MINISTRY OF EDUCATION

Automotive and Metal Technology

(Applied Technology)

for Senior High Schools

TEACHER MANUAL

YEAR 2

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

MINISTRY OF EDUCATION

REPUBLIC OF GHANA

Automotive and Metal Technology

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TEACHER MANUAL

Year Two

NATIONAL COUNCIL FOR CURRICULUM & ASSESSMENT OF MINISTRY OF EDUCATION

AUTOMOTIVE AND METAL TECHNOLOGY TEACHER MANUAL

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Introduction

The National Council for Curriculum and Assessment (NaCCA) has developed a new Senior High School (SHS) curriculum which aims to ensure that all learners achieve their potential by equipping them with 21st Century skills, competencies, character qualities and shared Ghanaian values. This will prepare learners to live a responsible adult life, further their education and enter the world of work.

This is the first time that Ghana has developed an SHS 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.

This Teacher Manual for Automotive and Metal Technology (Applied Technology) is a single reference document which covers all aspects of the content, pedagogy, teaching and learning resources and assessment required to effectively teach Year Two of the new curriculum. It contains information for all 24 weeks of Year Two including the nine key assessments required for the Student Transcript Portal (STP).

Thank you for your continued efforts in teaching our children to become responsible citizens.

It is our belief that, if implemented effectively, this new curriculum 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.

Acknowledgements

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SECTION 1: ENGINE COOLING, HEAT TREATMENT AND MACHINES I

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section, learners will acquire knowledge and understanding of engine cooling systems, the construction and operation of the air-cooling systems and the construction and operation of the thermosyphon and pump-assisted water-cooling systems. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of various heat treatment processes with engineering examples and knowledge of the twist drill, uses of drilling and grinding machines. All the above are treated from unit 1 to unit 4.

UNIT 1

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems.*

HINT

- *Assign Group Project in Week 2. This should be submitted after week 7. Refer to Teacher Assessment Manual and Toolkit pages 27-29 for how to conduct Project-Based Assessment. Refer to* ***Appendix A*** *which has been provided at the end of the section for the structure and rubrics of the group project.*
- *Assign Portfolio Assessment for the Academic Year by Week 3. Portfolio to be submitted by week 22. Refer to the Teacher Assessment Manual and Toolkit pages 22-25 for information on how to conduct Portfolio Assessment. Refer to* ***Appendix B*** *which has been provided at the end of the section for the structure and mark scheme/rubrics of the group project.*

INTRODUCTION AND UNIT SUMMARY

Studying air-cooled engines is important for developing technical skills, understanding fundamental engineering concepts, improving economic and environmental efficiency, appreciating historical developments and enhancing career opportunities. Air-cooled engines are excellent educational tools due to their relative simplicity, allowing learners to easily understand and visualise the working principles of internal combustion engines. Teaching by looking at engine air cooling systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the air-cooled engines. By incorporating a mix of DOK levels, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the main components and the working principle of an air-cooled engine.

- **The unit covers only week 1:** *Explain the engine cooling system and describe the construction and operation of the air-cooling systems.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching engine air-cooling systems can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate the main components and the working principle of an air-cooled engine, the teacher should employ a variety of strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding of air-cooled engine systems.

ASSESSMENT SUMMARY

When teaching about engine air cooling systems, assessments can span various levels to gauge learners' understanding and application of the concepts. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to engine air cooling systems. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 1

Learning Indicator: *Explain engine cooling systems and describe the construction and operation of the air-cooling systems*

Focal Area 1: Introduction to The Engine Cooling System

When an internal combustion engine is operating, a very large amount of heat is produced. Some of this heat is converted to mechanical energy in the engine, but a large proportion is wasted. In total, about 50% of the heat is lost down the exhaust, and about 25% is converted in the engine. The other 25% causes heat to build up around the engine. If this heat build-up is not controlled, then the engine components would get so hot that they would melt or at least cause the engine to seize up due to expansion. This is where the cooling system comes in.

Terminology in Engine Cooling System

1. **Coolant:** The liquid used to take heat from different parts of the engine, particularly the cylinder head around the combustion area. The coolant used for most motor vehicles is a mixture of water and antifreeze.
2. **Radiator:** Fitted in the air stream, the radiator allows excess heat to pass to the atmosphere. This is not as the name suggests by radiation but mostly by convection.
3. **Thermostat:** A temperature-controlled valve or tap to allow coolant to heat up more quickly and then be kept at a constant temperature by opening and closing automatically.
4. **Antifreeze:** An additive to a water-cooling system to prevent water from freezing. The most common type is made from ethylene-glycol. Some antifreeze also helps to inhibit corrosion.
5. **Core plugs:** When engine blocks are cast, holes are needed to construct water ways. Metal plugs are then used to seal these off. If the coolant freezes, the core plugs should be forced out rather than the block cracking.
6. **Air cooling:** Fins are used to dissipate the heat from the engine. A large fan is also needed to force air over the fins.
7. **Pressure cap:** Fitted to the radiator or a header tank, the cap allows the coolant pressure to build up to a set level. This increases the boiling point of the coolant and reduces the risk of boiling over.
8. **Water pump:** A belt driven pump used to circulate the coolant
9. **Cooling fan:** A fan driven by an electric motor or the engine. It is used to increase air flow over the engine and/or the radiator.
10. **Viscous coupling:** A thermally controlled coupling between the engine drive and a cooling fan. This only allows the fan to be coupled when it is required, so reducing drag.
11. **Drive belt:** Many engines now drive the water pump from the camshaft belt. Some use the fan belt, as traditionally it was used to drive the fan from the engine front pulley.

12. **Heater:** Some of the excess heat is used to work the car interior heater. Water systems use a separate small radiator inside the car, together with a blower motor.

Methods of Cooling

- Air cooled system
- Water cooled system

Water cooling is the best and most popular method, but many vehicles rely on air cooling. The basic principle of a cooling system is that excess or unwanted heat is passed to the surrounding air by either cooling fins (air cooling) or by a radiator (water cooling).

FOCAL AREA 2: Engine Air Cooling Systems

An engine air-cooled system refers to a cooling method where the heat generated by the engine is dissipated primarily through direct contact with ambient air, rather than using a liquid coolant. This type of cooling is commonly found in certain types of engines, especially smaller engines like those in motorcycles, some older cars and aircraft engines.

Key Features and Components of an Air-Cooling engine

1. **Fins:** Metal fins are attached to the engine cylinders and cylinder heads. These fins increase the surface area available for heat dissipation.
2. **Fan:** Many air-cooled engines use a fan to force air over the fins. This ensures a constant supply of air, even when the vehicle or machinery is stationary or moving slowly.
3. **Shrouds:** These are metal or plastic covers that direct the airflow from the fan over the fins and around the engine to maximise cooling efficiency.
4. **Materials:** Components are often made from or coated with materials that conduct heat well, such as aluminium.

Working Principle of Air-Cooling System

The internal combustion process generates a significant amount of heat, primarily in the cylinders. The heat is transferred from the engine components to the fins, which are in direct contact with the cylinders and cylinder heads. As air passes over the fins, it absorbs the heat from the metal surfaces. The heated air is then expelled away from the engine, dissipating the heat into the atmosphere.

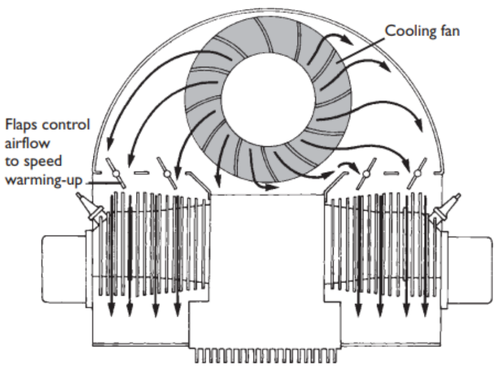


Figure 1.1: *Air cooled system*

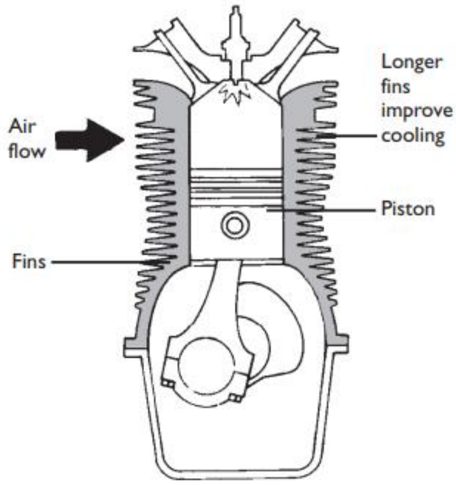


Figure 1.2: *Air cooled system showing cooling fins*

Common Applications

1. **Motorcycles:** Many motorcycles use air-cooled engines due to their simplicity and lightweight design.
2. **Small Aircraft:** The simplicity and reliability of air-cooled engines make them suitable for light aircraft.
3. **Lawn Equipment:** Lawnmowers and other small engines such as chainsaws and leaf blowers often use air cooling due to their simplicity and low cost.
4. **Classic Cars:** Some older automobiles, like the Volkswagen Beetle and Porsche 911, originally used air-cooled engines.

Example of air-cooled engines

1. **Volkswagen Beetle:** One of the most famous vehicles with an air-cooled engine.
2. **Porsche 911 (early models):** The original models used air-cooled engines before transitioning to water-cooled designs.
3. **Harley-Davidson Motorcycles:** Many models use air-cooled V-twin cylinder engines.

Advantages and disadvantages of air-cooled system

Table 1.1 **Advantages and disadvantages of air-cooled systems**

Advantages	Disadvantages
It is simple in design and construction.	There is uneven cooling of engine parts.
Water jackets, radiators, water pump, thermostat, pipes, hoses are not required. Therefore, no leaks or freeze ups of the water.	Engine temperature is generally high during working period.
It is more compact.	Not suitable for in-line engines due to heat build-up.

Lighter in weight.	Noisier because water reduces vibrations.
Operates in all climates.	Fan absorbs a significant amount of power from the engine.

Learning Tasks

1. Examine a real cooling system to see the layout and be able to name and state the purpose of all the parts.
2. Make a simple sketch to show the layout of an air-cooled system and describe the operation.
3. Describe three advantages and disadvantages of air-cooling systems over water cooled systems.

PEDAGOGICAL EXEMPLARS

1. **Problem based Learning:** Learners brainstorm in groups to discuss the purpose of cooling system and the two main types of engine cooling system.

   Assist learners to examine the layout and the main components of air-cooling systems on a motor vehicle and present a report for discussions.

   Have learners compare air-cooled and water-cooled engines. They can create charts or presentations that outline the advantages and disadvantages of each system.

2. **Experiential learning**

   Learners visit the school workshop to observe the working principle of air-cooled engines.

   Organise visits to workshops, motorcycle factories, or other places where air-cooled engines are used and serviced.

   Invite professionals, such as mechanics or engineers, to talk about their experiences with air-cooled engines. They can provide practical insights and answer questions from the learners.

KEY ASSESSMENTS

Level 2

1. Explain with a simple layout the main components of an air-cooled engine
2. Explain how an air-cooled engine work and state two common applications for air-cooled engines.

Level 3

1. Why are fins important in air-cooled engines?
2. What are the advantages and disadvantages of air-cooled engines over water-cooled engines?

HINT

*The recommended mode of assessment for week 1 is **class exercise.** You may use the key assessment level 2 question 1 as a sample question.*

UNIT 1 REVIEW

This unit reviews the main components and the working principle of an air-cooled engine which is important for several reasons, ranging from the theoretical understanding to practical applications as well as opportunities for skill development. They are essential for beginners learning the basics of engine sub systems. The lesson equips the learners with the purpose of engine cooling, the main components and essential parts of air-cooled engine, advantages and disadvantages of air cooled over water cooled engines and air-cooling system applications. Pedagogical exemplars such as problem based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of air-cooled engines. Assessment levels 2 and 3 are used to effectively measure and foster learners' depth of understanding, critical thinking skills, and ability to apply theoretical knowledge to practical scenarios within the context of engine air-cooling system.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the purpose and the type of engine cooling system?
3. Were learners able to identify the main components of an air-cooled engine?
4. Were the learners able to describe the working principle and applications of air-cooled engines?
5. Which resources best supported the delivery of air-cooled engines in automotive?
6. Did learners find the resources useful in studying the air-cooled engines?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 2

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines.*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines*

INTRODUCTION AND UNIT SUMMARY

This unit covers heat treatment of plain carbon steels and the various heat treatment processes with their engineering applications. The importance of studying heat treatment processes cannot be overlooked when the properties of the materials for a given metal work project needs to be improved. The unit highlights the meaning of heat treatment, objectives of heat treatment, classification of heat treatment and some common heat treatment processes. The unit also focuses on some key factors of heat treatment and the iron-carbon equilibrium diagram. Teaching heat treatment of metals involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches, learners can acquire a comprehensive and effective learning experience in studying the processes involved in heat treatment of metals. By incorporating a mix of DoK levels, teachers can accommodate different learning needs of the learners and ensure that learners develop a deep understanding of heat treatment processes with their engineering applications.

- ***The unit covers only week 2****: Describe various heat treatment processes with engineering examples*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, learners must explain heat treatment, the common processes in heat treatment and some key factors that influence heat treatment. Teachers should employ pedagogies such as groupwork/collaborative learning and problem-based learning. These strategies should be used in mixed-ability and mixed-gender groupings, in pairs and individual learning. Learners should be encouraged to participate fully in investigations and present findings. Teachers should employ differentiation strategies to accommodate diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of heat treatment and the processes involved, learners must show how they apply the concepts in real-world situations. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, and scores on practical group activities covering the basics of heat treatment processes which are valuable and widely used. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 2

Learning Indicator: *Describe various heat treatment processes with engineering examples and explain equilibrium diagrams.*

FOCAL AREA 1: Heat Treatment Of Plain Carbon Steels

Heat treatment is heating carbon steel to a predetermined temperature and cooling it at a suitable rate to obtain specific properties.

The properties obtainable from the process can be grouped as follows:

1. Making steel hard to cut other materials or resist wear.
2. Making steel, soft and plastic for further machining or for cold working processes to be performed.
3. Reducing internal stresses caused during heat treatment and to make it tough to resist shock loads.
4. Producing a hard surface with a soft core on a ductile material.

Objectives of Heat Treatment

1. **Hardening:** Increasing the hardness of a metal to make it more resistant to wear and abrasion.
2. **Softening:** Reducing hardness to improve ductility and workability, making the metal easier to shape or machine.
3. **Stress Relief:** Reducing internal stresses caused by previous manufacturing processes like welding or casting.
4. **Improving Toughness:** Enhancing the ability of the metal to absorb energy and deform plastically without fracturing.
5. **Improving Wear Resistance:** Making the surface more resistant to wear and erosion.
6. **Refining Grain Structure:** Modifying the size and distribution of grains in the metal to improve mechanical properties.
7. **Improving machinability:** Heat treatment improves machinability through several mechanisms by altering the material's microstructure and mechanical properties to make it easier to cut, shape and finish.
8. **Heat Treatment Classification**

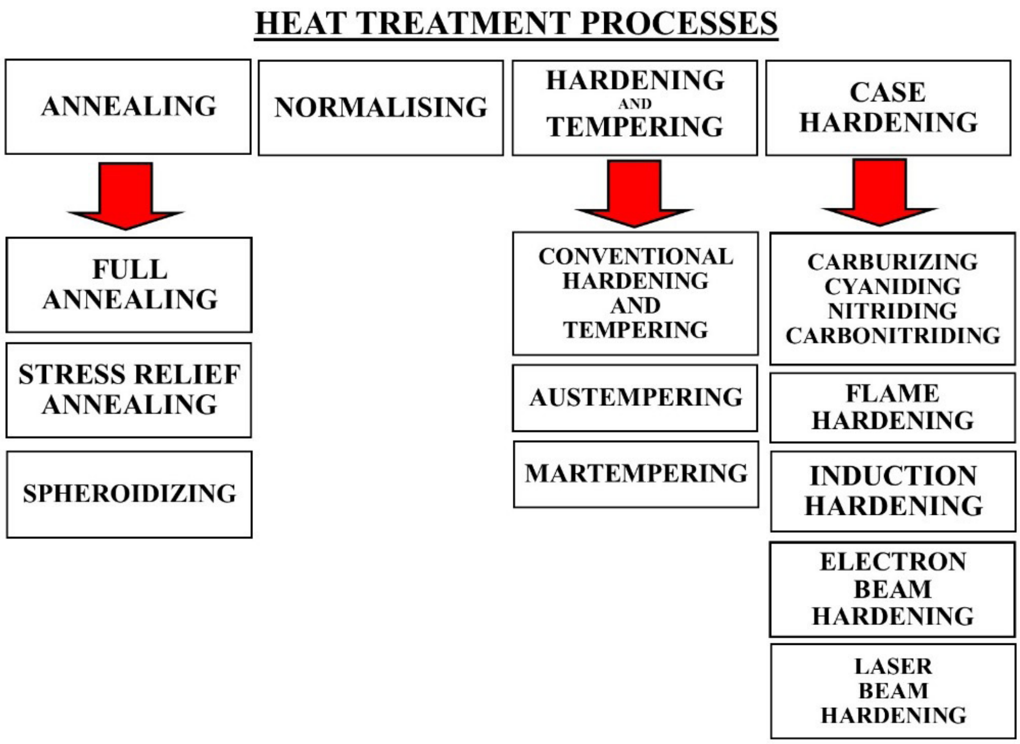


Figure 1.3: *Heat Treatment Process*

Common Heat Treatment Processes

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. There are various forms of annealing process as indicated in the diagram.

   Engineering Applications: 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.

   Engineering Applications: Normalised steels have improved mechanical properties and are 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.

Quenching Mediums

a. **Water:** Water is a commonly used quenching medium for many steels. It provides very rapid cooling rates, which can result in high hardness but may also induce distortion or cracking in some materials due to the rapid thermal contraction.

b. **Oil:** Various types of oils, such as mineral oils 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 distortion and reduced risk of cracking. It is often used for alloy steels and tool steels.

c. **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 certain applications.

d. **Polymer Quenchants:** Polymer solutions or synthetic quenching fluids offer even slower cooling rates than oil. They are used when minimal distortion and high toughness are required, especially for parts with complex shapes.

e. **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 specialized equipment and handling due to the high temperatures involved.

f. **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 distortion.

g. **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.

Engineering Applications: 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.

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.

   Engineering Applications: Tempered steels strike a balance between hardness and toughness, making them suitable for a wide range of applications including shafts, springs, and machine parts where a combination of strength and toughness is required.

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. This technique is valuable because 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.

6. **Carburising:** is a method of case hardening that involves heating the steel in a carbon-rich atmosphere (often using gases like methane or carbon monoxide) at high temperatures (typically 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: Gears, camshafts, and other components requiring wear resistance and high surface hardness benefit from carburising.

7. **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.

   Engineering Applications: Components such as crankshafts, piston rods, and valves benefit from nitriding due to improved wear and fatigue resistance.

Key Factors in Heat Treatment

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 (e.g., vacuum, inert gas) can affect surface chemistry and prevent oxidation.

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 fundamental in materials science and metallurgy because it helps in understanding the properties and behaviour of steels and cast irons, which are the most commonly used iron-carbon alloys.

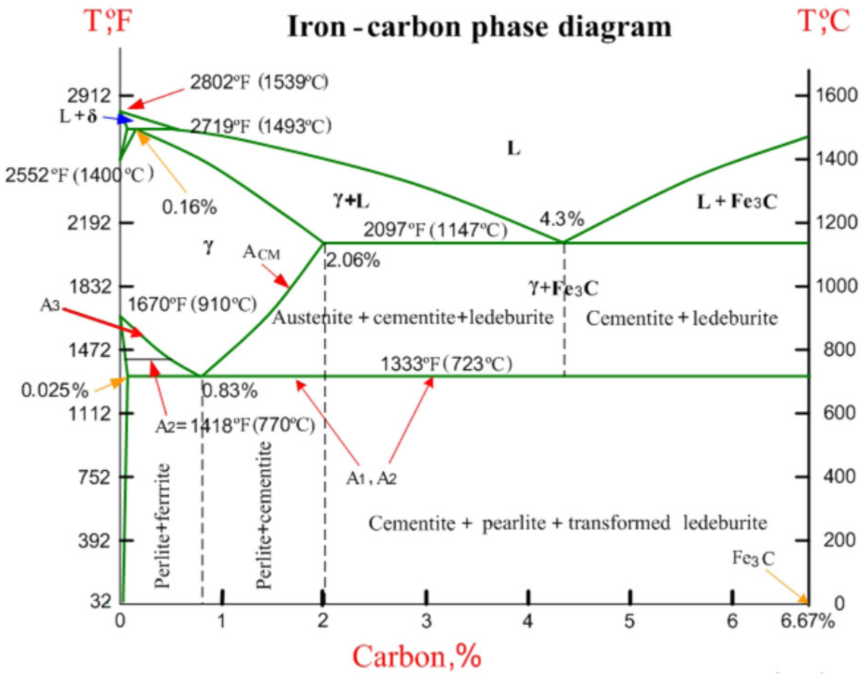


Figure 1.4: *Iron-carbon equilibrium diagram*

Key Features of the Iron-Carbon Equilibrium Diagram

1. **Phases**

   a. **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).

   b. **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).

   c. **Cementite (Fe_3 C):** 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**:

   a. The diagram shows how the phases change with temperature for alloys with different carbon contents.

   b. At low temperatures, the stable phase is ferrite or pearlite (a mixture of ferrite and cementite).

   c. 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.

Practical Applications

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.

Learning Tasks

1. Explain what is meant by ***heat treatment.***
4. Provide reasons why metals should be heat treated.
5. Describe processes of heat treatment of metals.
6. Describe the case hardening process and explain its advantages.
7. Discuss the main difference between carburising and nitriding in case hardening?

Pedagogical Exemplars

1. **Group work/collaborative learning**

   Group learners to discuss and heat treatment of plain carbon steels using video showing the heat treatment processes. Learners should be respectful of each other's views during discussions.

   Assist learners to use the iron carbon equilibrium diagram to explain the behaviour of plain carbon steels when heated and cooled.

2. **Problem-Based Learning**

   Learners carry out experiments to investigate the conventional technique for quenching a plain carbon steel when heated and record their findings.

Key Assessments

Level 1: Explain the term heat treatment.

- **Level 2:** Explain the following heat treatment processes.
  - **a.** Normalising
  - **b.** Tempering
  - **c.** Case hardening
  - **d.** Annealing
- **Level 3:** Explain why a metal should be case hardened?
- **Level 4**
  - **a.** Explain which appropriate heat treatment process would be required to heat treat gears, pistons and crankshafts and how would it be applied.
  - **b.** Discuss 2 relevance of case hardening of metals.

HINT

*Assign Group Project in Week 2. This should be submitted after week 7. Refer to Teacher Assessment Manual and Toolkit pages 27-29 for how to conduct Project-Based Assessment. Refer to **Appendix A** which has been provided at the end of the section for the structure and rubrics of the group project.*

UNIT 2 REVIEW

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

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain heat treatment?
3. Were learners able to explain the methods of heat treatment processes?
4. Were the learners able to apply the knowledge of heat treatment?
5. Which resources best supported the delivery of heat treatment processes?
6. Did learners find the resources useful in using the heat treatment?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 3

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems*

INTRODUCTION AND UNIT SUMMARY

Water-cooled engines are widely used in various applications and learning about them provides a fundamental understanding of how heat is managed in automotive engines. Most modern vehicles use water-cooled engines and therefore knowledge of these systems is crucial for beginners in the automotive technology discipline. The unit presents the main components of water-cooled engines, thermosyphon and pump assisted cooling and their advantages and disadvantages. Teaching engine water cooling system involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the water-cooled engines. By incorporating a mix of DOK levels, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the main components and the various methods used for circulating the water around the engine cylinders.

- ***The unit covers only week 3***: *Describe the construction and operation of the thermosyphon and pump assisted water-cooling systems*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching engine water-cooling systems can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate the main components and the various methods used for circulating the water around the engine cylinders, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to cater to different learning styles and help learners gain a thorough understanding of water-cooled engine systems.

ASSESSMENT SUMMARY

When teaching about water-cooled engine systems and the methods of circulating the water around the engine cylinders, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to water cooled engines. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 3

Learning Indicator: *Describe the construction and operation of the thermosyphon and pump assisted water-cooling systems*

Focal Area 1: Water Cooled Engines

Water cooled engines work by surrounding the hot areas inside the engine with a water jacket. The water takes on heat from the engine and, as it circulates through the radiator, gives it off to the atmosphere. The heat concentrates around the top of the engine, so a water pump is needed to ensure proper circulation. The main parts of a water-cooling system are as follows:

1. **Water jacket**

   A water jacket is a series of passages or cavities that surround the engine's cylinders and sometimes other critical engine parts like the cylinder head. These passages are designed to allow coolant (usually a mixture of water and antifreeze) to flow around the hottest parts of the engine to absorb and carry away excess heat.

2. **Water pump**

   The main function of the water pump is to circulate coolant through the engine, radiator, and heater core. It maintains a steady flow of coolant, ensuring that heat is effectively transferred away from the engine components.

3. **Thermostat**

   The thermostat controls the flow of coolant between the engine and the radiator. It remains closed when the engine is cold and gradually opens as the engine warms up. By regulating the coolant flow, the thermostat ensures the engine quickly reaches and maintains its optimal operating temperature.

4. **Radiator**

   The radiator provides a cooling area for the water and exposes it to the air stream. A reservoir for the water is included in the construction of the radiator. This is known as the header tank and is made of thin steel or brass sheet and is connected to the bottom tank by brass or copper tubes; these are surrounded by fins.

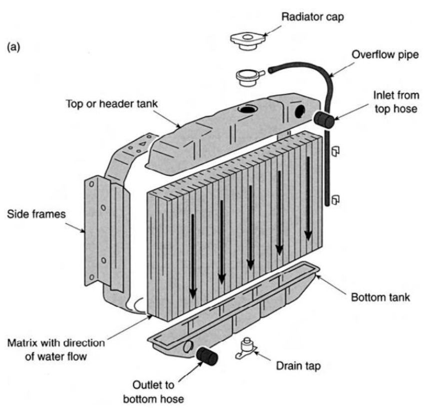


Figure 1.5: *Radiator*

5. **Cooling fan**

   The engine fan, which maintains the flow of air through the radiator, is mounted on the water pump pulley on older systems. Most cooling fans in modern vehicles are now electric. These are more efficient because they only work when needed. The forward motion of the car also helps the air movement through the radiator.

The following are the various methods used for circulating the water around the cylinders.

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

Thermosyphon Cooling

A thermosyphon cooling system is a passive method of cooling that relies on natural convection to circulate a coolant without the need for a mechanical pump.

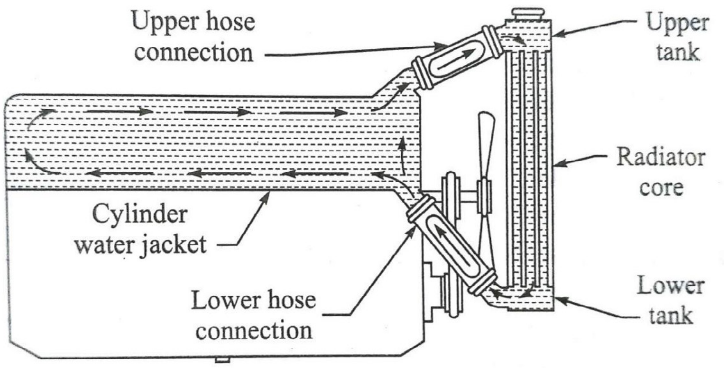


Figure 1.6: *Thermosyphon cooling or natural circulation cooling system*

1. Water circulation occurs due to temperature and density difference and is independent of engine speed.
2. Rate of circulation is slow and insufficient.
3. The circulation of water starts only after the engine has become hot enough to cause thermosyphon action.
4. The radiator should be above the engine to allow gravity flow of water to the engine.

The ***thermosyphon system*** is no longer used in the modern motor vehicle as it has several ***disadvantages***.

1. To ensure sufficient circulation the radiator must be arranged higher than the engine to ensure that the heated coolant will rise into the top of the radiator header tank and the cooled water in the radiator will flow into the bottom of the engine.
2. Water circulation will be slow, so a relatively large amount of water must be carried.

3. Large water passages must be used to allow an unrestricted flow of water around the system.

Advantages of Thermosyphon Cooling Systems

1. **Simplicity:** No moving parts such as pumps, making the system simple and less prone to mechanical failure.
2. **Reliability:** Fewer components mean fewer points of failure, leading to higher reliability.
3. **Low Maintenance:** Minimal maintenance requirements due to the absence of pumps and other mechanical components.
4. **Cost-Effective:** Lower initial and operating costs because of the simplicity and lack of active components.

Pump-Assisted Water Cooled System

The water pump is driven by a V-belt or multi-V-belt from the crankshaft pulley or by the cam belt. The pump is a simple impeller type and is usually fitted at the front of the engine (where the pulleys are). It assists with the thermosyphon action of the cooling system, forcing water around the engine block and radiator.

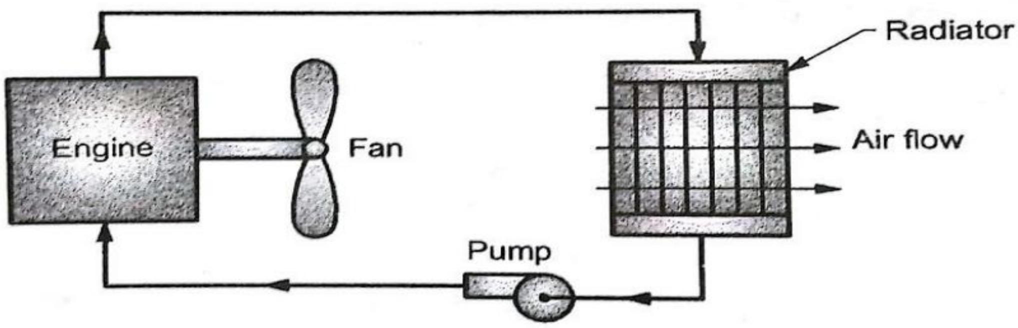


Figure 1.7: *Pump-assisted water-cooled system*

Most modern engines use a pump to provide a positive circulation of the coolant and it gives the following advantages:

1. A smaller radiator can be used than is required in the thermo-syphon system.
2. Less coolant is carried as the water is circulated faster and therefore the heat is removed more quickly.
3. Smaller passages and hoses are used because of (2) above.
4. The radiator does not need to be above the level of the engine, giving a lower bonnet line; this also has the advantage of less wind resistance giving a better fuel consumption.
5. Because the water flow is given positive direction the engine will operate at a more even temperature.

Drawbacks

1. The cooling is independent of temperature. This may under certain circumstances, result in overcooling the engine.
2. While moving uphill the cooling requirement is increased because more fuel is burned. However, the coolant circulation is reduced which may result in overheating of the engine.
3. As soon as the engine is stopped the cooling also ceases. This is undesirable because cooling must continue till the temperature is reduced to normal values.

Learning Tasks

1. Explain the main components and their purposes in the water-cooling system.
2. Describe the thermosyphon cooling system.
3. Describe the pump assisted cooling system.

Pedagogical Exemplars

1. **Group/collaborative learning:** Learners brainstorm in groups to discuss water cooled engines.

   Assist learners to examine the layout of thermosyphon and pump assisted water-cooling systems on a motor vehicle and present a report for discussions.

   Encourage learners to work in groups to tackle problems in thermosyphon and pump assisted promoting teamwork and the exchange of ideas.

2. **Experiential learning:** Learners will visit a school workshop to identify and observe the working principles of thermosyphon and pump assisted water cooled engines.

   Organise visits to engine manufacturing plants or automotive workshops where learners can see water-cooled engines in production and use.

Key Assessments

Level 2: Sketch the layout of a thermosyphon (natural circulation) system for a water-cooled engine and describe the operation

Level 3

1. How does a thermosyphon cooling system compare to a pumped cooling system?
2. What are the symptoms of the water pump not working? What could be the cause of this fault and how should it be repaired?
3. The layout of a thermosyphon (natural circulation) system for a water-cooled engine.

Scenario: The cooling system of uncle Essoun's BMW failed on Kanda highway.

   a. What are the possible causes?

   b. How can these be remedied?

HINT

Assign Portfolio Assessment for the Academic Year by Week 3. Portfolio to be submitted by week 22. Refer to the Teacher Assessment Manual and Toolkit pages 22-25 for information on how to conduct Portfolio Assessment. Refer to ***Appendix B*** *which has been provided at the end of the section for the structure and mark scheme/rubrics of the group project.*

UNIT 3 REVIEW

This unit reviews the main components of water-cooled engines and the various methods of circulating the water around the engine cylinders which is important for several reasons, ranging from the theoretical understanding to practical applications as well as opportunities for skill development. They are essential for beginners learning the basics of engine sub systems. The lesson equips the learners with the working principles of the thermosyphon and pump assisted cooling systems, along with their advantages and disadvantages. Pedagogical exemplars such as group work/ collaborative learning, problem based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of water-cooled engines. Assessment levels 2 and 3 are used to effectively measure and foster learners' depth of understanding, critical thinking skills, and ability to apply theoretical knowledge to practical scenarios within the context of water- cooled engines.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the main components of water-cooled engines?
3. Were learners able to explain the working principle of thermosyphon cooling system?
4. Were the learners able to describe the working principle of pump assisted cooling system?
5. Which resources best supported the delivery of water-cooled engines in automotive?
6. Did learners find the resources useful in studying the water-cooled engines?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 4

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines.*

INTRODUCTION AND UNIT SUMMARY

Twist drills, drilling and grinding machines are widely used in various manufacturing processes, offering high precision and fine surface finishes. They come in different types, each suited for specific applications and materials. Proper understanding and operation of twist drills, drilling and grinding machines are crucial for achieving optimal results and ensuring safety. The unit presents the main types of twist drills, parts and functions of the drilling and grinding machines focusing on their application. Teaching twist drills, drilling and grinding machines involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying twist drills, drilling and grinding machines. By incorporating a mix of DOK levels, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of twist drills, drilling and grinding machines.

- ***The unit covers only week 4:*** *Describe the twist drill and use drilling and grinding machines*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching twist drills and use of drilling and grinding machines can be carried out by employing various pedagogical examples and activities to ensure comprehensive understanding. For learners to appreciate the use of drilling and grinding machines, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive and theoretical approaches to cater for different learning styles and help learners gain a thorough understanding of twist drills and uses of the drilling and grinding machines.

ASSESSMENT SUMMARY

When teaching twist drills and use of drilling and grinding machines, assessments can span various levels to gauge learners' understanding and application of the concepts. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to twist drills and use of drilling and grinding machines. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 4

Learning Indicator: *Describe the twist drill and use drilling and grinding machines.*

Focal Area 1: Twist Drill, Drilling And Grinding Machines

A drill is a tool used to originate a hole in a solid material. A helical groove known as a '*flute*' is cut along the length of the drill. Different types of drills are:

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.

Figure 1.8: *Straight fluted drill*

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.

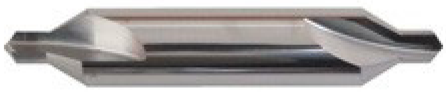


Figure 1.9: *Centre Drill*

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
   a. Straight shank twist drill and
   b. Taper shank twist drill.

   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.

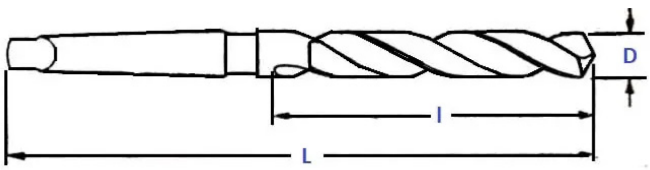


Figure 1.10: *Taper shank twist drill*

Figure 1.11: *Straight shank twist drill*

A ***twist drill*** has three principal parts

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

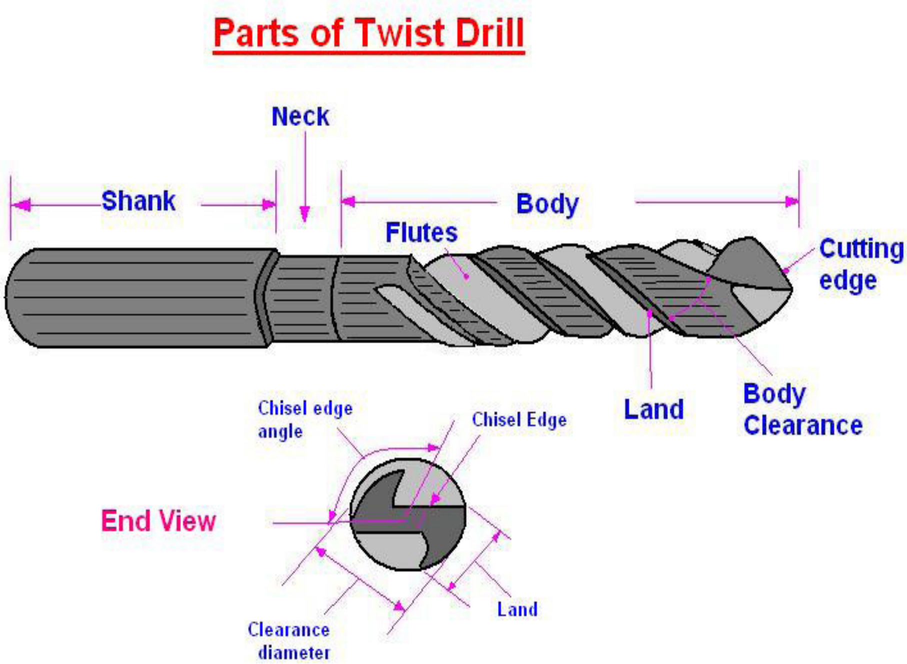


Figure 1.12: *Parts of twist drill*

Twist Drill Nomenclature

1. **Axis:** It is the longitudinal centre-line of the drill.
2. **Diameter:** Largest diameter measured across the top of the lands behind the point.
3. **Back Taper:**
   a. The diameter reduces slightly toward the shank end of the drill, this is known as "back taper".
   b. Back taper provides clearance between the drill and workpiece preventing friction and heat.
3. **Body:** It is the part of the drill from its extreme point to the commencement of the neck.
4. **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 in between body and 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 tang.
8. **Point:** It is the conical sharpened end of the drill. It consists of the following:
   a. **Dead centre:** It is the sharp edge at the extreme tip of the drill. This should always be the exact centre of the drill.
   b. **Lips:** these are the cutting edges of the drill.
   c. **Heel:** It is the portion of the point back from the cutting edge.
9. **Flank:** Surface of drill which extends behind the lip to flute.
10. **Flutes:** The grooves in the body of the drill are known as flutes.
11. **Flute Length**
    a. The length of flute measured from the drill point to the end of the flute runout.
    b. 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:** 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 two cutting lips meet at extreme tip.
16. **Chisel Edge Angle:** Angle between chisel edge and cutting lip measured plane normal to axis.

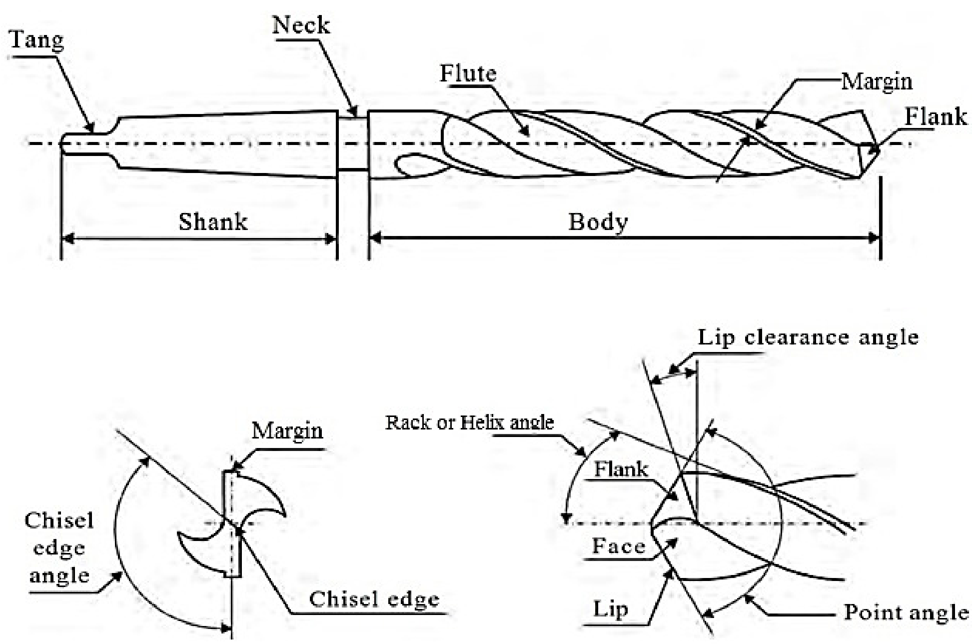


Figure 1.13: *Parts of twist drill*

Focal Area 2: 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 versatile machine tools in a workshop. A drilling machine is also referred to as a Drill Press. The work piece is held stationary i.e. 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 versatile machine tool. Many operations can be performed on it including:

1. **Drilling:** 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.
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 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 counter-sunk rivet. The tool used is known as counter-bore.
5. **Countersinking:** This is the operation of making a cone shaped enlargement of the end of a hole, as for the recess for a flat head screw.
6. **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 counter bore.
7. **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.
8. **Lapping:** This is the operation of sizing and finishing a hole by removing very small amounts of material by means of an abrasive. The abrasive material is kept in contact with the sides of a hole that is to be lapped, using a lapping tool.
9. **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.

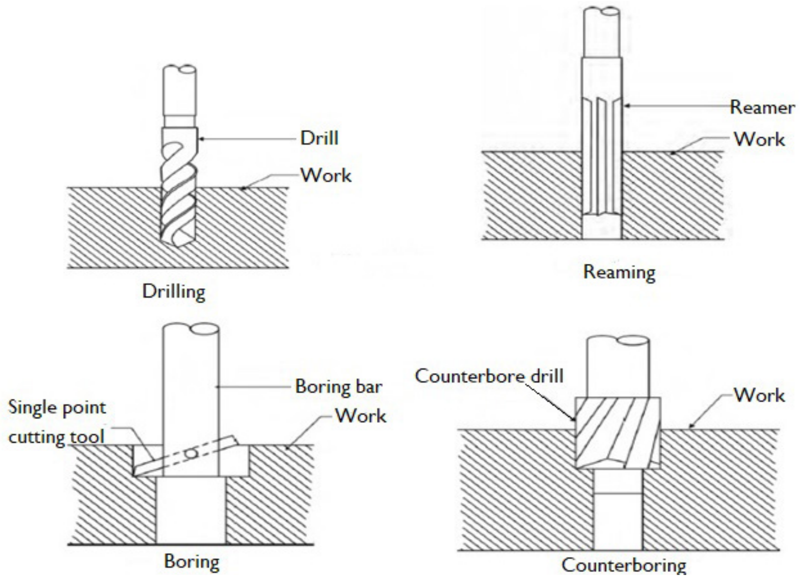


Figure 1.14: *Application of twist drill*

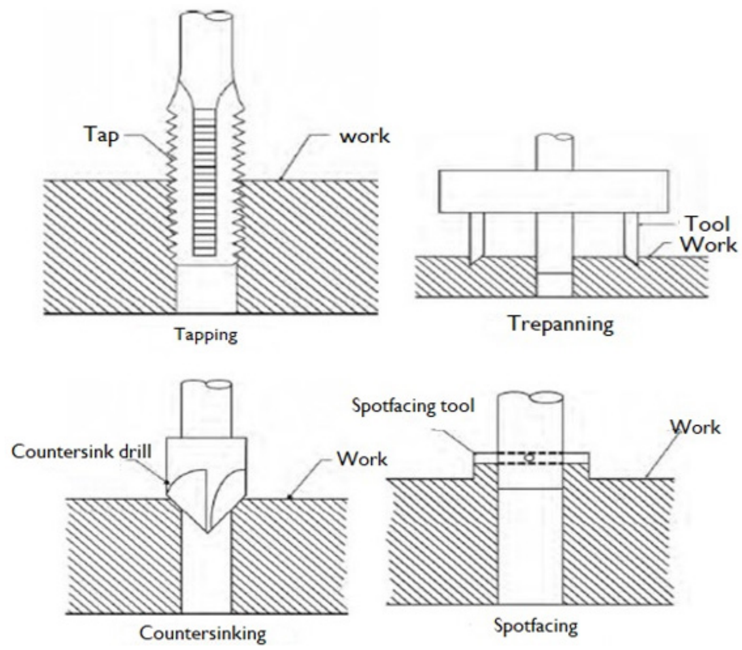


Figure 1.15: *Application of twist drill*

Figure 1.16: *Hole enlarging and finishing tools*

Construction and parts of drilling machine

The drilling machine consists of following parts:

- Base
- Pillar
- Main drive
- Drill spindle
- Feed handle
- Work table

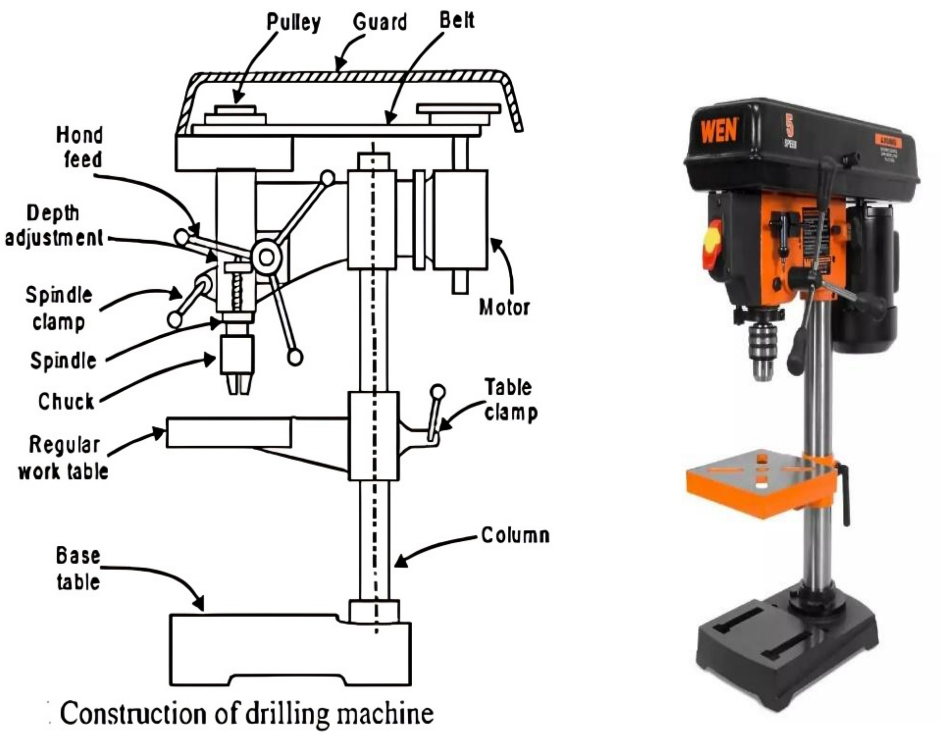


Figure 1.17: *Parts of a drill machine*

Types of Drilling Machines

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

Portable Drilling Machine

1. 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.
2. It may be used for drilling small diameter holes in large castings or weldments at that place where they are lying.
3. Portable drilling machines are fitted with small electric motors, which may be driven by both A.C. and D.C. power supply.
4. These drilling machines operate at fairly high speeds and accommodate drills up to 12 mm in diameter.
5. Portable drilling machine can be carried and used anywhere in the workshop.

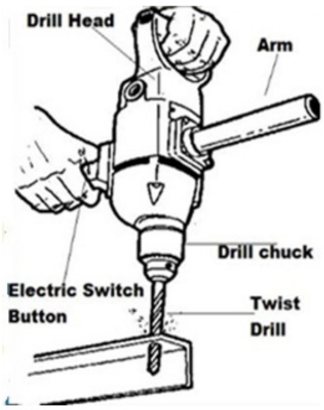


Figure 1.18: *Portable Drilling Machine*

Sensitive Drilling Machine

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

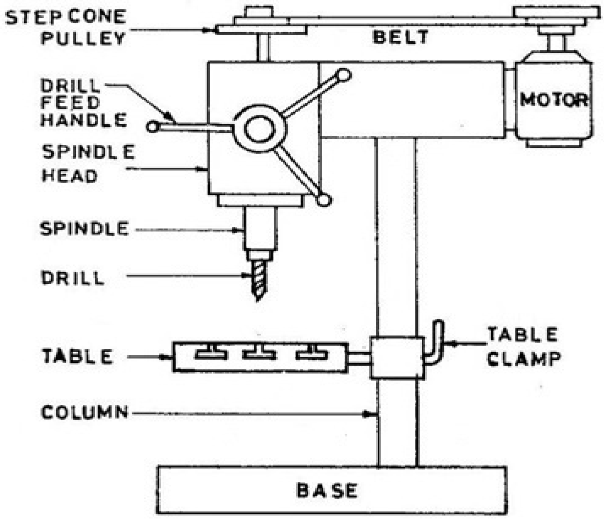


Figure 1.19: *Sensitive drilling machine*

Upright Drilling Machine

1. The upright drilling machine is larger and heavier than a sensitive drilling machine.
2. 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.
3. 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.

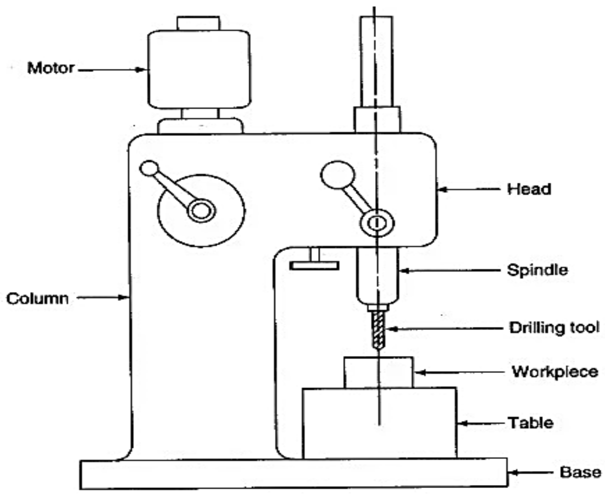


Figure 1.20: *Pillar/Upright Drilling Machine*

Radial Drilling Machine

1. The radial drilling machine consists of a heavy, round vertical column supporting a horizontal arm that carries the drill head.
2. 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.

3. 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.

Figure 1.21: *Radial Drilling Machine*

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

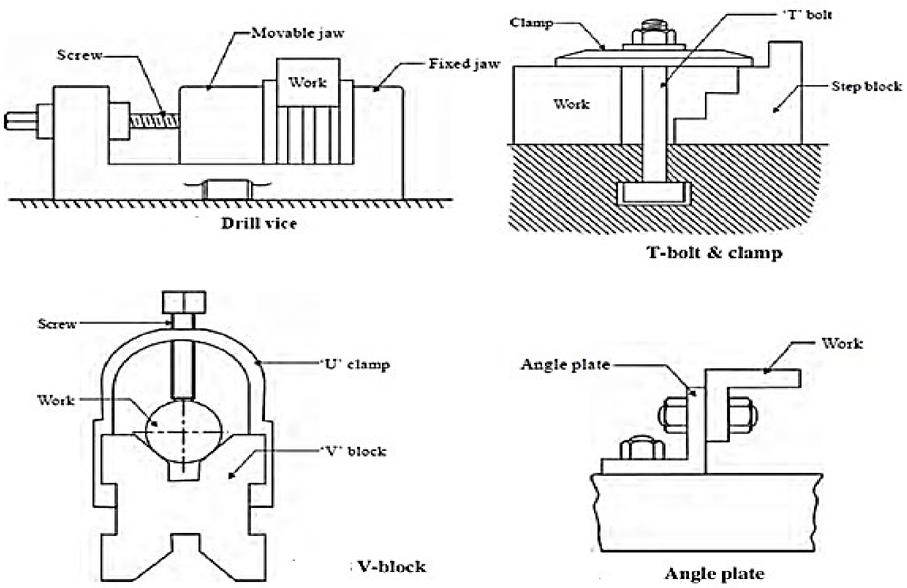


Figure 1.22: Some work holding devices in drilling machines

- **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:

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

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.

Focal Area 3: 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 grinding process is 0.000025mm. The amount of material removed from the work is substantially less than drilling.

Types of grinding machines: According to the accuracy of the work to be done on a grinding machine, they are classified as:

- Rough grinding machines
- Precision grinding machines

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:

   a. **Hand grinding machine:** An angle grinder is a hand-held tool carried to the work, with the disc secured at an angle to the body of the grinder.

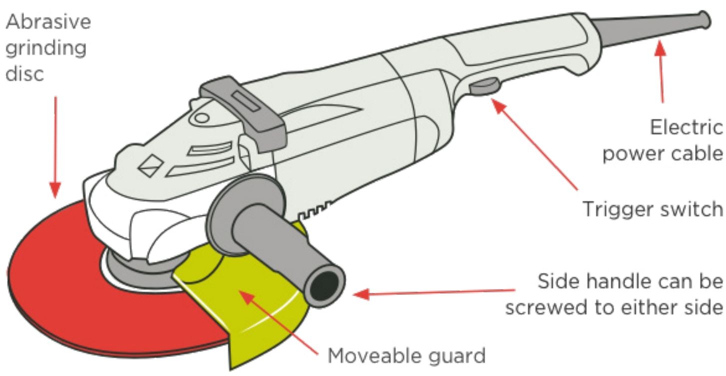


Figure 1.23: *Fixed hand-held grinder*

   b. **Bench grinding machine:** A bench grinder is a benchtop type of grinding machine used to drive abrasive wheels.

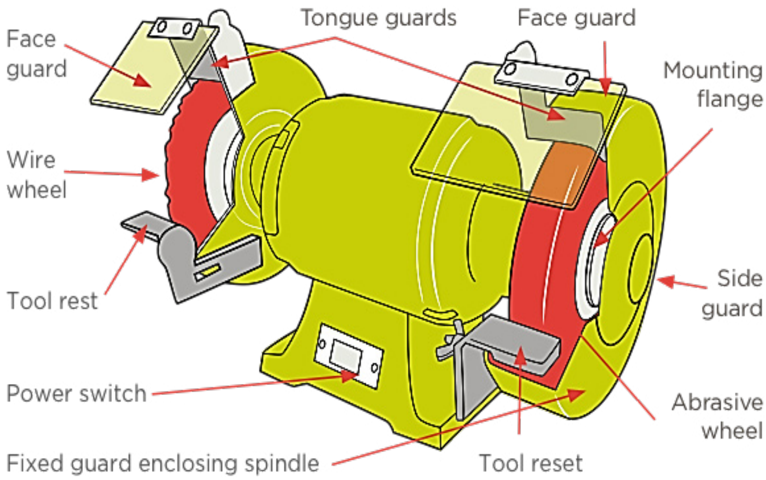


Figure 1.24: *Bench grinding machine*

c. **Floor stands 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.

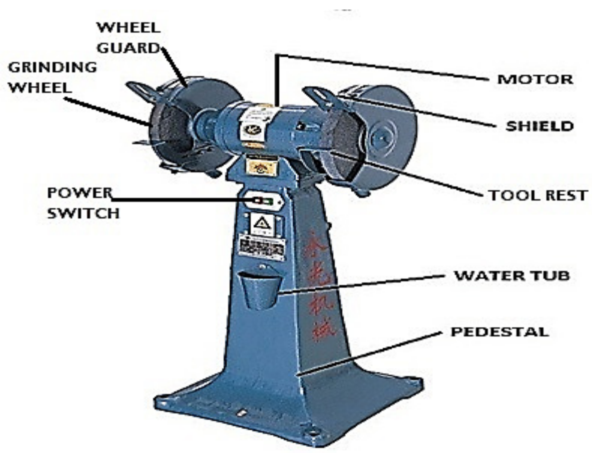


Figure 1.25: *Floor stand/pedestal grinding machine*

Some other types of rough grinding machines are flexible shaft grinding machine, swing frame grinding machine and abrasive belt grinding machine.

2. **Precision grinding machines:** Precision grinders are used to finish parts to very accurate dimensions. The main types of precision grinders are:
   a. Cylindrical grinding machines
   b. Internal grinding machines
   c. Surface grinding machines
   d. Tool and cutter grinding machines
   e. 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

Parameters of grinding operation

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 meter per minute (mpm) or meter per second (mps).
2. **Feed Rate:** Feed rate is a significant parameter in case of cylindrical grinding and surface grinding. Feed rate is defined as longitudinal movement of the workpiece relative to axis of grinding wheel per revolution of grinding wheel.
3. **Depth of Cut:** Depth of cut is the thickness of the layer of the metal removal 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

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:

- Natural abrasives
- Artificial abrasives

1. **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 brick work. There are two types of silicon carbide abrasives - green grit and black grit.
2. **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.
3. **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.

Grinding Terms

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 denoted 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 denoted 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. **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 an 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 grinding zone and wash the clips 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

Table 1.2: Safety measures

	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.
	Sturdy footwear must be worn at all times in work areas.		Close fitting/ protective clothing must be worn.		Rings and jewellery must not be worn.

Learning Tasks

1. Identify and explain the functions of the parts of the twist drill.
2. Explain the parts of the drilling machine and name some types of drilling machine.
3. Describe the operations to be performed on a drilling machine.
4. Identify and explain the types of grinding machines and grinding wheels.

Pedagogical Exemplars

1. **Group work/Collaborative learning:** Assist learners in mixed ability groups to describe the twist drill and perform operations using drilling and grinding machines.
2. **Experiential Learning**

   At the workshop, assist learners to describe the twist drill and identify the major parts of the drilling and grinding machines and brainstorm their functions.

   Visit a local workshop with learners, help them to identify the twist drill, and observe and demonstrate the use of the grinding and drilling machines.

Key Assessment

Level 2

1. Sketch, label and explain any four parts of the twist drill.
2. Describe the differences between portable drilling, bench/sensitive drilling and pillar/ upright drilling machines.
3. Explain the following drilling operations:
   - **a.** Reaming
   - **b.** Boring
   - **c.** Countersinking

d. Counter boring

e. Tapping

Level 3

1. Compare the steps one would take to change parallel and taper shank drill bits on a drilling machine.
2. Sketch the pedestal grinding machine and label the parts. Give an account of how to dress a glazed grinding wheel.

HINT

*The recommended mode of assessment for week 4 is **quiz. You may** use the key assessment level 2 question 3 as a sample question. Refer to the Teacher Assessment manual and Toolkit page 52 for further information on how to go about this mode of assessment*

UNIT 4 REVIEW

This unit provided an in-depth description of the twist drill and the use 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. This unit provided suggested appropriate pedagogical strategies for the teacher to employ during lesson delivery.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain twist drills?
3. Were learners able to explain the functions of the parts of the drill?
4. Were learners able to apply the knowledge gained on drills to create holes in workpieces?
5. Which resources best supported the teaching and learning of twist drill, drilling, grinding and lathe machines?
6. Did learners find the resources useful?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

APPENDIX A: GROUP PROJECT

PROJECT STRUCTURE & GUIDE

1. *Project Title (Heading)*

- Choose a short and clear heading for your project.
- Make sure it:

  a. Clearly shows what your project is about.

  b. Is concise *(not too long).*

  c. Accurately reflects the project's content.

2. *Project Design Brief*

- Write **50–60 words**.
- Clearly state:

  a. The aim of your project.

  b. What you will do or produce.

  c. The importance or purpose of the project.

  d. Any keywords spelled correctly.

- **Example**

  This project explores how solar cookers can be built using recycled materials. It aims to design a cost-effective and eco-friendly cooking device suitable for rural communities. The cooker will be tested for efficiency in boiling water. This approach promotes renewable energy use and reduces reliance on firewood.

3. *Team Roles & Responsibilities*

- List **each group member's role** *(e.g., researcher, designer, builder, recorder, presenter).*
- Agree on **how you will work together**

  a. Contribute to the group effort.

  b. Respect and listen to everyone's views.

  c. Tolerate different opinions.

  d. Resolve conflicts respectfully.

  e. Take responsibility for tasks.

4. *Research & Planning*

- Collect information related to your topic.
- Identify the materials, tools, and methods you will use.
- Plan the **step-by-step process** for completing the project.

- Draw a simple **project timeline** showing what will be done each week.

5. *Building/Creating the Project*

- Follow your planned steps carefully.
- Ensure the **final work meets specifications**
  - **a.** Functions as intended.
  - **b.** Is accurately documented (notes, measurements, processes).
  - **c.** Is eco-friendly where possible.
  - **d.** All parts are functional and safe.

6. *Testing & Refinement*

- Test your final work to see if it meets the purpose.
- Record results *(photos, tables, or written notes)*.
- Make improvements if needed.

7. *Final Report & Presentation*

Your final report should have:

a. **Title Page** – Project heading, group members' names, date.

b. **Design Brief** – Your 50–60 word project summary.

c. **Process Description** – Step-by-step explanation of how you completed the project.

d. **Results & Findings** – What happened when you tested your project.

e. **Conclusion** – Lessons learned, challenges faced, and how you solved them.

f. **References** – If you used any books, websites, or interviews.

g. **Presentation Plan** – Who will present what part during the final sharing.

8. Submission Checklist

Before you submit, check:

- Heading meets all criteria.
- Design brief is 50–60 words.
- All team members contributed.
- Technical specifications met.
- Work is eco-friendly and documented.
- Report is well-organised.

Table 1.3: Scoring Rubric

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
Heading (Caption of the Project)	Heading includes **4** of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes **3** of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes **2** of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 1 of the following; clear, concise, accurately reflects the project's content and follow syntax rule.
Project Design Brief	Brief is based on 4 of the following: has project specification, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 3 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 2 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 1 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords
Team work	Exhibit **4** of these Contributing to the group. Respecting the views of others Tolerating others Resolving conflicts Taking responsibility	Exhibit **3** of these Contributing to the group. Respecting the views of others Tolerating others Resolving conflicts Taking responsibility	Exhibit **2** of these Contributing to the group. Respecting the views of others Tolerating others Resolving conflicts Taking responsibility	Exhibit **1** of these Contributing to the group. Respecting the views of others Tolerating others Resolving conflicts Taking responsibility
Technical Specification	Final work shows **4** of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows **3** of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows **2** of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows **1** of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.

Appendix B: Sample Portfolio Assessment

Task: Compile and submit a comprehensive portfolio that represents your work for the entire academic year. The portfolio should include a selection of exercises/assignments, project work, reflective pieces, and both mid-semester and end of semester examination papers.

Structure and Organisation of the Portfolio

As part of the structure of the portfolio assessment, make sure the following information has been provided:

1. Cover Page with
   a. *learner's name*
   b. *class*
   c. *subject*
   d. *period/date, etc.*
2. Table of Contents which has the list of items included with page numbers.
3. Brief description/background of items such as background information for each included artefact, etc.

Learners' works to be included in the Portfolio

1. Class Exercises/Assignments
2. Folios
3. Project works
4. Mini-research work
5. Mid-semester examination papers
6. End of semester examination papers, etc.

Mode of Administration for Portfolios

1. Clearly explain the purpose of the portfolio and its various components to the learners. Provide examples and templates for each section to guide them in their work.
2. Set up regular review sessions, every 4 weeks, to monitor learners' progress. During these checkpoints, they offer feedback and guidance to help them improve their portfolios.
3. Share the scoring rubrics with the learners and thoroughly explain how their work will be evaluated.

Set the final due date for portfolio submission in Week 22 of the academic calendar. Offer a grace period for learners to make revisions based on the final feedback they receive.

Mode of Submission/Presentation

1. Clearly inform all learners of the final deadline for portfolio submission to ensure that all work is completed and submitted on time.
2. Learners should organise their portfolios in a clear and logical manner, with each section clearly labelled and easy to access.
3. Learners may submit their portfolios either in physical form or via the school's online submission system.
4. For digital submissions, learners should upload their portfolios either as a single file or in well-organised folders within the online platform.
5. Ensure the portfolio contains all required components: assignments, projects, quizzes, tests, reflective pieces, mini-research work, as well as mid-semester and end of semester examination papers.

Feedback Strategy

1. Schedule regular meetings to review learners' progress, set new goals, and make any necessary adjustments to their learning strategies.
2. Provide helpful comments throughout the learning process to support learners' development. Ensure that learners clearly understand how to use this feedback to continually improve their work and achieve better results.

Table 1.4: Scoring Rubric/ Marking scheme

Learner's pieces of work	Items	Marks per Item	Total Marks
Assignments/Exercises	2	1 mark each	2 marks
Projects works (Individual/ Group)	2	2.5 marks each	5 marks
Mini-project work	1	2 marks	2 marks
Folio	1	2 marks	2 marks
Mini-research Work	1	2 marks	2 marks
Mid-semester Examination Papers	2	2 marks each	4 marks
End of semester Examination Paper	1	3 marks	3 marks
Total Marks			20 marks

SECTION 2: ENGINE COOLING AND LUBRICATION AND MACHINES II

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section, learners will acquire knowledge and understanding of engine cooling systems, the construction and operation of the air-cooling systems and construction and operation of the thermosyphon and pump assisted water-cooling systems. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of various heat treatment processes with engineering examples and twist drill, uses of drilling and grinding machines. All the above are treated from unit 5 to unit 8.

UNIT 5

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems*

HINT

Mid-Semester Examination for the first semester is in Week 6. Refer to ***Appendix C*** *for the structure and table of specifications to guide you in setting the questions. Set questions to cover all the indicators covered for at least weeks 1 to 5.*

INTRODUCTION AND UNIT SUMMARY

Thermostats and pressurised cooling in an engine are essential for ensuring the engine operates efficiently, reliably, and safely. They play a critical role in temperature regulation, affecting fuel efficiency, emissions, component longevity, and overall performance. The unit covers the working principle of the thermostat, pressurised cooling systems, sealed cooling system and the comparison of air and water-cooled engines. Teaching these systems involve various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners will acquire a comprehensive and effective learning experience in studying the thermostat and pressurised cooling system. By incorporating a mix of DOK levels, teachers can tailor their instruction to different learning needs of the learners and ensuring that the learners develop a deep understanding of the working principle of thermostat, pressurised and sealed cooling system, and compare the advantages and disadvantages of air and water-cooled engines.

- ***The unit covers only week 5:*** *Describe the construction and operation of the thermostat and pressurized water-cooling systems*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the working principles of thermostats, pressurised and sealed cooling systems can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate the water-cooling systems and their operations, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of thermostat and pressurised cooling and other associated systems.

ASSESSMENT SUMMARY

When teaching the working principle of thermostat, pressurised and sealed cooling systems, assessments can span various levels to gauge learners' understanding and application of the concepts and the principles. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to thermostat, pressurised and sealed cooling systems. This approach will ensure a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 5

Learning Indicator: *Describe the construction and operation of the thermostat and pressurised water-cooling systems.*

Focal Area 1: Thermostat

A thermostat is a temperature-controlled valve. Its purpose is to allow coolant to heat up more quickly and then be kept at a constant temperature. The total coolant volume in an engine takes time to heat up. Modern engines run more efficiently when at the correct operating temperature. The thermostat prevents coolant circulation from the engine to the radiator until a set temperature is reached. When the valve opens, the coolant can circulate fully, and a good cooling action occurs because of full flow through the radiator.

The thermostat's constant action ensures the engine temperature remains constant. Almost all modern engines use a wax capsule type thermostat as compared to the bellow type. The figure below shows how this type works. Electronic thermostats are controlled by the engine control unit (ECU) for more precise temperature regulation. It uses sensors and actuators to open and close the valve. If the thermostat is faulty, ensure the correct type for the engine is fitted as some work at different temperatures.

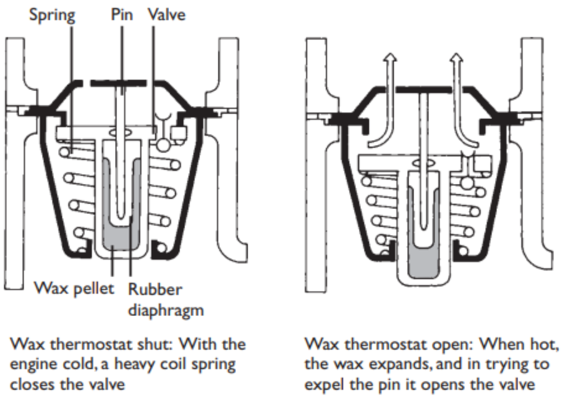


Figure 2.1: *Thermostat operation*

Pressurised Water Cooling

Pressurised cooling systems are used because they allow the engine to operate at a higher temperature. Figure below shows the layout and main components of a modern pressurised system.

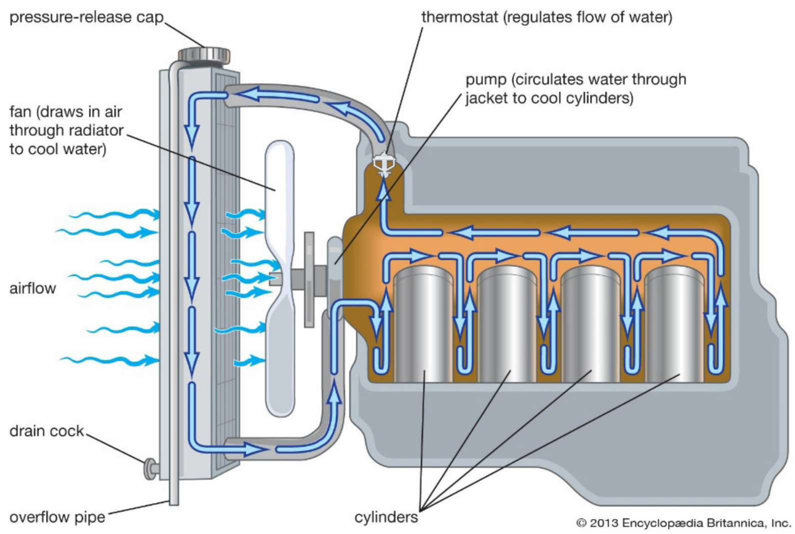


Figure 2.2: *Layout and main components of a modern pressurised system*

Key Features of Pressurised Cooling System

1. The boiling point of the coolant can be increased by increasing its pressure.
2. This allows a greater heat transfer to occur in the radiator due to a large temperature difference. Usually, the water pressure is kept between 1.5 to 2 bars.
3. Use of pressurised water cooling requires an additional valve called a vacuum valve, to avoid the formation of a vacuum when the water is cooled after engine has been stopped.
4. A safety valve in the form of pressure relief valve is provided so that whenever the filler cap is opened the pressure is immediately relieved.

The advantages of using a pressurised system are:

1. Elimination of coolant loss by surging of the coolant during heavy braking.
2. Prevention of boiling during long hill climbs, particularly in regions much above sea level.
3. Raising of the working temperature improving engine efficiency;
4. Allowing the use of a smaller radiator to dissipate the same amount of heat as a larger one operating at a lower temperature.

Radiator Pressure Cap

The cap contains two valves; one is the pressure valve; the other is the vacuum valve. As the temperature of the water increases it expands and in a sealed system this expansion increases the pressure until it reaches the relief pressure of the cap. As the system cools down it contracts and opens the vacuum valve drawing in air. If no vacuum valve was fitted the depression in the system, caused by the contracting effect of the water as it cools, could cause the rubber hoses in the system to collapse. Most pressure caps operate at 28–100 kN/m. The pressure is usually stamped on the cap indicating the maximum relief pressure for the system to which it is fitted. Figure below shows a pressure cap.

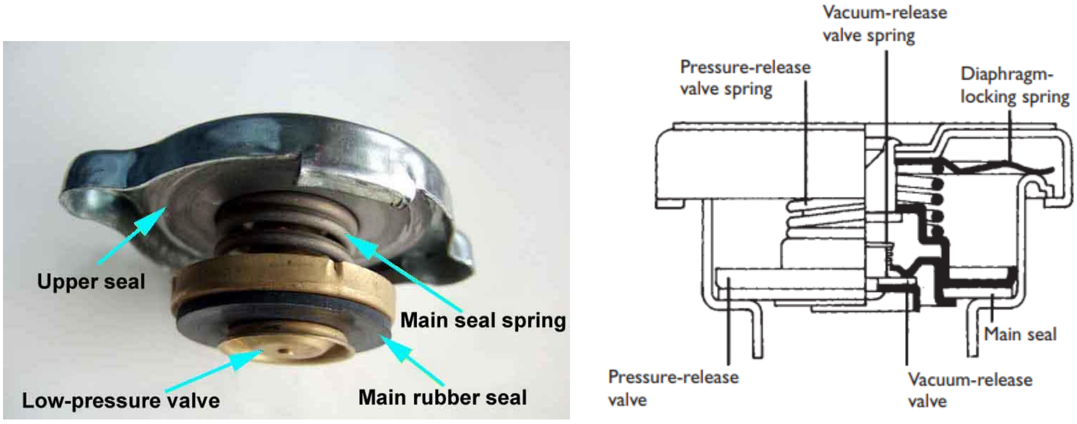


Figure 2.3: *Radiator pressure cap*

Sealed Cooling Systems

A further refinement of the pressurised cooling system consists of an arrangement where the system is kept completely full of coolant, expansion of the coolant being accommodated by providing an expansion tank into which the displaced coolant can pass and from which it can return to the system as the coolant in the system contracts on cooling. There are several variations of the arrangement. Figure below shows an addition to the pressurised system already described, the modification consisting of leading the vent pipe from the filler neck to the bottom of an expansion tank. A vent pipe is fitted to the top of the expansion tank, which may (though it is not necessary) have a drain tap and a filler cap.

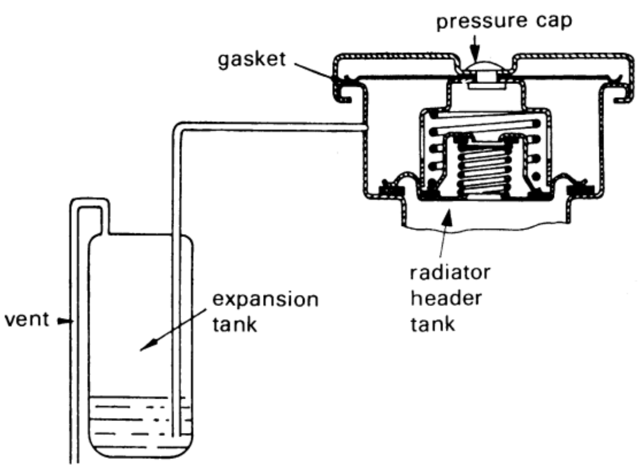


Figure 2.4: *A radiator expansion tank*

Comparison of Air- and Water-Cooled Systems

Advantages of air cooling

1. An air-cooled engine is generally lighter than an equivalent water-cooled engine.
2. It warms up to its normal running temperature very quickly.
3. The engine can operate at a higher temperature than a water-cooled engine.
4. The system is free from coolant leakage problems and requires no maintenance.

5. There is no risk of damage due to freezing of the coolant in cold weather.

Disadvantages of air cooling

1. A fan and suitable cowls are necessary to provide and direct the air flow. The fan can be noisy and absorbs a large amount of engine power.
2. The cowl makes it difficult to get to various parts of the engine when servicing is required.
3. The engine is more liable to over-heating under difficult conditions than a water-cooled engine.
4. Mechanical engine noises tend to be amplified by the fins.
5. The cylinders usually must be made separately to ensure proper fin formation. This makes the engine more costly to manufacture.
6. Cylinders must be spaced well apart to allow sufficient depth of fins.
7. It is more difficult to arrange a satisfactory car-heating system

Advantages of water cooling

1. The temperatures throughout the engine are more uniform, thus keeping distortion to a minimum.
2. Cylinders can be placed closer together making the engine more compact.
3. Although a fan is usually fitted to force air through the radiator, it is much smaller than the type required for an air-cooled engine. It therefore absorbs less power and is quieter in operation.
4. There is no cowl to obstruct access to the engine.
5. The water jacket absorbs some of the mechanical noise making the running engine quieter.
6. The engine is better able to operate under difficult conditions without over-heating.

Disadvantages of water cooling

1. **Weight:** not only of the radiator and connections but also of the water; the whole engine installation is likely to be heavier than an equivalent air-cooled engine.
2. As the water must be heated, it takes longer to warm up after starting from cold.
3. If water is used, the maximum temperature is limited to about 85 – 90oC to avoid the risk of boiling away the water. However, modern cooling systems are pressurised and this permits higher temperatures and better efficiency.
4. If the engine is left standing in very cold weather, precautions must be taken to prevent the water freezing in the cylinder jackets and cracking them.
5. There is a constant risk of a coolant leakage developing.
6. A certain amount of maintenance is necessary, for example, checking water level, anti-frost precautions, cleaning out deposits, etc.

Learning Tasks

1. Describe the thermostat operation in the engine cooling system
2. Explain the pressurised cooling system
3. Describe the sealed cooled system
4. Compare air cooled and water-cooled engines

Pedagogical Exemplars

1. **Group/collaborative learning:** Learners brainstorm in groups, to discuss the functions, construction and operation of the thermostat in engine cooling system.

   Assist learners to examine the layout of pressurised cooling system and sealed cooling systems on a motor vehicle and present a report for discussions.

   Learners to work in groups to tackle problems in thermostat operation, pressurised and sealed cooling systems promoting teamwork and the exchange of ideas.

   In mixed ability groups task learners to compare the advantages and the disadvantages of air-cooled and water-cooled engines and present a report.

2. **Experiential learning**

   Learners visit a school workshop to identify and observe the working principle of a thermostat, pressurised and sealed cooling systems for water-cooled engines.

   Organise visits to engine manufacturing plants or automotive workshops where students can see water-cooled engines in production and use.

Key Assessments

Level 2: Explain how the thermostat regulates engine temperature in a pressurised cooling system.

Level 3

1. Describe the operation of a pressurised cooling system and explain the purpose of pressure and vacuum valves in the radiator cap.
2. Describe the procedure for replacing a radiator in a pressurised cooling system.

Level 4

1. Compare four advantages and disadvantages of air-cooled and water-cooled engines.
2. Design and construct a model that demonstrates how a thermostat regulates engine temperature in a pressurised cooling system.

HINT

*The recommended mode of assessment for week 5 is **mini project**. Use the level 4 question 2 as a sample question.*

UNIT 5 REVIEW

This unit reviewed the thermostat and the pressurised cooling system which are critical components in an engine's cooling system. They play vital roles in maintaining optimal engine temperature, ensuring efficient operation, preventing overheating, and enhancing overall engine performance and longevity. They are essential for beginners learning the basics of engine cooling systems. The lesson equips the learners with the working principle of the thermostat, pressurised cooling systems, sealed cooling system and the comparison of air and water-cooled engines. Pedagogical exemplars such as group work/collaborative learning, problem based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of water-cooled engines. Assessment levels 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of water-cooled engines.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the main components of water-cooled engines?
3. Were learners able to explain the working principle of the thermostat in the engine cooling system?
4. Were the learners able to describe the working principle of a pressurised cooling system?
5. Which resources best supported the delivery of thermostat and pressurised cooling in the engine cooling system?
6. Did learners find the resources useful in studying the thermostat operation and pressurised cooling engines?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

UNIT 6

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines.*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines.*

INTRODUCTION AND UNIT SUMMARY

This unit covers the lathe and shaping machine and their uses. Understanding and mastering the use of a lathe machine is fundamental for machinists and engineers, as it provides the ability to create precise and intricate parts essential for many mechanical applications. It is also important to develop a full understanding of the operations of the lathe machine and apply them in designing and the manufacture of articles. 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. 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. They are particularly useful for producing keyways, splines and flat surfaces on small to medium-sized workpieces.

- ***The unit covers only week 6:*** *Demonstrate the use of lathe and shaping machines*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, learners must identify and explain the parts of the lathe and shaping machines. Teachers should employ pedagogies such as Group work/collaborative learning and experiential learning. Teachers should assist learners in mixed-ability groups, to identify the major parts of lathe and shaping machines. Learners should also be guided to brainstorm the functions of the lathe and shaping machine that is in the school workshop. The teacher should accompany learners to visit a local workshop where lathe and shaping machine operations are done for learners to identify and observe how the machines are used. The teacher should encourage learners to critically think and discuss the uses of the lathe and shaping machines. Learners should be encouraged to participate fully in investigations and present findings. Teachers should employ differentiation strategies to accommodate diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the ideas covered in this section, learners must show how they apply the concepts in real-world situations. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, and scores on practical group activities covering the basic lathe and shaping operations. Teachers should document learners' results in continuous assessment records. Tasks should encompass the significance, diverse branches, career prospects and dispelling of misconceptions surrounding Applied Technology. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 6

Learning Indicator: *Demonstrate the use of lathe and shaping machines.*

Focal Area 1: The Lathe Machine

Lathe Machine

A lathe is a machine which removes excess material in the form of chips by rotating the work piece against a stationary cutting tool. The lathe is one of the most important machine tools in the metal working 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 own axis causing the workpiece to be formed to 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

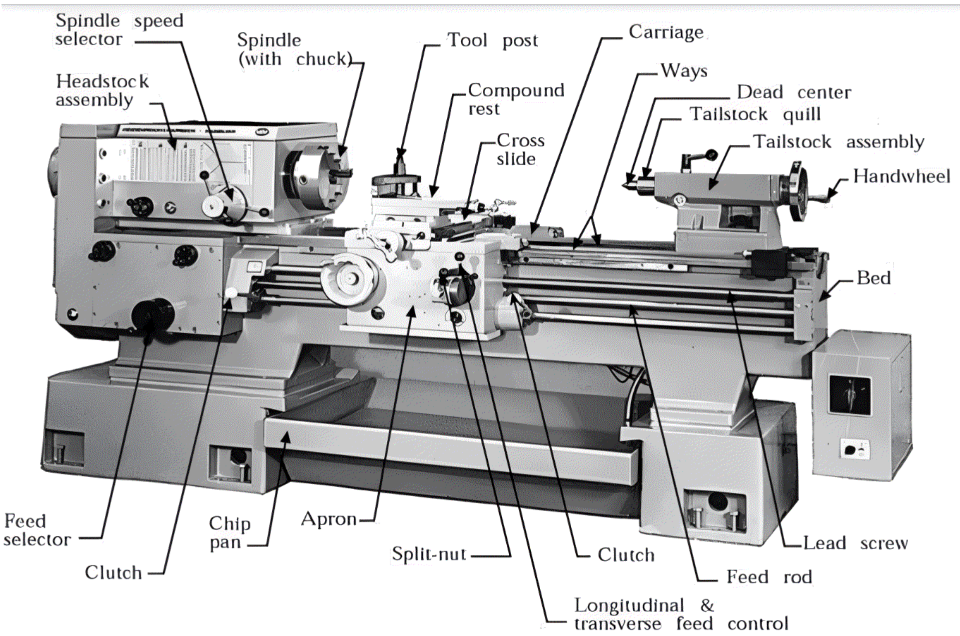


Figure 2.5: *Main parts of the lathe machine*

1. **Bed:** it supports all major components
2. **Headstock:** 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:** supports the other end of the workpiece
5. **Carriage:** 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.
   - **The parts of the carriage are:** saddle, apron, cross-slide, compound rest, compound slide, tool post
6. **Feed Rod and Lead Screw:** the feed rod is powered by a set of gears from the headstock

Types of Lathes

The various designs and constructions of lathes 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 mounted on the work bench
   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 head stock spindle.
   b. It consists of a head stock, a tail stock and tool post. It has no gear box.
   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 tail stock 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:** These are like turret lathes with the difference that the turret is not fixed but moves on an auxiliary slide. These are used for fast production of small parts.

Size of a Lathe (Specification 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
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

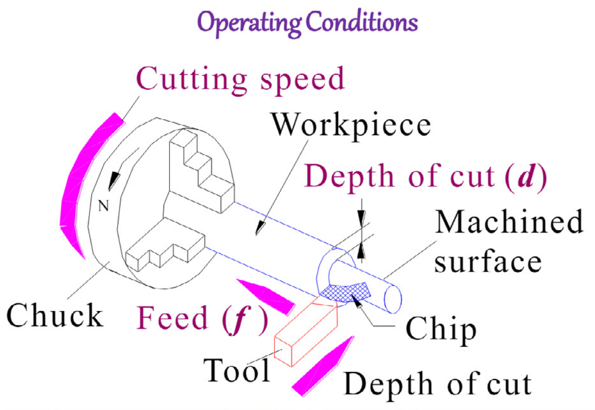


Figure 2.6: *Cutting speed*

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

- **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:** It refers to the distance the cutting tool penetrates into the workpiece material during each pass.
- **Machining time:** It is the time it takes to complete a particular cutting operation on a workpiece.

Lathe Operations

1. Operations, which can be performed in a lathe either by holding the work-piece 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

2. 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

3. Operations which are performed by using special lathe attachments are:
   a. Milling
   b. Grinding

Some of the operations are explained below:

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 finishing 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

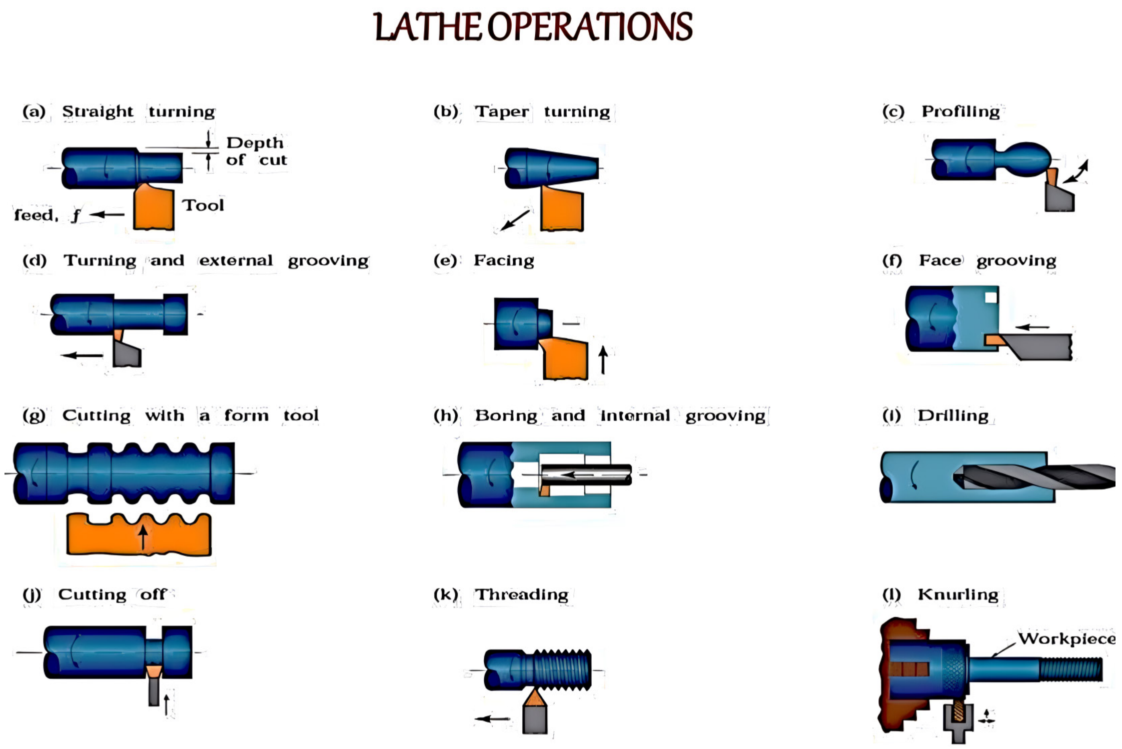


Figure 2.7: *Lathe operations*

Accessories and Attachments Of Lathe

There are many lathe accessories provided by the lathe manufacturer, which support the lathe operations. The important lathe accessories include centres, catch plates and carriers, chucks, collets, face plates, angle plates, mandrels, and rests. These are used either for holding and supporting the work or for holding the tool. Attachments are additional equipment provided by the lathe manufacturer, which can be used for specific operations. The lathe attachment includes stops, ball turning rests, thread chasing dials, milling attachment, grinding attachment, gear cutting attachment, turret attachment, crank pin turning attachment and taper turning attachment.

Work Holding Devices

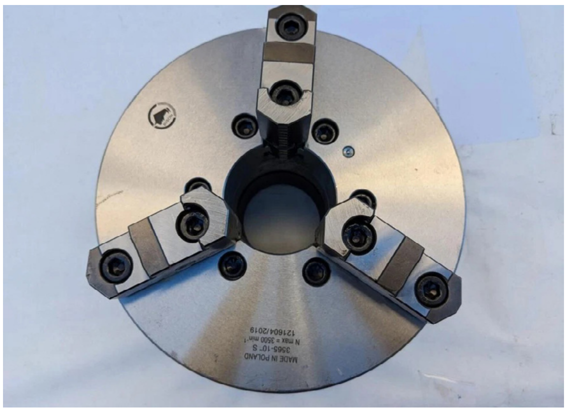
The work holding devices are used to hold and rotate the workpieces along with the spindle. Different work holding devices are used according to the shape, length, diameter and weight of the workpiece and the location of turning on the work. They include Chucks, Face plate, driving plate, Catch plate,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

1. **Chucks:** The chuck is one of the most important devices for holding and rotating a job in a lathe. It is basically attached to the headstock spindle of the lathe. The internal threads in the chuck fit on to the external threads on the spindle nose. Short, cylindrical, hol1ow 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.

The most commonly used lathe chucks are:

- **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

a. **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.



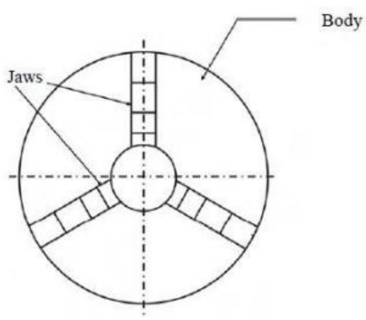


Figure 2.8: *Three-jaw Universal Chuck*

b. **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

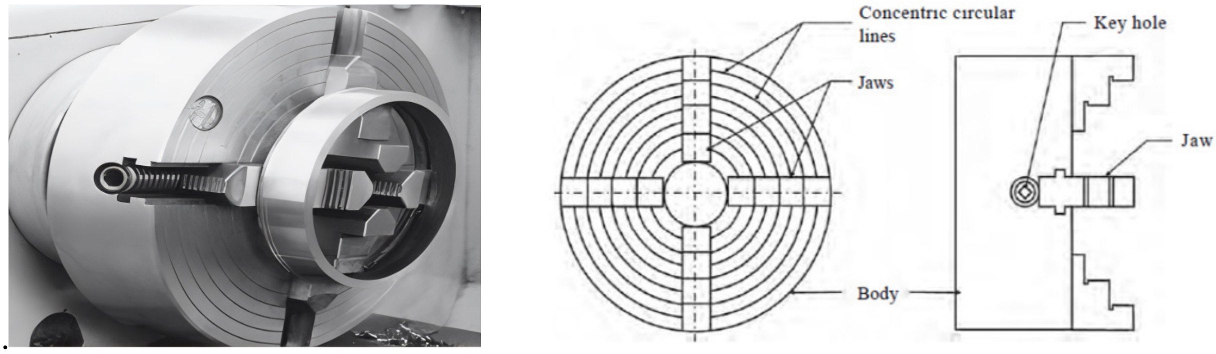


Figure 2.9: *Four-Jaw Independent Chuck*

c. **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.

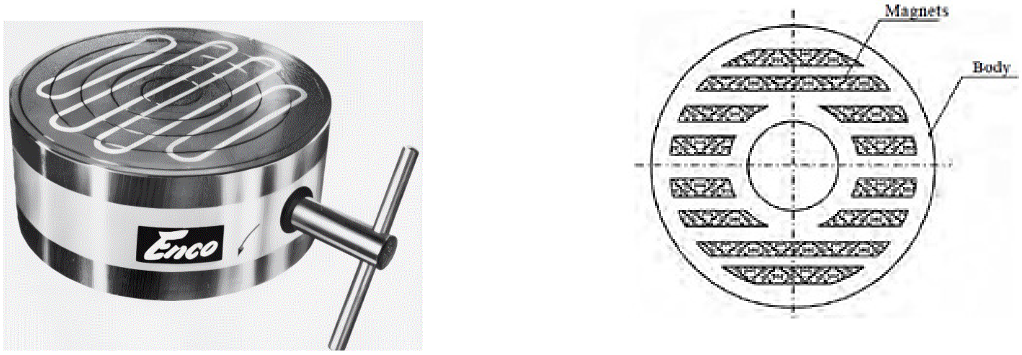


Figure 2.10: *Magnetic Chuck*

d. **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.

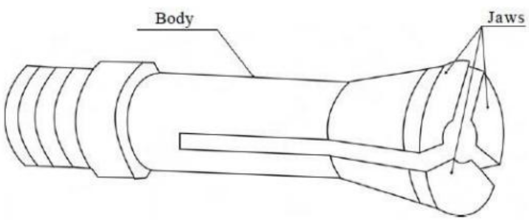


Figure 2.11: *Collet chuck*

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.

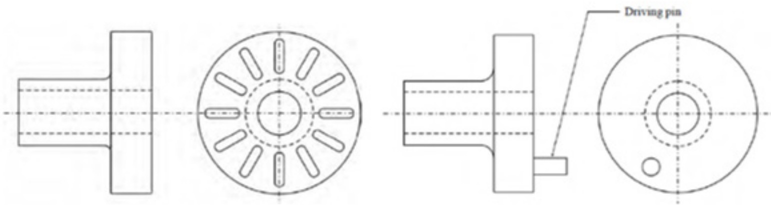


Figure 2.12: *Driving plate*

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.

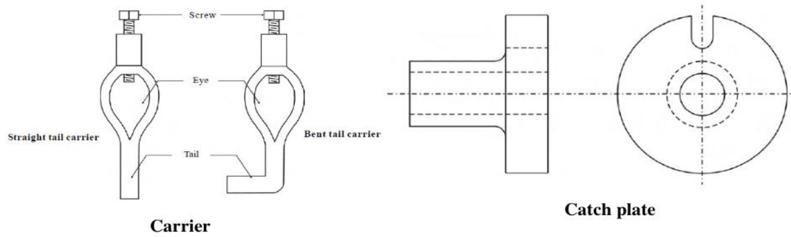


Figure 2.13: *Carrier*

6. **Mandrels:** A mandrel is a device used for holding and rotating a hollow job that has been previously drilled or bored. The job revolves with the mandrel, which is mounted between two centres. It is rotated by the lathe dog and the catch plate and it drives the work by friction.

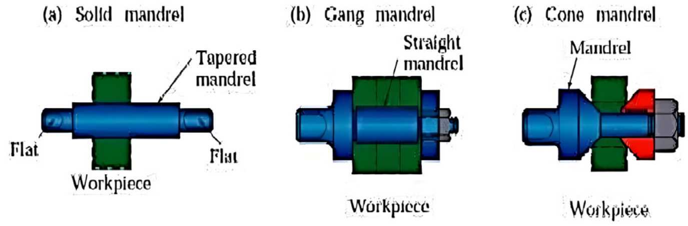


Figure 2.14: *Mandrels*

7. **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.

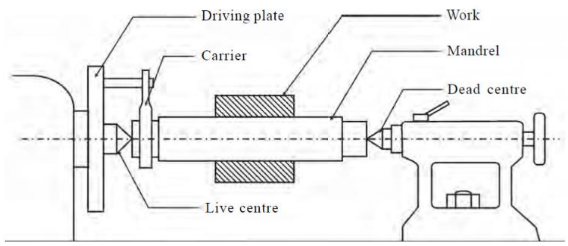


Figure 2.15: *Holding work between centres*

8. **Rests:** 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.

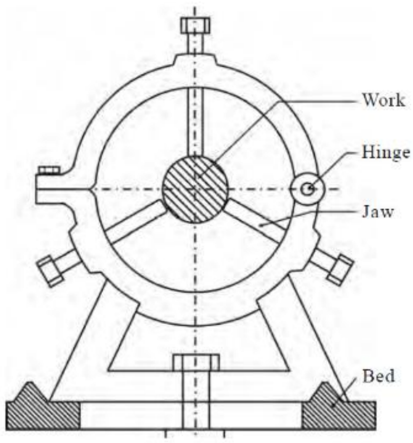


Figure 2.16: *Steady rest*

Safety Precautions

1. Always wear approved safety glasses.
2. Rollup sleeves, remove tie and tuck in loose clothing.
3. Never machine if safety guards removed.
4. Stop lathe before measuring work or cleaning, oiling or adjusting machine.

5. Always remove the chuck key after use.
6. Always remove chips with a brush.

Focal Area 2: 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 Principle 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 to 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 Operation

Generally, there are four types of operation 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 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

Principal Parts of Shaper

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

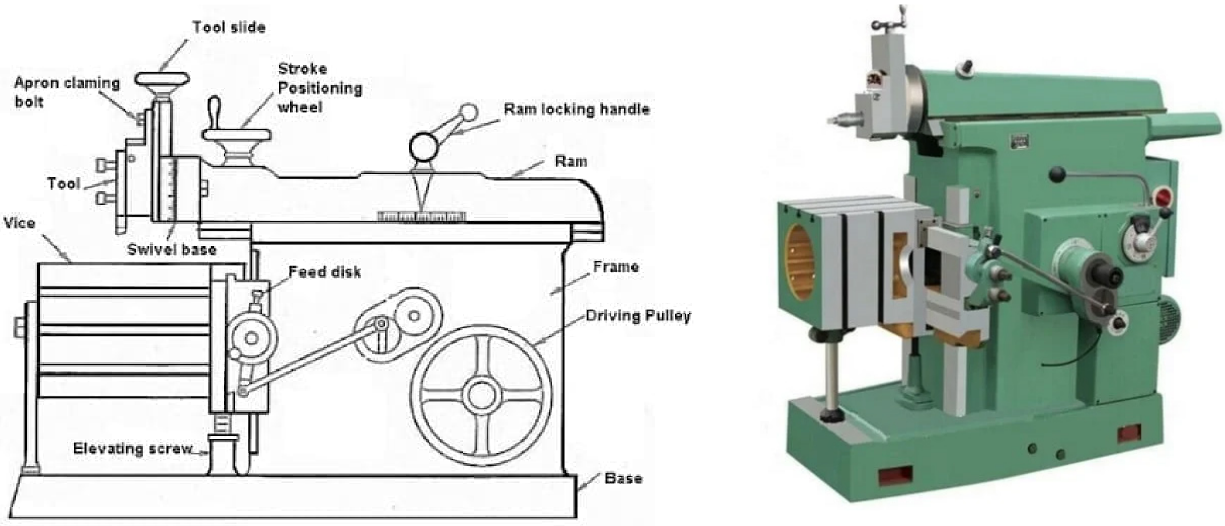


Figure 2.17: *Standard Shaper*

Some of the important parts are described below

1. **Base:** It is a rigid and heavy cast iron body to resist 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 on the bench according to the size of the machine.
2. **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.

3. **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 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:** 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:
   a. It holds the tool rigidly,
   b. It provides vertical and angular feed movement of the tool, and
   c. 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.

Advantages of Shaper Machine

1. The tool (Single Point cutting tool) cost 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.

Disadvantages of Shaper Machine

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.

Applications of Shaper Machine

1. A shaper 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.

Learning Tasks

1. Describe the working principle of the centre lathe and explain its main parts.
2. List and explain the accessories of a centre lathe with neat sketches.
3. Describe the operations which can be performed on a lathe machine.
4. Describe the working principle of the shaping machine and explain its main parts.
5. Describe the operations to be performed on the shaping machine.

PEDAGOGICAL EXEMPLARS

1. **Group work/collaborative learning:** In mixed ability groups, assist learners to identify the major parts of lathe and shaping machines and brainstorm their functions in the school workshop.
2. **Experiential Learning:** Visit a local workshop with learners and help them to identify, observe and demonstrate the use of lathe and shaping machines.

KEY ASSESSMENTS

Level 1: What is a lathe machine?

Level 2: Explain the following parts of a lathe machine using neat sketches:

- **i.** Lathe Bed
- **ii.** Carriage
- **iii.** Headstock
- **iv.** Tailstock

Level 3

1. Explain the difference between a three-jaw chuck and a four-jaw chuck.
2. Explain the functions of the main parts of the shaper machine.

Level 4

1. With help of a neat diagram, describe the following operations on the lathe machine:
   - **a.** Finish turning

b. Rough turning
c. Turning
d. Drilling
e. Knurling

2. Describe the working principle of the shaper.

HINT

The recommended mode of assessment for week 6 is Mid-Semester Examination. Refer to the Appendix C at the end of the section for more sample task and the Table of Specification.

UNIT 6 REVIEW

This unit provided an in-depth description of the parts and the use of the lathe and shaping machines. The unit delved into the types, parts and functions of lathe machine. The unit also highlighted the shaper machine, its parts and functions. Operations performed on the shaping machine were also discussed. This unit provided suggested appropriate pedagogical strategies for the teacher to employ during lesson delivery of the lesson.

REFLECTION

1. What was my best moment in today's lesson, and how can I create more of such situations?
2. Were learners able to identify the main components of water-cooled engines?
3. Were learners able to explain the working principle of the thermostat in the engine cooling system?
4. Were the learners able to describe the working principle of the pressurised cooling system?
5. Which resources best supported the delivery of thermostat and pressurised cooling in the engine cooling system?
6. Did learners find the resources useful in studying the thermostat operation and pressurised cooling engines?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

UNIT 7

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems.*

INTRODUCTION AND UNIT SUMMARY

The engine lubrication system is vital for the health and efficiency of an engine and ensures friction and wear are reduced and cooling is also achieved. The unit covers the working principle of the engine lubrication system, the components of the engine to be lubricated and the main parts of the engine lubrication system, their functions and locations. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the working principle of the engine lubrication system. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the workings of the main parts of the engine lubrication system.

- ***The unit covers only week 7****: Examine parts of the lubrication systems and the components to be lubricated*

SUMMARY OF PEDAGOGICAL EXEMPLARS

Teaching the working principle of the engine lubrication system can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. Learners will understand the working principle of the engine lubrication system, the components of the engine to be lubricated and the main parts of the engine lubrication system, their functions and locations. The teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the working principle of the engine lubrication system.

ASSESSMENT SUMMARY

In teaching the working principle of the engine lubrication system, assessments can span various levels to gauge learners' understanding and application of the concepts and the working principle of the engine lubrication system, the components of the engine to be lubricated and the main parts of the engine lubrication system, their functions and locations. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to engine lubrication system. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 7

Learning Indicator: *Examine the parts of the lubrication systems and the components to be lubricated*

Focal Area 1: Engine Lubrication System

The engine lubrication system is there to distribute oil to the moving parts in an engine to reduce friction between surfaces. Lubrication plays a key role in the life expectancy of an automotive engine. If the lubricating system fails, an engine will succumb to overheating and end up seizing quickly. The oil pump is located at the bottom of the engine. The oil is pulled through a strainer by the oil pump, removing larger contaminants from the mass of the fluid. The oil is then forced through an oil filter under pressure to the main bearings and the oil pressure gauge. From the main bearings, the oil passes into drilled passages in the crankshaft and the big-end bearings of the connecting rod. The oil dispersed by the rotating crankshaft lubricates the cylinder walls and piston-pin bearings. The excess oil is scraped off by the scraper rings on the piston. The engine oil also lubricates camshaft bearings and the timing chain or gears on the camshaft drive. The excess oil in the system then drains back to the sump to be recirculated.

1. **Lubrication:** The method of reducing friction by introducing a substance called a lubricant between the mating parts.

Importance of an engine lubrication system

- **a.** Reduces friction, thus increases efficiency
- **b.** Reduces wear and tear of moving parts
- **c.** Carries away heat
- **d.** Provides a sealing action between cylinder and piston rings, thereby reducing blow-by.
- **e.** Protects against corrosion.
- **f.** Lubrication film acts as a cushion and reduces vibration
- **g.** Carries away the grit and other deposits and provides a cleaning function
- **h.** Reduces noise

The main components of the internal combustion engine to be lubricated:

- **a.** Crankshaft main bearings
- **b.** Big end bearings
- **c.** Piston pins and small end bushes
- **d.** Cylinder walls
- **e.** Piston rings
- **f.** Timing Gears

g. Camshaft and bearings

h. Valves

i. Tappets and push-rods

j. Oil pump parts

k. Water pump bearings

l. In-Line Fuel Injection Pump bearings

m. Turbocharger bearings (if fitted)

n. Vacuum pump bearings (if fitted)

o. Air-compressor piston and bearings (in commercial vehicles for air-brakes)

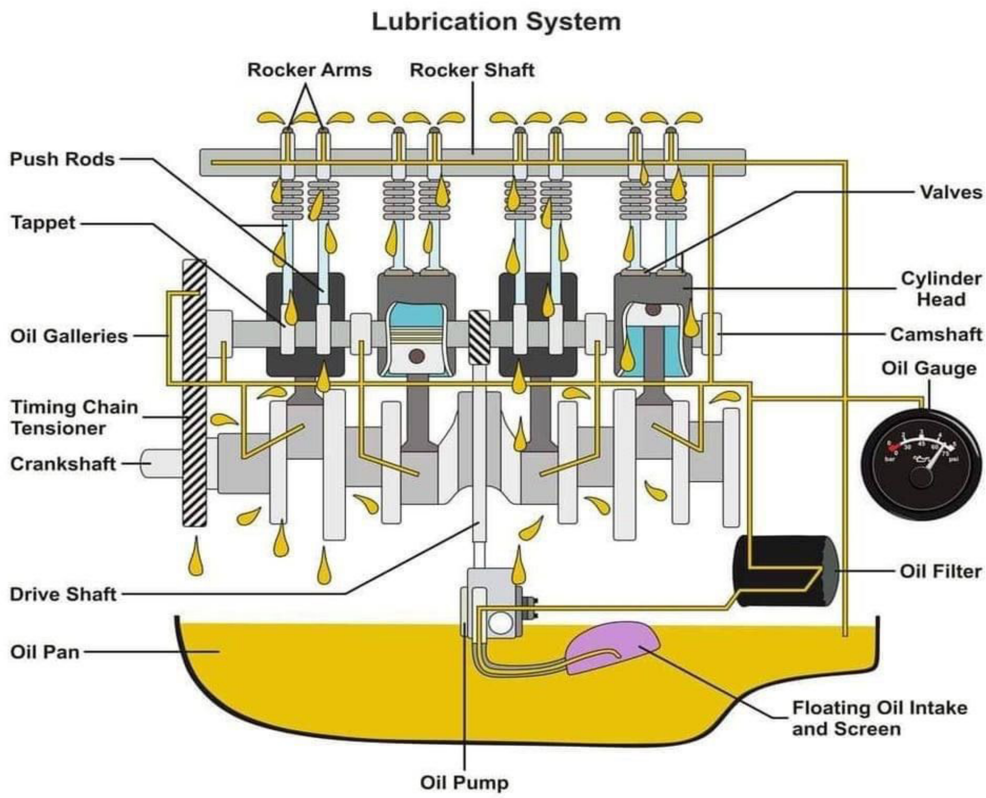


Figure 2.18: *Main Parts of Engine Lubrication System*

2. **Oil sump:** The oil sump, also known as the oil pan, is a crucial component of an automotive engine. It serves several important functions related to the lubrication and cooling of the engine. These are:

   a. **Oil Reservoir**: The primary function of the oil sump is to act as a reservoir for engine oil. It holds the oil that is used to lubricate various moving parts of the engine, ensuring smooth operation and reducing wear and tear.

   b. **Oil Collection**: As the engine operates, oil is pumped through the engine to lubricate components such as the crankshaft, camshaft, pistons, and bearings. After circulating through the engine, the oil drains back into the sump by gravity.

   c. **Cooling**: The oil sump also helps in cooling the engine. As the oil circulates through the engine, it absorbs heat generated by friction and combustion. When the oil returns to the sump, it releases some of this heat to the surrounding air, helping to regulate the engine's temperature.

d. **Filtration**: The oil sump often houses the oil filter, which removes contaminants and particles from the oil. Clean oil is crucial for the proper functioning and long life of the engine.

e. **Oil Pump Pickup**: Inside the sump, there is an oil pump pickup tube that draws oil from the sump and sends it through the oil pump to be recirculated throughout the engine.

f. **Sealing and Protection**: The oil sump is usually bolted to the bottom of the engine block and sealed with a gasket to prevent oil leaks. It also protects the internal components of the engine from debris and contaminants that might enter from the vehicle's underside.

3. **Engine oil filter:** An engine oil filter is a critical component of an automotive engine's lubrication system. Its primary function is to remove contaminants from the engine oil. These contaminants can include particles of dirt, metal shavings, carbon deposits, and other impurities that accumulate over time and can cause wear and damage to the engine's internal components. The oil filter is usually located on the side or bottom of the engine block. Its position allows it to be easily accessed and replaced during oil changes.
4. **Oil pump:** The primary function of the oil pump is to circulate engine oil under pressure to the rotating bearings, sliding pistons, and the camshaft of the engine. The oil pump is usually in the oil pan or attached to the engine block's front or side. Its position is designed to be close to the oil sump to efficiently draw and circulate oil.
5. **The oil galleries:** The oil galleries, also known as oil passages, are integral components of an automotive engine's lubrication system. They are a network of channels or pathways within the engine block and cylinder head that facilitate the flow of lubricating oil to various engine parts.
6. **Oil cooler:** An oil cooler is a component in an automotive engine's lubrication system designed to lower the temperature of the engine oil. This helps maintain optimal oil viscosity and prevents overheating, which can improve the overall performance and long life of the engine. Air-cooled oil coolers are typically mounted in front of the radiator or in a location with good airflow to maximise cooling efficiency. Liquid-cooled oil coolers are often integrated into the engine's cooling system, sometimes built into the radiator or as a separate heat exchanger connected to the coolant lines.
7. **The oil pressure indicator/light:** The primary function of the oil pressure indicator is to warn the driver of low oil pressure, which can lead to severe engine damage if not addressed promptly. It helps drivers monitor the health of the engine's lubrication system, ensuring that the engine receives adequate oil flow.

Learning Tasks

1. Explain the function of the engine lubrication system.

2. Explain the importance of the engine lubrication system.
3. List the main components of the automotive engine to be lubricated.
4. Describe the main parts of the engine lubrication system.

Pedagogical Exemplars

1. **Group work/collaborative learning:** Assist learners in explaining the purpose of the lubrication system. Learners brainstorm to discuss the engine components to be lubricated.

   In a mixed group, learners use appropriate real objects, sketches or charts to identify the parts of the lubrication system.

2. **Problem-based Learning**

   Learners work independently to identify the parts of the lubrication system and their functions and present individual reports.

   Learners work independently to identify engine components to be lubricated and present an individual report.

   Learners visit a school workshop to identify parts of the engine lubrication system.

Key Assessment

Level 1: What is the engine lubrication system**?**

Level 2: Explain four objectives of engine lubrication and list five components of the engine that are lubricated.

Level 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
- **g.** Oil pan

Level 4: Describe the procedure for changing dirty oil in the engine lubrication system.

HINT

*The recommended mode of assessment for week 7 is **questioning.** Use the level 3 question as a sample question. Refer to Teacher Assessment Manual and Toolkit page 30 for more information on how to go about this mode of assessment.*

UNIT 7 REVIEW

This unit reviews the introduction to engine lubrication systems which play vital roles in maintaining the health and efficiency of an engine and ensuring friction and wear are reduced and enhancing overall engine performance and long life. They are essential for beginners learning the basics of engine lubrication systems. The lesson equips the learners with the working principle of the engine lubrication system, the components of the engine to be lubricated and the main parts of the engine lubrication system, their functions and locations. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of the engine lubrication system. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learner's depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of engine lubrication system.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the main components of the engine lubrication system?
3. Were learners able to explain the working principle of the engine lubrication system?
4. Were the learners able to state the functions of the main components of the engine lubrication system?
5. Which resources best supported the delivery of the engine lubrication system?
6. Did learners find the resources useful in studying the t engine lubrication system?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 8

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines.

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines.*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines.*

INTRODUCTION AND UNIT SUMMARY

This unit covers the milling machine and its uses as well as cutting fluids. Understanding and mastering the use of a milling machine is fundamental for machinists and engineers, as it provides the ability to create precise and intricate parts essential for many mechanical applications. It is also imperative to develop a full understanding of the operations of the milling machine and apply them in the design and manufacture of articles. Milling machines are essential for various machining tasks, from simple drilling to complex contouring and finishing, making them invaluable in manufacturing and engineering industries. The setup, operation and safety practices associated with milling machines are essential for machinists and engineers, enabling them to produce accurate and high-quality components efficiently.

- ***The unit covers only week 8:*** *Demonstrate the use of the milling machine and cutting fluids*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, learners must identify and explain the parts of the milling machine. Teachers should employ pedagogies such as Group work/collaborative learning and experiential learning. Teachers should assist learners in mixed-ability groups, to identify the major parts of the milling machine. Learners should also be guided to brainstorm the functions of the milling machine at the school workshop. The teacher should accompany learners to visit a local workshop where milling operations are done for learners to identify and observe how the machine is used. The teacher should encourage learners to critically think and discuss the uses of the milling machine. Learners should be encouraged to participate fully in investigations and presentation of findings. Teachers should employ differentiation strategies to accommodate diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the milling machine, learners must show how they apply the concepts in real-world situations. As a result, levels 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, and provide scores on practical group activities covering the basic processes in using a milling machine. Teachers should document learners' results in continuous assessment records. Tasks should encompass the significance, diverse branches, career prospects, and dispelling of misconceptions surrounding applied technology. This will ensure learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 8

Learning Indicator: *Demonstrate the use of the milling machine and cutting fluids.*

Focal Area 1: 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.

1. **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.

    a. **Universal milling machine:** The table of a universal milling machine can be swivelled by 45° 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.

    b. **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.

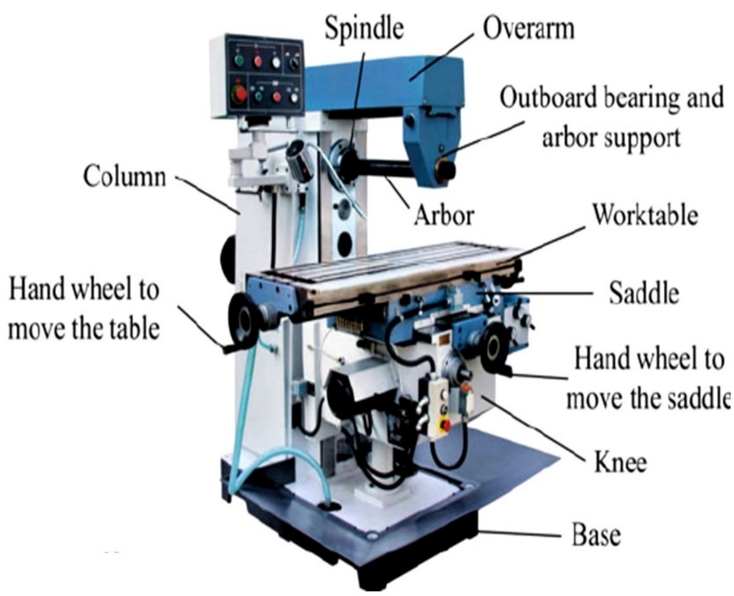


Figure 2.19: *Horizontal or knee milling machine*

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.

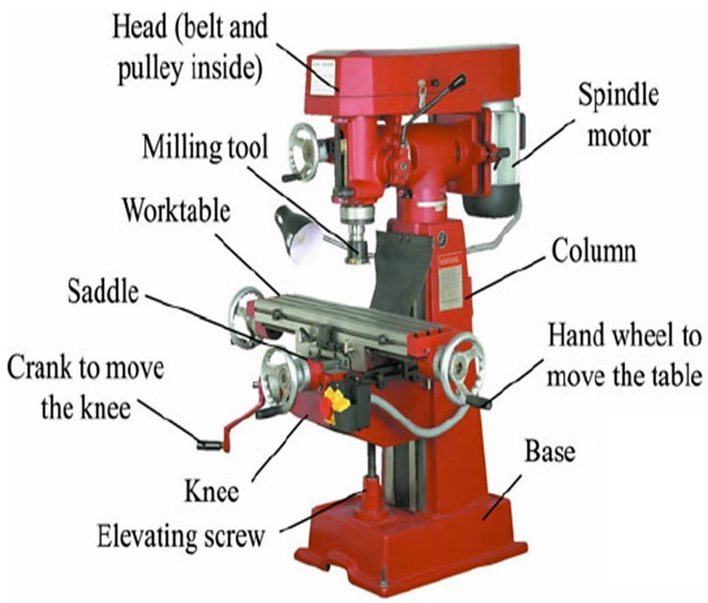


Figure 2.20: *Vertical milling machine*

Parts of the milling machine

a. **Arbor:** it is between the column and the outer arbor yoke. The cutter is fitted on the arbor.

b. **Outer arbor yoke:** it is at the end of the overarm and used as a support for the arbor.

c. **Overarms:** used for positioning the outer arbor yoke.

d. **Knee:** the overhang in front carrying the worktable that slides up and down.

e. **Knee longitudinal adjustment handle:** used to move the vertical feed of the table but is automatically disengaged whenever the power is engaged.

f. **Table traverse lever:** used to control the direction of movement of the table. It also controls longitudinal feed.

g. **Automatic feed lever:** used to engage and disengage the automatic mechanism of the worktable.

h. **Main drive clutch:** used for starting and stopping the arbor of the horizontal miller or the spindle arm of the vertical miller.

i. **Feed selector lever:** used for increasing or reducing the automatic-feed rate of the worktable.

j. **Speed selector lever:** used for selecting a required speed of the arbor or spindle.

k. **Worktable:** used for holding the work. It moves perpendicular to the arbor.

3. 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.

a. **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.

b. **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.

c. **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.

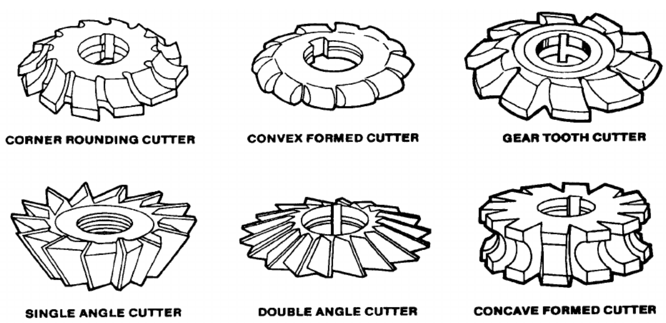


Figure 2.21a: *Holding milling cutters*

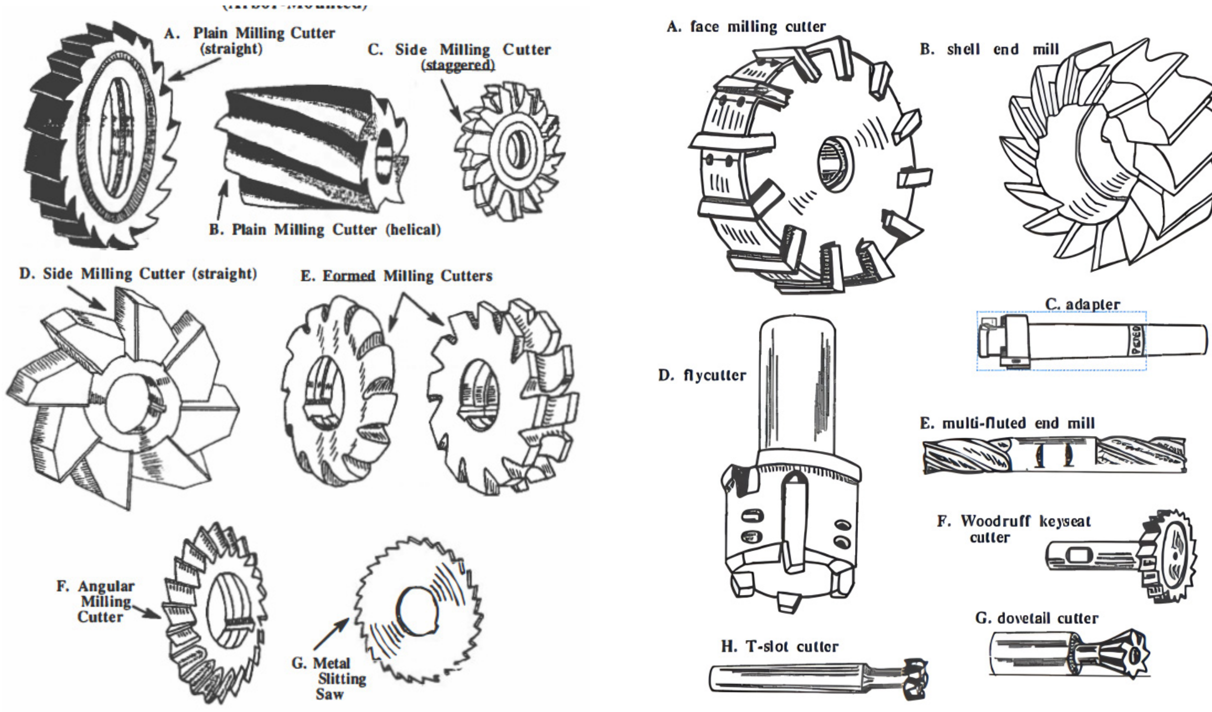


Figure 2.21b: *Holding milling cutters*

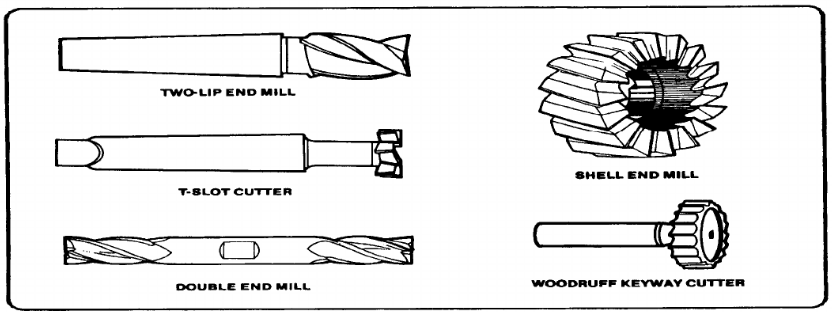


Figure 2.21c: *Holding milling cutters*

Milling operations

Peripheral milling: The machining is performed by the cutting edges on the periphery of the milling cutter. It is classified under two headings.

1. **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.
2. **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.

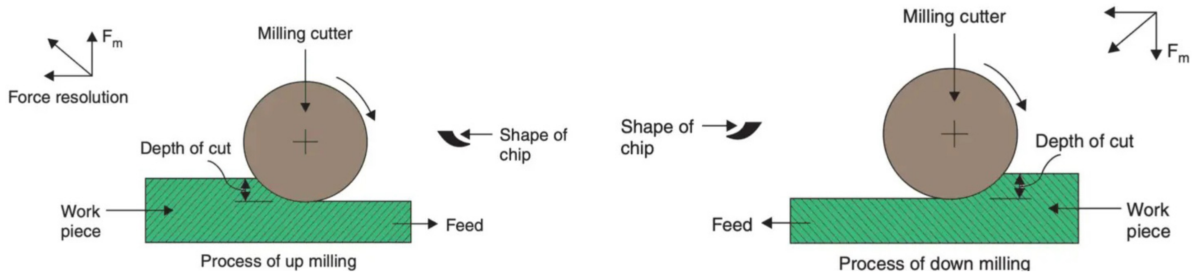
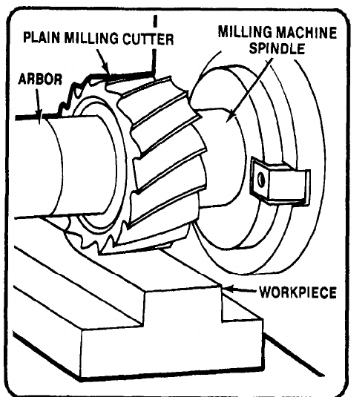
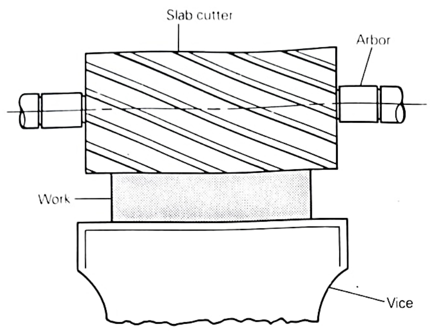


Figure 2.22: *Up and down milling*

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 arbor.
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 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 parallel to the axis of the cutter.
11. **Form milling:** The production of concave and convex surfaces.





Plain (slab) milling

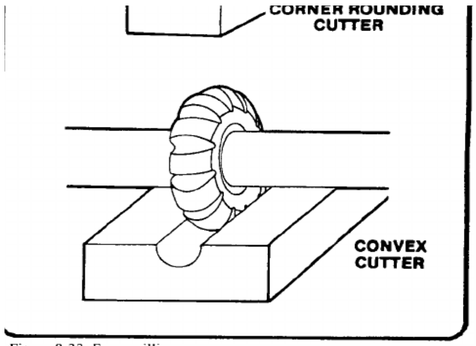
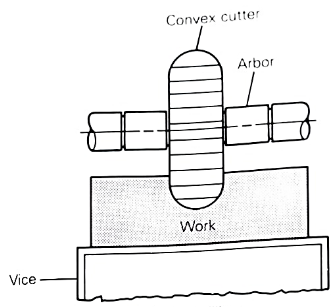


Figure 8-33. Form milling.



Form milling

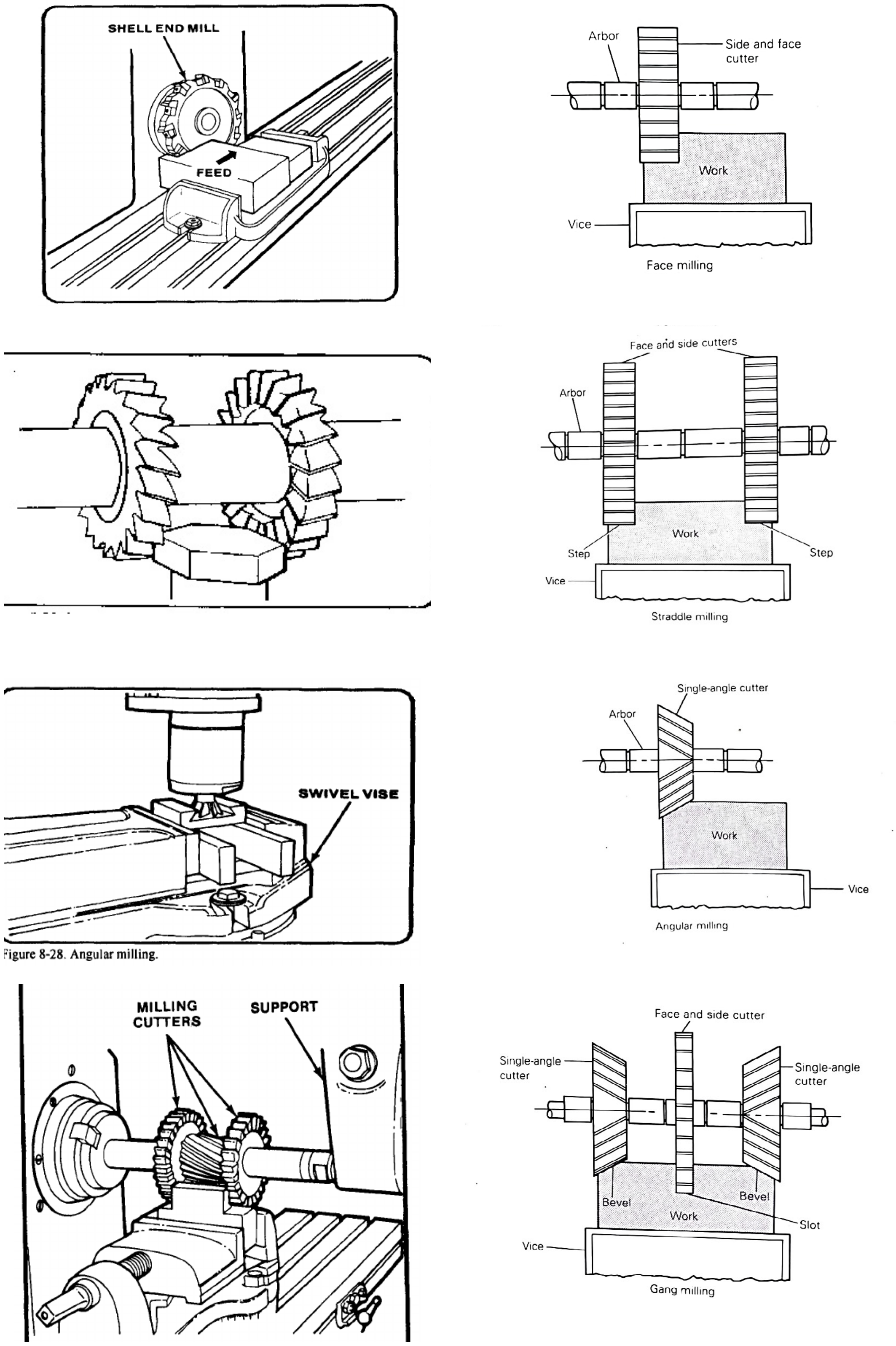


Figure 2.23: *Milling operations*

Focal Area 2: 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.

Types of Cutting Fluids

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.).

Advantages of straight oils

1. They have excellent lubrication.
2. They have good corrosion protection.
3. They have an easy maintenance effect.

Disadvantages of straight oils

1. They have poor heat removal.
2. They are toxic.
3. They have high viscosity.
4. 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%.

Advantages of emulsions

1. They have good lubrication.

2. They have good cooling capability.
3. They have good corrosion protection effect.
4. They are less expensive.
5. They are non-flammable.

Disadvantages of emulsions

1. They are toxic.
2. 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.

Advantages of synthetic fluids

1. They have very good cooling capability.
2. They have good lubrication properties.
3. They are very stability in hard water.
4. They have a very good in corrosion protection.
5. They have low mist.
6. They can be easily handled.
7. They have a good cleaning and maintenance effect.

Disadvantages of synthetic fluids

1. They have some toxicity.
2. They can be easily contaminated by foreign oils.
3. They are relatively expensive.

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 at some extent) of mineral emulsions and synthetic fluids.

Advantages of semi-synthetic fluids

1. They possess better corrosion protection.
2. They have better cooling and wetting capabilities,

3. They can be easily handled.

Disadvantages of semi-synthetic fluids

1. They have a misting effect
2. They are relatively unstable in hard water
3. They can be contaminated by foreign oils
4. 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 machines 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.

Selection Of The Appropriate Cutting 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 metalworking fluid:

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.

Learning Tasks

1. Explain the term *milling*.
2. Describe the milling machine, identify the parts and explain their functions.

3. Describe the milling operations performed on the milling machine.
4. Explain the function of cutting fluids and identify the types and some advantages and disadvantages.
5. Describe the conditions under which a particular cutting would be selected for a machining process.

PEDAGOGICAL EXEMPLARS

1. **Group work/collaborative learning:** In mixed ability groups, assist learners to identify the major parts of the milling machine and brainstorm their functions in the school workshop.
2. **Experiential Learning:** Visit a local workshop with learners and help them to identify, observe and demonstrate the use of the milling machine.

KEY ASSESSMENTS

Level 1: Explain what is meant by the term ***milling***.

Level 2: Describe the principles of operation of the milling machine.

Level 3: Explain the following milling operations.

- **a.** Face milling
- **b.** Straddle milling
- **c.** Gang milling
- **d.** Form milling

Level 4

1. Explain any ***four*** functions of cutting fluids.
2. Create a concept map on the principles of operation of the milling machine which includes; parts and functions, purpose of the machine and types of operations.

HINT

*The recommended mode of assessment for week 8 is **concept mapping.** You may use **Level 4** question 2 as a sample question.*

UNIT 8 REVIEW

This unit reviews the introductions to milling machines and cutting fluids, which are essential in metalworking processes. They are necessary for beginners learning basic metalworking processes employed in the engineering and manufacturing industries. The unit equipped learners with the knowledge of the types, parts and functions of milling machines. Milling operations were also discussed. The unit also introduced learners to the types and uses of cutting fluids. Factors for selecting a particular cutting were also discussed. Pedagogical exemplars such as group work/ collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the use of milling machines and cutting fluids in metalworking operations. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the milling and cutting fluids.

REFLECTION (ADDITIONAL READING)

1. What was my best moment in today's lesson, and how can I create more of such situations?
2. Were learners able to identify the main components of the engine lubrication system?
3. Were learners able to explain the working principle of the engine lubrication system?
4. Were the learners able to state the functions of the main components of the engine lubrication system?
5. Which resources best supported the delivery of the engine lubrication system?
6. Did learners find the resources useful in studying the t engine lubrication system?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

APPENDIX C: TABLE OF SPECIFICATIONS FOR MID-SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION: 15 Multiple Choice Questions (MCQ) to be answered individually within 20 minutes, questions should be selected from DoK level 1 to 3.

RESOURCES: Scannable sheets or A4 papers

SAMPLE QUESTIONS

Multiple Choice

1. Which component in cooling system is responsible for transferring heat from the engine to the coolant?

a. *Fan*

b. *Pump*

c. *Radiator*

d. *Thermostat*

MARKING SCHEME

Multiple Choice- 15 questions at 1 mark each.

1. Which component in cooling system is responsible for transferring heat from the engine to the coolant?

a. *Fan*

b. *Pump*

c. ***Radiator***

d. *Thermostat*

TABLE OF SPECIFICATION FOR MID SEMESTER 1

Table 2.1: *Table Of Specification For Mid Semester 1*

WKS	LEARNING INDICATORS	DoK level 1	DoK level 2	DoK level 3	DoK level 4	TOTAL
1	Describe the construction and operation of the air-cooling systems.	1	1	1		3
2	Describe various heat treatment processes with engineering examples.	1	1	1		3
3	Describe the construction and operation of the thermosyphon and pump assisted water-cooling systems.	1	1	1		3

4	Demonstrate the use of grinding, drilling and lathe machines.	1	2			3
5	Describe the construction and operation of the thermostat and pressurized water-cooling systems.		2	1		3
	TOTAL	4	7	4		15

SECTION 3: ENGINE LUBRICATION, SAND CASTING AND MACHINES III

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section learners will acquire knowledge and understanding of types of lubrication systems, oil pumps and oil filters and properties, classifications of engine lubricating oil as well as crankcase ventilation. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of various machining processes by relating them to manufacturing industry and the principle of sand casting to produce articles. All the above are treated from unit 9 to unit 12.

UNIT 9

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems.*

HINT

Remind learners of the end-of-semester examination in ***week 12****. Refer to Appendix D at the end of the section for a Table of Specifications to guide you in setting the questions for the examination.*

INTRODUCTION AND UNIT SUMMARY

The engine lubrication system is vital for the health and efficiency of an engine, as it reduces friction and wear while also ensuring adequate cooling. The unit covers the types of lubrication systems, oil pumps and oil filters. This equips learners with the basic knowledge and skills necessary to maintain, repair, and service engine lubrication systems, thereby contributing to improved lubrication systems, selecting the appropriate oil pumps, and integrating effective filtration methods to enhance engine performance and durability. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the various types of engine lubrication systems, oil pumps and oil filters. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of lubrication systems, oil pumps and oil filters.

- ***The unit covers only week 9***: *Describe types of lubrication systems, oil pumps and oil filters*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach types of lubrication systems, oil pumps and oil filters ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant, Teaching the working principle of the types of engine lubrication systems, oil pumps and oil filters can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate the various types of engine lubrication systems, oil pumps, oil filters and their working principles, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the types of lubrication systems, oil pumps and oil filters.

ASSESSMENT SUMMARY

Teaching the types of lubrication systems, oil pumps, and oil filters, assessments can span various levels to gauge learners' understanding and application of the concepts and their working principles. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to various types of engine lubrication systems, oil pumps, oil filters and their working principles. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. Teacher Assessment Manual and Toolkits (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 9

Learning Indicator: *Describe types of lubrication systems, oil pumps and oil filters*

Focal Area 1: 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.

Mist Lubrication System (Petroil)

1. Employed in 2 Stroke Petrol engines.
2. In this system, the petrol and lubricating oil are previously mixed in fuel tank from where it is supplied to the carburettor.
3. Proportion of oil is 2 to 3 %.
4. It provides lubrication to cylinder, piston, piston rings and connecting rod bearing via the crankcase.
5. Also, the separate lubrication is provided to those parts of the engines where the mixture of oil and petrol cannot reach or in case it gives unsatisfactory lubrication.

Table 3.1: Advantages and disadvantages of Mist lubrication

Item	Advantages	Disadvantages
Mist Lubrication system (Petroil)	• Economical and cheap • No oil pump, filter and oil carrying pipe needed • Quantity of oil is automatically regulated with load and speed • Probability of lubrication failure are low	• Carbon deposits and burning of oil film • Fouling of spark plug, increases maintenance cost. • Oil consumption is high, the engine is usually over oiled • During long duration of no load due to almost closed throttle valve, engine mating parts may not get adequate lubricating oil.

Wet Sump lubrication system: In this system, the bottom of the crankcase contains an oil pan or sump, and the oil pump supplies the oil to engine parts.

Types

1. **Splash Lubrication:** In this system, the rotating crankshaft splashes oil around the engine's internal components. It's commonly found in smaller, less complex engines

where oil is stored in a sump or oil pan. This method relies on gravity and the engine's motion to distribute oil.

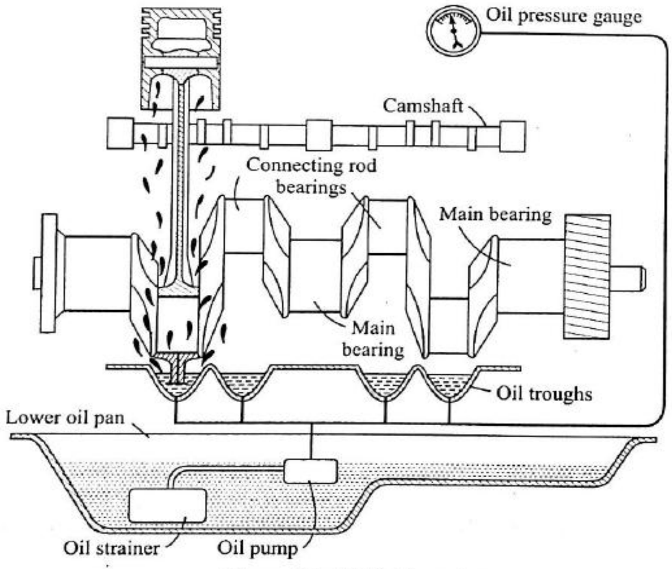


Figure 3.1: *Splash Lubrication*

2. **Pressure Lubrication:** This system uses an oil pump to pressurise and distribute oil throughout the engine. The pressurised oil is directed through channels and passages to critical engine parts, ensuring consistent lubrication even under varying engine speeds and loads. It's more common in modern engines and provides better control over oil flow.

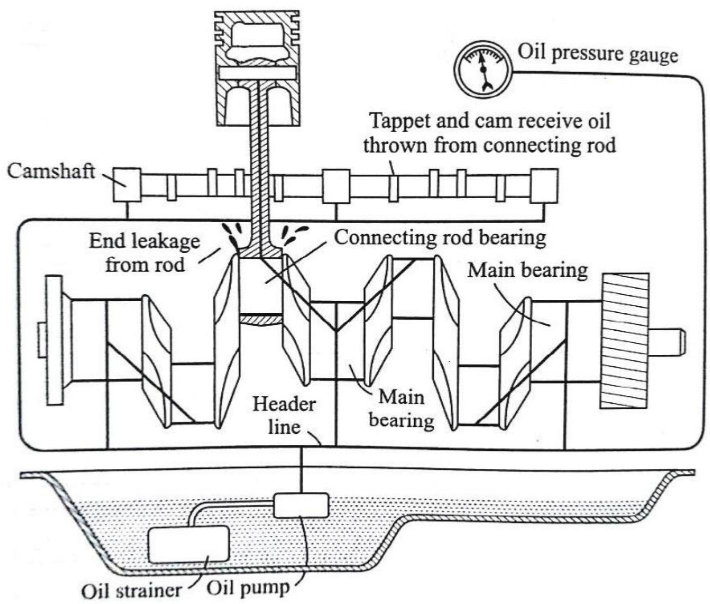


Figure 3.2: *Pressure lubrication*

Typically found in high-performance engines and some race cars, a dry sump system stores oil externally in a separate reservoir or tank rather than in the oil pan. It uses a pump to scavenge oil from the engine and send it to the external reservoir before returning it under pressure to lubricate the engine. Dry sump systems offer better oil control, reduce windage losses, and allow for a lower mounting position of the engine.

Table 3.2: *Advantages and disadvantages of wet sump lubrication and dry sump lubrication*

Item	Advantages	Disadvantages
Wet sump lubrication	• Compact design of the lubrication system • Higher reliability due to less complexity	• Can lead to insufficient lubrication in high-performance engines
Dry sump lubrication	• Reliably lubricates even powerful machines • More oil is used, which contributes to better cooling and longer oil change intervals	• Takes up more space in the vehicle due to additional components such as the oil tank • More components also increase the system's susceptibility to errors

Oil Pump

The oil enters the pump via a pipe with a strainer on the end, which is immersed in the oil reservoir in the sump. This strainer prevents larger particles from being sucked into the lubrication system. The oil pump creates the required pressure that forces the oil to the various lubrication points. The quantity of oil delivered by the pump varies greatly from vehicle to vehicle and also depends on engine speed, but will be approximately 120 litres when the speed of the vehicle is 100 km/h. The most common types of pumps used in the motor vehicle engines are the **gear**, **rotary**, **vane:**

a. **Gear pump:** As shown below, the gear pump consists of two gears in a compact housing with an inlet and outlet. The gears can be either spur or helical in shape (the helical being quieter in operation). The pump drive shaft is mounted in the housing and fixed to this is the driving gear. Oil is drawn via the inlet into the pump. It passes through the pump in the spaces between the gear teeth and pump casing, and out through the outlet at a faster rate than is used by the system. In this way pressure is created in the system until the maximum pressure is reached, at which time the pressure-relief valve will open and release the excess pressure into the sump.

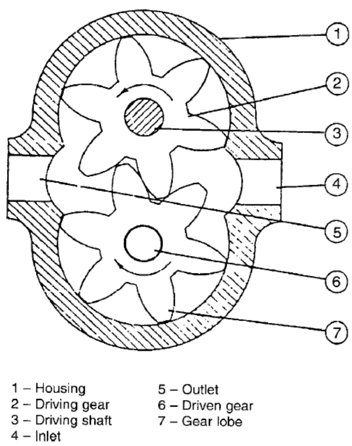


Figure 3.3: *Gear pump*

b. Rotary pump: The main parts of this type of pump shown below are the inner rotor, the outer rotor, and the housing containing the inlet and outlet ports. The inner rotor, which has four lobes, is fixed to the end of a shaft; the shaft is mounted off-centre in the outer rotor, which has five recesses corresponding to the lobes. When the inner rotor turns, its lobes slide over the corresponding recesses in the outer rotor turning it in the pump housing.

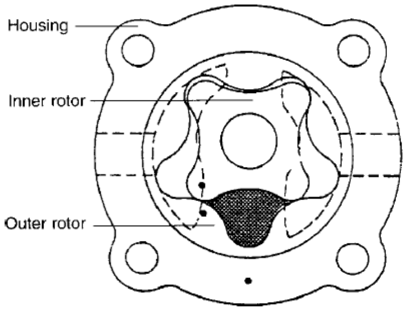


Figure 3.4: Rotary pump

c. Vane pump: The pump shown below takes the form of a driven rotor that is eccentrically mounted (mounted offset) inside a circular housing. The rotor is slotted and the eccentric vanes are free to slide within the slots, a pair of thrust rings ensuring that the vanes maintain a close clearance with the housing. When in operation the vanes are forced outwards by the centrifugal action of the rotor rotating at high speed. As the pump rotates the volume between the vanes at the inlet increases, thus drawing oil from the sump into the pump; this volume decreases as the oil reaches the outlet, pressurising the oil and delivering it to the oil gallery. This type has the advantage of giving a continuous oil flow rather than the pulsating flow that is rather a characteristic of the gear-type oil pump.

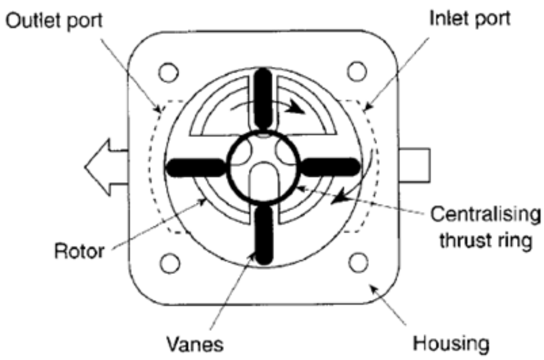


Figure 3.5: *Vane pump*

Pressure Relief Valve

Oil pumps can produce more pressure than is required. A valve is used to limit this pressure to a set value. The pressure relief valve is a simple device which in most cases works on the ball and spring principle. This means that when the pressure on the ball is greater than on the spring, the ball moves. The pressure relief valve is placed in the main gallery so that excess pressure is prevented. When the ball moves, oil is simply returned to the sump.

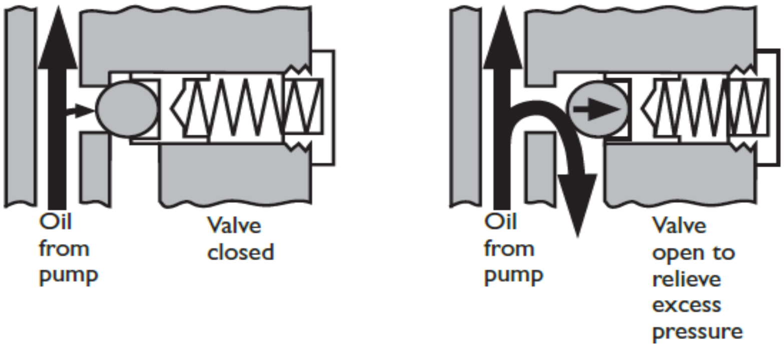


Figure 3.6: *Oil pressure relief valve*

Oil Filters

The purpose of the filters in a lubrication system is to remove from the oil abrasive particles that would cause rapid wear of the bearings. The position of the filter in the lubrication 'circuit' governs the name used to describe the type. The two common types are:

1. **Full-flow filter** treats all the oil delivered to the bearings, provided the filter is clean and the oil is not excessively viscous.

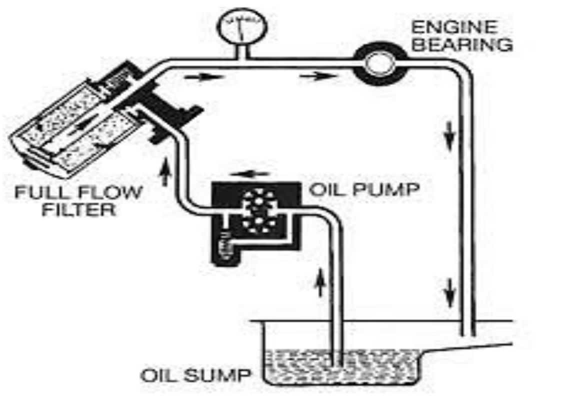


Figure 3.7: *Full-flow filter*

2. **A by-pass filter** is fed only a proportion of the oil delivered by the pump. Although this filters out finer particles than the full-flow filter, it only cleans a proportion of the oil passing into the filter; the rest of the oil passing to the bearings is unfiltered. For this reason, most engines today use full-flow filters.

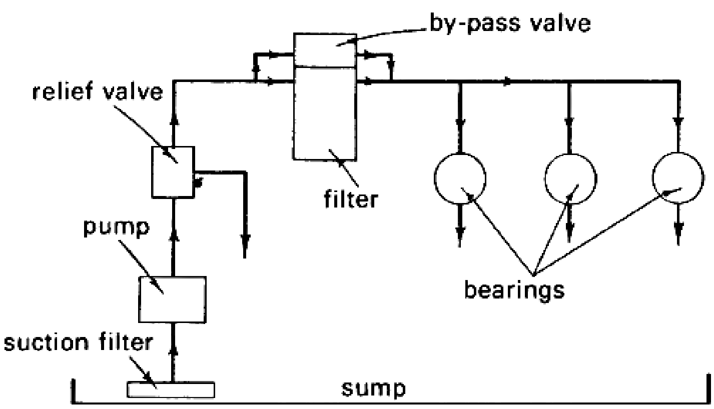


Figure 3.8: *By-pass filter*

Learning Tasks

1. Explain the main types of engine lubrication systems.
2. Describe how each system operates.
3. Describe the various oil pumps, oil filters and pressure relief valve.
4. Identify engine parts lubricated by splash and pressure feed lubrication system.

Pedagogical Exemplars

1. **Group work/collaborative learning**

   In mixed ability groups, learners use appropriate sketches or charts to describe types of lubrication systems (mist, wet and dry sump lubrication).

   Assist learners in small groups to discuss the various oil pumps and filters.

2. **Problem-based Learning:** Learners work independently or in small, mixed-ability groups to describe types of lubrication systems (mist, wet and dry sump lubrication) in relation to the various engines. Assist learners in brainstorming and discussing the various oil pumps and filters used on vehicles.

   Learners visit a school workshop to identify types of engine lubrication systems, oil pumps and filters.

Key Assessments

Level 1: List four components of the engine that are lubricated by splash and pressure feed methods of lubrication.

Level 2

1. Explain how a wet sump lubrication system operates and identify three key features of a Petrol (mist) lubrication system.
2. Describe the function of an oil pump, oil filter and pressure relief valve in an automotive lubrication system.

Level 3: Compare ***three*** advantages and disadvantages between wet sump and dry sump lubrication systems.

Level 4: Propose ***two*** improvements to an existing wet sump lubrication system to enhance its performance and reliability in modern automotive engines.

HINT

*The recommended mode of assessment for week 9 is **peer critique**. You may use the level 1 question as a sample task for the peer critique assessment.*

UNIT 9 REVIEW

This unit reviews the various types of engine lubrication systems, oil pumps and oil filters to ensure a comprehensive understanding and evaluation of the engine lubrication system. The lesson equips the learners with the types of lubrication systems such as mist lubrication, splash lubrication, pressure lubrication, dry sump lubrication, oil pumps and oil filters. The lesson also describes how each type of lubrication system works, including its components, oil flow paths, and mechanisms, as well as the pros and cons of each system. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help students recognise and appreciate the types of engine lubrication systems. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of the types of lubrication systems, oil pumps and oil filters.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the types of lubrication systems, oil pumps and oil filters?
3. Were learners able to explain the working principle of the types of lubrication systems?
4. Were the learners able to state the functions of the oil pumps and oil filters in the engine lubrication system?
5. Which resources best supported the delivery of the types of lubrication systems, oil pumps and oil filters?
6. Did learners find the resources useful in studying the types of lubrication systems, oil pumps and oil filters?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

UNIT 10

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines.*

INTRODUCTION AND UNIT SUMMARY

This unit covers the various machining processes and their applications in the manufacturing industry. Machining processes in the manufacturing industry play a crucial role in creating precise and intricate parts needed across various sectors. These processes involve material removal to shape components according to specific design requirements. The overview of key machining processes commonly used in the manufacturing industry are discussed. Pedagogical strategies have been suggested for teachers to deliver machining lessons. processes. By combining these pedagogical approaches, learners can acquire a comprehensive and effective learning experience in studying the various machining processes used in the manufacturing industry. By incorporating a mix of DoK levels, teachers can accommodate different learning needs of the learners and ensure that learners develop a deep understanding of machining processes in the manufacturing industry.

- ***The unit covers only week 10:*** *Explain the various machining processes and relate them to manufacturing industry.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, learners must explain machining processes in manufacturing industry. Teachers should employ pedagogies such as talk for learning approaches with the use of video or simulation to expose learners to the various machining processes in the manufacturing industry and discuss the processes effectively. The teacher can also employ experiential learning where learners embark on an educational visit to a manufacturing industry and observe the modern machining processes and present a report to the class. These strategies should be used in mixed-ability and mixed-gender groupings, in pairs and individual learning. Learners should be encouraged to participate fully in investigations and present their findings. Teachers should employ differentiated strategies to accommodate diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of machining processes in the manufacturing industry, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessment. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering the machining processes in manufacturing industry. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

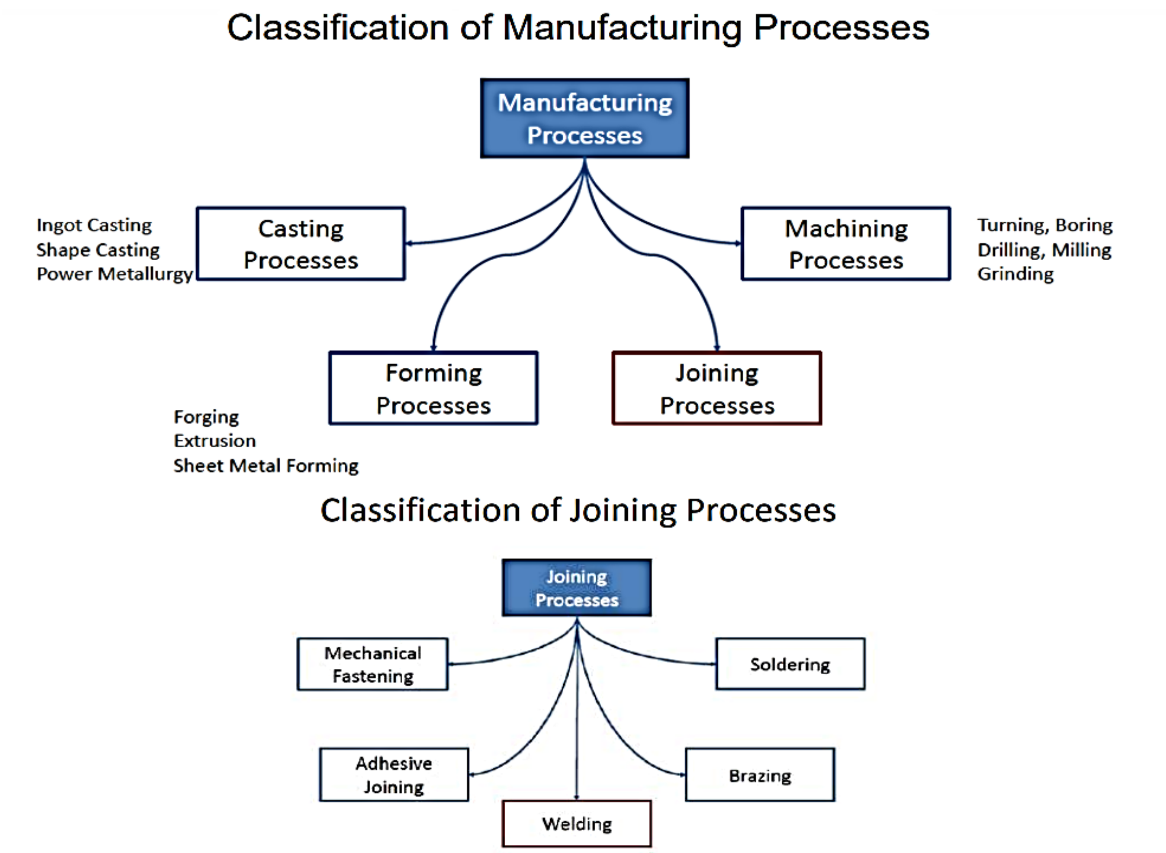
WEEK 10

Learning Indicator: *Explain the various machining processes and relate them to manufacturing industry.*

Focal Area: Machining Processes In Manufacturing Industry

MANUFACTURING PROCESSES

There are four basic manufacturing processes for producing the desired shape of a product. These are casting, machining, joining and deformation processes as shown below:



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.

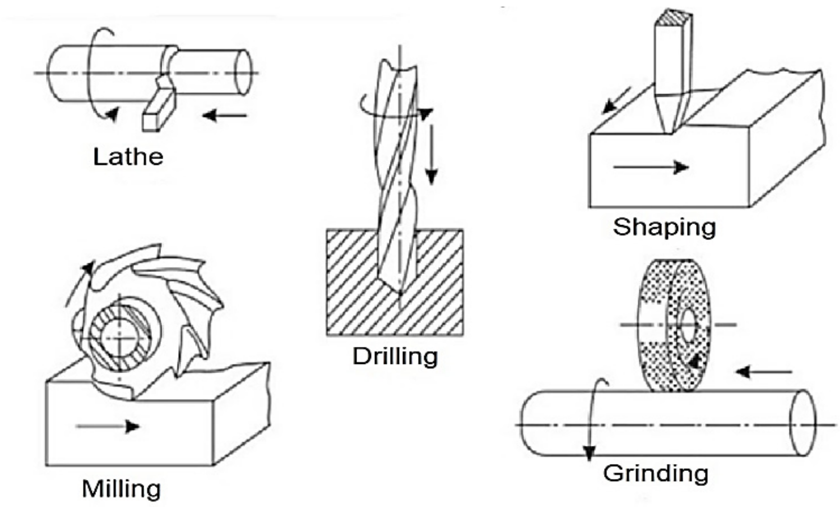


Figure 3.9: *Various machining process with the various relative motions*

1. For lathes and boring machines:
   a. **Drive motion:** Rotary motion of workpiece.
   b. **Feed motion:** Translatory motion of cutting tool in the axial or radial directions.
2. For Drilling machines:
   a. **Drive motion:** Rotary motion of drill.
   b. **Feed motion:** Translatory motion of drill.
3. For milling machine:
   a. **Drive motion:** Rotary motion of the cutter.
   b. **Feed motion:** Translatory motion of the workpiece.
4. For shaping, planning and slotting machines:
   a. **Drive motion:** Reciprocating motion of the cutting tool.
   b. **Feed motion:** Intermittent translation motion of workpiece.
5. For Grinding Machines:
   a. **Drive motion:** Rotary motion of the grinding wheel.
   b. **Feed motion:** Rotary as well as translatory motion of the workpiece.

The processes that can be performed on a lathe 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 tools are shown below.

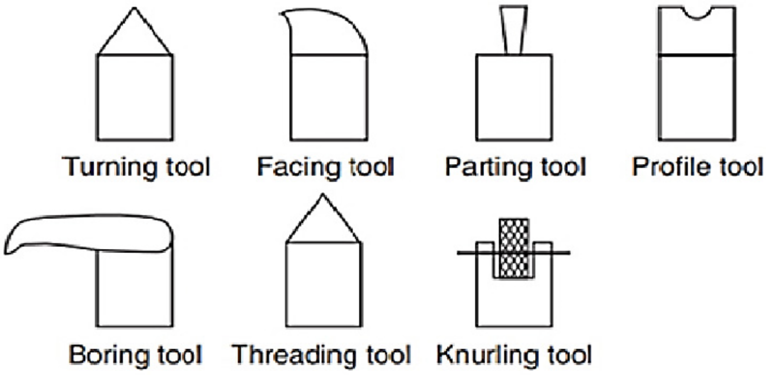


Figure 3.10: *Right-hand lathe tools*

Some of the machining processes are described as follows

1. **Turning:** is a machining process in which a cutting tool, typically a non-rotary tool bit, removes material from a rotating workpiece to shape it into a desired form. This process is typically performed on a lathe machine, which is specifically designed for this type of operation. There are different ways of turning in lathe machine work.

   a. **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.

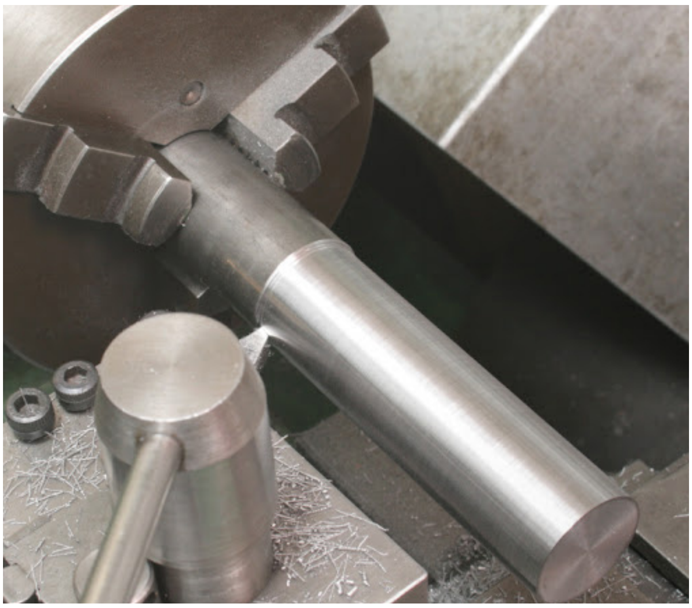


Figure 3.11: *Parrallel turning*

   b. **Taper turning:** Involves gradually reducing the diameter of a cylindrical workpiece to create a conical or tapered shape. This process is performed on a lathe, with the cutting tool moving along the workpiece's length at an angle relative to its axis.

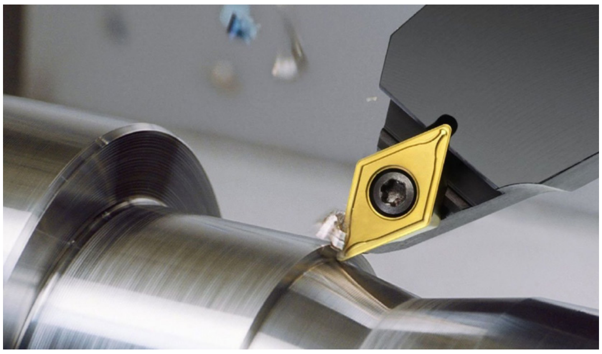


Figure 3.12: *Taper turning*

c. **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.

Figure 3.13: *Step turning*

2. **Knurling:** 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.

Figure 3.14: *Diamond knurling*

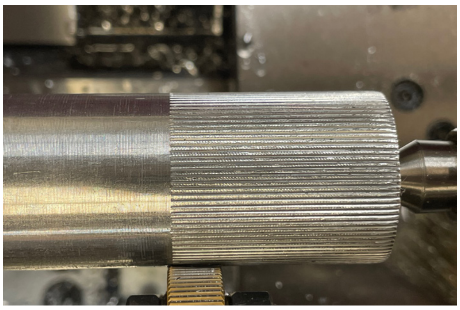


Figure 3.15: *Straight knurling*

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.

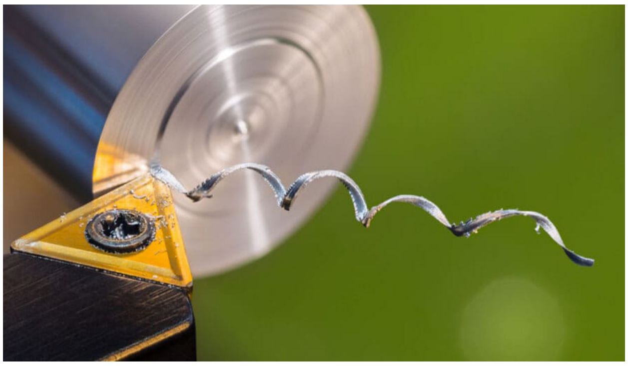


Figure 3.16: *Facing*

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 similar to form turning and is done with a chamfering tool that has its cutting edge at the desired chamfer angle, usually 45o.

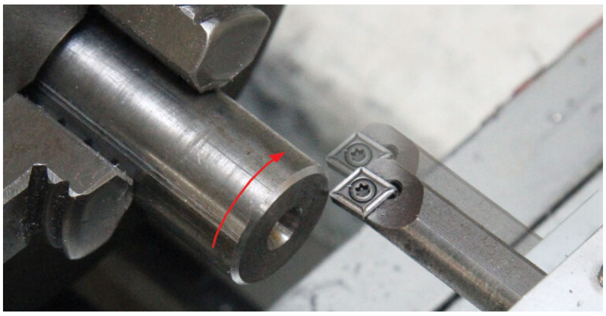


Figure 3.17: *Chamfering*

5. **Thread cutting:** Is the operation of producing a helical groove of specific shape on a cylindrical surface.

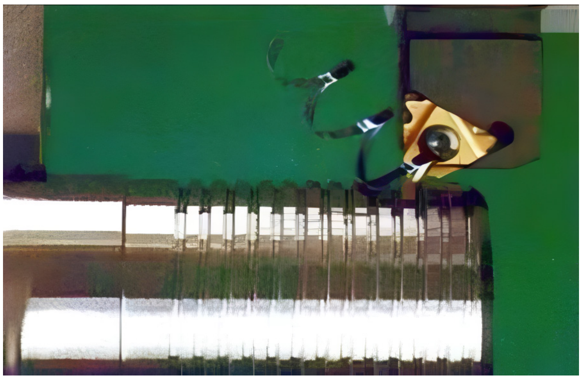


Figure 3.18: *Thread cutting*

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.

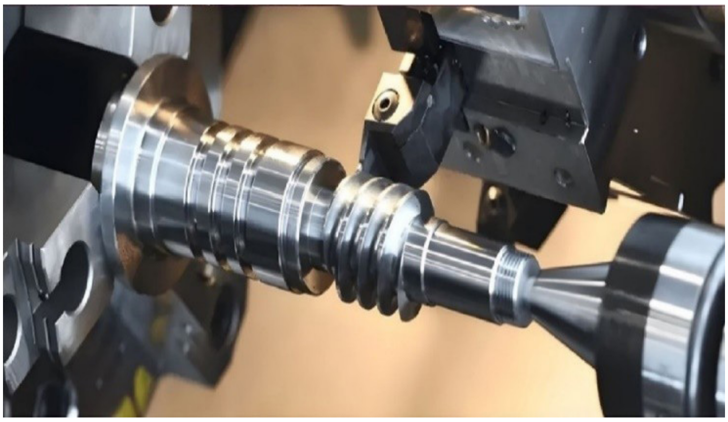


Figure 3.19: *Grooving*

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.

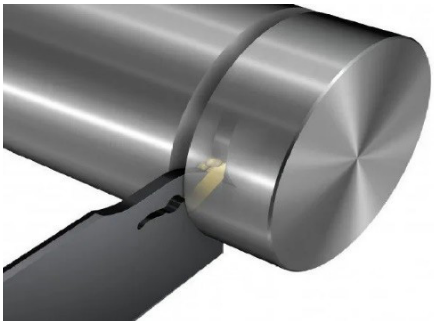


Figure 3.20: *Parting-off*

8. **Drilling:** 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.

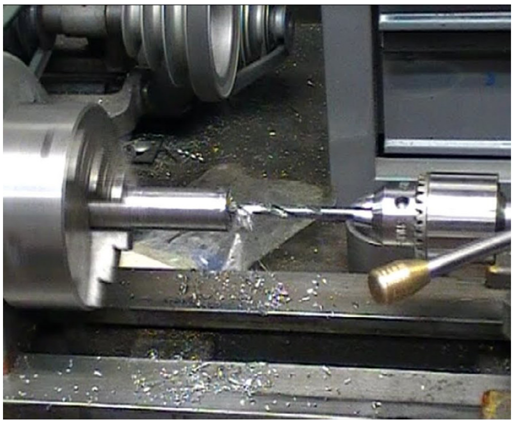


Figure 3.21: *Drilling on the lathe machine*

Figure 3.22: *Drilling using the drilling machine*

9. **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.

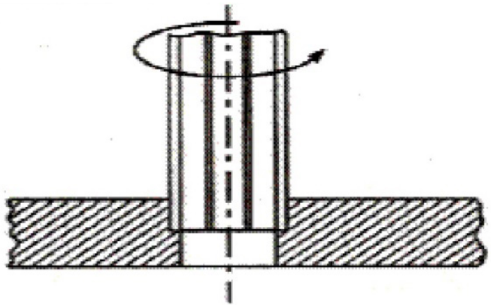


Figure 3.23: *Reaming*

10. **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.

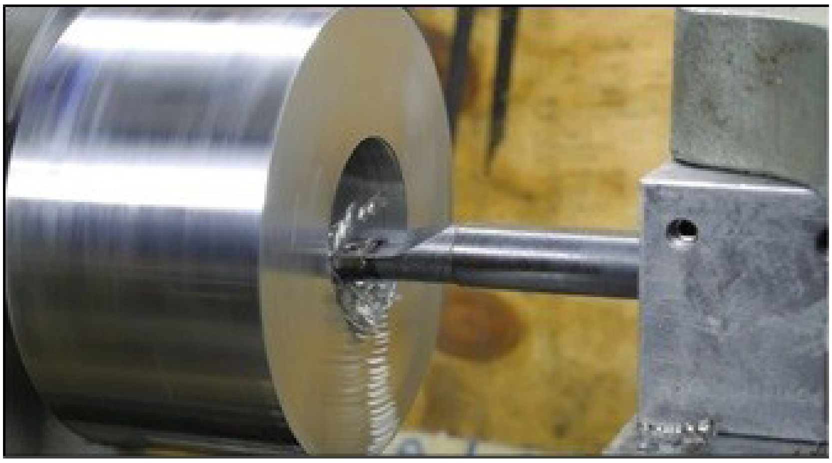


Figure 3.24: *Boring*

11. **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.

Figure 3.25: *Grinding*

12. **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.

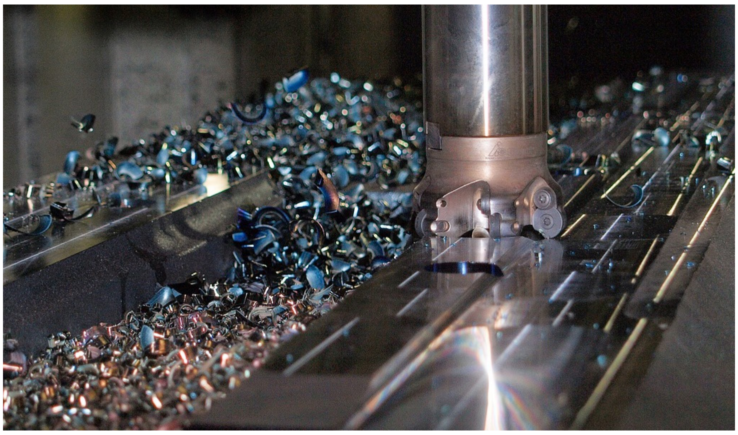


Figure 3.26: *Milling*

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. This is illustrated with an example. Imagine that you are asked to produce the component shown below from the stock (raw material) of size 30 mm diameter and 45 mm length.

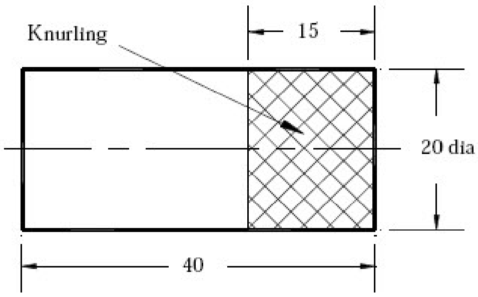


Figure 3.27: *Component to be produced*

To produce this component, one has to carry out:

1. turning to get desired diameter of 20 mm (reduce from 30 mm to 20 mm),
2. facing to reduce length from 45 mm to 40 mm and
3. knurling for the 15 mm length.

A possible 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. It is obvious that there is more than one possible sequence for producing the same component. The general steps when turning external work part hold 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.

Learning Tasks

1. Describe the basic manufacturing processes.
2. Explain the machining processes used in the manufacturing industry.
3. Explain how to carry out a named machining process.
4. Describe the sequential process to follow to produce a named machine part.
5. Explain machining processes that will be appropriate for producing gears.

Pedagogical Exemplars

1. **Talk for learning approaches:** Talk for learning approach, also known as dialogic teaching, emphasises the use of purposeful classroom talk to stimulate and extend students' thinking, understanding and learning. In the context of teaching and learning machining processes in the manufacturing industry, this approach can be particularly effective.

   With videos or visual aids introduce learners to the various machining processes in the manufacturing industry and discuss the processes effectively with the learners. Allow learners to investigate the processes and identify artefacts that can be produced using the various machining processes.

   The teacher should organise learners into small groups to discuss machining processes. Learners can share their understanding of different techniques such as turning, milling, or drilling.

   The teacher can also initiate learners into peer teaching where learners can take turns explaining specific machining processes to their peers. This reinforces their own understanding and helps clarify concepts for other learners.

2. **Experiential Learning:** Learners embark on an educational visit to a manufacturing site, observe the modern machining processes and present a report to the class.

   Learners should have hands-on practice on the machining processes at the workshop and undertake projects that require them to design, plan and manufacture a part or assembly using them. This gives learners a sense of the entire process, from conception to final product.

   Teachers can also arrange for learners to partner with a local industry to provide students with real-world problems to solve. This could include designing and machining a part for a specific application.

   Learners should also be encouraged to partner with local industries to provide internships or apprenticeships where learners can work under the supervision of experienced machinists. Experienced machinists in the locality should be arranged to mentor learners, providing guidance, feedback and real-time problem-solving strategies.

KEY ASSESSMENTS

Level 1: What are the four basic manufacturing processes?

Level 2: Explain at least three machining processes used in the manufacturing industry.

Level 3: Explain how to carry out a named machining process.

Level 4

1. Which machining processes will be appropriate when cutting gears? Explain why.
2. Write the process sequence to be used for manufacturing the component shown below.

   From raw material of 175 mm length and 60 mm diameter.

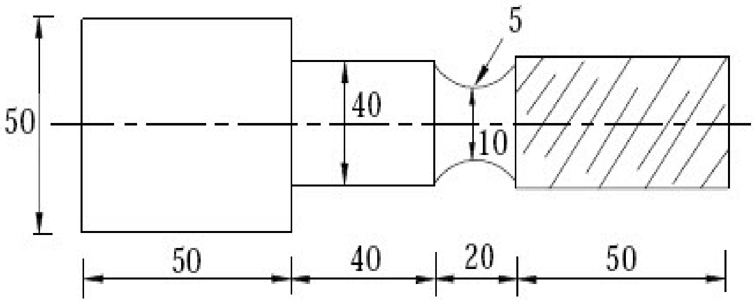


Figure 3.28: *Component to be produced*

3. Produce and exhibit the artifact shown above.

HINT

*The recommended mode of assessment for week 10 is **display and exhibition.** Use the level 1 question as a sample question.*

UNIT 10 REVIEW

This unit looked at machining processes in the manufacturing industry. Learners were taken through the machining processes in the manufacturing industry and how to use them to cut machine parts for use. Applications of the various machining processes were also discussed. Learners had the opportunity to visit a local manufacturing industry to have hands on practice on the machining processes. Teachers were given options of pedagogical strategies to use.

REFLECTION

1. What was my best moment in today’s lesson and how can I create more of such situations?

2. Were learners able to explain machining processes?
3. Were learners able to explain the various machining processes in the manufacturing industry?
4. Were the learners able to apply the knowledge acquired on the machining processes to solve a problem?
5. Which resources best supported the teaching and learning of machining processes in the manufacturing industry?
6. Did learners find the resources useful in the machining processes?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

UNIT 11

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Engine Technology.

Learning Outcome: *Perform engine cooling and lubrication system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate understanding in the working principles of engine cooling and lubrication systems.*

INTRODUCTION AND UNIT SUMMARY

The properties of engine lubricating oil are essential for the proper functioning, efficiency, and longevity of an engine. The unit covers the various properties of engine lubricating oil, classifications of engine oil and crankcase ventilation. This equips learners with the basic knowledge and skills needed to maintain, repair, and service engine lubrication systems contributing to better lubrication systems and selecting appropriate oil for the proper functioning and longevity of an engine. Teaching the various properties of engine lubricating oil, classifications of engine oil and crankcase ventilation involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the various properties of engine lubricating oil, classifications of engine oil and crankcase ventilation. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the workings of the engine lubricating oil and crankcase ventilation.

- ***The unit covers only week 11****: Explain the properties and classifications of engine lubricating oil and crankcase ventilation.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach properties of engine lubricating oil, classifications of engine oil and crankcase ventilation ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the various properties of engine lubricating oil, classifications of engine oil and crankcase ventilation can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the various properties of engine lubricating oil, engine oil classifications and crankcase ventilation.

ASSESSMENT SUMMARY

Teaching the various properties of engine lubricating oil, engine oil classifications and crankcase ventilation, assessments can span various levels to gauge learners' understanding and application of the concepts and the principles. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to properties of engine lubricating oil, classifications of engine oil and crankcase ventilation. This approach ensures a comprehensive evaluation of their knowledge and basic proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

Week 11

Learning Indicator: *Explain the properties and classifications of engine lubricating oil and crankcase ventilation.*

Focal Area 1: Properties of Engine Lubrication Oil

Engine lubricating oil has several critical properties that ensure it effectively protects and enhances the performance of an engine.

1. **Viscosity:** The measure of the oil's resistance to flow. It indicates how thick or thin the oil is. Correct viscosity ensures the oil can flow easily to all parts of the engine, providing adequate lubrication under various temperatures and operating conditions.
2. **Viscosity index (VI):** The viscosity index (VI) indicates the change in oil viscosity with temperature. Oils with a high VI exhibit less change in viscosity over a range of temperatures, ensuring consistent lubrication in both hot and cold conditions.
3. **Pour Point:** The pour point is the lowest temperature at which the oil remains fluid. A low pour point ensures the oil can flow and provide lubrication at low temperatures, essential for cold starts.
4. **Flash Point:** The flash point is the lowest temperature at which the oil vapours ignite. A high flash point indicates better resistance to high temperatures and reduced risk of ignition.
5. **Cloud point:** The temperature at which the oil starts solidifying is called cloud point. The cloud point is important for oils used in colder climates or applications where low temperatures are common.
6. **Oiliness:** The property of an oil to cling to the metal surface by molecular action and then to provide a very thin layer of lubricant under boundary lubrication conditions is called the oiliness, lubricity or film strength.
7. **Fire point:** Fire point is obtained if the oil is heated further after the flashpoint. Fire point is the temperature at which the oil, once lit with flame, will burn steadily for at least 5 seconds.

Additives for lubricant

These are the compounds added to the lubricating oils to promote and improve their desired properties.

1. **Detergents and Dispersants:** Detergents help prevent the formation of deposits and sludge by neutralising acidic contaminants formed during combustion. Dispersants keep contaminants suspended in the oil to prevent them from settling on engine surfaces.
2. **Anti-Wear Additives:** These form a protective layer on metal surfaces to reduce friction and wear, extending the lifespan of engine components.

3. **Viscosity Index Improvers:** Improve the viscosity-temperature relationship of the oil, ensuring consistent viscosity across a range of operating temperatures.
4. **Antioxidants:** Prevent oxidation and degradation of the oil at high temperatures, reducing the formation of sludge and varnish.
5. **Pour Point Depressants:** These lower the pour point of the oil, allowing it to flow more easily at lower temperatures, crucial for cold starts.
6. **Anti-Foam:** Prevents the formation of foam, which can reduce the oil's ability to lubricate effectively.
7. **Corrosion Inhibitors:** Protect engine components from corrosion caused by acidic byproducts of combustion and moisture.
8. **Anti-rust:** Protects engine components from rust caused by moisture and water contamination.

Classification of engine oil based on rating

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

1. **SAE rating:** The Society of Automotive Engineers (SAE) assigns viscosity grades to engine oils based on their viscosity characteristics at different temperatures. For example: SAE 5W-30, SAE 10W-40, etc. These multi-grade oils are denoted by a combination of two viscosity grades separated by the letter "W" (for winter). The numbers before and after the "W" (winter) indicate the oil's viscosity at low and high temperatures, respectively. Lower numbers denote thinner oils that flow better at cold temperatures (winter), while higher numbers indicate thicker oils suitable for higher temperatures (summer).

Figure 3.29: *SAE rating*

2. **API Service rating:** The American Petroleum Institute (API) establishes service categories that denote the performance standards and applications of engine oils. Example: **Petrol engine** (SA, SB, SC, SD, SE) and **Diesel engine** (CA, CB, CC, CD, CE). The API service categories denote the oil's performance level in terms of engine cleanliness, wear protection, and compatibility with emission control systems.

Figure 3.30: *API service rating*

Crankcase Ventilation

The crankcase ventilation system is an essential component of a vehicle's engine system. It is responsible for maintaining the engine's health and efficiency by removing harmful gases and excess pressure from the crankcase. This system plays a critical role in ensuring the proper functioning of the engine and preventing potential damage. The crankcase ventilation system consists of various components that work together to regulate the flow of gases and maintain optimal engine performance. These components include the PCV (Positive Crankcase Ventilation) valve, breather element, and various hoses and pipes as shown on the diagram.

1. The pressure inside the combustion chamber is high, so small amounts of gases escape through gaps between piston ring and cylinder and enter the crankcase.
2. These gases can dilute and contaminate the engine oil, cause corrosion to critical parts and contribute to sludge build up.

   At high speed, blowing gases increase crankcase pressure that causes oil leakage from sealed engine surfaces and consume some expansion work.
3. The crankcase ventilation system removes these blowby gases from the crankcase and reduces the pressure inside the crankcase.

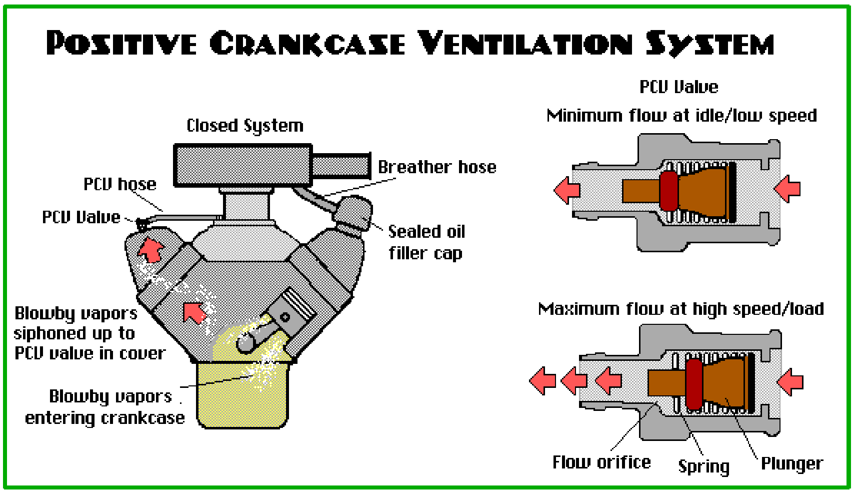


Figure 3.31: *Crankcase ventilation*

Learning Tasks

1. Explain the properties of engine lubrication oil.
2. Describe the various types of additives added to an oil lubricant.
3. Describe how engine lubricating oils are classified.
4. Explain the importance of crankcase ventilation.

Pedagogical Exemplars

1. **Group work/collaborative learning:** In a fair mixed groups learners use appropriate resources to identify the properties and classifications of engine lubricating oil. Assist learners to brainstorm the explain the purpose of the crankcase ventilation and their types.
2. **Problem based Learning:** Learners work independently or in groups to identify the type of lubricants used on the vehicles and brainstorm the procedure to change the engine oil.

   Learners work independently to identify properties of engine lubricating oil and present individual report**.**

   Learners visit a school workshop to observe how engine oil is changed and present a report.

Key Assessments

Level 2

1. Explain briefly the following properties of a lubricant:
   - **a.** Viscosity
   - **b.** Pour Point
   - **c.** Flash Point
   - **d.** Oiliness
2. What are additives and explain briefly the following additives:
   - **a.** Detergents and Dispersants
   - **b.** Anti-Wear Additives
   - **c.** Pour Point Depressants
   - **d.** Anti-Foam
   - **e.** Anti-rust

Level 3

1. How are lubricating oils classified? Explain what is meant by multi grade oils?

2. What do you understand by crankcase ventilation? Explain the differences between closed crankcase and open crankcase ventilation system.

HINT

*The recommended mode of assessment for **week 11** is **essay.** Use the level 2 question 2 as a sample question.*

UNIT 11 REVIEW

This unit reviews the properties and classifications of engine lubricating oil and crankcase ventilation to ensure a comprehensive understanding and evaluation of the engine lubrication system. The lesson equips the learners with knowledge of the lubricating oil properties such as viscosity, pour point, flash point, oiliness. etc. The lesson also describes the SAE and API service ratings of engine oil as well as closed and open crankcase ventilation with layouts. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the types of engine lubrication systems. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of engine lubricating oil and crankcase ventilation.

REFLECTION (ADDITIONAL READING)

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the properties of the engine lubrication oil?
3. Were learners able to explain the function of the properties of the engine lubrication oil?
4. Were the learners able to explain crankcase ventilation and their types?
5. Which resources best supported the delivery of the properties of lubrication oil and crankcase ventilation?
6. Did learners find the resources useful in studying the properties of lubrication oil and crankcase ventilation?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 12

STRAND: METAL TECHNOLOGY

Sub-Strand: Engineering Materials, Tools and Machines

Learning Outcome: *Develop and apply skills of heat treatment to a particular metal and perform operations using grinding, drilling, lathe, milling and shaping machines.*

Content Standard: *Demonstrate understanding in the use of engineering tools, materials and machines*

INTRODUCTION AND UNIT SUMMARY

This unit covers the principles of sand casting. Tools and equipment for sand casting and the various processes in sand casting are discussed in this unit. The origins of sand casting date back thousands of years, with evidence of its use in ancient civilization such as Egypt and China. Over centuries, the process has evolved, incorporating advancements in materials, mould-making techniques, and metal alloys to enhance its precision and efficiency. Sand casting one of the oldest and most versatile methods of metal casting, used in manufacturing to produce complex metal parts and components. This process involves creating a mould from a sand mixture and pouring molten metal into the cavity to form the desired shape once it solidifies. Its widespread use is attributed to its cost-effectiveness, flexibility in producing large or small parts and it is suitable for working with a wide range of metals. Pedagogical strategies have been suggested for teachers to employ in delivering lessons on sand casting principles. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the tools for sand casting and the processes involved in sand casting. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the principles of sand casting.

- ***The unit covers only week 12****: Apply the principle of sand casting to produce articles*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, the teacher must engage learners in various ways to explain the principles of sand casting. The teacher should group learners into mixed ability and task them to identify and discuss the uses of the tools and equipment for sand casting. Group learners into mixed-ability and in pairs to describe accurately the processes used in sand casting. The teacher should assist learners to design and make articles using the sand-casting process and use experiential learning where learners embark on an educational visit to a local industry where sand casting is used. Teachers should task learners to observe the sand casting tools and equipment and the process of sand casting. These strategies should be used in mixed-ability and mixed-gender groupings so learners can be encouraged to participate fully in investigations as well as presentation of findings. Teachers should employ differentiated strategies to accommodate the diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding about the principle of sand casting, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering the principles of sand casting. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

Week 12

Learning Indicator: *Apply the principle of sand casting to produce articles.*

Focal Area: 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.

Two of the main pieces of equipment to be seen in a foundry are:

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

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. Casting is one of the oldest manufacturing processes. It is the first step in making most of the products.

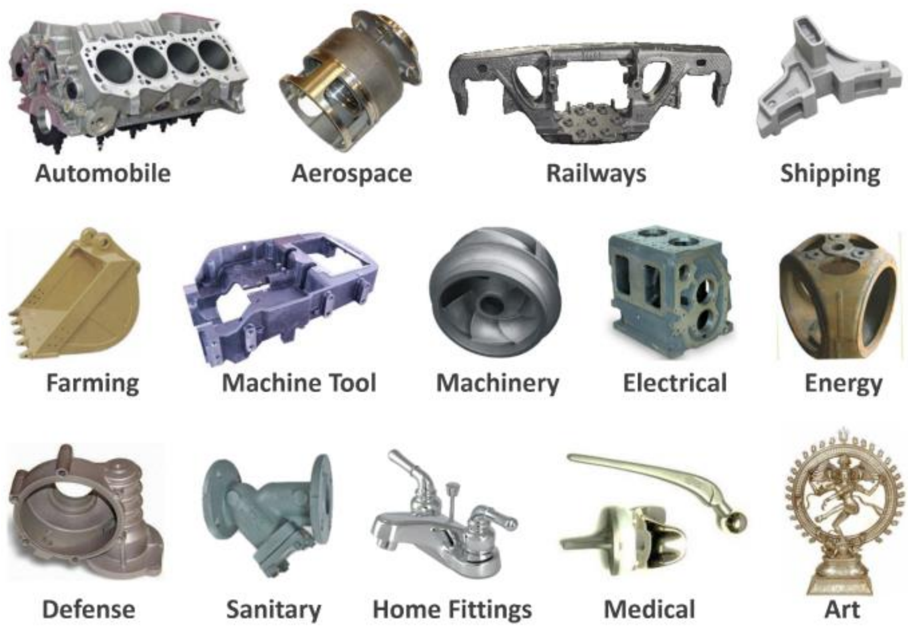
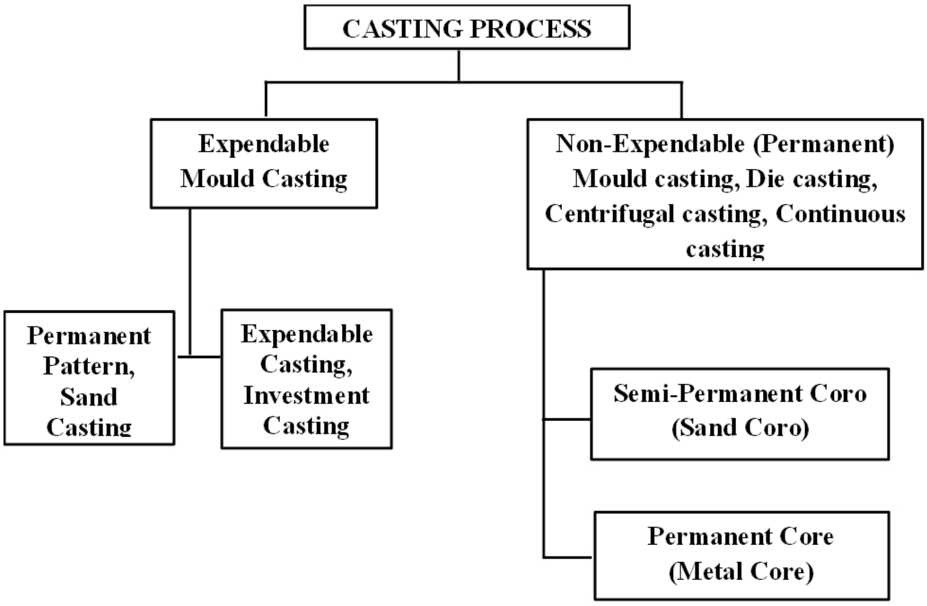


Figure 3.32: *Typical metal cast pasts*

Classification of Casting Process



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

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, up to 200 tonnes 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.

Moulding Sand

The ingredients of moulding sand are 80 to 90% Silica sand grains, 5 to 20m% Clay, Moisture, 2 to 5% Water, Oxides of Iron, Potash, Limestone, Magnesia and Soda.

Moulding sand properties

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.

Sand Casting Mould

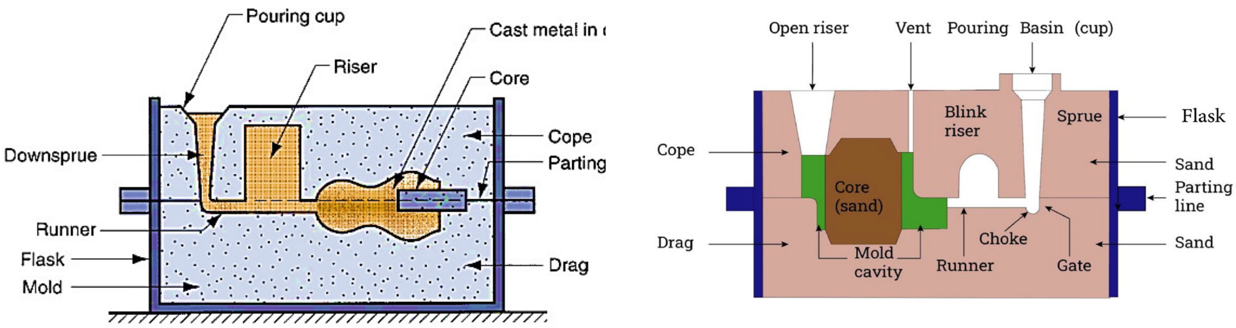


Figure 3.33: *Sand casting mould*

Terminology for sand casting mould

1. **Flask:** A metal or wood frame, without 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 the 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 makes 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.

Tools and Equipment Used in Sand Casting

1. **Hand riddle:** It consists of a screen of standard circular wire mesh equipped with circular wooden frame. It is generally used for cleaning the sand for removing foreign materials such as nails, shot metals, splinters of wood etc from it. Power operated riddles are available to help riddling large volumes of sand.

Figure 3.34: *Hard riddle*

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.

Figure 3.35: *Shovel*

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.

Figure 3.36: *Rammers*

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.

Figure 3.37: *Sprue pin*

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 plane and smooth. One of the edges is bevelled and the other end is kept perfectly smooth and plain.

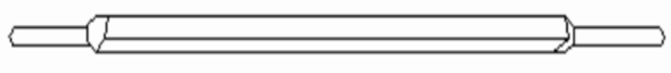


Figure 3.38: *Strike off bar*

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.

Figure 3.39: *Mallet*

7. **Draw spike/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.

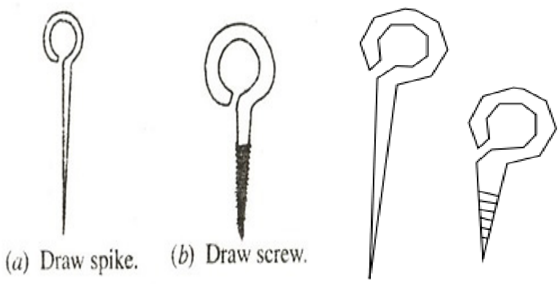


Figure 3.40: *Draw spike/draw screw*

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.

Figure 3.41: *Vent rod*

9. **Lifters:** They are also known as cleaners or finishing tools which are 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.

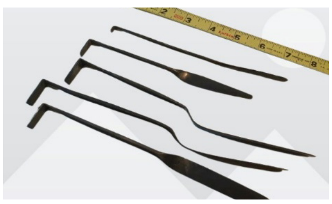


Figure 3.42: *Lifters*

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 are equipped with a wooden handle. The Common metal blade shapes of trowels may be or contoured or rectangular oriented. The trowels are basically employed for smoothing or slicking the surfaces of the moulds. They are also used to cut in-gates and repair the mould surfaces.

Figure 3.43: *Trowels*

11. **Slicks:** They are also recognized 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. The nomenclatures of the slicks are largely due to their shapes.

Figure 3.44: *Slicks*

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.

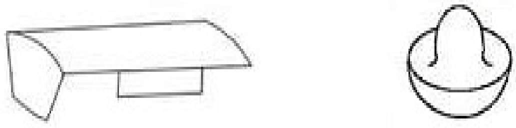


Figure 3.45: *Smoothers*

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.

Figure 3.46: *Swab*

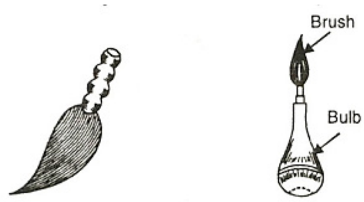


Figure 3.47: *Swab*

14. **Spirit level:** Is used to check whether the sand bed or the moulding box is horizontal or flat.

Figure 3.48: *Spirit level*

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.

Figure 3.49: *Gate cutter*

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.

Figure 3.50: *Bellows*

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

Figure 3.51: *Clamps, cotters and wedges*

NOTE

1. Use the link below to search for video on list of sand-casting tools and their uses:

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

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

Steps In Making Sand Castings

The basic steps in making sand castings are

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. Mould cavity is the primary cavity. The mould cavity contains the liquid metal and it acts as a negative of the desired product. The mould also contains secondary cavities for pouring and channelling the liquid material into the primary cavity and will act 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 scale 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.

Making A Simple Sand Mould

a. The drag flask is placed on the board.

b. Dry facing sand is sprinkled over the board.

c. Drag half of the pattern is located on the mould board. Dry facing sand will provide a non-sticky layer.

d. Moulding sand is then poured in to cover the pattern with the fingers and then the drag is filled completely.

- **e.** Sand is then tightly packed in the drag by means of hand rammers. Pein hammers (used first close to drag pattern) and butt hammers (used for surface ramming) are used.
- **f.** The ramming must be proper i.e. it must neither be too hard or soft.
- **g.** After the ramming is finished, the excess sand is levelled/removed with a straight bar known as the strike off bar.
- **h.** Vent holes are made in the drag to the full depth of the flask and to the pattern by the vent rod to facilitate the escape of gases during pouring and solidification.
- **i.** The finished drag flask is now turned upside down exposing the pattern.
- **j.** Cope half of the pattern is then placed on the drag pattern using locating pins. The cope flask is also located with the help of pins. The dry parting sand is sprinkled all over the drag surface and on the pattern.
- **k.** A sprue pin for making the sprue passage is located at some distance from the pattern edge. The riser pin is placed at an appropriate place.
- **l.** Filling, ramming and venting of the cope is done in the same manner.
- **m.** The sprue and riser are removed and a pouring basin is made at the top to pour the liquid metal.
- **n.** Pattern from the cope and drag is removed.
- **o.** Runners and gates are made by cutting the parting surface with a gate cutter. A gate cutter is a piece of sheet metal bent to the desired radius.
- **p.** The core for making a central hole is now placed into the mould cavity in the drag. Rests in core prints.
- **q.** Mould is now assembled and ready for pouring.

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.**

Pattern Materials

1. **Wood:** The most commonly used pattern material is wood, the main reason being the easy availability, low weight, easy shaping and cheap.
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, white metal can be used as pattern materials. Aluminium and White metal are also commonly used, these materials are light weight, 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. Eg Epoxy resin.

4. **Plasters:** It has high strength, can be easily formed into complex shapes and can be used only for small patterns. Eg. Gypsum cement

5. **Waxes:** They are excellent materials for investment casting and they have good surface finishes, high tensile strength and are very hard. Eg. Paraffin wax, Bees wax.

Types of Patterns

Pattern types include Solid or single piece pattern, Split pattern, Loose piece pattern, Match plate pattern, Gated 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.

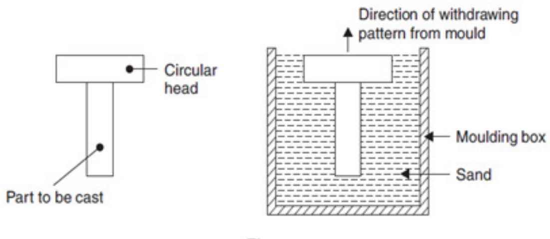


Figure 3.52

2. **Split pattern:** It is not practical to have one piece pattern for parts of complicated shapes, because it would not be possible to withdraw the pattern from the mould.

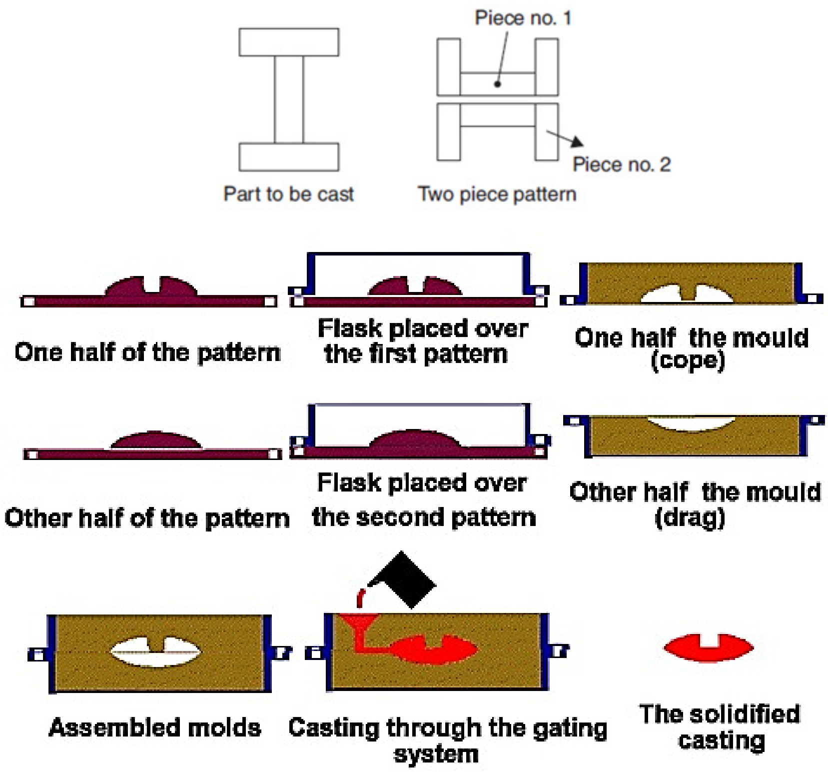


Figure 3.53: *Split pattern*

Die Casting

A sand mould is usable for production of only one casting. It cannot be used twice. A Die is essentially a metal mould, 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 (e.g., a piston in a cylinder pushes the material through cylinder nozzle), 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 metal solidifies.
4. Open die halves.
5. Eject the casting along with runner, riser etc.
6. The above cycle is repeated.

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 point e.g., aluminium, magnesium and their alloys.

Advantages and disadvantages of die casting

1. It is used for mass production of castings of small and medium size. e.g., pistons of motorcycle and scooter engines, valve bodies, carburettor housings etc.
2. The initial cost of manufacturing a die is very high. It is a disadvantage.
3. This process produces high quality, defect free castings.
4. 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.
5. Large size castings cannot be produced by this process. It is a disadvantage.
6. Castings with very complex shapes or with many cores are difficult to produce by die casting.
7. In the case of mass production, castings can be produced cheaply.

8. The process does not require the use of sand and requires much less space as compared to a conventional foundry using sand moulds.

Casting Defects

Some of the common defects in the castings are described below

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 faulty design of casting consisting of very thick and thin sections, a shrinkage cavity may be caused at the junction of such sections. Shrinkage cavity is totally internal.
3. **Misrun:** This denotes incomplete filling of mould cavity. It may be caused by bleeding of molten metal at the parting of cope and drag, inadequate metal supply or improper design of gating.
4. **Cold shut:** 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.
5. **Mismatch:** 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.
6. **Drop:** This happens when a portion of the mould sand falls into the molten metal. Loose sand inadequately rammed or lack of binder may cause this defect.
7. **Scab:** This defect occurs when a portion of the face of a mould lift or breaks down and the recess is filled up by molten metal.
8. **Hot tear:** 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.

Learning Tasks

1. Explain what is meant by ***sand casting***.
2. Identify and explain the functions of the tools and equipment for sand casting.
3. Explain the ***process of sand casting***.
4. Describe the sequential process to follow to produce a machine part using sand casting.
5. Describe some common casting defects.

Pedagogical Exemplars

1. **Group work/Collaborative learning:** Using samples of sand-casting tools and equipment, assist learners in their groups to identify and discuss their uses. Group learners to describe accurately the processes used in sand casting.

   Put learners in groups and assist them to design and make articles using sand casting process.

2. **Experiential learning:** Learners embark on an educational visit to a local workshop and observe the sand-casting processes and present a report to the class.

   Assist learners to identify and state the functions of each tool and equipment used in the sand-casting process and present a report.

Key Assessments

Level 1: Explain what is meant by sand casting.

Level 2: 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

Level 3: Describe how a bell can be produced using sand casting.

Level 4

1. How can a ball pein hammer head be produced by using the process of sand casting?
2. Specify four common casting defects and explain the reasons which cause these defects.

HINT

The recommended mode of assessment for week 12 is ***end-of-semester examination****. Refer to* ***Appendix D*** *at the end of the section for more sample tasks and the Table of Specifications*

UNIT 12 REVIEW

This unit covered the principle of sand casting. Sand casting has been thoroughly discussed including the tools and equipment for sand casting. The processes of sand casting have also been covered. Advantages of the sand-casting process were also covered. Learners had the opportunity to visit a local sand-casting factory to have hands on practice on articles produced by sand casting. Teachers were given options of pedagogical strategies to use.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain sand casting?
3. Were learners able to explain the process of sand casting?
4. Were learners able to identify and explain the tools for sand casting?
5. Which resources best supported the teaching and learning of the principle of sand casting?
6. Did learners find the resources useful in learning about sand casting?
7. How were the different subgroups catered for in the class?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

APPENDIX D: END OF SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

- 30 Multiple Choice Questions (MCQ) all should be answered within 45 minutes. Questions cover DoK level 1 to 3
- 10 essay type questions, 7 to be answered within 2 hours. Questions cover DoK level 1 to 3

RESOURCES: Scannable sheets, A4 paper, answer booklets, class list, etc.

SAMPLE QUESTIONS

Multiple Choice: 45 mins

SECTION A

1. Which of the following scenarios **best** illustrates the importance of workplace safety protocols? An employee…………

a. *attends team meeting regularly.*

b. *follows the dress code policy.*

c. *reports a minor injury to their supervisor.*

e. *uses (PPE) while handling hazardous materials.*

SECTION B: Essay type 1hour 45 minutes

Question A: Explain the concept cooling in engine system.

MARKING SCHEME

Multiple Choice: ***30 marks -1 mark for each***

1. Which of the following scenarios **best** illustrates the importance of workplace safety protocols? An employee…………

a. *attends team meeting regularly.*

b. *follows the dress code policy.*

c. *reports a minor injury to their supervisor.*

d. *uses PPE while handling hazardous materials.*

Essay - ***70 marks*** **(7 questions to be answered out of 10)**

Question A: Explain the concept of cooling in the engine system.

Expected Answer

An explanation of the concept with relevant technical words and phrases such as, coolant, heat removal, lower temperature, efficiency, etc. ***5 marks.***

TABLE OF SPECIFICATION

Table3.1: *Table Of Specification*

WKS	LEARNING INDICATORS	Question type	DoK level 1	DoK level 2	DoK level 3	Dok level 4	TOTAL
1	Describe the construction and operation of the air-cooling systems.	Multiple Choice	1	1	1		3
		Essay		1			1
2	Describe various heat treatment processes with engineering examples.	Multiple Choice	1	1	1		3
		Essay			1		1
3	Describe the construction and operation of the thermosyphon and pump assisted water-cooling systems.	Multiple Choice	1	1	1		3
		Essay	1				1
4	Demonstrate the use of grinding, drilling and lathe machines.	Multiple Choice	1	1	1		3
5	Describe the construction and operation of the thermostat and pressurized water-cooling systems.	Multiple Choice	1	1	1		3
		Essay		1			1
6	Demonstrate the use of the milling machine.	Multiple Choice	1	1	1		3
		Essay			1		1
7	Examine the parts of the lubrication systems and the components to be lubricated.	Multiple Choice	1	1	1		3

8	Demonstrate the use of the shaping machine.	Multiple Choice	–	1	1		2
		Essay	1				1
9	Describe types of lubrication systems, oil pumps and oil filters.	Multiple Choice	–	1	1		2
		Essay			1		1
10	Explain the various machining processes and relate them to manufacturing industry.	Multiple Choice	1	1	–		2
		Essay		1			1
11	Explain the properties and classifications of engine lubricating oil and crankcase ventilation.	Multiple Choice	1	1	–		2
		Essay	1				1
12	Apply the principles of sand casting to produce articles.	Multiple Choice		1	–		1
		Essay			1		1
	TOTAL		12	15	13		40

SECTION 4: VEHICLE STEERING AND METAL FORMING PROCESSES I

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section learners will acquire knowledge and understanding of front and stub axles as well as components of the steering system. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of basic metal forming processes with engineering products as well as forging, rolling and extrusion operations in sheet metal. All the above are treated from unit 13 to unit 16.

UNIT 13

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems*

HINT

Individual Project Work should be assigned to learners by the end of Week 13. Ensure that the project covers several learning indicators and spans over several weeks. Learners are expected to submit the individual project by week. Refer to Appendix E as guide.

INTRODUCTION AND UNIT SUMMARY

The front and stub axles are crucial components in a vehicle's suspension and steering systems. They play essential roles in ensuring the proper functioning, stability, and safety of a vehicle. These axles support the weight of the vehicle and provide stability. They connect the wheels to the vehicle, ensuring proper alignment and balance. The unit covers the functions, types and the construction of front axle assembly. It also describes the stub axle types and the parameters that are contained in the vehicle dimensions. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the various front axle assembly and vehicle dimensions parameters. By incorporating a mix of DoK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the functions of the front axle and the vehicle dimensions for effective steering and manoeuvrability contributing to safety and driving comfort.

- ***The unit covers only week 13***: *Explain front and stub axle, types and their functions*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach front axle assembly and vehicle dimensions ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the front axle assembly and vehicle dimensions can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the functions of the front axle assembly and stub axle types as well as vehicle dimensions.

ASSESSMENT SUMMARY

Teaching the functions of the front axle assembly, stub axle types and vehicle dimensions, assessments can span various levels to gauge learners' understanding and application of the concepts and the principles. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to front axle assembly and stub axle types as well as vehicle dimensions. This approach ensures a comprehensive evaluation of their knowledge and basic proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

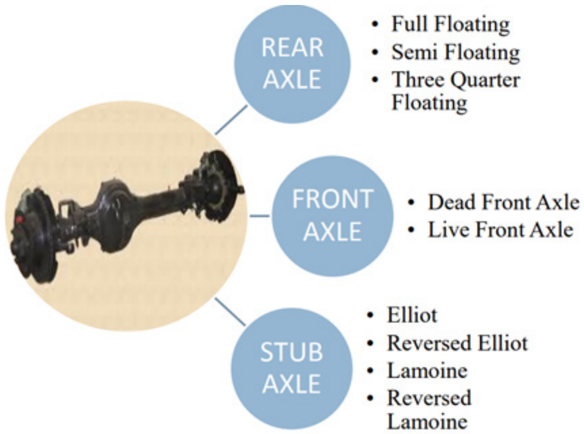
WEEK 13

Learning Indicator: Explain front and stub axle, types and their functions.

Focal Area 1: Front Axle

An axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle. Bearings or bushings are provided at the mounting points where the axle is supported.

TYPES OF AXLES



Front wheels of the vehicle are mounted on front axles. Functions of front axle include the following:

1. It supports the weight of front part of the vehicle.
2. It facilitates steering.
3. It absorbs shocks which are transmitted due to road surface irregularities.
4. It absorbs torque applied on it due to braking of vehicle.

Front Axle Construction

Front axle is made of an I-section in the middle portion and circular or elliptical section at the ends. The special X-section of the front axle design makes it able to withstand bending loads due to weight of the vehicle and torque applied due to braking. The front axle assembly consists of the main beam, stub axle, and kingpin or swivel pin. The wheels are mounted on stub axles.

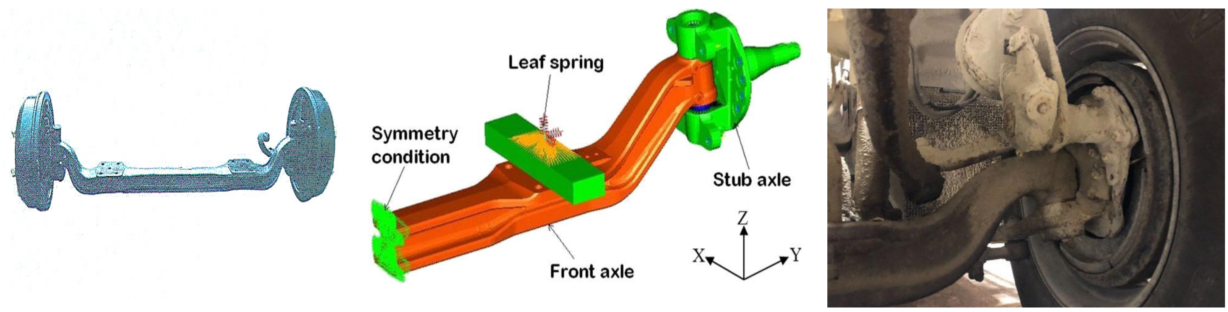


Figure 4.1: *Front axle construction*

Types of front axles: There are two types of front axles:

1. **Dead Front Axle:** Dead axles are those axles, which do not transmit power from gear box to the front wheels. These axles have sufficient rigidity and strength to take the weight. The ends of front axle are suitably designed to accommodate stub axles.

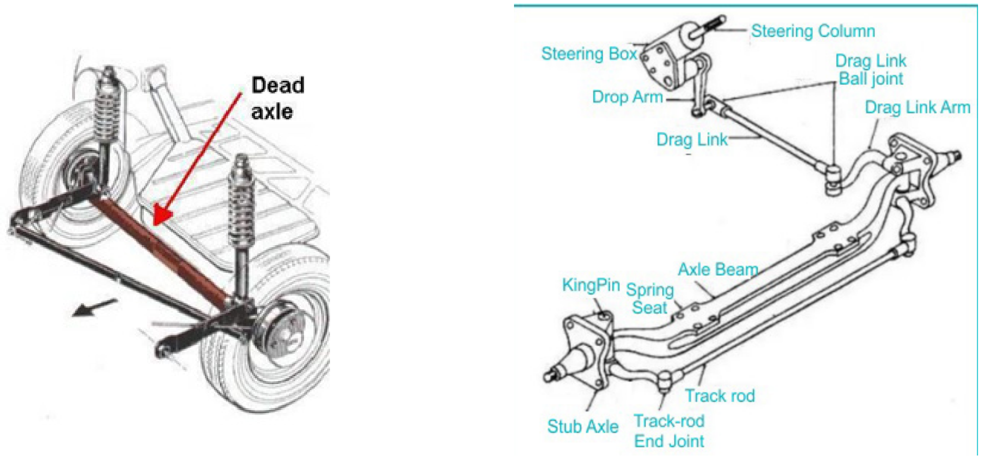


Figure 4.2: *Dead front axel*

2. **Live front axle:** Live axles are used to transmit power from gear box to front wheels. Live front axles resemble rear axles but they are different at the ends where wheels are mounted.

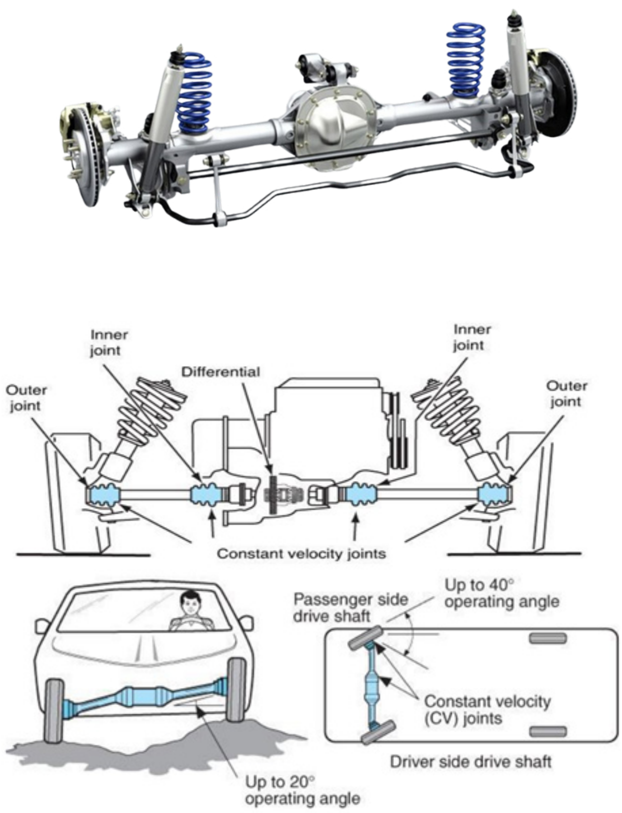


Figure 4.3: *Live front axle*

Stub axle

Stub axles are connected to the front axle by kingpins. Front wheels are mounted on stub axles and steering is connected to stub axles. Stub axles turn on kingpins. The kingpin is fitted in the front axle beam eye and is located and locked there by a taper cotter pin. Stub axles are of four types: Elliot, Reversed Elliot, Lemoine, Reversed lemoine. All are different from each other in the way they are connected to the front axle.

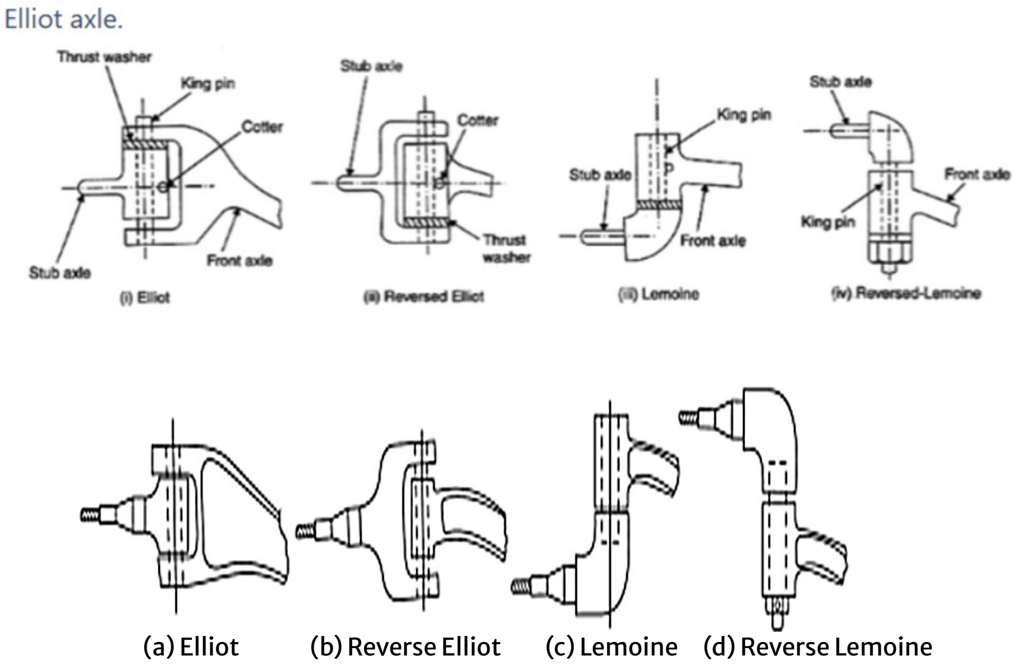


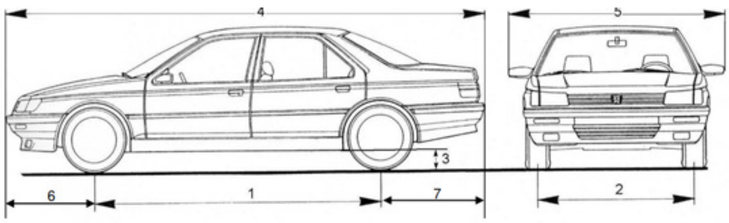
Figure 4.4: *Stub axle*

Vehicle Dimensions

Vehicle dimensions refer to the various measurements that define the size and shape of a vehicle. These dimensions are crucial for a variety of reasons, including design, functionality, safety, and compliance with road regulations. Some key vehicle dimensions are described below:

1. **Wheelbase:** The distance between the centres of the front and rear axles. This dimension affects the vehicle's stability, handling, and ride comfort.
2. **Wheel Track:** The distance between the centres of the left and right wheels on the same axle. It influences the vehicle's stability and cornering performance.
3. **Overall Length:** The total length of the vehicle from the frontmost point to the rearmost point. It includes all components, such as bumpers and body panels.
4. **Overall Width:** The total width of the vehicle at its widest point, excluding mirrors. This dimension is important for determining whether the vehicle can fit through narrow spaces.
5. **Overall Height:** The vertical distance from the ground to the highest point of the vehicle, usually the roof. It affects aerodynamics and parking in low-clearance areas.

6. **Front Overhang:** The distance from the front edge of the vehicle to the centre of the front wheels. It impacts the approach angle and the ability to clear obstacles.
7. **Rear Overhang:** The distance from the rear edge of the vehicle to the centre of the rear wheels. It affects the departure angle and the ability to clear obstacles when reversing.
8. **Ground Clearance:** The distance between the lowest point of the vehicle and the ground. It is critical for off-road capability and avoiding damage to the undercarriage.



1	Wheelbase
2	Track (width)
3	Ground clearance
4	Overall length
5	Overall width
6	Front overhang
7	Rear overhang

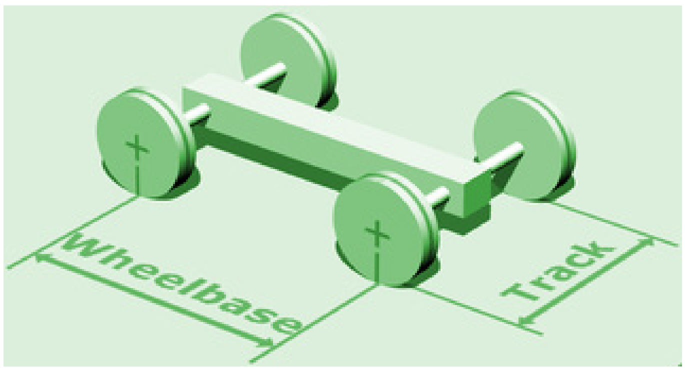


Figure 4.5: *Ground clearance*

Learning Tasks

1. Describe the front axle assembly.
2. Describe the various types of front axles.
3. Identify different types of stub axles.
4. Explain the terminology used in vehicle dimensions.

PEDAGOGICAL EXEMPLARS

1. **Group work/collaborative learning:** In mixed ability groups using relevant sketches or real objects, assist learners to identify front axle assembly and stub axle, used on vehicles. Learners also brainstorm various types of front axle assembly, stub axle and their functions.

Assist learners to brainstorm to discuss the vehicle dimensions parameter and present group or individual report.

2. **Experiential learning:** Learners visit a school workshop or local repair shop and observe the types of front axle assembly and stub axle, used on vehicles.

   Assist learners to identify and measure the vehicle dimension such as wheelbase and wheel track and present a report.

Key Assessments

Level 1: Write three functions of the front axle.

Level 2

1. Explain the differences between a live and dead axle.
2. What is the function of stub axles? Describe their use and list the different types.

Level 3

1. With the aid of a sketch explain what is meant by wheelbase, wheel track and overall length of a vehicle.
2. Draw and label the front axle of a vehicle.

HINT

The recommended mode of assessment for Week 13 is ***the Individual Project.*** *Refer to* ***Appendix E.***

UNIT 13 REVIEW

This unit reviews the front axle assembly and stub axles, which are vital for the overall performance and safety of a vehicle. They provide necessary support, enable effective steering, bear loads, and contribute to shock absorption. They are essential for beginners learning the vehicle's steering and suspension system. The lesson equips the learners with the knowledge of the functions, the construction of the front and stub axle assembly. It also describes the vehicle dimensions such as the wheelbase, wheel track, overall length, etc. of the vehicle. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the functions, the construction of front and stub axle assembly and the vehicle dimensions. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of front axle assembly and the vehicle dimensions.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the main components of the front axle assembly?
3. Were learners able to explain the functions of the front and stub axles?
4. Were the learners able to identify and explain the vehicle dimensions?
5. Which resources best supported the delivery of the front axle assembly and the vehicle dimensions?
6. Did learners find the resources useful in studying the front axle assembly and the vehicle dimensions?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 14

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers the basic metal forming processes. Metal forming techniques like forging, rolling and extrusion are fundamental in manufacturing industries. They are used to produce a wide range of products, from automotive parts to household items. Teaching these systems involves various pedagogical approaches to ensure effective learning. Pedagogical strategies have been suggested for teachers to deliver lessons on metal forming processes. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the basic metal forming processes. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the basic metal forming processes.

- ***The unit covers only week 14:*** *Explain basic metal forming processes with engineering products*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, the teacher must engage learners in various ways to explain the basic metal forming processes and their uses. The teacher should group learners into mixed ability and task them to identify and discuss the basic metal forming processes and their uses and assist learners to design and make articles using the metal forming processes. The teacher can also employ experiential learning where learners embark on an educational visit to a local industry where the metal forming processes are used. These strategies should be used in mixed-ability and mixed-gender groupings to encourage learners to participate fully in investigations and present findings. Teachers should employ differentiated strategies to accommodate the diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the basic metal forming processes and their uses, learners must show how they can apply the concepts in real life situations to develop a project.

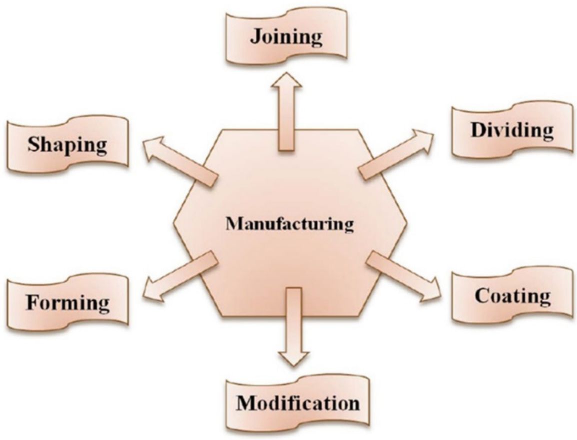
As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering the machining processes in the manufacturing industry. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 14

Learning Indicator: *Explain basic metal forming processes with engineering products.*

Focal Area: Metal Forming Processes With Engineering Applications

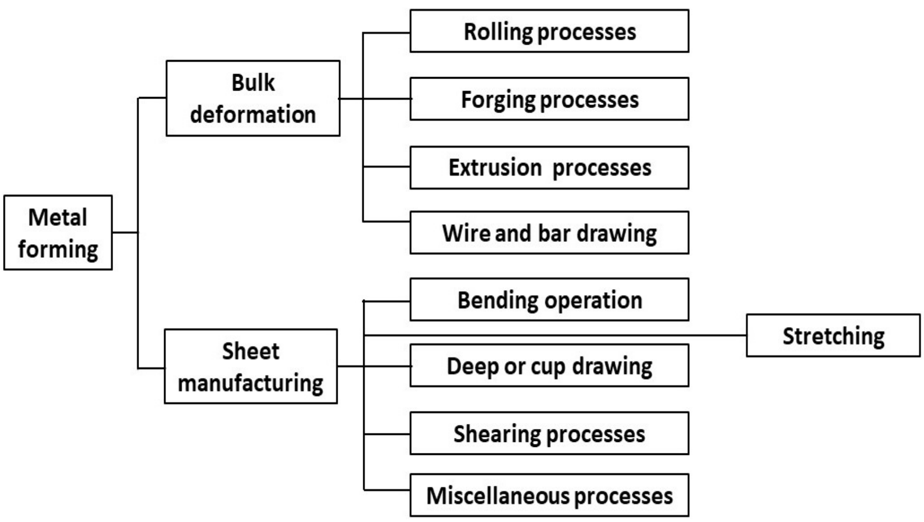
Metal forming is a very important manufacturing operation. It enjoys industrial importance among various production operations due to its advantages such as cost effectiveness, enhanced mechanical properties, flexible operations, higher productivity and considerable material saving. Materials are converted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



Various manufacturing operations on materials

Out 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



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 metal piece undergo a change. The tools used for such deformation are called die, 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. Mostly done in hot working conditions.

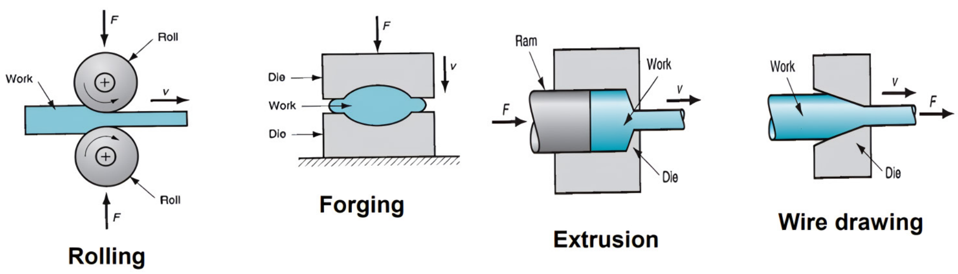


Figure 4.6: *Bulk forming*

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 workpiece is compressed between two dies containing shaped contours. The die shapes are imparted into the final part.
4. **Extrusion:** In this, the workpiece 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.

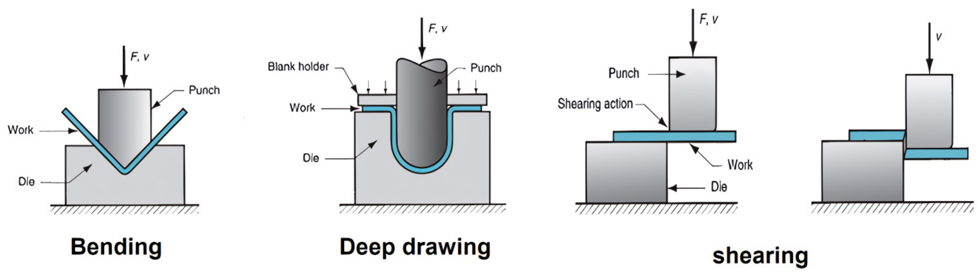


Figure 4.7: *Sheet forming*

2. **Bending:** In this, the sheet material is strained by 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.

Types 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 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.

Advantages of cold working

1. It is widely applied as a forming process for steel.
2. Cold working is done at room temperature, so no oxidation and scaling of work naturally occurs.
3. Provides an excellent surface finish, which reduces the secondary machining process.
4. High dimensional accuracy.
5. Highly suitable for mass production and automation because of low working temperature.

Disadvantages of cold working

1. The strength of the metal is high, so large forces are needed for deformation.
2. Complex shapes cannot be formed.

3. Tools must be specially designed, so tool costs are high.
4. Stress formation in the metal during cold working is higher so this requires stress relieving.

Applications of Cold Working

Cold working is used in various industries to produce parts that require high strength, precise dimensions, and good surface finish. Common applications include:

1. **Automotive Components:** Such as fasteners, springs, and body panels.
2. **Construction Materials:** Such as steel beams and reinforcement bars.
3. **Consumer Goods:** Such as metal cans, kitchen utensils, and electronic device casings.
4. **Aerospace Parts:** Such as 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 recrystallisation temperature is 30 to 40% of 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.

Types 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.

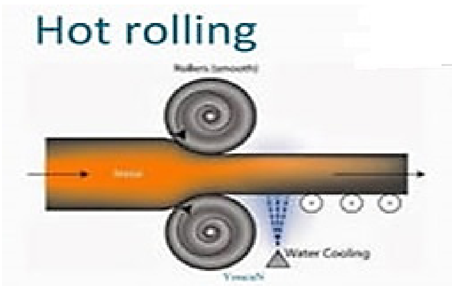


Figure 4.8: *Hot rolling*

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.

Figure 4.9: *Hot forging*

3. **Hot Extrusion:** Forcing metal through a die to create long parts with uniform cross-sections, such as pipes or rods.

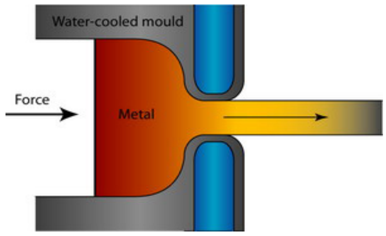


Figure 4.10: *Hot extrusion*

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

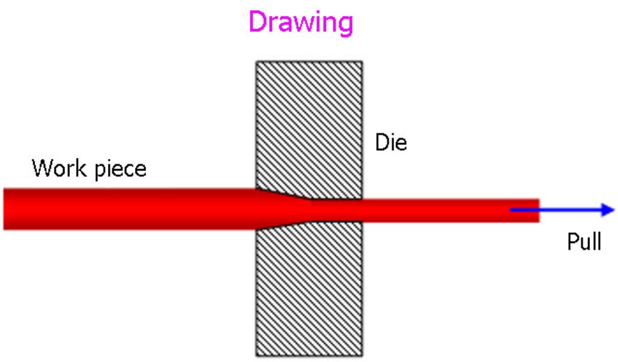


Figure 4.11: *Hot drawing*

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

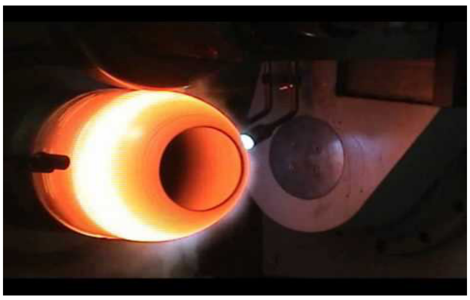


Figure 4.12: *Hot spinning*

7. **Hot Pressing:** Applying pressure to metal within a mould to achieve the desired shape, often used for intricate or complex parts.

Advantages of Hot Working

1. Lower working force is enough to give shape.
2. A very dramatic shape change is possible.

3. Properties such as strength, ductility and toughness are improved.
4. Density increases by removing voids.
5. Desired shape can be easily obtained under plastic deformation.
6. The effect of impurities can be reduced.
7. Good grain structure is obtained.
8. Atoms in the same direction leads to better strength.

Disadvantages of Hot Working

1. The process takes place at higher temperatures that is above 7300C so special protection of machines is necessary otherwise machine and tool life will reduce.
2. Handling cost is high.
3. Automation is difficult.
4. If the die or the tool wears the surface finish is affected.
5. While the object cools from its recrystallisation temperature, its dimension may vary due to shrinkage of the parts.

Applications of Hot Working

Hot working is widely used in industries that require the shaping of large or complex metal components. Common applications include:

1. **Structural Components:** Such as beams, columns, and rails used in construction and infrastructure.
2. **Automotive Parts:** Including crankshafts, connecting rods, and gears.
3. **Aerospace Components:** Such as 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.

Comparison Between Hot Working and Cold Working

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 of the other differences between hot and cold working

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.
4	Impurities are removed from the metal.	Impurities are not removed from the metal.

5	Elongation of metal takes place.	Elongation decreases.
6	Large size metals are deformed.	Limited to size.
7	Internal stress is not formed.	Internal stress is formed.

Learning Tasks

1. Explain metal forming processes.
2. Explain how each basic metal forming process is used in making articles.
3. Describe how two or more metal forming processes can be combined to produce a named item.
4. Explain the advantages of using the metal forming processes to produce articles.
5. Describe the differences between hot forming and cold forming.

Pedagogical Exemplars

1. **Group work/Collaborative learning:** Group learners to describe the processes involved in basic metal forming processes and identify items made by them.

   Assist learners to discuss the differences between rolling, forging and extrusion and present the report to the group.

   In a mixed ability groups learners also brainstorm the differences between cold working and hot working processes and present a report on the differences.

2. **Experiential learning:** Learners embark on an educational visit to a local workshop and observe the basic metal forming processes and present a report to the class,

   Assist learners to identify the tools and equipment used in process and present a group or individual report.

Key Assessments

Level 1

1. Explain any 2 metal forming processes
2. Explain the meaning of the expression ‘metal forming’ and give the names of five metal forming processes.

Level 2: State at least two processes each under basic bulk metal forming and sheet metal forming and explain them.

Level 3: Explain the difference between hot forming and cold forming.

Level 4: Describe a real-world application where forging is preferred over other metal forming processes. Explain why forging is chosen in this context.

HINT

*The recommended mode of assessment for week 14 is **homework.** Use the level 1 question 1 as a sample question.*

UNIT 14 REVIEW

This unit reviews the basic metal forming processes like forging, rolling, extrusion and bending which are fundamental in manufacturing industries. They are used to produce a wide range of products, from automotive parts to household items. The lesson equips the learners with the two general classifications of the metal forming processes. It also describes the processes under bulk metal forming and basic sheet metal forming. Hot and cold working of metals with engineering applications are also reviewed. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of meal forming processes. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of metal forming processes as well as cold and hot forming of metals.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the basic metal forming processes?
3. Were learners able to explain the basic metal forming processes?
4. Were learners able to identify and explain cold and hot working of metals?
5. Which resources best supported the teaching and learning of the basic metal forming processes?
6. Did learners find the resources useful in learning the basic metal forming processes?
7. How were the different subgroups catered for in the class?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT15

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems.*

INTRODUCTION AND UNIT SUMMARY

The steering system is a critical component of any vehicle, essential for controlling its direction and ensuring safety, comfort, and performance. Therefore, studying the vehicle steering system is crucial for learners. The unit covers the main components of the steering system and explains steering geometry and the angles involved. This equips learners with the basic knowledge and skills needed to maintain, repair and service vehicle steering systems. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the main components of the steering systems various steering geometry angles and Ackermann principle. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the various angles in the steering geometry and their importance to wheel alignment.

- ***The unit covers only week 15:*** *Describe the main components of the steering system and explain steering geometry and the angles*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach the function, the main components of the steering system and steering geometry ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging and relevant. Teaching the main components of the steering system and steering geometry can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the main components of the steering system and the various steering geometry angles.

ASSESSMENT SUMMARY

Teaching the function, the main components of the steering system and steering geometry, assessments can span various levels to gauge learners' understanding and application of the concepts and the principles. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to the main components of the steering system and the various steering geometry angles. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 15

Learning Indicator: *Describe the main components of the steering system and explain steering geometry and the angles involved.*

Focal Area 1: Main Components Of The Steering System

The purpose of the steering system is to control the direction of the vehicle's movement. It enables the driver to turn right, left or remain in a straight-ahead position. The system also allows the driver to guide the vehicle down the road.

Requirements of the steering system

The steering system should:

1. Enable the driver to control accurately the path taken by the vehicles at all times,
2. Be light and easy to operate,
3. Be self-centering,
4. Be as direct as possible in action,
5. Not be affected by the action of the suspension and braking systems.

Main components of the manual steering system

The vehicle manual steering system consists of the following:

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

POWER-ASSISTED STEERING

Power steering is a driver-assistance feature that helps turn the wheels with minimal effort. There are generally two types of power steering systems: electronic and hydraulic. In an electronic power steering setup, an electric motor controls the steering gear and provides steering assistance. This setup has parts like the steering gear and motor, a control module, and sensors. Meanwhile, a hydraulic power steering system uses an engine-driven pump and hydraulic fluid to turn the wheels. It has a steering gear, power steering pump, reservoir, and hoses.

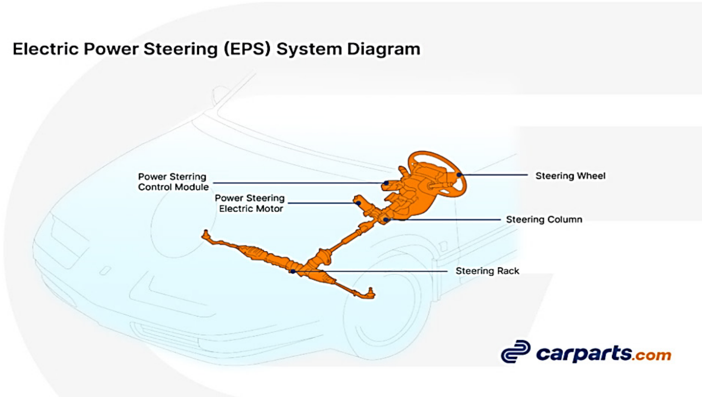


Figure 4.13: *Power-assisted steering*

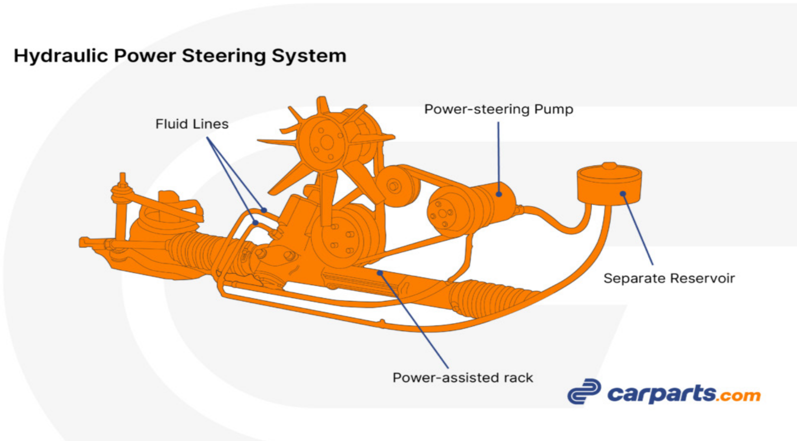


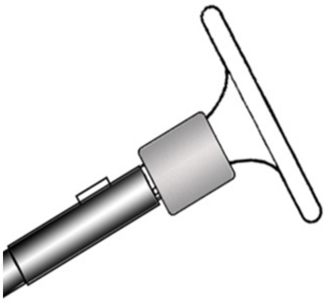
Figure 4.14: *Power-assisted steering*

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

- **Power Steering Pump**: Provides hydraulic pressure to assist in turning the wheels.
- **Hydraulic Lines**: Transfer hydraulic fluid between the pump, steering gearbox, and steering cylinders.
- **Power Steering Fluid**: Transfers hydraulic pressure and lubricates components.
- **Steering Gearbox or Rack**: Is similar to manual steering, but with additional valves and hydraulic assist.
- **Power Steering Control Module**: Controls the operation of the power steering system in modern vehicles.

1. **Steering wheel:** This is the circular part of the steering system in the driver's compartment. It enables the driver to direct the vehicle movement and is used to rotate the steering shaft that passes through the steering column. Many cars have steering wheels that can be tilted at various angles. The tilt steering wheel allows the driver to change the angle as desired. Some cars also have a telescoping steering wheel that can be extended or shortened to suit the driver.

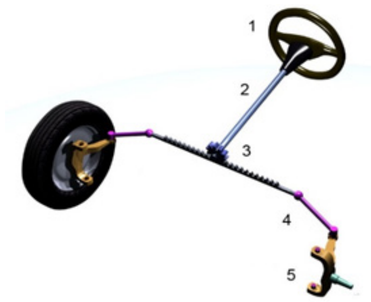

Steering wheel


Steering column with wheel


Steering shaft

Figure 4.15: *Steering wheel*

2. **Steering column:** The steering column supports the steering shaft. Collapsible steering column collapses during an impact or collision. It is a safety device incorporated in the steering system.
3. **Steering shaft:** This is the shaft which links the steering wheel to the steering gearbox. It transfers the turning motion of the steering wheel to the steering gearbox.
4. **Steering linkages:** These are systems of rods, levers and ball joints. The steering linkages carry the movement of the steering wheel from the steering gearbox to the steering arms or track arms of the road wheels. In beam axle suspension a solid beam connects the two wheels, the transverse drag and longitudinal drag steering linkages that are used. Three-piece track rod and split track rod linkages are employed on an independent front suspension (IFS) system. The various rods and links are connected by ball pin joints which permit movement in more than one plane.



1. Steering wheel
2. Steering shaft
3. Rack and pinion steering gearbox
4. Steering links/arms
5. Stub axle

Figure 4.16: *Steering linkages*

5. **Steering gearbox:** This is a housing which carries two engaged gears. The steering gearbox changes the rotary motion of the steering wheel to the lateral (side-to-side) movement of the track rod. It also reduces the driver's effort needed or required to steer the road wheels.

Types of steering gearbox

Some of the types of steering gearboxes used on the vehicle are:

a. Rack and pinion
b. Recirculating ball
c. Cam and roller
d. Cam and peg

e. Worm and sector

f. Screw and nut

g. Worm and roller

a. **Rack and pinion steering gearbox:** This type of steering gearbox is the modern type used in most vehicles. The rack is housed in a tubular section on the track rod and the steering shaft is connected to the pinion. The pinion meshes with the rack and as the steering wheel is turned the rack moves either to the left or right to control the road wheels.

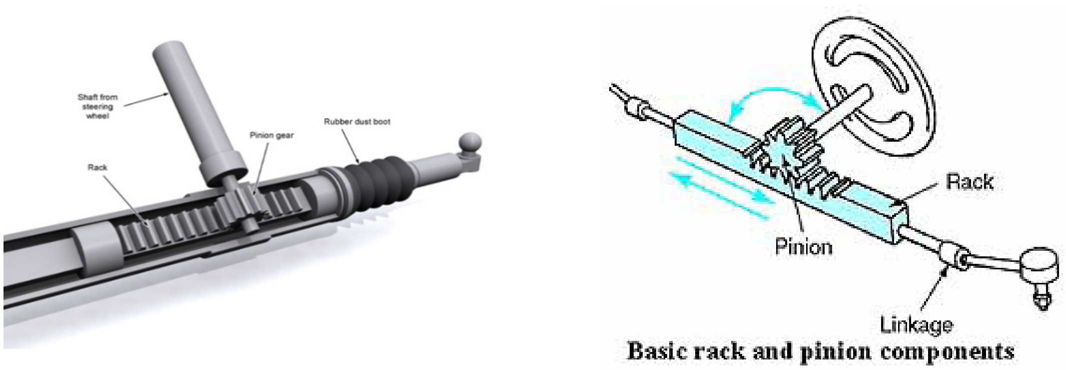


Figure 4.17: *Rack and pinion steering gearbox*

b. **Recirculating ball**

This type consists of a half nut which carries the balls in engagement with the worm on the steering shaft. The half nut is linked to the drop arm. Rotation of the half nut moves the drop arm to control the steering. This is an improved version of the obsolete worm and nut.

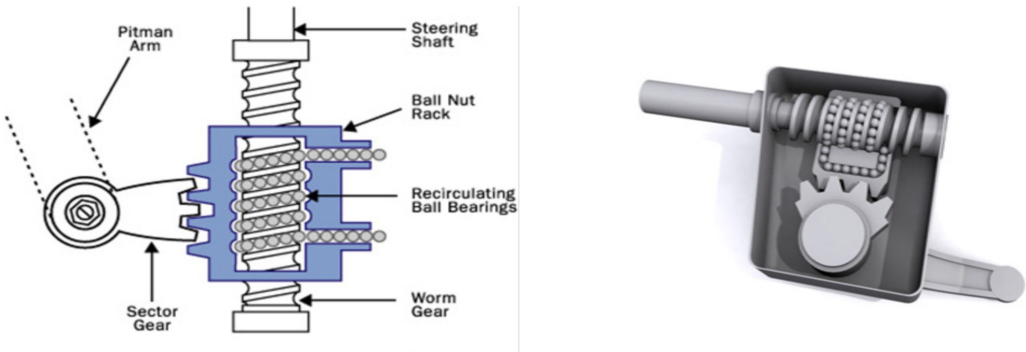


Figure 4.18: *Recirculating steering gearbox*

Focal Area 2: Steering Geometry

Steering geometry refers to the various angles between the front wheels, frame and attachment parts. It ensures that the road wheels roll truly or freely without slip or scab. The following are the main elements of steering geometry: Castor, Camber, Kingpin inclination (K.P.I) (swivel axis inclination SAI), Toe-in and toe-out, Steering ratio.

1. **Caster angle:** Caster angle is the angle formed by the projected centre line of the kingpin and the vertical view from the side of the vehicle and the distance between the two lines

at the ground level is called castor trail. When the kingpin is tilted forward of the centre line of the wheel is termed negative castor and when tilted backwards of the centre line, positive castor is achieved. Caster action ensures that the steering system maintains a straight course and provides self-centering action automatically after negotiating a curve.

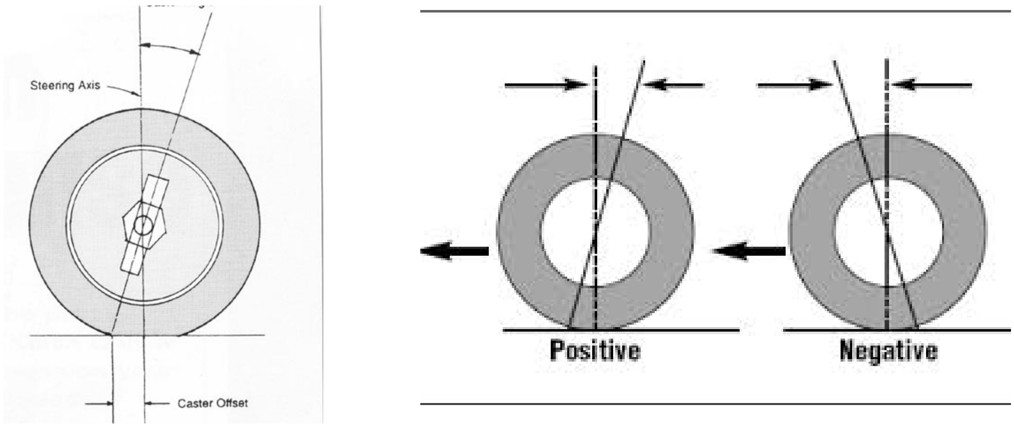


Figure 4.19: *Caster angle*

2. **Camber angle:** This is the angle formed between the centre line of the wheel and its vertical view from the front or rear of the vehicle. It can be positive or negative. When the wheel tilts outwards at the top it is called positive camber and inwards at the top is termed negative camber. Camber provides lighter steering.

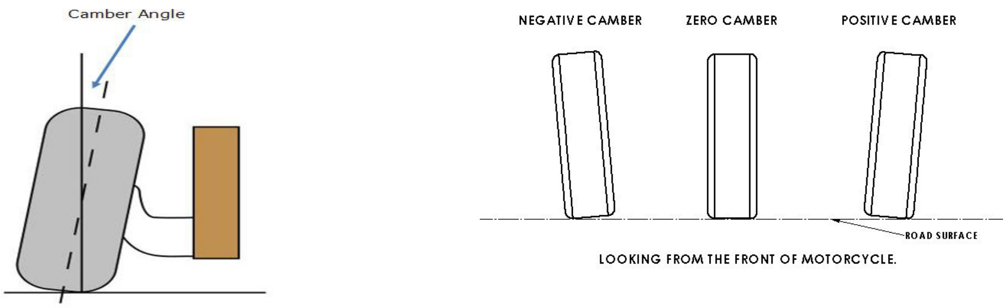


Figure 4.20: *Camber angle*

3. **Kingpin inclination (KPI):** Kingpin inclination (KPI). The angle formed between the centre line of the kingpin and the vertical is known as the kingpin inclination angle and in independent suspension the angle is referred to as swivel axis inclination (SAI).

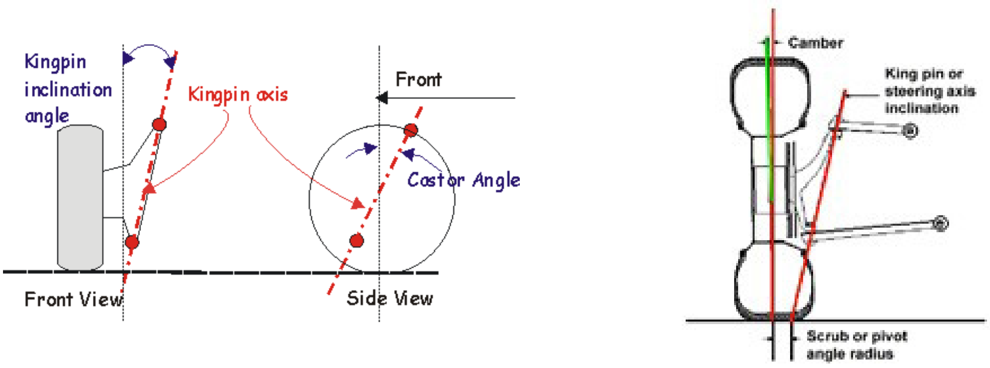


Figure 4.21: *Camber angle*

The effects of combined use of camber and kingpin inclination are to 1) provide easier steering 2) reduce the effect of braking on the steering 3) provide self-centering effect. The sum of the K.P.I and camber angles are called the included angle. This angle is very important because it determines the point of intersection of the wheel and the kingpin centre line. This in turn determines whether the wheel will tend to toe-out or toe-in. If the point of intersection is above the ground, the wheel tends to toe-out and below the ground the wheel will tend to toe-in.

4. **Centre point steering:** This is the condition where the centre of the road wheels meet the centre line of the kingpin at the road surface. At this point the wheel keeps its straight-ahead position without any tendency to toe-in or toe-out. It can be obtained by camber, SAI/ KPI and wheels that are dished towards the middle of the vehicle.
5. **Toe-in or toe-out:** Toe is the measured difference in the distance between the front of the tyres and the back of the tyres. When the distance between the front portions of the tyres is closer than the rear portion that is known as Toe In. When the distance between the rear portions of the tyres is closer than the front portion that is known as Toe Out.

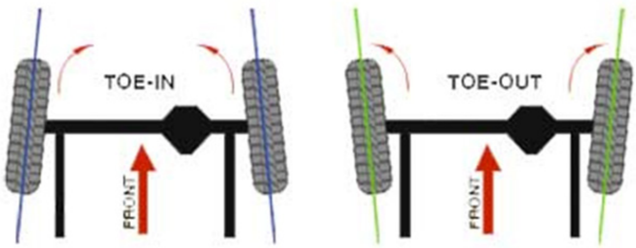


Figure 4.22: *Toe-in or toe-out*

6. **Steering Ratio:** The steering ratio represents the relationship between the movement of the steering wheel and the resulting turning of the front wheels. It indicates how much steering input is needed to turn the wheels of the vehicle.
7. **Ackermann Steering Geometry:** Ackermann steering is a geometric arrangement of a vehicle's front wheels that allows all of the wheels to follow different turning radii when the vehicle turns. It allows the inner wheel to turn at a greater angle than the outer wheel when the vehicle is cornering or negotiating a curve. This means that the inner wheel rotates more, allowing it to follow a smaller radius, while the outer wheel rotates less, allowing it to follow a larger radius.

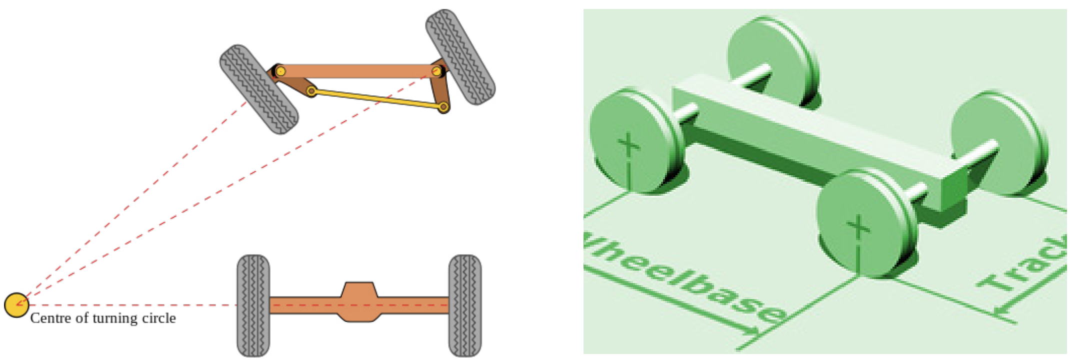


Figure 4.23: *Ackerman Principle*

8. **Toe-out on turns:** Toe-out on turns, sometimes called turning radius, is the difference in angles between the two front wheels when they are making a turn or negotiating a curve.
9. **Slip angle:** This is the angle between the wheel inclination and the path taken by the vehicle. Factors affecting slip angle are road camber, cornering force, side winds, tyre pressure and variation in the load on either the front or rear axle.

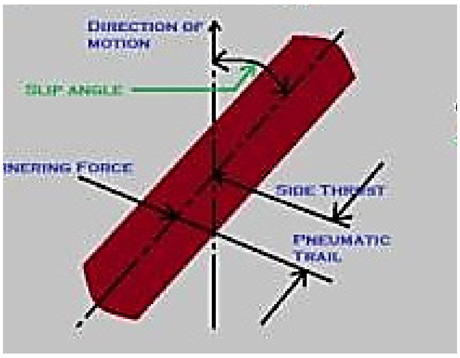


Figure 4.24: *Slip angle*

Understeer, oversteer and neutral steering

When the slip angle is greater at the rear wheels than at the front wheels the vehicle tends to oversteer. That is, it turns into the curve more than the driver intended. Understeer condition prevails when the slip angle at rear is smaller than the slip angle at the front wheels. Understeer is preferred to oversteer because correction by the driver involves rotating the wheel a little more in the direction of the turn. Neutral steering arises when the slip angles of the rear wheels is the same as the front wheels.

Learning Tasks

1. Explain the function of the vehicle steering system.
2. Describe the main components of the manual steering system.
3. Describe the various angles in steering geometry.
4. Explain the Akermann principle of steering geometry.

Pedagogical Exemplars

1. **Group work/collaborative learning:** In mixed ability groups using relevant sketches or real objects assist learners to identify the main component parts of the steering system on a vehicle.

   Assist learners to discuss how the steering system operates or works. Learners are also to brainstorm aspects of steering geometry and the various angles.

2. **Experiential learning:** Learners visit a school workshop or local repair workshop to observe and identify the main components of the steering system. Learners also observe

in the workshop the procedure in carrying out vehicle wheel alignment and present a group or individual report on the process.

Key Assessments

Level 1: State the function of steering in an automobile and list the main components of manual and power assisted steering systems.

Level 3

1. Analyse at least 2 importance of steering in an automobile system.
2. Describe briefly with the aid of sketches, the construction and action of a rack and pinion type of steering gearbox.
3. Describe, with the aid of sketches, the principle of the Ackerman system of steering
4. Explain the following steering geometry with the help of diagrams:
   a. Caster
   b. Camber
   c. King pin inclination
   d. Toe-in and Toe-out

HINT

*The recommended mode of assessment for week 15 is **task analysis.** You may use the level 3 question 1 as a sample question.*

UNIT 15 REVIEW

This unit reviews the main components of the steering system and explain steering geometry and the angles involved. It helps learners understand how to ensure that the system functions correctly, preventing accidents and enhancing driver and passenger safety. They are essential for beginners learning the vehicle steering and suspension system. The lesson equips the learners with knowledge of the main components of the manual and power steering system. It also describes the steering geometry angles such as camber, caster, kingpin inclination angle, toe in and toe out. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of the vehicle steering system. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of manual and power-assisted steering as well as the fundamental steering geometry.

REFLECTION

1. What was my best moment in today's lesson, and how can I create more of such situations?
2. Were learners able to identify the main components of the manual and power-assisted steering?
3. Were learners able to explain the functions of the main components of manual and power-assisted steering?
4. Were the learners able to explain the various angles in the steering geometry?
5. Which resources best supported the delivery of the main components of the manual and power-assisted steering?
6. Did learners find the resources useful in studying the steering system and steering geometry?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go, and what improvement(s) can be made to make it a better learning experience?

UNIT 16

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers forging, rolling and extrusion in sheet metal work as metal forming processes. These processes are fundamental to modern manufacturing, contributing to the production of high-quality components used in a wide range of industries. Forging excels in producing strong, durable and reliable components with minimal defects. Rolling is highly efficient for mass production, offering improved material properties and excellent surface finish and extrusion enables the creation of complex shapes with uniform quality, material efficiency, and is suitable for continuous, large-scale production. Pedagogical strategies have been suggested for the teacher to employ in the delivery of lessons in forging, rolling and extrusion in sheet metal work. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying how forging, rolling and extrusion in sheet metal work are used. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the process involved in forging, rolling and extrusion in sheet metal work.

- ***The unit covers only week 16:*** *Demonstrate forging, rolling and extrusion operations in sheet metal*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, the teacher must engage learners in various ways to explain forging, rolling and extrusion in sheet metal work. The teacher should place learners into mixed ability groups and task them to identify and discuss forging, rolling and extrusion in sheet metal work. The teacher can also employ experiential learning where learners embark on an educational visit to a local industry where forging, rolling and extrusion in sheet metal work are done. These strategies should be used in mixed-ability and mixed-gender groupings for the learners to participate fully in investigations and presentation of findings. Teachers should employ differentiated strategies to accommodate the diverse learning needs of the learners.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of forging, rolling and extrusion in sheet metal work, learners must show how they can apply the concepts in real life situations to develop a project. As a result, ***level 1, 2, 3 and 4*** of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering forging, rolling and extrusion in sheet metal work. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 16

Learning Indicator: *Demonstrate forging, rolling and extrusion operations in sheet metal.*

Focal Area 1: 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's 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.

FORGING OPERATIONS

1. **Upsetting:** Is the process of increasing the cross-section at the expense of the length of a work piece. It is the simplest example of open die forging.

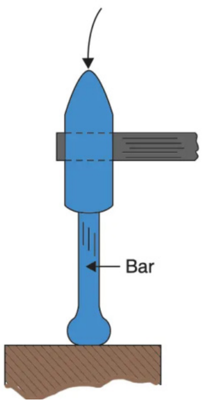


Figure 4.25: *Upsetting*

2. **Drawing down:** It is the reverse of upsetting process. In this process length is increased and the cross-sectional area is reduced.

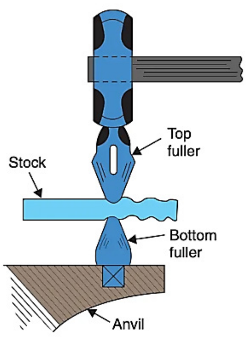


Figure 4.26: *Drawing down*

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. The workpiece is heated, kept on the anvil and a punch of suitable size is forced to about half the depth of the workpiece by hammering. The workpiece is then turned upside down and the punch is forced in from the other side, this time through and through. 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:** Sometimes, it may become necessary to join two pieces of metal. Forge welding of steel is quite common and consists of heating the two ends to be joined to white heat (1050°C – 1150°C). Then the two ends of steel are brought together having previously been given a slight convex shape to the surfaces under joining.

Steps Followed in Forging of Connecting Rod

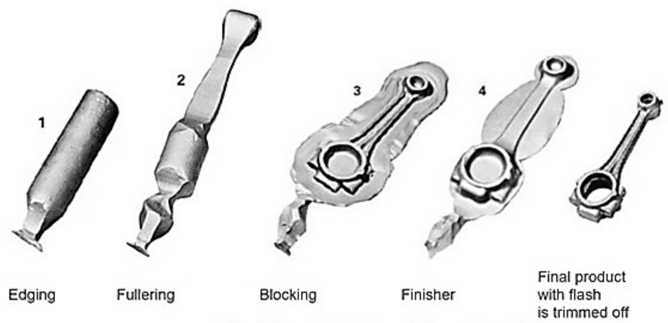


Figure 4.27: *Forge welding*

Forging tools and equipment: Below are the different types of forging tools and their uses:

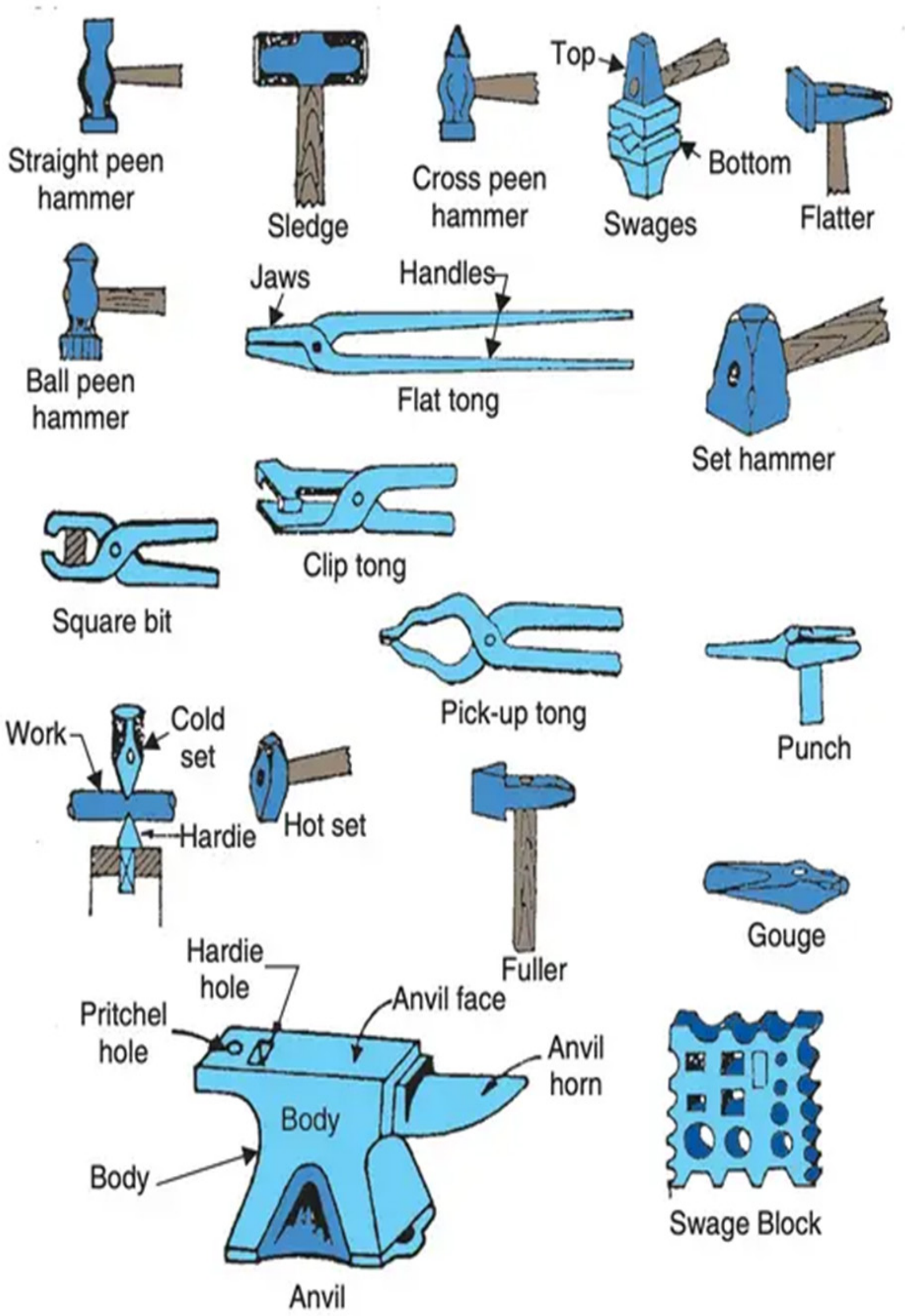


Figure 4.28: *Drawing down*

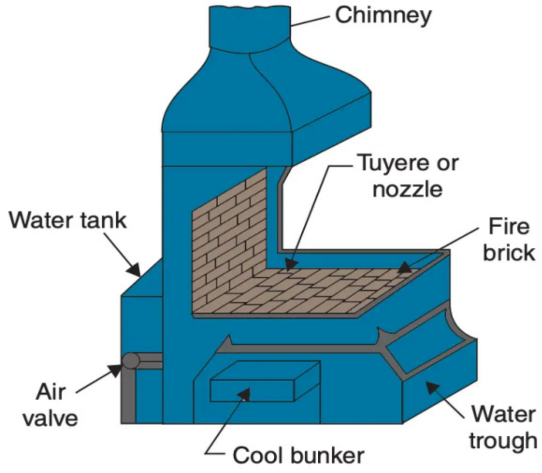


Figure 4.29: *Smith's forge*

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.
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. **Hammer:** Hammers are types of forging tools used in several ways, based on the type of forging needed to be performed, such as hot forging, cold forging, closed die forging, upset forging, press forging, etc. The hammer serves as a forging tool used in achieving shapes on workpieces. It is used as a striking tool and can be classified as a drop hammer and power hammer.
   a. **Drop hammer:** a heavy ram falls onto the metal by gravity. It is used by the smith's hand power.

b. **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.

7. **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.
8. **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.
9. **Swage:** Swage is a forging tool type that gives various shapes to the workpiece. It is also made of high-carbon steel.
10. **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.
11. **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.
12. **Clamping vice:** This forging equipment is used in holding work pieces in the smithy show. It consists of two jaws, a spring, and a flat bottom. The work pieces are clamped between two jaws and tightened to hold them strongly.
13. **Bick iron:** This forging equipment is made of tool steel and it is hardened. It has a tapered tail at one side and the other portion is similar to the horn of an anvil. This forging equipment can also work on an anvil due to its taper shank.
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.

    a. **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.

    b. **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.

15. **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.

    a. **Open die:** an open die does not completely encase the metal, providing free flow everywhere except the metal meets the die.

b. **Closed die:** a closed die completely encases the metal when hammered or pressed against the metal.

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.

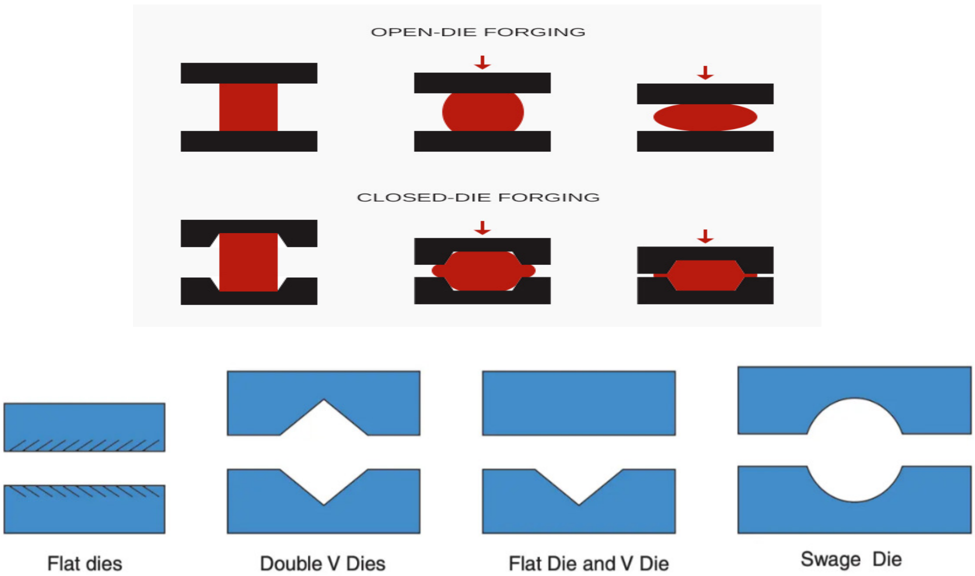


Figure 4.30: *Open die forging*

Advantages of open die forging

a. Simple process.

b. Dies are inexpensive.

c. Useful for small quantities.

d. Wide range of job sizes can be handled.

Limitations of open die forging

a. Limited to simple shapes.

b. Close dimensional tolerances not possible.

c. Machining to final shape required if necessary.

d. Low production rate.

e. 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.

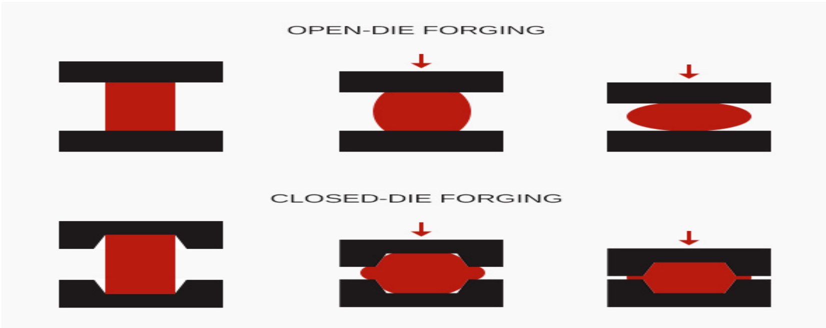


Figure 4.31: *Closed die forging*

Pros of closed-die forging

a. Better surface finish and superior mechanical properties.

b. Reduced or no machining.

c. Cost-effective for large production runs.

d. Dimensions with tighter tolerances and various shapes can be achieved.

e. More precise, consistent impressions.

f. Ability to reproduce nearly any shape and/or size.

Cons of closed-die forging

a. Not typically economical for short or small production runs due to the cost of die production.

b. Higher setup cost due to costly machines and furnaces.

Types of forging process based on method of application of force: The different types of forging operations are:

- Hand forging
- Drop forging
- Press forging

a. **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.

b. **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.

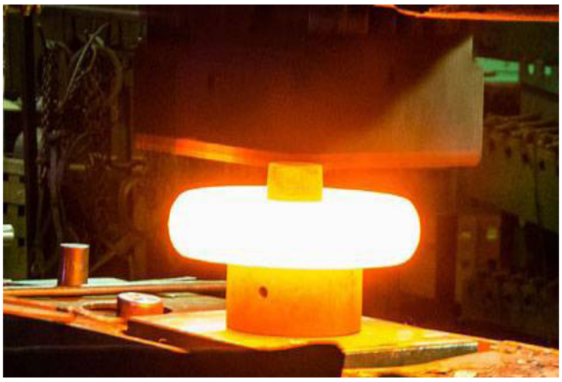


Figure 4.32: *Drop forging*

c. **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.

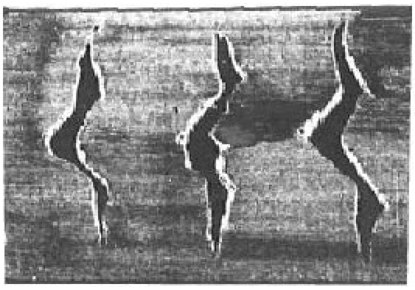
d. **Forging with Power Hammering:** The use of hand forging is restricted to small forgings only. When a large forging is required, comparatively light blows from a hand hammer or a sledgehammer wielded by the striker will not be sufficient to cause significant plastic flow of the material. It is therefore 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.

e. **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.

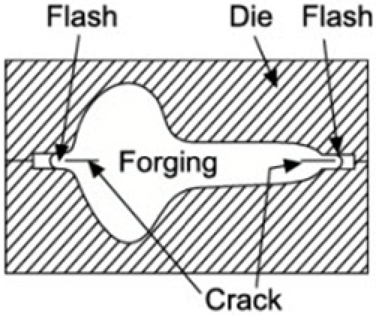
Forging Defects

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

1. **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.



Surface cracking



Cracking at the flash

Figure 4.33: *Laps and cracks*

2. **Incomplete forging:** either due to less material or inadequate or improper flow of material.
3. **Mismatched forging** due to improperly aligned die halves.

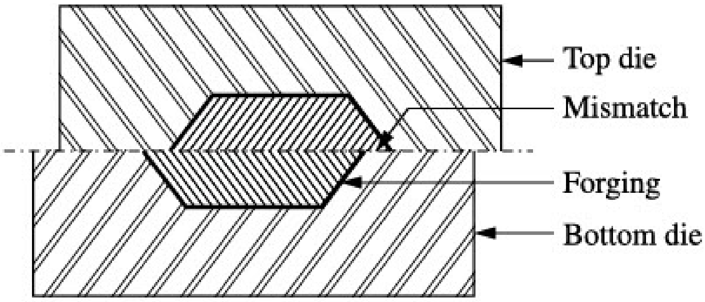


Figure 4.34: *Drawing down*

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** 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.

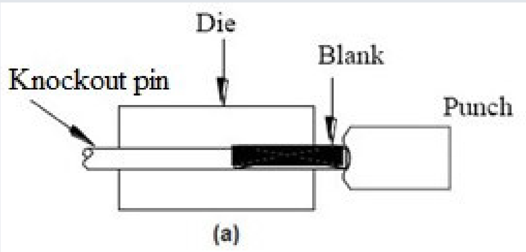
- **Cold forging:** Cold forging is a process that takes place near room temperature, rather than at higher temperatures like warm and hot forging. It's done by placing the workpiece in-between two dies and pounding the dies until the metal assumes their shape.

Worked Example

Example 1: Explain the procedure of making the head of rivet by forging operation.

Solution: Step by step procedure to be followed in making the head of a rivet by forging operation is explained below:

1. Keep the blank in the die as shown in ***figure (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 (b).***
3. Now, remove the rivet by pushing the knockout pin.



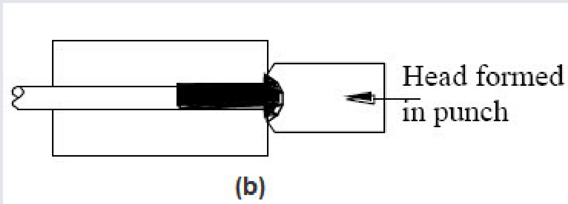


Figure 4.35: *Rivet head formation*

Focal Area 2: Rolling

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

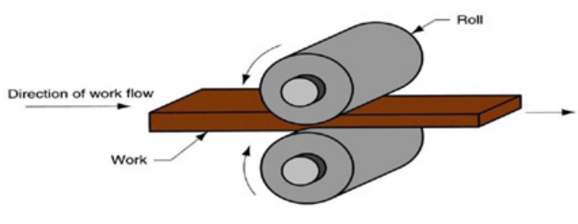


Figure 4.36: *Rolling*

The rotating rolls perform two main functions

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

Types of Rolling

By geometry of work

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

By temperature of work

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

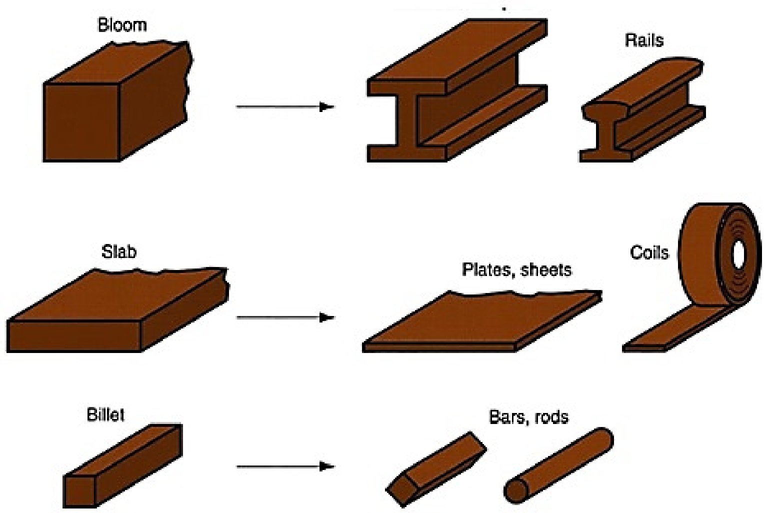


Figure 4.37: *Some of the steel products made in a rolling mill*

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:

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. **Billet:** A semi-finished metal product that has been cast and is used as raw material for rolling.
4. **Slab:** A semi-finished steel product obtained by rolling ingots on a rolling mill or by continuous casting and having a rectangular cross-section.
5. **Bloom:** A semi-finished product, larger than billets, usually having a square cross-section of more than 150 mm by 150 mm.
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 less than 0.2 mm thick.
9. **Flat:** Flats are available in various thickness and widths and are long strips of material of specified cross-section.
10. **Foil:** It is a very thin sheet.

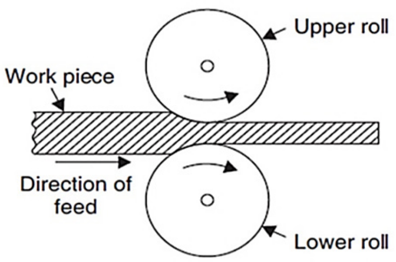
11. **Bar:** Bars are usually of circular cross-section and of several metres length. They are common stock (raw material) for capstan and turret lathes.
12. **Wire:** A wire is a length (usually in coil form) of a small round section, the diameter of which specifies the size of the wire.
13. **Gauge:** 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.

Types of Rolling Mills

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

1. Two high rolling mills
2. Three high rolling mills
3. Four high rolling mills
4. Tandem rolling mills
5. Cluster rolling mills

1. **Two high 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.



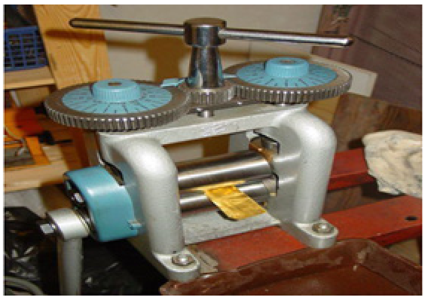


Figure 4.38: *Two high mills*

2. **Three high mills:** A three high rolling mill arrangement is shown below. It consists of three rolls positioned directly over one another as shown

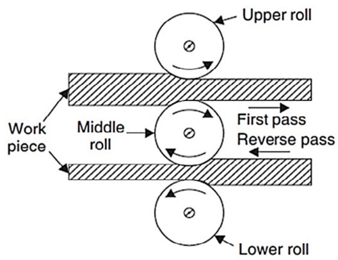


Figure 4.39: *Three high mills*

3. **Four high mills:** As shown in Fig., 4.38 this mill consists of four horizontal rolls, two of small diameter and two much larger ones. The larger rolls are called backup rolls.

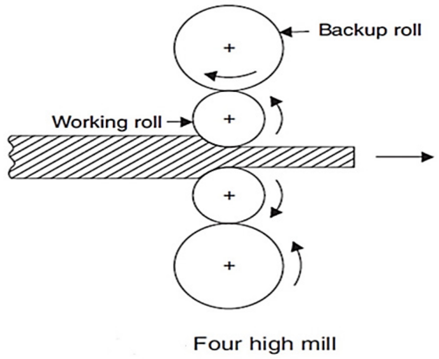


Figure 4.40: *Four high mills*

Cold Rolling

It 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 4.1: *Comparison between Hot Rolling and Cold Rolling*

Feature	Hot Rolling	Cold Rolling
Temperature	Above 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

1. **Surface defects:** Surface defects include rusting and scaling, surface scratches, surface cracks, pits left on the surface of due to subsequent detachment or removal of scales which may have been pressed into the surface.
2. **Structural defects:** Structural defects are more important rolling defects, some of which are difficult to remedy. These defects include the following:
   a. Wavy edges
   b. Zipper cracks
   c. Edge cracks

d. Centre split

e. Alligatoring

f. Folds

g. Laminations

Focal Area 3: 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.

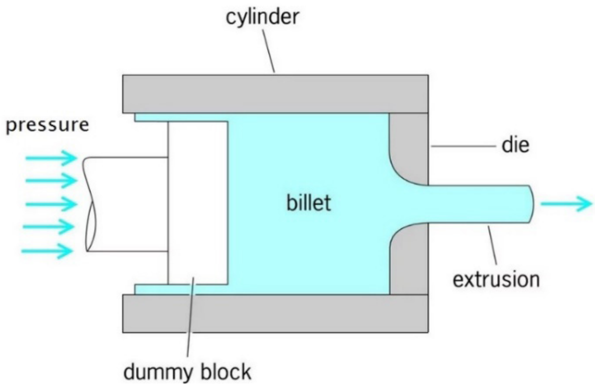
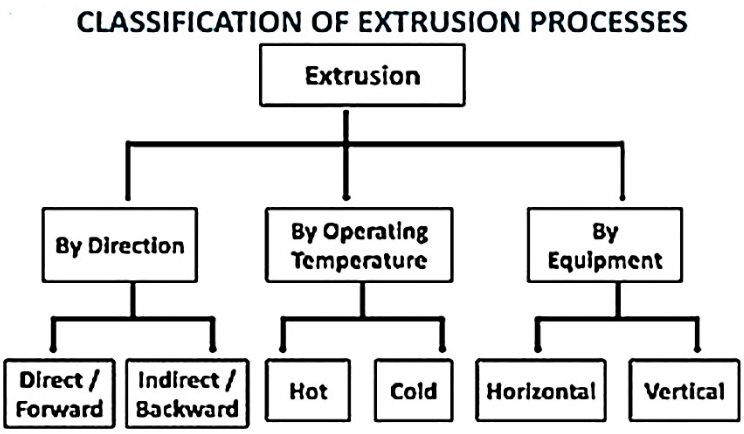


Figure 4.41

Some advantages of extrusion process

1. The complexity and range of parts which can be produced by extrusion process is 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 case of rolling, 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



1. **Direct extrusion:** it is a process in which the metal billet 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 backward flow of material.

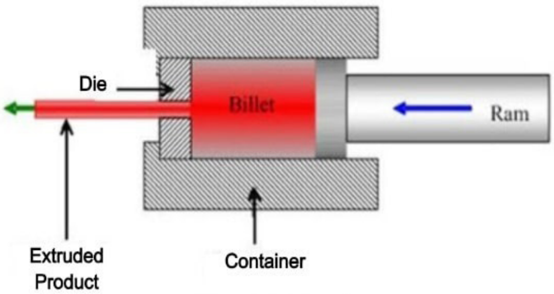


Figure 4.42: *Direct extrusion*

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.

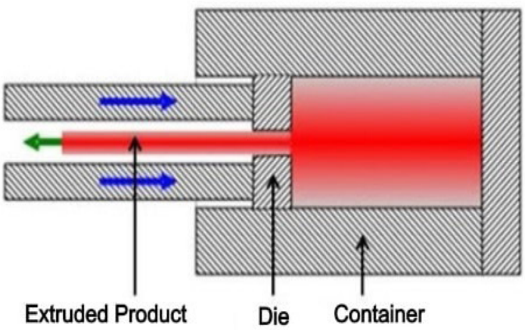
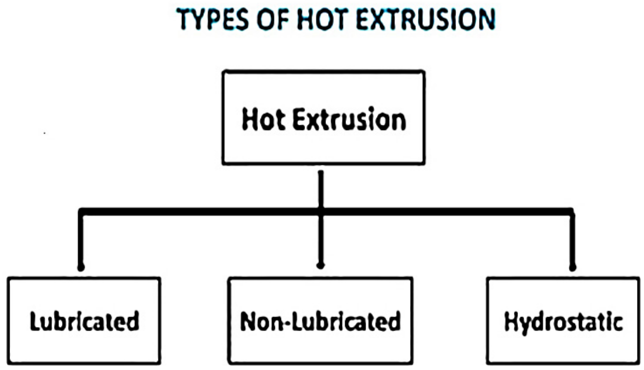


Figure 4.43: *In-direct extrusion*

3. **Hot extrusion:** It is done at 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.



4. **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.
5. **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.
6. **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.

Comparison between Hot and Cold Extrusion

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

Learning Tasks

1. Identify and explain forging, rolling and extrusion processes in sheet metal work.
2. Explain how forging, rolling and extrusion in sheet metal work are used in making articles.
3. Describe the process for using forging, rolling and extrusion to produce specific articles.
4. Describe how forging, rolling and extrusion can be combined to produce an article.

Pedagogical Exemplars

1. **Group work/collaborative learning:** Group learners to accurately describe and demonstrate the processes involved in forging, rolling and extrusion operations in sheet metal. Assist learners to discuss the differences between rolling, forging and extrusion processes and present a report to the group.
2. In mixed ability groups learners can also brainstorm the differences between cold rolling, hot rolling, cold extrusion and hot extrusion and present a report to the group.
3. **Experiential learning:** Learners embark on an educational visit to a local workshop and observe forging, rolling and extrusion processes and present a report to the class.

   Assist learners to identify the functions of the tools and equipment used in forging, rolling and extraction and present a group or individual report.

Key Assessments

Level 1: Explain the following processes connected with forging:

a. Upsetting
b. Drawing down
c. Fullering.

Level 2: Describe the process of forge welding.

Level 3: Describe the process of rolling. Illustrate your answer with a suitable explanatory sketch.

Level 4

1. You are supplied with a stock of MS rods having a dimension shown in figure (a).
2. You are asked to create a round headed bolt and a square headed nut as shown in Figure (b). List the process sequence involved.
3. Run simulation on upsetting as a process connected with forging.

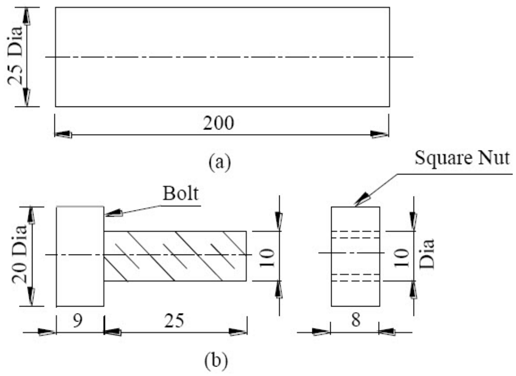


Figure 4.44

HINT

*The recommended mode of assessment for week 16 is **simulation.** Use the level 3 question 1 as a sample question.*

UNIT 16 REVIEW

This unit covered forging, rolling and extrusion processes in sheet metal work and their uses. Different forging operations, the processes, tools and equipment have been discussed. Rolling which is another key area in metal work has also been covered focusing on the types of rolling mills and the differences between cold rolling and hot rolling. Extrusion and its advantages and disadvantages have also been treated in this unit.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the basic metal forming processes?
3. Were learners able to explain forging, rolling and extrusion in sheet metal work?
4. Which resources best supported the teaching and learning of forging, rolling and extrusion in sheet metal work?
5. Did learners find the resources useful in learning forging, rolling and extrusion in sheet metal work?
6. How were the different subgroups catered for in the class?
7. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

APPENDIX E: INDIVIDUAL PROJECT

PROJECT STRUCTURE & GUIDE

1. Project Title (Heading)

- Choose a **clear, concise** heading that matches your project content.
- Make sure it:

  a. *Clearly describes the project's focus.*

  b. *Is short and to the point.*

  c. *Accurately reflects the main content.*

  d. *Follows proper grammar and syntax.*

Example

- Instead of *"**Making Bread**"*, write *"**Cost Analysis for Bread Production at Golden Taste Bakery**"*.

2. Project Design Brief

- Write **50–60 words**.
- Include:

  a. *What your project is about (main focus).*

  b. *The purpose of the project.*

  c. *The approach or method you will use.*

  d. *Correct spelling and keywords.*

Example

- *This project analyses the production cost of a loaf of bread at **Golden Taste Bakery.** It aims to determine the cost of materials, labour, and overheads using cost accounting techniques. The results will help in making informed pricing decisions and improving bakery efficiency.*

3. Research & Planning

- Gather relevant information from textbooks, the internet, interviews, or observations.
- Identify materials, data, and tools you will need.
- Make a **step-by-step plan** for completing your project.

4. Technical Work (Project Execution)

- Follow your plan to complete the project.

- Ensure your work meets all technical specifications:
  - **a.** Tested *and meets purpose.*
  - **b.** *Accurately documented (records, notes, calculations).*
  - **c.** *Fully functional.*
  - **d.** *Eco-friendly where possible.*

5. Testing & Results

- Test your work to ensure it functions as intended.
- Record your findings (tables, diagrams, photos).
- Adjust or improve where needed.

6. Final Report

Your report should include:

a. **Title Page:** Project title, your name, date.

b. **Design Brief:** Your 50–60-word summary.

c. **Methodology:** Step-by-step explanation of how you completed the project.

d. **Findings & Results:** Data, charts, calculations, or diagrams.

e. **Conclusion:** Lessons learned and recommendations.

f. **References:** Sources of your information.

Table 4.2: Scoring Rubric

Criteria	Excellent (4)	Good (3)	Fair (2)	Needs Improvement (1)
Heading (Caption of the Project)	Heading includes 4 of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 3 of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 2 of the following; clear, concise, accurately reflects the project's content and follow syntax rule.	Heading includes 1 of the following; clear, concise, accurately reflects the project's content and follow syntax rule.
Project Design Brief	Brief is based on 4 of the following: has project specification, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 3 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 2 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords	Brief is based on 1 of the following: written, (50-60 words), provides comprehensive overview of the project and correct spelling of keywords

Technical Specification	Final work shows 4 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 3 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 2 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.	Final work shows 1 of the following: test meets specifications, accurately documented, all parts functional and ecofriendly.

SECTION 5: VEHICLE SUSPENSION AND METAL FORMING PROCESSES II

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section learners will acquire knowledge and understanding of layout of vehicle suspension systems, as well as leaf, coil and air suspension systems. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of basic cutting and bending operations in sheet metal fabrication as well as perform drawing, die and presses operation in sheet metal fabrication. All the above are treated from unit 17 to unit 20.

UNIT17

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems.*

HINT

Mid-Semester Examination for the first semester is in Week 18. Refer to ***Appendix F*** *for the structure and table of specifications to guide you in setting the questions. Set questions to cover all the indicators covered for at least weeks 1 to 5.*

INTRODUCTION AND UNIT SUMMARY

This lesson explores the fundamental layout and components of vehicle suspension systems which is a crucial aspect of automotive engineering that ensures your ride is not only comfortable but also safe and efficient. The suspension layout directly affects how a vehicle absorbs bumps and irregularities on the road. A well-designed layout ensures that passengers experience a smooth ride, minimising the impact of road conditions. The unit covers introduction and requirements of suspension systems, the basic components that constitute the vehicle suspension systems, list of springs, suspension system terms and basic suspension movements. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the layout and requirements of suspension. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the various suspension systems and components and their importance to vehicle's ride, handling and safety.

- ***The unit covers only week 17:*** *Describe the layout of vehicle suspension systems.*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach the introduction and requirements of suspension system ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the basic components that constitute the vehicle suspension systems can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the functions of the suspension systems.

ASSESSMENT SUMMARY

Teaching the introduction and requirements of suspension systems, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to the vehicle suspension systems. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter.

WEEK 17

Learning Indicator: *Describe the layout of vehicle suspension systems.*

Focal Area 1: Introduction To Suspension System

The suspension system of an automobile is one which separates the wheel/axle assembly from the body. The purpose of the suspension system is to isolate the vehicle body from road shocks and vibrations due to irregularities on the road surface.

Requirements of a Suspension System

1. Minimum deflection is consistent with required stability.
2. Comparability with other vehicle components-type, frame wheelbase, steering linkage.
3. Minimum wheel hop.
4. Low maintenance and operating costs.
5. Low initial cost.
6. Minimum weight
7. Minimum wear.

Components of a suspension system

The suspension system is made up of the following components:

1. Spring.
2. Dampers (or shock absorber).
3. Stabiliser.
4. A linkage system which holds the above components in place and to control the longitudinal and lateral movements of the vehicle.

Springs

The springs are fitted between the chassis frame and the road wheels. The purpose of the spring is to absorb shocks and bumps transmitted from the road surface and prevent them from reaching the body and the occupants of the vehicle.

Types of springs

The various types of automotive springs are:

1. Laminated or leaf springs
2. Helical or coil springs
3. Torsion bars

4. Rubber springs
5. Air and gas springs

Leaf Spring

Coil Spring

Torsion bar

Figure 5.1: *Springs*

Rubber spring

Air Spring

Figure 5.2: *Springs*

Dampers

Dampers are needed because springs do not 'settle down' fast enough. After the spring has been compressed and released, it continues to oscillate for some time. The purpose of the damper is to absorb the energy stored in the spring and so reduce the number of oscillations occurring between the initial bump and the return (rebound) of the spring to its rest position. It is fitted between the chassis frame and the road wheels. This term shock absorber describes the action of a spring. It is often used incorrectly to describe a damper.

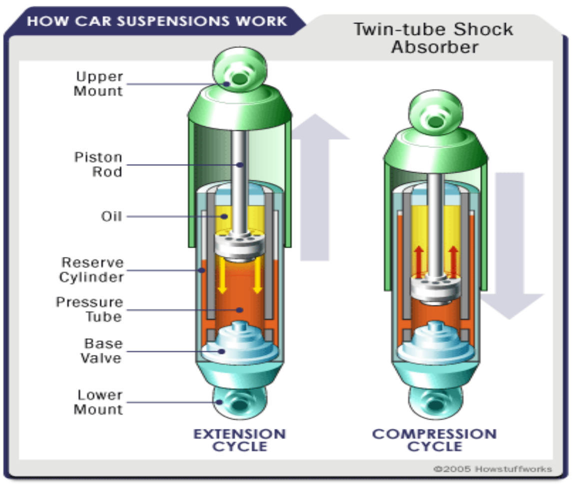


Figure 5.3: *Dampers*

Stabiliser

This is sometimes called anti-roll bar or sway bar. It is similar to the torsion bar and fitted to the lower control arms. The purpose is to try and keep the car's body from "rolling" in a sharp turn. It also equalises the load on the two springs of the independent suspension.

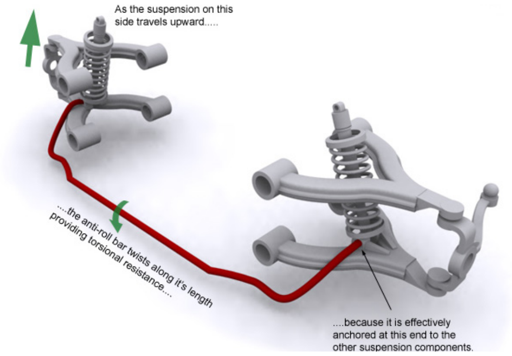


Figure 5.4: *Stabiliser*

Types of Suspension System

1. **Rigid/beam axle suspension system (Conventional):** In this type of suspension system, two wheels are rigidly mounted on each side of the axle. When one wheel is displaced upward due to uneven road surface, the other one also gets displaced since both are rigidly connected through an axle

Figure 5.5: *Rigid Axle*

2. **Independent suspension system:** In this type of suspension system, both left and right wheels are connected to the axle via different links. This arrangement eliminates the effect of one wheel on the other. In other words, when a wheel rolls over a bump, it doesn't cause the other wheel to tilt.

Figure 5.6: *Independent Suspension*

a. **A passive suspension** has the ability to store energy via a spring and to dissipate it via a damper. Passive suspension systems rely on fixed components such as springs, shock absorbers, and dampers. Its parameters are generally fixed, being chosen to achieve a certain level of compromise between road handling, load carrying and ride comfort.

b. **An active suspension system** has the ability to store, dissipate and to introduce energy to the system. Active suspension systems use sensors, actuators, and electronic controls to adjust the suspension settings in real-time. It may vary its parameters depending upon operating conditions.

Suspension System Terms

1. **Strut:** is often the combination of a coil spring with a damper inside it, between the wheel stub axle and the inner wing. This is a very popular type of suspension
2. **Wishbone:** is a triangular shaped component with two corners hinged in a straight line on the vehicle body and the third corner hinged to the moving part of the suspension
3. **Bump stop:** When a vehicle hits a particularly large bump, or if it is carrying a heavy load, the suspension system may bottom out (reach the end of its travel). The bump stop, usually made of rubber, prevents metal to metal contact which would cause damage
   a. **IFS** means Independent front suspension
   b. **IRS** means Independent rear suspension

Independent Suspension

This allows a wheel of the vehicle to move without affecting the one at the other side

1. **Link:** A very general term to describe a bar or similar component that holds or controls the position of another component. Other terms may be used such as tie bar.
2. **Beam axle:** A solid axle from one wheel to the other. Not now used on the majority of light vehicles, but still common on heavy vehicles as it makes a very strong construction.

Gas/Fluid Suspension

The most common types of spring are made from spring steel. However, some vehicles use pressurised gas as the spring (think of a balloon or a football). On some vehicles a connection between wheels is made using fluid running through pipes from one suspension unit to another.

1. **Sprung mass:** refers to vehicle parts supported on the springs, such as the body, frame, and engine.
2. **Unsprung mass:** includes parts of the steering and suspension not supported by springs, such as wheels, tires, and brake assemblies.
3. **Jounce:** Jounce refers to the bounce or vertical movement of the vehicle suspension upward when it contacts a bump in the road.

4. **Rebound:** Rebound refers to the movement of the vehicle suspension in the opposite direction of jounce.
5. **Ride:** a car's ability to smooth out a bumpy road.
6. **Handling:** a car's ability to safely accelerate, brake and corner.

Basic suspension movements

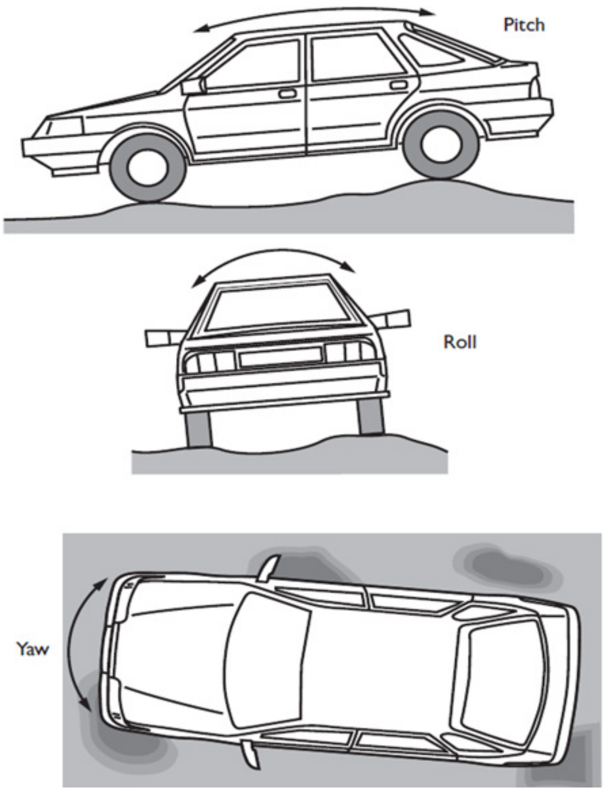


Figure 5.7: *Suspension movements*

1. **Pitch** is the rotation of a vehicle about the transverse or lateral axis.
2. **Roll** is the rotation of a vehicle about the longitudinal axis.
3. **Yaw (Bounce)** is the rotation of a vehicle about the vertical axis.

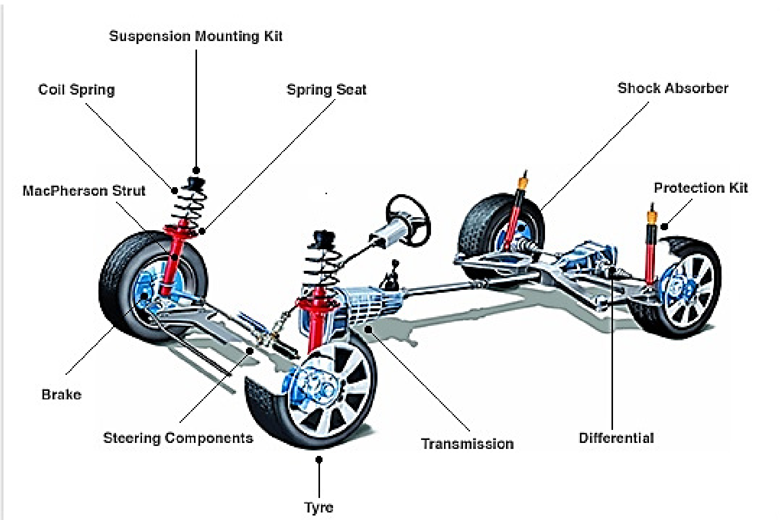


Figure 5.8: *suspension movements*

Learning Tasks

1. Explain the functions of vehicle suspension system and associated terms.
2. Describe the suspension system components.
3. Explain what is meant by sprung weight and unsprung weight.
4. Describe the meaning of roll, pitch and yaw in vehicle suspension system.

Pedagogical Exemplars

1. **Group work/collaborative learning:** In groups using relevant sketches or real objects assist learners to identify the main component parts of the suspension system on a vehicle. Assist learners to discuss how the main components function and present individual or group report. With the support of the teacher, learners also brainstorm various suspension system terms.
2. **Project based learning:** Group learners to discuss basic suspension system terms and present group report in class. Also, guide learners to examine the main components in the suspension system of cars and trucks and note the appropriate differences

   Learners visit a school workshop or local repair workshop to observe critically and identify the main components of the suspension system.

Key Assessments

Level 1: What is the function of vehicle suspension system?

Level 2

1. Explain briefly the function of the spring, dampers and stabiliser (anti-roll bar) in the suspension system.
2. Explain the difference between sprung and unsprung weight and give two examples of each.

Level 3

1. Describe briefly the following three basic suspension movements of a car and how they are related to the vehicle axis
   a. Bouncing
   b. Rolling
   c. Pitching
2. Examine a real suspension system and make a simple sketch of how the suspension components are connected.

HINT

*The recommended mode of assessment for week 17 is **checklist**. You may use the level 1 question as a sample question.*

UNIT 17 REVIEW

This unit reviews the importance and the functions of vehicle suspension which is to absorb shocks and vibrations from the road surface, providing a smoother ride for passengers by minimising the impact of bumps, potholes, and other road irregularities. The lesson equips the learners with the introduction and requirements of suspension systems, the basic components that constitute the vehicle suspension systems, list of springs, suspension system terms and basic suspension movements. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the introduction to the suspension systems. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of vehicle suspension system.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to state the functions and the requirements of vehicle suspension system?
3. Were learners able to explain the main components that constitute the suspension system?
4. Were the learners able to explain the various suspension system terms?
5. Which resources best supported the delivery of the introduction and the layout of vehicle suspension system?
6. Did learners find the resources useful in studying the basics in the suspension system?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 18

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers the basic cutting and bending operations in sheet metal fabrication which are essential for shaping and forming metal sheets into desired configurations. Cutting operations such as shearing, blanking, punching and laser cutting are fundamental in sheet metal fabrication and ensure that the sheet metal is trimmed to precise dimensions and shapes, which is crucial for the assembly and functionality of the final product. It also presents bending operations such as v- bending, roll bending, bottom bending, rotary bending and other associated terms which allows for the creation of various shapes and angles, making it essential for producing parts with complex geometries. Teaching these operations involve various pedagogical approaches to ensure effective learning. Pedagogical strategies have been suggested for teachers to employ in the delivery of lessons on basic cutting and bending operations in sheet metal fabrication. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the basic operations in sheet metal fabrication. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the basic cutting and bending operations in sheet metal fabrication.

- ***The unit covers only week 18:*** *Perform basic cutting and bending operations in sheet metal fabrication*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach cutting and bending operations in sheet metal fabrication, ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the various operations in cutting and bending sheet metal can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher can employ a variety of pedagogical strategies such as problem-based learning; group work/

collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help students gain a thorough understanding of the main operations in metal forming and sheet metal fabrication.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the basic cutting and bending operations in sheet metal fabrication, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessment. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering the machining processes in manufacturing industry. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 18

Learning Indicator: *Perform basic cutting and bending operations in sheet metal fabrication.*

Focal Area: 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 thicker is considered as 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.

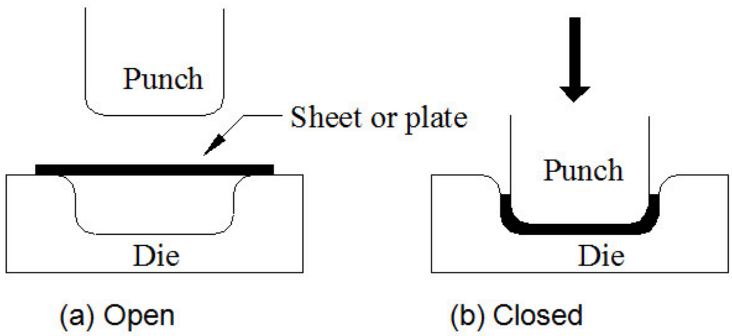


Figure 5.9: *Punches and Dies*

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 materials 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.

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 commonly used for straight cuts in sheet metal and uses a machine called power shear or square shear.

Figure 5.10: *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.

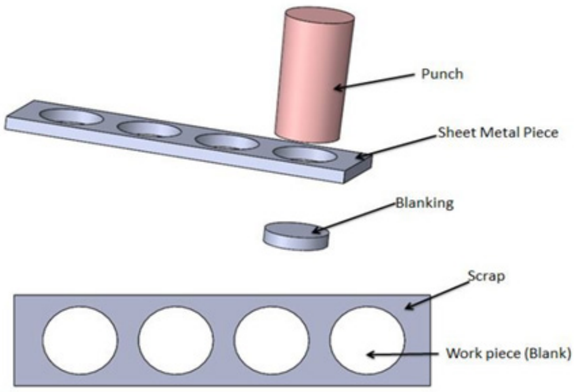


Figure 5.11: *Blanking: Sheet metal cutting operation*

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.

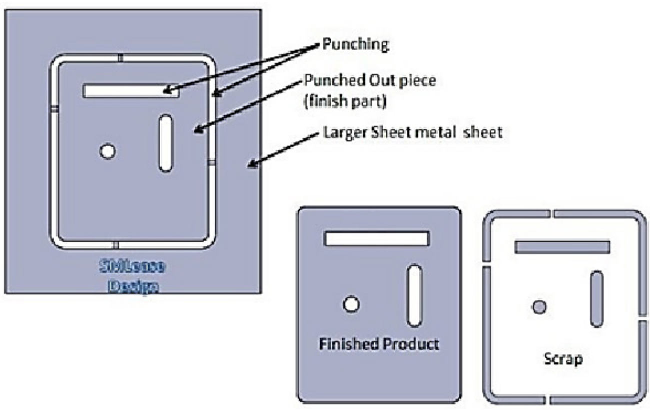


Figure 5.12: *Sheet metal cutting using punching operation*

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.

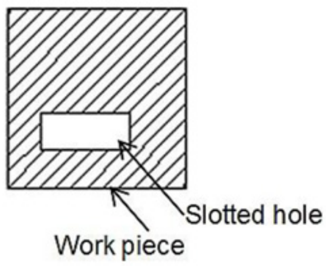


Figure 5.13: *Slotting*

5. **Lancing:** Lancing is the operation of cutting a sheet of metal through part of its length and bending the cut portion.

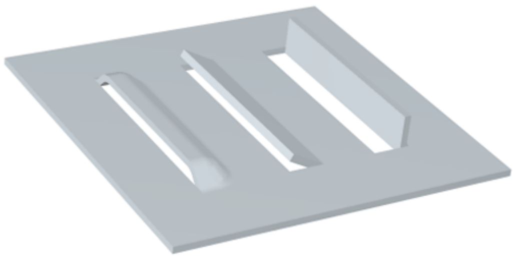


Figure 5.14: *Sheet metal cutting using Lancing Operation*

6. **Slitting:** Slitting is the operation of cutting a sheet metal along a straight line along the length. Slitting is shown below.

Figure 5.15: *Slitting*

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.

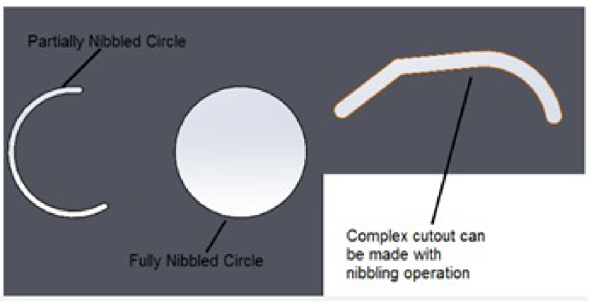


Figure 5.16: *Sheet metal Nibbling Operation*

8. **Parting:** Parting is separating apart from the remaining sheet, by punching away the material between parts.

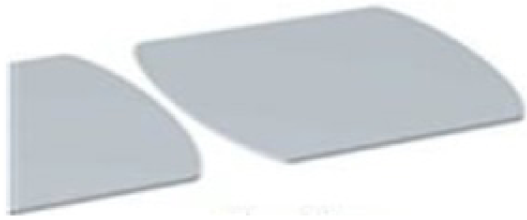


Figure 5.17: *Parting*

9. **Cut off:** Separating apart from the remaining sheet, without producing any scrap. The punch will produce a cut line that may be straight, angled, or curved.

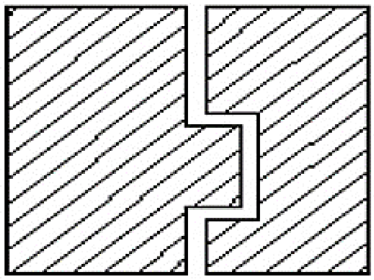


Figure 5.18: *Cut-off*

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.

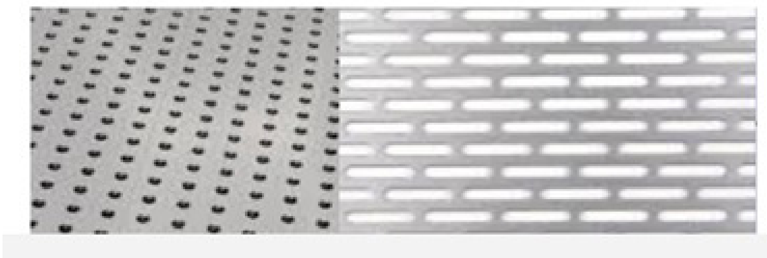


Figure 5.19: *Sheet Metal Cutting Operation Perforation*

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.

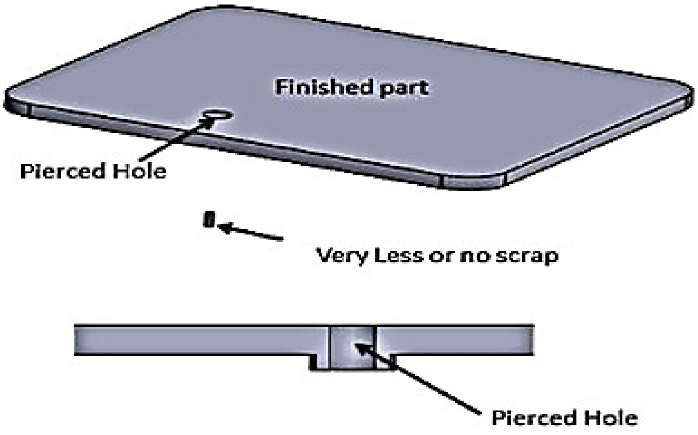


Figure 5.20: *Sheet Metal Piercing Operation*

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.

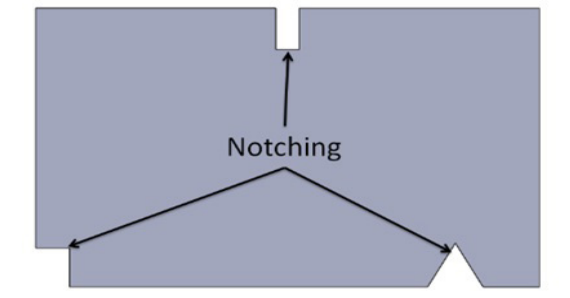


Figure 5.21: *Sheet metal Notching Operation*

13. **Trimming:** Punching away excess material from the perimeter of a part, such as trimming the flange from a drawn cup.

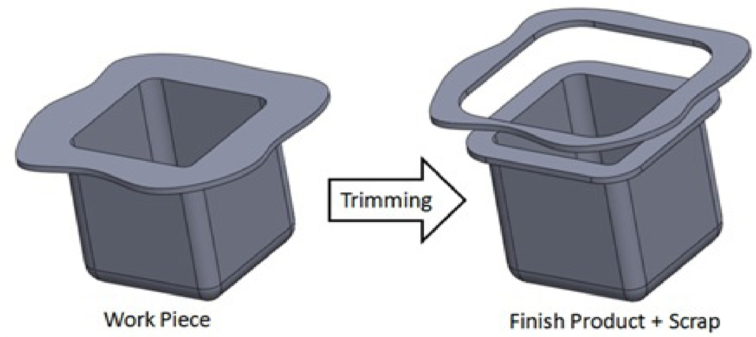
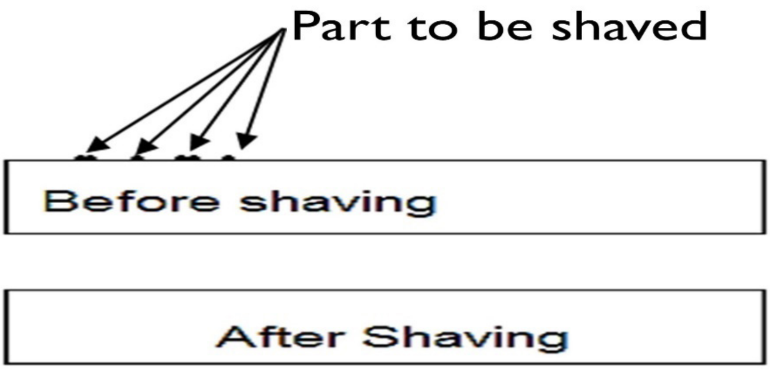


Figure 5.22: *Sheet Metal Trimming Operation*

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.



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.

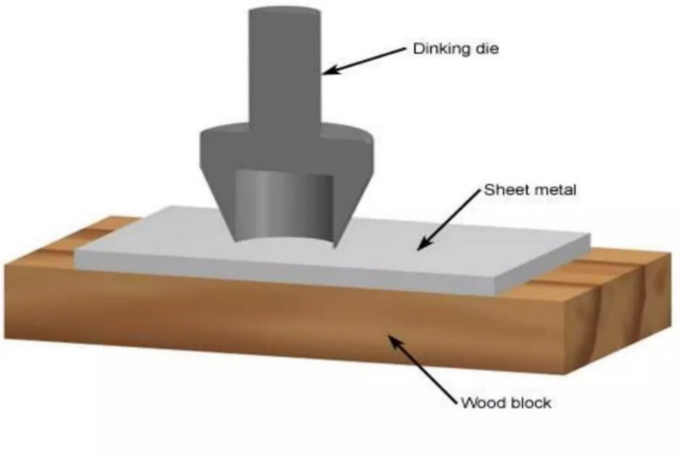


Figure 5.23: *Dinking operation*

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.

Figure 5.24: *Noga DB1000 sheet metal deburring tool*

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.

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.

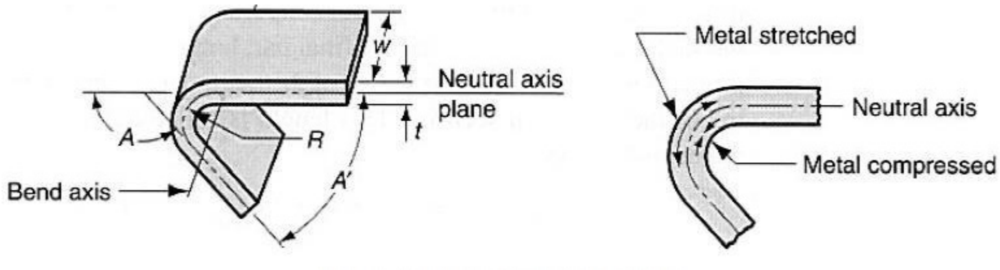


Figure 5.25: Bending

Sheet Metal Bending Methods

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 workpiece 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.

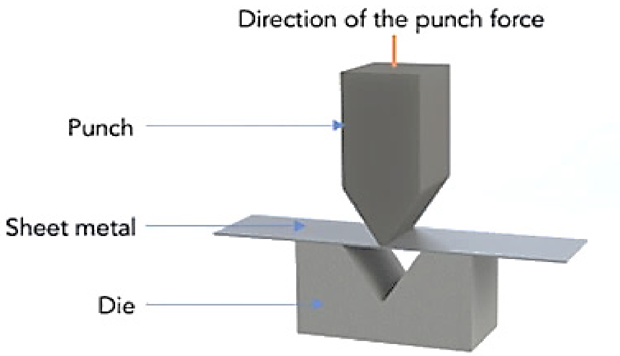


Figure 5.26: *V-bending before the application of force*

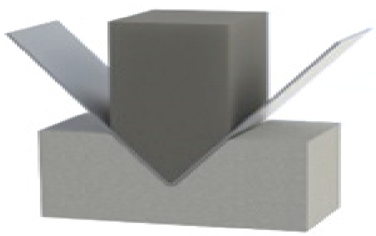


Figure 5.27: *V-bending after the punch force*

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.

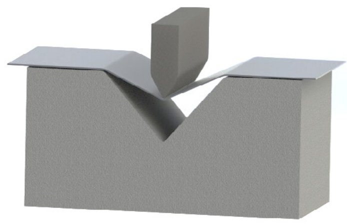


Figure 5.28: *Air Bending*

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.

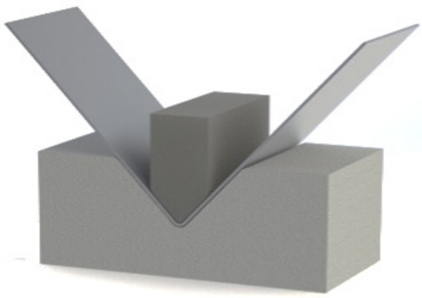


Figure 5.29: *Bottom bending*

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.

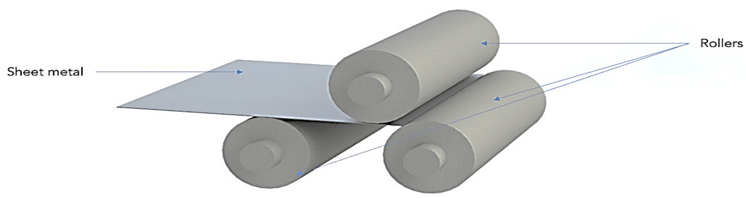


Figure 5.30: *R*oll Bending

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.

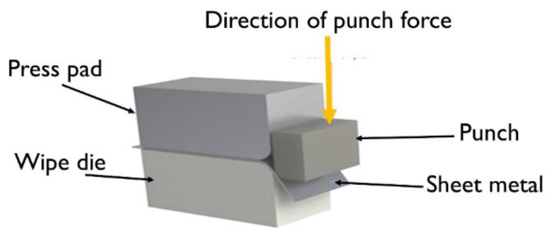


Figure 5.31: *Wipe bending*

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.

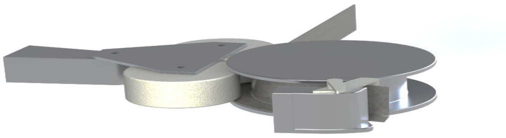


Figure 5.32: *Rotary bending*

Bending Operations

1. **Flanging:** Flanging is one kind of bending operation in which the edge of the sheet metal part is bending at 90o 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:
   a. Straight
   b. Stretch
   c. Shrink

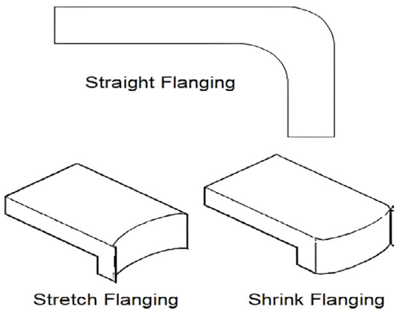


Figure 5.33: Flanging

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 safer, non-jogged edge. There are two types of hemming, namely as:
   a. Flat hemming
   b. Open hemming

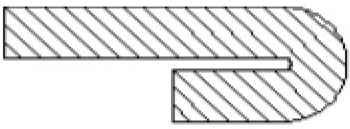


Figure 5.34: *Flat hemming*

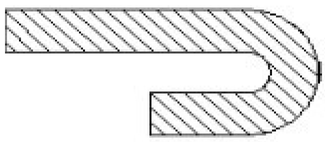


Figure 5.35: *Open hemming*

3. **Seaming:** It is an operation where two sheet metal edges are assembled as shown below.

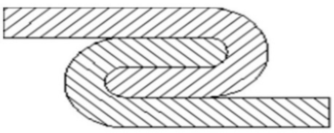


Figure 5.36: *Seaming*

4. **Curling:** form the edges of the part into a roll or curl as shown in the figure below.

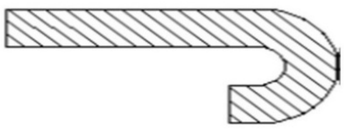


Figure 5.37: *Curling*

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.

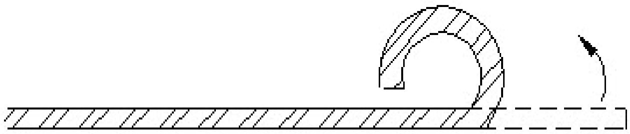
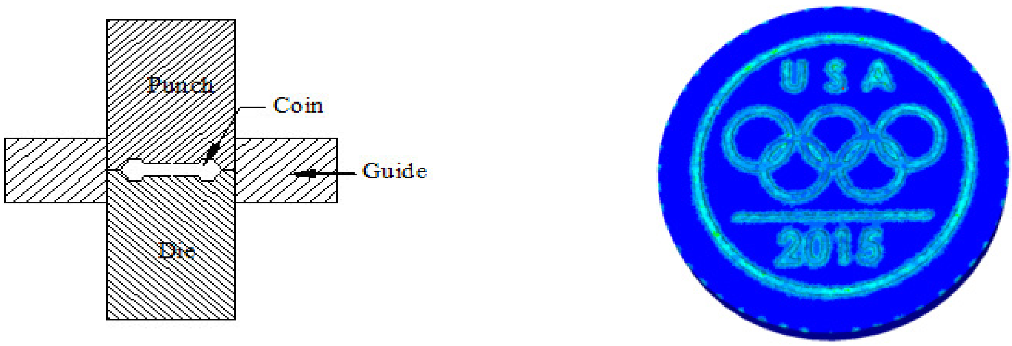


Figure 5.38: *Beading*

6. **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.



Embossing *Coining*

Figure 5.39: *Coining*

7. **Embossing** is the operation of producing raised or depressed impression of figures, letters or designs on sheet metal parts. The major use of the embossing process in the production of nameplates, identification tags and aesthetic designs on thin sheet metal or foil.

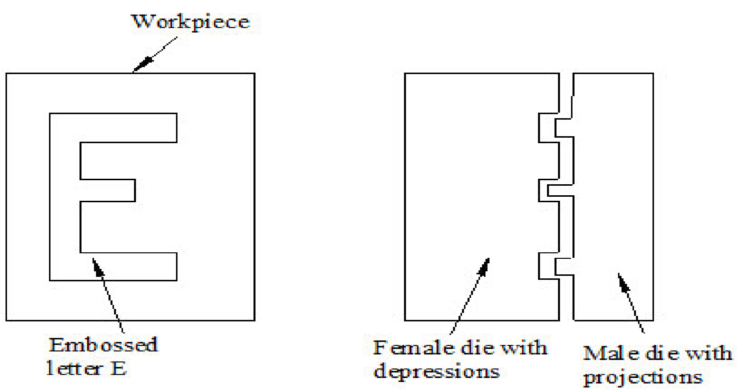


Figure 5.40: *Embossing process*

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, as shown in the figure below.

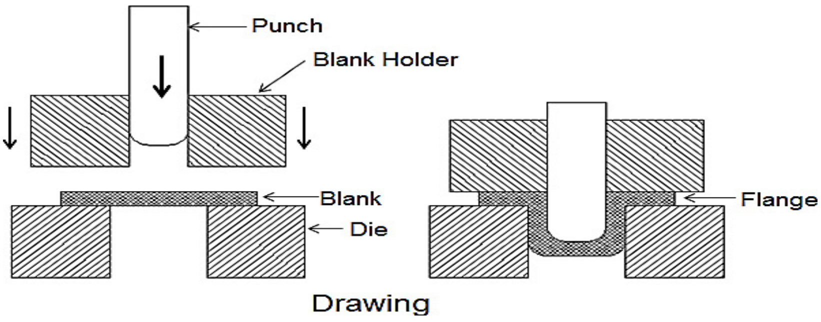


Figure 5.41: *Drawing*

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.

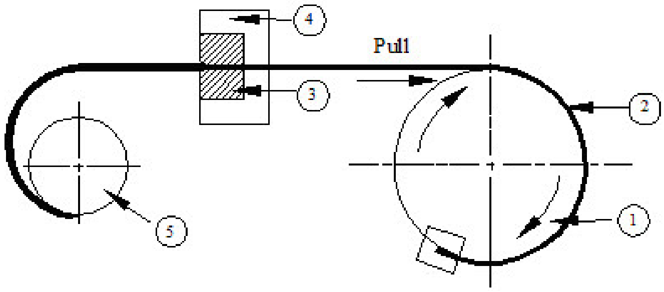


Figure 5.42: *Wire drawing process*

Sheet Metal Hand Tools

1. **Measuring tools:** *Steel rule, Folding rule, Circumference rule, Vernier Calliper, Micrometre, Thickness Gauge, Sheet Metal Gauge, Straight Edge*
2. Steel Square
3. Scriber
4. Divider
5. Trammel Points
6. Punches
7. Chisel
8. Hammers
9. Snips or shears
10. Pliers
11. Stakes
12. Groovers
13. Rivet Set
14. Soldering Iron

Sheet Metal Working Machines

1. **Shearing machine:** Used to cut or shear metal sheets.
2. **Bar folder:** Used to bend and fold the edges of metal sheets.
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 metal.

Worked Example

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 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.

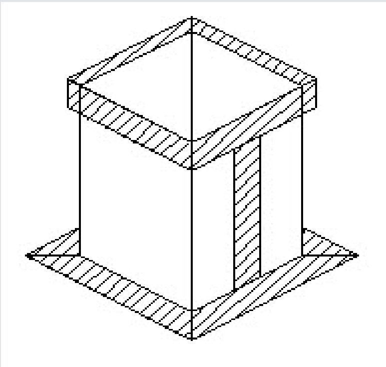


Figure 5.43: *Duct to be manufactured*

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

1. Bending or folding to get the square shape,
2. Seaming at the edges of the sheet after folding to join the two edges,
3. Hemming at the top edge, and
4. Flanging at the bottom edge.

The stages of manufacturing the duct are illustrated in below:

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

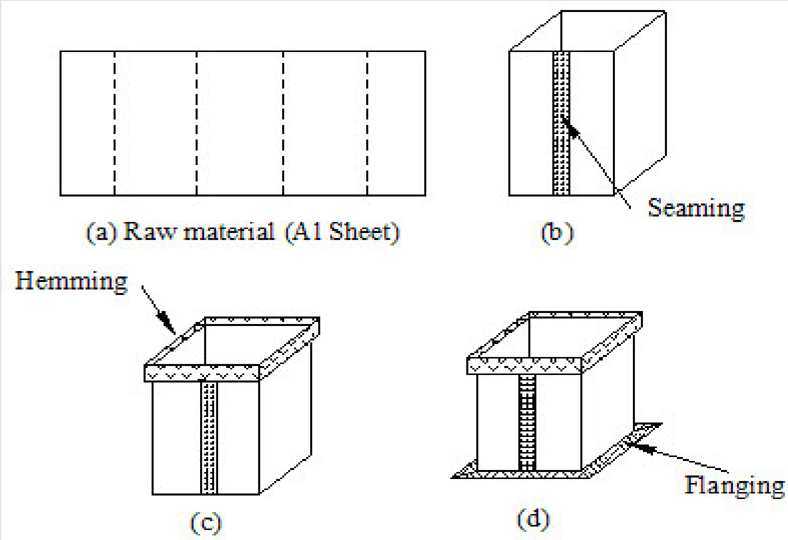


Figure 5.43: *Different stages in producing ductwork*

Learning Tasks

1. Explain sheet metal operations.
2. Describe the various cutting and bending operations in sheet metal fabrication and how to carry out these operations.
3. Describe the sequential process to follow to produce articles using cutting and bending operations in sheet metal fabrication.

Pedagogical Exemplar

Project-based Learning: Guide learners to explain sheet metal operations and the basic cutting and bending operations in sheet metal fabrication incorporating appropriate sheet metal specifications and selection using appropriate tools and equipment available and assist learners to present individual report.

Assist learners to describe the sequential process to follow to mark out and cut sheet metal to shape using hand and machine tools as well as bending sheet metal to form articles using hand and machine tools.

In groups using relevant sketches or real objects assist learners to identify various cutting and bending operations and share the results with the group.

Key Assessments

Level 2: What is a sheet metal and explain two sheet metal operations.

Level 3: Explain at least three operations each for cutting and bending in sheet metal fabrication.

Level 3: Describe the sequential process to follow to make a rectangular aluminium duct for use.

Level 4: A galvanised steel plate of size 500mm x 500mm. Propose and describe processes to follow to produce a tray.

HINT

*The recommended mode of assessment for week 18 is **Mid-Semester Examination.** Refer to the Appendix F at the end of the section for more sample task and the Table of Specification.*

UNIT 18 REVIEW

This unit looked at how to perform basic cutting and bending operations in sheet metal fabrication. Learners were taken through some cutting and bending operations in sheet metal fabrication. The procedure for cutting and bending sheet metals was thoroughly discussed. Learners had the opportunity to use the cutting and the bending operations to produce articles for use. Learners had the opportunity to visit a local industry where cutting and bending operations in sheet metal fabrication are done to have hands-on experience. The learners were guided by the teacher to mark out and cut sheet metal to shape using hand and machine tools as well as bending sheet metal to form articles.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain the basic cutting and bending operations in sheet metal fabrication?
3. Were learners able to mark out, cut and bend sheet metal to form articles for use?
4. Which resources best supported the teaching and learning the basic cutting and bending operations in sheet metal fabrication?
5. Did learners find the resources useful in learning the basic cutting and bending operations in sheet metal fabrication?
6. Were the different subgroups in the class catered for?
7. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

Resources: Heat treatment equipment, video clips/YouTube on heat treatment process, chart showing the heat treatment processes, real objects that has been heat treated, Industrial visit to heat treatment workshop.

UNIT19

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems*

INTRODUCTION AND UNIT SUMMARY

This lesson explores springs, a fundamental component of vehicle suspension systems. Springs play a crucial role in absorbing shocks from the road, supporting the vehicle's weight, and maintaining ride comfort. It also explores how springs function within the suspension system, their various types, and their impact on vehicle performance. Understanding these concepts is essential for appreciating how vehicles provide a smooth and stable ride, even on rough surfaces The unit covers laminated or leaf springs, helical or coil springs, torsion bars, rubber springs, air and gas springs and their features. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the various springs used in the suspension. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the various springs in the suspension systems and their importance to vehicle's ride, handling and safety.

- ***The unit covers only week 19***: *Explain leaf, coil and air suspension systems*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach various forms of springs in the suspension system ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the various spring systems in the vehicle suspension can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning, group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the springs in the suspension systems.

ASSESSMENT SUMMARY

Teaching the various springs in the suspension systems, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to springs in the vehicle suspension system. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter.

WEEK 19

Learning Indicator: *Explain leaf, coil and air suspension systems.*

Focal Area 1: Springs In Suspension System

The springs are fitted between the chassis frame and the road wheels. The purpose of the spring is to absorb shocks and bumps transmitted from the road surface and prevent them from reaching the body and the occupants of the vehicle.

Types of Springs

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

Leaf Spring

Coil Spring

Torsion bar

Figure 5.44: *Springs*

Rubber spring

Air spring

Figure 5.45: *Springs*

The factors governing the choice of springs used are:

1. Total weight of suspension system
2. Total cost of installation
3. Relative capacity for storing energy
4. Guide linkage required

5. Location
6. Fatigue life

Laminated or Leaf Springs

This type of spring consists of several layers of metal called "leaves" bound together to act as a single unit. The leaves are of different length to give even stress distribution and allow for varying frequency of spring vibration. This laminated spring is also called semi-elliptic spring. Due to the sliding action between the leaves, friction occurs between the leaves and this helps to dampen the vibration of the spring. This is termed self-damping of the leaf spring.

Leaf spring has the following:

1. **Centre bolt:** This is used to hold leaves together and also position the leaves on the axle.
2. **Clip:** This holds the leaves together to prevent any lateral movement of the leaves and also transfers load to other leaves.
3. **U-bolts:** The U-bolts locate and hold the spring onto the axle
4. **Swinging shackle:** This allows the spring to vary its length as the axle moves up and down.
5. **Shackle pins:** This connects one end of the spring to the chassis called the fixed shackle and the other end to the swinging shackle.
6. **Rubber bush:** This is filled in the eyes of the master leaf. It allows movement of the leaf and prevent noise to be transmitted to the body.

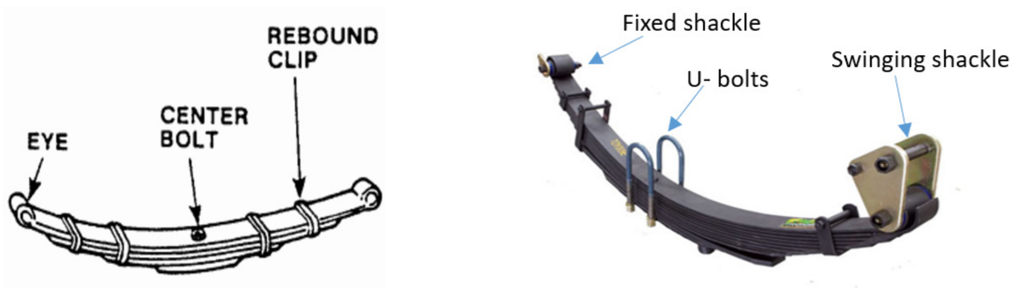


Figure 5.46: *Laminated or leaf springs*

The stiffness or spring rate which is the force required to deflect the spring depends on the:

1. Length of spring, shorter spring higher rate
2. Width of the leaf, the wider the leaf the higher the rate
3. Thickness of the leaf, thicker spring higher rate
4. Number of leaves, greater number higher rate

Hardness of the spring can be reduced by using:

1. rubber bushes in the eyes of the master leaf instead of bronze bushes
2. inter-plate material of low friction material
3. a smaller number of leaves.

Helper springs: are provided on many commercial vehicles in addition to the main leaf springs. A helper spring is just like a semi elliptical spring but without eyes at the ends

Helical or coil springs

This type of spring also called 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. The coil springs compress and expand to absorb the up and down motion of the wheels. It is mostly used at the front end of the vehicle. The spring rate depends on the length and the diameter of the wire

Figure 5.47: *Coil Spring*

Advantages of coil spring over leaf spring

1. Higher spring rate
2. Lighter in weight than the leaf spring
3. Energy store is higher than the leaf spring
4. Easy to accommodate in confined spaces

Disadvantages of coil spring

Inability to control accelerating, braking and cornering reactions. Whenever coil springs are used anti-roll bars are used to deal with the driving, braking thrust and cornering reactions. Braking thrust or reaction is the attempt by the axle to rotate as the vehicle brakes or stops and driving or accelerating thrust is the tendency of the axle to rotate as the vehicle moves.

Air Spring Systems

An air spring system replaces the traditional spring suspension, replacing steel coil springs (or leaf suspension) above the vehicle wheels with airbags made of rubber and polyurethane. These airbags are inflated by an onboard air compressor or electric pump, to a certain pressure to behave in a similar way to traditional springs. The air direction is controlled by air valves that let the air go into different parts of the system to inflate.

Figure 5.48: *Air Spring system*

Advantages

1. **Comfort:** One of the main benefits of air suspension cars is the improved comfort behind the wheel, making it good for daily driving. The adjustable air suspension makes for a more comfortable ride on poor quality roads and can improve control when off-roading.
2. **Reduced noise and vibration:** Another advantage of air suspension is less wear and tear on the suspension system and vehicle components, due to reduced harshness and vibration, particularly with heavy-duty driving.
3. **Versatility on the road:** An air spring system allows the driver to adjust the car to suit their personal preferences for ride comfort and handling.
4. **Versatility on load:** Another advantage of air suspension is its versatility on load. The height of the car can be adjusted according to the load, the 'kneel' or 'raise' functions making loading easier from the outset.
5. **Fuel economy:** As vehicles with air suspension can be adjusted to road type, they benefit from better fuel economy. For example, a lower ride height for motorway driving means better aerodynamics and reduced wind resistance. Conversely, a suspension that is better suited to a particular road surface with better control can achieve higher corner speeds and lead to time-saving on routes with many turns.

Disadvantages

1. **Cost:** One disadvantage of an air spring system is the cost to buy, which is higher than a traditional spring suspension system. Only luxury cars tend to have a built-in air spring system as standard.
2. **Maintenance:** Another air suspension disadvantage is the cost of maintenance. In the short term, air suspension cars are reliable but tend to see longer distance travel and time on the road where frequent repairs may become necessary.
3. **Mechanical issues:** Air suspension systems are also prone to mechanical issues. The suspension may suffer malfunctions from rust or moisture damage from the inside, or an air fitting failure of the air tubing connecting to the air system. Leaks in air springs are also common and could lead to compressor burn out.

Rubber Springs

The use of rubber as a means of suspension has the following advantages:

1. Rubber is more reliable and as such a rubber suspension cannot suddenly fail like the metal springs.
2. The rubber has excellent vibration damping properties.
3. It can store greater energy per unit weight than steel, therefore, the rubber springing system can be made more compact.
4. The absence of squeaking which is always present in steel springs.

Rubber springs have a good fatigue life strength in compression but worst in tension. They are free of maintenance. Rubber springs are used in the commercial vehicles.

Torsion Bar

A torsion bar is a long, alloy-steel bar which has one end anchored to the frame and the other end connected to the lower arm. Torsion bar twist to provide spring action as the wheel moves up and down. Spring rate depends on the length of the bar, and its diameter. The shorter and thicker the bar, the stiffer its spring rate. It can be placed parallel to the chassis frame or across the frame.

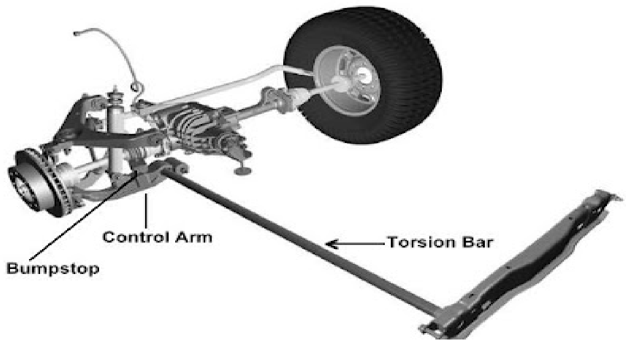


Figure 5.49: *Torsion bar*

Learning Tasks

1. Explain the functions of springs in the suspension system.
2. Describe the various types of springs in the vehicle suspension system.
3. Explain factors that affect the stiffness of the springs.
4. Examine the advantages and disadvantages of the various types of springs.

Pedagogical Exemplars

1. **Group work/collaborative learning:** In groups using relevant sketches or real objects assist learners to identify the various springs in the suspension system on a vehicle. Assist learners to discuss leaf and coil springs and present individual or group report.

   With the support the teacher, learners also brainstorm factors affecting the stiffness of the springs.

2. **Project based learning:** Group learners to discuss the various types of springs and present group report in class. Also, guide learners to examine the main differences between the springs and note the appropriate differences.

   Learners visit a school workshop or local repair workshop, observe critically and identify the various types of springs in the suspension system and present report.

KEY ASSESSMENTS

Level 2

1. Explain briefly how the following springs work:
   a. Leaf spring
   b. Coil springs
2. Describe briefly any two of the following:
   a. Torsion bar
   b. Air and gas spring
   c. Rubber springs

Level 3

1. Compare the advantages and disadvantages of leaf and a coil spring.
2. Why is a leaf spring self-dumping and explain four factors that affect the stiffness of the leaf spring.
3. Examine ***three*** advantages and disadvantages of air spring system.

HINT

*The recommended mode of assessment for week 19 is **gamification.** You may use the level 3 question 3 as a sample question.*

UNIT 19 REVIEW

This unit reviews the importance of spring systems in the vehicle suspension. The lesson equips the learners with the knowledge of different types of springs used in vehicle suspension systems, including coil springs, leaf springs, and torsion bars. The unique characteristics of each type of spring was presented as well as the advantages and disadvantages of each spring type, and their applications in different vehicle designs. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of springs in the suspension systems. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of vehicle suspension systems.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?

2. Were learners able to identify the main springs in the vehicle suspension system?
3. Were learners able to explain the functions of the various springs and torsion bar?
4. Were the learners able to explain the factors that affect the stiffness of the springs?
5. Which resources best supported the delivery of the springs in the vehicle suspension system?
6. Did learners find the resources useful in studying the springs in the vehicle suspension system?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 20

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers drawing, die and presses operations in sheet metal fabrication and knowledge of them provides the foundation for many manufacturing processes. These are essential skills for creating complex metal components with precision. Learning these processes enhances problem-solving skills, as one must analyse and troubleshoot issues that arise during sheet metal work and fabrication. Teaching these operations involve various pedagogical approaches to ensure effective learning. Pedagogical strategies have been suggested for teachers to employ in the delivery of lessons on drawing, dies, and presses in sheet metal fabrication. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the basic operations in deep drawing, die and presses in relation to metal forming. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of deep drawing, dies, and presses in sheet metal operations.

- ***The unit covers only week 20***: *Perform drawing, die and presses operation in sheet metal fabrication*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach drawing, die and presses operations, ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching the various operations in deep drawing, die and presses can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help students gain a thorough understanding of the main operations in deep drawing, die and presses.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of drawing, die and presses operation in sheet metal fabrication, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessment. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering drawing, die and presses operation in sheet metal fabrication. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 20

Learning Indicator: *Perform drawing, die and presses operation in sheet metal fabrication.*

Focal Area: Sheet Metal Work Operations

DRAWING OPERATION IN SHEET METAL FABRICATION

Drawing: It is the operation of producing cup and box shaped products from flat metal sheet. It is performed by placing a sheet metal blank over die cavity and then pushing the metal into the opening with a punch as show 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.

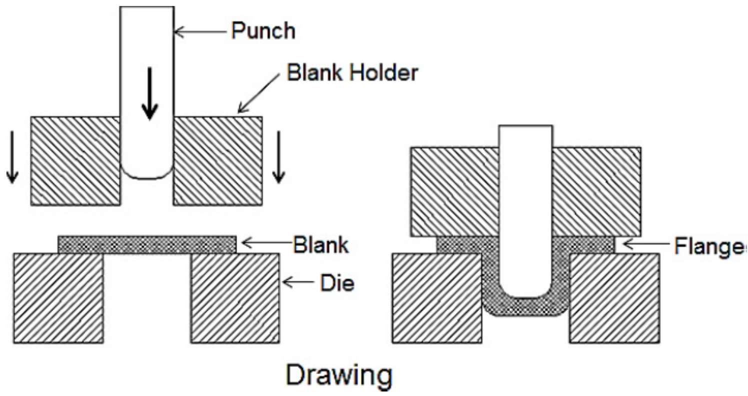


Figure 5.50: *Drawing*

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

1. **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.

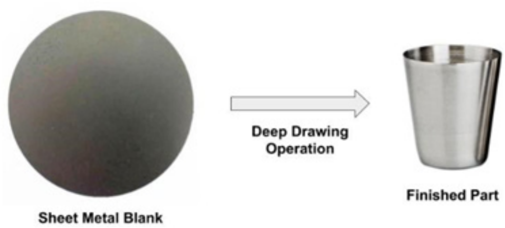


Figure 5.51: *Deep drawing*

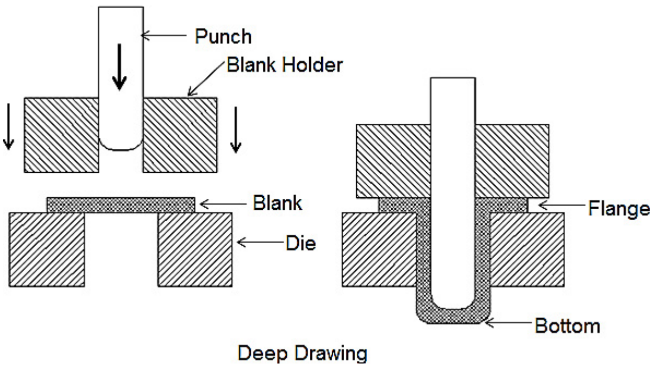


Figure 5.52: *Deep drawing*

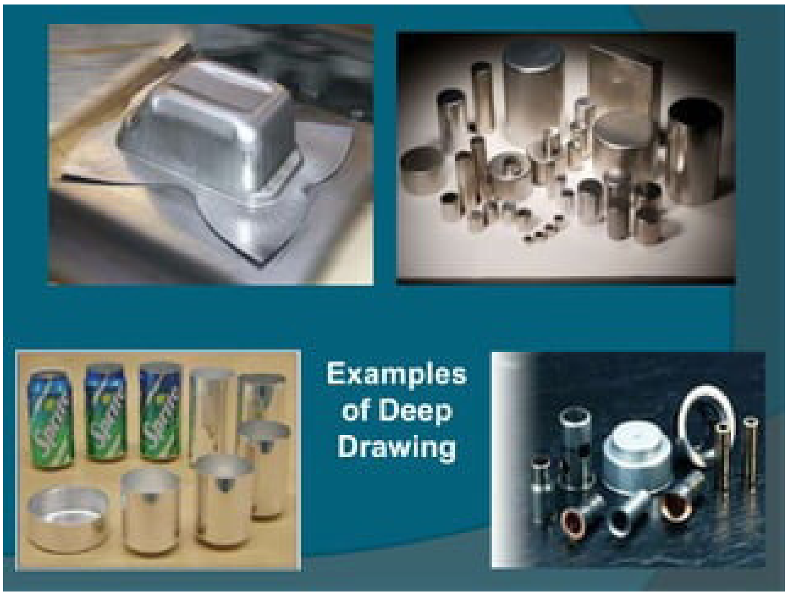


Figure 5.53: *Some products of deep drawing*

Advantages of deep drawing

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

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 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 sheet metal forming operation can convert a sheet metal blank into a deep-drawn sheet metal part. After sheet metal forming, part finishing operation is done (trimming, cutting, cleaning and a powder coating).

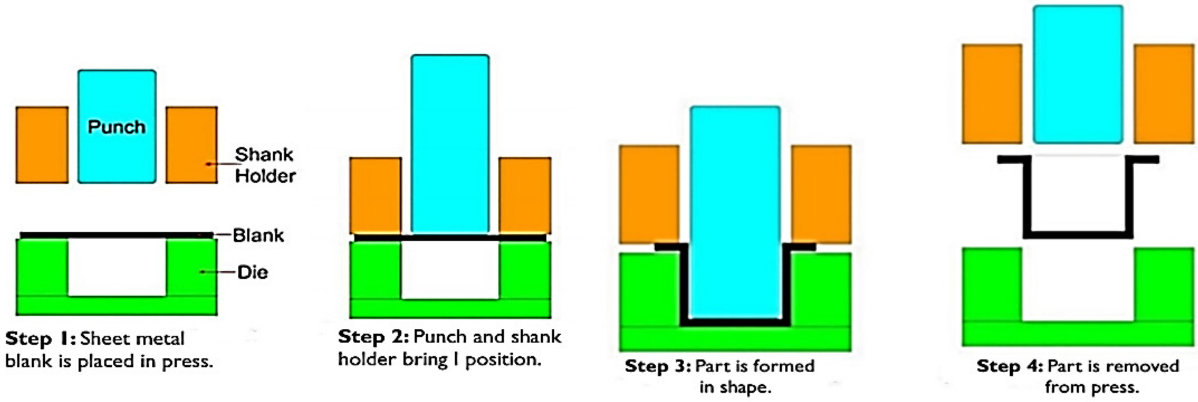


Figure 5.54: *Sheet metal deep drawing process*

- **Step1: Part Alignment:** Place the sheet metal blank inside the deep drawing die after sheet metal blanking operation.
- **Step 2**: **Gripping**: Shank holder grips the sheet metal blank in between the die and shank holder with the required pressure.
- **Step 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.
- **Step 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

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 may often occur if the blank holder force is too low.
3. Excessive thinning in areas of the sheet metal.
4. Earing which is the formation of wavy edges at the open end of the drawn cup.
5. Surface scratches irregularities may appear on drawn part.

Metal Drawing Process

The drawing process can be categorized into the following three types: Wire drawing, rod drawing and tube drawing

- **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 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%.

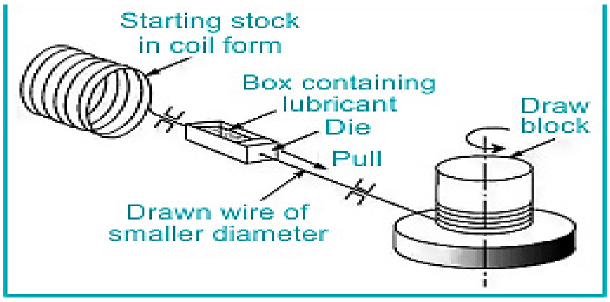


Figure 5.55: *Wire drawing*

- **Rod Drawing:** Similar to wire drawing, rod drawing is used to produce rigid rods with larger diameters than wires. This process requires heavier equipment because the rods need to be kept straight, unlike 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

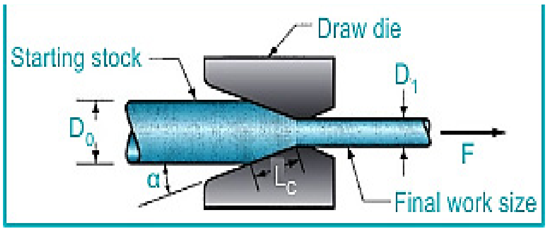


Figure 5.56: *Rod drawing*

- **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.

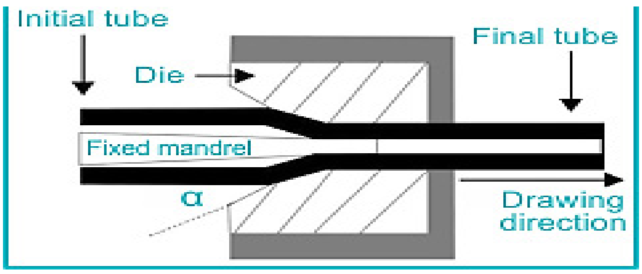


Figure 5.57: *Tube drawing*

Applications of Metal Drawing Process

1. Metal drawing is utilised to produce wires used in electrical industries made from materials like copper and aluminium.
2. Products like paper clips and helical springs are manufactured using the metal drawing process.
3. Small diameter rods and tubes are also obtained through metal drawing.
4. The process enables the production of long pieces 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:** 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

- **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 die, round split die, adjustable die, die nut, die plate, pipe die, acorn die.

1. **Simple dies** or single action dies perform 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.

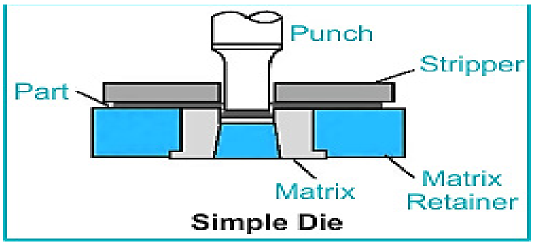


Figure 5.58: *Simple dies*

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.

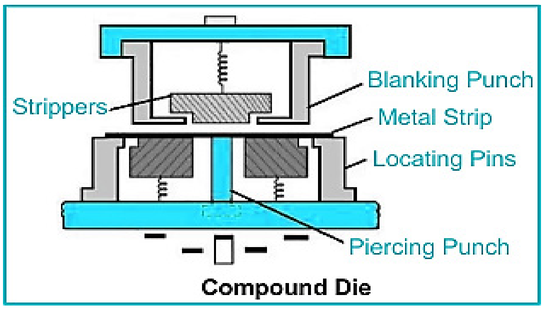


Figure 5.59: *Compound die*

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.

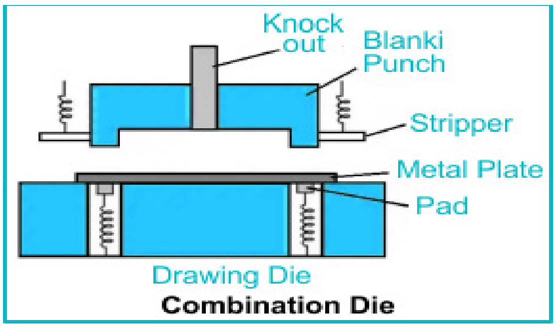


Figure 5.60: *Combination die*

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.

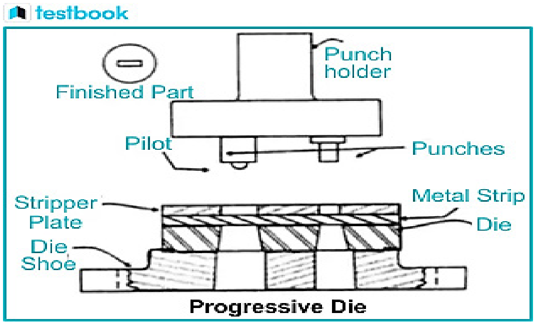
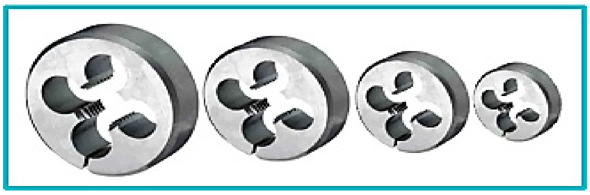


Figure 5.61: *Progressive die*

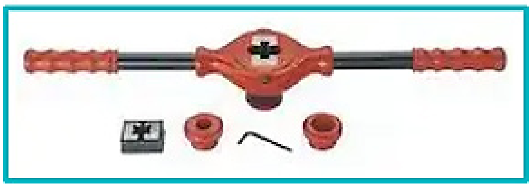
Other types of dies are shown below:

Multiple die

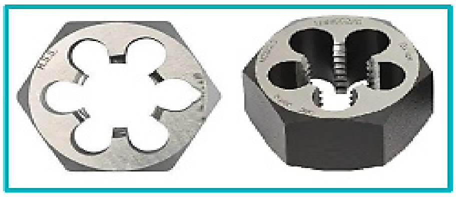


Round Split die

Figure 5.62: *Other dies*



Adjustable Die



Die nut

Figure 5.63: *Other dies*

5. **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.

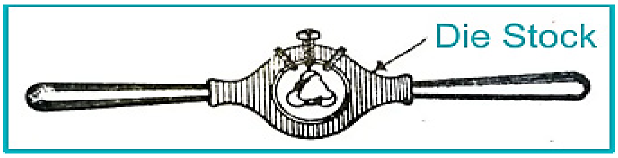


Figure 5.64: *Die stock*

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.

Classification On the Basis of Source of Power

1. **Manual Presses.** These are either hand or foot operated through levers, screws or gears. A common press of this type is the arbor press used for assembly operations.

Figure 5.65: *Manual presses*

2. **Mechanical presses.** These presses utilise flywheel energy which is transferred to the work piece by gears, cranks, eccentrics, or levers.

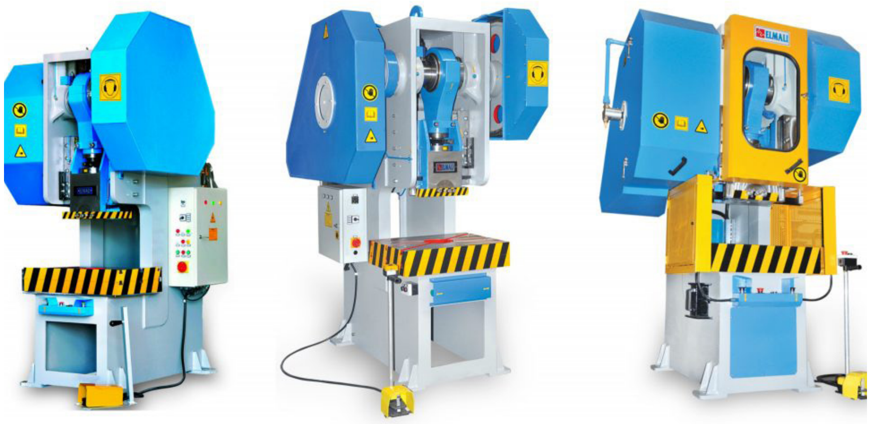


Figure 5.66: *Mechanical presses*

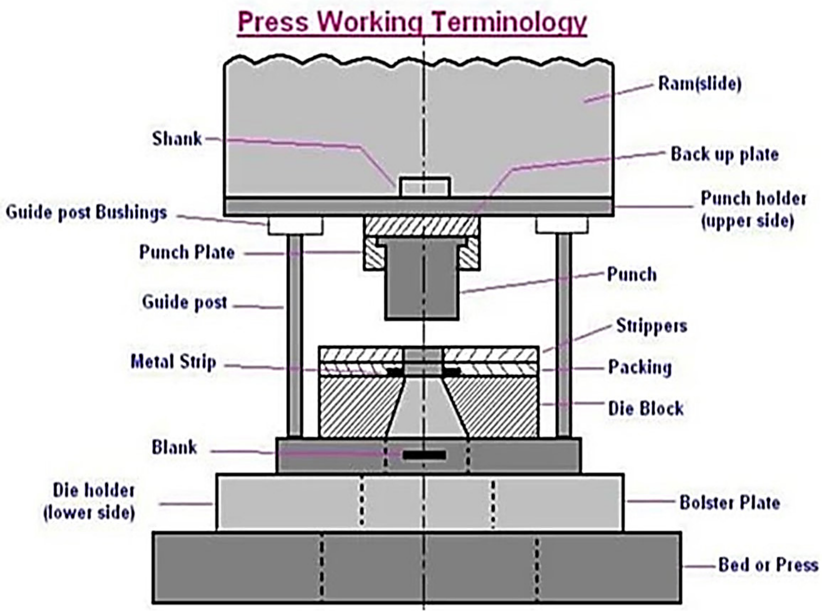


Figure 5.67: *Press working Terminology*

3. **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.

Figure 5.68: *Hydraulic Presses*

4. **Pneumatic Presses.** These presses utilise air cylinders to exert the required force. These are generally smaller in size and capacity than hydraulic or mechanical presses and therefore find use for light duty operations only.

Figure 5.69: *Pneumatic Presses*

Classification on the Basis of Number of Slides

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.

Learning Tasks

1. Explain drawing, die and presses operations in sheet metal fabrication.

2. Describe the various types of drawing, dies and presses in metal forming and sheet metal operations.
3. Demonstrate how to produce artefacts using deep drawing, die and presses operation in sheet metal fabrication.

Pedagogical Exemplar

Project-based Learning: In mixed ability groups, using relevant sketches or real objects, assist learners to explain drawing, die and presses operations in sheet metal fabrication and present individual or group report**.** Guide learners to brainstorm to identify and describe the various types of drawing, dies and presses in metal forming and sheet metal operations and present individual report for discussion.

Assist learners to perform accurate deep drawing operations in sheet metal incorporating appropriate sheet metal specifications and selection using appropriate tools and equipment available.

Assist learners to use the die and presses to cut and form sheet metal to the desired specifications.

Key Assessment

Level 2

1. Explain drawing operation in sheet metal fabrication.
2. Describe the difference between deep and shallow drawing in sheet metal fabrication.

Level 3: How is a simple die used in sheet metal fabrication and compare two advantages and disadvantages between any of the dies?

Level 4: Develop a detailed report on comparing the features of mechanical and hydraulic press machines.

HINT

*The recommended mode of assessment for week 20 is **peer assessment.** Use the level 2 question 1 as a sample question.*

UNIT 20 REVIEW

This unit reviews drawing, die and presses operation in sheet metal fabrication. They are used to produce a wide range of products, from automotive parts to household items. The lesson equips the learners with the types of drawing, dies and presses with their engineering applications. It also describes the various processes in drawing, die and presses operation used in making metal artefacts. Pedagogical exemplars such as group work/collaborative learning and problem-based learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of meal forming processes. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of the use drawing, die and presses operation in sheet metal fabrication.

REFLECTION

1. What was my best moment in today's lesson, and how can I create more of such situations?
2. Were learners able to explain the drawing operation in sheet metal fabrication?
3. Were learners able to explain die and press operation in sheet metal fabrication?
4. Which resources best supported the teaching and learning of drawing, die and presses operations in sheet metal fabrication?
5. Did learners find the resources useful in learning about drawing dies and presses operation in sheet metal fabrication?
6. How were the different subgroups catered for in the class?
7. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

Resources: Metal forming tools, sketches /chart and video/YouTube on sheet metal operations, real object made from the sheet metal operations, an industrial visit to a sheet metal workshop, sheet metal tools.

APPENDIX F: MID-SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

15 Multiple Choice Questions (MCQ) all to be answered within ***20 minutes***. Questions cover DoK levels 1 to 4

RESOURCES: Scannable sheets, A4 sheets, class list, etc.

SAMPLE QUESTIONS

15 Multiple Choice - 20 mins

1. What is the primary function of vehicle's suspension system?
   - **a.** *Absorb road shock*
   - **b.** *Enhance vehicle's aerodynamics*
   - **c.** *Improve fuel efficiency*
   - **d.** *Increase engine power*

MARKING SCHEME

Multiple Choice - *15 questions at 1 mark each.*

1. What is the primary function of a vehicle's suspension system?
   - **a.** ***Absorb road shock***
   - **b**. *Enhance the vehicle's aerodynamics*
   - **c.** *Improve fuel efficiency*
   - **d**. *Increase engine power*

TABLE OF SPECIFICATIONS FOR MID-SEMESTER TWO EXAMINATION

Table 5.1: *Table of Specifications for Mid-Semester Two Examination*

WKS	LEARNING INDICATORS	DoK level 1	DoK level 2	DoK level 3	Dok level 4	TOTAL
13	Explain front and stub axle, types and their functions.	1	2			3
14	Explain basic metal forming processes with engineering products.	1	1	1		3
15	Describe the main components of the steering system and explain steering geometry and the angles involved.	1	1	1		3

16	Demonstrate forging, rolling and extrusion operations in sheet metal.	1	1	1		3
17	Describe the layout of vehicle suspension systems.		2	1		3
	TOTAL	**4**	**7**	**4**		**15**

SECTION 6: VEHICLE SUSPENSION, WHEELS AND METAL FORMING PROCESSES III

The section covers the following unit (strands); Automotive technology and Metal technology.

In this section learners will acquire knowledge and understanding of independent suspension system and its working principles as well as vehicle wheels and tyres. In the metal construction technology unit, learners are expected to gain the knowledge and understanding of the sequence of operation involved in the making of artefacts and various tools and equipment for soft and hard soldering. All the above are treated from ***unit 20 to unit 24.***

UNIT 21

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems.*

HINT

Remind learners of the end-of-semester examination in week 24. Refer to Appendix G at the end of the section for a Table of Specification to guide you to construct the items for the examination.

INTRODUCTION AND UNIT SUMMARY

This lesson explores independent suspension systems, a vital innovation in automotive engineering that significantly improves vehicle handling and comfort. It also explores what makes independent suspension systems unique compared to other types of suspension and how these systems allow each wheel to move independently, enhancing stability and ride quality. The unit covers the types of independent suspension systems, advantages and disadvantages of independent front suspension (IFS) compared to rigid axle suspension, the features of

MacPherson and double wishbone suspension systems as well as the various types of independent rear suspension (IRS). Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the independent front suspension (IFS) and independent rear suspension (IRS) systems. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the types of independent suspension systems and their importance to vehicle's ride, handling and safety.

- ***The unit covers only week 21***: *Describe an independent suspension system and its working principles*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach independent suspension systems, ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant, Teaching the various types of independent suspension systems can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the main features and the various types of independent suspension systems.

ASSESSMENT SUMMARY

Teaching the various forms of independent front suspension (IFS) and independent rear suspension (IRS) systems, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to independent suspension system. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 21

Learning Indicator: *Describe an independent suspension system and its working principles.*

Focal Area 1: Independent Suspension System

A vehicle suspension system is a critical component of automotive engineering designed to support the vehicle's weight, absorb and dampen road shocks, and maintain tyre contact with the road surface. It plays a vital role in ensuring a comfortable ride, stable handling, and overall vehicle safety.

Types of Suspension System

Rigid/Beam Axle Suspension

Beam axle suspension has both right and left wheels attached to the same axle. When one wheel hits a bump in the road, its upward movement causes a slight tilt of the other wheel. This type of suspension system employs leaf spring at both front and rear end of the vehicle or mostly at the rear end of the vehicle. Beam suspension is mostly used on heavy commercial vehicles.

Figure 6.1: *Beam axle suspension*

Advantages of beam axle suspension over independent suspension

1. The construction of the axle is simple and therefore the number of components is few.
2. Maintenance of the axle is simple.
3. The construction of the axle is strong.
4. Wheel change their alignment when the axle moves up and down therefore tyre wear is reduced.

Disadvantages of beam (rigid) axle suspension

1. High unsprung weight which provides reduced comfort
2. Steering geometry is not accurately controlled
3. The movement of one wheel will also influence the movement of the other wheel fitted to the same axle.

Independent suspension

Independent suspension is a term used to describe any arrangement by which the wheels are connected to the carriage unit in a manner such that the rise and fall of one wheel has no effect on the others. There are two main types of independent suspension system. These are:

1. Independent front suspension (IFS)
2. Independent rear suspension (IRS)

Figure 6.2: *Independent suspension*

1. **Independent front suspension system:** This term is used to describe any system connecting the front wheels to the frame or vehicle body in which the movement of one wheel has no direct effect on the other wheel. This is type of suspension system employed coil spring, torsion bar or semi leaf spring at the front end to control the wheels up and down movement of the vehicle.

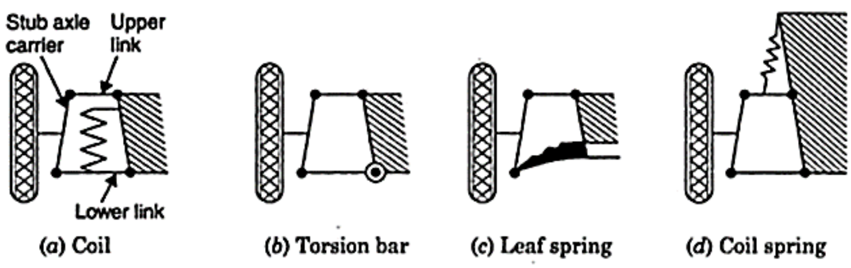


Figure 6.3: *Parallelogram independent front suspension*

Advantages of independent front suspension (IFS)

a. Better road adhesion.
b. Less unsprung weight.
c. Deflection of wheel does not affect steering geometry.
d. More space for the engine.
e. Softer suspension is possible.

Disadvantages of independent front suspension (IFS)

a. Better shock absorber required.
b. Expensive or high initial cost.
c. Tyre wear increases due to transmission of torque.

Types of Independent Front Suspension Systems

a. **Double wishbone type:** This type of IFR is made up of upper and lower arms connected to a stub axle with a coil spring fitted between the arms. This type is also called parallelogram suspension system. The lower arm is always longer than the upper arm and the two arms are not parallel. This arrangement allows the wheels to maintain constant track as it moves up and down. It provides excellent handling, stability, and adjustability. Often used in sports cars and performance vehicles due to its superior control characteristics.

Figure 6.4: *Double wishbone type*

b. **MacPherson strut:** This is a common and simple design where the strut assembly, consisting of a shock absorber and a coil spring, is integrated into the steering knuckle. It is lightweight and takes up less space, making it ideal for compact and mid-size vehicles. It is also compact and cost-effective, offering a good balance of handling and ride comfort. Commonly used in many passenger cars and some SUVs.

Figure 6.4: *MacPherson strut*

c. **Trailing Arm Suspension:** It uses trailing arms that mount to the chassis and connect to the wheel hub. It is less common as a front suspension but can be found in some vehicles. It has a simplified design with good durability and often used in off-road vehicles or vehicles requiring a robust suspension setup.

2. **Independent rear suspension (IRS) system:** An independent rear suspension (IRS) system allows each rear wheel of a vehicle to move independently of the other. This design improves ride quality, handling, and overall vehicle dynamics compared to traditional dependent suspension systems where both wheels on the same axle are connected.

Key Features of Independent Rear Suspension

a. **Individual Wheel Movement:** Each rear wheel is connected to the vehicle's body through its own set of suspension components, allowing it to respond separately to road conditions. This reduces the impact of road irregularities and enhances comfort and control.

b. **Improved Handling:** Independent rear suspension systems maintain better tyre contact with the road during cornering, acceleration, and braking, leading to improved handling and stability.

c. **Reduced Road Noise and Vibration:** By isolating the wheels from each other, IRS systems can reduce the transmission of road noise and vibrations into the cabin.

Common Types of Independent Rear Suspension (IRS) Systems

a. **Multi-Link Suspension**

   i. **Description**: Utilises multiple arms (links) that connect the wheel hub to the vehicle's chassis. The configuration allows precise control of wheel motion and alignment.

   ii. **Advantages**: Offers superior handling and ride comfort and can be finely tuned for performance. It is often found in luxury and high-performance vehicles.

b. **Double Wishbone (Double A-arm) Suspension**

   i. **Description**: Features two parallel arms (upper and lower control arms) that connect the wheel hub to the vehicle's frame. This design allows for greater control over wheel alignment and movement.

   ii. **Advantages**: Provides excellent handling and stability. It's commonly used in sports cars and performance-oriented vehicles.

c. **MacPherson Strut**

   i. **Description**: Combines the shock absorber and spring into a single unit, which is mounted to the vehicle's chassis and connected to the wheel hub via a lower control arm.

   ii. **Advantages**: Compact and cost-effective, often used in vehicles with limited rear space. It offers a good balance of handling and ride comfort.

d. **Toe-Control Link Suspension**

   i. **Description**: Incorporates additional links to control the toe angle of the wheels. This system helps manage wheel alignment changes during driving.

   ii. **Advantages**: Enhances stability and handling by maintaining proper wheel alignment under various driving conditions.

e. **Trailing Arm Suspension**

   i. **Description**: Uses a single rear arm connected to the vehicle's chassis, with the wheel hub mounted at the other end. The arm controls the wheel's movement.

   ii. **Advantages**: Simple design with good durability and ease of maintenance. Often used in off-road vehicles and trucks.

f. **Double Wishbone Multi-Link Combination**

i. **Description**: Combines aspects of both double wishbone and multi-link designs to optimise handling and ride comfort.

ii. **Advantages**: Provides enhanced performance characteristics by integrating the benefits of both suspension types.

Independent Front Suspension (IFS)

Advantages

1. **Improved Handling:** IFS systems enhance vehicle handling by allowing each front wheel to move independently, which improves steering response and stability.
2. **Better Ride Comfort:** By absorbing road impacts more effectively, IFS provides a smoother ride, reducing vibrations and harshness transmitted to the cabin.
3. **Enhanced Vehicle Control:** IFS systems help maintain better tire contact with the road, improving traction and control during cornering and braking.

Disadvantages

1. **Complexity and Cost:** IFS systems are more complex and expensive to manufacture and repair compared to traditional suspension systems.
2. **Limited Space:** The components of IFS, particularly the struts and control arms, can take up more space, potentially limiting engine bay or cargo space.
3. **Potential for Wear:** The additional moving parts in IFS systems can be prone to wear and require more frequent maintenance or alignment adjustments.

Independent Rear Suspension (IRS)

Advantages

1. **Enhanced Ride Quality:** IRS allows each rear wheel to move independently, which reduces the impact of road imperfections and provides a smoother ride.
2. **Improved Handling:** By maintaining better tyre contact with the road, IRS enhances vehicle handling, particularly during cornering and when driving on uneven surfaces.
3. **Reduced Road Noise and Vibration:** IRS helps in isolating road noise and vibrations from the cabin, contributing to a quieter and more comfortable driving experience.

Disadvantages

1. **Increased Complexity and Cost:** IRS systems are more complex and can be more expensive to manufacture and repair than traditional rear suspension systems.
2. **Higher Maintenance:** The added complexity and number of components can lead to higher maintenance and repair costs over the vehicle's lifespan.

3. **Potential for Reduced Load Capacity:** IRS systems may have a lower load-carrying capacity compared to traditional rear suspension systems, which could be a consideration for vehicles that need to carry heavy loads or tow.

Learning Tasks

1. Explain the independent suspension system of a vehicle
2. Describe both independent front and rear suspension systems
3. Describe the various types of independent front and rear suspension systems
4. Examine the advantages and disadvantages of MacPherson and double wishbone suspension system.

Pedagogical Exemplars

1. **Group work/collaborative learning:** In mixed ability groups, using relevant sketches or real objects, assist learners to identify the beam /rigid axle and independent suspension of the vehicle. Assist learners to discuss independent front and rear suspension systems and present individual or group report.

   With the support of the teacher and in mixed ability groups, learners also brainstorm the constructional difference between MacPherson strut and double wishbone suspension system with aid of a sketch and share the results with the group.

2. **Project based learning:** Group learners to discuss the various types of independent front suspension and present group report in class. Also, guide learners to examine the main differences between the front and rear suspension and note the appropriate differences

   Learners visit a school workshop or local repair workshop, observe critically and identify the various types of dependent and independent suspension systems and present report.

Key Assessments

Level 2

1. Explain the difference between rigid axle and independent suspension.
2. State three advantages and disadvantages of independent suspension over rigid axle suspension.

Level 3

1. Describe the features of the MacPherson strut assembly of independent front suspension and how it differs from double wishbone suspension.
2. Compare three advantages and disadvantages of MacPherson strut and double wishbone of independent front suspension.

Level 4

1. 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.
2. Produce a picture which distinguishes between rigid axle and independent suspension.

HINT

*The recommended mode of assessment for week 21 is **poster presentation.** You may use the level 4 question 2 as a sample question.*

UNIT 21 REVIEW

This unit reviews the foundational understanding of the importance of independent suspension on the vehicle. The lesson equips the learners with the types of independent suspension systems, advantages and disadvantages of independent front suspension (IFS) compared to rigid axle suspension, the features of MacPherson and double wishbone suspension systems as well as other arrangements of independent rear suspension (IRS). Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of the independent suspension systems and dependent suspension systems. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of the vehicle suspension systems

REFLECTION

1. What was my best moment in today's lesson, and how can I create more of such situations?
2. Were learners able to identify the two main types of suspension systems?
3. Were learners able to explain the difference between independent front suspension (IFS) compared to rigid axle suspension?
4. Were the learners able to explain the features of the double wishbone and MacPherson strut types of independent front suspension?
5. Which resources best supported the delivery of independent front and rear suspension systems?
6. Did learners find the resources useful in studying the independent suspension system?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 22

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers sequence of operations or design process in making artefacts. The design process or sequence of operation in making artefacts is fundamental in developing solutions to problems, creating new products/artefacts, or improving existing ones used in our daily lives. It involves a series of iterative steps that guide learners from identifying a problem to delivering a final solution. Pedagogical strategies have been suggested for the teacher to employ in the delivery of lessons on the design process / sequence of operation in making artefacts. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the sequence of operations in making artefacts. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the sequence of operations in making artefacts.

- ***The unit covers only week 22:*** *Generate and outline the sequence of operation involved in the making of artefacts*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, the teacher must engage learners in various ways to explain the design process/sequence of operations in making artefacts. Teaching the stages in the design process can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help students gain a thorough understanding in identifying a problem to delivering a final solution.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the design process / sequence of operation in making artefacts, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering sequence of operations in making artefacts. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 22

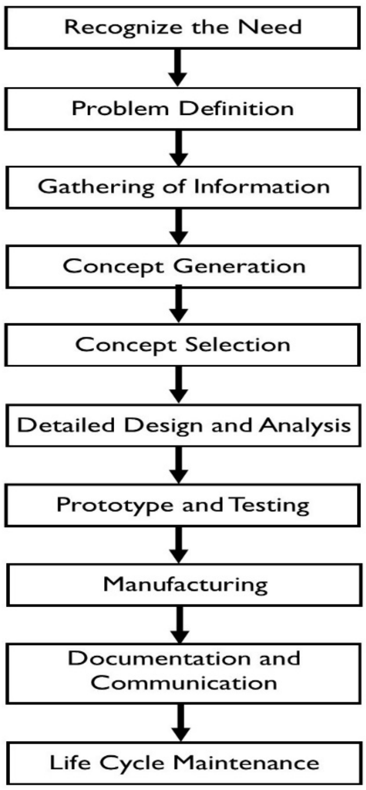
Learning Indicator: *Generate and outline the sequence of operation involved in the making of artefacts.*

Focal Area 1: Sequence Of Operations In Making Artefacts

Engineering design is a systematic and iterative process used to develop solutions to problems, create new products/artefacts, or improve existing ones. This process involves a series of steps that guide engineers from the initial identification of a need or problem to the final implementation of a solution. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing and evaluation. Mechanical design means the design of components and systems of a mechanical nature - machines, products, structures, devices and instruments.

STAGES IN DESIGN PROCESS

The key stages of the basic engineering design process in making artefact are shown below.



1. **Recognise the Need:** Recognising the need is the first and one of the most critical steps in the engineering design process. This stage involves identifying a problem or opportunity that requires a solution or improvement. Understanding and defining the need provides the foundation for all subsequent steps in the design process.
2. **Problem Definition:** This is one of the most critical steps of the design process. There is an iteration between the definition of the problem and the recognition of need. Often

the true problem is not what it first seems. The problem definition is more specific than recognising the need. The problem definition must include all the specifications for the thing that is to be designed. Anything which limits the designer's freedom of choice is a specification.

3. **Gathering of Information:** This stage helps to collect relevant information, study existing solutions and understand the market and technical constraints. Some information sources are:
   a. textbooks
   b. trade journals & magazines
   c. technical reports from government sponsored research and development (R&D)
   d. company catalogues, web pages and technical personnel
   e. handbooks
   f. company reports
   g. patents
   h. people
4. **Concept Generation:** Concept generation is a critical phase in the engineering design process, where ideas are developed to address the design problem. It involves creativity, exploration and systematic methods to ensure a broad range of potential solutions. Some approaches to concept generation are:
   a. **Adaptation:** A solution of a problem in one field is applied to a similar problem in another field (wine press → printing press → pistol grip)
   b. **Area thinking:** Improve an existing product by concentrating on one of its important characteristics (cost, performance, function, appearance, safety, etc.)
   c. **Brainstorming:** Group of people who are familiar with the general nature of the problem; everyone says what comes to 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 stimulate idea generation.
5. **Concept Selection:** Concept selection in the engineering design process is the stage where various ideas or solutions generated during the concept generation phase are evaluated and compared to identify the most promising ones for further development. This process is crucial because it helps narrow down a broad range of potential concepts to those that best meet the project's objectives, requirements, and constraints. A decision matrix is a tool used to evaluate different design ideas; specifically, it's a table used for scoring and comparing multiple prototypes. An example of weighted decision matrix template is shown below. This table is completed by filling out the score for each option based on each criterion, then multiply that score by the weight of the criterion to get the weighted score. Sum these up for each option to get the total weighted score:

Weighted Decision Matrix Template

Table 6.1: *Weighted decision matrix template*

Criteria	Weight	Option 1	Option 2	Option 3
Criterion 1	0.3	Score 1.1	Score 2.1	Score 3.1
Criterion 2	0.5	Score 1.2	Score 2.2	Score 3.2
Total weighted score		Total weighted 1	Total weighted 2	Total weighted 3

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.
7. **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 is a stage of making the product. In industry 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.
8. **Manufacturing:** 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 ensure that the product is produced efficiently, cost-effectively, and with high quality.
9. **Documentation and Communication:** Maintain detailed records of the design process and communicate findings and results to stakeholders.
10. **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.

Worked Example 1

In the school workshop hand tools are scattered on the floor which pose dangers to the workshop users. You are to design a custom metal toolbox focussing on each step in the design process and fabrication skills. The steps below will guide learners through to accomplish the project.

Project: Designing a Custom Metal Toolbox

1. **Define the Problem**
    a. **Problem Statement**: Design and fabricate a durable, portable metal toolbox for carrying hand tools.
    b. **Objectives**: Ensure the toolbox is sturdy, easy to carry, and efficiently organizes tools.
    c. **Constraints**: Must be made from available metal sheets in the workshop, cost less than Gh¢300.00 to produce and fit tools up to 600mm x 250mm x 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**: Create rough sketches of potential designs, showing different compartment arrangements and handle placements.
    c. **Feature List**: 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 organization.
    b. **Decision Matrix**: Use a matrix to compare designs, scoring them on each criterion. For example, a rectangular box might score high on ease of fabrication but lower on weight.
    c. **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**: Create detailed technical drawings with precise measurements and specifications using CAD software.
    b. **Material Selection**: Finalise metal choice, considering cost, workability, and durability. For instance, choose lightweight aluminium for portability.

c. **Design for Manufacturability**: Ensure the design can be easily cut, bent and assembled with available tools like shears, brakes, and welders.

6. **Prototyping**
   a. **Create Prototype**: Use metalworking tools to cut, shape, and assemble a prototype of the toolbox.
   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.

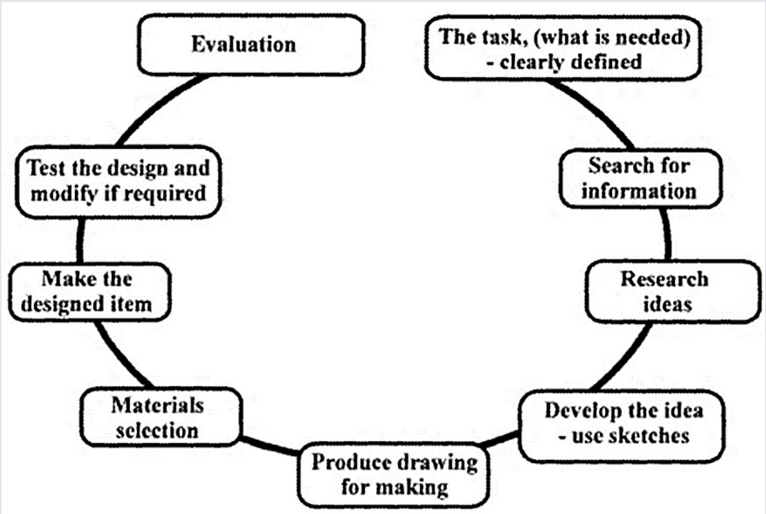
8. **Evaluation and Optimisation**
   a. **Performance Monitoring**: Use the toolbox in real-world scenarios to assess durability, ease of use, and tool organisation.
   b. **User Feedback**: Continue gathering feedback to identify any areas for improvement.
   c. **Optimise**: Make design or process adjustments, such as reinforcing weak points or improving the handle design for better comfort.

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 learnings.

10. **End-of-Life Considerations**
    a. **Recycling Plan**: Design the toolbox for easy disassembly 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.

Worked Example 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.



Solutions

During the ***"materials selection"*** stage of the design process, it is crucial 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 handle 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. **Supply Chain and Availability**: Ensure that the material is readily available and can be sourced in the required quantities within the project timeline. Consider potential supply chain risks that could affect availability.

c. **Manufacturability**: Consider how easily the material can be processed, shaped, and finished using available manufacturing techniques and equipment, as well as any associated costs.

At the ***"evaluation" stage*** of the engineering design process, it is crucial to assess the performance and viability of the design solution. ***The two important points to consider during this stage are:***

1. **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 the design complies with all necessary criteria.

2. **User Feedback and Iteration**
   a. **User Experience Evaluation**: Gather feedback from end-users or stakeholders to assess how well the design meets their needs and expectations. Consider factors like usability, ergonomics, and overall satisfaction.
   b. **Iterative Improvement**: Use the insights gained from testing and feedback to make necessary refinements and optimisations to the design. This iterative process can help address any identified shortcomings and enhance the product's performance and user satisfaction.

Learning Tasks

1. Explain the design process involved in the making of artefacts.
2. Generate a sequence of operation for making a named artefact.
3. Explain how the design process is used in the making of the artefact.

Pedagogical Exemplar

Group work/collaborative learning: Organise learners into mixed ability and gender inclusive groups and task them to explain the design process/sequence of operations in making artefacts and identify a design problem from a given situation.

Learners brainstorm in mixed ability groups to discuss and generate a sequence of operation for making a given artefact and present individual report.

KEY ASSESSMENT

Level 1: What is an engineering design process?

Level 2: Explain five stages of design process in making artefacts/products.

Level 3

1. In a school workshop, there is the need to design and make a watering can. Generate and explain the design process/sequence of operation in making the watering can. Produce three conceptual designs of the watering can and use appropriate criteria to select the final design.
2. A basic wheelchair design is shown.
   a. Using simple sketches and notes, give details of two improvements to this design.
   b. Write field trip report on four materials used in the manufacture of a wheelchair. State a reason for the use of each material.

Figure. 6.5: *Wheelchair*

HINT

*The recommended mode of assessment for week 22 is **field trip report**. You may use the level 3 question 2b as a sample question.*

UNIT 22 REVIEW

This unit reviews the design process or sequence of operation in making artefacts which is a systematic and iterative process used to develop solutions to problems, create new products/artefacts, or improve existing ones. The lesson equips the learners with the knowledge on the various stages of the design process used to develop solutions to problems. How to create new designs or improve existing ones. It also describes the factors to consider in selecting the conceptual designs and materials to be used in producing the artefact. Pedagogical exemplars such as group work/collaborative learning and problem-based learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of the design process. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of the learning the design process / sequence of operation in sheet metal fabrication.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain the design process?
3. Were learners able generate the stages or sequence of operation for making the named artefact?
4. Which resources best supported the teaching and learning design process / sequence of operation in making artefacts?
5. Did learners find the resources useful in learning the design process / sequence of operations in making artefacts?
6. Were the different subgroups in the class catered for?
7. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

Resources: Videos showing the design process, chart showing the stages of the deign process / sequence of operation,

UNIT 23

STRAND: AUTOMOTIVE TECHNOLOGY

Sub-Strand: Introduction to Vehicle Technology

Learning Outcome: *Perform steering and suspension system inspection, maintenance, diagnosis and repairs with limited supervision.*

Content Standard: *Demonstrate knowledge and understanding in vehicle steering and suspension systems.*

INTRODUCTION AND UNIT SUMMARY

This lesson explores the fundamental functions of wheels and tyres, how they contribute to vehicle performance, and the various types and components involved. Understanding these basics will help the learner appreciate the critical role they play in safety, handling and comfort. The unit covers the functions of wheels and tyres, the various types of wheels and tyres, the differences between radial and cross-ply (bias) tyres, the importance of tyre marking which will help learners make informed decisions when selecting or maintaining tyres for different vehicles as well as wheel balancing among others. Teaching these systems involves various pedagogical approaches to ensure effective learning. By combining these pedagogical approaches used in the lesson, learners can acquire a comprehensive and effective learning experience in studying the various wheels and tyres on the vehicle. By incorporating a mix of DOK levels, teachers can tailor their instruction to the different learning needs of the learners and ensure that the learners develop a deep understanding of the various types of wheels and tyres and their importance to vehicle's handling and safety.

- ***The unit covers only week 23***: *Describe vehicle wheels and tyres*

SUMMARY OF PEDAGOGICAL EXEMPLARS

The appropriate pedagogy to teach the various types of wheels and tyres on the vehicle ensures that learners not only learn the theoretical aspects but also develop the basic practical skills and critical thinking abilities necessary for their career progression. It makes the learning process more effective, engaging, and relevant. Teaching various forms of wheels and tyres can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning, group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help learners gain a thorough understanding of the difference between wheels and tyres, tubed and tubeless tyres as well as radial and cross-ply (bias) tyres.

ASSESSMENT SUMMARY

Teaching the wheels and tyres, tubed and tubeless tyres as well as radial and cross-ply (bias) tyres, assessments can span various levels to gauge learners' understanding and application of the concepts and the principle. By employing a mix of DOK at different levels, teachers can effectively measure learners' understanding, application, and critical thinking skills related to wheel assembly. This approach ensures a comprehensive evaluation of their knowledge and proficiency in the subject matter.

WEEK 23

Learning Indicator: *Describe vehicle wheels and tyres.*

Focal Area 1: Wheels and Tyres

Wheels and tyres are essential components of any vehicle. They play a crucial role in the performance, handling, and safety of the vehicle. A wheel must be light, to help to reduce unsprung weight. The lighter the wheel and unsprung weight, the better it will enable the tyre to follow the contour of the road. A wheel must also be strong to resist the many forces acting on it because of normal use. Wheels are typically made from steel, aluminium alloy, or sometimes carbon fibre for high-performance vehicles. They come in various sizes (diameter and width) depending on the vehicle type and intended use.

Basic requirements of wheels

1. They should be balanced both statically as well as dynamically.
2. They should be as light as possible so that the unsprung weight is least.
3. It should be possible to remove or mount the wheel easily.
4. Its material should not weaken with weathering and age. In case, the material is susceptible to corrosion, it must be given suitable protective treatment.
5. The wheel along with the tyre must take the vehicle load, provide a cushioning effect and cope with the steering control.
6. Must be of maximum strength to take the weight, road shocks, driving torque and must be able to compensate all sorts of load varying in magnitude and direction.
7. Must be strong enough to resist local deformation or when it hits a road kerb or any other obstacle.

Types of Wheels

The ***three*** main types of car wheels are:

1. Pressed steel disc wheels,
2. The wire wheels,
3. The light alloy wheels.

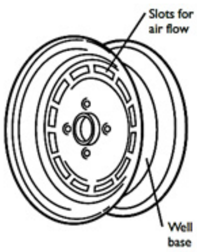


Figure 14.11 Features of a pressed steel wheel

Figure 14.12 Alloy wheel

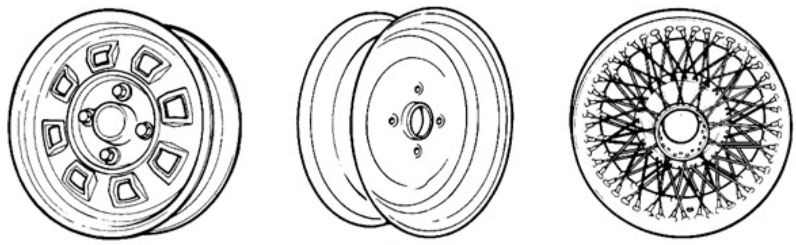


Figure 6.6: *Types of Wheels*

Pressed Steel Disc Wheels

These wheels are most popular and most of the cars are fitted with this type of wheels. They have the following merits/advantages

1. Simple and robust in construction,
2. Easy to produce in large numbers at low cost,
3. Require negligible maintenance,
4. Easy in cleaning.

This type of wheels consists of two parts, a steel rim which is generally well based to receive the tyre and pressed steel disc. The rim and disc may be integral, permanently attached or attachable depending upon design.

Figure 6.7: *Pressed steel dis wheels*

Spoke or Wire Wheels

1. Oldest in design but remained in use largely because of light weight and strong construction but costly.
2. Unlike the disc wheel the wire wheel has a separate hub which attached to the rim through a number of wire spokes.
3. Each spoke is individually hooked at one end of the hub while the other end is pushed through a hole in the rim, where a tapered nut is screwed down pulling the spoke tight.
4. If a spoke is two loose or too tight, the rim would distort.
5. The spokes carry the weight, transmit the driving and braking torques and withstand the side forces while cornering, in tension.

Advantages

1. Light in weight
2. High strength
3. Provides better cooling of brake drum
4. Very easy to change the wheel when required because only one nut has to be removed.

Disadvantages

1. Can not sustain compressive and bending stresses.
2. Expensive due to their intricate construction.
3. Can not be used with tubeless tyre.

Alloy Wheels

These wheels are manufactured as a single-piece rim and disc. Car wheels are generally cast or extruded, but truck wheels are forged. Magnesium and aluminium alloys are most commonly used for reduction in weight.

Figure 6.8: *Alloy wheels*

Types of Wheel Rim

Many people use the word rim interchangeably with wheel. The rim is actually just the outer lip of a wheel. When a wheel is pressed from a single piece of metal, the rim and wheel are closely connected.

1. **Well-base rims:** Well-base rims, also known as drop-centre rims, are a common type of wheel rim design used in most modern vehicles. They are characterised by a distinctive profile that includes a deep centre section or "well" and elevated outer edges. This design makes tyre mounting and removal easier, as it allows the tyre bead to be positioned in the well, creating slack to facilitate tyre manipulation.

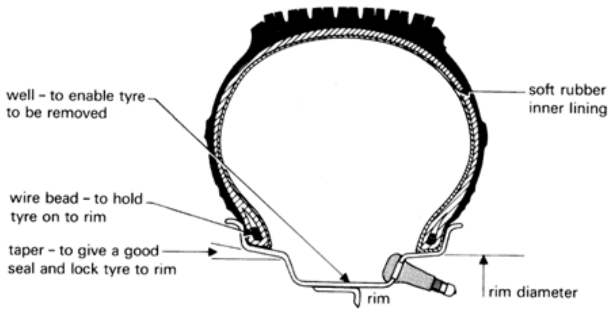


Figure 6.9: *Well-base rims*

2. **Flat-base three-piece rims:** As the name suggests, these rims consist of three separate components: the outer lip (or barrel), the inner barrel, and the centre piece (or face). The components are bolted together, allowing for easy assembly and disassembly. This design enables customisation of each component according to specific requirements.

Figure 6.10: *Flat-base three-piece rims*

3. **Semi-drop centre rims:** Semi-drop centre rims are a type of wheel rim design that combines features of both flat-base and well-base rims. They are commonly used in commercial vehicles, heavy-duty trucks, and buses.
4. **Flat-based divided type:** Flat-based divided type rims, also known as split rims or multi-piece rims, are a type of wheel rim design used primarily in heavy-duty applications, such as trucks, buses, and some industrial vehicles. These rims are characterised by their construction, which allows them to be separated into different parts.

Tyres

Tyres play an important part in the steering, braking, traction, suspension and general control of the vehicle. The tyre consists of mainly the outer cover and the inner tube. The tyre tube assembly is mounted over the wheel rim. It is the air inside the tube that carries the entire load and provides the cushion.

Figure 6.11: *Tyre*

The tyre performs the following functions

1. Supports the vehicle load.
2. Provides cushion against shocks.
3. Transmits driving and braking forces to the road.
4. Provides cornering power for smooth steering.

Types of tyres

1. Conventional tubed tyre
2. Tubeless

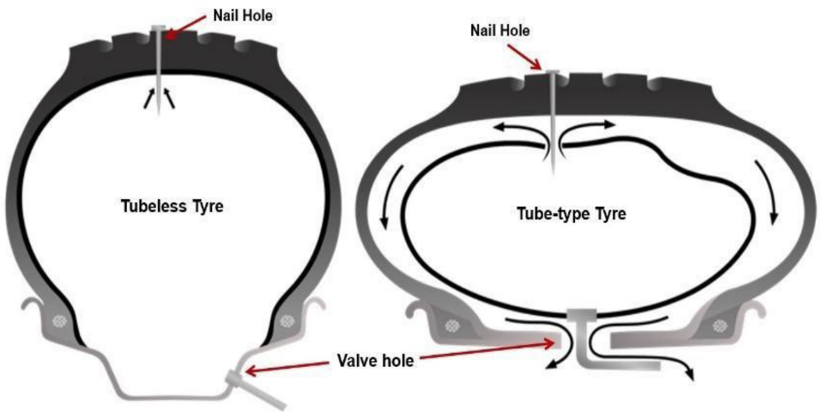


Figure 6.12: *Conventional tubed tyre and tubeless*

1. **The tubed tyre** uses a rubber inner tube, similar to that used on a bicycle. The valve fitted to the inner tube protrudes through a hole in the wheel rim, the valve being used to inflate or deflate the tyre. The disadvantage of the tubed tyre is that, if the inner tube becomes punctured, the tyre deflates very quickly. The tubed tyre is, however, not now commonly used on passenger cars.
2. **Tubeless tyres** are now used on nearly all cars. The inside of the casing and outer surface of the bead is lined with a soft rubber. This rubber forms an air-tight seal with the rim and eliminates the need for a separate inner tube. The air valve is a separate component which fits directly to the wheel rim.

Advantages of tubeless tyres over tube-type tyres

1. **Slow Air Leakage:** In case of a puncture, the air in the tubeless tyre leaks more gradually. In tubed tyre instant air leakage happens due to punctures.
2. **Better safety:** Less chances of accidents due to slower air leakage. It provides the driver, enough time to control the vehicle.
3. **Better Fuel Efficiency:** Lightweight due to the absence of a tube, which results in better fuel efficiency.
4. **Easy Repair:** In case of a puncture or leak, tubeless tyres are much easier to repair than tube-type tyres. In tubeless tyres, the repair is easy as there is no need to dismount the tyre from the wheel in the temporary filler method.
5. **Better fuel efficiency:** The absence of a tube makes tubeless tyres lighter, which results in better fuel efficiency.
6. **Better heat dissipation:** Tubeless tyres are designed to dissipate heat more effectively than tube-type tyres because they are in direct contact with the rim.

Tyre Construction

Two types of tyre construction are in use. These are:

- cross-ply tyres
- radial-ply tyres

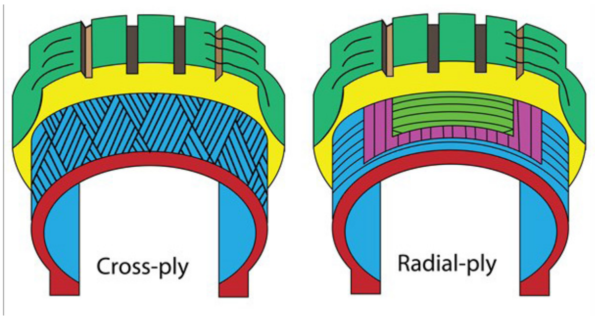


Figure 6.13: *Cross-ply and radial-ply*

1. **Cross-ply tyres:** the fabric plies are arranged diagonally across the tyre, with the cords crisscrossing each other. This pattern typically forms an angle of 30 to 40 degrees with the direction of travel.
   a. **Advantages:** Better ride comfort on rough terrains, durable under harsh conditions, and often cheaper to produce.
   b. **Disadvantages:** Higher rolling resistance, less efficient at high speeds, and shorter tread life compared to radial tyres. In radial ply tyres the cords are arranged in a manner such that they form an angle of 90° to the bead (i.e. the cords are radially disposed to the wheel).
2. **Radial-Ply**
   a. **Advantages:** Superior traction, handling, fuel efficiency, and tread life. Better high-speed performance.
   b. **Disadvantages:** Can be more expensive and may offer less cushioning on very rough surfaces.

Tyre Marking

Tyre markings are the alphanumeric codes and symbols found on the sidewall of a tyre. They provide essential information about the tyre's specifications, capabilities, and manufacturing details. Understanding these markings can help you choose the right tyre for your vehicle and driving needs.

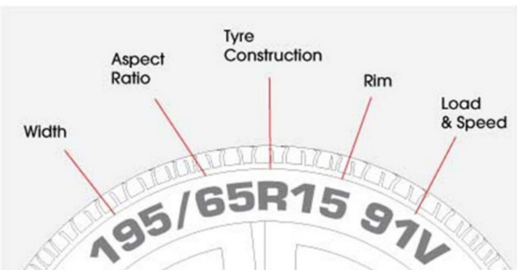


Figure 6.14: *Tyre marking*

1. **Width:** The section width of the tyre in millimetres, from the inner sidewall to the outer sidewall. Example: 195mm.
2. **Aspect Ratio:** The height of the tyre from the base of the tread to the rim, as a percentage of the tread width. Low profile tyres have smaller aspect ratios. Example: The height of this tyre is 65% of its width.
3. **Tyre Construction:** The method used to construct the tyre. Example: R, for radial ply construction. This is the most common method of construction for passenger tyres.
4. **Rim:** The diameter of the wheel rim in inches. If you are buying wheels for existing tyres, this is the size you will need. Example: 15 inches.

Load Index and Speed Symbol

The maximum load capacity under which the tyre can safely operate, and at what speed. This is subject to the tyre being in sound condition, correctly fitted, and with the recommended inflation pressure. ***Example:*** *91 V.*

Tyre Wear

Abnormal or incorrect tyre wear is usually caused by either incorrect steering and suspension geometry or incorrect tyre pressures. Other causes can be brake imbalance, incorrect type of tyre for the vehicle, or incorrect use of the tyre. Tyres that are wearing in the expected manner, but at a more rapid pace than expected may have been subjected to regular hard acceleration and breaking, or the vehicle may have carried excessive loads on a regular basis. Figure below shows the main types of abnormal wear on the tyre and the cause(s) of each.

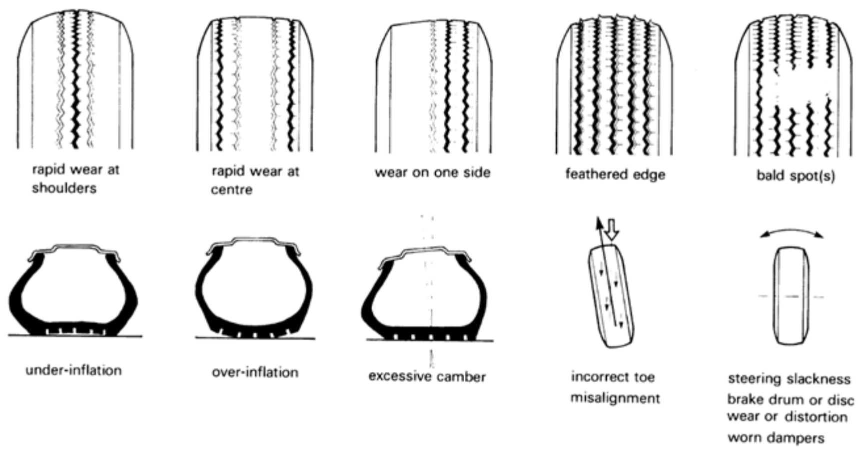


Figure 6.15: *The main types of abnormal wear and the cause(s) of each*

Wheel Balance

The balance of a tyred wheel is essentially required to avoid front wheels wobble which affects steering and increase tyre wear rates The wheel may be checked on or off the car. This is done by either of two methods: static or dynamic.

1. **In static balancing:** the wheel is taken off the car and put on a bubble balancer to detect any imbalance. A wheel that is out of balance is heavier in section. This will cause the

bubble in the centre of the balancer to move off the centre. To balance the wheel, weights are added to the wheel rim until the bubble returns to centre

2. **In dynamic balancing or spin balance:** the wheel is spun either on or off the car. Dynamic balancing requires the wheel to be spun on a balancing machine that measures imbalances on both the inner and outer planes of the wheel. Weights are added to correct any detected imbalances.

Figure 6.16: *Wheel balancing machine*

Learning Tasks

1. Explain the requirements of wheels and tyres
2. Specify various types of wheels and rims
3. Describe the various types of tyres
4. Explain cross ply and radial ply tyre construction and tyre markings

Pedagogical Exemplars

1. **Group work/collaborative learning:** In groups, using relevant sketches or real objects, assist learners to identify the various wheels and tyres on the vehicle. Assist learners to discuss the requirements of wheels and tyres and present individual or group report.

   With the support of the teacher and in mixed ability groups, learners also brainstorm the differences between tubed, tubeless, cross-ply and radial construction with the aid of sketches and share the results with the larger group.

2. **Project based learning:** Group learners to discuss the various types of wheels and tyres and present group report in class. Also, guide learners to examine the main differences between the cross ply and radial ply tyres and note the appropriate differences.

   Learners visit a school workshop or local repair workshop observe critically and identify the various types of tyre markings, interpreted them and present report.

Key Assessments

Level 2

1. What are the functions of wheels in an automobile and state three requirements?
2. Explain briefly pressed steel disc wheels.

Level 3

1. Compare the features of a wire and light alloy casting wheels.
2. Explain briefly the following types of tyre and why tubeless type is better
   a. Tubed
   b. Tubeless
3. Compare ***three*** advantages and disadvantages of radial ply tyres over cross ply (bias) tyres.

Level 4: Given a vehicle equipped with tyres that do not meet the recommended load index and speed rating as specified by the manufacturer, analyse the potential effects on vehicle performance, safety, and tyre longevity.

UNIT 23 REVIEW

This unit reviews the foundational understanding of the importance and functions of wheels and tyre assembly. The lesson equips the learners with the knowledge of the functions of wheels and tyres, the various types of wheels and tyres, the differences between radial and cross-ply (bias) tyres. The interpretation of the markings on the tyres and static and dynamic wheel balancing. Pedagogical exemplars such as group work/collaborative learning, problem-based learning and experiential learning are used to accommodate different learning styles and help learners recognise and appreciate the importance of the wheels and tyre assembly. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of vehicle wheels and tyres.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to identify the main parts of wheels and tyre assembly
3. Were learners able to explain the functions of the wheels and tyres
4. Were learners able to describe the various types and features of vehicle wheels
5. Were the learners able to explain the difference between tubed and tubeless, radial ply and cross ply tyres?
6. Which resources best supported the delivery of the various types of wheels and tyres

7. Did learners find the resources useful in studying the wheel assembly?
8. Were the different subgroups in the class catered for?
9. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

UNIT 24

STRAND: METAL TECHNOLOGY

Sub-Strand: Welding Technology

Learning Outcome: *Apply knowledge of key processes and tools in welding technology and fabrication to carry-out tasks on sheet metal projects.*

Content Standard: *Demonstrate knowledge and understanding of key processes, tools and equipment for welding.*

INTRODUCTION AND UNIT SUMMARY

This unit covers soldering process which creates strong and reliable joints between components and introduces the basic tools used in soldering, such as soldering iron, solder wire, soldering flux, and wire cutters. These tools and equipment for soldering are fundamental to modern manufacturing, contributing to the production of high-quality components for use as well as understanding the difference between soft and hard soldering is crucial for selecting the appropriate soldering method for different applications. Pedagogical strategies have been suggested for the teacher to employ in the delivery of lessons on the various tools and equipment for soft and hard soldering and their uses. By using these pedagogical approaches, learners will acquire a comprehensive and effective learning experience in studying the various tools and equipment for soft and hard soldering and their uses. By incorporating a mix of DoK levels, teachers should accommodate the different learning needs of learners and ensure that learners develop a deep understanding of the various tools and equipment for soft and hard soldering and their uses.

- ***The unit covers only week 24:*** *Explain and use the various tools and equipment for soft and hard soldering*

SUMMARY OF PEDAGOGICAL EXEMPLARS

For this unit to be accomplished, the teacher must engage learners in various ways to explain the various tools and equipment for soft and hard soldering and their uses. Teaching soft and hard soldering can be enriched with various pedagogical exemplars and activities to ensure comprehensive understanding. For learners to appreciate this lesson, the teacher should employ a variety of pedagogical strategies such as problem-based learning; group work/collaborative learning, scaffold learning, experiential learning and project-based learning. These pedagogical exemplars combine practical, visual, interactive, and theoretical approaches to accommodate the different learning styles and help students gain a thorough understanding of the soldering processes.

ASSESSMENT SUMMARY

To demonstrate conceptual understanding of the various tools and equipment for soft and hard soldering and their uses, learners must show how they can apply the concepts in real life situations to develop a project. As a result, level 1, 2, 3 and 4 of the DoK should be substantially covered in the assessments. To gather data regarding learners' progress and provide timely feedback, teachers should utilise a range of formative assessment tools, including pairs of tasks, reports, oral and written presentations, and home assignments. Teachers should administer tests such as class exercises (including individual worksheets) after each lesson, homework, scores on practical group activities covering various tools and equipment for soft and hard soldering and their uses. This ensures learners grasp the broader context and relevance of technology across different domains. The teacher can refer to the Teacher Assessment Manual Toolkit (TAMTK) (NaCCA 2023) on how to use the assessment strategies effectively.

WEEK 24

Learning Indicator: *Explain and use the various tools and equipment for soft and hard soldering.*

Focal Area 1: Tools And Equipment For Soft Soldering

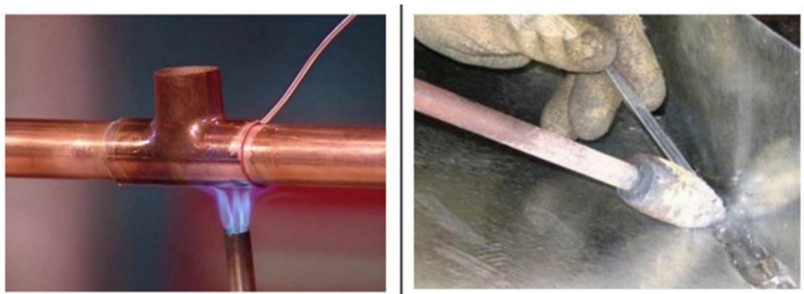
Soldering is a process that joins two or more types of metals through melting solder. Soldering uses a filler rod or metal with a low melting point, also known as solder, to join metal surfaces. In soldering the key elements are iron, solder, flux and components. The solder is usually made up of an alloy consisting of tin and lead whose melting point is 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.

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.

Commercially produced fluxes and their uses are shown below.

Table 6.2: Fluxes

Flux	Application
Resin (powdered)	For electrical work
Zinc chloride	Used on tinplate, brass and copper
Sal ammoniac (powered)	Used for copper and iron
Tallow	Used by plumbers in soldering lead
Hydrochloric acid	For soldering zinc and galvanised iron



Soldering copper pipe | Sheet metal fabrication

Figure 6.17: *Soldering process*

Figure 6.18: *The soldering process*

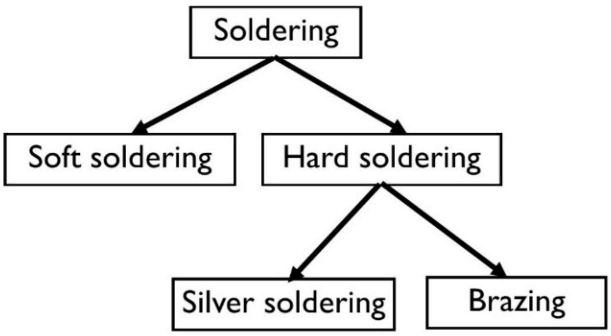
WELDING, SOLDERING AND BRAZING

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 soldering or in brazing process, the temperatures used are not high enough to cause melting of 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 brazing process, temperatures above 427°C are employed.

Soldering works well with the following base metals: ***Gold, Silver, Iron, Brass, Copper, Aluminium, Steel, Titanium.***

Types of Soldering

There are mainly two types of soldering.



Soft Soldering

1. Soft soldering is performed at relatively low temperatures, usually below 400°C (752°F).
2. It uses soft solders, typically alloys of tin and lead (though lead-free solders are now common due to health and environmental concerns).
3. This method is commonly used in electronics, plumbing, and other applications where the joint does not need to withstand high temperatures or heavy loads.
4. Soft soldering is easy to perform and requires less equipment and skill. It is suitable for delicate work, such as circuit board assembly.

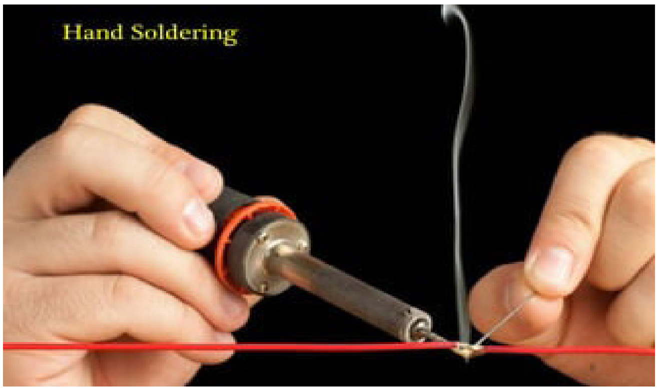


Figure 6.19: *Soldering a wire*

Hard Soldering

Hard soldering includes techniques like silver soldering and brazing, and it requires higher temperatures compared to soft soldering.

1. Hard soldering is carried out at temperatures above 450°C (842°F).
2. It uses stronger alloys, often based on silver, copper, or brass, which have higher melting points.
3. 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.
4. 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.

Figure 6.20: *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 types of solder based on its composition and intended application. The main types of solder include:

	
Different guages of solder wire	Solder composition is labelled (Lead free on left)

Figure 6.21: *Different types of solder*

1. **Lead-based Solder**
   a. Typically, an alloy of tin (Sn) and lead (Pb), such as a 60/40 ratio (60% tin, 40% lead).
   b. Melting point around 183-190°C (361-374°F).
   c. 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**
   a. Alloys like tin-copper (Sn-Cu), tin-silver-copper (SAC), and tin-silver (Sn-Ag).
   b. Higher meeting point than lead-based solders, typically around 217-230°C (423-446°F).
   c. Used in consumer electronics and other applications due to regulations like the RoHS directive that restrict the use of lead.

3. **Silver Solder**
   a. Alloys containing silver, often combined with copper and zinc.
   b. Higher melting point than both lead and lead-free solders, typically above 450°C (842°F).
   c. 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.
   a. **Rosin Flux:** Used mainly in electronics.
   b. **Water-soluble Flux:** Easier to clean after soldering.
   c. **No-clean Flux:** Leaves minimal residue, eliminating the need for cleaning

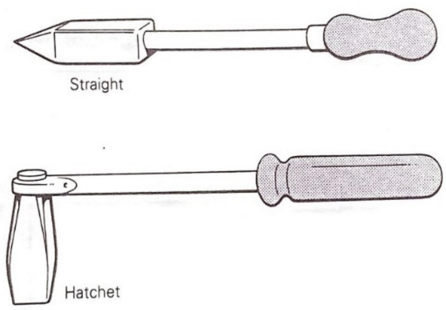
Soldering Tools

1. **Soldering irons:** 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

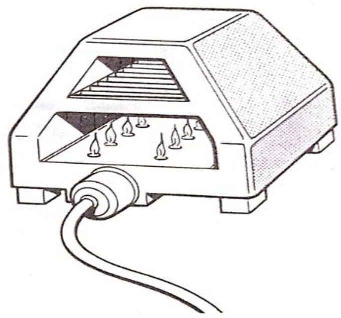
important tools used in soldering and it can come in a few variations such as pen or gun form.

Figure 6.22: *Standard Electric Soldering Iron*

2. **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

Figure 6.23: *Soldering irons*

3. **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.

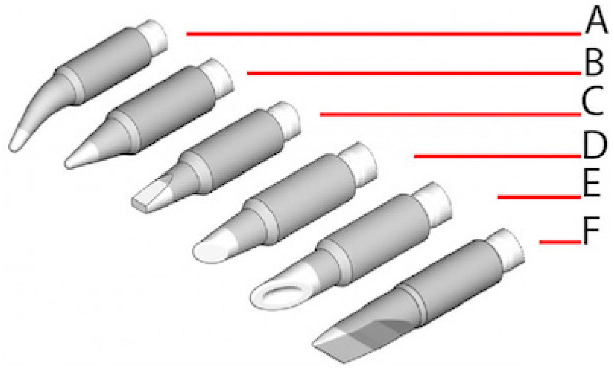


Figure 6.24: *Soldering irons tips*

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 in 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.

Figure 6.25: *Soldering Iron Stand*

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.

Figure 6.26: *Brass or Conventional Sponge*

6. **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.
7. **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.

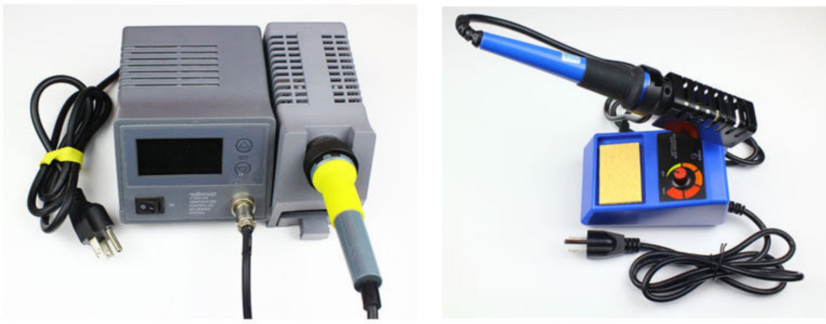


Figure 6.27: Soldering tools

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.

Figure 6.28: Solder wire cutters

Advantages and Disadvantages of Soldering

Table 6.3: Advantages and Disadvantages of Soldering

S/N	Advantages of Soldering	Disadvantages of Soldering
1.	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.

Learning Tasks

1. Explain soldering and the various types of solder.
2. Describe soft and hard soldering processes.
3. Describe tools and equipment used in soldering to produce artefacts.

Pedagogical Exemplar

Group work/collaborative learning: Organise learners into mixed ability groups, and task them to explain soldering and the various types of solder and present group or individual report for class discussion**.** With the support from the teacher learners describe the soft and hard soldering processes and note and share the differences between them.

In mixed ability groups, using relevant sketches or real objects, assist learners to identify and describe tools and equipment used in soldering and learners share their description with the group

Learners embark on educational visit and observe with safety guidelines the soft and hard soldering processes and present report in group to the class.

Key Assessment

Level 1: What is soldering and solder?

Level 2

1. Explain three differences between soft and hard soldering.
2. Describe any two tools used in soft and hard soldering.

Level 3

1. Compare three advantages and disadvantages of soldering.
2. How does the choice of solder influence the quality and durability of the solder joint?

Level 4: 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.

HINT

The recommended mode of assessment for week 24 is ***end-of-semester examination****. Refer to Appendix G at the end of the section for a Table of Specification to guide you to construct the items for the examination.*

UNIT 24 REVIEW

This unit reviews soldering process and the various tools and equipment for soft and hard soldering. The lesson equips the learners with the knowledge on the differences between the soft and hard soldering. Pedagogical exemplars such as group work/ collaborative learning and problem-based learning are used to accommodate different learning styles and help learners acquire knowledge on the various tools and equipment for soft and hard soldering. Assessment levels 1, 2, 3 and 4 are used to effectively measure and foster learners' depth of understanding, critical thinking skills and ability to apply theoretical knowledge to practical scenarios within the context of soft and hard soldering processes.

REFLECTION

1. What was my best moment in today's lesson and how can I create more of such situations?
2. Were learners able to explain soldering and various types of solder in joining of metals
3. Were learners able to explain the difference between soft and hard soldering
4. Were learners able to describe the various tools and equipment used in the soldering
5. Which resources best supported the teaching and learning of soft and hard soldering?
6. Did learners find the resources useful in learning the various tools and equipment for soft and hard soldering?
7. Were the different subgroups in the class catered for?
8. Overall, how did the lesson go and what improvement(s) can be made to make it a better learning experience?

Resources: Soft and hard soldering equipment, articles made from soft and hard soldering, videos on soft and hard soldering.

APPENDIX G: END OF SEMESTER EXAMINATION

STRUCTURE OF EXAMINATION

- ***30 Multiple Choice Questions (MCQ)*** all should be answered within 45 minutes. Questions cover DoK level 1 to 3
- ***10 essay type questions, 7 to be answered within 2 hours.*** Questions cover DoK level 1 to 3

RESOURCES: Scannable sheets, A4 paper, answer booklets, class list, etc.

SAMPLE QUESTIONS

Multiple Choice

SECTION A

1. *How should a company respond to a safety incident to prevent future occurrences?*

- **a.** *Blame the employee involved and issue a warning.*
- **b.** *Ignore the incident if no one was seriously injured.*
- **c.** *Increase the workload to make up for lost time.*
- **d.** *Investigate and implement corrective actions.*

SECTION B: ESSAY

a. Explain how the vehicle suspension system works, etc.

MARKING SCHEME

Multiple Choice

SECTION A

D. ***Investigate and implement corrective actions.***

SECTION B

Essay

Expected response

When a vehicle drives over a bump, the wheel moves up compressing the spring. The spring absorbs the energy from the bump, shocks absorbers aid the spring from continuous bouncing.

Key phrases like drive over a bump, compressing the spring, shock absorbers, continuous bouncing, etc ***5 marks.***

TABLE OF SPECIFICATION FOR SECOND SEMESTER EXAMINATION

Table 6.4: Table of Specification for Second Semester Examination

WKS	LEARNING INDICATOR	Type of Que.	DoK level 1	DoK level 2	DoK level 3	DoK level 4	TOTAL
13	Explain front and stub axle, types and their functions.	MCQ	1	1	1		3
		Essay			1		1
14	Explain basic metal forming processes with engineering products.	MCQ	1	1	1		3
		Essay		1			1
15	Describe the main components of the steering system and explain steering geometry and the angles involved.	MCQ	1	1	1		3
		Essay	1				1
16	Demonstrate forging, rolling and extrusion operations in sheet metal.		1	1	1		3
17	Describe the layout of vehicle suspension systems.	MCQ	1	1	1		3
		Essay	1				1
18	Perform basic cutting and bending operations in sheet metal fabrication.	MCQ	1	1	1		3
		Essay		1			1
19	Explain leaf, coil and air suspension systems.	MCQ	1	1	–		2
		Essay			1		1
20	Perform drawing, die and presses operation in sheet metal fabrication.		–	1	1		2
21	Describe an independent suspension system and its working principles.	MCQ	–	1	1		2
		Essay	1				1
22	Generate and outline the sequence of operations involved in the making of artefacts.	MCQ	1	1	–		2
		Essay			1		1
23	Describe vehicle wheels and tyres.	MCQ	1	1	–		2
		Essay		1			1
24	Explain and use the various tools and equipment for soft and hard soldering.	MCQ	–	1	1		2
		Essay			1		1
	TOTAL		12	15	13		40

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12. Willacy, M. D. (1989). *Craft & Design in Metalwork*: London, Hutchinson.

Online Images

No.	Name of Image	Reference (link)
1	Parts of drill machine	*https://i.ebayimg.com/images/g/tkgAAOSwdAtku~mn/s-l1600.webp*
2	Portable Drilling Machine	*https://tiimg.tistatic.com/fp/1/008/270/light-weight-and-portable-electric-drill-machine-770.jpg*
3	Sensitive drilling machine	*https://shikshartin.wordpress.com/wp-content/uploads/2018/09/sensitive-drill.jpg*
4	Radial Drilling Machine	*https://www.usitools.com/7118-medium_default/radial-drilling-machine--big-capacity-dr80.jpg*
5	Horizontal or knee milling machine	*https://www.researchgate.net/figure/Two-basic-milling-operations-a-up-milling-and-b-down-milling_fig10_286842300*
6	Parrel turning	*http://www.homews.co.uk/page318.html*
7	Taper turning	*https://www.xometry.com/resources/machining/step-turning/*
8	Step turning	*https://www.shutterstock.com/search/turning-operation*
9	Diamond knurling	*https://waykenrm.com/blogs/what-is-knurling/*
10	Straight knurling	*https://www.youtube.com/watch?v=RIVRNlcVLZY*
11	Facing	*https://winndeavor.com/the-facing-operation-in-machining-explained/*
12	Chamfering	*https://www.kitplanes.com/chamfers-and-tapers/*
13	Thread cutting	*https://msvsdei.vlabs.ac.in/mem103/Unit5lesson4.html#:~:text=Chamfering%20is%20the%20operation%20of,chamfer%20angle%2C%20usually%2045o.*
14	Grooving	*https://at-machining.com/grooving-machining/*
15	Parting-off	*https://www.sandvik.coromant.com/en-us/knowledge/parting-and-grooving/parting-off*
16	Drilling on the lathe machine	*https://www.dreamstime.com/stock-photo-drilling-lathe-machine-turning-mold-part-turning-image48900998*
17	Drilling using the drilling machine	*https://www.xometry.com/resources/machining/drilling-machines/*
18	Reaming	*https://engineering.myindialist.com/2009/drilling-operations-reaming/*
19	Boring	*https://proleantech.com/cnc-programming-for-boring-operations/*
20	Grinding	*https://www.mmsonline.com/articles/machining-101-what-is-grinding*
21	Milling	*https://www.zintilon.com/blog/horizontal-vs-vertical-milling/*
22	Component to be produced	*https://msvsdei.vlabs.ac.in/mem103/Unit5lesson4.html#:~:text=Chamfering%20is%20the%20operation%20of,chamfer%20angle%2C%20usually%2045o*

23	SAE rating	*https://www.amazon.com/Formula-Shell-550049239-Clean-Engine/dp/B07S64WJDG*
24	API service rating	*https://www.pngwing.com/en/free-png-kxlqx#google_vignette*
25	Crankcase ventilation	*https://kamsiparts.medium.com/crankcase-ventilation-system-and-how-it-works-a5370fbeeb10*
26	Sand casting mould	*https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.iitg.ac.in%2Fengfac%2Fganu%2Fpublic_html%2FMetal%2520casting%2520processes_1.pdf&psig=AOvVaw2vEOyv6UkxBoq5CcAerC9a&ust=1721228102912000&source=images&cd=vfe&opi=89978449&ved=0CA8QjRxqFwoTCPi7-8Poq4cDFQAAAAAdAAAAABAE*
27	Hard riddle	*https://www.shutterstock.com/image-photo/stainless-steel-mesh-sieve-laboratory-soil-1186425790*
28	Shovel	*https://www.amazon.com/Shovel-Digging-Shovel%EF%BC%8CCamp-%EF%BC%8CGarden-Gardening/dp/B097GK2NP7*
29	Rammers	*https://yanthrist.com/top-18-foundry-tools-equipment/*
30	Sprue pin	*http://smelko.com/?page_id=480*
31	Strike off bar	*https://www.expertsmind.com/topic/hand-tools/strike-off-bar-and-vent-wire-918660.aspx*
32	Mallet	*https://foundryworkshop.blogspot.com/2012/12/the-hand-moulding-tools-used-in-foundry_2057.html*
33	Draw spike/draw screw	*https://www.jhotpotinfo.com/2022/06/study-of-foundry-shop-patterns-molding.html*
34	Vent rod	*https://www.expertsmind.com/topic/hand-tools/strike-off-bar-and-vent-wire-918660.aspx*
35	Lifters	*https://www.worthpoint.com/worthopedia/antique-foundry-tool-sand-casting-2071497927*
36	Trowels	*http://smelko.com/?page_id=477*
37	Slicks	*https://trowelcollector.blogspot.com/2014/04/brass-foundry-moulding-tools.html*
38	Smothers	*https://www.slideshare.net/slideshow/casting-tool/240316948*
39	Swab	*1. https://foundryworkshop.blogspot.com/2012/12/the-hand-moulding-tools-used-in-foundry_2057.html* *2. https://www.jhotpotinfo.com/2022/06/study-of-foundry-shop-patterns-molding.html*
40	Spirit level	*https://www.amazon.com/Sands-Level-Tool-SL2828-Professional/dp/B0002YQW92*
41	Gate cutter	*https://www.slideshare.net/slideshow/casting-tool/240316948*
42	Bellows	*https://www.artisanfoundry.co.uk/product_info.php?products_id=64*
43	Clamps, cotters and wedges	*https://hebeileicheng.en.made-in-china.com/product/UmsrMhgVVGpf/China-Adjustable-Ut-Cable-Wedge-Clamp-Strain-Clamp-for-Power-Line-Accessories.html*
44	Split	*https://en.wikipedia.org/wiki/Sand_casting*

45	Ground clearance	https://en.wikipedia.org/wiki/Wheelbase
46	Hot rolling	https://www.doitpoms.ac.uk/tlplib/metal-forming-2/rolling.php
47	Hot forging	https://depositphotos.com/photos/hot-forging.html?qview=60631633
48	Power assisted steering	1. https://www.carparts.com/blog/how-does-power-steering-work-with-example-diagrams/ 2.https://www.carparts.com/blog/how-does-power-steering-work-with-example-diagrams/
49	Steering linkage	https://en.wikipedia.org/wiki/Steering_column
50	Rack and pinion steering gearbox	https://www.slideshare.net/slideshow/steering-34116460/34116460
51	Recirculating steering gearbox	https://www.slideshare.net/slideshow/steering-34116460/34116460
52	Ackerman Principle	https://en.wikipedia.org/wiki/Ackermann_steering_geometry
53	Drop forging	https://en.wikipedia.org/wiki/Forging
54	Figure. 4.39	https://leadrp.net/blog/a-complete-guide-to-aluminum-extrusion/
55	Direct extrusion	https://engineeringlearn.com/types-of-extrusion-process-working-advantages-disadvantages/
56	Indirect extrusion	https://engineeringlearn.com/types-of-extrusion-process-working-advantages-disadvantages/
57	Springs	https://m.indiamart.com/nalin-rubber-private-limited/railway-products.html
58	Springs	https://www.etrailer.com/question-510909.html
59	Dampers	https://www.researchgate.net/figure/Twin-Tube-Shock-Absorber-8_fig3_343290661
60	Stabilizer	https://i.pinimg.com/736x/f4/96/9e/f4969e72c0628ae0f6a31221425122af.jpg
61	Rigid Axle	https://spnsta.spinny.com/blog/20220228143404/ezgif.com-gif-maker-2021-1201T143915.461.jpg?dpr=1.0&q=70&compress=true&quality=80&w=800
62	Independent Suspension	https://shmuker.oss-cn-hangzhou.aliyuncs.com/data/oss/0/623ac220a13aae6c973c7518/20220822/5d71953eb6d2c43bef62277dddcdbbdc.jpg
63		https://media.proprofs.com/images/QM/user_images/2503852/New%20Project%20(55)(160).jpg
64	Punches and dies	https://msvs-dei.vlabs.ac.in/mem103/images/mem/Unit2/Lesson6n/2.jpg
65	Sheet metal shearing machine	https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcSiwpXLH4pi-meUdeAitKhrcFZwofl6AjhiwcWZHlVYHF9bzMCIC
66	Blanking: Sheet metal cutting operation	https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcTDEJ5zs5JAuRfe_RnRPQo8xh706_xyMpgTlw&s
67	Sheet metal cutting using punching operation	https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcT_NuvC8CnbPY-Gu8NTPTXfmn6bYFnl7ctiISQ&s
68	Bending	https://www.china-machining.com/blog/sheet-metal-bending/

69	V-bending after the punch force	*https://www.china-machining.com/blog/sheet-metal-bending/*
70	Air bending	*https://www.china-machining.com/blog/sheet-metal-bending/*
71	Bottom bending	*https://www.china-machining.com/blog/sheet-metal-bending/*
72	Roll bending	*https://www.china-machining.com/blog/sheet-metal-bending/*
73	Wipe bending	*https://www.china-machining.com/blog/sheet-metal-bending/*
74	Rotary bending	*https://www.china-machining.com/blog/sheet-metalbending/*
75	Flanging	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
76	Open hemming	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
77	Seaming	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
78	Curling	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
79	Beading	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
80	Coining	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
81	Embossing process	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
82	Drawing	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
83	Wire drawing process	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
84	Duct to be manufactured	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
85	Different stages in producing ductwork	*https://msvs-dei.vlabs.ac.in/mem103/Unit2lesson6.html*
86	Springs	*1. https://m.indiamart.com/nalin-rubber-private-limited/railway-products.html* *2. https://www.etrailer.com/question-510909.html*
87	Laminated or leaf spring	*https://www.tradeindia.com/products/mahindra-vehicle-leaf-springs-642754.html*
88	Coil spring	*https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcTNez_pdvSdn10E_ZjaNyZ7OtqfRsR9fOur2nf4kalFRyOeaSwS*
89	Air spring system	*https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcQugDfmBO4b-jE7rGvyvVkNAzsbNfqvmGiU8W61HYHayfuKHqqvh*
90	Torsion bar	*https://encrypted-tbn3.gstatic.com/images?q=tbn:ANd9GcRjnIh4Y-KVmx5lpYBdITGvnddoOBOvbCSJ5ewgT8fWVe6BIly0R*
91	Deep drawing	**1.** *https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQIT2uY9HZ0UJAKU-TpkDRschGgG9FTuk53ww&s* **2.** *https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQIT2uY9HZ0UJAKU-TpkDRschGgG9FTuk53ww&s*
92	Some products of deep drawing	*https://image.slidesharecdn.com/deepdrawing-160725105005/75/Deep-drawing-11-2048.jpg*
93	Sheet metal deep drawing process	*https://www.precintl.com/wp-content/uploads/2021/05/Sheet-Metal-Deep-Drawing-picture-1024x343.jpg*

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95	Rod drawing	*https://blogmedia.testbook.com/blog/wp-content/uploads/2023/08/rod-drawing-78178fa1.png*
96	Tube drawing	*https://blogmedia.testbook.com/blog/wp-content/uploads/2023/08/tube-drawing-f7cc3688.png*
97	Simple die	*https://testbook.com/mechanical-engineering/types-of-dies*
98	Compound die	*https://testbook.com/mechanical-engineering/types-of-dies*
99	Combination dies	*https://testbook.com/mechanical-engineering/types-of-dies*
100	Progressive die	*https://testbook.com/mechanical-engineering/types-of-dies*
101	Other dies	*1. https://testbook.com/mechanical-engineering/types-of-dies* *2. https://testbook.com/mechanical-engineering/types-of-dies*
102	Die stock	*https://testbook.com/mechanical-engineering/types-of-dies*
103	Manual presses	*https://www.indiamart.com/proddetail/hand-press-machine-18355776733.html*
104	Mechanical presses	*http://www.atromak.com/mechanical-presses/*
105	Hydraulic Presses	*https://tackly.com/product/nichi-t-61230a-hydraulic-press-30-ton-air-manual/*
106	Pneumatic Presses	*https://www.indiamart.com/proddetail/pneumatic-press-24578850533.html*
107	Beam axle suspension	*https://stories.hemmings.com/wp-content/uploads/2024/03/origin-16731.jpg*
108	Independent suspension	*https://encrypted-tbn1.gstatic.com/images?q=tbn:ANd9GcTVp0tanE0CIcW-BjdaBvnGp3fVNBtPZWOPOR6YqeZ2fpks1OXK2*
109	Double wishbone type	*https://encrypted-tbn3.gstatic.com/images?q=tbn:ANd9GcT0cwZ48mbHKhb-WzFTlXhx5EjvoeSj2oV3uqkcE1ZHcA9_RT-By*
110	MacPherson strut	*https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcTkDQUKIRPN-86L5Kf2Fgn0xY7DDIMjzDPGlh8Q7GYp3y84wNLs_*
111	wheelchair	*https://www.creativefabrica.com/product/medical-tool-wheel-chair-realistic/*
112	Soldering process	*1. https://www.uts.edu.au/sites/default/files/Soldering_0.pdf* *2. https://tameson.com/pages/soldering-iron-tips*
113	Soldering a wire	*https://www.shutterstock.com/image-photo/technician-soldering-two-wires-together-on-91195211*
114	Hard soldering of pipes	*https://www.slideshare.net/slideshow/types-of-soldering/94365117#12*
115	Different types of solder	*https://www.uts.edu.au/sites/default/files/Soldering_0.pdf*
116	Standard Electric Soldering Iron	*https://www.makerspaces.com/how-to-solder/*
117	Soldering irons tips	*https://tameson.com/pages/soldering-iron-tips*
118	Soldering Iron Stand	*https://www.makerspaces.com/how-to-solder/*

119	Brass or Conventional Sponge	*https://www.makerspaces.com/how-to-solder/*
120	Soldering tools	*https://www.makerspaces.com/how-to-solder/*
121	Solder wire cutters	*https://beaducation.com/products/solder-cutting-plier*