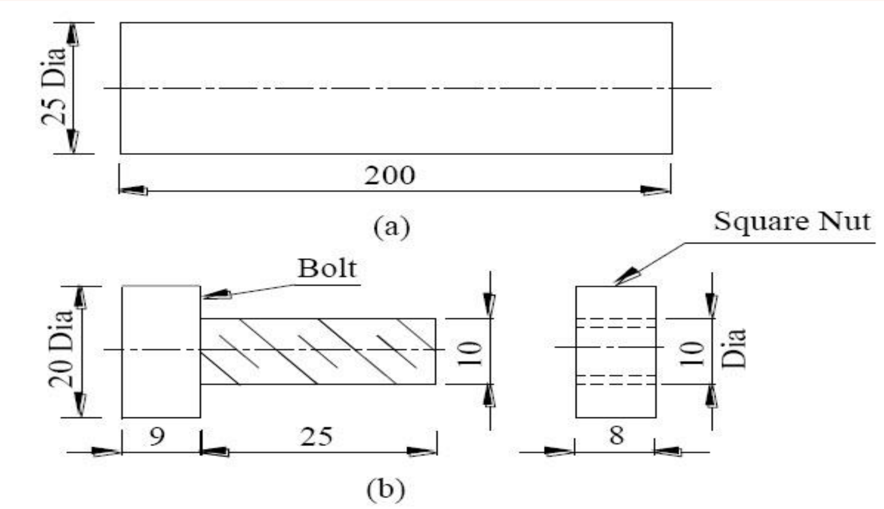
1. Your Applied Technology Teacher has assigned you to groups to discuss the concept of metal forming. Explain the meaning of the expression 'metal forming'.
2. A group of learners enters the workshop for their practical session on metal forming. The instructor starts by introducing various tools laid out on a table. Identify five tools used for metal forming processes.
3. Imagine a manufacturing company producing car parts. Some components, like gears and engine blocks, require, require bulk metal forming, while others, such as car body panels, require sheet metal forming. State and explain at least two processes each under basic bulk metal forming and sheet metal forming.
4. A company needs to produce cylindrical metal rods for an industrial application. The metal used is steel, and the manufacturing team must use hot forming or cold forming processes based on the product's required properties. Explain the difference between hot forming and cold forming processes.
5. A crankshaft is a critical component in automotive engines, responsible for converting the linear motion of pistons into rotational motion to drive the vehicle. It must withstand high stresses, cyclic loading, and extreme temperatures while maintaining precise dimensional accuracy. Describe a real-world application where forging is preferred over other metal forming processes, and explain why forging is chosen in this context.

Questions 4.3

1. Explain the function of the vehicle steering system.
2. Explain the Ackermann principle of steering geometry.
3. State the function of steering in an automobile and list the main components of manual and power-assisted steering systems.
4. Describe briefly with the aid of sketches, the construction and action of a rack and pinion type of steering gearbox.

Questions 4.4

1. Imagine you are a blacksmithing tasked with creating a chisel. The three forging techniques: upsetting, drawing down, and fullering, will help you shape the tool effectively. Explain the following processes connected with forging:
   a. Upsetting.
   b. Drawing down.
   c. Fullering.
2. A manufacturing workshop is tasked a steel rod with a tapered profile used in an automotive suspension system. The rod starts as a cylindrical steel billet describe the process of forge welding.
3. Metal stock, often in the form of slabs, billet or ingots, is heated in a furnace to a temperature where it becomes more malleable. Describe the process of rolling. Illustrate your answer with a suitable explanatory sketch.
4. You are supplied with a stock of Mild Steel rods having a dimension shown in figure (a). You are asked to make a round headed bolt and a square headed nut as shown in Figure (b). List the process sequences involved in making the project.



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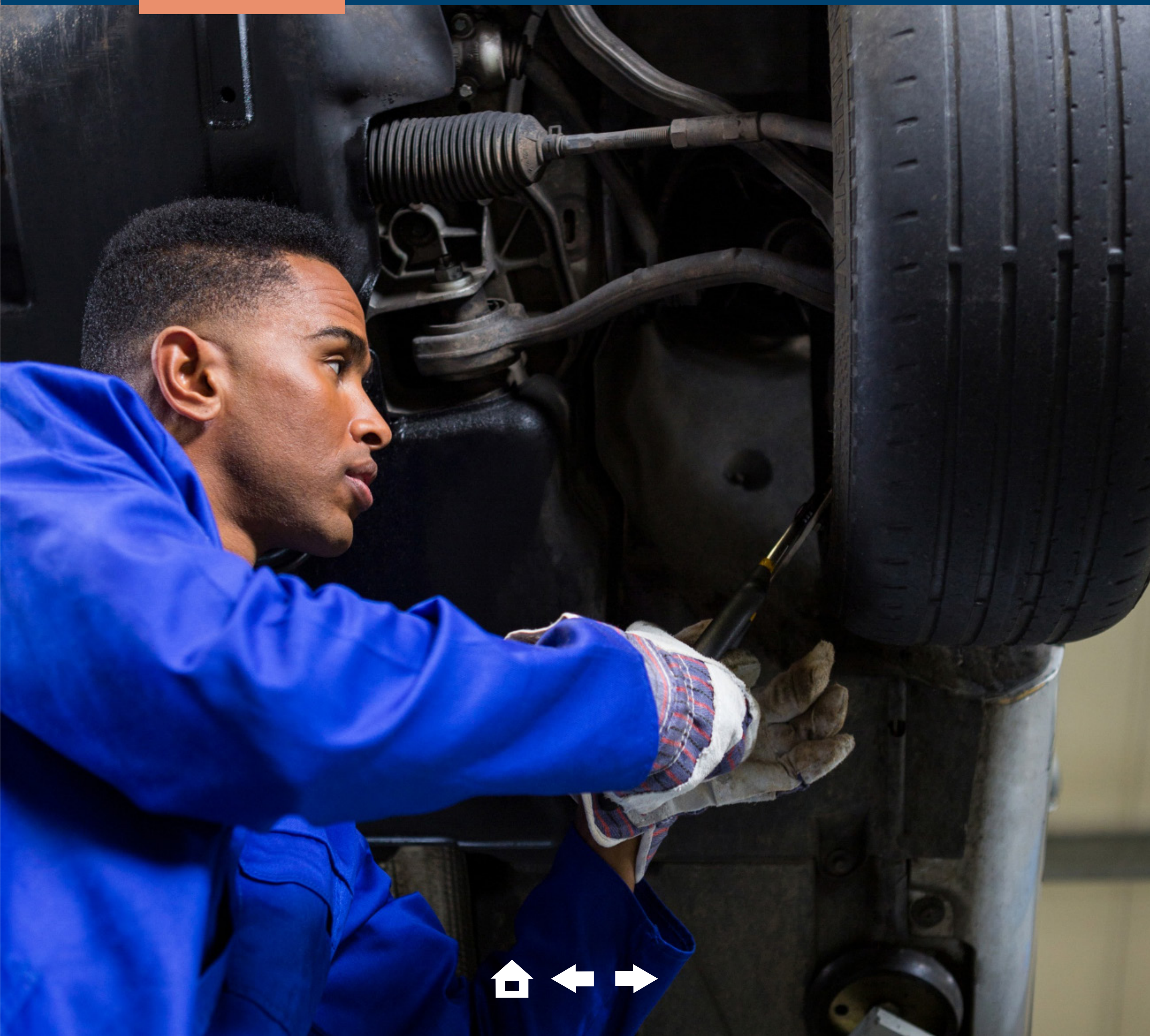
VEHICLE SUSPENSION AND METAL FORMING PROCESSES II



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AUTOMOTIVE TECHNOLOGY

Introduction to Engine Technology

Introduction

A vehicle suspension system is an important part of every automobile because it helps provide comfort, stability, and safety by supporting the vehicle, absorbing shocks, and keeping the tyres in proper contact with the road. In this lesson, students will learn about the main requirements of a suspension system, the basic components that make it work, and the different types of springs and dampers used in vehicles. The lesson will also introduce the various types of suspension systems, the common terms used in suspension design, and the basic suspension movements that occur when a vehicle is in motion. After studying this lesson, students should be able to explain why suspension systems are necessary, identify and describe the key suspension components, list the different springs and dampers, distinguish between the types of suspension systems, and understand the basic movements and terms used in suspension operation.

KEY IDEAS

- Active suspension uses sensors to adjust in real-time for better performance whilst passive suspension relies on fixed components like springs and shock absorbers.
- Dependent systems link wheels, while independent systems let each wheel move separately.
- It divides the vehicle's weight into sprung and unsprung mass.
- It reduces vibrations and shocks for a smoother ride.
- Key components of the suspension system include springs, dampers, linkages, and stabilisers or anti-roll bars.
- The suspension system connects the vehicle's body to its wheels.

INTRODUCTION TO SUSPENSION SYSTEM

The suspension system is a set of components that connects the vehicle's body to its wheels. Its primary function is to minimise vibrations, road shocks and wheel movements to guarantee a smoother and more comfortable ride for the driver and passengers as the wheels roll over uneven road surfaces. The suspension components divide the entire mass of the vehicle, with the load it carries, into sprung and unsprung mass.

The purpose of the suspension system is to:

1. Position the wheels while enabling them to move vertically and steer effectively.
2. Keep the wheels in constant contact with the road while reducing road noise.
3. Distribute the vehicle's weight evenly to the wheels.
4. Minimise overall vehicle weight, especially the unsprung mass.
5. Counteract the forces generated by steering, braking, and acceleration.
6. Work alongside tyres and seat springs to provide a comfortable ride.

Requirements of a Suspension System

To effectively achieve the intended purpose, the suspension system should be able to:

1. Allow minimal vertical movement to maintain stability while still providing adequate cushioning.
2. Align with the design and function of other parts, such as the frame, wheelbase, track and steering linkage, for optimal performance.
3. Prevent excessive bouncing or hopping of the wheels to ensure better grip and handling.
4. Absorb road shocks to ensure a comfortable ride, stable handling, and good vehicle control.
5. Durable and require minimal upkeep, keeping long-term expenses low.
6. Cost-effective to manufacture and install.
7. Reduces the vehicle's overall weight, improving fuel efficiency and performance.
8. Resist wear and tear, ensuring longevity and reliable operation.
9. Transfer braking and engine power effectively without causing instability.
10. Balance passenger comfort and safety while being cost-effective and reliable.

Components of A Suspension System

There are three basic components that make up the vehicle suspension system. They are springs, dampers and linkages.

Figure 17.1: Suspension system components

Springs

Springs enable the wheels to move up and down without impacting the vehicle body. They operate by absorbing road shocks and allowing the wheels to adapt to uneven road surfaces. Together with the suspension components, wheels and brake assemblies, the springs constitute the unsprung mass (or unsprung weight) of the vehicle, serve as a link between the sprung and unsprung weight of the vehicle.

Dampers

A damper, commonly known as a shock absorber, is a hydraulic device filled with oil that functions like a pump. When the vehicle hits a bump, the suspension experiences jounce, causing the wheel to move upward toward the frame. The dampers act by absorbing and dissipating the energy stored in the suspension springs, reducing rebound oscillations. This helps maintain vehicle stability and ensures a smoother, more comfortable ride when the wheels encounter bumps or irregularities on the road.

The most common types of dampers are telescopic and piston designs, both of which are direct-acting. Depending on their construction, shock absorbers can be either single (mono) tube or twin-tube. Mono-tube dampers provide better heat dissipation and consistent performance, while twin-tube dampers are more robust and better suited for heavy-duty use.

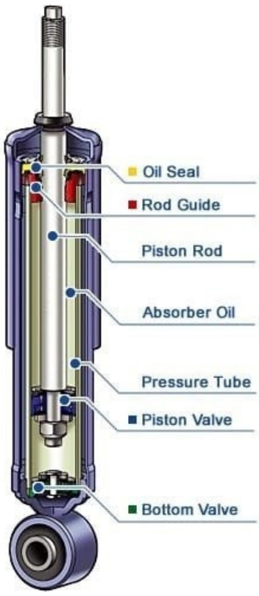

Figure 17.2: A damper

Linkages

The linkage system, which is made up of a group of links, such as bars, struts and control arms (or wishbones) that support the wheels, springs and shock absorbers and hold the entire suspension components in place and control the longitudinal and lateral movements of the vehicle. Among their several benefits, the links help to control wheel movement, maintain wheel alignment, and transmit forces from the wheel to the frame.

Figure 17.3: Suspension linkages

Stabiliser

The stabiliser or anti-roll bar helps reduce body roll during cornering. It connects the left and right suspension units in independent suspension systems, usually linking the lower suspension arms to the vehicle's body or sub-frame. Bushes attach the roll bar to the vehicle body, allowing it to twist freely.

When the vehicle corners, weight shifts to the outer wheels, causing the body to lean or roll. The anti-roll bar resists this by twisting and transferring force to the opposite side, pulling the body down and reducing the roll. This improves stability and handling during turns.

Figure 17.4: A stabiliser bar

Types of Suspension Systems

There are two types of suspension systems: dependent (or rigid) and independent.

Dependent or Rigid suspension system

A dependent suspension system features a solid axle that spans the entire width of the vehicle frame, connecting the wheels on both sides. This design means that the movement of one wheel directly affects the other, as they are mechanically linked and operate as a single unit. For example, if one side of the vehicle tilts or bends due to road irregularities or cornering forces, the other side will follow the same motion.

While dependent suspension systems are robust and simple in design, making them ideal for heavy-duty vehicles, they may not provide the same level of comfort or precise handling as independent suspension systems, where each wheel operates independently.

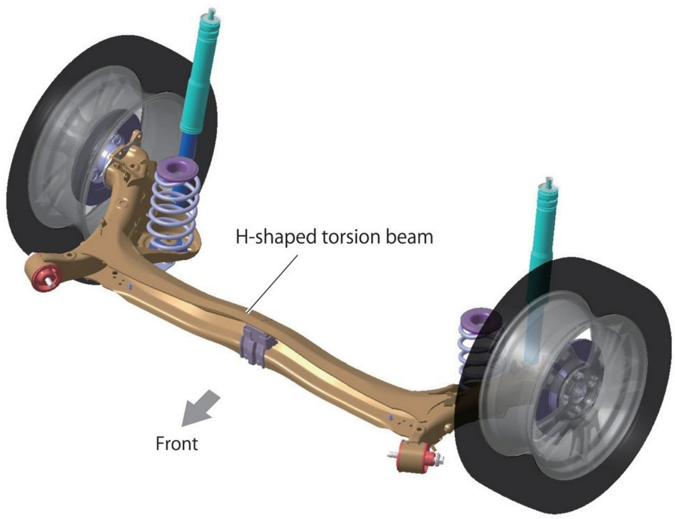

Figure 17.5: Dependent/axle beam suspension system

Independent Suspension System

An **independent suspension system** allows each wheel to move separately using its own suspension mechanisms. This means the reaction from one wheel does not affect the other. For example, if one side of the vehicle encounters a bump or uneven surface, the movement and reaction are isolated to that side, ensuring the other wheel remains unaffected. This design provides better ride comfort, improved handling, and increased stability compared to dependent suspension systems. For improved ride comfort, many modern vehicles are equipped with independent front suspension (IFS) and independent rear suspension (IRS) systems.

An independent suspension system provides several advantages, including:

1. Movement of one wheel, whether lifted or dropped, does not impact the opposite wheel.
2. The lower unsprung mass ensures better contact between the road wheel and the road surface.
3. Steering geometry issues caused by suspension movement are minimised.
4. It allows for increased space at the front of the vehicle, providing more room for the engine.
5. Softer springs and greater wheel travel can be achieved, enhancing ride comfort.

Figure 17.6: Independent suspension arrangement

Forms of Suspension Systems

Vehicle suspension systems come in two primary forms: passive and active.

1. A passive suspension system relies on non-adjustable components like springs and shock absorbers. These components strike a balance between ride comfort and stability, based on the vehicle's intended use. However, they do not adapt to changing driving conditions or road surfaces.
2. An active suspension system utilises advanced technology, including sensors, actuators, and a control unit. This system continuously monitors and responds to road conditions and driving inputs, making real-time adjustments to suspension stiffness and damping. Active suspension

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systems provide enhanced comfort, stability, and performance. Due to their complexity, active systems are typically found in high-end or performance vehicles.

Basic Suspension Movements

1. **Roll:** Rotation of the vehicle's body around its longitudinal axis, which often occurs during cornering.
2. **Pitch:** Rotation of the vehicle's body around its transverse axis, often during braking or acceleration.
3. **Yaw:** Rotation of the vehicle's body around its vertical axis, often during cornering or steering.

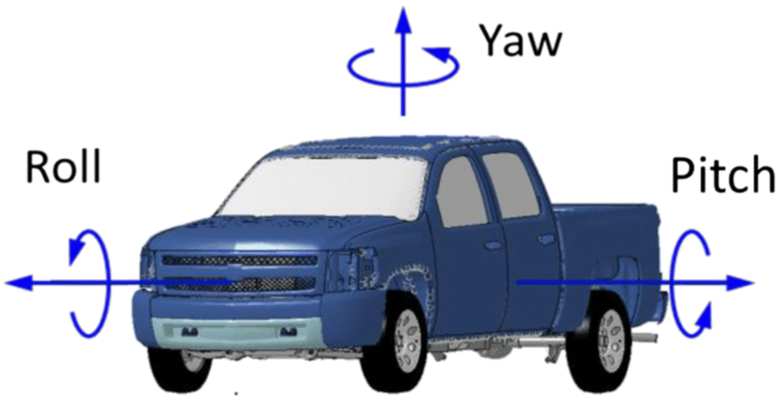

Figure 17.7: Various suspension movements in vehicles

Activity 17.1

Function of the suspension system

Arrange yourselves into groups of no more than 5 and sub-divide your group into two: Group 1 and Group 2.

Task 1: for group 1

1. Recall an experience you have had when you felt road shocks transmitted to you when the car you were travelling in ran over a bump or a pothole.
2. Based on what you have learnt, brainstorm the reason for that rough experience.

Task 2: for group 2

1. Share your experiences where, despite the car running over a bump or a pothole, you did not feel the impact as severely as the first group had.
2. Based on what you have learnt, brainstorm the reason for the comfortable ride.

3. In both groups, analyse and answer the following scenarios:
   a. Why do high jumpers and pole vaulters land on landing pads?
   b. Why do many of your shoes feature rubber soles?
   c. Why are fragile items and electronic appliances packaged in expanded polystyrene (Styrofoam)?
4. Now, in a whole group discussion, explore the reasons for the inclusion of suspension systems in the design of automobiles.
5. Write a one-page article on the importance of suspension systems in cars. Present this to the class for discussion and feedback.

Activity 17.2

Describing the components of the suspension system

CAUTION: Wear appropriate safety gear and handle tools and components with care to avoid injuries.

Your teacher will arrange for you to visit the school auto workshop or a nearby workshop.

1. In your groups, visit the auto workshop (or a mechanic shop in your community) where you can have access to a vehicle frame with a complete suspension system.
2. Examine the various suspension components.
3. Make neat sketches of the suspension system components (spring, damper and anti-roll bar), indicating how they are connected to the vehicle frame and wheels.
4. Write down the function of each of the suspension components.
5. Briefly explain to the class the function of each of the suspension components, as other groups also take turns to share their views.

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UNIT 18

METAL TECHNOLOGY

Introduction to Welding Technology

Introduction

Sheet metal fabrication is an important process in manufacturing because it allows metal sheets to be cut and shaped into the parts needed for machines, vehicles, appliances, and many everyday products. This lesson introduces the basic cutting and bending operations used to form sheet metal into the desired shapes. Students will learn about key cutting operations such as shearing, blanking, punching, and laser cutting, which help trim sheet metal to accurate sizes and shapes needed for proper assembly and performance. The lesson will also cover bending operations such as V-bending, roll bending, bottom bending, rotary bending, and related terms that allow metal sheets to be formed into different angles and complex shapes. After studying this lesson, students should be able to explain the importance of cutting and bending in sheet metal work, identify the main cutting processes, describe the different bending methods, and understand how these operations help create accurate and functional sheet metal components..

KEY IDEAS

- Sheet metal fabrication is important for shaping and forming metal sheets into accurate and usable parts.
- Cutting operations are used to trim sheet metal to precise dimensions.
- Bending operations help create different angles and complex shapes.
- Both cutting and bending processes are essential for producing components that fit correctly and function properly in final products.

SHEET METAL OPERATIONS

The term sheet metal refers to any metal that can be formed into flat pieces of varying thickness. In sheet metal thickness is between 0.006 (0.15mm) and 0.25 inches (6.35mm). Anything thinner is referred to as a foil, and anything thicker is considered a plate. Products made by sheet-metal forming processes are all around us. They include utensils, file cabinets, appliances, vehicle bodies, fuel tank, etc. Compared to casting and forging, sheet-metal parts offer the advantages of lightweight and versatile shapes. Because of low cost and generally good strength and formability characteristics, low-carbon steel is the most commonly used sheet metal. Some of the sheet metal operations are shearing, piercing and punching, blanking, notching, beading, flanging, hemming, seaming, perforating, slitting, lancing, drawing, coining, embossing and wire drawing.

Punches and Dies: Sheet metal operations are usually carried by using punch and die. The mechanism of operation of punch and die is shown below. Die is having the negative shape of the contour and punch has the positive contour of the shape to be produced. Sheet or plate to be shaped is kept over the die as shown.

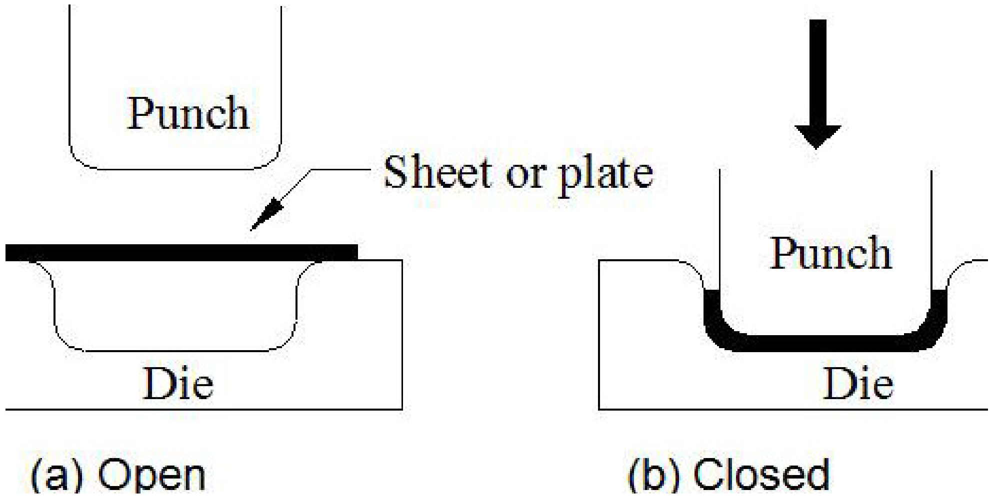


Figure 18.1: Punches and Dies

Cutting Operations in Sheet Metal

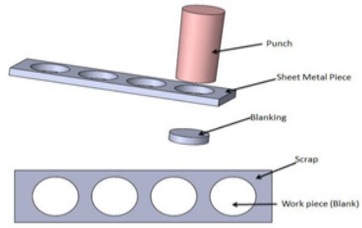
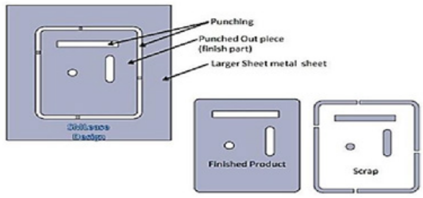
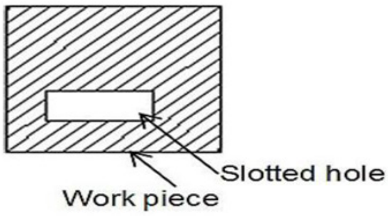
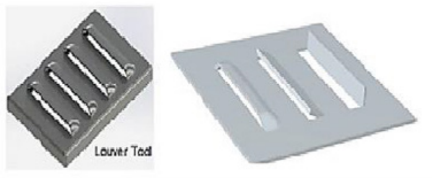
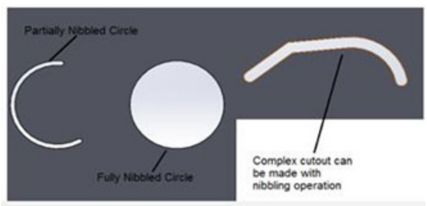
Sheet metal cutting operations remove the sheet metal materials from large sheets by applying high forces on the cutting edge. The cutting tool (punch & die, or shearing blade) cuts the materials if the applied shear stress exceeds the material's shear strength.

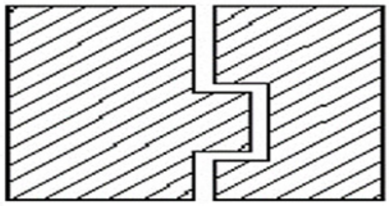
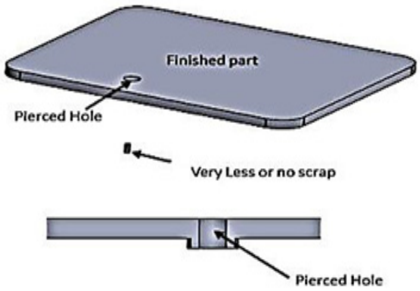
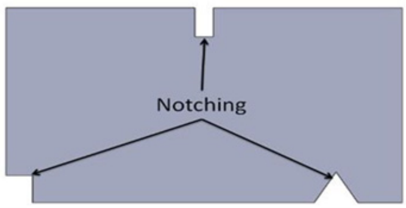
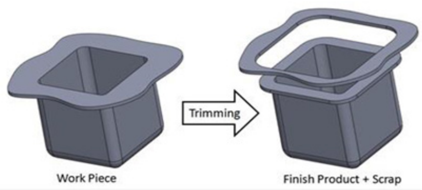
Types of Sheet Metal Cutting Operations

The various types of sheet metal cutting processes are available to remove material from sheet metal stock. The following are widely used sheet metal cutting processes to get the desired profile from sheet metal stock.

Table 18.1: Sheet metal cutting operations

S/N	Cutting Operation	Description of The Operation	Picture of Operation or Tools and Equipment Used for The Operation
1	**Shearing**	Shearing is a process that cuts metal sheets into smaller sections using a shear press. It involves two blades: one is stationary, and the other moves to cut through the metal. It is commonly used for straight cuts in sheet metal and uses a machine called a power shear or square shear.	 Sheet metal shearing machine

2	**Blanking**	Blanking is similar to punching, but the removed piece is the desired part, while the rest is scrap. It is used to produce flat, precise parts called blanks.	
3	**Punching**	Punching involves removing a scrap piece of material from the workpiece using a punch and a die. This operation creates holes or cut-outs of various shapes and sizes in the metal.	
4	**Slotting**	Slotting is a sheet metal process where a slot is put in the metal to do its job. Also known as slitting, the machines used in the process are called slitting machines. The process involves cutting notches in the steel sheets and removing the excess metal with a chisel.	
5	**Lancing**	Lancing is the operation of cutting a sheet of metal through part of its length and bending the cut portion.	
6	**Slitting**	Slitting is the operation of cutting a sheet metal along a straight line along the length. Slitting is shown below.	 
7	**Nibbling**	Nibbling is punching a series of small overlapping slits or holes along a path to cut out a larger contoured shape. This eliminates the need for a custom punch and die but will require secondary operations to improve the accuracy and finish of the feature.	

8	**Parting**	Parting is separating a part from the remaining sheet, by punching away the material between parts.	
9	**Cut off**	Separating a part from the remaining sheet, without producing any scrap. The punch will produce a cut line that may be straight, angled, or curved.	
10.	**Perforation**	Perforating is the process where manufacturers put holes in the metal. Also known as punching operation, it is accomplished using a specialised tool called a press hammer. Unless the press hammer punches the hole on the sheet, it doesn't count as perforating.	
11	**Piercing**	Piercing is cutting out the metal sheets with holes in them. Because the process involves cutting out the metal sheets with holes in them, it's a combination of the punching and shearing processes. The only difference between perforating and piercing is the coverings in every hole.	
12	**Notching**	The process involves cutting a rectangular piece of metal out of the larger sheet. Notching happens to the edge of the metal sheet and is used to attach the sheet to something else. The process is done with a notching machine or a shearing machine.	
13	**Trimming**	Punching away excess material from the perimeter of a part, such as trimming the flange from a drawn cup.	
14	**Shaving**	Shearing away minimal material from the edges of a feature or part, using a small die clearance. It is used to improve accuracy or finish.	

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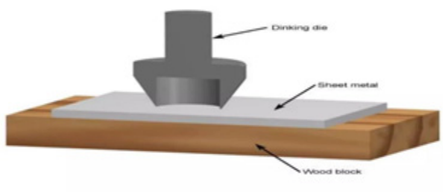
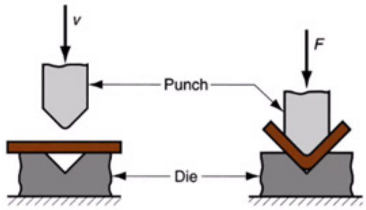
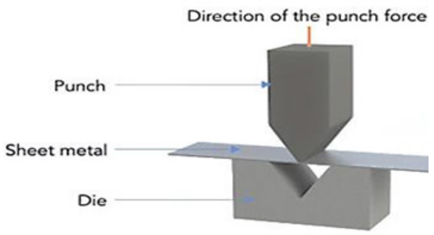
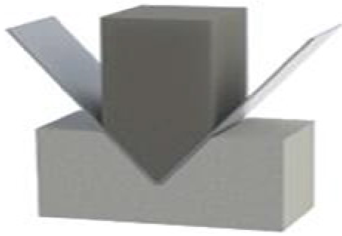
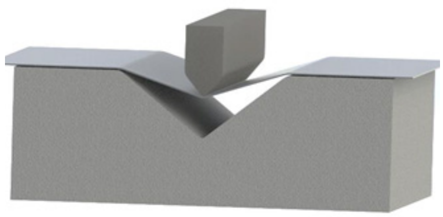
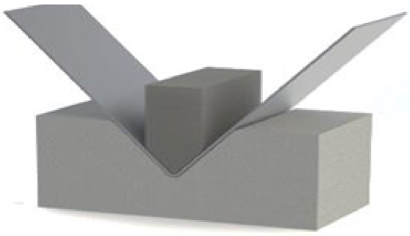
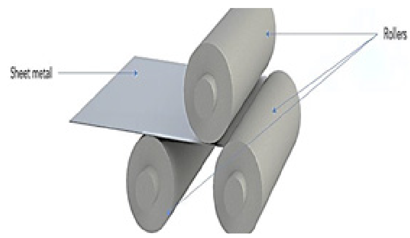
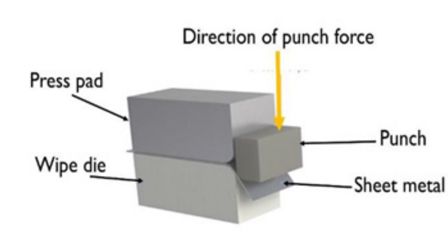
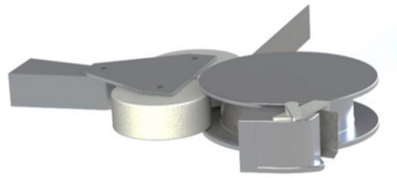
15	**Dinking**	A specialised form of piercing used for punching soft metals. A hollow punch, called a dinking die, with bevelled, sharpened edges presses the sheet into a block of wood or soft metal.	
16	**Deburring in sheet metal**	Deburring of sheet metal is the removal of irregularities and sharp edges on metal products. The burrs are tiny pieces of metal that are stuck to the surface of the sheet metal, mostly around the cut edges.	
17	**Laser Cutting**	Laser cutting uses a high-energy laser beam to cut through metal. It offers high precision and is suitable for complex shapes and intricate designs.	
18	**Bending**	Bending is a manufacturing process; it is defined as the straining of the sheet metal around a straight edge. It produces a V-shape, U-shape, or channel shape along a straight axis in ductile materials called sheet metal. Bending induces plastic deformation in the material, so the part retains its shape after the bending force is released. The press brake is a commonly used tool to bend sheet metal. It works by lowering a punch onto a sheet metal positioned on a die, creating the desired geometry.	 

Sheet Metal Bending Methods

Sheet metal bending is a key process in manufacturing and fabrication. Each bending method is chosen based on the material, bend requirements, production volume and precision needed.

Table 18.2: Examples of sheet metal bending methods

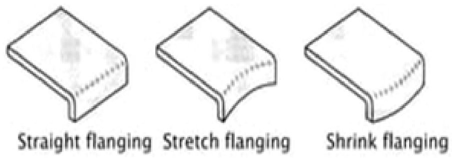
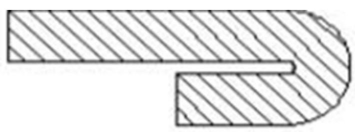
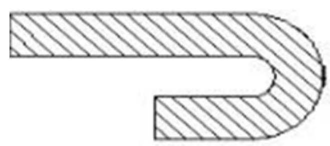
S/N	Method of Bending	Description of the Method of Bending	Picture of the Method of Bending
1	**V-bending**	V-bending is the most common sheet metal bending method. As its name implies, the V-bending method employs a V-shaped die and a punch to bend metals at desired angles. The V-shaped punch forces the sheet metal work piece into the "V-shaped" groove in the die, forming sheet metals with different bend angles. For example, you can achieve acute, obtuse, or 90° bend angles, depending on the V-shaped punch and die angle.	 V-bending before the application of force  V-bending after the punch force
2	**Air Bending**	Air bending is quite similar to the V-bending method: it relies on a V-shaped punch and die to bend sheet metals. However, unlike the conventional v-bending process, the punch in the air bending method does not force the sheet into the bottom of the cavity. Instead, it leaves space (or air) underneath the sheet, allowing more bend angle control than conventional v-b.	
3	**Bottom Bending**	Bottoming (or bottom bending) is a type of v-bending that also solves the springbuck challenge. It involves deforming the sheet metal in the bend region by applying additional force through the tip of the punch after completion of bending.	
4	**Roll Bending**	Roll bending uses three rollers to form metal sheets or plates into curved shapes or cylindrical forms. It's commonly used for large-radius bends.	

5	**Wipe Bending**	In the wipe bending method, the sheet metal is held against a wipe die by a pressure pad. The punch then forces against the edge of the sheet that extends beyond the die and pressure pad, causing it to bend over the end of the die.	
6	**Rotary Bending**	Rotary bending uses a rotating die that forms the metal around a fixed form, creating precise bends with minimal force. It is efficient for complex bending tasks.	

What are Bending Operations?

Bending is a key operation in sheet metal forming, where the material is deformed along a straight axis to create angular or curved shapes. It involves applying force to the sheet metal to achieve the desired bend angle without breaking the material. Bending operations are widely used in the manufacturing of parts such as brackets, enclosures, and frames.

Table 18.3: Bending operations

S/N	Type of Bending Operation	Description of Bending Operation	Picture of Bending Operation
1	**Flanging**	Flanging is one kind of bending operation in which the edge of the sheet metal part is bent at 90° angle to form a rim or flange. It is often used to strengthen or stiffen the sheet metal part. There are three types of flanging, they are: • Straight • Stretch • Shrink	
2	**Hemming**	Hemming refers to the process of folding over the edge of a piece of sheet metal and pressing it flat. This stiffens the sheet and creates a safer, non-jogged edge. The two types of hemming are: • Flat hemming • Open hemming	 Flat hemming  Open hemming

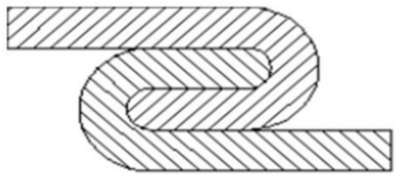
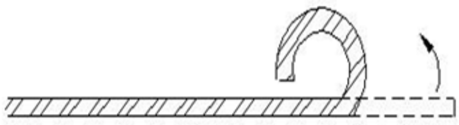
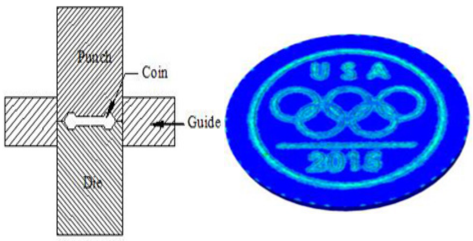
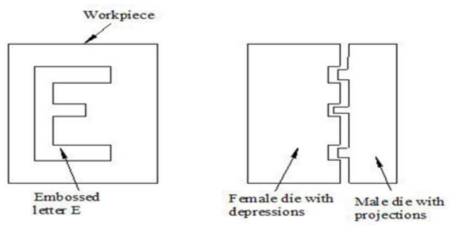
3	**Seaming**	It is an operation where two sheet metal edges are assembled.	
4	**Curling**	Curling forms the edges of the part into a roll or curl.	
5	**Beading**	Beading is the forming of the rolled edge by bending the edge of sheet metal. Beading is one of the common bending operations which are used to form beads at the end of the sheets. It gives strength and stiffness to the edge, and sharp edges that might injure the users of the part are avoided.	

Table 18.5: Sheet metal forming operations

S/N	Forming Operation	Description of Forming Operation	Picture of Forming Operation
1	**Coining**	The term coining refers to the cold squeezing of metal while all of the surfaces are confined within a set of dies. The process is used to produce coins, medals, etc. The metal is coined in a completely closed die cavity.	
2	**Embossing**	Embossing is the operation of producing raised or depressed impression of figures, letters or designs on sheet metal parts. The major use of embossing process in the production of nameplates, identification tags and aesthetic designs on thin sheet metal or foil.	

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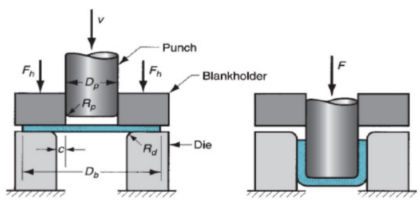
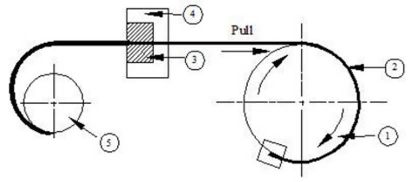
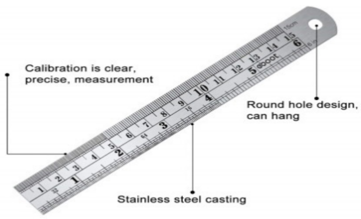
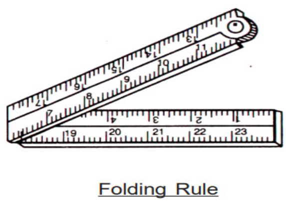
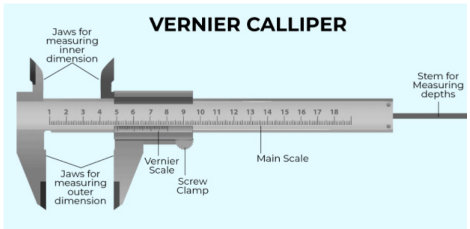
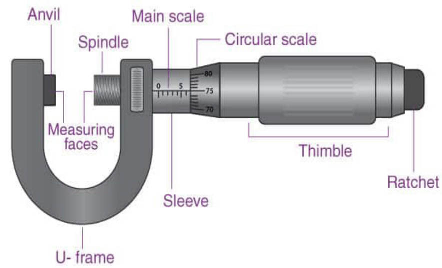
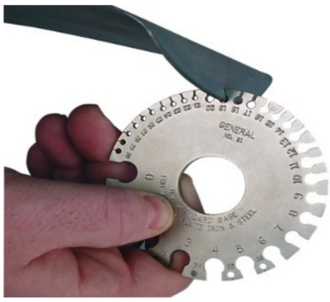
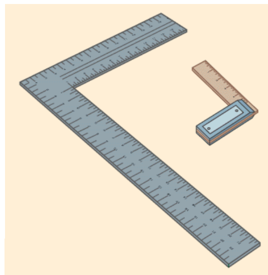
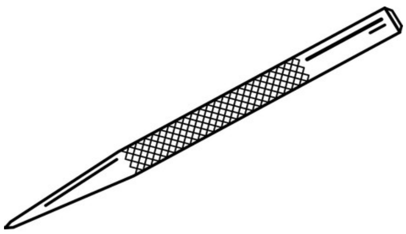
3	**Drawing**	Drawing is sheet-metal forming operation used to make cup-shaped, box shaped or other more complex curved, hollow shaped parts. It is performed by placing a sheet metal blank over die cavity and then pushing the metal into the opening with a punch.	
4	**Wire Drawing**	Wire drawing involves pulling metal through a die. A tensile force is applied to the metal on the exit side of the die. The process of wire drawing is shown in below.	

Table 18.6: Sheet Metal Hand Tools

S/N	Name of Tool	Description and Uses Of Tool	Picture of Tool
1	**Steel rule**	A straight measuring tool made of steel, used for measuring lengths or marking straight lines.	
2	**Folding rule**	A foldable measuring stick, typically made of wood or plastic, used for taking measurements in tight or hard-to-reach places	
3	**Circumference rule**	A specialized measuring tool for calculating the circumference or curved dimensions of objects, often used for pipes and cylinders.	
4	**Vernier Calliper**	A precision instrument used to measure internal, external, and depth dimensions with high accuracy	

<table>
<tr><td>5</td><td>Micrometre</td><td>A highly accurate tool for measuring small dimensions, such as thickness or diameter, to a fraction of a millimetre.</td><td>
</td></tr>
<tr><td>6</td><td>Thickness Gauge</td><td>A tool with multiple blades of various thicknesses used to measure the gap or thickness of materials.</td><td></td></tr>
<tr><td>7</td><td>Sheet Metal Gauge</td><td>A tool that indicates the thickness of sheet metal in standard gauge numbers.</td><td></td></tr>
<tr><td>8</td><td>Straight Edge</td><td>A long, flat tool used to check the straightness of surfaces or to draw straight lines.</td><td></td></tr>
<tr><td>9</td><td>Steel Square</td><td>A metal tool with two arms forming a 90-degree angle, used for measuring and marking right angles.</td><td></td></tr>
<tr><td>10</td><td>Scriber</td><td>A pointed tool used for scratching or marking lines on metal surfaces for cutting or machining</td><td></td></tr>
</table>

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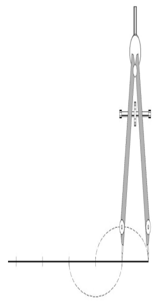
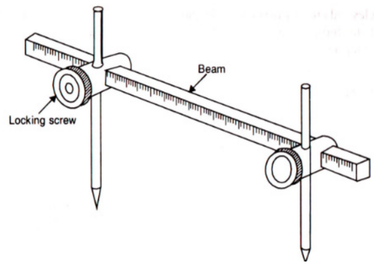
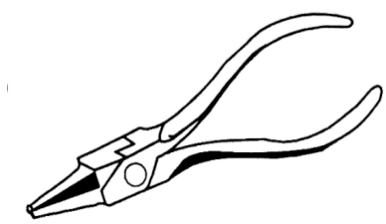
11	**Divider**	A compass-like tool with two sharp points, used for marking circles or arcs on metal or transferring measurements	
12	**Trammel Points**	Adjustable tools attached to a beam or bar, used to draw large circles or arcs	
13	**Punches**	Tools with a pointed or flat tip, used to make holes or indentations in metal by striking with a hammer	
14	**Chisel**	A cutting tool with a sharp edge, used to cut or carve metal, wood, or stone.	
15	**Hammer**	It's a hand tool with a heavy head, used for striking, shaping, or joining materials	
16	**Snips or shears**	Cutting tools for sheet metal, used to cut straight or curved lines.	
17	**Pliers**	Hand tools used for gripping, bending, or cutting wire and small materials.	

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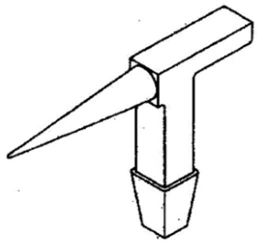
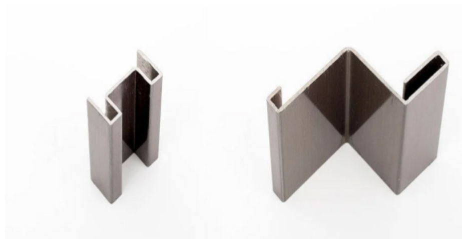
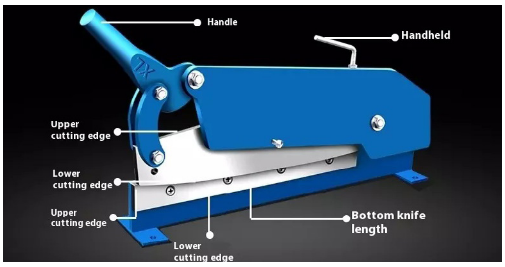
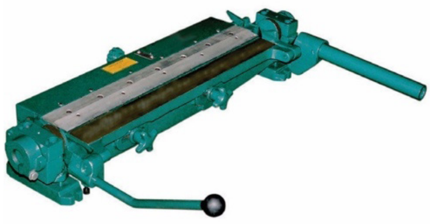
18	**Stake**	Metal tool with various shapes, used as supports for hammering or shaping sheet metal.	
19	**Grooves**	Tools used to create grooves or channels in metal sheets for joints or decorative purposes	
20	**Rivet Set**	A tool used to secure rivets in place by compressing them to fasten materials together.	
21	**Soldering Iron**	A tool with a heated tip used to melt solder and join metal parts, especially in electrical and plumbing work.	

Table 18.7: Sheet metal working machines

S/N	Type of Machine	Description and Uses of The Machine	Picture/Sketch of The Machine
1	**Shearing machine**	Used to cut or shear metal sheets.	
2	**Bar folder**	Used to bend and fold the edges of metal sheets.	

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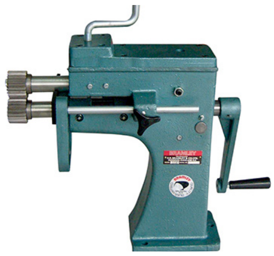
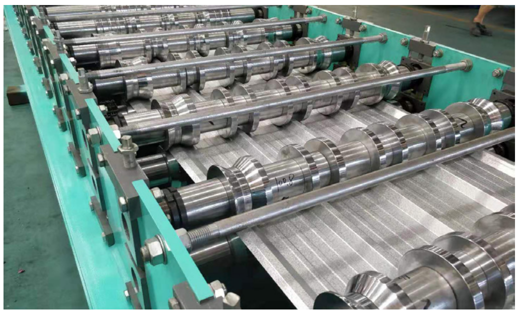
3	**Burring machine**	Used to make burr of the edges of the bottom for a can on the end of a cylinder.	
4	**Turning Machine**	Similar to burring machine and used to produce a rounded edge for wiring operation and for double seaming.	
5	**Wiring Machine**	Is used to press the wire inserted into turned sheet after the hammering.	
6	**Forming Machine**	Used to form stove pipes, cans etc. It consists of three rolls between which the curves are made. metal.	
7	**Brake**	Is a machine used for bending and folding sheet metals	

Example 18.1

A square duct required for an air-conditioning system is to be made from aluminium sheet metal. The duct is shown in the figure below, and the shaded portions in the figure indicate places where sheet metal work has to be done. Identify the different sheet metal operations involved in manufacturing the duct. Illustrate the sequence of these operations.

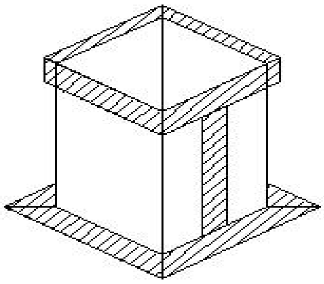


Figure 18.2: Duct to be manufactured

Solution: The duct is made from sheet metal by performing the following operations, illustrated below:

1. First, the raw material (Al sheet) is marked, that is, the lines at which the sheet is to be bent or folded, to form the square duct, are marked. See Image **(a)** in **Figure 5.18.3**.
2. Next, the sheet is folded over a die and seaming is done to join the two edges of the sheet, as shown in **image (b)**.
3. Next, hemming is done at the top edge of the square duct formed in the previous step. It is shown in **image (c)**.
4. Finally, the lower edge of the duct is flanged (folded) to produce the final duct. This is shown in **image (d)**.

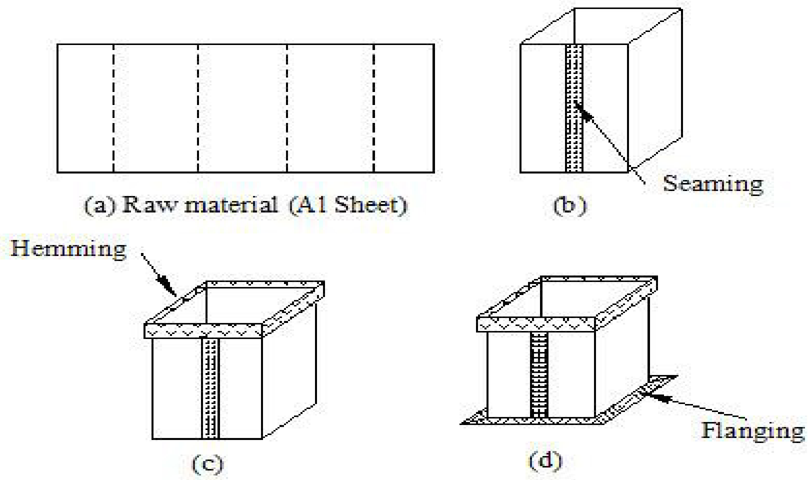


Figure 18.3: Different stages in producing the ductwork

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Conclusion

Sheet metal fabrication is the process of forming metal sheets into desired shapes and sizes using various techniques. It plays a crucial role in industries like automotive, aerospace, construction and consumer goods. The key processes include cutting, bending, punching, and assembling.

Learning about sheet metal fabrication and operations highlights the importance of precision, material selection, and process control in manufacturing. Mastery of techniques like cutting, bending, and joining is essential for creating high-quality products. Additionally, understanding safety measures and efficient workflow ensures better productivity and sustainability.

Activity 18.1

Describing and demonstrating the various cutting and bending operations in sheet metal fabrication

Arrange yourselves into groups of no more than 5. Your teacher will assist you in performing the following activities:

1. Brainstorm and explain sheet metal operations. Make notes of your discussion.
2. Prepare a table and use it to describe the various cutting and bending operations in sheet metal fabrication and how to carry out these operations.
3. Research on the sequential process to follow to produce articles using cutting and bending operations in sheet metal fabrication. You can make a flow chart diagram to create a visual of this sequential process.
4. Present your findings to the class for a discussion.

Activity 18.2

Demonstrate the sequential process to follow for marking out and cutting sheet metal into shapes

Using realia (real tools and equipment), demonstrate the sequential process to follow to mark out and cut sheet metals to shape using hand and machine tools, as well as bending sheet metal to form articles using hand and machine tools.

Activity 18.3

Making a sketch or photo album and displaying it in class for appraisal

Make sketches or take pictures of tools and equipment used for cutting and bending operations in sheet metal. Make a sketch or photo album and display it in class for appraisal.

Activity 18.4

Embarking on a visit to a local fabrication workshop

Your teacher will arrange for your group to visit a local welding and fabrication workshop. Once there, complete the following activities.

1. Identify the tools and equipment used for making artefacts.
2. Observe how the various operations are demonstrated at the workshop and ask questions to gain further knowledge of the work being done.
3. Prepare a report and discuss it in class in groups after the visit.

Note:

a. Observe the basic safety precautions during the visit.

b. Wear your PPE at all times.

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AUTOMOTIVE TECHNOLOGY

Introduction to Vehicle Technology

Introduction

Springs are an important part of a vehicle's suspension system because they help support the weight of the vehicle, absorb shocks from the road, and provide a comfortable and stable ride. This unit introduces the main types of springs used in vehicles, including laminated or leaf springs, helical or coil springs, torsion bars, rubber springs, and air or gas springs. The lesson will explain the features of each spring type and compare their advantages and disadvantages to help students understand why different vehicles use different spring designs. After studying this lesson, students should be able to identify the various types of springs, describe their key features, compare their benefits and limitations, and understand how each spring type affects vehicle comfort, stability, and performance.

KEY IDEAS

- Air springs offer adjustable ride height and comfort but are expensive and require frequent maintenance.
- Factors affecting spring choice include weight, cost, energy capacity, location, and durability.
- Spring stiffness depends on length, width, thickness, and the number of leaves.
- Springs help maintain consistent tyre contact with the road for safe braking and cornering.
- Springs support the vehicle's weight and maintain its ride height.
- They absorb shocks and vibrations, ensuring a smoother ride and better handling.

SPRINGS IN SUSPENSION SYSTEM

Springs support the weight of the vehicle, determine its ride height, and keep the wheels correctly positioned in relation to the road and the vehicle's frame. By absorbing road shocks and vibrations, springs enable the wheels to track the road surface accurately. This ensures a smoother ride and improved handling. All this helps to reduce the impact of bumps and potholes on the vehicle and its occupants.

Additionally, springs help to maintain consistent tyre contact with the road, which is essential for stable braking and cornering. Overall, the springs work in conjunction with other suspension components to provide a comfortable ride, responsive handling, and improved safety.

Springs can be made from several materials, each having different characteristics in the way they react to impact.

The Factors Governing the Choice of Springs Used

1. **Total weight of the suspension system**
    - The type of spring chosen must be able to support the weight of the suspension components while maintaining the desired ride height and performance. Heavier suspension systems require springs with higher load-bearing capacities.
2. **Total cost of installation**
    - The total cost of the spring and its installation must fit within the allocated budget without compromising performance or durability. Simpler designs tend to be less expensive than more complex systems.
3. **Relative capacity for storing energy**
    - Springs must be able to store and release energy during compression and extension. The selected spring should have adequate energy storage capacity to absorb all the road shocks without failing or fracture, provide the desired ride comfort, and maintain stability.
4. **Guide linkage required**
    - Some spring types, like leaf springs, can provide both suspension and structural support, reducing the need for additional guide linkages. Others, like coil springs, may require extra components for guidance and stabilisation.
5. **Location**
    - The type of spring to choose must be guided by the location where it is going to be placed on the vehicle (front, rear, or both). Different spring types may be used for the front and rear suspensions, depending on the specific requirements and design limitations.
6. **Fatigue life**
    - The spring must be durable enough to withstand repeated cycles of compression and extension over time without failing. This ensures long-term reliability, safety, and performance, even under demanding driving conditions.

Types of Springs

1. Laminated or leaf springs
2. Helical or coil springs
3. Torsion bars
4. Rubber springs
5. Air and gas springs

Laminated or leaf springs

Laminated springs consist of a bundle of long, slender steel strips of varying lengths, known as leaves, which are attached at both ends to the vehicle's frame. The leaves are layered on top of one another, with the thickest leaves at the bottom and the thinnest at the top. All the blades are bound together using steel straps called rebound clips.

The topmost leaf, called the master leaf, has eyes on its ends by which the entire spring is attached to the vehicle frame. One end of the spring is mounted on the frame with a simple pin, while a flexible connection is provided on the other end with a shackle, which swings to accommodate variation in spring length when the vehicle comes across a bump on the road surface.

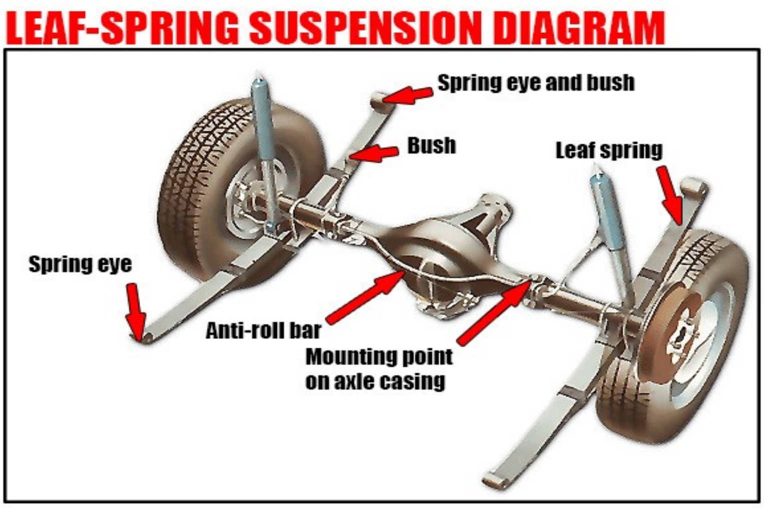

Figure 19.1: Leaf spring in suspension

The axle is suspended in the middle of the leaf spring, allowing it to move up and down as the vehicle moves over bumps and uneven surfaces. U-bolts support the spring on the axle. Leaf springs are commonly used in older cars and heavy vehicles.

Parts of leaf springs

1. **Metal plates or leaves:** A leaf spring consists of several metal plates, also known as leaves, stacked together in decreasing size. These plates are curved to form a camber, which gives the spring its characteristic semi-elliptical shape.

2. **Master leaf:** The master leaf is the longest and strongest leaf at the top of the spring assembly. Its ends are curved to form spring eyes, which are used to attach the spring to the vehicle's chassis or axle using bolts.
3. **Centre bolt:** The centre bolt is located in the middle of the leaf spring assembly and holds all the leaves together. It maintains the structural integrity of the spring and ensures the leaves do not separate.
4. **U-bolt:** The U-bolt is responsible for fastening the leaf spring to the axle and associated components, such as the top plate, axle seat, and bottom plate. It provides the necessary clamping force to keep the assembly secure.
5. **Rebound clip:** Rebound clips are steel bands that keep the leaves aligned and prevent lateral movement during vehicle operation. They are positioned near the centre bolt to maintain the spring's stability.
6. **Spring eye:** The spring eye is a loop formed at the ends of the master leaf. It allows the spring to be fastened to the chassis or axle using shackles or bolts, enabling secure attachment and flexibility.
7. **Swinging Shackle:** A swinging shackle is used to connect one end of the spring to the chassis. It allows the spring to flex as it compresses and expands, creating a soft springing action and absorbing shocks effectively.
8. **Shackle pins:** Shackle pins connect the fixed shackle at one end of the spring to the swinging shackle at the other. These pins ensure proper movement and alignment of the spring during operation.
9. **Rubber bush:** Rubber bushings are inserted into the spring eyes to cushion the connection between the leaf spring and the vehicle's chassis. They reduce vibrations and noise, enhancing ride comfort. Some bushings are encased in steel for added durability, while others are made entirely of rubber for flexibility.

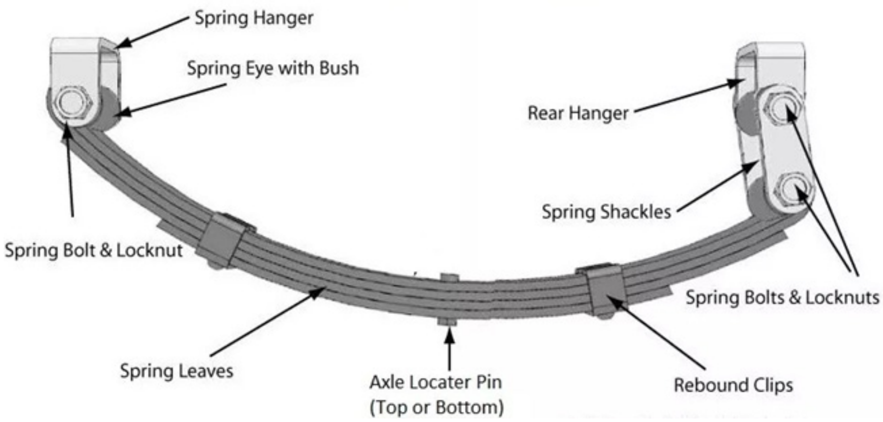

Figure 19.2: Parts of a leaf spring

Factors that affect the stiffness of a leaf spring

1. **Length of spring** – shorter spring, higher rate: A shorter spring is stiffer and has a higher spring rate because it is less flexible and resists bending

more effectively. Conversely, a longer spring has more flexibility, reducing its stiffness.

2. **Width of leaf** – wider spring, higher rate: Wider leaf springs are stiffer and have a higher spring rate because the increased width provides greater resistance to bending forces.
3. **Thickness of leaf** – Thicker leaf, higher rate: Thicker leaves increase the stiffness of the spring because they are stronger and more resistant to deformation. A thicker leaf requires greater force to bend, resulting in a higher spring rate.
4. **Number of leaves** – greater number, higher rate: Adding more leaves to a leaf spring assembly increases its stiffness. With a greater number of leaves, the load is distributed across multiple layers, reducing individual deflection and enhancing the overall spring rate.

Hardness of the spring can be reduced by using:

The **hardness** of a leaf spring refers to its ability to resist deformation when subjected to loads or stress. It determines how rigid or firm the spring feels, affecting its ability to absorb shocks and provide a comfortable ride. A hard leaf spring may increase load-carrying capacity but can lead to a stiffer and less comfortable ride. The hardness of the spring can be reduced by using applying the following design considerations:

1. Using rubber bushes in the eyes of the master leaf instead of bronze bushes.
2. Inserting low-friction inter-plate material between the leaves reduces stiffness and allows smoother movement of the leaves relative to each other.
3. Using a smaller number of leaves in the spring decreases its load-carrying capacity, making it less rigid and improving ride comfort.
4. **Reducing the thickness of the leaves, as** thinner leaves are more flexible.

Helper springs

Helper springs (or auxiliary springs) are supplementary springs, normally of laminated leaves, similar to the leaf spring but without eyes. The basic function of these springs is to enhance a vehicle's suspension system by providing additional load-carrying capacity when required. They are designed to work in conjunction with the primary spring, but they engage only when the vehicle is heavily loaded or when the suspension reaches a certain compression point.

Helper springs prevent suspension sag, maintain optimal ride height, and ensure stability under heavy loads. They are typically found in heavy-duty vehicles like trucks and vans, all while preserving ride comfort during standard driving conditions.

Figure 19.3: A Leaf spring with a helper spring.

Helical or coil springs

This type of spring, also called a coil spring, is the most common type of spring used on modern vehicles. It is made from a wire of special spring steel formed into the shape of a coil.

Figure 19.4: Coil spring

Coil springs are typically positioned between two key components: the axle or lower control arm and the chassis. The springs compress and expand to absorb the up and down motion of the wheels. They are commonly used in most modern vehicles, are generally suitable for cars, and are especially effective in independent suspension setups where each wheel needs to move independently.

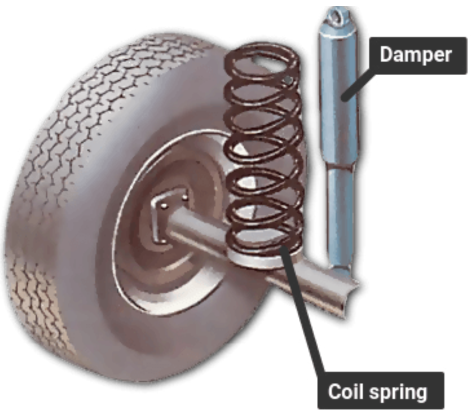

Figure 19.5: Coil spring in suspension assembly.

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Advantages of coil springs over leaf springs

1. Coil springs are lightweight compared to leaf springs.
2. They are resistant to wear and tear, and can withstand repeated compression and extension cycles without losing their shape or effectiveness.
3. Coil springs have a compact design that allows them to be installed in tight spaces.
4. They can compress and extend over a wider range than leaf springs, providing a smoother ride and better handling.
5. Coil springs are relatively simple to manufacture and install.

Disadvantages of coil springs

1. Coil springs have a limited ability to support heavy loads, which can cause them to compress excessively or even collapse.
2. Coil springs can be unstable when subjected to lateral forces, such as cornering or braking, which can cause them to twist or bind.
3. Coil springs can lose their shape and sag or lose their shape and spring rate over time, especially when subjected to heavy loads or extreme temperatures.
4. Coil springs can produce noise when they are compressed or extended rapidly.
5. Coil springs have a limited range of motion, which can restrict suspension travel and affect ride quality.
6. Coil springs can be affected by friction between the spring coils and other suspension components, which can reduce their effectiveness and lead to wear and tear.

Torsion Bars

Torsion bars are a type of suspension component that consists of a straight, sturdy bar with a circular or square cross-section. One end is securely attached to the vehicle's frame, while the other end is connected to the axle or lever arm onto which the wheel is fitted. As the wheel moves up and down, the torsion bar rotates or twists around its central axis, resisting the movement. The amount of resistance the bar provides to twisting determines its spring rate, effectively controlling the suspension's stiffness.

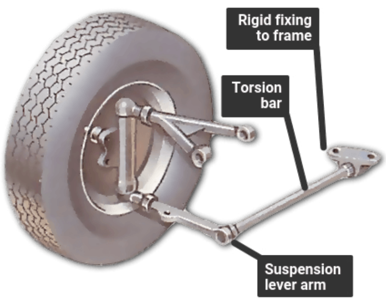


Figure 19.6: Torsion bar in suspension system

Torsion bars are often used in heavier vehicles and commercial minibuses.

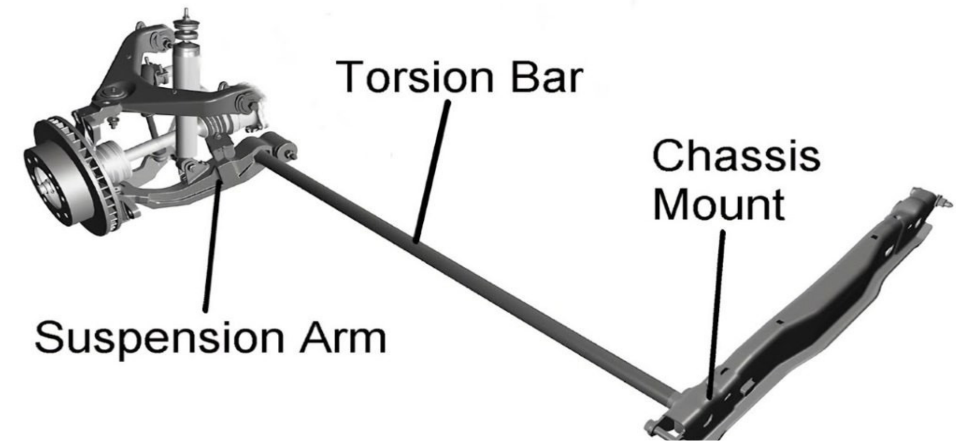


Figure 19.7: Torsion bar assembly.

Advantages of Torsion Bars

1. Torsion bars are compact and require minimum space to install.
2. They are relatively low-cost.
3. They have a high strength-to-weight ratio.
4. They have a simple design with few moving parts.
5. Some torsion bars can be adjusted to change their stiffness.
6. They are durable and have a long service life.

Disadvantages of Torsion Bars

1. Torsion bars have limited travel.
2. They can exhibit non-linear spring rates.
3. Torsion bars are sensitive to friction.
4. They require great expertise to install.
5. They are not suitable for heavy loads
6. They do not allow for a progressive spring rate.

Activity 19.1

Types of springs

Arrange yourselves into groups of no more than 5. Your teacher will arrange for you to visit the school auto workshop or a local workshop in the community.

1. In your groups identify at least three different types of vehicles (saloon, pick-up, minibus, bus, tipper truck, etc.)

2. For each vehicle type, examine the type of spring used in the suspension system.
3. Sketch the vehicle and show the suspension types.
4. Describe the physical characteristics of the different types of springs you have identified for the various vehicles.
5. Take turns to explain why different vehicles have different springs in their suspension systems.
6. Discuss the advantages and disadvantages of the different types of springs.

Air Spring Systems

Air springs, also referred to as airbags, utilise compressed air to provide support for the vehicle's weight and absorb shocks. Air springs offer superior ride quality and adaptability to various load conditions. One notable advantage of air springs is their adjustable ride height, allowing drivers to customise the vehicle's height based on driving conditions or personal preference. They are typically found in luxury and heavy-duty commercial vehicles.

Air springs are available in three different types:

1. Double convoluted
2. Tapered sleeve
3. Rolling sleeve

Figure 19.8: A double convoluted air spring

Advantages of Air Springs

1. Air springs offer a smoother and more comfortable ride by reducing the effect of bumps and vibrations on the vehicle and occupants.
2. There is a reduction in noise and vibration, which results in less wear and tear on the suspension components.

3. The ride height can be adjusted to suit the personal preferences of the driver, road and driving conditions.
4. Air springs adjust to changes in weight.
5. By reducing energy lost to vibrations, air springs help vehicles to use fuel efficiently.

Disadvantages of Air Springs

1. Air springs are more expensive to purchase compared to traditional steel springs, and they are mostly only found in luxury vehicles.
2. Air springs require frequent repairs over time.
3. Air springs can suffer from mechanical issues such as air leaks, rust, or moisture damage inside the components.

Activity 19.2

Air spring systems

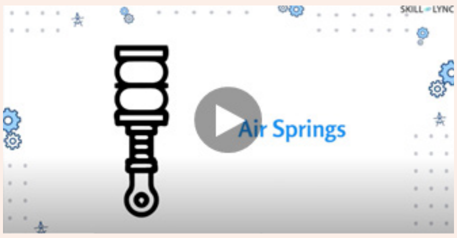
Materials needed

- Sketch pad
- Pen/pencil
- Internet

Arrange yourselves into groups of no more than 5.

Activity Steps

1. Watch the following video: https://www.youtube.com/watch?v=xg1-YNP46Ns



2. Name at least three vehicles that use air springs in their suspension system.
3. Sketch the bellows-type air suspension system and label the parts.
4. Compare your work with other groups' work and discuss the advantages and disadvantages of air springs.

Rubber Springs

Rubber springs are a specially shaped piece of suspension component made from rubber or elastomeric materials. They provide a smooth ride and are often used in lighter vehicles to absorb bumps and vibrations, similar to traditional steel springs.

Rubber springs can be used as primary or auxiliary springs and are often used in conjunction with other suspension components, such as coil springs or torsion bars. They can reduce the upward travel of suspension components by serving as bump stops, which prevent direct metal-on-metal contact, especially between the axle and the chassis.

Figure 19.9: A rubber spring

Advantages of rubber springs

1. Rubber springs are relatively inexpensive compared to metal springs.
2. They are often more compact than traditional coil springs.
3. Rubber springs are resistant to corrosion and can withstand exposure to harsh environmental conditions.
4. Rubber springs have inherent damping properties, which can help reduce vibrations and oscillations.
5. Rubber springs require little to no maintenance, as they do not need lubrication or adjustment.

Disadvantages of rubber springs

1. Rubber springs can deform or fail under heavy loads above their load-carrying capacity.
2. Rubber springs can be affected by temperature changes, which can alter their stiffness and performance.
3. Rubber springs typically have limited travel, which can restrict their ability to absorb large bumps or shocks.
4. Rubber springs can experience gradual deformation over time.

UNIT 20

METAL TECHNOLOGY

Welding Technology

Introduction

Drawing, die, and press operations are important processes in sheet metal fabrication because they allow metal sheets to be shaped into accurate and high-quality parts used in vehicles, appliances, machinery, and many other products. This unit introduces the basic principles of drawing operations, the different types of dies used in forming sheet metal, and the various presses that provide the force needed for shaping. Students will also learn about the applications of these processes and how they help produce parts with different shapes, depths, and dimensions. After studying this lesson, students should be able to explain the purpose of drawing, dies, and press operations, identify the different types and their uses, and understand how these processes contribute to creating precise and functional sheet metal components.

KEY IDEAS

- Drawing, die, and press operations are used to shape sheet metal into accurate and high-quality parts.
- Drawing is used to form metal into deeper shapes without cracking the material.
- Dies are special tools that shape the metal and are used for different forming operations.
- Presses provide the force needed to shape sheet metal.

SHEET METAL WORK OPERATIONS

Drawing Operation in Sheet Metal Fabrication

Drawing

It is the operation of producing cup and box-shaped products from a flat metal sheet. It is performed by placing a sheet metal blank over the die cavity and then pushing the metal into the opening with a punch, as shown in **Figure 20.1** below. The blank sheet must usually be held down flat against the die by a blank holder. When the metal is forced through the die by a tensile force applied to the metal at exist of die, it is called drawing, while when a compressive force is applied at the entry of the die, it is called extruding.

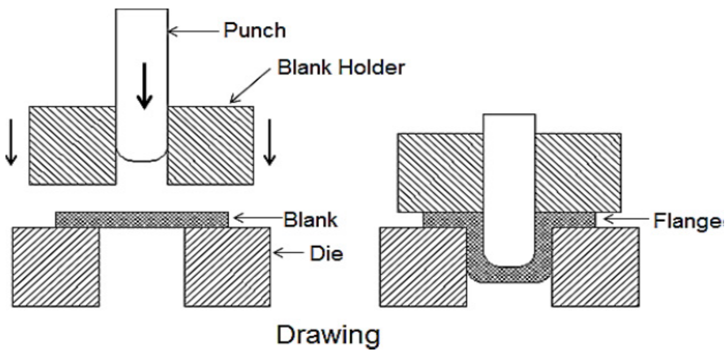


Figure 20.1: Drawing

Applications of drawing include: beverage cans, cooking pots and automobile body panels. It is divided into the following parts.

Deep drawing

Deep drawing is a sheet metal forming operation where sheet metal blank is drawn into hollow shapes by utilising the combination of tensile and compressive forces. The component is considered deep drawn if the depth of the drawn part is greater than or equal to the part radius. Deep drawing is one of the most widely used processes in sheet metal forming. Apart from its use in many other sectors, it is applied in the automotive industry for the manufacturing of car body parts.

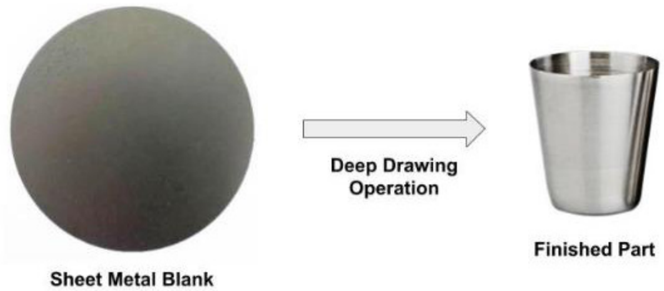


Figure 20.2: Deep drawing

Figure 20.3: Some products of deep drawing

Advantages of deep drawing

The deep drawing process in sheet metal has the following advantages when manufacturing sheet metal parts in large production volumes.

1. Manufacture hollow cylindrical, rectangular, square, and other complex geometries.
2. Low manufacturing/labour cost.
3. Less material consumption.
4. High productivity.
5. Highly precise parts.
6. High-strength and minimum-weight parts.
7. Low tool construction cost compared to a progressive stamping tool.

Sheet Metal Deep Drawing Process

Compressive and tensile forces are used in the deep drawing operation to convert a flat sheet metal blank into a hollow body. Following the creation of sheet metal, the forming operation can convert a sheet metal blank into a deep-drawn sheet metal part. After sheet metal forming, the part finishing operation is done (trimming, cutting, cleaning and powder coating).

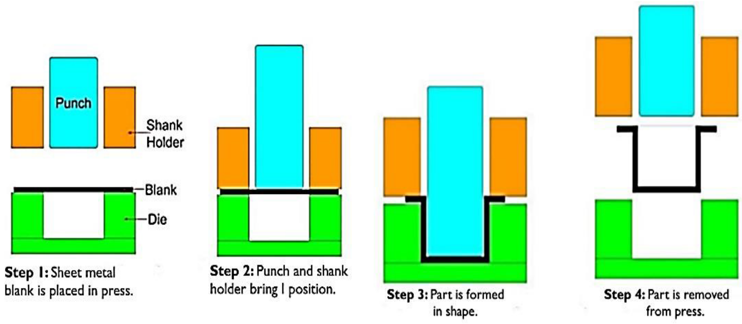


Figure 20.4: Sheet metal deep drawing process

Table 5.20.1: Sheet metal deep drawing process

Step	Process	Description of Process
1	**Part Alignment**	Place the sheet metal blank inside the deep drawing die after the sheet metal blanking operation.
2	**Gripping**	The shank holder grips the sheet metal blank between the die and the shank holder with the required pressure.
3	**Drawing Operation**	Deep-drawing punch stretches the sheet metal blank inside the die. During this operation, reduce the shank holder pressure continuously to ensure the free movement of the material. High shank holder pressure can cause wrinkles in sheet metal parts. Thinning is a common problem during stretching operations.

4	**Part Removal**	Remove the finished part from the die and send it for final finish operations.

Shallow Drawing

In this process, the depth of the drawn part is less than its diameter. It involves less deformation and is used for making items like shallow trays, lids, and pans.

Typically, it requires fewer drawing stages, as the deformation is less severe, reducing the risk of defects and often allowing the part to be drawn in a single operation. It can use a wider range of materials, as the deformation is less intense and the material's ductility is less of a limiting factor. In shallow drawing, simpler tooling and equipment can be used as the forces and deformation are lower.

Defects in Deep Drawing

Deep drawing is a widely used metal forming process for shaping sheet metal. However, it is prone to various defects that can affect the quality of final product. Common defects in deep drawing include those discussed in the Table below:

Table 20.2: Defects in Deep Drawing

S/N	Type of Defect	Description of Defect
1	**Tearing**	Maximum thinning of the cup wall occurs near the base, so tearing of the sheet metal is most likely to occur in this region even if the stress is originating somewhere else.
2	**Wrinkling**	Wrinkling may often occur if the blank holder force is too low.
3	**Thinning**	Excessive thinning in areas of the sheet metal.
4	**Earing**	Earing, which is the formation of wavy edges at the open end of the drawn cup.
5	**Surface**	Surface scratches and irregularities may appear on the drawn part scratches

Metal Drawing Process

The drawing process can be categorised into three types: Wire drawing, rod drawing and tube drawing.

Table 20.3: Metal Drawing Process

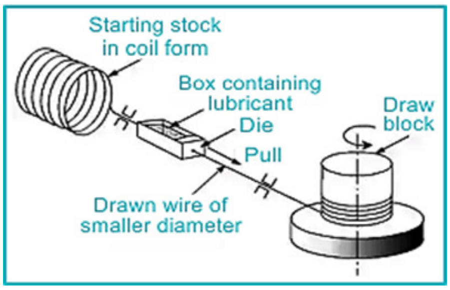
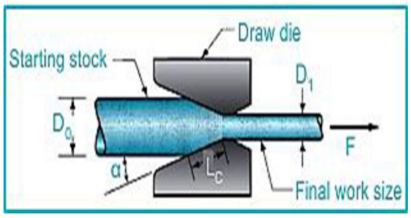
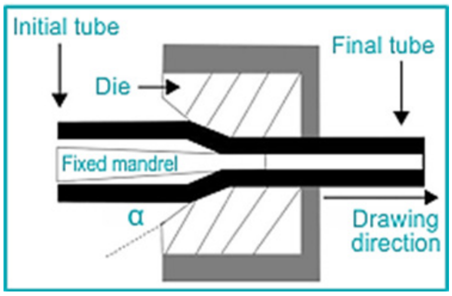
S/N	Type of Process	Description of Process	Picture of Process
1	**Wire Drawing**	Wire drawing is a cold working process used to produce circular, small-diameter flexible rods called wires. It involves reducing the diameter of a thick wire by passing it through a series of wire drawing dies, with each successive die having a smaller diameter than the previous one. The dies are typically made from chilled cast iron, tungsten carbide, diamond, or other tool materials. The maximum reduction in the wire's area in one pass is usually less than 45%.	
2	**Rod drawing**	Rod drawing wires that can be coiled. The work piece is fed into a die and pulled by a carriage, increasing its length and reducing its cross-section. After drawing, the rod is cut into sections.	
3	**Tube Drawing**	Tube drawing, like the other two processes, involves using a mandrel to reduce the wall thickness and cross-sectional diameter of a tube. The mandrel is placed within the die and a carriage system, similar to rod drawing, pulls the workpiece. The tube can be circular or rectangular and multiple passes are often required to complete the drawing operation.	

Table 20.4: Applications of metal drawing

S/N	Application	Description of Application
1	**Wires**	Metal drawing is utilised to produce wires used in electrical industries, made from materials like copper and aluminium.
2	**Paper clips and helical springs**	Products like paper clips and helical springs are manufactured using the metal drawing process
3	**Small diameter rods and tubes**	Small diameter rods and tubes are also obtained through metal drawing.

4	**long pieces with small cross-sectional areas**	The process enables the production of long pieces of metal with small cross-sectional areas.
5	**Wire drawing**	Used to produce wires for electrical industries, including copper and aluminium wires.
6	**Rod and tube drawing**	Creates small diameter rods and tubes for various applications
7	**Spring manufacturing**	Used to produce helical springs, which find use in various mechanical and industrial applications.
8	**Fasteners**	Is employed to manufacture various fasteners like screws, bolts, and nails.
9	**Precision components**	Drawing is used to produce precise and intricate components for industries such as automotive and aerospace.
10	**Jewellery making**	Is utilised in the production of fine wire used in jewellery-making processes.
11	**Musical instruments**	Is applied to produce various components for musical instruments, such as brass instruments and strings for guitars and violins.
12	**Medical devices**	The process is used in manufacturing precise components for medical devices and equipment.
13	**Electrical contacts**	It is utilised to create electrical contacts for switches and connectors.
14	**Household products**	Drawing is used in producing various household products like paper clips, safety pins, and hairpins.

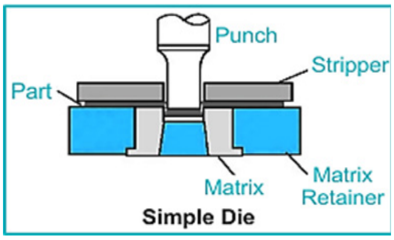
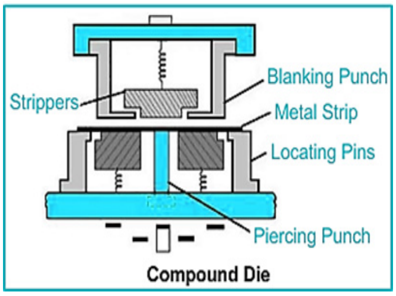
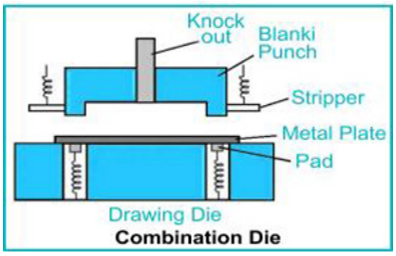
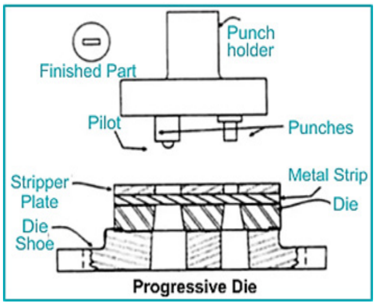
Dies and presses in sheet metal fabrication

In sheet metal fabrication, dies and presses are crucial components used for shaping and cutting metal sheets into specific forms.

Dies: Dies are specialised tools used in conjunction with presses to shape or cut metal. They are essential components in manufacturing processes, as they determine the final shape and features of metal parts. Dies are typically made from hardened steel and are precision-engineered to meet specific design requirements.

The different types of dies used in sheet metal operations are: simple die, compound die, progressive die, transfer die, combination die, multiple dies, round split die, adjustable die, die nut, die plate, pipe die, and acorn die.

Table 20.5: Different types of dies used in sheet metal operations

S/N	Type of Dies	Description of the Type of Dies	Picture of The Type of Dies
1	**Simple dies or single-action dies**	Simple dies or single-action dies perform a single operation for each stroke of the press slide. The operation may be one of the cutting or forming operations. Cutting dies are used to cut metal into specific shapes. Examples include blanking dies (which cut out flat pieces) and trimming dies (which remove excess material). Forming dies are used to bend or shape metal without cutting it. These include bending dies, drawing dies, and embossing dies.	 Simple Die
2	**Compound Die**	In this dies, two or more operations may be performed at one station. Such dies are considered as cutting tools since only cutting operations are carried out. In other words, it performs multiple operations, such as cutting and shaping, in one stroke. They are efficient for high-volume production	 Compound Die
3	**Combination Die**	In this die, more than one operation may be performed at one station. It is different from compound die in that in this die a cutting operation is combined with a bending or drawing operation due to that it is called combination die.	 Combination Die
4	**Progressive die**	A progressive die has a series of operations. At each station, an operation is performed on a work piece during a stroke of the press. It features a series of stations, each performing a different operation on a metal strip as it passes through the die. This process allows for the continuous production of parts.	 Progressive Die
5	**Multiple die**	A multiple die is used to perform more than one operation on a sheet metal piece in a single press stroke. For example, it can cut and shape the metal at the same time. This saves time and improves efficiency in making items like car parts or cans.	

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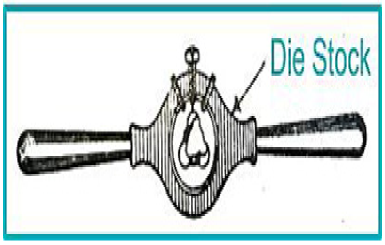
6	**Round Split die**	A round split die is a tool made of two halves that fit together to form a round shape. It is used to shape or form round objects, like pipes or metal rings. The split design allows the die to open and release the finished piece easily	
7	**Hexagonal die**	A hexagonal die is a tool used to cut or form external threads on rods, pipes, or bolts. It has a hexagonal shape, making it easy to hold with a wrench or die stock. This die is commonly used for threading because its shape allows better grip and control during the operation	
8	**Die Stock**	Commonly referred to as a die handle, this tool plays a crucial role in achieving the precision of a die, working in tandem with the die skids. The die skids are securely housed within the handle or the stock. Die handles come in various sizes to accommodate different die dimensions, and they are categorised into two main types: Adjustable Die Handles and Solid Die Handles.	

What are Presses?

Presses are machines used to shape or cut metal by applying pressure through a die. They are essential tools in manufacturing for producing a wide variety of metal parts and components. Types of presses for sheet metal working can be classified by one or a combination of characteristics, such as source of power, number of slides, type of frame and construction, type of drive and intended applications.

Table 20.6: Classification of Presses Based on Source of Power

S/N	Type of Press	Descriptions of Types of Press	Pictures of Presses
1	**Manual Presses**	These are either hand or foot operated through levers, screws or gears. A common press of this type is the arbour press used for assembly operations.	

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2	**Mechanical Presses**	These presses utilise flywheel energy which is transferred to the work piece by gears, cranks, eccentrics, or levers.	

Press Working Terminologies

Press working terminologies refer to the specifications and language used in the field of press working, which is a manufacturing process involving the shaping, cutting or forming of metal or other materials using presses.

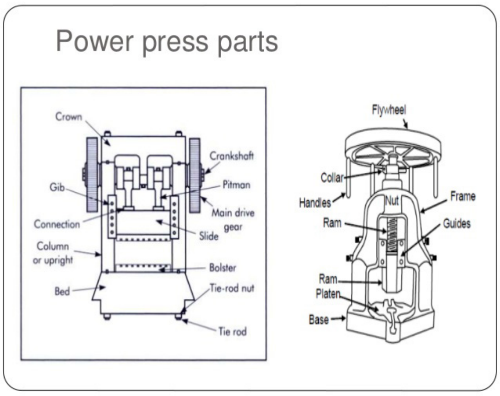
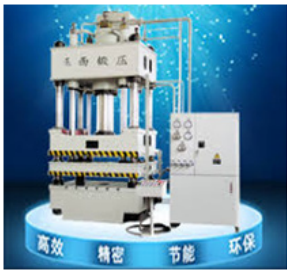


Figure 20.5: Press working Terminologies

Table 20.7: Types of Press

S/N	Type of Press	Description of Press	Picture of Type of Press
1	**Hydraulic Presses**	These presses provide working force through the application of fluid pressure on a piston by means of pumps, valves, intensifiers, and accumulators. These presses have better performance and reliability than mechanical presses.	
2	**Pneumatic Presses**	These presses use air cylinders to apply the required force. These are generally smaller in size and capacity than the hydraulic or mechanical presses, and therefore used for light-duty operations only.	

Table 20.8: Classification of Press, Based on Number of Slides

S/N	Class of Press	Description of Class of Press	Picture of Class
1	**Single-action Presses**	A single-action press has one reciprocation slide that carries the tool for the metal forming operation. The press has a fixed bed. It is the most widely used press for operations like blanking, coining, embossing, and drawing.	
2	**Double Action Presses**	A double action press has two slides moving in the same direction against a fixed bed. It is more suitable for drawing operations, especially deep drawing, than single action press.	
3	**Triple action Presses**	A triple action press has three slides, two of which are located above and one within the bed. Each ram performs a specific operation like drawing, trimming, or shaping, making it ideal for complex products like car body panels.	

Conclusion

This unit has covered the important operations of drawing, dies, and presses in sheet metal fabrication, which are essential for making a wide range of products, from car parts to household items. Students have learned about different types of drawing, such as shallow and deep drawing, and the various types of dies, including simple, compound, and combination dies, and how they are used to shape metal into accurate designs. The lesson also explained the use of mechanical and hydraulic presses, highlighting their advantages and applications in metal forming. Understanding these processes is important for producing high-quality, precise, and durable components in industries such as automotive, construction, and aerospace.

Activity 20.1

Brainstorming the various sheet metal operations

- Organise yourselves into groups of no more than 5 to perform all the following activities:
- Using sketches provided by your teacher or by researching on the internet, brainstorm the meanings of drawing, die and presses operations in sheet metal fabrication. Present your findings to the class.

Activity 20.2

Identifying and describing the various types of sheet metal operations

Identify and describe the various types of drawing, dies and presses in metal forming and sheet metal operations. Present your findings in a table form and share with the class for a discussion.

Activity 20.3

Demonstration of how to produce artefacts using sheet metal fabrication processes

- Your teacher will support you in undertaking the following task in the school workshop.
- Following all safety procedures and using real objects, tools and equipment, demonstrate how to produce artefacts using deep drawing, die and presses operation in sheet metal fabrication.

Table 20.9: Deep drawing - Use the following process for deep drawing

1	**Part Alignment**	Place the sheet metal blank inside the deep drawing die after the sheet metal blanking operation.
2	**Gripping**	Shank holder grips the sheet metal blank between the die and the shank holder with the required pressure.
3	**Drawing Operation**	Deep-drawing punch stretches the sheet metal blank inside the die. During this operation, reduce the shank holder pressure continuously to ensure the free movement of material. High shank holder pressure can cause wrinkles in sheet metal parts. Thinning is a common problem during stretching operations.
4	**Part Removal**	Remove the finished part from the die and send it for final finishing operations.

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Die operations - Use the following process for die operations.

- **Step 1 – Mould Design**

  The initial step in the die casting process is creating a mould called a die. This mould is usually made from steel or aluminium and is designed to withstand the high temperatures and pressures of the die casting process.

  The mould design begins with developing a CAD design of the required mould. This design is then used to create a mould by CNC machining, which is further used in the casting process.

- **Step 2 – Metal Preparation**

  The next step is to prepare the metal for injection. This metal is typically an alloy, such as aluminium, magnesium, or zinc. Melt the chosen metal in a furnace and then pour into a ladle.

- **Step 3 – Injection Process**

  Once the metal is in a liquid state, inject it into the desired mould under high pressure. The molten metal fills the mould cavity and cools to create the desired shape.

- **Step 4 – Casting Process**

  After the metal has cooled and hardened, open the mould, and the part is ejected. Ensure that the part has cooled entirely before handling to avoid any potential injuries.

- **Step 5 – Finishing Process**

  The final step in the process is to finish the part. Surface finishing plays a vital role in die casting, as it can impact the durability and function of the part. Standard finishing processes include anodizing, powder coating, wet plating, and many more.

Press operations - Use the following process for press operations.

Please note the creation of sheet metal in a school workshop is impractical and unsafe. Students will use prefabricated sheet metal for this activity.

1. **Obtain Pre-made Sheet Metal:** Instead of starting with an ingot, students will typically begin with pre-made sheets of metal. These sheets are readily available in various thicknesses and materials (like aluminium or mild steel).
2. **Cutting:** Use hand shears, tin snips, or a small bench-top guillotine, cut the sheet metal to the desired size and shape.
3. **Forming:**
   a. **Bending:** Using hand tools like hammers and mallets, or simple bending tools, students can form bends and curves in the sheet metal.
   b. **Punching:** Holes can be created using hand punches or a small punch press.

4. **Finishing:**
   a. **Smoothing:** The edges of the formed parts can be smoothed using files or abrasive paper.
   b. **De-burring:** Removing any sharp edges to ensure safety.

Activity 20.4

Visiting a local workshop to observe and demonstrate modern sheet metal operations

1. Your teacher will arrange a visit to a local welding and fabrication workshop to observe the die and press operations.
2. During the visit, you will be required to;
   a. Make sketches of tools and equipment used for sheet metal operations in the workshop
   b. Take pictures of some operations/ demonstrated at the workshop.
   c. Prepare sketch and photo albums and display in class for appraisal
   d. Prepare your visit report and discuss in class

Note:

a. *Observe the basic workshop safety during the visit*
b. *Wear your PPE at all times.*

EXTENDED READING

- Sprung vs Unsprung Weight: https://www.cjponyparts.com/resources/sprung-vs-unsprung-weight?srsltid=AfmBOooeOcmXNhCAJbrc0sdR-IdEfnXhePuZwBnflx9Mx_-i8paq8nDc
- 9 Car Suspension Components and Their Functions: https://wuling.id/en/blog/autotips/9-car-suspension-components-and-their-functions
- Leaf Spring Suspension: Diagram, Parts, Types, Uses: https://www.theengineerspost.com/leaf-spring-suspension/
- Air Springs and Suspensions: https://www.brakeandfrontend.com/air-springs-and-suspensions/
- Punches and dies https://msvs-dei.vlabs.ac.in/mem103/images/mem/Unit2/Lesson6n/2.jpg
- Sheet metal shearing machine https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9Gc-SiwpXLH4pimeUdeAitKhrcFZwofl6AjhiwcWZHlVYHF9bzMCIC
- https://gptcadoor.org/assets/downloads/81j4gdxcg415rw7.pdf
- Blanking: Sheet metal cutting operation https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTDEJ5zs5JAuRfe_RnRPQo8xh706_xyMpgTlw&s

- Sheet metal cutting using punching operation https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcT_NuvC8CnbPYGu8NTPTXfmn6bYFnl7ctiISQ&s
- Bending https://www.china-machining.com/blog/sheet-metal-bending/
- Deep drawing: https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQIT2uY9HZ0UJAKU-TpkDRschGgG9FTuk53ww&s
- https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQIT2uY9HZ0UJAKU-TpkDRschGgG9FTuk53ww&s
- Some products of deep drawing: https://image.slidesharecdn.com/deepdrawing-160725105005/75/Deep-drawing-11-2048.jpg
- Sheet metal deep drawing process https://www.precintl.com/wp-content/uploads/2021/05/Sheet-Metal-Deep-Drawing-picture-1024x343.jpg

Review Questions

Questions 5.1

1. Explain what is meant by sprung weight and unsprung weight.
2. Describe briefly the following basic suspension movements of a car and how they are related to the vehicle axis.
    a. Bouncing
    b. Rolling
    c. Pitching
    d. Yaw

Questions 5.2

1. In a workshop, a group of learners is learning about manufacturing processes. Their instructor introduces them to sheet metal, explaining its importance in industries like automotive, construction and appliances. The instructor demonstrated two essential operations: **bending** and **punching**. What is sheet metal and explain these two sheet metal operations.
2. Imagine a workshop is producing custom metal enclosures for electronic devices. The fabrication process involves cutting and bending a stainless-steel sheet to create the enclosure. Explain at least three operations each for cutting and bending in sheet metal fabrication.
3. A Refrigerator Engineer provides specifications for making a duct, including dimensions, air volume requirements, and the aluminium sheet. Describe the sequential process to follow to make a rectangular aluminium duct for use.
4. You are tasked with proposing and manufacturing a tray that will be used in a school cafeteria. The tray must be lightweight, durable, easy to clean, and economically designed for learners of all ages. It should also have apartments for different types of food. A galvanised steel plate of size 500mm x 500mm has been provided. Propose and describe the processes to follow to produce the tray.

Questions 5.3

1. Explain the functions of springs in the suspension system.
2. Explain factors that affect the stiffness of the springs.
3. Explain briefly how the following springs work:
    a. Leaf spring

   b. Coil springs
4. Describe briefly any two of the following:
   a. Torsion bar
   b. Air and gas spring
   c. Rubber springs
5. Compare the advantages and disadvantages of leaf and a coil spring.
6. Why is a leaf spring self-dumping and explain four factors that affect the stiffness of the leaf spring.

Questions 5.4

1. A factory needs to produce aluminium cans for packaging beverages. Explain the drawing operation in sheet metal fabrication.
2. Imagine you are designing two types of metal containers for a factory: shallow containers and deep container. Describe the difference between deep and shallow drawing in sheet metal fabrication.
3. A simple die is often employed in sheet metal fabrication for cutting, forming or bending metal sheets into desired shapes.
   a. Describe how a simple die is used in sheet metal fabrication
   b. State two advantages and two disadvantages of each of the Compound Die and Combination Die.
4. An automotive workshop is tasked with fabricating metal components for car doors. These components require precise shaping and punching from metal sheets. The shop is evaluating whether to use a mechanical press or a hydraulic press for the task. Develop a detailed report on comparing the features of mechanical and hydraulic press machines.

SECTION

6

VEHICLE SUSPENSION, WHEELS AND METAL FORMING PROCESSES III

AUTOMOTIVE TECHNOLOGY

Introduction to Vehicle Technology

Introduction

Suspension systems are fundamental to vehicle performance, safety, and comfort, ensuring stability and road adaptability. Rigid/beam axle suspension, characterised by a solid axle linking the wheels, provides durability and simplicity but compromises ride comfort and handling. In contrast, independent suspension system, where each wheel operates separately, enhances ride quality, stability, and road contact.

This unit explores the key features, advantages, and limitations of both systems, highlighting their roles in supporting different vehicle designs and performance requirements. By comparing these systems, you will gain insights into their impact on ride dynamics, maintenance demands, and suitability across various driving conditions.

KEY IDEAS

- Independent rear suspension reduces unsprung weight and improves handling.
- Independent suspension allows each wheel to move separately.
- Independent suspension improves comfort and vehicle control.
- Multi-link, double wishbone, and toe-control links are types of independent rear suspension.
- Rigid axle suspension is strong and handles heavy loads, but makes the ride less comfortable on uneven roads.
- Rigid suspension suits rough conditions, while independent suspension suits smooth and high-performance needs.

INDEPENDENT SUSPENSION SYSTEM

An independent suspension system allows each wheel on an axle to move vertically without affecting the other, resulting in a smoother ride and better handling. Unlike a solid axle that connects both wheels, an independent system is designed so that the movement of one wheel, such as hitting a bump, does not impact the other wheel on the same axle.

Types of Suspension System

Rigid/Beam axle suspension

In a rigid axle front suspension, the front wheels are connected by a solid axle. The wheels rotate on antifriction bearings that are mounted on the steering spindle. This spindle is part of the steering knuckle assembly, which allows the wheels to turn when the vehicle is being steered. To enable this turning motion, the steering spindle and knuckle assemblies are hinged at the ends of the axle. This rigid axle suspension is strong and durable, but it does not provide the best ride comfort because bumps on one wheel affect the wheel on the other side of the axle. This can make the ride bumpy and uncomfortable on uneven roads.

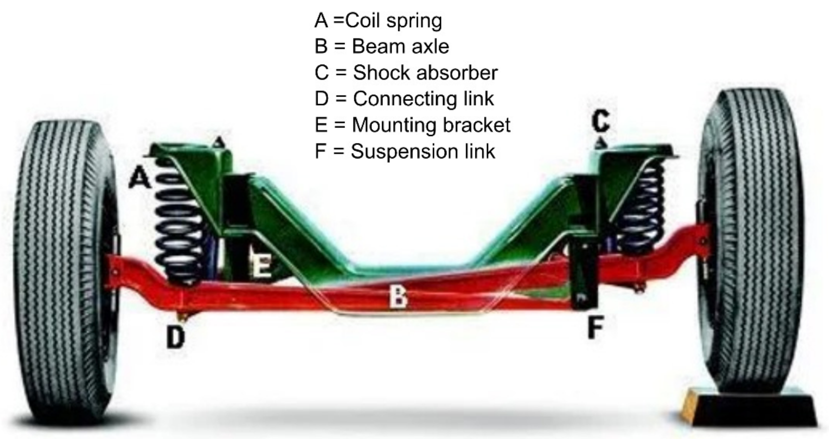

Figure 21.1: Dependent beam axle suspension system

Advantages of rigid axle suspension

1. Rigid axle suspensions are durable and can handle heavy loads and rough terrain.
2. They have a relatively simple design with fewer parts.
3. They are often less expensive to produce and maintain.
4. They provide better traction on uneven surfaces.

Disadvantages rigid axle suspension

1. Because the wheels are connected by a single, solid axle, when one of the wheels hits a bump, the shock is transferred to the other wheel, making the ride less comfortable.
2. They have high unsprung weight, which reduces ride comfort.
3. They offer poor vehicle handling, less precise control and stability.
4. Their size adds to the overall weight of the vehicle, which can negatively affect fuel efficiency.
5. They possess limited ability to absorb impacts and provide a smooth ride.

Independent suspension system

This term is used to describe any system used to connect the wheels to the frame in which the movement of one wheel has no effect on the other wheel. This type of suspension system employs a coil spring, a torsion bar or a semi-leaf spring at the front end to control the wheel's up and down movement. Independent suspension was developed to meet the demand for improved ride quality and control. An independent suspension system can be utilised in the suspension design at the front or rear of the vehicle, or both.

Independent Front Suspension (IFS)

In an independent front suspension system, each front wheel operates separately from the other. Each wheel is supported by its own spring mechanism. The coil spring is the most commonly used spring in independent front suspension. The wheels move independently of each other over bumps and dips, which improves ride comfort and handling. Because the wheels move independently, the car can maintain better contact with the road surface. Independent front suspension system was developed to meet the demand for improved ride quality and control.

Figure 21.2: Independent suspension system.

Types of Independent front suspension systems

Independent front suspension systems mostly employ one of the following mechanisms, to attach the front wheel to the vehicle's frame:

1. Double-wishbone arm system
2. Trailing arm system
3. Macpherson strut system

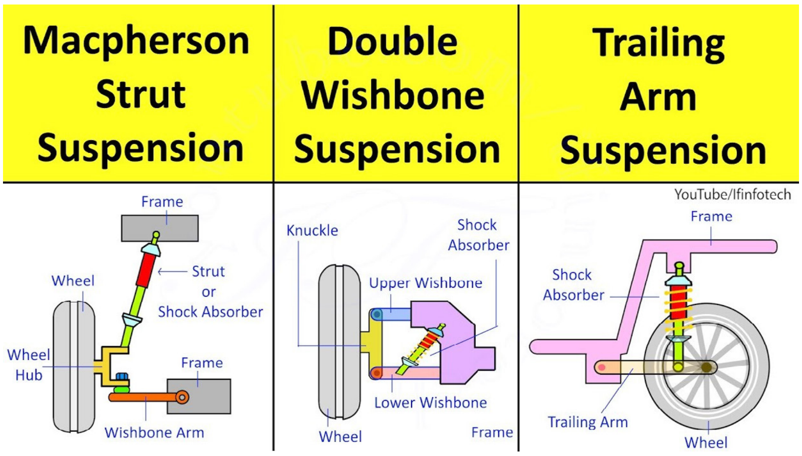

Figure 21.3: Types of Independent front suspension systems

Double-wishbone arm system

The double wishbone suspension, also known as the parallelogram suspension, uses two arms to connect the wheel to the vehicle's frame, creating a parallelogram shape. These two arms, an upper and a lower one, allow for better control over wheel movement and alignment. This design helps maintain consistent tyre contact with the road, improving handling and stability. It also allows for a smoother ride by minimising the impact of road irregularities.

Figure 21.4: Double-wishbone arm linkage

Trailing arm system

The trailing arm suspension uses arms that are mounted to the vehicle's frame at one end and the wheel hub at the other. These arms allow the wheels to move up and down independently, providing better ride comfort. It offers a simple, robust design that balances handling and comfort. The coil springs and dampers are mounted between the trailing arms and the vehicle body.

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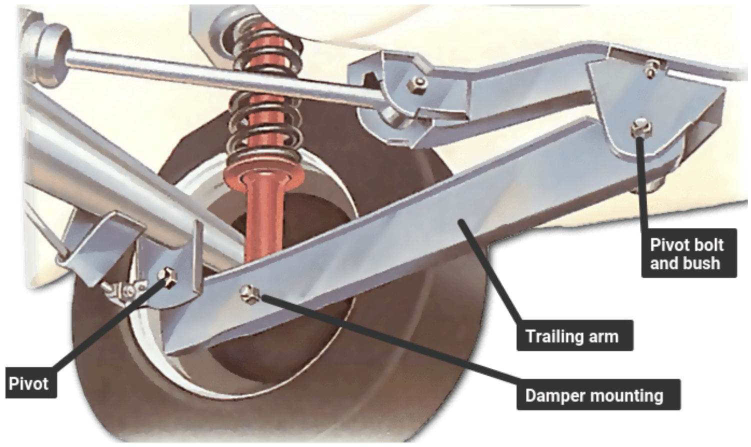

Figure 21.5: Trailing arm linkage

Macpherson strut system

The MacPherson strut independent front suspension system is a widely used design due to its simplicity and efficiency. It combines a shock absorber and a coil spring into a single unit, mounted vertically between the wheel hub and the car's body. The lower control arm connects the wheel hub to the chassis, allowing for controlled vertical movement.

In a typical application, it is positively attached at the top to a body structure and positively attached at the bottom to the knuckle. It is designed to support vertically applied suspension loads and rotate on the upper bearing with the wheel during vehicle steering.

Figure 21.6: Macpherson strut linkage

Advantages of Independent Front Suspension (IFS) systems

1. They possess improved ride comfort
2. Each wheel has better contact with the road surface in all driving conditions.
3. There is a reduction in the unsprung weight of the vehicle
4. They can be adapted for a wide range of vehicles.
5. They offer **improved** traction and stability.

Disadvantages of independent front suspension (IFS)

1. They have a **complex** design and construction.
2. The more intricate design can be less durable under heavy loads or extreme conditions.
3. The increased number of components and complexity make them more expensive to produce and maintain.
4. Improper alignment settings can lead to uneven tyre wear and poor control.

Independent rear suspension (IRS) system

Similar to the front counterpart, the independent rear suspension system allows each rear wheel to move independently of the other. This design contributes to a reduction in the unsprung weight in rear-wheel drives, where the differential unit and brake assembly are mounted on the rear axle. This actively improves ride comfort, handling, and stability of the vehicle on the road.

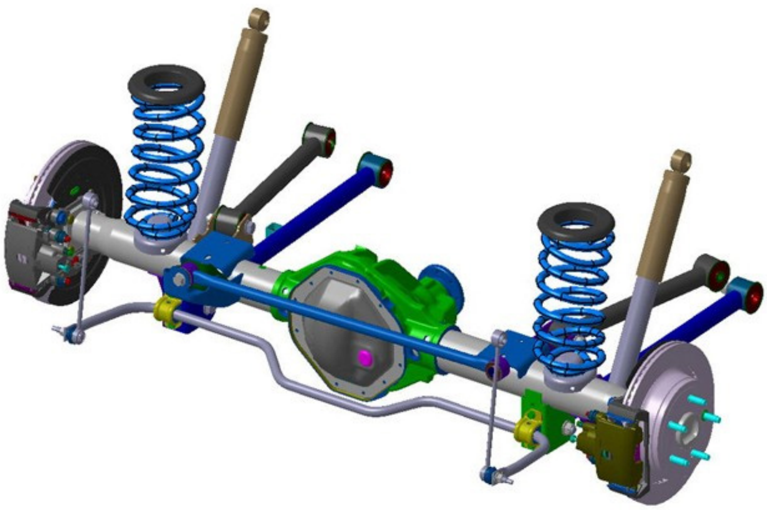

Figure 21.7: Independent rear suspension system

Key Features of Independent Rear Suspension

a. **Independent Wheel Movement**: Each rear wheel can move up and down independently of the other, allowing for better absorption of road irregularities and a smoother ride.

b. **Improved Handling**: By allowing each wheel to maintain better contact with the road, independent rear suspension enhances vehicle handling, especially during cornering and on uneven surfaces.

c. **Reduced Unsprung Weight**: This design reduces the weight of the components that are not supported by the springs (un-sprung weight), improving ride quality and responsiveness.

d. **Enhanced Stability**: The ability to control wheel movement individually provides improved traction and stability, contributing to safer driving conditions.

e. **Complex Linkage System**: Typically includes a combination of control arms, links, and joints to provide precise control over wheel motion and alignment.

f. **Versatile Design**: Can be adapted and tuned to suit different vehicle types and performance requirements, from compact cars to high-performance sports vehicles.

g. **Camber and Toe Control**: Many independent systems allow for better control over camber (the tilt of the wheels) and toe (the direction the wheels are pointing), leading to better tyre wear and handling characteristics.

h. **Comfort and Performance Balance**: Provides a balance between ride comfort and handling performance, making it suitable for a wide range of driving conditions and vehicle designs.

Types of Independent rear suspension systems

1. Multi-link suspension

The multi-link suspension employs multiple arms (usually four or five) to control wheel movement, offering flexibility in tuning for both ride comfort and handling. This type of suspension provides superior handling and ride comfort with precise control over wheel motion. It is widely used in modern cars, including sedans, sports cars, and some SUVs.

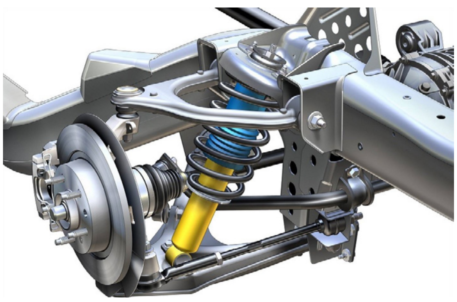

Figure 21.8: Multi-link suspension

2. Double wishbone suspension

The double wishbone suspension uses upper and lower control arms to allow the wheel to move vertically while maintaining optimal alignment. This setup provides excellent handling, better camber control, and a smooth ride. It is commonly found in high-performance cars and some luxury vehicles.

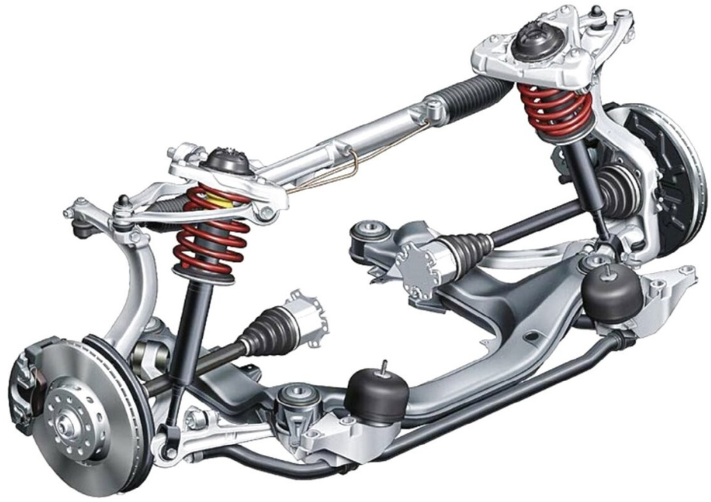

Figure 21.9: double wishbone suspension

3. MacPherson strut suspension

The MacPherson strut suspension, similar to its front design, combines a shock absorber and a coil spring into a single unit, adapted for rear suspension. This setup is space-efficient and cost-effective, suitable for smaller and mid-sized vehicles, though it is less commonly used in rear applications compared to front.

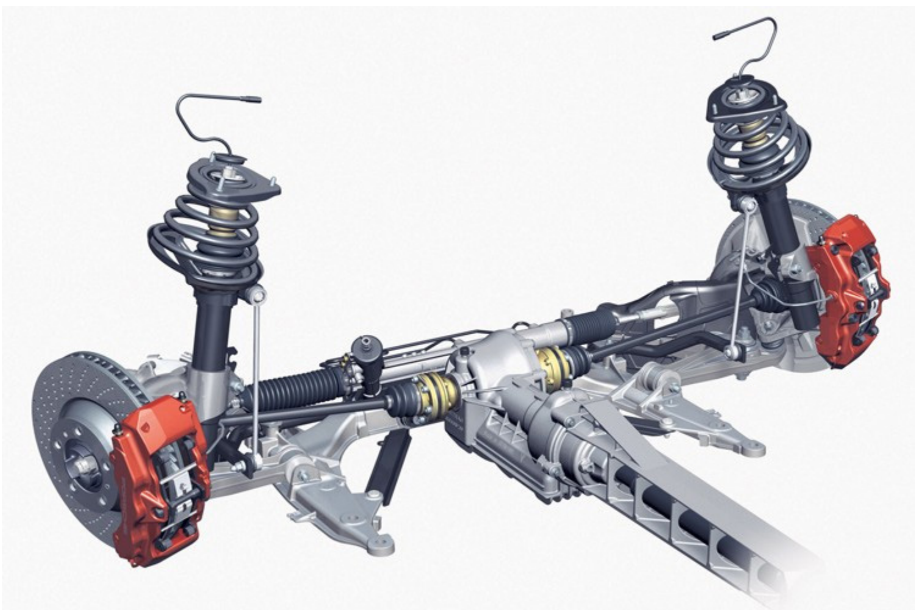

Figure. 21.10: MacPherson strut suspension

4. Toe-control link suspension

This is a type of independent rear suspension that uses lateral links to control the toe angle of the wheels. These links help maintain proper wheel alignment as the suspension moves up and down, ensuring better handling and tyre wear. The toe-control links are adjustable, allowing mechanics to fine-tune the wheel alignment for optimal performance. This type of suspension is often found in vehicles that require precise handling and stability, such as sports cars and performance-oriented. models.

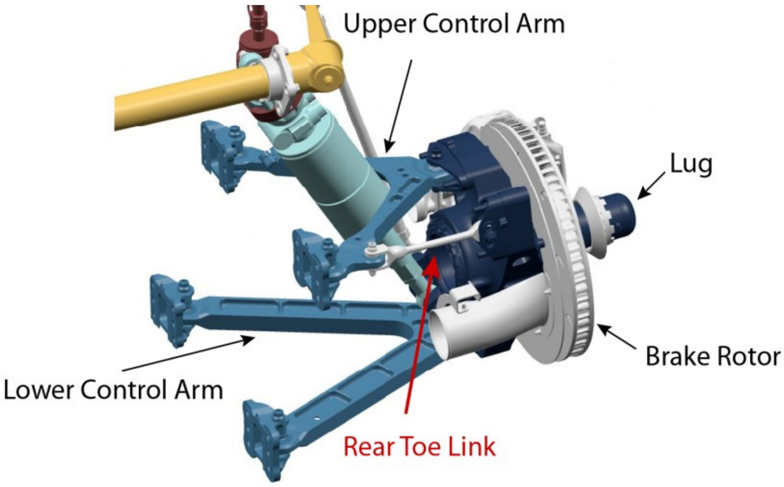

Figure 21.11: Toe-control link suspension.

5. Trailing arm suspension

In the trailing arm suspension, each wheel is mounted on a trailing arm that pivots at one end, allowing the wheel to move up and down. This simple and robust design balances ride comfort and handling, making it often used in the rear suspension of smaller vehicles and some SUVs.

Figure 21.12: Trailing arm suspension

6. The double wishbone multi-link combination

The Double Wishbone Multi-Link Combination Suspension is a hybrid suspension system that merges the upper and lower control arms of a double wishbone design with the additional links of a multi-link system. This combination allows for precise control of wheel movement and alignment, providing superior handling and ride comfort. By maintaining optimal camber and toe angles, it ensures better tyre contact with the road and improved stability. Commonly used in high-performance and luxury vehicles, this suspension type offers a balanced approach, enhancing both driving dynamics and overall ride quality.

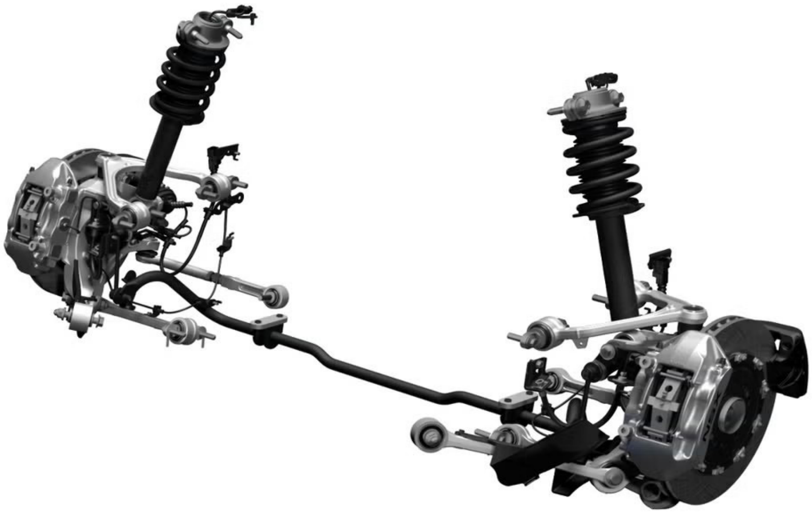

Figure 21.13: The double wishbone multi-link combination

Advantages of the Independent Rear Suspension System

1. Each rear wheel moves independently, allowing the suspension to absorb bumps and road irregularities more effectively, providing a smoother and more comfortable ride.
2. Independent rear suspensions maintain better contact with the road during cornering and uneven surfaces, leading to improved vehicle handling and stability.
3. By not having a solid axle connecting the wheels, the unsprung weight is reduced, which enhances ride quality and responsiveness.
4. Improved traction and stability result from the wheels' ability to move independently, maintaining optimal contact with the road surface.
5. Various types of independent rear suspension systems can be tailored for different vehicles and performance needs, from luxury sedans to high-performance sports cars.

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Disadvantages of the Independent Rear Suspension System

1. The design and construction of independent rear suspensions are more complex compared to solid axles, leading to higher manufacturing and maintenance costs.
2. The more intricate design may be less durable under heavy loads or extreme driving conditions compared to simpler, more robust systems.
3. The complexity and increased number of components can make independent rear suspension systems more expensive to produce and repair.
4. They require precise alignment settings, since improper alignment can result in uneven tyre wear and compromised handling.
5. The increased number of moving parts and joints can lead to more frequent wear and tear, requiring regular maintenance to ensure optimal performance.

Activity 21.1

Independent suspension system

Organise yourselves into groups of no more than 5.

1. **Watch the following video:** [Independent suspension system (https://www.youtube.com/watch?v=J9gELaeVTmQ)](https://www.youtube.com/watch?v=J9gELaeVTmQ), or search the internet for other videos or images on the independent suspension system.

2. Prepare neat sketches of the MacPherson strut assembly and describe how it differs from the double wishbone suspension.
3. Describe the features of the MacPherson strut assembly of independent front suspension and how it differs from double wishbone suspension.
4. Briefly explain the design and operation of the different types of independent suspension systems.
5. Share your findings with other group members and, together, compare three advantages and disadvantages of MacPherson strut and double wishbone independent front suspension systems.
6. Discuss the advantages of independent suspension over dependent suspension systems.

Activity 21.2

Comparative analysis of independent and dependent suspension systems

Your teacher will arrange for you to visit the school auto workshop and assign your group a particular vehicle to be used for this activity.

Conduct a comparative analysis of independent suspension systems and dependent suspension systems on a given vehicle and evaluate the impact of each system on vehicle performance, safety, and maintenance.

Materials needed

- A real vehicle
- Writing pad/tools
- Internet resources

CAUTION: Do not use any tool on the vehicle provided without guidance.

Wear appropriate PPE and observe safety rules.

Activity Steps

Use the template below as a guide.

Criteria	Independent suspension	Dependent suspension
Definition		
Design and construction		
Manufacturing complexity		
Durability of parts		
Ride control		
Load capacity		
Handling		
Safety		
Stability		
Response to road conditions		
Performance in off-road conditions		
Maintenance		
Common applications		
Environmental impact		
User feedback		

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1. Examine the parts of the vehicle provided to draw comparisons between independent and dependent suspension systems.
2. Use the internet to search for information that cannot be obtained directly from the vehicle.
3. Write a summary for each suspension type, emphasising their strengths and weaknesses.
4. Share your findings with the larger class.

UNIT 22

METAL TECHNOLOGY

Welding Technology

Introduction

The sequence of operations, or design process, in making artefacts is an important part of engineering and manufacturing because it helps develop solutions to problems, create new products, and improve existing ones used in everyday life. This lesson introduces the main steps involved in the design process, guiding students from identifying a problem to producing a final artefact. Students will learn about the key concepts of analysing problems, planning, designing, prototyping, testing, and final production. After studying this lesson, students should be able to explain the importance of the design process, describe the sequence of operations involved, apply the steps to create or improve artefacts, and understand how iterative design helps produce effective and functional products.

KEY IDEAS

- Recognising and clearly defining the problem or need that the artefact will address.
- Gathering information, exploring possible solutions, and deciding on materials, tools, and methods.
- Creating drawings, models, or diagrams to visualise the artefact and plan its construction.
- Building a model of the artefact and testing it to identify improvements or issues.
- Producing the finished artefact, checking for quality and functionality.

SEQUENCE OF OPERATIONS IN MAKING ARTEFACTS

In engineering, designing is a systematic and iterative process used to develop solutions to identified problems, generate new products/artefacts, or improve on existing ones. This process involves a series of steps that guide engineers from the initial identification of a need or problem to the final execution of a solution. Among the fundamental elements of the design process are the identification of the problem, statement of design brief, analysis of the problem, researching into the problem, writing the specifications, developing the possible and final solutions, preparing the cutting list, planning the workshop for making the artefacts, testing and evaluating the made artefacts for modifications. Mechanical design, therefore, means the design of components and systems of mechanical-related components, instruments, devices, tools, equipment, machines, products and structures.

Stages of The Design Process

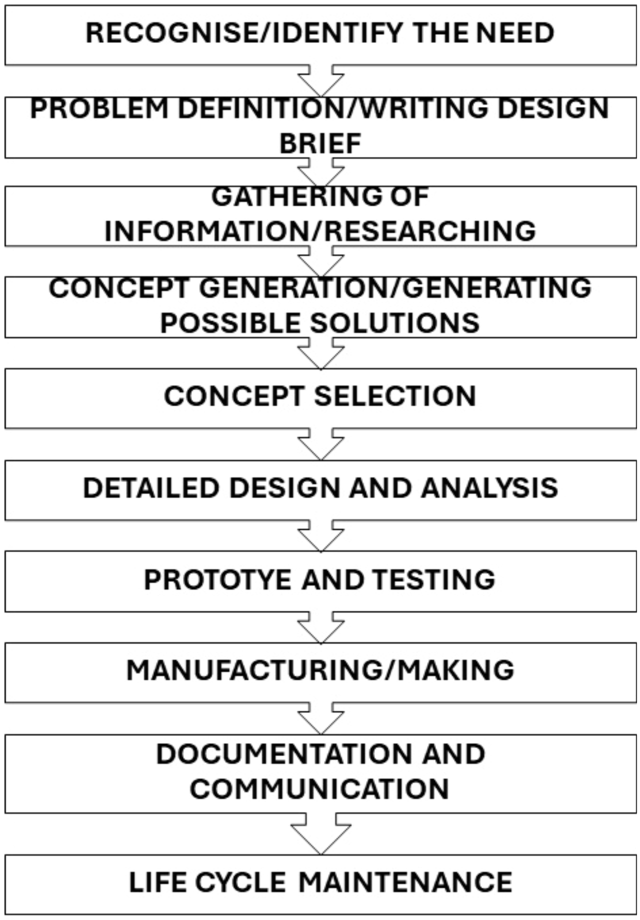

Figure 22.1: Flow Chart of Key Stages of Basic Engineering Design Process

The Stages of the Engineering Design Process Explained

1. **Recognising/Identifying the Need**: Recognising or identifying the need is the first stage of the design process. This stage involves identifying a problem or opportunity that requires a solution or improvement. Understanding and defining the need provides the basis for all subsequent stages in the design process.

2. **Problem Definition or Design Brief**: This is one of the most critical stages of the design process. This is the stage where the problem is briefly defined. It is the stage where the designer intends to define what he/she wants to design and make.

3. **Gathering of Information**: This is the stage where relevant data needed to solve the problem is gathered based on analysis factors. At this stage the designer studies existing solutions to understand the market and technical constraints. The sources of information gathered are in two forms; primary or secondary.
   a. **Primary sources**: Interviewing people (learners, parents, technical personnel, engineers etc.)
   b. **Secondary sources**: Using textbooks, trade journals and magazines, technical reports from government sponsored research and development, company catalogues, websites, handbooks and company reports.
4. **Concept Generation or Possible Solutions**: The concept generation is a critical stage of the design process, where ideas are generated to address the design problem. It involves creativity, exploration and systematic methods to ensure a broad range of potential ideas for solving the problem. Annotated notes are used to describe each idea from which the best solution is selected.

Key approaches required for the concept generation are as follows:

a. **Adaptation:** This is where a solution to a problem in one field is applied to a similar problem in another field
b. **Area thinking**: This is to improve an existing product by concentrating on one of its important characteristics (cost, performance, function, appearance, safety, etc.).
c. **Brainstorming:** This is where a group of people who are familiar with the general nature of the problem gather and during this time, everyone says what comes to his or her mind. Brainstorming sessions are organised with diverse team members to generate a broad range of ideas. They encourage free thinking and avoid criticism to foster a creative environment. Use techniques such as mind mapping, sketching, and listing to arouse idea generation.
d. **Concept Selection**: This is the stage where the various ideas or solutions generated during the concept generation stage are evaluated and compared to identify the most promising ones for further development. This process is crucial because it helps to narrow down a broad range of potential concepts to those that best meet the project's requirements, and constraints.

6. **Detailed Design/Drawing and Analysis:** This stage draws the chosen design including all the details that are important to its construction. Detailed or working drawings are essential components of the engineering design process, serving as the definitive guides for manufacturing and assembling a product. These drawings provide precise specifications and instructions needed to transform a design concept into a physical object.

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f. **Prototype Development and Testing**: Prototype development and testing are crucial stages in the engineering design process, where initial design concepts are transformed into tangible models to evaluate their feasibility, functionality, and performance. In short, it is a stage of making the miniature product. In industries, a pilot model is usually built first and the final product is developed from it, but in most classrooms, the model is the final product. Testing is on-going as the construction progresses, but a final test of the entire system or model proves if the project does the job for which it is designed.

g. **Manufacturing/Construction/Making**: Manufacturing is a crucial stage in the engineering design process, where the designs and plans created in earlier stages are transformed into physical products. This stage involves several key steps to ensuring that the product is produced efficiently, cost-effectively, and with high quality.

h. **Documentation and Communication:** Maintain detailed records of the design process and communicate findings and results to stakeholders.

i. **Life Cycle Maintenance**: Life cycle maintenance in the engineering design process involves planning and implementing strategies to ensure that a product remains functional, reliable, and efficient throughout its entire life span. This includes all activities related to the upkeep, repair, and eventual disposal or recycling of the product.

Example 6.22.1

In the school workshop, hand tools are scattered on the floor, posing dangers to the workshop users. You have therefore been tasked to design and make a custom metal toolbox following each step in the design process and fabrication skills.

Project Title: Make a Custom Metal Toolbox

Follow the steps below to realise the unit:

1. Define the Problem

a. **Problem Statement**: Design and fabricate a durable, portable metal toolbox for carrying hand tools.

b. **Specifications**: The unit should be:

- sturdy/durable
- easy to carry,
- efficiently organises tools,
- must be made from available metal sheets in the workshop,
- cost less than Gh¢300.00 to produce
- fit tools up to 600mm × 250mm × 200mm in size.

2. Research and Information Gathering

a. **Material Properties**: Investigate metals like steel and aluminium for their strength, weight and corrosion resistance.

b. **Existing Products**: Analyse commercial toolboxes for size, shape, and compartment design.

c. **User Needs**: Survey peers or professionals to understand their toolbox preferences and needs.

3. Conceptualisation

a. **Brainstorming:** Generate ideas for different toolbox shapes and compartment layouts, such as trays, drawers, or modular sections.

b. **Initial Sketches**: Generate sketches of potential designs, showing different compartment arrangements and handle placements.

c. **Features:** Decide on key features like a lockable lid, fold-out trays, or a detachable shoulder strap.

4. Concept Evaluation and Selection

a. **Evaluation Criteria**: Rate designs based on durability, ease of fabrication, weight, and tool organisation.

b. **Select Concept**: Choose the design that best balances all criteria, such as a rectangular box with a top handle and two internal trays.

5. Detailed Design

a. **Technical Drawings**: Make detailed drawings with precise measurements and specifications using CAD software when possible.

b. **Material Selection**: Finalise metal choice, considering cost, workability, and durability. You can select lightweight aluminium for portability.

c. **Manufacturing**: Ensure the design can be easily cut, bent and assembled with available tools such as shears/snips and folding bar.

6. Prototyping

a. **Make Prototype**: Use metalworking tools to cut, shape, and assemble a prototype of the toolbox. Observe the basic safety precautions.

b. **Testing:** Test the prototype for functionality, such as checking compartment sizes, handle strength, and overall weight.

c. **Feedback**: Gather feedback from potential users on the design's functionality and aesthetics.

7. Implementation

a. **Finalise Design**: Incorporate feedback and make necessary adjustments to the design.

b. **Production Plan**: Develop a step-by-step manufacturing plan, including cutting, bending, welding, and finishing processes.

c. **Begin Production**: Start small-scale production, ensuring quality control in each step.

8. Evaluation and Optimisations

a. **Performance Monitoring**: Use the toolbox in real-world situations to assess durability, ease of use, and tool organisation.

b. **User Feedback**: Continue to gather feedback to identify any areas for improvement.

c. **Modifications:** Make design or process adjustments, such as reinforcing weak points or improving the handle design to ease handling.

9. Documentation and Communication

a. **Maintain Records**: Document all stages of the design and fabrication process, including materials used, techniques, and design changes.

b. **Presentation**: Prepare a presentation or report, summarising the project, highlighting design decisions and key lessons.

10. End-of-Life Considerations

a. **Recycling Plan**: Design the toolbox for easy dismantling and recycling of materials at the end of its life.

b. **Lifecycle Assessment**: Reflect on the environmental impact of material choices and explore sustainable alternatives.

Example 6.22.2

1. A simple model of a design process is shown. List any two important points which should be considered at the "materials selection" stage.
2. List two important points to be considered at the ""evaluation" stage.

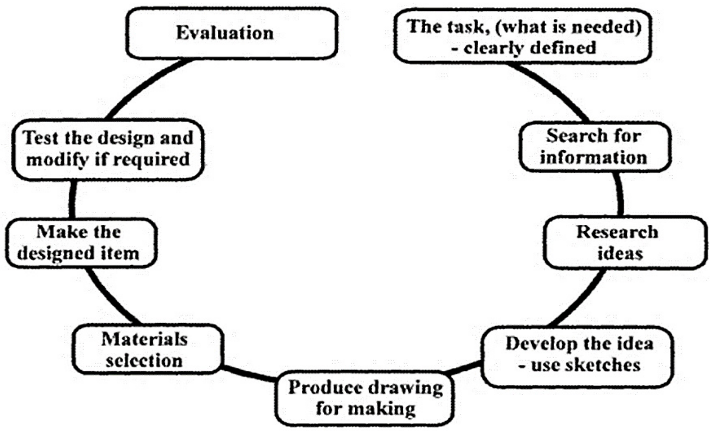

Figure 22.2: A simple Model of Basic Engineering Design Process

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Solution

During the "materials selection" stage of the design process, it is important to consider various factors to ensure that the chosen materials will meet the design requirements and constraints. The two important points to consider are:

1. **Material Properties**:
    a. **Mechanical Properties**: Consider properties such as strength, durability, hardness, and toughness to ensure the material can withstand the expected loads and stresses.
    b. **Thermal Properties**: Assess the material's ability to withstand temperature variations, including thermal expansion, conductivity, and resistance to heat.
    c. **Electrical Properties**: For applications involving electrical components, consider conductivity, resistivity, and dielectric strength.
    d. **Chemical Resistance**: Evaluate the material's resistance to corrosion, oxidation, and chemical degradation, especially if it will be exposed to harsh environments.
2. **Cost and Availability:**
    a. **Material Cost**: Analyse the cost-effectiveness of the material in relation to the project budget, considering both the initial purchase price and any long-term maintenance costs.
    b. **Availability**: Ensure that the material is readily available and can be sourced in the required quantities within the project timeline.
    c. **Manufacturing:** Consider how easily the material can be processed, shaped, and finished using available manufacturing techniques, tools and equipment, as well as any associated costs.

At the "evaluation" stage of the engineering design process, it is important to assess the performance and feasibility of the design solution. The two important points to consider during this stage are:

3. **Performance Testing and Validation:**
    a. **Functional Testing:** Verify that the design meets all specified requirements and performs its intended functions under expected operating conditions. This includes checking for reliability, efficiency, and durability.
    b. **Compliance and Standards:** Ensure that the design adheres to relevant industry standards, regulations, and safety guidelines. This might involve testing for safety, environmental impact, and quality assurance to ensure that the design complies with all necessary criteria.
4. **User Feedback:**
    a. **User Experience Evaluation:** Gather feedback from end-users or stakeholders to assess how well the design meets their needs and

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expectations. Consider factors like usability, ergonomics, and overall satisfaction.

b. **Improvement:** Use the insights gained from testing and feedback to make necessary refinements and optimisations to the design. This process can help address any identified shortcomings and enhance the product's performance and user satisfaction.

Conclusion

The basic engineering design process is iterative and flexible, encouraging constant refinement of ideas to meet specific requirements. It emphasises a methodical approach that integrates creativity with technical expertise.

Through stages like conceptualisation, prototyping, and testing, engineers can innovate while ensuring practicality and efficiency. The process encourages learning from failure and refining designs, ultimately leading to better, more effective artefacts. understanding these stages is essential for developing the problem-solving skills needed to create functional, innovative products.

Activity 22.1

Explanation of the design process

Organise yourselves into groups of no more than 5 to undertake the following activities:

1. In your groups, discuss and explain the design process. Then discuss the sequence of operations in making artefacts (you can select any one). You can consolidate your discussion and findings in a flow chart or table.
2. Once you have decided upon your artefact identify at least one design problem with it and how it can be overcome

Activity 22.2

Extension activity – field trip

1. Your teacher will arrange a visit to an engineering workshop to observe how artifacts are made following the design process
2. Prepare or take pictures of charts showing the design process and display in class for appraisal
3. Write a visit report and discuss in class.

Note:

a. *Observe the basic safety precautions during the visit*

b. *Wear your Personal Protective Equipment (PPE)*

UNIT 23

AUTOMOTIVE TECHNOLOGY

Introduction to Vehicle Technology

Introduction

Wheels and tyres are essential components of every vehicle because they support the weight of the vehicle, allow movement, provide traction, and ensure safety and comfort while driving. Understanding wheels and tyres is important for vehicle performance, handling, and maintenance. This lesson will introduce students to the basic functions of wheels and tyres, the different types of wheels such as steel, alloy, spoked, and cast wheels, and the various types of tyres including tubed, tubeless, bias-ply, radial, all-season, and performance tyres. Students will also learn how each type is used and its advantages in different driving conditions. After studying this lesson, students should be able to explain the purpose of wheels and tyres, identify and describe the different types of wheels and tyres, understand their features and applications, and recognise how they affect vehicle performance and safety.

KEY IDEAS

- Balancing wheels reduce vibrations, enhance safety, and prolong the lifespan of tyres.
- Essential information about tyres, including size, load capacity, and speed rating, is indicated on the sidewall.
- Tyres provide traction, absorb shocks, and assist in braking.
- Wheels enable vehicle movement and support weight, while rims secure tyres on the wheel.

WHEELS AND TYRES

Wheels

A wheel is a circular component that is designed to rotate on an axle and is used to facilitate movement or transportation. It is one of the fundamental components of machinery and vehicles, allowing for the efficient transfer of weight and motion. Wheels can be found in a variety of applications, from automobiles and bicycles to industrial machines and everyday items like office chairs and luggage. They play a crucial role in reducing friction and enabling smooth movement across surfaces.

Basic requirements of wheels

The basic requirements of wheels, especially in the context of vehicles and machinery, are as follows:

1. Wheels must be made of strong materials that can withstand the stresses of weight, impact, and wear over time.
2. They must be able to support the weight of the vehicle and its cargo, ensuring safe and efficient movement without risk of collapse or deformation.
3. It must provide adequate grip with the tyre to prevent slipping, especially during acceleration, braking and cornering.
4. They must be balanced to prevent vibrations and ensure smooth operation.
5. They should be easy to remove and mount.
6. They must be compatible with the vehicle's specifications to ensure proper fitment and performance.
7. They should be designed to effectively dissipate heat generated by braking and friction to prevent overheating.
8. They should be as light as possible to minimise the unsprung weight.
9. Their design must contribute to the overall beauty of the vehicle.

Types of Wheels

The three main types of car wheels are:

1. Pressed steel disc wheels
2. Spoke or wire wheels
3. light alloy wheels

Pressed steel disc wheels

Pressed steel wheels are robust and affordable, made by stamping sheet steel. They are durable and cost-effective, but heavier, which can affect fuel efficiency and handling.

Figure 23.1: A pressed steel wheel

Advantages of pressed steel wheels

1. They are simple in construction and easy to produce.
2. They are strong and capable of withstanding impacts and rough conditions.
3. They are cheaper to produce and repair.
4. They are easy to clean.

Disadvantages of pressed steel wheels

1. They are relatively heavy, which negatively impacts fuel efficiency and control.
2. They are less attractive than and thus require decorative wheel caps to beautify them.
3. They can easily corrode if not properly maintained.

Spoke or Wire Wheels

Spoke wheels, featuring a central hub connected to the rim by spokes, offer a classic look and light weight. They provide flexibility and a smooth ride but require regular maintenance for optimal performance.

Figure 23.2: A spoke wheel.

Advantages of spoke or wire wheels

1. They are lightweight, which improves vehicle performance and handling.
2. They offer a very attractive and elegant look.
3. They are fairly strong in construction.
4. There is better cooling of brake assembly due to improved air circulation.
5. They are easy to remove since only one nut is used in securing the wheel.

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Disadvantages of spoke or wire wheels

1. They require regular inspection and tightening of spokes.
2. They cannot be used with tubeless tyres.
3. They are generally expensive due to their intricate construction.
4. They cannot sustain compressive and bending stresses.
5. Damaged spokes are difficult and time-consuming to repair.

Light Alloy Wheels

Light alloy wheels, made from aluminium or magnesium, are lighter than steel, improving performance and fuel efficiency. They offer better heat dissipation and come in various designs, though they can be more expensive and susceptible to cosmetic damage.

Figure 23.3: A light alloy wheel

Advantages of light alloy wheels

1. **Their low weight** enhances performance, handling, and fuel efficiency.
2. **They have b**etter heat-dissipating properties.
3. They are available in numerous designs and finishes.

Disadvantages of light alloy wheels

1. They are more expensive than steel wheels.
2. They are prone to scratches and curb damage.
3. They may crack under severe impact or harsh conditions.

Rims

The rim is the outer edge of the wheel, specifically designed to hold and support the tyre. The rim provides the following functions:

1. It ensures a seal for the air in tubeless tyres.
2. It transfers forces from the tyre to the wheel or vice versa without the tyre slipping or rotating on the wheel.

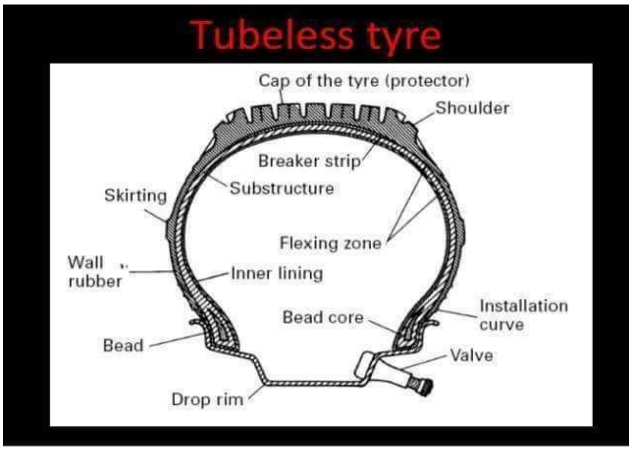

Figure 23.4: Features of a tyre and rim assembly

Types of wheel rims

The common types of wheel rims include:

1. Well-base rims
2. Flat-base three-piece rims
3. Semi-drop centre rims
4. Flat-based divided rims

Well-base rims

Well-base rims, often referred to as drop-centre rims, are a widely used wheel rim design in modern vehicles. They feature a unique profile with a deep central section, or well, flanked by raised outer edges. This design simplifies tyre mounting and removal by providing space for the tyre bead to sit in the well, creating the necessary slack for easier handling.

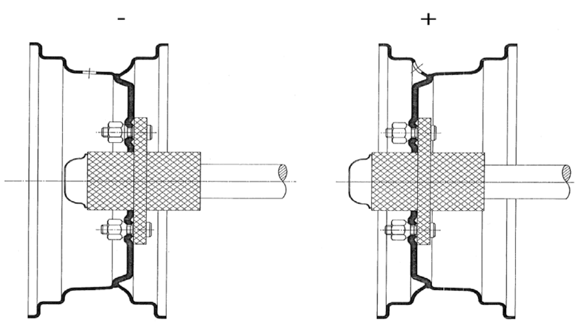

Figure 23.5: A well-base rim

Flat-base three-piece rims

Flat-base rims are composed of three distinct parts: the outer lip (or barrel), the inner barrel, and the centre piece (or face). These components are secured together with bolts, allowing for convenient assembly and disassembly.

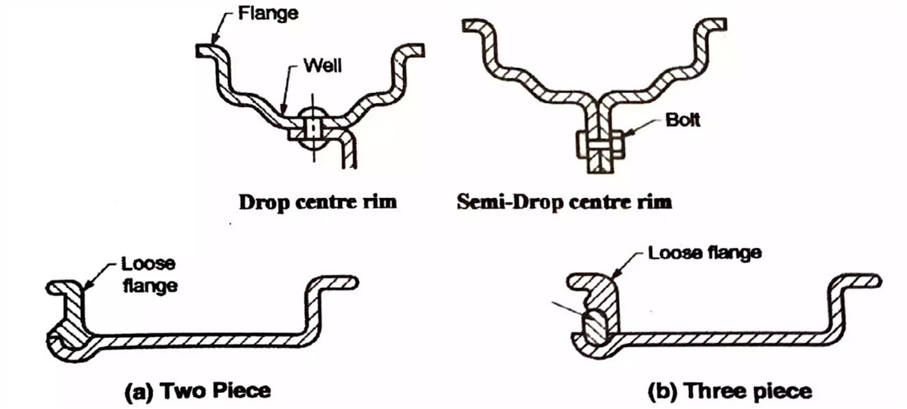

Figure 23.6: Flat-base rims

Semi-drop centre rims

Semi-drop centre rims are a wheel rim design that combines features of both flat-base and well-base rims. They are commonly found on commercial vehicles, heavy-duty trucks, and buses.

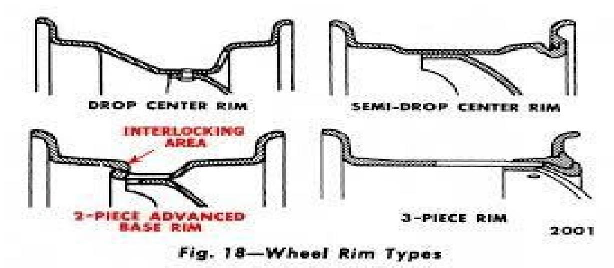

Figure 23.7: A semi-drop centre rim

Flat-based divided rims

Flat-based divided type rims, also called split rims or multi-piece rims, are designed primarily for heavy-duty applications like trucks, buses, and certain industrial vehicles. Their defining feature is a construction that allows them to be disassembled into separate components.

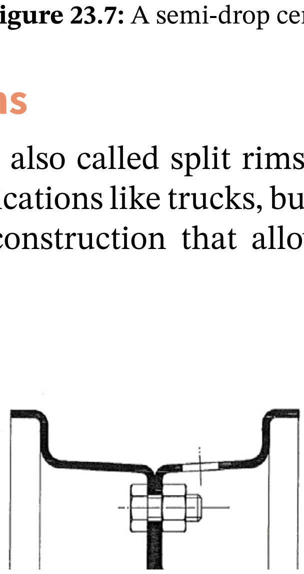

Figure 23.8: A divided rim

Activity 23.1

Specifying wheels and rims

Materials needed

- Samples of wheels or their images
- Sketch pad/pencil/pen

Activity Steps

Organise yourselves into groups of no more than 5 and complete the following.

1. In your activity group, examine different types of vehicles with different wheels. You may collect unused wheels from the community for closer observation.
2. Examine the various rim types used on each wheel your group has selected.
3. Make sketches of the wheels. You may search the internet and other materials for the unique features of the three-wheel types.
4. Write a description of each wheel type.
5. Discuss and note down the advantages and disadvantages of each wheel type. Share your group's findings with other groups.

Tyres

The tyre is a pneumatically inflated component that encases the wheel rim, transferring the vehicle's load to the ground. It acts as a flexible cushion, absorbing shocks and providing traction on the road surface.

Tyres play an important role in the steering, braking, suspension and general control of the vehicle. They primarily consist of an outer cover and an inner tube. The air is trapped inside the tube area and provides the cushioning effect that supports the overall weight of the vehicle.

Functions of the tyre

The tyre performs the following functions:

1. Enhances the ride comfort for vehicle occupants.
2. Supports the vehicle's weight on an air cushion.
3. Transmits driving and braking forces to the road.
4. Provides excellent road traction and handles significant forces during braking, accelerating, and cornering.

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Requirements of a tyre

1. A tyre must be durable enough to resist damage while remaining flexible to absorb the load.
2. It should respond precisely to steering inputs without being deflected by road irregularities.
3. The tyre should operate quietly across various road conditions.
4. It must ensure reliable traction in all weather conditions, on both wet and dry surfaces.

Types of tyres

Tyres come in two main types: tubed (or conventional) and tubeless. Tubed tyres include a flexible inner tube that is inflated to maintain shape. Tubeless tyres, which are more common in modern vehicles, eliminate the inner tube and instead feature a thin rubber layer inside to act as a seal.

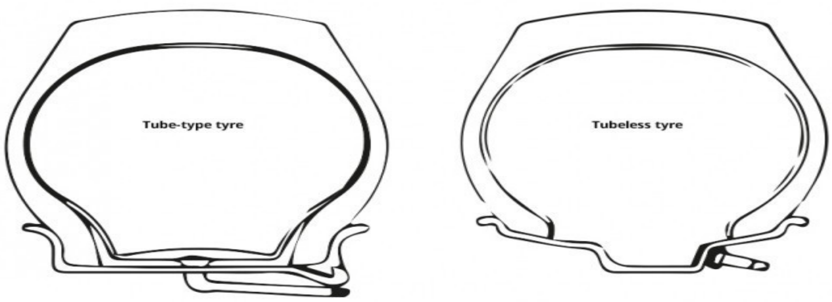

Figure 23.9: Tubed and tubeless tyre designs

Tubed tyres

Tubed tyres consist of an outer tyre casing and an inner tube. The inner tube is a separate inflatable, soft, flexible rubber component that holds the air pressure. This inner tube sits between the tyre and the rim.

Advantages of tubed tyres

1. Tubed tyres can be easily repaired in case of a puncture.
2. They are generally less expensive to produce and purchase compared to tubeless tyres.
3. They can be used on a wide variety of vehicles.
4. They are widely available, making replacements and repairs convenient.

Disadvantages of tubed tyres

1. Tubed tyres are more prone to punctures and blowouts because the inner tube can get pinched between the tyre and the rim, leading to sudden air loss.
2. The inner tube adds extra weight to the tyre, which can negatively impact fuel efficiency and vehicle performance.
3. Tubed tyres tend to generate more heat during operation, which can affect tyre longevity and performance.
4. Mounting and dismounting tubed tyres can be more complicated and time-consuming compared to tubeless tyres.

Tubeless tyres

Tubeless tyres are designed to hold air pressure directly without the need for a tube. The tyre forms an airtight seal with the rim, preventing air from escaping. Tubeless tyres are considered safer because they deflate more slowly when punctured, giving drivers more time to react. They are also lighter, which can improve fuel efficiency and vehicle performance. Moreover, tubeless tyres have better heat dissipation, which can extend their lifespan. However, repairing a puncture in a tubeless tyre can be more challenging and may require special kits. Tubeless tyres are generally more expensive upfront compared to tube tyres.

Advantages of tubeless tyres

1. Tubeless tyres are generally safer because they deflate more slowly when punctured, giving drivers more time to react and manage the situation.
2. They are lighter than tubed tyres since they do not have an inner tube, which can improve fuel efficiency and vehicle performance.
3. Tubeless tyres have better heat dissipation, reducing the chances of overheating and extending the tyre's lifespan.
4. Small punctures in tubeless tyres can be temporarily sealed by the tyre's sealant, allowing you to continue driving until a proper repair can be made.
5. The absence of an inner tube reduces friction, resulting in a smoother and more comfortable ride.
6. Due to the reduced risk of pinch flats and less internal friction, tubeless tyres often have a longer lifespan compared to tubed tyres.

Disadvantages of tubeless tyres

1. Tubeless tyres are generally more expensive to purchase compared to tubed tyres.
2. It is difficult to repair punctures in a tubeless tyre and may require special tools or kits, making it less convenient.

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3. Tubeless tyres require compatible rims that can maintain an airtight seal, which might not be available on all vehicles, especially older models.
4. Regular maintenance and attention are required to ensure the rims and tyres remain sealed.

Tyre Construction

Tyres are made from reinforced synthetic rubber, forming a flexible casing. Fabric plies, known as the 'carcass', are wrapped around bead wires located at the inner edges. The fabric plies are coated with rubber, which is shaped into the tyre's sidewalls and tread. Beneath the tread lies a reinforcing band made from materials like steel, rayon, or glass fibre. The bead wires provide a stiffer edge for the tyre and help to secure the tyre firmly to the wheel rim.

There are two types of tyre construction in use. They are:

1. Cross-ply tyres
2. Radial-ply tyres

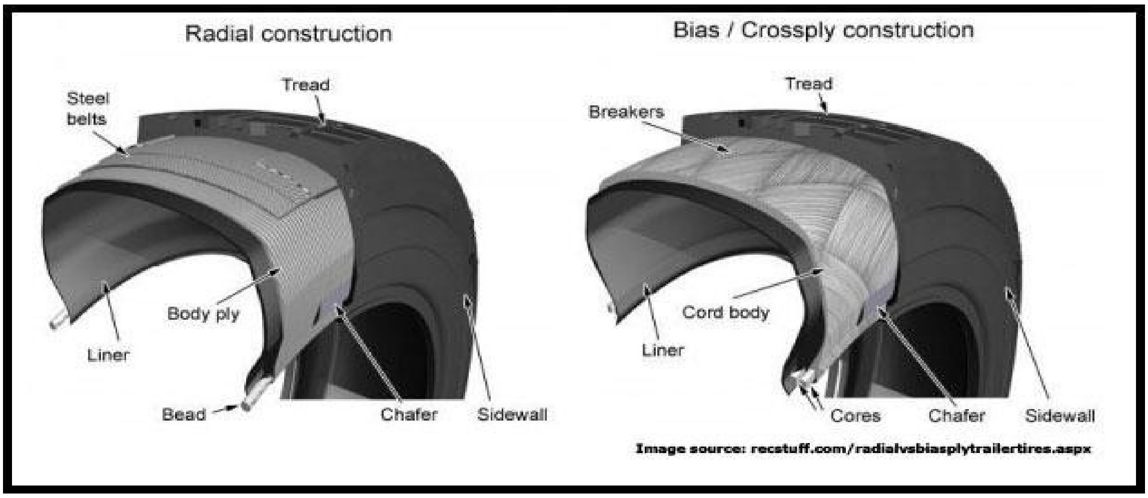

Figure 23.10: Radial-ply and cross-ply tyre construction

Cross-ply (bias) tyres

Cross-ply tyres have several textile plies that are laid across each other, running from bead to bead in alternate directions. The number of plies depends on the size of the tyre and the load it must carry. The same number of plies is used on the crown and the sidewalls.

Advantages of cross-ply tyres

1. The crisscross pattern of the plies results in strong and sturdy sidewalls, which are beneficial for vehicles carrying heavy loads and those used in rough terrain.
2. Cross-ply tyres are highly durable and resistant to cuts and tears.

3. Cross-ply tyres are less expensive to manufacture and purchase.
4. They are suitable for a wide range of applications, including trucks and agricultural vehicles.

Disadvantages of cross-ply tyres

1. The stiffer sidewalls can result in a harsher ride compared to radial tyres.
2. They offer less traction and poorer handling, especially on paved roads.
3. The increased rolling resistance and weight can lead to lower fuel efficiency.
4. The tread wears out faster due to uneven contact with the road.

Radial-Ply tyres

Radial-ply tyres consist of a carcass ply formed by textile arcs running from one bead to the other. Each ply is laid in an arc at an angle of 90 degrees to the direction the tyre rolls. At the top of the tyre crown (under the tread), there is a belt made up of several plies reinforced with metal wire, laid on top of the carcass ply. These crown plies, laid one on top of the other, overlap at an angle determined by the type of the tyre.

Advantages of radial-ply tyres

1. The flexible sidewalls provide a smoother and more comfortable ride.
2. They offer excellent traction and handling, especially at higher speeds and on various road surfaces.
3. The lower rolling resistance of radial tyres improves fuel efficiency.
4. Radial-ply tyres have longer tread life due to even contact with the road.
5. Radial tyres dissipate heat better, reducing the risk of overheating and prolonging tyre life.

Disadvantages of radial-ply tyres

1. Radial-ply tyres are generally more expensive to manufacture and purchase.
2. The sidewalls can be more prone to damage from impacts or rough terrain.
3. Repairing radial-ply tyres can be more complex, requiring specialised skills.

Activity 23.2

Description of tyres

Organise yourselves into groups of no more than 5. Your teacher will arrange a visit to a local vulcanising shop for the next activity.

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1. While in the vulcanising shop and observe how the following servicing tasks are performed:
   a. Removal of the tyre from the rim
   b. Fixing of punctures
   c. Assembling of the tyre
   d. Inflation of the tyre
2. Search the internet to find additional information about the tasks listed above and how they are performed on different types of tyres.
3. Prepare a presentation note, describing how the tasks differ for:
   a. Tubed tyres and
   b. Tubeless tyres
4. Give reasons why you would choose either of the tyre types for particular vehicles and road conditions.
5. Discuss the findings of your activity with the larger class.

Tyre Markings

Tyre markings are the alphanumeric codes and symbols printed on the sidewall of a tyre. These markings provide essential information about the tyre's specifications, capabilities, and performance, including its size, load capacity, speed rating, and manufacturing details. Understanding these markings helps ensure you select the right tyre for your vehicle, contributing to safe and efficient driving.

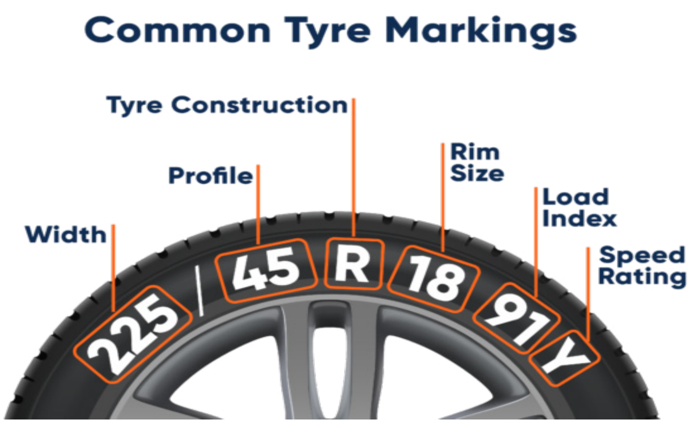

Figure 23.11: Tyre sidewall markings

Interpretation of tyre sidewall marking symbols (225/45 R18 91Y)

1. **Width (225):** The inner section width of the tyre from sidewall to sidewall. This is measured in millimetres.

2. **Aspect Ratio (45):** This refers to a percentage of the tyre's height to its width. The height is measured from the base of the tread to the rim seat.
3. **Tyre Construction (R):** The method used to lay the tyre plies. Radial-ply tyres are indicated by 'R' displayed as part of the sidewall marking string. Tyres without this letter are of cross-ply construction.
4. **Rim diameter (18):** The diameter of the wheel rim measured in inches.
5. **Load Index (91):** The load index is identified at the end of the tyre size string it is the number that appears before the last letter. This code indicates the maximum allowable load the tyre can carry.
6. **Speed Rating (Y):** The speed rating is the letter that follows the load index next to the tyre size, indicated by a specific letter. This indicates the maximum allowable speed the tyre can service.

Activity 23.3

How to decode tyre sidewall markings

Materials needed

- Sample tyres or a sidewall marking chart customised for each group
- Tyre load index and speed rating charts
- Paper and pens/pencils

Organise yourselves into groups of no more than 5.

Activity Steps

In your activity group:

1. Select a tyre having visible sidewall markings. In the absence of a physical tyre, use the sidewall marking chart provided by your teacher.
2. Interpret or decode the markings on the sidewall or chart you have been given.
3. Use the load index and speed rating chart as a guide.
4. Write down what each marking means.
5. A member from your group will present your answer to the entire class.
6. Discuss the importance of tyre sidewall markings to the operation and safety of vehicles.
7. Analyse the potential effects of tyres that do not meet the recommended load index and speed rating on the vehicle performance and safety, as well as the service life of the tyre.

Tyre Wear

Tyre wear refers to the gradual reduction of tread depth on a tyre due to friction between the tyre and the road surface. Abnormal or uneven tyre wear often results from issues with steering and suspension geometry or improper tyre pressures. Other contributing factors include brake imbalance, using the wrong type of tyre for the vehicle, or improper tyre use. Tyres that wear out normally but more quickly than anticipated may be due to frequent hard acceleration and braking, or consistently carrying heavy loads.

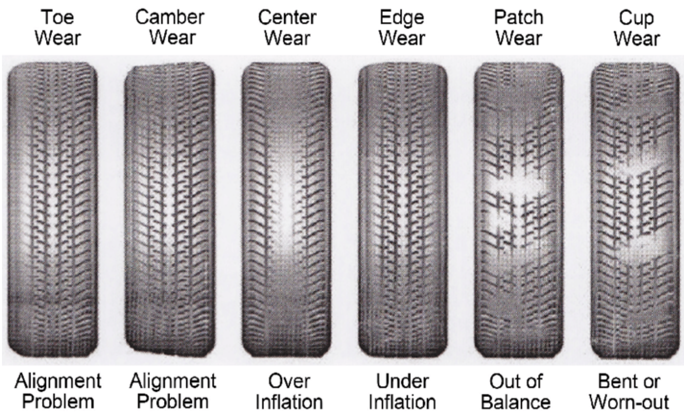

Figure 23.12: Uneven or abnormal tyre wear (Source: www.researchgate.net)

Wheel Balancing

Wheel or tyre balancing is the process of evenly distributing the weight across a tyre and its wheel assembly to ensure uniform rotation at any speed. This involves detecting and correcting imbalances that can cause uneven wear, vibrations, or wobbling during motion. Properly balanced tyres enhance driving comfort by providing a smoother ride, improve vehicle handling by maintaining stability and control, and extend the lifespan of both tyres and suspension components by reducing unnecessary strain. Balancing is typically achieved by adding small weights to specific points on the wheel to counteract imbalance or uneven weight distribution.

There are two main types of tyre balancing techniques used to ensure smooth and even tyre rotation. They are static balancing and dynamic balancing.

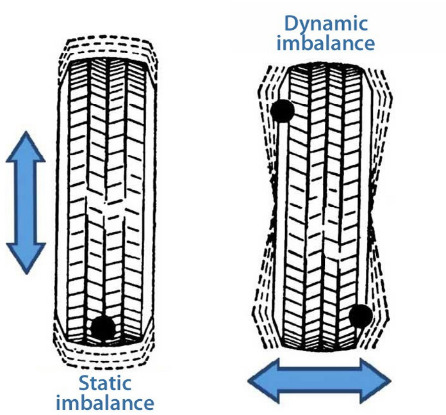

Figure 23.13: Static and dynamic imbalance

Static Balancing

Static balancing is carried out to correct the imbalance in a single plane. It helps to ensure the tyre's weight is evenly distributed around its circumference. In this method, the tyre is removed and mounted either on a vertical balancing machine (which is a type of bubble level stand), or by deprogramming a computerised spin balancer. The tyre is then spun to identify any heavy spots. A bubble in the centre of the balancing machine moves off the centre to help identify the points of imbalance. Counterweights are then added to the rim to balance the tyre.

Static balancing is used to correct "tramp" but does not get rid of wobble.

Dynamic Balancing

Dynamic balancing is carried out either on or off the vehicle. When carried out off the vehicle, the tyre is mounted on a horizontal balancing machine and spun at high speeds. The machine detects imbalances in both the outer and inner sides of the tyre. Counterweights are added to the inner and outer edges of the rim to achieve balance.

Dynamic balancing corrects imbalances in multiple planes, addressing both vertical and lateral forces.

Figure 23.14: A wheel tyre balancing machine

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UNIT 24

METAL TECHNOLOGY

Welding Technology

Introduction

Soldering is an important process used to join metal parts together in manufacturing, electronics, plumbing, and metalwork. It is relevant because it provides a strong, leak-proof, and durable connection without melting the base metals. This lesson introduces the two main types of soldering: soft soldering, which uses low-temperature solder for delicate work, and hard soldering which uses high-temperature solder for stronger joints. Students will also learn about the various tools and equipment used in soldering, different types of solder materials, and the advantages and disadvantages of soldering in different applications.

After studying this lesson, students should be able to explain the difference between soft and hard soldering, identify and use the required tools and equipment, select the appropriate type of solder for a task, and understand the benefits and limitations of soldering in practical work.

KEY IDEAS

- Soft soldering uses low temperatures while hard soldering uses higher temperatures for stronger connections.
- Soldering requires specific tools such as soldering irons, torches, flux etc
- Different solders are used depending on the materials and strength required.
- Soldering creates strong, leak-proof joints, allows joining of different metals.
- It requires heat control and improper technique can damage components.

TOOLS AND EQUIPMENT FOR SOFT SOLDERING

Materials, Tools and Equipment for Soft Soldering

Soldering is a process that joins two or more types of metals through melting solder. Soldering uses a filler rod or metal with a low melting point, also known as solder, to join metal surfaces. In soldering, the key elements are iron, solder, flux and components. The solder is usually made up of an alloy consisting of tin and lead, whose melting points are around 235°C and 350°C, respectively. The alloy is melted by using a hot iron at above 316 °C (600 °F). As the solder cools, it creates a strong electrical and mechanical bond between the metal surfaces. The bond allows the metal parts to achieve electrical contact while it is held in place. Soldering is commonly used in electronics, as it is simple and safe in joining sensitive materials. Likewise, the process is also known for metalworking, plumbing, roofing and joining wires.

The flux is a cleaning agent used to prevent oxidation of metals at the soldering point. It helps the solder to melt quickly and allows it to flow freely to unite more firmly. E.g., zinc chloride, ammonium chloride, hydrochloric acid, borax, resin, turpentine oil etc. A flux improves the bonding properties of the solder. It reduces the surface tension of the solder and (to some extent) chemically cleans the surfaces of the metal. There are two main types. Fluxes that prevent oxide formation are known as active fluxes. They are acids. Passive fluxes only protect the joint from further oxidation. They come in pasty or greasy forms.

Table 24.1: Commercially produced fluxes and their uses

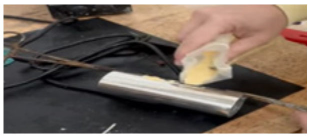
S/N	Type of Flux	Application of Flux	Picture of Flux
1	**Resin (powdered)**	For electrical work	
2	**Zinc chloride**	Used on tinplate, brass and copper	
3	**Sal ammoniac (powered)**	Used for copper and iron	
4	**Tallow**	Used by plumbers in soldering lead	
5	**Hydrochloric acid**	For soldering zinc and galvanised iron	

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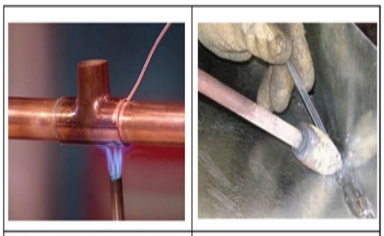
Table 24.2: Soldering and Brazing Processes

S/N	Application	Description	Picture
1	**Soldering Process**	Soldering works well with the following base metals: Gold, Silver, Iron, Brass, Copper, Aluminium, Steel, Titanium.	 Soldering copper pipe; Sheet metal fabrication
2	**Welding, Soldering and Brazing**	Brazing, soldering, and welding are techniques for joining two or more metal pieces. The main difference between welding on one hand and soldering and brazing on the other is that, in either the soldering or brazing process, the temperatures used are not high enough to cause melting of the parent metals to be joined. The difference in soldering and brazing is again based on temperature considerations. In soldering, temperatures up to 427°C are used, and in the brazing process, temperatures above 427°C are employed.	

Two types of soldering, namely **soft soldering** and **hard soldering**.

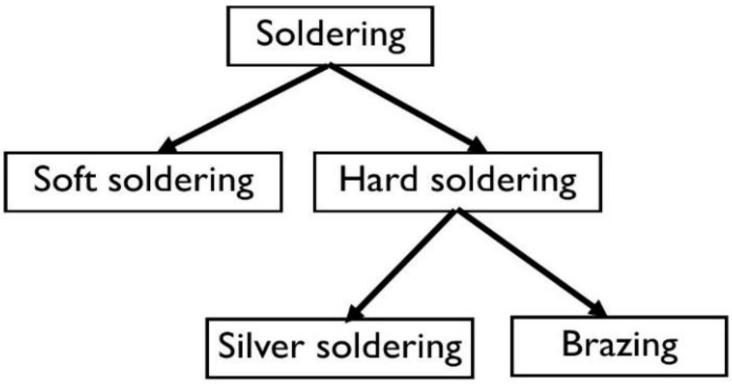


Figure 24.1: Types of Soldering

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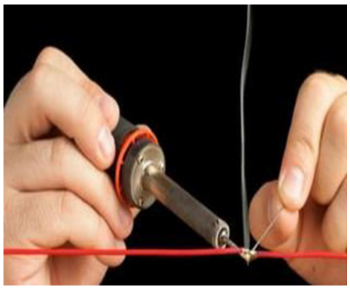
Table 24.3: Soft Soldering

S/N	Type of Soldering	Description of Type of Soldering	Picture
1	**Soft soldering**	Soft soldering is performed at relatively low temperatures, usually below 400°C (752°F). It uses soft solders, typically alloys of tin and lead (though lead-free solders are now common due to health and environmental concerns). 281 This method is commonly used in electronics, plumbing, and other applications where the joint does not need to withstand high temperatures or heavy loads. Soft soldering is easy to perform and requires less equipment and skill. It is suitable for delicate work, such as circuit board assembly.	 *Soldering a wire*
2	**Hard Soldering**	Hard soldering includes techniques like silver soldering and brazing, and it requires higher temperatures compared to soft soldering. Hard soldering is carried out at temperatures above 450°C (842°F). It uses stronger alloys, often based on silver, copper, or brass, which have higher melting points. Hard soldering is used in situations where strong, durable joints are needed, such as in jewellery making, metal sculpture, and plumbing for certain types of pipe connections. It produces stronger joints that can withstand higher temperatures and stresses. This makes it ideal for structural applications and in environments where the joint will be exposed to significant mechanical or thermal stress.	 *Hard soldering of pipes*

Types of Solder

Solder is a metal alloy with a relatively low melting point. Typically, it is made from lead and tin which both have relatively low melting points. There are many different

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types of solder based on their compositions and intended applications. The main types of solder include:

Different guages of solder wire

Solder composition is labelled (Lead free on left)

Figure 24.2: Different types of solder

Table 24.4: Different Types of Solder

S/N	Type of Solder	Examples of Types of Solder
1	**Lead-based Solder**	Typically, an alloy of tin (Sn) and lead (Pb), such as a 60/40 ratio (60% tin, 40% lead). Melting point around 183-190°C (361-374°F). Traditionally used in electronics due to its low melting point and good wettability, though its use has decreased due to health and environmental concerns.
2	**Lead-free Solder**	Alloys like tin-copper (Sn-Cu), tin-silver-copper (SAC), and tin-silver (Sn-Ag). Higher meeting point than lead-based solders, typically around 217-230°C (423-446°F). Used in consumer electronics and other applications due to regulations like the RoHS directive that restrict the use of lead
3	**Silver Solder**	Alloys containing silver, often combined with copper and zinc. Higher melting point than both lead and lead-free solders, typically above 450°C (842°F). Used in jewellery, plumbing, and applications requiring strong joints.
4	**Flux-cored Solder**	Solder wire with a core of flux material, which helps clean the surfaces and improve the flow of solder. Rosin Flux: Used mainly in electronics. Water-soluble Flux: Easier to clean after soldering. No-clean Flux: Leaves minimal residue, eliminating the need for cleaning.

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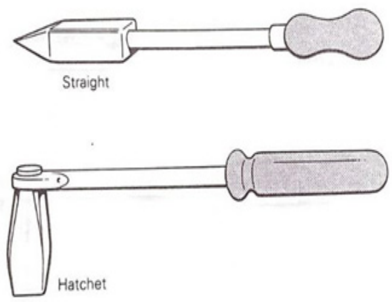
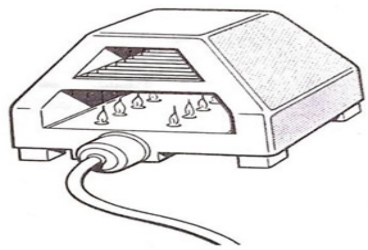
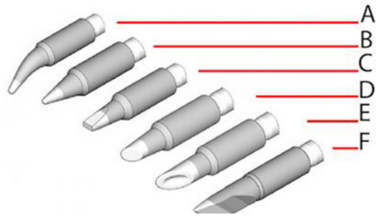
Table 24.5: Soldering Tools, Descriptions and Uses

S/N	Tool	Description and Uses	Picture
1	**Standard Electric Soldering Iron**	A soldering iron is a hand tool that plugs into a standard 120v AC outlet and heats up to melt solder around electrical connections. This is one of the most important tools used in soldering and it can come in a few variations such as pen or gun form.	
2	**Soldering irons**	Soldering irons or bits are made of copper: In gas-powered soldering irons, the two main shapes are hatchet and straight as shown in the figure below alongside the tinman's stove (gas soldering stove). The bits are used in soft soldering. They are heated in soldering stoves before melting the solder. If a stove is not available, forge hearth can be used. Heat the bit until the green fame shows. This is an indication that the correct temperature has been reached. There is no need for the stove if you use electric soldering bits. Soldering lead is mainly an alloy of lead and tin. The range of temperature over which it becomes pasty depends on the proportion of tin to lead. The melting point of fine solder, which is composed of 65 per cent tin and 35 per cent lead, is 183 °C. Plumber's solder (70 per cent lead, 30 per cent tin) melts at 250 °C. The melting point of solder can be reduced by adding bismuth and antimony. This type of solder is referred to as low melting point (LMP) solder. Soldering bits Gas-powered soldering stove	 *Soldering bits*  *Gas-Powered soldering stove*

3	**Soldering irons tips**	**Soldering Iron Tips**: At the end of most soldering irons is an interchangeable part known as a soldering tip. There are many variations of this tip and they come in a wide variety of shapes and sizes. Each tip is used for a specific purpose and offers a distinct advantage over another.	 ***Types of soldering iron tips:*** *needle (A), conical (B), bevelled (C), chisel (D), hollow point (E), and knife (F) tips.*
4	**Soldering Iron Stand**	A soldering iron stand is very basic but very useful and handy to have. This stand helps prevent the hot iron tip from coming into contact with flammable materials or causing accidental injury to your hand. Most soldering stations come with this built in and include a sponge or brass sponge for cleaning the tip.	
5	**Soldering Iron cleaning**	Using a sponge will help to keep the soldering iron tip clean by removing the oxidation that forms. Tips with oxidation will tend to turn black and not accept solder as it did when it was new. A conventional wet sponge could be used but this tends to shorten the lifespan of the tip due to expansion and contraction. Also, a wet sponge will drop the temperature of the tip temporarily when wiped. A better alternative is to use a brass sponge as shown on the left.	 *Brass or Conventional Sponge*
6	**Soldering guns**	Soldering guns are employed when higher temperatures require more power. A soldering gun heats quicker and offers better flexibility as it can be operated in confined spaces, heavy electrical connections, and metalworks.	

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7	**Soldering tools**	Soldering stations are multipurpose devices that have everything covered for minor projects. They are more durable than regular soldering irons due to them being equipped with sensors, fuses, alerts and temperature regulation.	
8	**Solder wire cutters**	Solder wire cutters, often referred to as flush cutters or nippers, are specialised tools used in electronics and soldering for cutting soldered wires and leads.	

Table 24.6: Advantages and Disadvantages of Soft Soldering

S/N	Advantages of Soldering	Disadvantages of Soldering
1	Soft Soldering is operated at lower temperatures compared to common welding methods.	Weaker joints compared to other welding methods such as MIG and TIG.
2	Most metals and non-metals can be soldered.	Soldering isn't suitable at high temperatures, as the solder has a low melting point
3	A simple process makes it easy to learn.	Heavy metals aren't suitable for soldering.
4	The base metal isn't melted in the process, unlike welding techniques such as stick welding, flux-cored welding, etc.	Melted solder might leave a toxic flux residue.
5	Soft soldering can be undone using a desoldering tool without damaging the base materials.	Improper heating may cause deformities or voids in the solder.

Conclusion

This unit has focused on understanding the processes, tools, and techniques involved in joining metal components using solder. Soft soldering typically uses lower melting-point solder (example, tin-lead alloys) and is ideal for electronics and delicate work. Hard soldering (example, brazing or silver soldering) involves higher melting point solder and is used for the strongest joint in plumbing, jewellery, or industrial applications.

Mastering the tools and equipment for soft and hard soldering ensures precision, efficiency, and safety in various applications. Soft soldering is preferred for delicate tasks, while hard soldering is crucial for strong, durable joints. Practising proper techniques, maintaining equipment, and adhering to safety protocols are essential for success in soldering tasks. This knowledge is fundamental for fields like electronics, metalwork, and plumbing.

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Activity 24.1

Knowledge of soldering and identification of types of solder

Organise yourselves into groups of no more than 5 to perform the following activities:

1. In your groups, brainstorm what is meant by soldering. Discuss the various types of solder and make notes on your findings.
2. Research and discuss what is meant by soft and hard soldering. Make notes on the process for each and outline the differences between them. You can use a table to note down your findings.
3. Using the internet, identify pictures of tools and equipment used in the soldering process. Don't forget to research the description for each of these tools as well.
4. Compile all your findings in a digital or paper-based presentation. Present this to the class for discussion and feedback.

Activity 24.2

Embarking on an educational visit to a local Radio/Television/Mobile Phone repairing workshop.

Your teacher will arrange a visit to a local repair workshop for you to complete the following.

1. At the local workshop, observe and demonstrate both soft and hard soldering processes. Make sure you are under qualified supervision.
2. Make sketches or take pictures and prepare photo albums.
3. Write a visit report (including all pictures/sketches you have made) and present this to the class for discussion and feedback.

Note:

a. Observe the basic safety precautions during the visit.

b. Always wear your PPE.

EXTENDED READING

- **Understanding the Different Types of Suspension Systems:** https://scottyscompleteautorepair.com/2023/06/understanding-the-different-types-of-suspension-systems/
- **Car Suspensions and Their Types:** https://www.dubizzle.com/blog/cars/types-suspension-systems-automobile/

- **Types of Wheels:** https://www.cjponyparts.com/resources/types-of-rims?srsltid=AfmBOooD7IS7N3StnSWc74ObKKCOALPcb3t2guLftu3z_Xzo5VHSl_sB
- **Your Complete Guide To Different Tyre Types:** Type of tyres
  - **Tubeless Tyre vs Tube Tyre – Find Out the Top Differences:** Type of tyres 2 (https://carfromjapan.com/article/tubeless-tyre-vs-tube-tyre/)
  - **Tyre Construction and Design:** Tyre construction and design (https://www.national.co.uk/blog/tyre-construction-and-design)
  - **Tyre Balancing: What You Need to Know:** Tyre balancing (https://evanstire.com/tire-balancing-what-you-need-to-know/)
  - **Tire Sidewall Markings:** Tyre markings (https://goodxtires.com/tire-sidewall-markings/)
- **Wheelchair:** https://www.creativefabrica.com/product/medical-tool-wheel-chair-realistic
- **Soldering process**:
  - **Soldering process**-Click here (https://www.uts.edu.au/globalassets/sites/default/files/Soldering_0.pdf)
  - **Soldering process** - click here (https://tameson.com/pages/soldering-iron-tips)
- **Soldering a wire:** SOLDERING A WIRE - Click here
- **Hard soldering of pipes:** https://www.slideshare.net/slideshow/types-of-soldering/94365117#12

Review Questions

Questions 6.1

1. Explain the difference between a rigid axle and an independent suspension.
2. State three advantages and disadvantages of independent suspension over rigid axle suspension.
3. Describe both the independent front and rear suspension systems
4. Examine the advantages and disadvantages of MacPherson and double wishbone suspension systems.

Questions 6.2

1. A rural community lacks access to clean drinking water, leading to waterborne illness. The goal is to design an affordable portable water filtration system. What is an engineering design process?
2. You are tasked with designing a desk lamp for use in the school. You conducted interviews with some learners to understand their needs and challenges. Explain five stages of the design process you will follow for making the artefact/product.
3. In a school garden, there is a need to design and make a watering can.
   a. Explain the design process/sequence of operation in making the watering can.
   b. Generate three possible solutions for the watering can
   c. Use appropriate criteria to select the best design.
   d. State four reasons why you will make a mock-up of the watering can.
4. **Figure 24.3** shows a design of a user-friendly, functional, and aesthetically pleasing wheel chair that meets the needs of an individual with mobility challenges.
   a. Using simple sketches and annotated notes, show details of two improvements to this design.
   b. Identify two materials you will use to manufacture the wheelchair.
   c. State two reasons each for your choice of materials (in b) above.

Figure 24.3: A wheelchair

Questions 6.3

1. Explain the requirements of wheels and tyres
2. Explain cross ply and radial ply tyre construction and tyre markings
3. What are the functions of wheels in an automobile and state three requirements?
4. Explain briefly pressed steel disc wheels.
5. Explain briefly the following types of tyres and why the tubeless type is better
   a. Tubed
   b. Tubeless
6. Compare three advantages and disadvantages of radial ply tyres over cross ply (bias) tyres.

Questions 6.4

1. You are in a school electronics class working on a project to build a simple LED circuit. The teacher hands you a small circuit board, a few wires, an LED, and a resistor. To connect these components securely, you will use a process called soldering using solder. What is soldering and solder?
2. You are assembling two different projects: a delicate electronic circuit board and a sturdy metal jewellery piece. Depending on the project, you will choose either soft or hard soldering. Explain three differences between soft and hard soldering.
3. Philip is assembling a do-it-yourself (DIY) circuit board for a school project. The process involves both soft soldering (for electrical components) and hard soldering (for joining metal parts of the case). Describe any two tools used in soft and hard soldering.
4. You are working on a DIY electronics project to build a small FM radio. The kit includes a circuit board, various components like resistors, and capacitors and transistors, and instructions on how to assemble them. To complete the assembly, you need to solder the components onto the printed circuit board (PCB). Compare three advantages and disadvantages of soldering over any other type of assembly process.
5. You are a manufacturer producing electronics circuit boards for smartphones. These devices are subjected to frequent thermal cycling (heating and cooling) and physical stresses during use. How does the choice of solder influence the quality and durability of the solder joint?
6. You are to design a simple project that utilises both soft and hard soldering techniques. Explain the rationale for choosing specific soldering methods for different sections of the design.

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GLOSSARY

Abrasives	Abrasives are materials used to wear away surfaces through friction.
Adjustments	Refers to changes or modifications made to improve, correct, or accommodate something.
Air-cooled	Cooling system using air to dissipate heat from the engine.
Annealing	Annealing is a heat treatment process used to alter the physical and sometimes chemical properties of a material, typically metals and glass.
Annealing	A heat treatment process used to soften metal and restore ductility after rolling or extrusion.
Applicable	Means something that is relevant or appropriate to a particular situation, subject, or condition.
Artefact	refers to any object made of metal that has been crafted, shaped, or modified by human hands, often with artistic, functional, or symbolic intent.
Atmospheric	Refers to anything related to the atmosphere, which is the layer of gases surrounding a planet.
Austenite	Is a phase of iron and steel that is characterised by a face-centred cubic (FCC) crystal structure.
Auxiliary	Refers to something that provides additional help or support.
Bazing	A joining process using a filler metal with a higher melting point than soldering (above 450°C) to bond metal parts together.
Beading	A forming process that creates a raised edge or groove in metal for strengthening or decorative purposes.

Billet	A small, solid piece of metal used as the starting material for forging or extrusion.
Bind	A condition where the coil spring becomes stuck or jammed together, restricting its ability to compress or extend smoothly.
Blank	A flat, pre-cut piece of material that is used as the starting point for further shaping or forming in a press.
Blanking	A type of cutting process where a flat piece (blank) of metal is cut from a larger sheet to create a specific shape.
Bolster	A thick, sturdy plate or surface that supports the die and workpiece during the pressing operation.
Bonds	A bond is an adhesive substance that is employed to hold abrasive grains together in the form of grinding wheels.
Boring	Boring is an operation used to enlarge a hole by means of an adjustable cutting tool with only one cutting edge.
Brine	Is a high-concentration solution of salt (sodium chloride) in water.
Bump stop	A cushion or buffer that limits the suspension's compression to prevent damage or excessive movement.
Carburising	Carburising is a heat treatment process used to harden the surface of steel and other iron-based alloys by increasing their carbon content.
Carriage	Refers to a movable component of a machine tool that holds and supports tools or workpieces, allowing them to move in relation to each other.
Case hardening	is a heat treatment process used to harden the surface of a metal while maintaining a softer, ductile core.

Cavitation	Formation of air pockets in coolant, potentially damaging engine components.
Cementite	is a hard and brittle compound of iron and carbon.
Centre drill	A centre drill is a specialised tool used in machining and metalworking, primarily for creating a small, precise hole at the centre of a workpiece.
Chemical properties	refer to the characteristics of a substance that describe its ability to undergo specific chemical changes or reactions.
Chip	Refers to the small pieces or shavings of metal that are removed from a workpiece during machining processes such as cutting, drilling, milling, or grinding.
Chucks	A chuck is a specialised tool used to hold and secure workpieces or cutting tools on a machine, such as a lathe, drill press, or milling machine.
Clearance	refers to the space or gap between the drill bit and the walls of the hole being drilled.
Coining	A process that uses high pressure to form detailed shapes or impressions into metal, often used for creating coins or patterns.
Compliance	refers to the act of conforming to rules, regulations, standards, or laws set by authorities or governing bodies.
Conceptualisation	is the process of forming and developing an idea or concept in the mind.
Condense	The process where hot combustion gases cool down and change from a gas to a liquid, leading to the formation of moisture or sludge in the crankcase.
Convection	A heat transfer process through fluid circulation.

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Cost effectiveness	Cost-effectiveness refers to the ability to achieve the desired result or outcome at the lowest possible cost, without sacrificing quality, efficiency, or performance.
Counter boring	Counterboring is a machining process used to create a flat-bottomed hole that allows a fastener, such as a bolt or screw, to sit below the surface of the material.
Counter sinking	is a machining process used to create a conical-shaped recess at the top of a hole.
Critical	Generally, refers to something that is essential or of utmost importance.
Curling	A process that bends the edge of a metal sheet into a rounded shape, often for aesthetic or functional purposes.
Detailed drawing	is a highly precise, scaled representation of an object, structure, or concept that includes intricate features and dimensions.
Devices	Devices are tools employed to shape, cut, form, and assemble metal materials.
Die	A specialised tool used to shape material during forging, rolling, or extrusion.
Dies	Tools or moulds used to shape, cut, or form metal by applying pressure, often used in conjunction with punches.
Direct Extrusion	Forcing metal through a die in the same direction as the applied force.
Direct-acting	A mechanism or component that operates straightforwardly without intermediate connections or linkages
Documentation	refers to the process of creating, organising, and storing written or digital records that provide detailed information about a particular subject, process, or system.

Down milling	Also known as conventional milling, is a machining process in which the cutter rotates in the opposite direction to the movement of the workpiece.
Draft Angle	The angle added to facilitate the removal of metal from a die during forging or extrusion.
Draft	The reduction in thickness of metal during rolling or extrusion.
Drawing	A process where metal is stretched or pulled into a desired shape, typically used to form deep or complex shapes like cans or containers.
Drilling	Drilling is a machining process used to create cylindrical holes in various materials, such as wood, metal, plastic, and masonry.
Duct	A tube or channel, often made from metal, used to carry air, water, or other materials.
Ductile	Refers to a material's ability to deform under tensile stress, meaning it can be stretched into a wire or drawn into other shapes without breaking.
Electrical properties	refer to the characteristics of a material or substance that determine how it behaves in the presence of an electric field or when it conducts electric current.
Elongation	The extent to which a material stretches before breaking, often measured as a percentage of its original length.
Embossing	The process of creating raised designs or patterns on the surface of metal, often for decoration.
Emulsifiable	refers to the ability of a substance to be mixed or dispersed in another liquid to form an emulsion.
Engineering	is the application of scientific principles, mathematics, and practical knowledge to design, build, and analyse structures, machines, systems, and processes.

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Equilibrium	refers to a state in which opposing forces or influences are balanced, resulting in stability.
Eutectic	refers to a specific composition of a mixture of substances that has the
Expansion tank	A reservoir for accommodating coolant expansion.
Expansion tank	A reservoir accommodating coolant expansion and contraction.
Fabrication	The process of making products by cutting, shaping, or assembling materials.
Face turning	refers to a machining process used to create flat surfaces on the end of a cylindrical workpiece.
Feed rod	is a component used in various types of machinery, particularly in metalworking equipment such as lathes and milling machines.
Feed	Refers to the rate at which the cutting tool or the workpiece moves relative to each other during machining operations.
Ferrite	is a phase of iron and its alloys that is characterised by a body-centred cubic (BCC) crystal structure.
Filler	A material (such as solder) used to fill gaps or joints during the soldering process to create a bond between parts.
Flanging	The process of bending the edge of a metal sheet to form a lip or flange, often used in joining parts together.
Flank	Flank refers to the side surface of a cutting tool or drill bit that engages with the material being cut.
Fluids	Refers to substances that can flow and take the shape of their containers. Fluids include both liquids and gases, and they exhibit unique properties compared to solids.

Flute	Refers to the grooves or channels that are cut into the body of a cutting tool, such as a drill bit or end mill.
Flux	A chemical substance used to clean the surfaces of metals before soldering, helping solder to flow smoothly and preventing oxidation.
Foundation	Principles or ideas that serve as the groundwork for a theory, system, or practice.
Foundry	A foundry is a facility where metals are melted and poured into moulds to create various metal castings.
Furnace	A furnace is a high-temperature device used for heating or melting materials in various industrial, laboratory, and residential applications.
Galvanised	A coating of zinc applied to metal to prevent rust, often requiring special flux and techniques when soldering due to the protective layer.
Gang milling	is a machining process that involves using multiple cutters mounted on a single arbor to machine several surfaces of a workpiece simultaneously.
Geometries	refer to the shapes, dimensions, and structural configurations of objects, parts, or systems.
Glazing	refers to a surface condition that occurs on metals, particularly during machining or grinding processes.
Grinding	is a machining process that involves the use of an abrasive wheel or tool to remove material from a workpiece.
Groove	Refers to a long, narrow channel or indentation that is cut or formed into a material's surface.
Groove cutting	Refers to the machining process used to create grooves or channels in a material, typically metal or plastic.

Hardening	Hardening is a heat treatment process used to increase the hardness and strength of a material, particularly metals and alloys.
Head gasket	An engine component which provides a seal between the cylinder head and block.
Headstock	a critical component that houses the main drive mechanism and spindle of the machine.
Heat exchanger	A device for transferring heat from coolant to ambient air.
Heat transfer	the process of transferring thermal energy from the engine to the coolant.
Heat treatment	Heat treatment is a process used to alter the physical and sometimes chemical properties of a material, usually metals or alloys.
Helix angle	the helix angle is measured in degrees and is typically defined as the angle between the tangent to the helix and the axis of the cylinder around which it wraps.
Hemming	The process of folding the edge of a metal sheet over itself to create a smooth, finished edge.
Horsepower	a unit of measurement for power, commonly used to quantify the power output of engines and motors, including those found in metalworking machinery.
Hydraulics	The use of pressurised liquid to generate mechanical force, often used in machines like hydraulic presses for shaping or forming materials.
Ingot	A large block of metal, cast into a shape suitable for further processing, such as rolling or forging.
Instantaneous Centre of Rotation	This is the theoretical point around which the vehicle rotates during a turn.

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Jewellery	Jewellery refers to decorative items worn for personal adornment, typically made from precious metals, gemstones, and other materials.
Kingpin	A hardened steel pin that is passed through the eyes of the steering knuckle and the axle beam, around which the steering knuckle pivots.
Knurling	Is a manufacturing process used to create a patterned texture on the surface of a workpiece, typically cylindrical, such as rods or handles.
Lactuca	This is a soluble microemulsion lubricant for general machining equipment.
Lapping	Lapping is a precision machining process used to achieve a high degree of flatness, smoothness, and dimensional accuracy on the surfaces of materials.
Laser	A technology that uses a focused beam of light to cut or engrave metal with high precision.
Lathe	Is a versatile machine tool used primarily for shaping and machining materials, especially metals and wood.
Lead screw	Is a mechanical component used in various types of machinery, including lathes and CNC machines, to convert rotary motion into linear motion.
Ledeburite	is a microstructural phase found in certain cast iron and steel alloys, particularly in high-carbon and high-chromium compositions.
Longevity	The length of time something lasts, particularly its durability or lifespan.
Longitudinal	Refers to something that is oriented along the length or the longer dimension of an object or structure.
Lubricant	A substance (example, oil, grease) used to reduce friction and wear between moving parts in direct contact.

Lubrication	The application of oils or greases to reduce friction and wear during forging, rolling, or extrusion.
Machine	A tool or device used to perform mechanical tasks, such as cutting, bending, or shaping metal.
Mandrels	A tool used in metalworking and machining to support, shape, or hold a workpiece during various operations.
Manoeuvrability	the ability of a vehicle to navigate and handle various driving conditions effectively.
Margins	refer to the areas of material that are left as allowances or features in a part or component.
Mechanical properties	refer to anything related to machinery, physical forces, or mechanical systems, and it is a broad term used across various fields like engineering, physics, and technology.
Metal Flow	The movement of metal during forging, rolling, or extrusion operations.
Microstructural	refers to the arrangement and organisation of phases, grains, and other features at the microscopic level within a material.
Milling	is a machining process that involves the removal of material from a workpiece using rotary cutters.
Mismatch	Refers to a misalignment or disparity between two mating surfaces or parts, which can occur during various stages of production.
Misrun	is a type of casting defect that occurs when molten metal fails to completely fill the mould cavity during the casting process.
Molten	refers to a state in which a solid material has been heated to the point that it has melted and turned into a liquid.

Neck	The portion with reduced diameter between the body and shank.
Nitrides	Nitrides are chemical compounds composed of nitrogen and another element, typically a metal.
Normalising	Normalising is a heat treatment process used to improve the mechanical properties of metals, particularly steel.
Off-road vehicle	A vehicle specifically designed to handle rough terrains and challenging driving conditions that standard vehicles might struggle with.
Operation	A specific task or set of tasks performed in a manufacturing process such as cutting, shaping, or forming metal.
Oscillations	Repeated up-and-down or back-and-forth movements, such as vibrations in suspension systems.
Overarm	The overarm is a structural component of some milling machines, particularly horizontal milling machines.
Parameter	refers to a measurable factor or variable that can influence the outcome of a process or the characteristics of a product.
Parting off	Is a machining process used to separate a piece of material from a larger workpiece, typically on a lathe.
Pearlite	is a two-phase microstructure found in steel and cast iron, consisting of alternating layers (or lamellae) of ferrite (a relatively soft phase) and cementite (iron carbide, a much harder phase).
Petroil	A mixture of petrol and oil, often used in two-stroke engines to lubricate moving parts

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Pneumatic	The use of compressed air to generate force, commonly used in tools or machines for operations such as lifting, pressing, or powering other systems.
Polymer	A polymer is a large molecule composed of repeating structural units called monomers, which are connected by covalent chemical bonds.
Predetermined	refers to something that has been decided or established in advance, often implying that the outcome is set before it occurs.
Pressurised cooling	A sealed system maintains positive pressure to optimise heat transfer.
Pressurised water-cooling	A system using pressure to enhance cooling.
Profiling	is a term used in various fields with different meanings, but it generally refers to the process of creating, analysing, or defining a profile or shape of an object.
Properties	refer to the characteristics or attributes of a material, substance, or system that define its behaviour and performance.
Prototype	is an early, working model of a product, system, or concept, created to test and validate ideas, designs, or features before final production or implementation.
Pump-assisted cooling	Using a mechanically operated pump to circulate coolant in an engine.
Punch	A tool used in pressing or shaping, often to create holes or specific shapes by applying force to a metal sheet.
Punches	Tools used in sheet metal fabrication to apply force and create holes or shapes by pressing into the metal.

Quenchants	are substances used in the quenching process of heat treatment to rapidly cool heated metal parts, thereby hardening them.
Ram	The part of a press machine that moves up and down to apply force to a workpiece used in operations like punching or forming.
Reaming	Reaming is a machining process used to finish a hole to a precise diameter and improve its surface finish.
Rebound	The upward movement of a vehicle's suspension after compressing due to a bump or load.
Reciprocating	Refers to a back-and-forth motion that occurs in a straight line.
Resin	A type of flux, typically derived from natural or synthetic sources, used to help solder flow and bond to surfaces.
Roll Pass Design	The arrangement of roller shapes in a rolling mill to achieve specific cross-sections.
Rolling Mill	A machine with rollers used to perform the rolling operation on metal sheets or billets.
Rotary motion	Refers to the circular movement of an object around a central point or axis.
Routing	Milling to an irregular outline while guiding the hand.
Scaling	The formation of an oxide layer on the surface of metal during hot forging or rolling.
Scavenging	The process of using a pump to recover and reuse oil that has drained from the engine to the sump.
Scrub radius	This is the distance between where the SAI intersects the ground and the centre of the tyre.
Sealed system	A closed-loop cooling system that prevents air entry and coolant loss.

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Seaming	Joining two pieces of metal together by folding or bending the edges to form a seal.
Shank	The shank of a tool refers to the part that is inserted into a machine or holder
Shank	The part of a tool or machine part that is inserted into another piece, like the body of a punch, drill, or press tool.
Shearing	A cutting process where metal is sliced using a shear or blade, often to cut straight edges.
Sheet metal	Thin, flat pieces of metal that are used in fabrication processes like cutting, bending, and shaping.
Slab milling	is a machining process used in milling operations where a flat surface is cut into a workpiece using a slab mill.
Slip	The movement of metal layers over each other during deformation.
Sludge	A thick, sticky, and semi-solid substance that forms when combustion gases mix with engine oil in the crankcase.
Solidification	is the process by which molten metal cools and transitions from a liquid to a solid state as it fills the mould cavity.
Specification	refers to detailed descriptions or requirements that define the characteristics, quality, and standards of materials, processes, or products.
Spindle	It is a crucial component in various machining and manufacturing equipment, particularly in lathes, milling machines, and CNC machines.
Spinning	is a manufacturing process used to form symmetrical parts by rotating a metal disc or tube at high speeds against a stationary tool.

Spot facing	Spot facing is a machining process used to create a flat surface around a hole, typically to ensure a proper fit for a fastener or to provide a smooth surface for seating.
Strain Hardening	Strengthening a material through plastic deformation, common in rolling and extrusion.
Strip	A long, narrow piece of material that is fed through a die to be shaped, cut, or formed.
Structure	The relative spacing occupied by the abrasives and the bond
Sturdy	Means something that is strong, well-built, and able to withstand pressure, weight, or rough conditions without breaking or failing.
Sturdy	Strong and durable, capable of withstanding stress or heavy use without breaking.
Tail stock	Is a key component of a lathe and other machining equipment, positioned opposite the headstock.
Tallow	Animal fat used historically as a flux in soldering, helping to clean metal surfaces and improve solder flow.
Tang	A tang refers to the part of a tool, knife, or blade that extends into the handle to provide stability and durability.
Taper	refers to a gradual decrease in thickness, width, or diameter along the length of an object.
Tapping	is the process of cutting internal threads inside a hole so that screws or bolts can be securely fastened into it.
Tempering	Tempering is a heat treatment process applied to hardened metals, particularly steel, to reduce brittleness and improve toughness.

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Tensile Strength	The maximum stress a material can withstand while being stretched or pulled.
Terrain	the physical features, layout, and characteristics of a specific area of land
Thermal properties	refers to the use of heat to alter or treat materials, typically to achieve a specific desired outcome such as strengthening, shaping, or preserving.
Thermosiphon cooling	Using a natural convection process to cool engines.
Threading	refers to the process of creating a helical ridge, or thread, on a cylindrical workpiece.
Transformation	refers to the changes in the phase or microstructure of a material as a result of changes in temperature, pressure, or composition.
Traverse	Traverse can be referred to as the movement of a machine part (like a cutting tool or workpiece) along a specified path or axis, such as the horizontal or vertical movement in milling machines or lathes.
Trepanning	A technique used for drilling larger hole diameters where machine power is limited, as it is not as power-consuming as conventional drilling, where the entire hole is converted into chips.
Troubleshooting	The process of diagnosing and fixing problems in soldered connections or circuits.
Twist drill	is a common type of drill bit used to create holes in materials like metal, wood, and plastic.
Undercutting	refers to a machining process where material is removed from an area below the surface of a workpiece, creating a recess or groove.
Up milling	is a machining process in which the cutter rotates in the opposite direction to the movement of the workpiece. Here are some key features and characteristics of up milling.

Variables	Factors or elements that can change and affect the outcome of a process or experiment.
Versatility	refers to the ability of the casting process to produce a wide range of parts, from simple to complex shapes, using various metals and alloys.
Water-cooled	Cooling system using water or coolant to dissipate heat from engine.
Waxes	Waxes are primarily used in the lost wax casting process (also known as investment casting).
Wobble	A side-to-side movement or oscillation of the wheel caused by dynamic imbalance.
Working drawing	is a detailed and precise set of technical drawings used in construction, manufacturing, or engineering projects.
Workpiece	The piece of material being shaped in a forging, rolling, or extrusion process.

This book is intended to be used for the Year Two Automotive and Metal Technology Senior High School (SHS) Curriculum. It contains information and activities to support teachers to deliver the curriculum in the classroom as well as additional exercises to support learners' self-study and revision. Learners can use the review questions to assess their understanding and explore concepts and additional content in their own time using the extended reading list provided.

All materials can be accessed electronically from the Ministry of Education's Curriculum Microsite.

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