RWANDA TVET BOARD

RQF LEVEL 5

MATMO501

MANUFACTURING TECHNOLOGY

Milling Machine Operations

TRAINEE'S MANUAL

October, 2024

MILLING MACHINE OPERATIONS

2024

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TABLE OF CONTENT

ACRONYMS

2D: Two Dimension

3D: Three Dimension

ADOC: Axial Depth Of Cut

CBT: Competency-Based Training

CMM: Coordinate Measuring Machine

CNC: Computer Numerical Control

DOC: Depth Of Cut

Ft: Feed Per Tooth

HQ: Head Quarter

IC: Indicative Content

KOICA: Korea International Coperative Agency

LED: Light Emitting Diode

LO: Learning Outcome

MAT: Manufacturing Technology

MO: Milling Operation

MRR: Material Remove Rate

PPEs: Personal Protective Equipment's

PVD: Physical Vapor Deposition

RDOC: Radial Depth Of Cut

RPM: Revolutions Per minutes

RQF: Rwanda qualification forum

RTB: Rwanda Tvet Board

TQUM: Tvet Quality Management Project

UV: Ultra Violet rays

VOCs: Volatile Organic Compounds

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in Manufacturing Technology specifically for the module of **"Milling Machine Operations ".** Trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies. The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

As a trainee, you will start by addressing questions related to the activities, which are designed to foster critical thinking and guide you towards practical applications in the labor market. The manual also provides essential information, including learning hours, required materials, and key tasks to complete throughout the learning process.

All activities included in this training manual are designed to facilitate both individual and group work. After completing the activities, you will conduct a formative assessment, referred to as the end learning outcome assessment. Ensure that you thoroughly review the key readings and the 'Points to Remember' section.

MODULE CODE AND TITLE: MATMO501 MILLING MACHINE OPERATIONS

Learning Outcome 1: Organize the workplace
Learning Outcome 2: Set the milling machine
Learning Outcome 3: Mill the workpiece

Learning Outcome 1: Organize the Workplace

Indicative contents
1.1 Introduction to Milling machine operation **1.2 Controlling Hazards** **1.3 Interpreting product drawing** **1.4 Preparing Materials, tools, attachments and accessories and equipment**

Key Competencies for Learning Outcome 1: Organize the Workplace

Knowledge	Skills	Attitudes
• Definition of key terms used in milling machine operation • Description of milling machine operations • Identification of safety and security measures used in milling machine operation • Identification of milling machine accessories and equipment	• Controlling hazard while organizing workplace for milling machine operations • Interpreting product drawing before milling machine operations • Selecting materials, tools, equipment and attachments	• Having time management while preparing workplace for milling machine operations • Have self-confidence while organizing workplace for milling machine operations • Having a critical thinking while organizing workplace for milling machine operations • Working as team while organizing work place for milling operations

Duration: 15 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Define correctly the key terms used in milling machine operation.
2. Describe properly milling machine found in manufacturing technology.
3. Identify properly safety and security measures applied for milling machine operation.
4. Apply effectively safety and security measures required in milling machine operation.
5. Interpret correctly product drawing to be produced on milling machine.
6. Describe properly materials, tools, accessories and attachments to be used in milling machine operations.
7. Select properly materials, tools, accessories and attachments to be used in milling machine operations.

Resources

Equipment	**Tools**	**Materials**
• Plain milling machine • Universal milling machine • Vertical milling machine • Fixed bed type milling machine • Ram type milling machine • Turret type milling machine • Planer Type milling • Special type milling machine	• Computer • Pain milling tools • Face milling tools • Side milling tools • Straddle milling tools • Angular milling tools • Gang milling tools • Form milling tools • End milling tools • Key way milling tools • Drilling and reaming tools • Boring tools	• Steel bar • Cutting fluid/coolant • Cloth rugs

- Table type milling machine - Gloves - Safety Boots - Safety glasses - Overall - Fire extinguisher - Air compressor - Dust pan	- Gear cutting tools - Flute milling tools - Thread milling tools - Cam milling too Thread Gauge - Oil Level Tester - Allen keys - Spanner - Drilling tools inserts - Steel ruler - Vernier calliper - Micro-meter - Dial indicator	

Indicative content 1.1: Introduction to Milling machine operation

Duration: 6 hrs

Theoretical Activity 1.1.1: Description of milling machine

Tasks:

1. Answer the following questions related to milling machine description.

   i. What do you understand by the following terms:
      a) Milling machine
      b) Feed rate
      c) Table
      d) feed
      e) Spindle speed
      f) Depth of cut
      g) Tool path
      h) Milling cutter
      i) Indexing head
      j) Indexing plate

   ii. What should be the typese of milling machne and their components

   iii. What could be the working principle of milling machine?

2. Provide the answer for the asked questions and write them on papers.
3. Present the findings/answers to the whole class
4. For more clarification, read the key readings 1.1.1. and ask questions where necessary

Key readings 1.1.1.: Description of milling machine.

- **Definition of key terms**
  - ✓ **Milling machine** is a machine which removes material from a work piece by rotating a cutting tool (cutter) and moving it into the work piece. Milling machines, either vertical or horizontal, are usually used to machine flat and irregularly shaped surfaces and can be used to drill, bore, and cut gears, threads, and slots.
  - ✓ **Feed rate:** is simply the distance the tool travels during one revolution of the part. We measure it in inch per revolution (inch/rev) or millimeter per revolution (mm/rev).

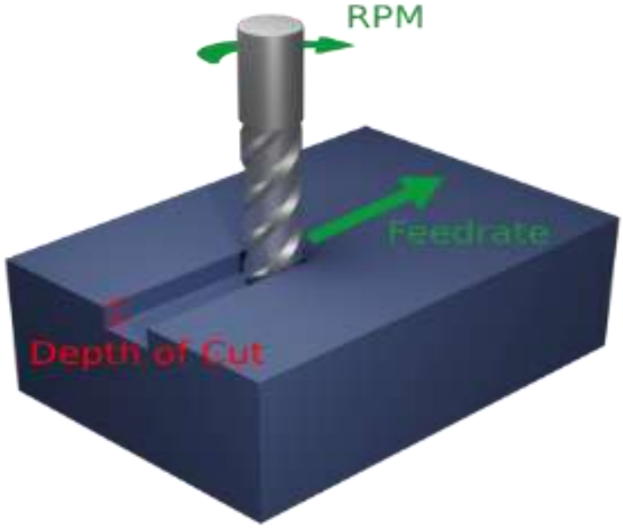
    CALCURATION OF FEED RATE

- Multiplying the Feed per Tooth by the Number of Teeth and then by the Spindle Speed.
- Multiplying the Feed per Revolution by the Spindle Speed.
- It is the actual parameter that is input into the machine as the feedrate. The table feed is not specific for an application or cutter, and it needs to be calculated based on the Chip Load, Cutter Geometry, Radial Depth of cut, and Cutting Speed.

$$V_f = F_n \times n$$

$$V_f = F_z \times Z \times n$$

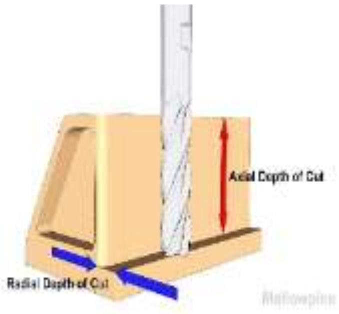
Vf:Table Feed [mm/min or Inch/min]
Fn:Feed per revolution [mm/rev or Inch/rev]
Fz:Feed per Tooth [mm/tooth or Inch/tooth]
n:Spindle Speed [RPM]



✓ **Spindle speed:** Spindle speed is the rotational speed of the cutting tool. It is usually measured in revolutions per minute (RPM) or surface feet per minute (SFM). Spindle speed determines how fast the cutting edges of the tool contact the workpiece, and how much force is applied on the material.

Spindle Speed (RPM)=$\frac{V*1000}{\pi*D}$

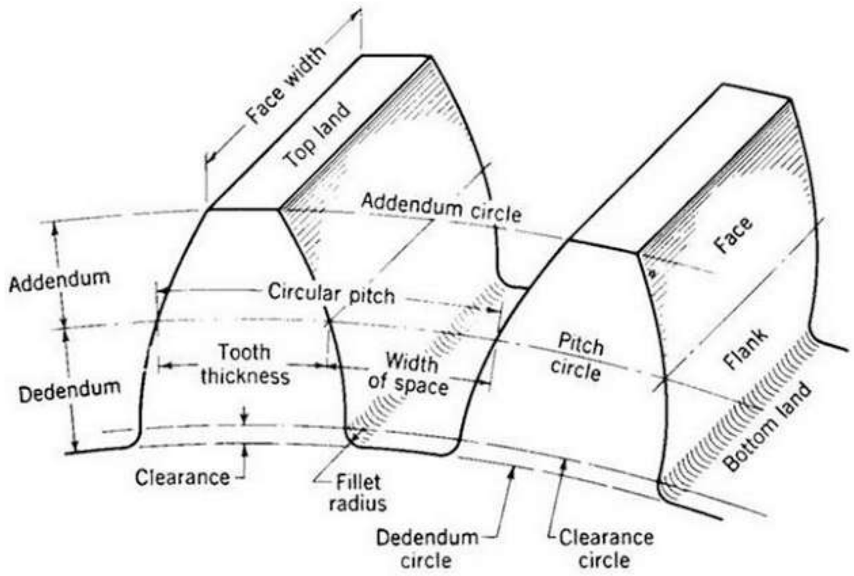
✓ **Depth of cut**: In the machining process, depth of cut is simply how deep the cutting tool gets into a workpiece and cuts through it to create a chip. In an ideal cutting process, when the CNC cutting tool moves to the left with a certain depth inside the workpiece's surface, it creates a chip. This depth is named Depth of Cut or DOC.



✓ **Tool path:** are the information that the milling machine uses to direct the drill bit through the material, they are the single most important thing in CNC milling. Toolpaths operate as vectors, they have direction, magnitude and position in space.

✓ **Milling cutters**: are cutting tools typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools).

Nomenclatures Of Milling Cutter



Milling cutters come in various shapes and sizes, each designed for specific types of milling operations. To understand them fully, it's essential to grasp the nomenclatures of a milling cutter, which describe its various features and parts. Below is a detailed explanation of these key terms:

- **Addendum Circle**

The circle on a gear that passes through the top of the teeth. This circle represents the outermost boundary of the gear tooth, above the pitch circle.

- **Dedendum Circle**

The circle passing through the bottom of the gear teeth, also known as the root circle. It marks the lowest point of the tooth spaces, below the pitch circle.

- **Pitch Circle**

An imaginary circle on which the teeth of two meshing gears theoretically contact each other.It is critical in gear meshing because the speed ratio of two gears depends on the ratio of their pitch circles.

- **Face Width**

The length of the gear tooth in the axial direction.

It measures how wide the gear teeth are and contributes to the strength of the gear and its ability to transmit torque.

- **Top Land**

The flat surface on top of a gear tooth.

It provides a slight clearance at the tip of the teeth to avoid sharp edges and reduce the risk of tooth tip breakage.

- **Addendum**

The radial distance between the pitch circle and the addendum circle.

This determines the height of the tooth above the pitch circle, affecting the engagement between gears.

- **Dedendum**

The radial distance between the pitch circle and the dedendum circle.

This is the depth of the tooth below the pitch circle and determines the tooth root's profile and strength.

- **Clearance**

The space between the top of the gear tooth on one gear and the bottom of the tooth space on the mating gear.

Clearance ensures that the teeth do not touch at their tips, preventing jamming and allowing lubrication.

- **Width of Space**

The width of the space between two adjacent teeth, measured along the pitch circle.

It affects how the gears mesh and ensures proper spacing and engagement between gear teeth.

- **Fillet Radius**

The radius of the curved portion between the tooth root and the tooth flank.

It prevents stress concentration at the base of the teeth, increasing the gear's strength and durability.

- **Clearance Circle**

The circle that passes through the tips of the teeth of the mating gear when engaged with another gear.

It helps to define the minimum clearance between the teeth of the two gears.

- **Face**

The surface of the gear tooth that comes into contact with the mating gear tooth.

It is the working surface of the gear, important for transmitting power.

- **Flank**

The surface of the gear tooth that lies between the pitch circle and the root circle (below the pitch circle).

The flank helps in transmitting force between meshing gears.

- **Bottom Land**

The surface at the bottom of the space between two adjacent teeth.

It serves as the bottom surface of the tooth gap, helping distribute load and maintain proper spacing in gear teeth.

These terms relate to how gear teeth are designed, cut, and engaged, and are critical in determining the mechanical behavior and performance of gears and milling cutters.

- ✓ **Indexing head:** also known as a dividing head or spiral head, is a specialized tool that allows a workpiece to be circularly indexed; that is, easily and precisely rotated to preset angles or circular divisions.

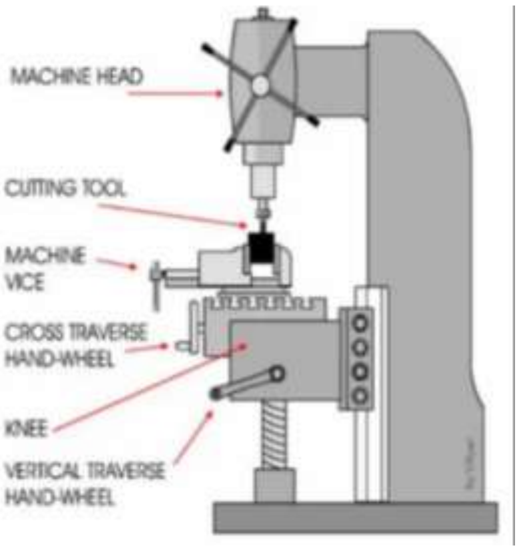
- ✓ **Indexing plate**: is a graduated circular plate or one with circular rows of holes differently spaced that is used in machines (as for graduating circles or cutting gear teeth)

- **Types of milling machine**

  ✓ **Vertical milling machine**

The position of the spindle on a vertical milling machine is perpendicular or vertical to the table. You can use this machine for slots, machining grooves, and flat surfaces.

The spindle head is fixed to a vertical column, which rotates at an angle. The milling cutter is fixed on the spindle to work with angular surfaces. In some vertical milling machines, you can adjust the spindle up and down.



Advantages of Vertical Milling Machines:

- The vertical orientation of the spindle allows the operator to easily view and monitor the machining process. This enhances precision and makes tasks like drilling, boring, and facing simpler.
- Vertical milling machines are well-suited for a wide range of operations, including contouring, engraving, slotting, and die-sinking. They are also ideal for machining flat surfaces and complex shapes.

Disadvantages of a Vertical Milling Machine

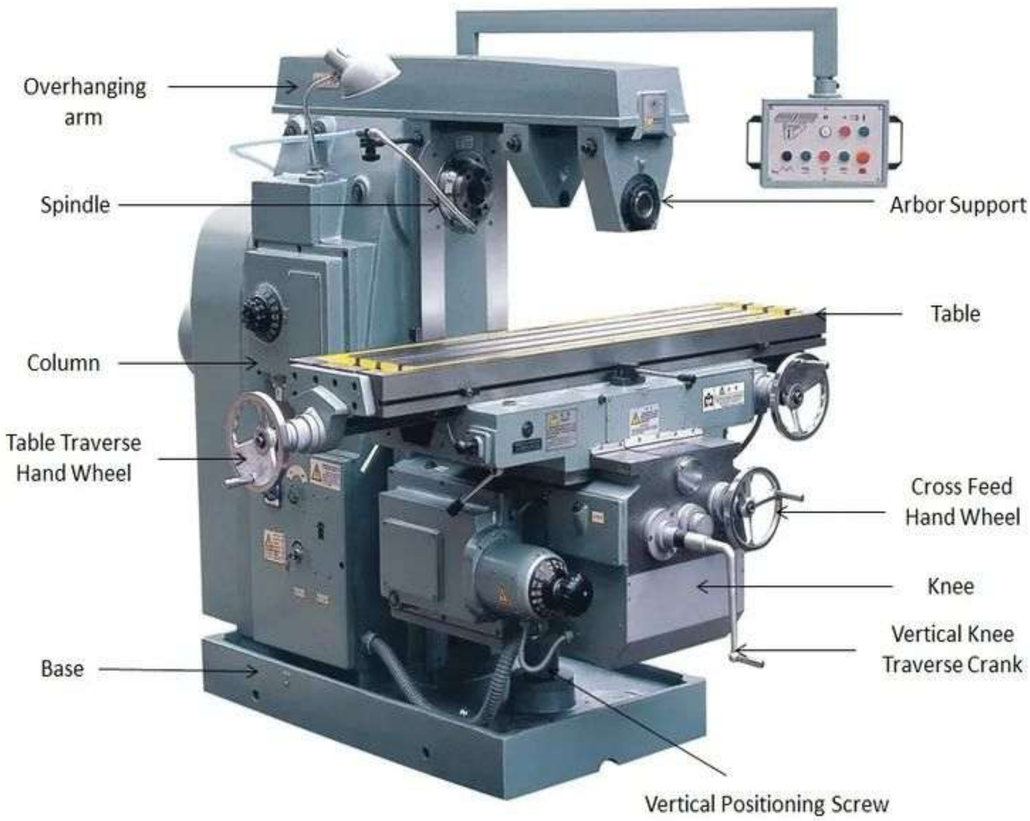
- Vertical milling machines are less efficient for deep cuts or heavy material removal compared to horizontal milling machines, as they rely on vertical forces, which may cause instability or deflection in the workpiece or tool.
- The design and orientation make it challenging to machine large, heavy, or bulky workpieces, as the workpiece weight is directly supported by the machine table, limiting size and weight capacity. Horizontal machines are better suited for such tasks.

✓ **Horizontal or Plain Milling Machine.**

Plain milling machines are more robust than hand millers. Plain milling machines that have horizontal spindles are also called horizontal milling machines. You can feed the table in vertical, cross, or horizontal directions.

horizontal milling machines mount the cutting tool on a horizontally oriented spindle that's able to selectively remove material from the stationary workpiece.

Furthermore, horizontal milling machines usually feature different cutting tools than vertical milling machines.



Advantages of Horizontal Milling Machines:

- Horizontal milling machines are more robust and can accommodate larger, heavier workpieces. With the spindle and cutters aligned horizontally, they provide better chip evacuation and allow deeper and faster cuts, improving the material removal rate.
- The horizontal design allows the use of multiple cutters simultaneously, enabling machining of multiple surfaces or features in one pass. This is especially beneficial for complex operations like gear cutting, slotting, and large-scale production.

Disadvantages of a horizontal milling machine:

- Horizontal milling machines are less versatile compared to vertical milling machines. They are primarily suited for tasks such as heavy material removal, slab milling, and cutting grooves but are not ideal for detailed or intricate work, such as drilling or working on complex shapes.
- Horizontal milling machines are generally more expensive to purchase and maintain due to their robust construction and complexity. They also require more skilled operators for proper setup and use.

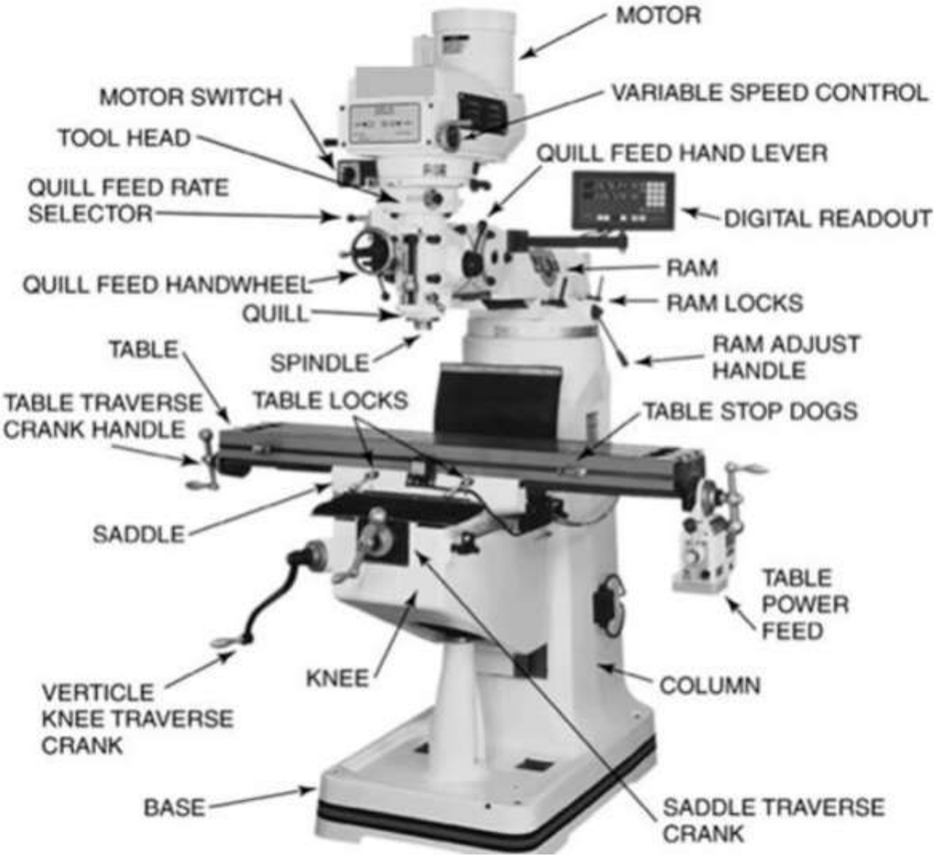
✓ **Universal Milling Machine.**

Universal Milling Machine is a milling machine having a table fitted with all motions and a dividing head with change gears so that it can perform any type of milling operation. It can adapt to perform a wide range of operations. The table can pivot at any angle for up to 45-degrees on both sides from the normal position. As the table of the horizontal milling machine can move in three directions, it also boasts the fourth movement.

This machine can also perform helical milling operations. You can also use additional attachments to increase the capacity of the machine.

Some special attachments include:

- Slotting attachment
- Rotary attachment
- Vertical milling attachment
- Index head or dividing head



Advantages of universal milling machines:

- The universal milling machine features a swiveling table, allowing it to perform a wide range of operations such as angular milling, helical milling, gear cutting, and slotting. This makes it suitable for handling complex and multi-angle machining tasks.
- It can accommodate various attachments and cutters, enabling tasks like drilling, boring, planing, and profiling. This adaptability makes it ideal for both small-batch production and customized machining projects.

Disadvantages of a universal milling machine:

- The universal milling machine allows for more flexibility with the ability to swivel the table and adjust the spindle angles. However, this flexibility comes at the cost of complexity in setup and operation. Operators need to be more skilled to correctly set up the machine for various tasks, and it may take longer to adjust the machine for different angles and positions.

- Due to its versatility and additional components (like the swivel table and more complex spindle arrangements), universal milling machines tend to be more expensive than simpler machines. Additionally, the increased number of moving parts can lead to higher maintenance costs and a greater chance of mechanical failure, particularly if the machine is used extensively for a wide range of tasks.

  - ✓ **CNC Milling Machine.**

CNC milling, or computer numerical control milling, is a machining process that employs computerized controls and rotating multipoint cutting tools to progressively remove material from the workpiece and produce a custom-designed part or product.

A CNC Milling Machine uses a rotating cylindrical cutter to move along multiple axes, and create slots, holes, and details in material to turn it into a vehicle or mechanical part. Most machines operate on three to five axes, creating much more precision and detail.

Modern CNC milling machines are assembled as both horizontal and vertical machining centers. Components can be made with materials such as plastics, ceramics, and composite materials, in addition to metals.

Technical features include automatic tool changers, tool carousels & magazines, coolant systems, and enclosures to keep machines running smoothly on their own without manual interference.

Advantages of CNC Milling Machines:

- CNC milling machines offer extremely high precision and accuracy in machining. The use of computer-controlled movements ensures that each part is manufactured to exact specifications, reducing human error and variability in the final product.
- CNC milling machines can operate autonomously with minimal human intervention, increasing productivity. They can run continuously and perform complex tasks, allowing for faster production, reduced labor costs, and consistent results, especially in high-volume manufacturing.

Disadvantages of cnc milling machines:

- CNC milling machines have a high upfront cost, including the machine itself, software, and additional setup requirements. This can be a significant financial burden, especially for smaller businesses or startups.
- Operating a CNC milling machine requires specialized knowledge, including understanding programming, machine setup, and software. This means operators must undergo training, which can increase operational costs and the time needed for employees to become proficient.

- ✓ **Tracer Controlled Milling Machine.**

Tracer-controlled milling machines are equipped with copying capabilities through tracer control, and hence car reproduces or duplicates external or internal geometries in two dimensions. Tracer-controlled milling machines are used for machining cams, grooves, contoured surfaces.

This machine is perfect for tracing the elements and reproducing dies with complex and irregular shapes. The stylus energizes the oil relay system, operating the primary hydraulic system of the table. This type of arrangement is called servomechanism and is complicated.

Tracer-controlled milling machines are used for machining cams, grooves, contoured surfaces, etc. Die sinking and other processes involving the machining of cavities can be done on three-dimension profilers or duplicators.

Advantages of Tracer Controlled Milling Machines:

- Tracer-controlled milling machines use a stylus to trace the shape of a template or pattern, which is then automatically followed by the cutting tool. This results in high precision and consistency, particularly for complex or intricate shapes, making it ideal for repeatable parts in mass production.
- The ability to automatically follow a template or pattern reduces the need for manual adjustments and minimizes operator intervention. This leads to increased productivity, especially when machining complex, detailed, or contour-shaped components that would otherwise require multiple setups.

Disadvantages of a tracer controlled milling machine are:

- Tracer-controlled milling machines are limited to reproducing only the specific shapes or profiles that are programmed or traced. They lack the flexibility to modify or create entirely new, complex shapes on the fly.
- These machines are expensive due to their specialized control systems and tracing mechanisms. Additionally, they require regular maintenance and calibration to ensure accurate operation, which can lead to higher operational costs over time.

✓ **Drum Milling Machine.**

A drum milling machine is a type of milling machine where the workpiece is mounted on a drum that rotates. As the drum turns, the milling cutters, positioned around the drum, machine the workpiece. This setup allows for continuous or semi-continuous machining, as multiple operations can occur during a single drum rotation.The cutters are of face mill type and usually both roughening and finishing cutters similar to those of a rotary-table miller are employed.

Automobile cylinder heads and small shafts are milled on this machine. These are the types of milling machines in general used in industrial operation.

Advantages of a drum milling machine

- Since the workpieces are mounted around the rotating drum, multiple milling operations can occur simultaneously. This enables high-speed and continuous machining, increasing the overall production rate, especially in batch manufacturing.

- The drum milling machine is ideal for mass production of identical parts. The setup allows for minimal tool changes and fewer machine resets, making it highly efficient for repetitive tasks, such as cutting gears or creating uniform patterns across a large number of parts.

Disadvantages of a drum milling machine

- Drum milling machines are primarily designed for repetitive, mass production tasks with fixed tooling and settings. This makes them less adaptable to complex or custom machining operations compared to more versatile machines like CNC mills. Changing the setup for different parts or processes can be time-consuming.
- Drum milling machines can be expensive to purchase and maintain, particularly when compared to simpler machines. Their specialized design for high-volume production may not justify the cost in smaller or more varied production environments, making them less economical for low-volume or job shop operations.

  ✓ **Simplex Milling Machine.**

Simplex Milling Machine: is a type of horizontal milling machine where the milling cutter is mounted on a single horizontal spindle, and the machine allows the table to move only in one direction (usually longitudinally along the X-axis). It is specifically designed for simpler milling operations and is often used for tasks requiring less complexity.

Advantages of a Simplex Milling Machine

- Simplex milling machines have a straightforward design and fewer complex features compared to more advanced milling machines (like universal or CNC machines). This makes them more affordable, making them a good choice for small workshops or businesses with budget constraints.
- With their simple design and basic controls, simplex milling machines are easy to operate. They are ideal for less experienced machinists or those performing basic machining tasks, reducing the learning curve associated with more complex machines.

Disadvantages of Simplex Milling Machines:

- Simplex milling machines usually have a single-axis movement, which restricts their ability to perform complex or multi-directional machining operations. This limits their use for more intricate tasks that require additional flexibility, such as angular or helical milling.
- Due to the lack of advanced features (like multi-axis movement or automated controls), simplex milling machines are less efficient for high-volume or complex production runs. They may require more manual intervention and setup, leading to lower overall productivity compared to more advanced milling machines like duplex or CNC machines.

✓ **Duplex Milling Machine.**

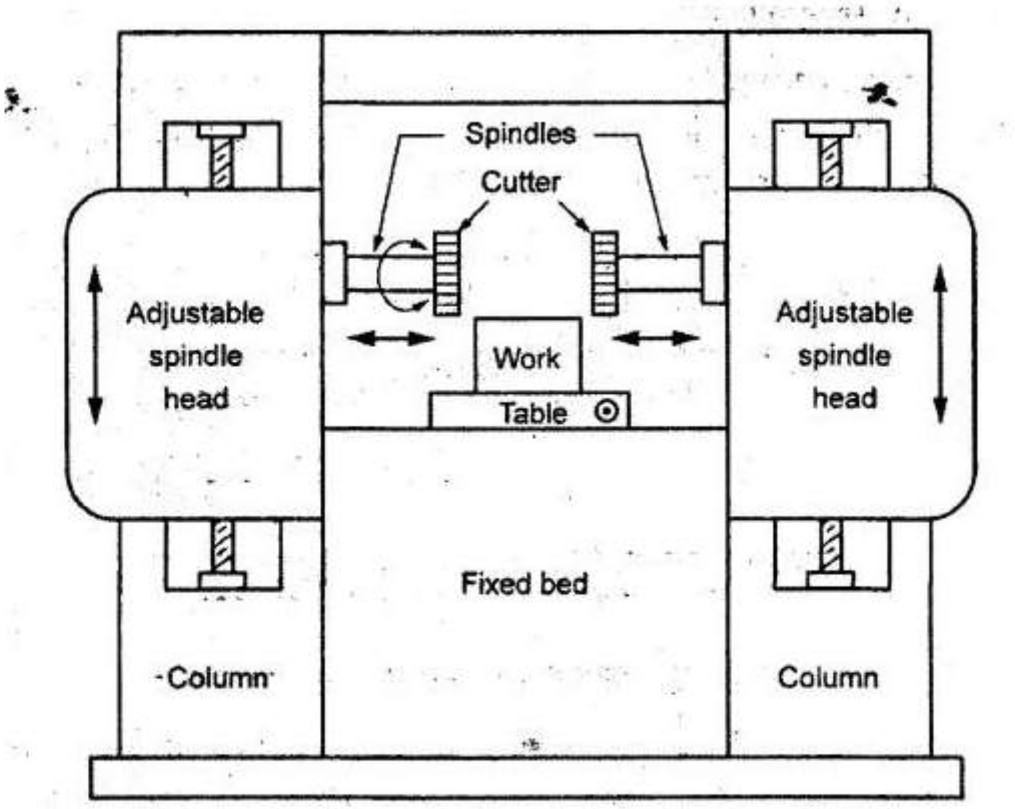
Duplex milling machines are two machines located opposite the other, which can work separately or as a single milling machine when the workpiece can be machined with 2 simultaneous spindles. The spindle can move in both horizontal and vertical directions.

Advantages of a Duplex Milling Machine:

- A duplex milling machine features two spindles, allowing for simultaneous cutting operations on both sides of the workpiece. This leads to faster processing times, especially in mass production, as it reduces the need for multiple setups or re-fixturing.
- Since the workpiece is being machined on both sides simultaneously, the load is evenly distributed between the two cutting tools. This results in better control over the machining process, leading to improved surface finish and more accurate cuts.

Disadvantages of a Duplex Milling Machine

- Duplex milling machines, which have two spindles for simultaneous cutting, tend to have a higher initial purchase price due to their more complex construction and added features. This can be a significant investment for smaller workshops.
- The additional spindles and moving parts in duplex milling machines require more maintenance and care. The increased complexity in design can lead to higher maintenance costs and more frequent servicing, especially if any part of the dual-spindle system malfunctions.



- ✓ **Triplex Milling Machine.**

The spindle can move in all three directions i.e. X Y and Z axis.

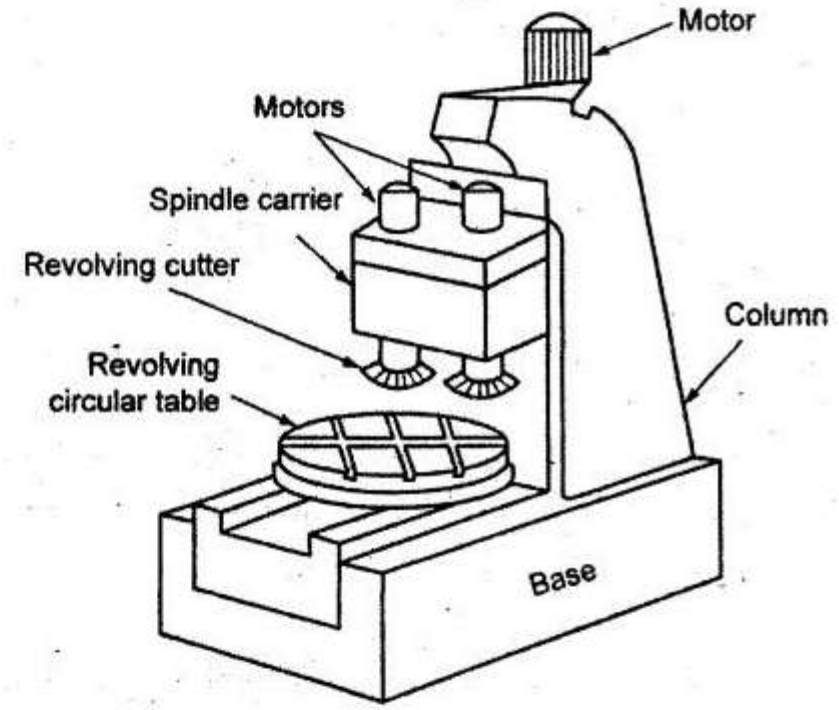
- Special application based on the customer's requirements of related accuracies.
- Highly productive and accurate.

- ✓ **Rotary Table Milling Machine.**

Rotary Milling is the ability to perform 2D and 2.5D machining cycles around or on the end of a cylinder. When performing radial machining (around the cylinder), the tool is restricted to moving parallel to and around the rotary axis. The tool is always oriented radially to the centreline of the rotary axis.

The rotary table milling machine consists of a circular table that rotates on a vertical axis. You need to set multiple cutters at different heights. The machine works with one cutter roughing up the workpiece, and the rest of the cutters finishing the surface.

The operator can load and unload the workpieces continuously while the machine is working, and that is the most significant advantage of the rotary table milling machine.



- ✓ **Turret Milling Machines.**

A turret machine is a versatile milling machine that can be used in the creation of many parts. Also, known as a Bridgeport-type milling machine, these machines can be repositioned opening a broader range of uses.

- ✓ **C-Frame Milling Machines.**

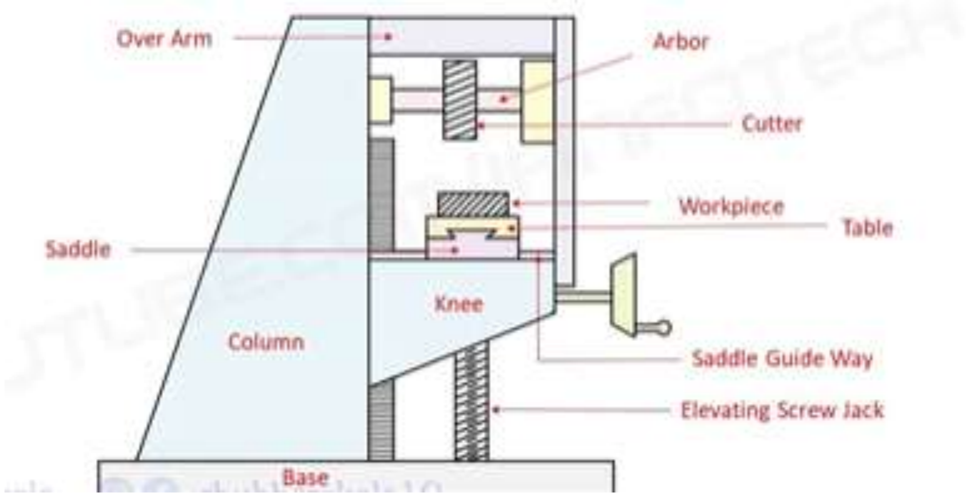
C-frame milling machines are sturdy and powerful. They use a hydraulic motor and are best utilized in industrial settings.

- ✓ **Bed Type Milling Machines.**

The worktable of a bed-type milling machine is placed on the bed itself, as opposed to on top as with other milling machines. On a bed-type machine, the knee is omitted to allow for longitudinal movement.

14. Column Milling Machines.

Often used for creating car parts, a column milling machine is one of the simplest types of milling machine. They consist of 5 key parts the worktable, head, saddle, knee, and over the arm, and use a vertically suspended drill.



15. Omniversal milling machine.

This is a customized horizontal milling machine. It consists of two spindles, one of which is in horizontal plane, as other is carry through a universal swivelling head.

Latter can set in a vertical point and swivelled up to 45° on equally sides. Knee of this machine can too be swivelled in horizontal plane, therefore enable it to perform a large number of operations

In addition to the table movements obtained in a universal milling machine, the knee can be tilted to a required angle. It is useful for machining helical grooves, reamer and bevel gears. It is mostly used in tool room work.

- **Mechanical components of milling machine**

The components of milling machine include: Column and Base, Knee, Saddle and Swivel Table, Power Feed Mechanism, Table, Spindle, Over Arm/ Overhanging Arm, Arbor Support, and Ram. Find out what milling machine parts and functions are available below.

✓ **Column and base:** Column and base provide supports for the other parts of a milling machine. There is an oil reservoir and pump in the column to lubricate the spindle. The column rests on the base and also it has a coolant reservoir and a pump to provide coolant in machining operations.

✓ **Knee:**

The gearing mechanism is enclosed within a knee. The knee is fastened to the column by dovetail ways. It is supported and adjusted by a vertical positioning screw also known as an elevating screw. The use of the elevating screw is to adjust the knee up and down by raising or lowering the lever with the help of hand or power feed.

✓ **Saddle and Swivel Table:**

The saddle is on the knee and supports the table. Saddle slides on horizontal dovetail on the knee and dovetail are parallel to the axis of the spindle (in horizontal milling m/c). Swivel table is attached to the saddle that swiveled (revolved) horizontally in both directions.

✓ **Power Feed Mechanism:**

The power feed mechanism is in the knee. The power feed mechanism is used to control in longitudinal (left and right), transverse (in and out), and vertical (up and down) feeds. For the desired rate of feed on the machine, the feed selection lever is placed to indicate on the feed selection plates. For some universal knee and column milling machines, feed is obtained by turning the speed selection handle till the required rate of feed is shown on feed dial. Almost in every milling machine, there is a rapid traverse lever which is used when a temporary increase in the speed of the longitudinal, transverse, or vertical feeds is required. This lever is used when the operator is aligning or positioning the work.

✓ **Table:**

A table is a rectangular casting that is presented on the top of a saddle. The table is used to hold the work or for work holding devices. There are several T-slots to hold work and work holding devices (jigs and fixtures). It can be operated by hand or by power. For moving the table by hand, it engages and turns the longitudinal hand crank. For moving it by power, it engages longitudinal direction feeds control lever.

- ✓ **Spindle:**

The spindle is used to hold and drive the cutting tools of a milling machine. It is mounted on the bearings and has the support of the column. The spindle is driven by an electric motor via gear trains and gear trains are on the column. The spindle face lies near the table and has an internal taper machined on it. There are two keys at the front face provide a positive drive for cutter holder or arbor.

- ✓ **Over Arm/ Overhanging Arm:**

Overarm is a horizontal beam and it is on the top face of the column. It may be a single casting and slides on the dovetail way which is on the top face of the column.

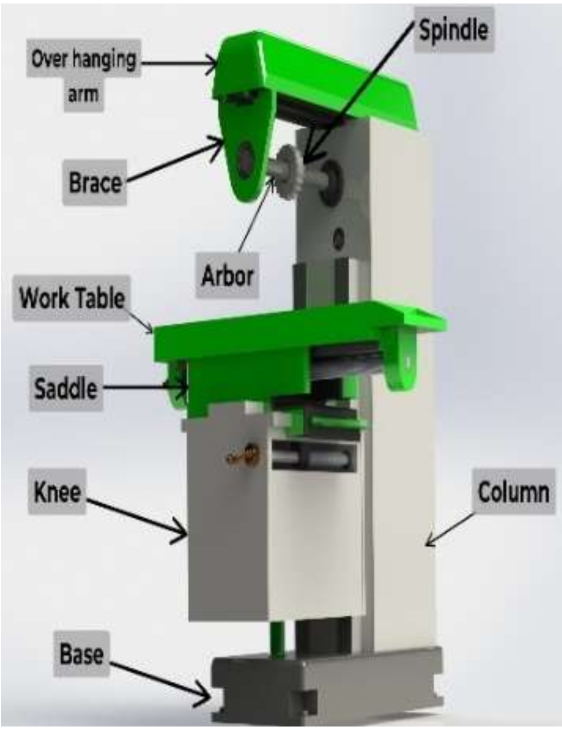
- ✓ **Arbor Support**

Arbor support is casting with a bearing that supports the outer end of a arbor. It also helps to align the outer end of the arbor with the spindle. Arbor support prevents the springing of the outer end of arbor in cutting operations. Generally, there are two types of arbor supports used in the milling machines. The first one has a small diameter bearing hole of a maximum diameter of 1 inch. The second one has a large diameter bearing hole of up to 23/4 inch.

- ✓ **Ram**

The ram is an overhanging arm in a vertical milling machine. The one end of the ram is mounted on the top of the column and the milling head is attached to another.

Fig: main components of milling machine



•Milling machine specifications

While working in an industry, the types of these machines are considered. But there are terms that the machine shop operators discuss before shipping or considering investing in these machines. They are called a specification of milling machines.

1. Movement range of the worktable with its size measurements
2. Maximum longitudinal movement allowed
3. Maximum speed of the spindle in rpm
4. Power capacity of the motor
5. Total floor space required
6. Overall weight of the machine

•Working principle of milling machine

Before you proceed with the working of the milling machine, it is important to understand the working principle behind it.

The workpiece is held firmly on the machine's worktable. The feed of the workpiece against the rotating cutter is controlled by adjusting the working table. This rotating cutter revolves at a great speed and is generally attached to the arbor or spindle. The only motion that the cutter has is the rotary motion. The workpiece is advanced slowly, and the metal from its surface is removed by the teeth of the cutter. This helps achieve the desired shape.

- **Application of milling machine**

Now, the applications of these machines are almost known. Yet, this section summarizes the application of milling machine.

✓ **Milling Flat Surfaces:** Milling machines are commonly used to create flat surfaces on workpieces. This is achieved by moving the workpiece across the milling cutter in a straight line.

✓ **Milling Grooves and Slots:** Milling machines are used to create grooves and slots on workpieces. This is particularly useful in creating keyways in shafts or dovetail slides.

✓ **Drilling Holes:** Milling machines can be equipped with drill bits to drill holes in workpieces accurately and efficiently.

✓ **Milling Contours:** With the appropriate cutting tools and programming, milling machines can create intricate contours on workpieces, allowing for complex shapes to be produced.

- ✓ **Gear Cutting:** Milling machines are commonly used for gear cutting operations. Specialized cutters and techniques are used to create gears with precise teeth profiles.
- ✓ **Thread Milling:** Milling machines can be used to mill threads on workpieces. This is often done using specialized thread milling cutters.
- ✓ **Milling T-slots:** T-slots are commonly used in machine tool tables. Milling machines can be used to create T-slots by using T-slot cutters.
- ✓ **Milling Recesses:** Milling machines can be used to create recesses in workpieces. This is useful for creating pockets or cavities in parts.
- ✓ **Milling Surfaces at Angles:** Milling machines can be used to mill surfaces at various angles, allowing for the creation of chamfers, bevels, and other angled features.
- ✓ **Prototype Development:** Milling machines are commonly used in rapid prototyping and production of small quantities of parts due to their versatility and ability to work with a wide range of materials.

Points to Remember

- Always wear proper PPE, including safety glasses, hearing protection, and steel-toe shoes.
- Ensure all machine guards, emergency stops, and interlock systems are functional.
- Operate the machine only if trained and perform pre-operation checks before use.

Application of learning 1.1.

Attend the study visit organized by your trainer to a local machining workshop and describe milling machine found in place by referrering to it’s working principles and their applications.

Indicative content 1.2: Controlling Hazards

Duration: 3 hrs

Practical Activity 1.2.1: Applying safety and security measures

Task:

1: You are requested to go to the workshop to apply safety and security measures required for milling machine operation by following the step.

2: Present the criteria to consider when implementing safety and security measures during milling machine operation .

3: Referring to the steps and procedures provided on step 2 , apply safety and security measures required for milling machine operations.

4: Present your work to the trainer and whole class.

5: Read key reading 1.2.1 and ask clarification where necessary.

7: Perform the task provided in application of learning 1.2

Key readings 1.2.1: Applying safety and security measures

- **Controlling hazard**

  Controlling hazards when using a milling machine is crucial for ensuring the safety of operators and preventing accidents. Milling machines, like other machinery, can present various hazards, including mechanical, electrical, and ergonomic risks.

  ✓ **Apply safety and security measures**

  Applying safety and security measures in milling machine operations involves:

Wearing required personal protective equipment (PPE)

- **Eye Protection:** Always wear safety glasses or goggles with side shields to protect against flying chips, debris, and coolant spray.
- **Hearing Protection:** Use earplugs or earmuffs to prevent hearing damage from the loud noise generated during milling operations.
- **Hand Protection:** Wear appropriate gloves when handling sharp tools or workpieces, but **remove gloves before operating the machine** to avoid entanglement with rotating parts.

- **Body Protection:** Wear close-fitting clothing to prevent it from getting caught in moving parts. Avoid loose sleeves, jewelry, and neckties. An apron can provide additional protection.
- **Foot Protection:** Wear sturdy safety shoes with steel toes to protect your feet from falling tools or workpieces.

Perform machine safeguarding

- **Machine Guards:** Ensure all machine guards are in place and properly adjusted. These guards protect against contact with rotating parts such as the cutter, spindle, and drive mechanisms.
- **Emergency Stop Devices:** Be aware of the location of all emergency stop buttons and switches. Ensure they are easily accessible and test them periodically.
- **Interlock Systems:** Check that interlock systems on guards and doors are functioning correctly. These systems prevent the machine from operating if a guard is open or a door is ajar.
- **Workpiece Clamping:** Use appropriate clamps, vises, or fixtures to securely hold the workpiece. This prevents it from moving during machining, which could cause injury or damage.

Apply safe operating procedures

- **Training and Authorization:** Only trained and authorized personnel should operate milling machines.
- **Pre-operation Checks:** Before starting the machine, inspect it for any damage or wear. Check the condition of the cutting tools, ensure proper lubrication, and verify that all guards are in place.
- **Speeds and Feeds:** Select appropriate cutting speeds and feed rates for the material and cutting tool being used. Consult machining data charts or handbooks for guidance.
- **Tool Holding:** Ensure cutting tools are securely mounted in the spindle or arbor. Use appropriate tool holders and tighten them properly.
- **Cutting Tool Handling**: Handle cutting tools with care, as they are sharp. Use gloves or rags when necessary and store tools properly when not in use.
- **Manual Material Handling:** Use proper lifting techniques or mechanical aids when handling heavy workpieces or tooling to prevent back injuries.

Practical Activity 1.2.2: Apply 5S Principles

Task:

1: You are requested to go to the workshop and apply 5S Principles required for milling machine operation by following the step.

2: Present the steps by steps of applying 5S Principles during milling machine operation

3: Referring to the steps provided on step 2 , apply 5S Principles required for milling machine operations.

4: Present your work to the trainer and whole class.

5: Read key reading 1.2.2 and ask clarification where necessary.

7: Perform the task provided in application of learning 1.2

Key readings 1.2.2: Apply 5S Principles

The 5S principles are a methodology used for organizing a workshop for efficiency and effectiveness by identifying and storing items used, maintaining the area and items, and sustaining the new order.

- **Sort:** The first step is to sort through all items in the workspace and separate necessary items from unnecessary ones. Remove all unnecessary items from the work area.

- **Set in Order:** Arrange necessary items so that they are easy to find and use. A place for everything, and everything in its place. This step often involves creating visual management systems such as labels and shadow boards.
- **Shine:** Clean the work area thoroughly. Regular cleaning not only ensures a pleasant work environment but also helps in identifying any defects or issues early on.
- **Standardize:** Standardize the best practices in the workplace. Develop and implement a set of standards for maintaining the first three S's, ensuring consistency and sustainability.
- **Sustain:** Make a habit of maintaining proper procedures. Ensure that everyone follows the rules and participates in continuous improvement efforts.

Points to Remember

- While controlling hazards during milling machine operations is crucial to ensure the safety of operators and accidents prevention is necessary.
- While applying 5S principles you should know all the steps needed from the sort up to sustain

Application of learning 1.2

Go to your manufacturing workshop and perform the following tasks:

a) Applying safety and security measures used milling operation

b) apply 5S principles on milling operation

Indicative content 1.3: Interpreting Product Drawing

Duration: 3hrs

Practical Activity 1.3.1: Interpreting product drawing during milling machine

Task:

You are asked to interpreting product drawing required for milling machine operations by Reading product drawing annotations include: machining drawing symbols, work drawing views, work drawing dimensions and tolerances even work drawing assembly by using the following steps:

1: Interpret the product drawing required for milling machine operations.

2: Present out the procedures of interpret the product drawing by reading product drawing annotations

3: Referring to the procedure provided on step 2, Interpret the product drawing required for milling machine operations

4: Present your work to the trainer.

5: Read key reading 1.3.1, and ask for clarification where necessary.

6: Perform the task provided in application of learning 1.3

Key readings 1.3.1 : Interpreting product drawing during milling machine operations

- **Reading Product drawing annotations**

  ✓ **Machining drawing symbols**

  In machining, including milling, technical drawings use standardized symbols to communicate machining requirements clearly and effectively. These symbols provide critical information about dimensions, tolerances, surface finishes, and more.

Graphical representations used in machining drawing symbols

- ✓ **Work drawing views**

As already said, such a technical drawing has all the information for manufacturing a part or welding and building an assembly. The info includes dimensions, part names and numbers, etc. So once a manufacturing engineer gets the drawing, he can start the production process without a second thought.

Basic Components of an Engineering Drawing

Let's see what makes up an engineering drawing. A single drawing includes many elements with quite a few variations to each of them. So let's take a closer look here.

Different Types of Lines

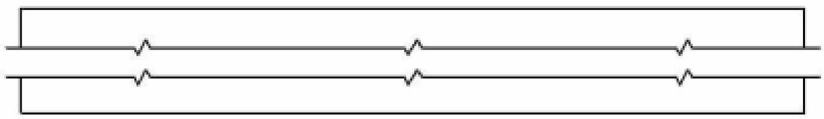
Not every line on an engineering drawing is equal. The different options make it possible to show both visible and hidden edges of a part, centre lines, etc.

The most common is a continuous line, also known as a drawing line. This represents the physical boundaries of an object. Put simply, these lines are for drawing objects. The line thickness varies – the outer contour uses thicker lines and the inner lines are thinner.

Hidden lines can show something that would not be otherwise visible on the drawings. For example, hidden lines may show the length of an internal step in a turned part without using a section or a cutout view (we explain both later).

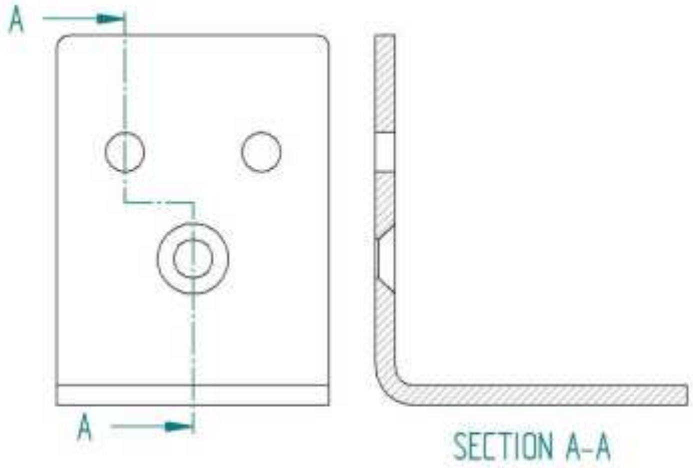
Centre lines are used to show holes and the symmetric properties of parts. Showing symmetricity can reduce the number of dimensions and make the drawing more eye-pleasing, thus easier to read.

Extension lines annotate what is being measured. The dimension line has two arrowheads between the extension lines and the measurement on top (or inside, like in the image above) the line.



Break lines indicate that a view has been broken. If you have a part that is 3000 mm long and 10 mm wide with symmetric properties, using a break-out makes gives all the info without using as much space.

While a good way for giving information to people, **CNC machines need full views in order to cut the parts**. Otherwise, the manufacturing engineer has to reconstruct the whole part from the measurements.



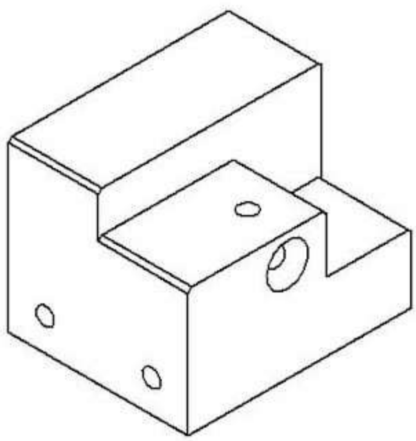
When using a cutout view, the cutting plane lines show the trajectory of the cutout. Here you can see that the A-A cutting line brings both types of holes into the view.

Types of Views

So let's take a closer look at the different types of views that are often present in a manufacturing drawing. Each serves a certain purpose. Bear in mind that adding views should follow the same logic as dimensioning – include as little as possible and as much as necessary.

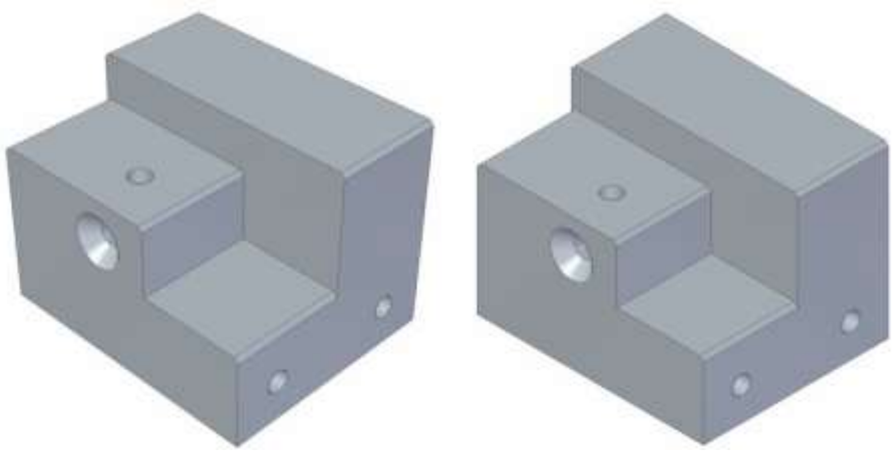
A tip for good engineering practice – only include a view if it contributes to the overall understanding of the design.

Isometric View



Isometric drawings show parts as three-dimensional. All the vertical lines stay vertical (compared to the front view) and otherwise parallel lines are shown at a 30-degree angle.

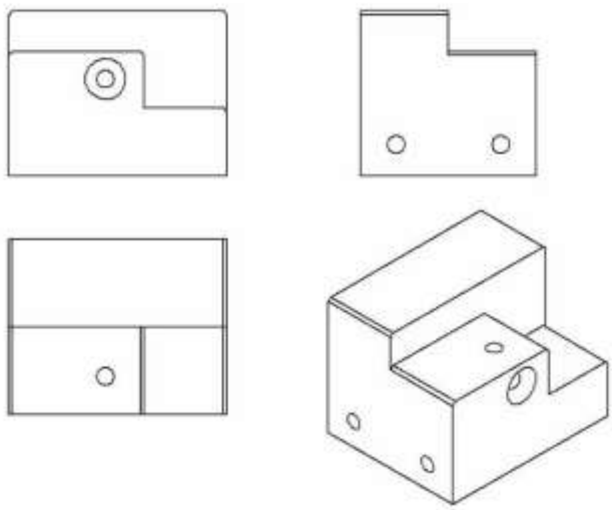
The lines that are vertical and parallel are in their true length. This means you can use a ruler and the scaling of the drawing to easily measure the length straight from a paper drawing, for example. The same does not apply to angled lines.



Left – perspective; right – isometric

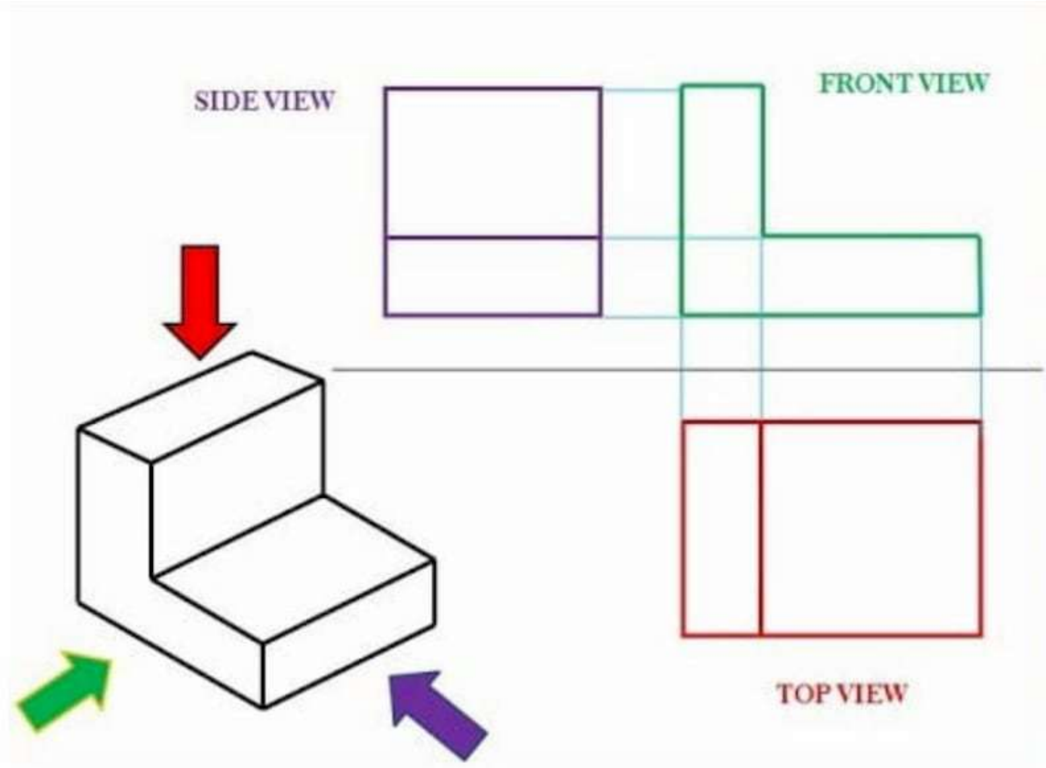
It is important to distinguish the isometric view from a perspective view. A perspective view is an artistic one that represents an object as it seems to the eye. Engineers stay true to the dimensions rather than optical illusions.

Orthographic View



This is the bread and butter of an engineering drawing. An orthographic view or orthographic projection is a way of representing a 3D object in 2 dimensions.

Thus, a 2D view has to convey everything necessary for part production. This kind of representation allows avoiding any kind of distortion of lengths.

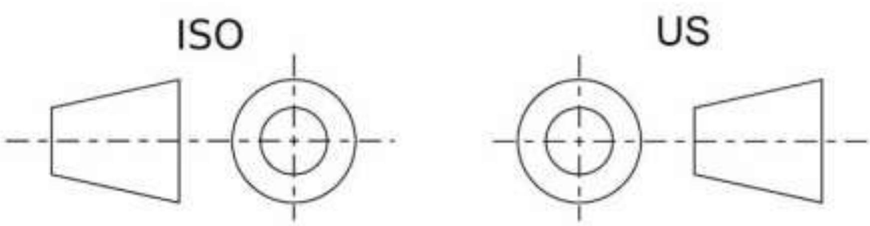


Orthographic projection (ISO standard)
The most common way to communicate all the information is by using three different views in a multiview drawing:

- Front view
- Top view
- Side view

It may be possible that some additional views are necessary to show all the info. But again, less is more.

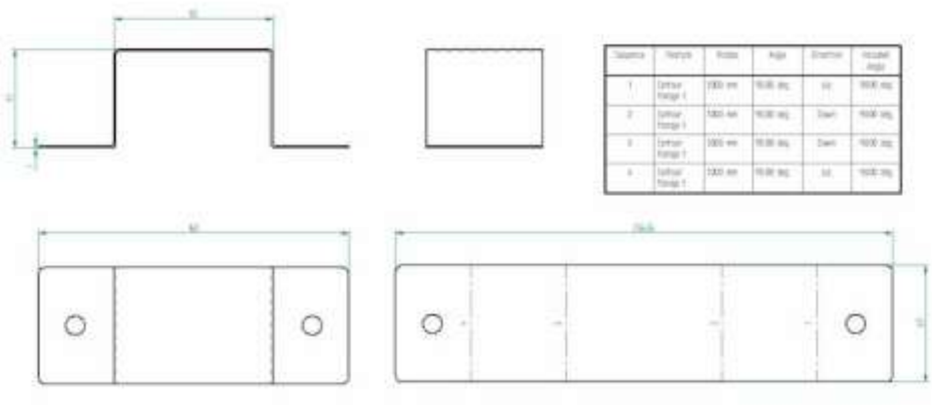
The positioning of the views differs a bit regionally. For example, look at the image below to compare the US and ISO layouts.



The one on the left is called first-angle projection. Here, the top view is under the front view, the right view is at the left of the front view, etc. The ISO standard is primarily used in Europe.

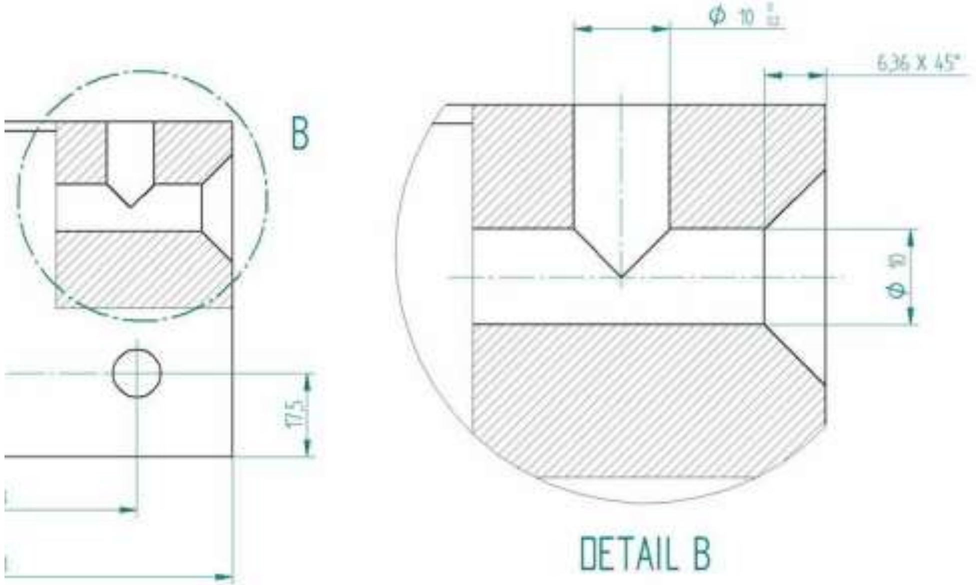
On the right, you can see a third-angle projection. The right view is on the right, the top view is on the top of the front view, etc. This system is especially popular in the US and Canada.

Flat Pattern



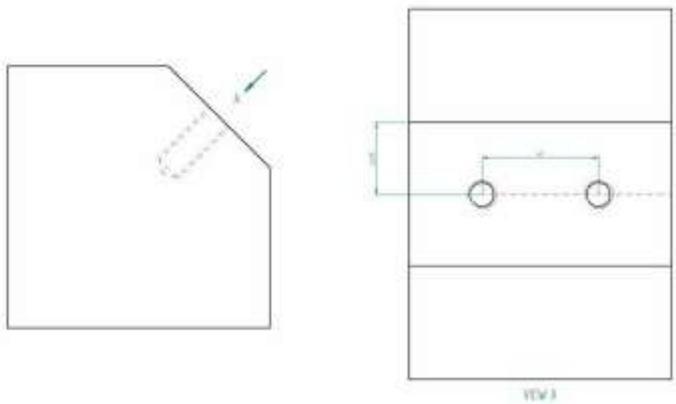
If you are making a folded sheet metal part, do not forget to add a flat pattern view. The cutting job comes before bending. When it comes to our customers, the easiest way is just to upload a step file without any accompanying drawings.

Detail View



The detail view gives us a close-up of a selected section of a larger view. This can be especially useful if an otherwise large part includes many important dimensions in a small area. Using the detail view improves the readability of these measurements.

Auxiliary View



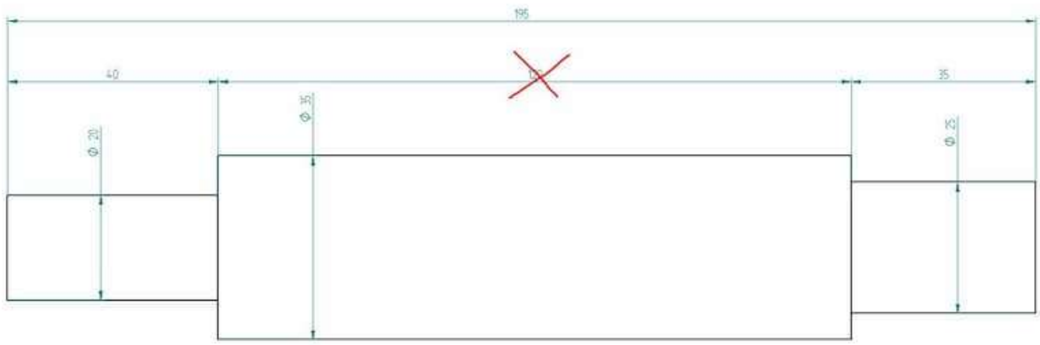
An orthographic view to represent planes that are not horizontal or vertical. It helps to show inclined surfaces without any distortion.

Dimensions

As said before, new CNC machines are actually able to read the dimensions straight from the lines. But a traditional manufacturing drawing shows all the necessary dimensions for producing the parts.

The keyword here is necessary. **Avoid using the auto-dimensioning feature** that a lot of CAD programs offer because they tend to show everything they can find. For a beginner, it may seem like adding it all ensures that no mistakes can be made.

Actually, it can result in a confusing web of measurements that is left for the manufacturing engineer to untangle. Also, adding all dimensions you can find makes it hard to pinpoint which ones are the most important.



The image above shows a shaft with all the measurements. In reality, it creates a closed system whereby the manufacturer cannot guarantee all these dimensions 100%. Therefore, you have to determine the most important ones. In our case, we chose the end steps to be more important than the length of the central part. Thus, we should delete the 120 mm dimension.

- ✓ **Work drawing dimensions and tolerances**

The process of adding size information to a drawing is known as dimensioning the drawing.and tolerancing the shapes and locations of features on objects. Once the shape of a part is defined with an orthographic drawings, the size information is added also in the form of dimensions.

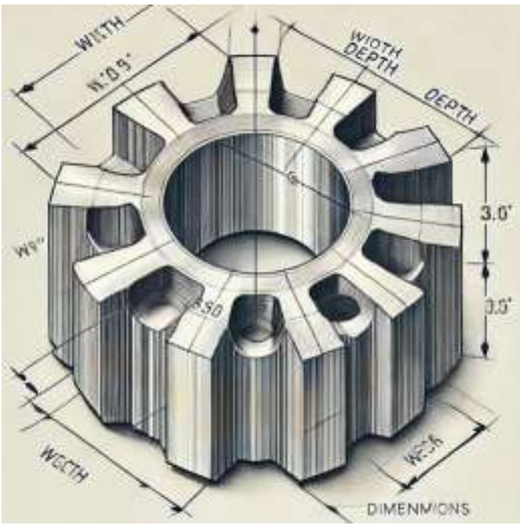
Types of dimensions in technical drawing

- ➢ **Linear dimension**

Linear dimension is a type of technical drawing dimension that can be expressed as any of the following two distances:

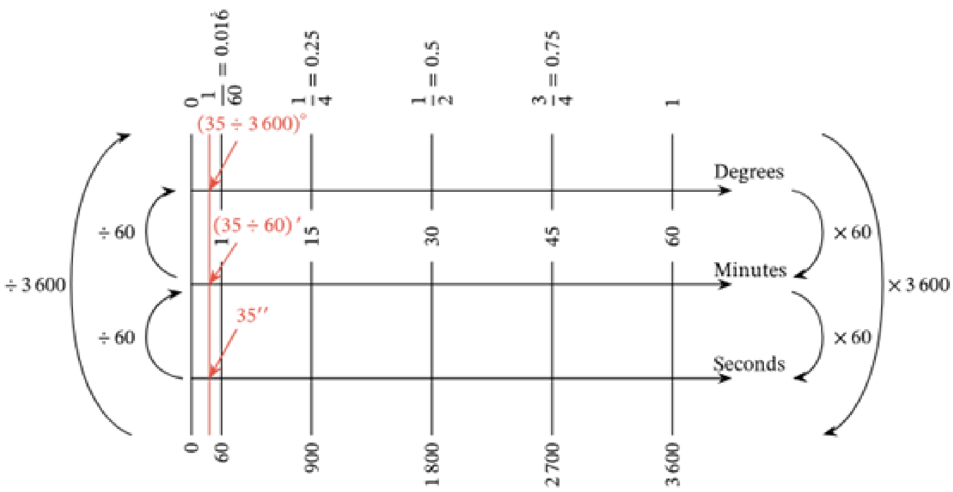
(A) Horizontal: this distance or measurement is made from left to right (or vice versa) relative to the drawing plane (paper or computer), as shown by the width (the horizontal dimension) in Figure 2. Horizontal and vertical distances can be expressed in standard units of linear measurement—mainly in meters, millimeters, inches, and feet.

(B) Vertical: this distance or measurement is made from up to down (or vice versa) relative to the drawing plane (paper or computer), as shown by depth or height (the vertical dimension)



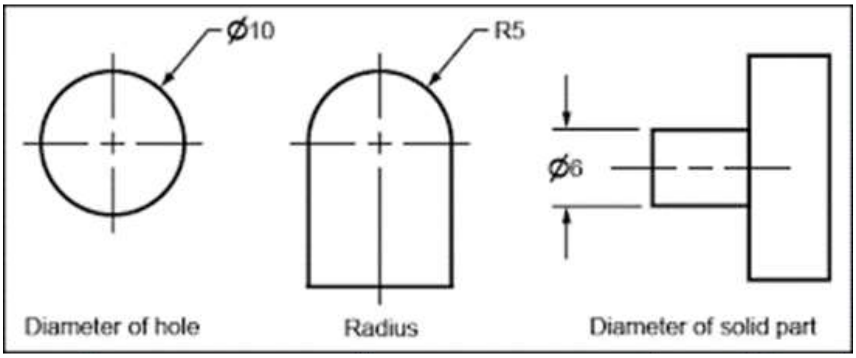
- **Angular dimension**

Angular dimension is the measurement of an angle between two intersecting lines, planes, or surfaces, typically expressed in degrees (°), minutes ('), and seconds ("). In milling operations, angular dimensions are used to define and control the geometry of angled features such as chamfers, tapers, grooves, or slots..



➢ **Diametral dimension**

Diametral dimension is a type of technical drawing dimension that expresses the magnitude of the diameter or straight line connecting the centre of a circle with two points on its perimeter. Diametral dimension is used on mostly full circles or arcs whose magnitude is more than half of a full circle. The symbol for diameter is the Greek letter phi Ø.

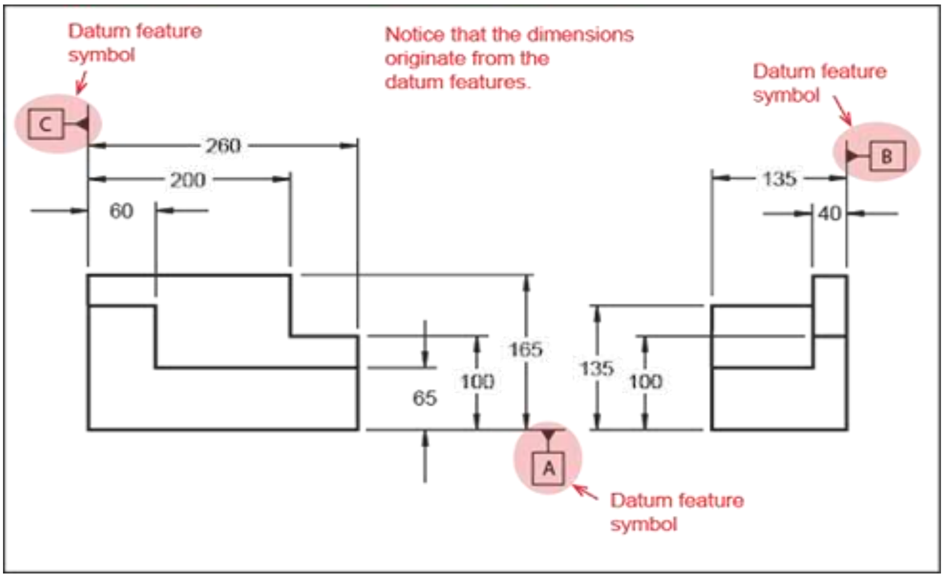


➢ **Radial dimension**

Radial dimension is a type of technical drawing dimension that expresses the magnitude of the radius or distance between the center of a circle or arc (that is less than half of a circle) and any point on a circle's or arc's perimeter. The symbol for radius is the capital letter

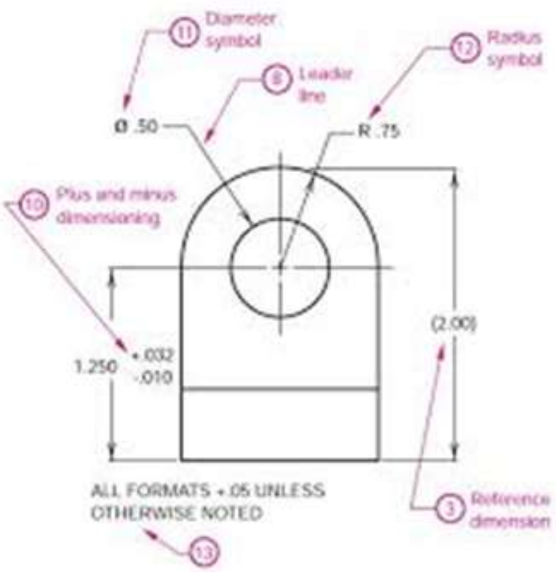
➢ **Ordinate (or coordinate) dimension**

Ordinate dimension is the type of technical drawing dimension that is indicated via rectangular coordinates or rectangular coordinate dimensioning in which a datum line or baseline is established for each Cartesian coordinate and every other dimension is positioned with respect to the datum line or baseline.



- **Reference dimension**

Reference dimension is the type of technical drawing dimension that provides extra information that is not essential for fabricating or creating a part or feature. Reference dimension is usually enclosed in parentheses [such as (2.00) as shown in Figure 6] on drawings, only providing certain information which cannot be used to fabricate a feature or part.



- **Note dimension**

Notes are the type of technical drawing dimension described by written specifications or words, more detailed than numerical values and clearly point out specific information and sizes of a feature or features.

There are two types of notes:

(A) Specific (or local) note: this is the type of technical drawing dimension that provides information applicable or relevant to specific features and not the whole drawing. Local notes are linked to specific features on drawing views. Three examples of specific notes include:

- **Tool Selection Note**:

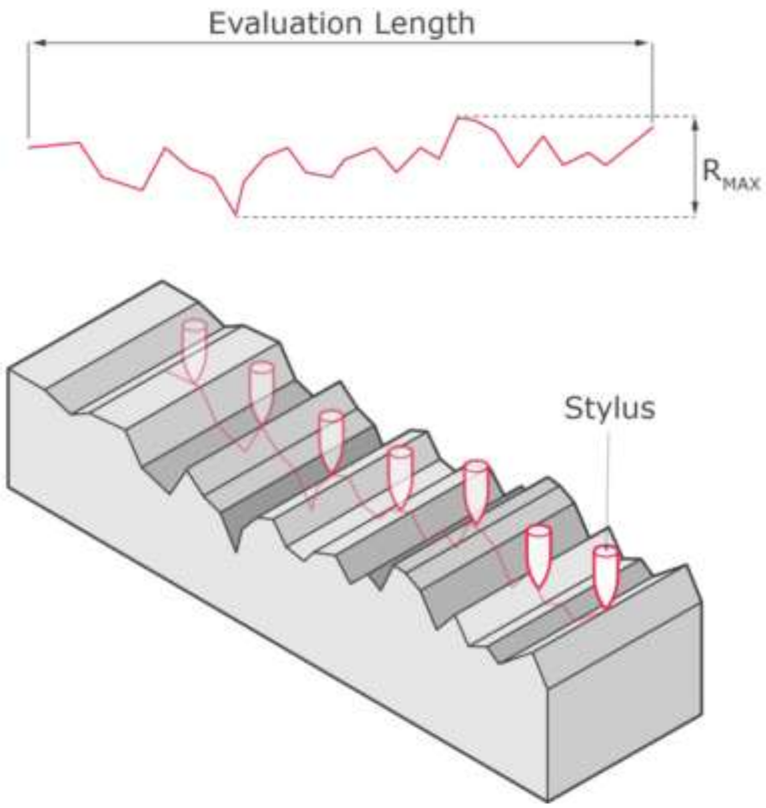
Use a 12 mm carbide end mill for roughing and a 6 mm ball nose end mill for finishing operations. Ensure proper tool changes between operations."

- **Surface Finish Note**:

Achieve a surface finish of 1.6 µm Ra on all visible milled surfaces. Perform a final light pass at a feed rate of 100 mm/min with a reduced depth of cut to achieve the required finish."

- **Cutting Parameters Note:**

Set spindle speed to 2500 RPM and a feed rate of 0.2 mm per tooth for aluminum workpiece. Depth of cut should not exceed 3 mm for each pass during roughing."



- ✓ **Work drawing assembly**

A work drawing assembly is a type of technical or engineering drawing that provides detailed information about how individual components fit and work together to form a complete assembly. It is specifically used in milling operations to guide machinists in manufacturing and assembling the various parts of a product.

This drawing combines dimensional, geometric, and machining instructions to ensure that the milling operation produces components that fit correctly when assembled.

Points to Remember

- Understand machining symbols, lines, and views to accurately interpret product drawings.
- Focus on key views and precise dimensions to ensure clarity and avoid over-dimensioning.
- Follow assembly drawings and notes for proper component fitting and machining compliance.

Application of learning 1.3

Visit to the drawing workshop and provide the product drawing to be executed on the milling machine. Interpret the provided drawing by analyzing its annotations, including machining symbols, work drawing views, dimensions with tolerances, and assembly details.

Indicative content 1.4: Preparing Materials, Tools, Attachments and Accessories and Equipment

Duration: 3hrs

Theoretical Activity 1.4.1: Identify milling machine accessories and equipment

Tasks:

1: You are requested to answer the following questions reflect on identification of milling machine accessories and equipment.

i. What do you understand by the following accessories used for milling machine operations?

a) Cutter holding device

b) Work holding devices

c) Chip guards and

d) Coolant system

ii. What should be types of milling machine equipment

2: Provide the answer of asked questions and write them on papers.
3: Present the findings/answers in whole class
4: Pay attention to the trainer's clarification and ask questions where necessary.
5: Read the key readings 1.4

Key readings 1.4.1: Identify milling machine accessories and equipment

- **Milling machine accessories**
  - ✓ **Cutter Holding Devices**

    These devices are used to securely hold the milling cutters in place on the spindle of the milling machine.

    - **Collets:** Holds small-diameter milling cutters or tools by clamping them tightly. Provides a precise and secure hold for end mills and other cutters.

- **Arbor:** Supports the cutter when using large-diameter tools like slab milling cutters, side-and-face cutters, or plain milling cutters. Fits into the spindle and supports the cutter through a long shaft, clamped at the other end by a support bracket.

- **End Mill Holder:**
  Holds the end mill tool securely for vertical or horizontal milling operations.
  Has a specific bore for holding the shank of the end mill, ensuring rigid and accurate positioning.

- **Drill Chuck:**
  Holds drill bits or small cylindrical tools during milling operations such as drilling or boring.

Provides quick installation and removal of tools but offers less precision than other cutter holding devices.

- ✓ **Work Holding Devices**

These devices are essential for securing the workpiece to the milling machine table to ensure stability and accuracy during milling.

- **Machine Vise:**

It Holds the workpiece securely on the machine table for general milling operations.

- **Clamping Kits (Step Blocks and T-slot Clamps):**

Used to clamp large or irregularly shaped workpieces directly to the milling machine table using the T-slots.
Features: Includes clamps, bolts, step blocks, and nuts for versatile clamping configurations.

- ✓ **Chip Guards**

A chip guard is a safety device used in milling operations to protect the operator and surrounding environment from flying chips, debris, and coolant produced during the machining process. These guards act as physical barriers, enhancing safety and cleanliness while allowing visibility of the cutting area.

- ✓ **Coolant System**

A coolant system ensures the proper cooling and lubrication of the cutter and workpiece, reducing heat buildup, tool wear, and improving surface finish. While Coolant is a liquid or gas used in milling operations to reduce heat, minimize friction, lubricate cutting tools, and improve machining performance. It is applied to the cutting zone to enhance the efficiency, quality, and lifespan of tools and the workpiece.

- **milling machine equipment**
  - ✓ **Types of Milling Machine Equipment**

- **Milling heads:** These are interchangeable heads that can be attached to the milling machine spindle to change the shape and size of the cutting tool. Common milling heads include end mills, face mills, and slotting heads

- **Collects:** These are cylindrical sleeves that hold the milling cutter in place on the spindle they come in different sizes and shapes to accommodate various types of cutters
- **Milling arbors:** These are long slender shafts that can be attached to the spindle toprovide additional reach and versatility when milling large or complex work pieces

- **Milling chucks:** These are specialized chucks that can be attached to the spindle to hold different cutters.

- **Milling stands:** These are adjustable stands that can be used to support and position the work piece during milling operation

- **Miilling vices:** These are clamping devices that can be attached to the milling machine table to securely hold the work piece in place during milling

- **Milling guides:** These are precision guides that can be attached to the milling machine spindle or head to improve the accuracy of milling operations

  - ✓ **Factors for Selecting Milling Equipment**

When choosing milling machine equipment, several factors must be considered to ensure optimal performance, precision, and cost-effectiveness. Below are the key factors to consider:

- **Material Type**

The material being machined (e.g., aluminum, steel, titanium, plastic) influences the type of cutting tool and the machine's power requirements.

- **Harder materials**: Require more robust equipment with higher cutting power and rigid setups.
- **Softer materials**: Can be machined on lighter, less powerful machines.

- **Size of Workpiece**

Larger workpieces require machines with greater travel distances, table size, and load-bearing capacity. Bed-type and planer-type milling machines are ideal for large workpieces. For smaller parts, a standard vertical or horizontal mill is sufficient.

- **Complexity of Operations**

Simple operations: Can be performed with manual milling machines.

While **Complex 3D contouring or high-precision tasks**: Require CNC milling machines with advanced controls and multi-axis capabilities. **Angular milling or multi-surface machining**: Requires universal milling machines or machines with rotary tables.

- **Machine Rigidity and Stability**

The machine's ability to withstand vibrations, especially when cutting hard materials, affects the accuracy and quality of the workpiece.

- **Power Requirements**

The power of the milling machine's motor should match the material being milled and the desired speed of operation. **High-power machines** are essential for heavy-duty milling tasks involving hard materials.

Lower-power machines are suitable for lighter milling tasks involving soft metals or plastics.

- **Cutting Tool Selection**

The type of cutting tool depends on the material and the milling operation (e.g., slotting, contouring, surface finishing).

- **End mills** are versatile for vertical milling, while **slab mills** are for horizontal, heavy-duty material removal.
- **Tool material** (e.g., HSS, carbide, or cobalt) should be selected based on the material being milled.

Practical Activity 1.4.2: Selecting milling equipment

Task:

You are requested to go in store/workshop and select milling equipment. This task should be done individually.

2: Apply safety precautions (Wear the PPE)

3: Present out the procedure of selecting milling equipment

4: Referring to the procedure provided on step 3, select milling equipment.

5: Present your work to the trainer

6: Read key reading 1.4.2 and ask clarification where necessary

7: Perform the task provided in application of learning 1.4

Key readings 1.4.2: The factors for selecting milling equipment

- **Main procedure for selecting milling machine attachments:**

1. Assess Machining Needs and Capabilities:

Understand Machining Requirements: Identify the specific machining operations needed, such as drilling, boring, slotting, etc., and the materials to be machined.

✓ Evaluate Machine Capabilities: Assess the existing capabilities of the milling machine and determine which additional functionalities or operations are required.

✓ Define Performance Criteria: Establish performance criteria including speed, accuracy, repeatability, and versatility required from the attachments.

2. Research and Evaluate Attachments:

- ✓ Explore Available Options: Research and identify milling machine attachments available in the market that match the identified machining needs.
- ✓ Compatibility Check: Ensure that the attachments are compatible with your milling machine in terms of size, mounting options, spindle type, and power requirements.
- ✓ Functional Analysis: Evaluate the functionalities of each attachment in relation to the machining tasks required and compare them based on their features and capabilitie

The following are list of the common milling machine attachments, including their uses:

1. Vertical Head

- **Use**: Converts a horizontal milling machine into a vertical milling machine by mounting this head on the horizontal spindle.
- **Features**: Allows vertical machining, such as drilling and vertical slotting, on a horizontal machine.
- **Application**: Ideal for tasks like face milling, end milling, and boring.

2. **Horizontal Head**

- **Use**: Standard attachment for horizontal milling operations.
- **Features**: Allows for heavy-duty milling on larger workpieces and for cutting horizontal surfaces, slots, and keyways.
- **Application**: Used for slab milling, slotting, and side milling.

3. **Indexing Head Attachment (Dividing Head)**

- **Use**: Allows precise rotation and positioning of the workpiece to mill different faces, slots, or features at specific angles.
- **Features**: Can be used for milling gear teeth, splines, or cutting helical gears.
- **Application**: Essential for operations requiring angular indexing, such as dividing a circle into equal parts or cutting gears and splines.

4. **Offset Boring Head**

- **Use**: For boring holes with adjustable offsets from the spindle centerline.
- **Features**: The boring bar can be adjusted for different diameters, and the head allows for precision boring of non-standard holes.
- **Application**: Used in precision boring operations for enlarging holes or achieving tight tolerances.

5. **Vertical Spindle Attachment**

- **Use**: Converts a horizontal spindle machine into a vertical spindle machine for vertical machining operations.
- **Features**: Mounted to the horizontal spindle, enabling the machine to perform vertical operations such as drilling or vertical milling.
- **Application**: Used for a range of vertical milling tasks when the machine's original configuration is horizontal.

6. **Universal Attachment**

- **Use**: Provides angular adjustment of the spindle in both horizontal and vertical planes, allowing the cutting tool to be tilted at an angle.
- **Features**: Adds versatility to the machine by enabling complex machining of angled surfaces or inclined slots.
- **Application**: Ideal for complex angular milling, cutting tapers, and multi-axis machining.

7. **Circular Attachment (Rotary Table)**

- **Use**: Allows circular interpolation, machining circular or spiral paths, or dividing circular workpieces into specific sections.
- **Features**: Equipped with a rotating table that can be indexed to specific angles.
- **Application**: Used for milling arcs, circles, and curved surfaces, and for cutting circular slots, or drilling evenly spaced holes around a circumference.

8. **Slotting Attachment**

- **Use**: Converts the milling machine into a slotter, allowing vertical reciprocating motion for cutting internal or external keyways, slots, and grooves.
- **Features**: Vertical stroke with adjustable length, suitable for internal machining where a horizontal cutter cannot reach.
- **Application**: Perfect for slotting operations, such as keyway cutting and internal splines.

9. **High-Speed Attachment**

- **Use**: Increases the spindle speed of the milling machine to perform high-speed machining.
- **Features**: Boosts spindle speeds beyond the normal limits of the machine, ideal for machining smaller and more delicate workpieces.
- **Application**: Used for milling with smaller diameter cutters, or for finishing operations that require higher cutting speeds.

10. **Rack Milling Attachment**

- **Use**: Specifically designed for cutting rack teeth on a workpiece using a rack cutter.
- **Features**: Facilitates the milling of straight gear teeth (racks), which are used in rack-and-pinion mechanisms.
- **Application**: For machining long, straight gear racks or cutting parallel gear teeth on workpieces.

Points to Remember

- While identifying milling machine accessories and equipment remember that it is necessary to classify the types of milling machine.
- We select attachments for milling machine operations based on the work to be performed, it is essential to consider the specific requirements of the job to be performed

Application of learning 1.4

You are requested to go to the manufacturing workshop where there are mixed tools , materials and attachment of different manufacturing machine (lather attachment, milling attachment, CNC) attachment then perform the following:

1. Select the following milling machine attachment vertical head, horizontal head, indexing head attachment, offset boring head, vertical spindle attachment, universal attachment, circular attachment, slotting attachment, high speed attachment and rack attachment.
2. Select milling materials and milling tools.

Learning outcome 1 end assessment

Written assessment

Q1. Read carefully the following statement concerning the description of milling machine and answer by True if the statement is correct or False if the statement is wrong.

- **a)** Milling machine is a machine which removes material from the machine by rotating a cutting tool (cutter) and moving it into the work piece.
- **b)** Milling machine is a machine which removes material from a work piece by rotating a cutting tool (cutter) and moving it into the work piece.
- **c)** Feed rate is simply the distance the tool travels during one revolution of the part.
- **d)** Spindle speed is the rotational speed of the cutting tool. It is usually measured in revolutions per minute (RPM) or surface feet per minute (SFM).
- **e)** In the machining process, depth of cut is simply how deep the cutting tool gets into a machine and cuts through it to create a chip.

Q2. Ready the following statetment milling machine tools ,materials, attachment and equipment and choose the correct answer by encircling the corresponding letter

I. Which one of the following is a real meaning of milling cutters among the followings by writing the letter corresponding to the answer?
   - **a)** Tools typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools).
   - **b)** Equipment typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools).
   - **c)** Material typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools).
   - **d)** Attachment typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools).

II. The following are the components of milling machine **except**
   - **a)** Column and Base
   - **b)** Saddle and Swivel Table
   - **c)** Power source mechanic
   - **d)** Table

III. The following are common types of milling machine used in manufacturing workshops except
   - a) Vertical milling machine:
   - b) Horizontal milling machine
   - c) Universal milling machine
   - d) Drilling machine

IV. The following are the applications of milling machine **except**

a) Gear Cutting
b) Gear painting
c) Thread milling
d) Milling T-slots

Q3. Read carefully the meaning of 5S principles in column **A** and match them to their corresponding 5S in column B then put the answer in provide column of answers.

Answers	Column A	Column B
……	1. Develop and implement standards for maintaining workspace organization.	A. Sort
……	2. Clean the workspace thoroughly to identify defects and maintain a pleasant environment.	B. **Select**
……	3. Arrange necessary items for easy access and use, creating visual management systems.	C. Shine
……	4. Create a habit of following procedures and promoting continuous improvement.	D. Set in Order
……	5. Separate necessary items from unnecessary ones and remove the latter from the work area.	E. Sustain
		F. Section
		G. Standardize

Practical assessment

KANYANA Machining company has won a tender from Car Furniture Company Ltd to manufacture the gears. Due to long holdays, workshop is not well organized. You are requested to prepare the workshop by applying the 5S principles and preparing the tools, materials and equipment to be used in manufacturing of that gears.
All needed tools, materials, attachment, accessories and equipment are available in workshop of KANYANA Machining Company.

Reference

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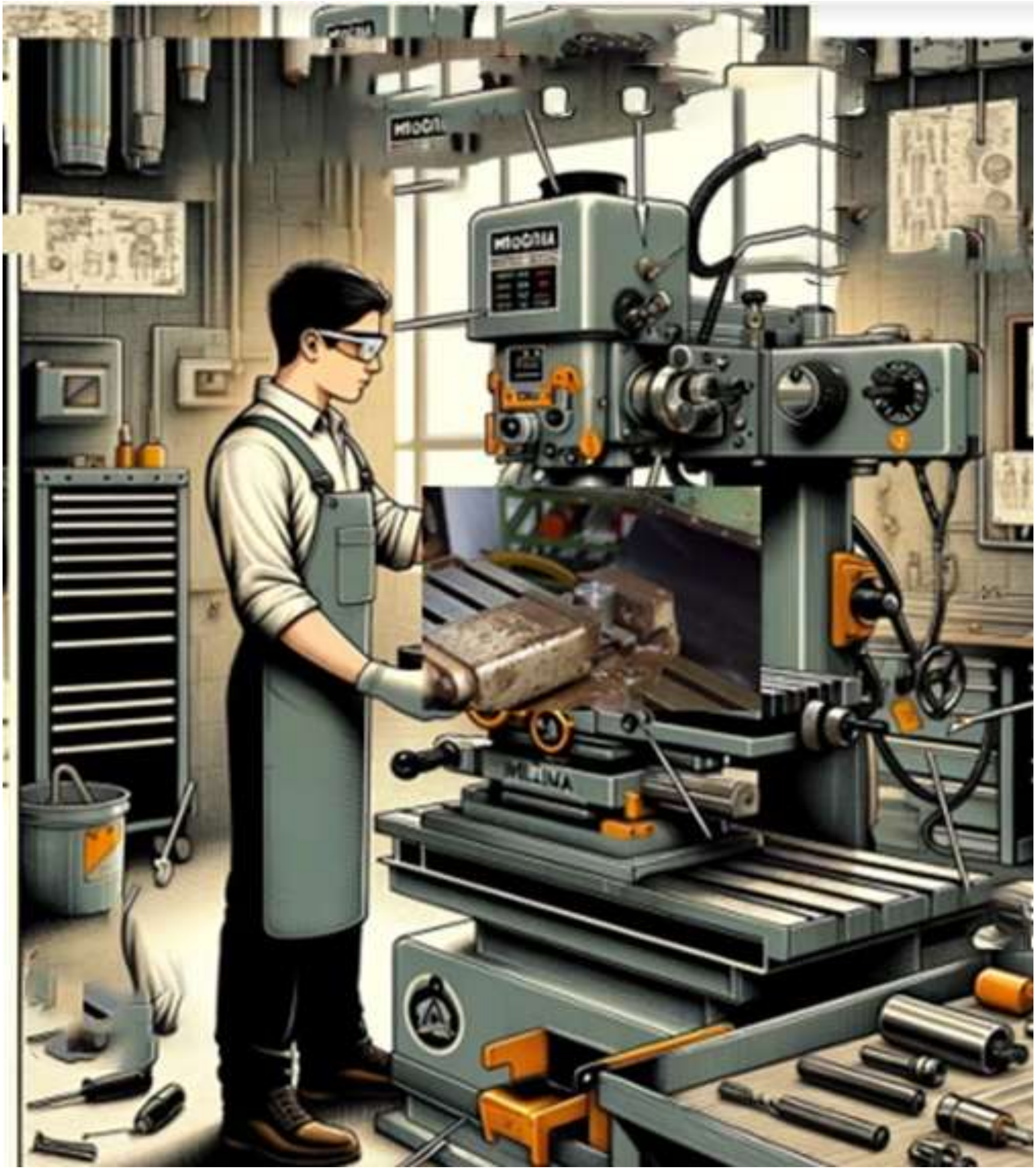
Learning Outcome 2: Set the Milling Machine



Indicative contents
2.1 Setting mechanical components **2.2 Adjusting parameters for milling operation** **2.3 Mounting the work piece in milling machine**

Key Competencies for Learning Outcome 2: Set the Milling Machine

Knowledge	Skills	Attitudes
• Identification of factors that determine the spindle speed adjustment • Identification of factors that determine milling feed adjustment • Identification of factors that determine depth of cut adjustment	• Mounting cutter holding devices and mill cutters on milling machine • Set up work holding device while operating milling machine. • Apply Indexing methods while operating milling machine • Adjusting parameters for milling operations • Selecting work holding methods while operating milling machine operations • Applying Procedures of mounting work piece on milling machine operations	• Working on time while mounting cutters on milling machine • Working in team while operating milling machine operations • Having self-confidence while setting the milling machine • Being attentive while setting milling machine operations • Respect workshop rules and regulations while setting milling machine

Duration: 35 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Mounting correctly milling cutters holding devices and mill cutters on milling machine
2. Set properly work holding device on milling machine .
3. Apply properly Indexing methods while operating milling machine
4. Adjust efficiently parameters for milling operations
5. Select correctly work holding on milling machine operations
6. Apply correctly procedures of mounting work piece on milling machine.

Resources

Equipment	**Tools**	**Materials**
• Plain milling • machine • Universal milling machine • Vertical milling machine Fixed bed type milling machine • Ram type milling, Turret type milling - Planer Type milling • Special type milling machine • Table type milling machine • PPEs	• Arbor • Collet • tapers • adapter • bolt and nut • wrenches • Plain vice • Swivel Vise Universal Vise • V- Block • T bolts • Angle Plate • Plain milling cutter • Side milling cutter • Metal slitting saw • Angle milling cutter	• Steel bar

	• End milling cutter • ‘T’ – Slot milling cutter • Fly cutter • Formed cutter • Indexing head • Indexing pate • Angle plate	

Indicative content 2.1: Setting Mechanical Components

Duration: 10hrs

Practical Activity 2.1.1 Mounting milling cutters holding devices and mill cutters on milling machine

Task:

1: you are requested to go in manufacturing workshop and mount milling cutters devices and mill cutters on milling machine according to the work to be performed.

2: Select and Wear appropriate PPE related to the task.

3: Mount milling cutters devices and mill cutters on milling to be used.

5: Present your work to the trainer and your classmates

6: Read the key readings 2.1.1

7: Perform the task provided in application of learning 2.1

Key readings 2.1.1 : Mounting milling cutters holding devices and mill cutters on milling machine

- **Mounting cutter holding devices**
  - ✓ **Selection criteria of cutter holding devices**

    - **Type of milling operation:** Choose a device that can securely hold the cutter type needed for the operation.
    - **Cutter size and shape:** The cutter size, diameter, and shape determine the type of holder. Ensure the holding device accommodates the specific cutter dimensions.
    - **Precision and rigidity:** A rigid holding device is necessary for precise and stable cutting, especially during heavy cuts or high-speed operations. Choose a device with good clamping force and stability to avoid vibrations and ensure accuracy.

- **Machine compatibility:** The device must be compatible with the machine's spindle and mounting system. Check that the holder fits the spindle type and is designed for the specific milling machine.

- **Tooling and Tool Changeability:** Some applications require quick tool changes for efficiency, especially in CNC milling operations.

- **Material and Durability:** The holding device should be made of strong, durable materials like steel or alloy to withstand cuttinSelect a device made of high-strength material that ensures long-lasting performance.

- **Safety Features: The** device must securely hold the cutter to prevent accidental dislodging during operation.
  - ✓ **Apply procedures for mounting cutter_holiding devices**

Step 1: Wear appropriate personal protective equipment (PPE), including safety glasses, gloves, and hearing protection.
Step 2: Check if the milling machine is turned off and unplugged before starting any setup
Step 3: Collect the necessary tools, including wrenches, a torque wrench (if required), and any specific tools needed for the cutter-holding device.
Step 4: Select the appropriate cutter-holding device by considering the type of cutter
Step 5: Prepare the cutter-holding device by removing any chips or debris and applying a light coat of lubricant to the device's moving parts.
Step 6: Mounting the cutter-holding device on the Spindle
Step7: Check alignment and tightness
Step 8: Test the setup by plugging in the milling machine and powering it on, allowing it to reach the desired speed.

- **Mounting mill cutters**
  - ✓ **Use standard mill cutter**

Standard mill cutters are essential tools used in milling operations for shaping and machining materials. The different standard milling cutters are :

- **Face Milling Cutters:** Face milling cutters are specialized tools used in milling operations to create flat surfaces, contours, and other complex geometries on a workpiece. Used for face milling operations to produce flat surfaces

- **Side Milling Cutters:** Suitable for side milling, strand milling, and cutting deep and narrow slots. Sidemilling cutters are specialized tools used in milling operations to cut along the sides of a workpiece. They are designed to create grooves, slots, and contours in various materials.

- **Angle Milling Cutters:** Applied for angular milling operations other than 90°. Angle milling cutters are specialized tools designed for creating angular surfaces, grooves, and slots in a workpiece. They are useful in machining operations where precise angled cuts are required.

- **T Slot Milling Cutter:** A T-slot milling cutter is a specialized tool used in milling operations to create T-slots in various materials. T-slots are essential for accommodating clamps, fixtures, and other components in machining and assembly processes Specifically used for making T slots.

- ✓ **Apply the method of mounting cutters**

Applying the method of mounting cutters involves several steps, ensuring that the cutter is securely and accurately attached to the milling machine. Here’s a general guide on how to mount different types of milling cutters:

- **Collet chucks**

Collet chucks are used to hold cylindrical shank cutters. The cutter is inserted into the collet, which is then tightened to secure the cutter in place.This method is commonly used for end mills and smaller diameter cutters.

Procedures

- Select the collet by choosing the appropriate collet size for your cutter.
- Insert the cutter, and slide the cutter into the collet.
- Secure the collet by inserting it into the spindle and tightening the drawbar to secure it.

- **End mill holders**

An end mill holder is a type of tool holder that has a set screw to secure the cutter. The cutter is inserted into the holder, and the set screw is tightened against the flat side of the cutter shank and suitable for end mills and other types of milling cutters.

Procedures

- Insert the cutter: Place the end mill into the holder.
- Tighten: Use the set screws on the holder to secure the cutter firmly.
- Mount to Spindle: Insert the holder into the spindle and tighten the drawbar.

Face mill arbor

Similar to a shell mill arbor, a face mill arbor is specifically designed for face mills. The face mill is mounted onto the arbor and secured with screws. Provides stability and allows for the use of larger face mills.

Procedures

- Attach the Cutter: Align the face mill with the holder's mounting surface and secure it using screws or bolts.
- Mount the Holder: Insert the holder into the spindle and secure it.

Tapered Shanks

Tapered shanks are a type of tool shank that has a conical shape, allowing for a secure fit into the spindle of a milling machine or other machining equipment. The taper provides a self-locking mechanism that holds the tool in place during operation, ensuring stability and precision

Procedures:

- Insert the Tool: Directly insert the tapered shank into the spindle.
- Lock in Place: Use the spindle lock to secure the tool in position.

Tool Holders with Set Screws

Tool holders with set screws are devices used to securely hold cutting tools, such as end mills or drills, in place on a milling machine. These holders feature a mechanism that uses set screws to clamp the tool firmly within the holder, ensuring stability and precision during machining operations.

Procedures:

- Place the Cutter: Position the cutter in the holder.
- Tighten the Screws: Use the set screws to hold the cutter in place securely.
- Mount to Spindle: Insert into the spindle and tighten.

Magnetic Chucks (for workpieces)

Magnetic chucks are specialized workholding devices used in milling machines and other machining equipment to securely hold ferromagnetic workpieces in place during machining operations. They utilize magnetic force to clamp the workpiece, providing a stable and rigid setup that enhances precision and efficiency.

Procedures:

- Position the Workpiece: Place the workpiece onto the magnetic chuck.

- Activate the Magnet: Turn on the magnet to hold the workpiece securely.

Points to Remember

- When mounting milling cutter holding devices and milling cutters on a milling machine, it is crucial to follow proper procedures to ensure safe and efficient operations based on the work to be performed.
- Choose a holding device based on the type of milling operation, ensuring it accommodates the cutter's size, shape, and the required precision and rigidity for stable cutting. Always verify compatibility with the machine's spindle and prioritize safety features to prevent accidental dislodging during operation

Practical Activity 2.1.2 : Setting work holding device on milling machine

Task:

1: You are requested to go in the manufacturing workshop and set work holding device on milling machine according to the work to be performed .
2: Select and Wear appropriate PPE related to the task.
3: Set work holding device on the milling machine.
5: Present your work to the trainer and your classmates
6: Read the key readings 2.1.2
7: Perform the task provided in application of learning 2. 1

Key readings 2.1.2 Setting Work Holding Device on Milling Machine

- **Set up of holding device**

✓ **Plain vice**
Plain vices bolted directly on the Milling machine table, The vice may be fastened to the table with the jaws set either parallel or at right angles to the table T-slots. Work piece is clamped between the fixed and movable jaws.

- ✓ **Swivel vice**

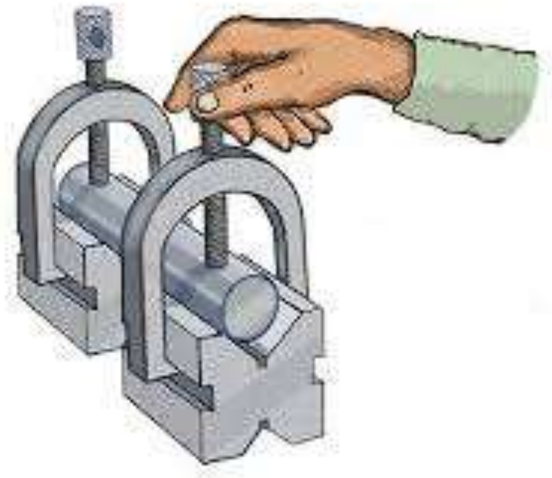
A swivel vice is a specialized clamping tool used on milling machines. Its primary purpose is to hold workpieces securely while allowing for angular adjustments. Position a workpiece exactly where you need it with this versatile vise. The quick-change design allows for mounting multiple accessories. Having the ability to quickly rotate and position a workpiece is a huge advantage when performing certain tasks

- ✓ **Universal vice**

Universal vice allows the workpiece to be set at any desired compound angle. Manufactured to consistent accuracy to give prolonged reliable service. Totally enclosed design prevents the ingress of foreign matter and damage to the screw and nut.Swivel base graduated fully 360°.

- ✓ **V- Block**

V-Blocks are precision metalworking jigs typically used to hold round metal rods or pipes for performing drilling or milling operations. They consist of a rectangular steel or cast iron block with a 120 degree channel rotated 45-degrees from the sides, forming a V-shaped channel in the top.



- ✓ **Clamps**

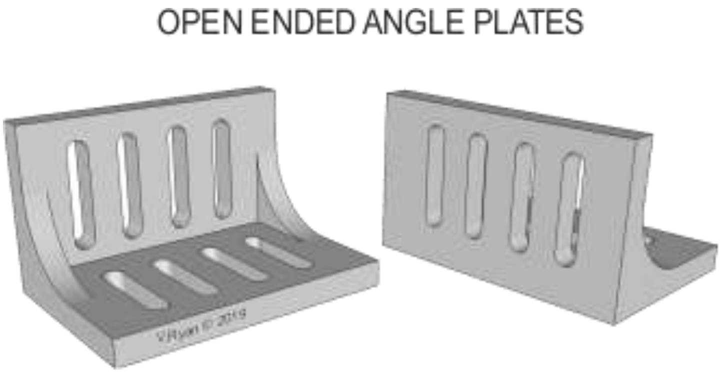
Milling clamps are tools used to hold the workpiece in place on the machine. There are various types of milling clamps, but their common purpose is to ensure that the workpiece is always well held in the machining position during the process and to guarantee machining accuracy.

- **T bolts**

T-bolts and T-slot bolts have a head that fits into a T-slot groove to clamp workpieces onto positioning and milling machine tables

- **Angle Plate**

The main purpose of the angle plate is that it effectively rotates one surface, for example, a milling table, into another surface at right angles to the first. If a workpiece is clamped to an angle plate, it effectively rotates it through 90º.



Procedures for setting up of holding device

Step 1: Personal protective equipment (PPE) such as safety glasses and gloves

Step 2: Prepare tools and equipment based on the type of holding device

Step 3: Prepare the Milling Machine**:** Ensure the milling machine is powered off and unplugged before making any adjustments.

Step 4: Determine the appropriate position for the workholding device on the milling machine table based on the size of the workpiece and the type of machining operation.

Step 5: Use bolts to secure the workholding device to the table. Tighten the bolts evenly to ensure stability

Step 6: Check the alignment and tightness of the Workholding device

Points to Remember

- When setting up a work holding device on a milling machine, precision and safety are crucial to ensure accurate machining and to prevent accidents remember to follow all the guide needed setting up a work holding device on milling machine.

Practical Activity 2.1.3: Applying Indexing methods on milling machine

Task:

1: You are requested to go to the manufacturing workshop and apply Indexing methods on milling machine according to the work to be performed.
2: Select and Wear appropriate PPE related to the task.
3: Apply Indexing methods on milling machine
5: Present your work to the trainer and your classmates
6: Read the key readings 2.1.3
7: Perform the task provided in application of learning 2.1

Key readings 2.1.3: Applying Indexing methods on milling machine

- **Apply Indexing methods**

✓ **Direct or Rapid Indexing**

This method of indexing is used for indexing a large number of identical pieces by very small divisions. The operation is performed on a plain dividing head and universal dividing head. When a universal dividing head is used, the worm and worm gear are disengaged. The indexing is done with the help of a direct index plate. This index plate is fitted to the front end of the spindle nose. Direct indexing utilises index heads that allow for faster indexing by disconnecting the worm from the worm wheel. A knob controls the index head, facilitating quick and efficient indexing.

The formula for calculating the number of turns required for direct indexing on a milling machine is:

Number of Turns = (N1 / H)

Where:
"N1" represents the number of divisions on the index plate.

"H" represents the total number of divisions required for the desired direct indexing.

Example

Find index movement to mill hexagonal bolt by direct indexing if the rapid index plate has 24 slots.

Answer

Number of slots to be moved=24/6=4

After machining, one side of the bolt, index plate has to be moved by 4 slots for 5 times to finish the work.

- ✓ **Plain or Simple Indexing**:

Plain or Simple Indexing on a milling machine is a method used to divide the circumference of a workpiece into equal parts for machining operations like cutting gears, splines, or flats on a shaft. The indexing process utilises several components, including a worm, crank, index head, and worm wheel. Typically, the worm wheel is equipped with 40 teeth, while the worm itself is single, threaded. This configuration ensures that as the crank completes one full revolution, the work wheel
rotates by 1/40th of a complete revolution.

Moreover, the worm wheel turns by 2/40th (or 1/20) of a revolution. Consequently, for every single revolution of the workpiece, the crank needs to complete 40 revolutions. Additionally, the holes in the index plate play a crucial role in further subdividing the rotation of the workpiece, enhancing the precision of the indexing process.

Number of Turns = (Number of divisions on index plate) / (Number of divisions required)

Example:

Find the crank movement for dividing the periphery of the workpiece into 10 divisions.

Index crank movement=40/N=40/10=4

- ✓ **Compound Indexing**

Compound Indexing on a milling machine is a more advanced method of indexing used when plain or simple indexing cannot achieve the required division directly. It involves using two separate index plates in combination to achieve non-standard divisions that are not available using the standard indexing formula

Number of Turns = (N1 * N2) / H

Where:

"N1" represents the number of divisions on the first index plate.

"N2" represents the number of divisions on the second index plate.

"H" represents the total number of divisions required for the desired compound indexing.

Example:
Determine the indexing crank movement for compound indexing for 87 divisions.

Answer:
required movment of the workpiece: 40/N=40/87

- ✓ **Differential Indexing**

Differential Indexing on a milling machine is a specialized technique used when the number of divisions required cannot be achieved by simple or compound indexing. It involves using a combination of rotary motion from both the indexing crank and the spindle of the dividing head, with the crank movement adjusted by connecting it to the spindle through a set of gears.

The formula for calculating the number of turns required for differential indexing on a milling machine is:

Number of Turns = (N1 * N2 - 1) / H
Where:
"N1" represents the number of divisions on the first index plate.
"**N2"** represents the number of divisions on the second index plate.
"H" represents the total number of divisions required for the desired differential indexing.
Example: Calculate the gear ratio, the indexing movement and the number of idler gears used for milling 119 teeth spur gear on a gear blank.

Answer: There is no 119 hole circle in an index plate, the divisions cannot be indexed by simple or plain indexing. So,

differential indexing is selected.

Assume A = 120
(a)Gear ratio

Gear ratio$= \frac{\text{Gear on spindle head}}{\text{Gear on bevel gear shaft}}$=(A-N)*$\frac{40}{A}$=(120-119)*$\frac{40}{120}$

=1*$\frac{40}{120}$=$\frac{1}{3}$=$\frac{1*24}{3*24}$=$\frac{24}{72}$
A simple gear train is used

Gear on spindle will have 24 teeth
Gear on bevel gear shaft will have 72

- ✓ **Angular Indexing**

Angular indexing is a technique used on milling machines to rotate the workpiece or the cutter to a specific angular position, allowing for the precise cutting of slots, grooves, or features at desired intervals.

Since the crank and spindle ratio is 40 : 1 and hence when the crank moves through one revolution, the spindle or the job moves through 1/40 of revolution, i.e., the job will revolve through an angular movement of 9°.

Setup for simple indexing may be used. Must calculate indexing with angular distance between divisions instead number of divisions

One complete turn of index crank turns work 1/40 of a turn

– 1/40 of 360° equals 9 degrees

$$\text{Indexing in degrees} = \frac{\text{no. of degrees required}}{9}$$

Points to Remember

- While applying indexing methods on a milling machine, precision and accuracy are essential for achieving the desired results in machining complex shapes and features

Application of learning 2.1

You are request to go to the manufacturing workshop and perform the following task:

1. Select cutter-holding devices
2. Apply procedures for mounting cutter-holding devices and use standard mill cutter
3. Apply the method of mounting cutters.
4. Set work holding device on the milling machine by using either the plain vice, swivel vice, universal vice, v-block
5. Apply different indexing methods

Indicative content 2.2: Adjusting Parameters for Milling Operation

Duration: 10hrs

Practical Activity 2.2.1: Adjusting parameters for milling operations

Task:

1:You are requested to go to the manufacturing and adjust parameters for milling operations according to the work to be done.
2: Select and Wear appropriate PPEs related to the task.
3: Adjust parameters on the milling operations
5: Present your work to the trainer and your classmates
6: Read the key readings 2.2.1
7: Perform the task provided in application of learning 2.2

Key readings 2.2.1: Adjusting parameters for milling operations

- **Adjust spindle speed**

✓ **Factors that determine the spindle speed adjustment**

- **Material of the Workpiece:** Different materials have different hardness and properties, requiring adjustments in spindle speed. for Soft materials Higher spindle speeds and Hard materials Lower spindle speeds to avoid overheating and tool wear.
- **Cutting tool material**: The material of the cutting tool affects how fast it can work without wearing out:
  - **High-Speed Steel (HSS)**: Typically used at lower spindle speeds compared to carbide tools.
  - **Carbide Tools**: Can handle much higher spindle speeds due to their toughness and heat resistance.
- **Tool diameter**
  - Larger tools require lower spindle speeds, while smaller tools can operate at higher speeds.
  - The surface speed at the edge of the tool increases with diameter, so larger tools need slower spindle speeds to maintain the same cutting conditions.

- **Depth of cut and feed rate**
  - Deeper cuts and faster feed rates generally require lower spindle speeds to prevent tool damage and excessive heat generation.
  - Shallow cuts or slow feed rates can allow higher spindle speeds.
- **Type of milling operation:** Different milling operations, such as roughing **or** finishing, require different spindle speeds.
  - **Roughing:** Typically uses lower speeds to remove more material quickly.
  - **Finishing:** Requires higher speeds for smoother surface finishes.
- **Machine rigidity and condition**
  - Older or less rigid machines may require slower spindle speeds to avoid chatter and vibrations.
  - More modern, robust machines can handle higher speeds, particularly with advanced vibration-damping technology.
- **Spindle power and torque:** The machine's motor power and the available torque at different speeds influence the maximum spindle speed that can be used. Higher spindle speeds require more power, especially when cutting hard materials.

✓ **Apply procedures for adjusting spindle speed**

Step 1: Wear appropriate personal protective equipment (PPE), such as safety glasses and gloves.
Step 2: Ensure the machine is powered off to avoid accidental startup
Step 3: Identify the speed control mechanism, which varies depending on the machine type, manual or variable speed.
Step 4: Consult the spindle speed chart usually found on the machine to determine the recommended speed for the specific tool and material
Step 5: Adjust the Speed:

For belt-driven machines:

- Loosen the motor mount to relieve tension on the drive belts.
- Move the belt to the appropriate pulley combination that provides the desired speed.
- Tighten the motor mount to restore tension

For gear-driven machines:

- Shift the gear lever to the appropriate speed setting indicated on the machine's chart.

For variable-speed machines

- Rotate the speed adjustment dial or lever until the desired RPM is displayed

Step 6: Turn on the milling machine and observe the spindle's rotation to verify that the speed is appropriate for the operation

- **Adjust feed rate**

✓ **Factors that determine milling feed adjustment**

- **Material Properties:** The characteristics of the raw material, such as moisture content, particle size, and hardness, significantly influence feed adjustments. For instance, materials with higher moisture content may require different feed rates to ensure optimal milling.
- **Milling Equipment:** The type and condition of the milling equipment play a vital role. Different mills (e.g., hammer mills, roller mills) have varying feed requirements based on their design and operational capabilities.
- **Desired Particle Size:** The target particle size of the finished product will dictate feed adjustments. Finer particle sizes may require slower feed rates to allow for thorough milling.
- **Milling process type (the type of cutter):** Whether the process is continuous or batch can influence feed rates. Continuous processes may require more stable feed adjustments to maintain consistent output.
- **Production capacity (The accuracy required)** :The overall production goals and capacity can affect feed rates. Higher production demands may necessitate adjustments to optimize throughput without compromising quality.
- **Operational Parameters (the tooling setup):** Factors such as speed of the mill, temperature, and pressure can affect how feed is adjusted. Operators must consider these parameters to ensure efficient milling.
- **Quality Control Standards (The finish required):** Compliance with industry standards and customer specifications may require adjustments in feed to meet specific quality criteria for the final product.
- **Energy Consumption (The power and rigidity of the machine)**: Efficiency in energy use can influence feed adjustments. Higher feed rates may lead to increased energy consumption, so finding a balance is essential.

✓ **Apply procedures of adjusting feed rate**

- **Evaluate the current milling operation's effectiveness**: look at Factors such as surface finish, cutting tool wear, and machining time to determine if the feed rate needs adjustment.
- **Set clear objectives for the feed rate adjustment**: such as improving surface finish, increasing production speed, or enhancing tool life. This focus will guide your decisions.

- **Assess material properties:** Ensure that the cutting tools and workpiece materials are suited for the intended feed rate. Different materials may require specific feed rates to achieve optimal performance.
- **Read Machine Manual:** Always consult the machine's manual for specific instructions on adjusting the feed rate.
- **Adjust the Feed Rate**: Locate the feed rate dial or power feed lever
- **Perform a test cut on scrap material** to verify the feed rate, spindle speed, and depth of cut by observing the machining process to ensure that Chips are formed properly, No excessive vibration and Surface finish meets the requirement.

- **Adjust depth of cut**

✓ **Apply steps of adjusting depth of cut for milling machine**

Step 1: Understand the workpiece and tooling

- Material Type**:** The depth of cut will vary depending on the hardness and toughness of the material being milled (e.g., steel, aluminum, or wood).
- Cutter Type**:** Consider the type and size of the cutting tool, as larger diameter cutters or end mills can handle greater depths of cut.

Step 2: Machine Setup

- Secure the Workpiece: Ensure the workpiece is clamped properly on the milling machine's table or in a vise to prevent any movement during the cutting process.
- Install the Cutting Tool: Insert the appropriate cutting tool into the spindle and tighten it properly to prevent slippage.
- Zero the Machine: If starting a new job, move the cutter close to the workpiece surface and set the machine to zero at the point where the cutter touches the surface.

Step 3: Initial depth setting

- Adjust the Quill or Knee**:** Depending on your machine type, use the quill feed (on smaller machines) or the knee feed (on larger machines) to adjust the depth of cut.
- Manual Adjustment: Use the handwheel to move the table or workpiece vertically. On a CNC machine, input the depth directly into the program.

Step 4: Start with a shallow depth

- Pilot Cuts: Begin with a shallow depth of cut for the first pass, typically 0.1 to 0.5 mm for harder materials. This helps verify machine alignment, tool engagement, and tool sharpness.
- Check the Feed Rate: Maintain an appropriate feed rate that corresponds to the tool diameter, workpiece material, and depth of cut to avoid tool breakage or excessive wear.

Step 5: Make Adjustments Incrementally

- Increase Depth Gradually: After each pass, if the machine performs well and the cut is clean, increase the depth incrementally based on machine capacity and material type. Typically, depths of cut range from 0.5 mm to 3 mm for larger milling machines.
- Avoid Overloading: Monitor the machine and the tool for any signs of overloading (e.g., excessive vibration or noise). Reducing the depth of cut or feed rate can alleviate this.

Step 6: Monitor tool Wear and Heat

- Check for Signs of Wear: After each cut, inspect the cutting tool for wear or damage, which could affect the precision and finish of subsequent cuts.
- Coolant or Lubrication: If necessary, use coolant or lubrication to manage heat buildup, particularly when milling harder materials.

Step 7. Fine tuning for precision cuts

For finishing passes or high-precision cuts, adjust the depth of cut to very shallow values (around 0.05 to 0.2 mm) to ensure a smooth surface finish and exact dimensions.

Step 8. Final Pass

- Final Adjustment: Before completing the process, make one final, shallow pass to achieve the desired finish and dimensional accuracy.
- Deburr the Workpiece: Once milling is complete, deburr any sharp edges to clean up the workpiece.

  ✓ **Factors that determine depth of cut adjustment**

- **Material of the Workpiece**

- Hardness: Harder materials like steel require shallower depths of cut compared to softer materials like aluminum or plastic to prevent tool wear or breakage.
- Toughness and Brittleness: Brittle materials may crack or chip with deep cuts, so shallower cuts are advisable.

Cutting tool type and condition

- Tool Diameter: Larger diameter cutting tools can handle greater depths of cut as they are more rigid and distribute the cutting forces over a larger area.
- Tool Material: High-speed steel (HSS) tools may require smaller depth adjustments than carbide tools, which can endure higher stress.
- Tool Sharpness: Worn or dull tools may need shallower cuts to avoid excessive heat generation or poor surface finish.
- Number of Cutting Edges (Flutes): Tools with more cutting edges can handle deeper cuts more effectively due to improved chip removal.

Milling machine rigidity and power

- Machine Type: Heavy-duty milling machines are more capable of handling deeper cuts, whereas lighter or less rigid machines may deflect or vibrate with deep cuts.
- Spindle Power: Machines with higher spindle power can maintain the required torque for deeper cuts without slowing down or stalling.
- Vibration Resistance: Machines with better vibration damping allow for deeper cuts, as excessive vibration can cause poor surface finishes and tool damage.

Cutting speed and feed rate

- Cutting Speed: The speed at which the tool rotates (RPM) affects heat buildup. Higher speeds may require shallower depths to avoid tool overheating.
- Feed Rate: Faster feed rates demand shallower cuts to reduce stress on the tool and maintain cutting precision. A slow feed rate can allow for a deeper cut without sacrificing quality.

- **Type of milling operation**
  - Roughing vs. Finishing: In roughing operations, deeper cuts can be used to remove more material quickly, while finishing operations require very shallow cuts to achieve a smooth surface and precise dimensions.
  - Climb Milling vs. Conventional Milling: Climb milling often allows for slightly deeper cuts as it provides better chip evacuation, while conventional milling may require shallower cuts to avoid tool deflection.
- **Workpiece clamping and setup**
  - Workpiece Rigidity: If the workpiece is thin, flexible, or poorly clamped, deep cuts can cause movement or deformation, affecting accuracy and surface quality.
  - Support and Fixtures: Well-supported workpieces with proper fixtures can handle deeper cuts, as there's less risk of movement or vibration.
- **Chip evacuation and cooling**
  - Chip Removal: For materials that produce large chips (e.g., aluminum), deeper cuts may be possible if chips are evacuated effectively to prevent clogging.
  - Coolant and Lubrication: Adequate cooling prevents overheating during deep cuts. If cooling is insufficient, the depth of cut may need to be reduced.
- **Tolerance and Surface Finish Requirements**
  - Tight Tolerances: When precision is critical, such as in finishing cuts, the depth of cut must be minimal to avoid overshooting the desired dimension.
  - Surface Finish: To achieve a fine surface finish, shallow depths of cut are typically required, particularly on the final pass.
- **Toolpath and Geometry**
  - Complex Geometries: For complex shapes, the depth of cut may need to be reduced to maintain accuracy and prevent the tool from gouging the material.
  - Cutter engagement: In full-width cuts or when the tool is fully engaged with the workpiece, the depth must be shallower to avoid tool overload. Partial engagement (i.e., side milling) allows for deeper cuts.

Heat Generation

- Material and Tool Heat Sensitivity: Materials like stainless steel or titanium generate more heat, requiring smaller depths of cut to avoid tool wear, material warping, or thermal expansion.
- Tool Coatings: Coated tools (like TiN or TiAlN) can handle higher temperatures, which can sometimes allow for deeper cuts.

- **Adjust coolant follow rate.**

  ✓ **Steps for adjusting coolant flow rate**

Locate the coolant flow controls

- Manual machines: There may be a simple valve or dial on the machine to increase or decrease the flow.
- CNC machines: Coolant flow can often be adjusted through the machine's control panel. Look for a setting in the program or coolant function keys.

Adjust the coolant flow rate

- Manual Adjustment: Open or close the valve to increase or decrease the flow.
- CNC Program Control: In G-code programming, coolant can be controlled using:
  - M08 (turn coolant on)
  - M09 (turn coolant off)
  - Flow rates might be adjustable through custom commands, depending on the machine model. Check the machine's manual for the specific coolant flow adjustment commands.

Test and fine-tune

- Run the machine at the adjusted flow rate and observe the cutting process:
  - Too much coolant: This can cause flooding, inefficient cooling, and excess misting.
  - Too little coolant: It might not cool the workpiece and tool effectively, increasing the risk of overheating or poor surface finish.

Monitor for proper distribution

- Ensure coolant reaches the tool tip directly and flows evenly across the cutting area. You might need to adjust nozzles or delivery points to achieve optimal distribution.

Check nozzle condition

If you're not getting enough coolant, it may be due to a blocked or clogged nozzle. Clean or replace any faulty nozzles as needed.

Points to Remember

- While adjusting parameters for milling operations it is necessary for achieving the desired machining results, including proper surface finish, dimensional accuracy, and tool life because all the parameters include spindle speed, feed rate, depth of cut and coolant flow rate are properly adjusted.

Application of learning 2.2

Go to the manufacturing workshop and adjust parameters for milling operations on milling machine by referring to spindle speed, feed rate, and depth of cut and coolant flow rate.

Indicative content 2:3: Mounting the Work Piece in Milling Machine

Duration: 15hrs

Practical Activity 2.3.1: Mounting the Work Piece in Milling Machine

Task:

1:You are requested to go to the manufacturing workshop and mount the Work Piece in Milling Machine by apply procedures of mounting work piece.
2: Select and Wear appropriate PPEs related to the task.
3: Apply procedures of mounting work piece on milling machine
5: Present your work to the trainer and your classmates
6: Read the key readings 2.3.1
7: Perform the task provided in application of learning 2.3

Key readings 2.3.1: Mounting the Work Piece in Milling Machine

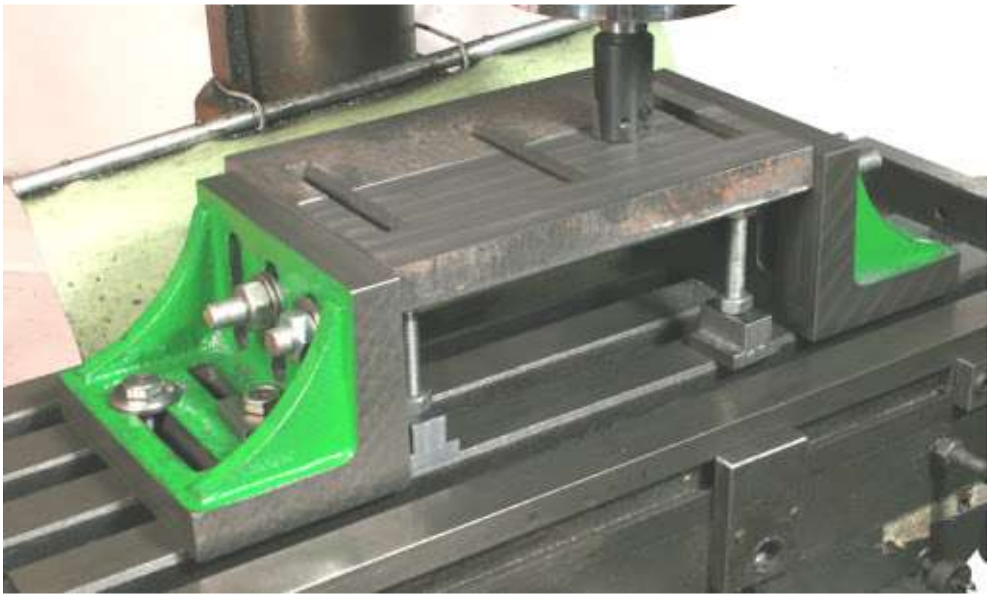
- **Select work holding methods**

✓ **Clamping to the table:**

Directly fastening the workpiece to the milling machine table using T-bolts, clamps, or strap clamps.The purpose is used for large, flat workpieces where accuracy and rigidity are required. Common in operations where the entire surface needs to be machined.

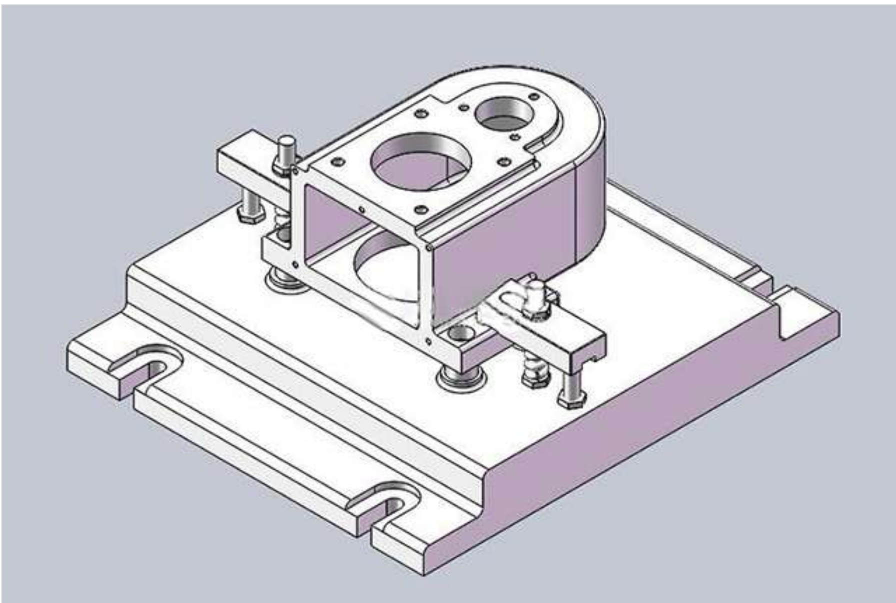
- ✓ **Clamping to the angle plate:**

The workpiece is bolted to an angle plate, which is clamped to the table. This allows for perpendicular or angled machining operations.
Ideal for machining operations that require the workpiece to be oriented at a 90° or other specific angles. Good for parts needing side machining or multi-plane operations.



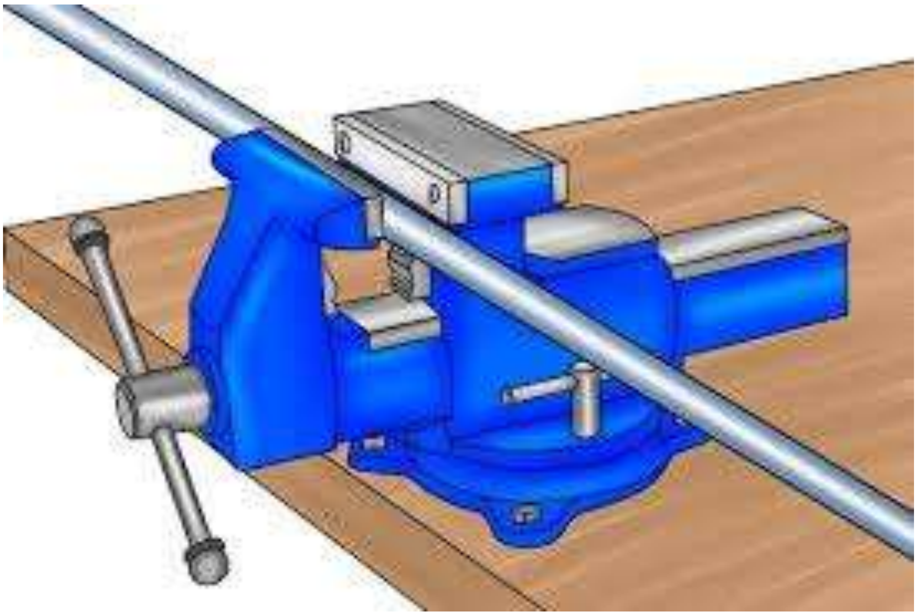
- ✓ **Clamping in fixtures:**

Custom or standard fixtures are used to secure the workpiece, providing precision and repeatability.
Often used in production settings where the same part is repeatedly machined. Fixtures hold complex or irregular shapes.



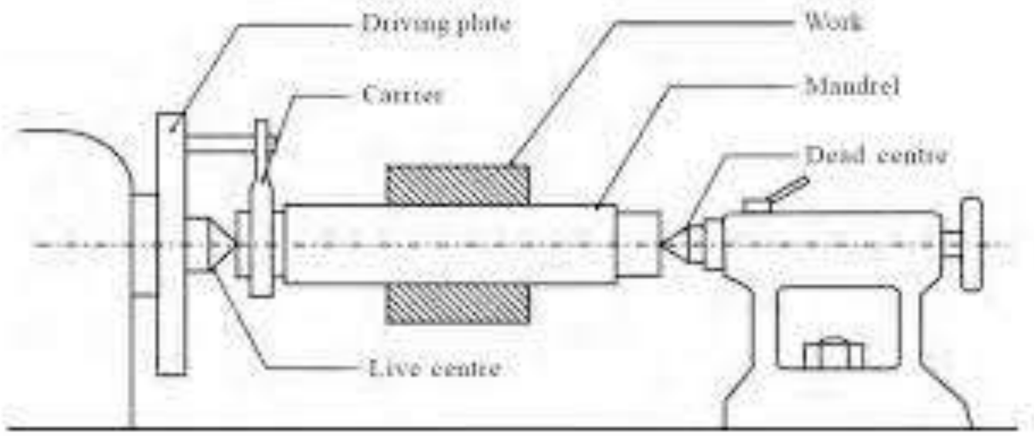
- **Holding in the vice:**

The workpiece is clamped between the jaws of a milling vice, which is attached to the table.
This vice is Suitable for small to medium-sized workpieces, particularly those with regular shapes .



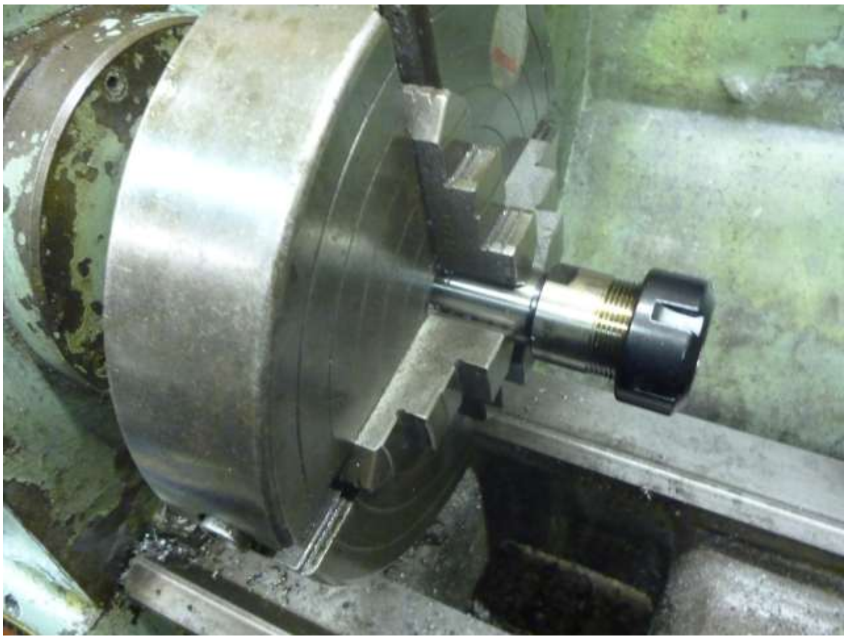
- **Holding between centers:**

The workpiece is held between two centers (typically in turning operations), where each end is supported by a live or dead center.
Used for cylindrical workpieces that need accurate concentric machining, such as shaft work.



✓ **Holding in a chuck:**

The workpiece is clamped in a chuck (usually three or four-jaw) attached to a milling machine or lathe spindle.
Chuck is ideal for round or irregularly shaped workpieces that need multi-axis machining or turning.



- **Apply Procedures of mounting work piece**

Step 1 :Prepare the milling machine table:
Preparing the milling machine table involves several key steps to ensure accurate and safe machining operations.

- Clean the table thoroughly to remove any debris, chips, or coolant residue.
- Check the table for any damage or wear that could affect precision.
- Check if table is properly aligned and leveled,

Step2 : Position the workpiece
Positioning the workpiece for a milling machine involves several important steps to ensure accuracy and stability during machining.

- Select the appropriate workholding device based on the shape and size of the workpiece.
- Place the workpiece securely in the device.
- Align the workpiece with the machine's coordinate system, using reference points or edges for precision.
- Adjust the position as needed, often using a dial indicator or other measuring tools to confirm alignment.

- Tighten the clamps or screws to secure the workpiece firmly in place, preventing any movement during the milling process.

Step 3: Secure the workpiece

Securing the workpiece in a milling machine involves using appropriate workholding devices, such as vises or clamps, to firmly hold the workpiece in place during machining. The process includes positioning the workpiece accurately, ensuring it is stable and aligned with the machine's axes, and applying sufficient clamping pressure to prevent movement without causing deformation. After securing, it's important to double-check the alignment and perform final tightening to ensure the workpiece remains stable throughout the milling operation. Properly securing the workpiece is crucial for achieving accurate cuts and maintaining safety.

Step 4 : Check the workpiece alignment and positioning

- Make visual inspection: Examine the workpiece to ensure it is flat and properly seated in the workholding device.
- Use measuring tools: Utilize tools like dial indicators, calipers, or squares to measure the alignment of the workpiece with the machine's spindle and cutting tool.
- Make any required adjustments to the workpiece's position or angle to achieve precise alignment.
- Conduct a final check to confirm that the workpiece is stable and correctly positioned before beginning the milling operation.

Points to Remember

- Choose the right clamping technique—whether clamping directly to the table, using an angle plate, fixtures, a vice, holding between centers, or in a chuck—based on the workpiece's shape, size, and machining requirements to ensure stability and accuracy

Application of learning 2.3

you are requested to go to the manufacturing workshop and mount the work piece by applying the procedures of mounting work piece on milling machine by using work holding device methodes

Learning outcome 2 end assessment

Written assessment

Q1. The following are statements used in milling machine operations, answer by True if the statement is correct otherwise False if the statement is wrong.

i. A Shrink Fit Tool Holder uses thermal expansion to clamp the tool.
ii. The Weldon Shank Holder is commonly used for light-duty applications.
iii. Collet Chucks are not suitable for high-speed machining.
iv. Morse Taper Holders self-lock under cutting forces.
v. End Mill Holders use hydraulic pressure to secure the tool.

Q2. Ready the following statetment and choose the correct answer by writing the letter corresponding to the answer

I. Which cutter-holding device is ideal for holding small and precision tools?
   a) End Mill Holder
   b) Collet Chuck
   c) Milling Cutter Arbor
   d) Quick Change Tool Holder
II. What is the primary advantage of a Hydraulic Tool Holder?
   a) Low cost
   b) Excellent vibration damping
   c) High speed
   d) Easy maintenance
III. Which of the following is specifically designed to hold end mills?
   a) Morse Taper Holder
   b) End Mill Holder
   c) Shrink Fit Tool Holder
   d) Weldon Shank Holder
IV. What does a Milling Cutter Arbor primarily hold?
   a) Small drills
   b) Large cutting tools
   c) Precision tools
   d) Quick change tools
V. What is a key feature of the Quick-Change Tool Holder?
   a) It can only hold one type of tool.
   b) It is designed for heavy cutting.
   c) It uses hydraulic pressure.
   d) It allows fast tool changes

Q3. Ready carefully the following work holding method of milling machine found in column B and match With their appropriate application in column A by writing the answer in provided column of answers .

Answers	**Columun A**	**Column B**
………	1. Used for cylindrical workpieces needing accurate concentric machining.	A. Clamping to the table
………	2. Ideal for machining operations requiring the workpiece to be oriented at specific angles	B. Clamping to the angle plat
………	3. Common in operations where the entire surface of large, flat workpieces needs to be machined.	C. Clamping in fixture
………	4. Suitable for small to medium-sized workpieces with regular shapes	D. Holding in the vice
………	5. Ideal for round or irregularly shaped workpieces needing multi-axis machining.	E. Holding in a chuck
		F. Milling machine
		G. Drilling machine

Q4. Ready the following statements related to the factors that determine depth of cut adjustment and filling the gaps by using words which are in blacket (**dimension, cooling finishing, rigid, shallower).**

I. The hardness of the workpiece material affects the depth of cut; harder materials like steel require ______ depths of cut compared to softer materials.

II. Larger diameter cutting tools can handle greater depths of cut because they are more ______ and distribute cutting forces over a larger area.

III. In roughing operations, deeper cuts are used to remove material quickly, while ______ operations require shallower cuts for a smooth surface.

IV. Adequate ______ prevents overheating during deep cuts, allowing for more effective machining without damaging the tool.

V. When precision is critical, such as in finishing cuts, the depth of cut must be minimal to avoid overshooting the desired ______.

Practical assessment

UHN Ltd needs to maintain their machines, which includes fabricating shafts to replace damaged ones. You are requested to mount the workpiece in 5 milling machines within 2 hours by following the proper procedures for mounting a workpiece on the milling machine.

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Learning Outcome 3: Mill the Workpiece

Indicative contents
3.1 Carrying out Milling operations
3.2 Inspecting milled parts.
3.3 Finishing the milled part.

Key Competencies for Learning Outcome 3: Mill the Workpiece

Knowledge	Skills	Attitudes
• Identifying selection factors of surface finishing techniques.	• Executing milling operations. • Checking the accuracy of the milled part after milling operations • Applying milled parts inspection methods after milling machine operations • Applying surface Finishing techniques after milling machine operations	• Working on time while mill the workpiece • Working in team while mill the workpiece • Having self-confidence while mill the workpiece • Respect workshop rules and regulations while operating moiling machine

Duration: 60hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Execute properly the operations performed on milling machine.
2. Check correctly the accuracy of the milled part after milling operations.
3. Apply efficiently milled parts inspection methods after milling machine operations
4. Identify properly selection factors of surface finishing techniques after mill the work pieceApply efficiently surface Finishing techniques after milled workpiece.
5. Apply efficiently surface Finishing techniques after milled workpiece.

Resources

Equipment	**Tools**	**Materials**
● Plain milling machine ● Universal milling machine ● Vertical milling machine Fixed bed type milling machine ● Ram type milling, Turret type milling - Planer Type milling ● special type milling machine ● table type milling machine ● computer	● Arbor and support ● Plain milling cutter ● Side milling cutter ● Metal slitting saw ● Angle milling cutter ● End milling cutter ● 'T' – Slot milling cutter ● Fly cutter ● Formed cutter ● Vertical head - Horizontal head - Dividing head - Offset boring head ● Vertical Spindle Attachment ● Universal milling attachment	● Carbon and alloy steel ● High-speed steel (HSS) ● Steel bar.

• polishing machine • compressor • spray gun • Angle grinder	• Circular milling attachment • wrenches, • pliers.	

Indicative content 3.1: Carrying Out Milling Operations

Duration:30hrs

Practical Activity 3.1.1: Executing milling operations

Task:

1:You are requested to go to the manufacturing workshop and execute milling operations on milling machine according to the work to performed

2: Select and Wear appropriate PPEs related to the task.

3: Execute milling operations on milling machine

5: Present your work to the trainer and your classmates

6: Read the key readings 3.1.1

7: Perform the task provided in application of learning 3.1

Key readings 3.1.1: Executing milling operations

- **Perform milling operations.**
  - ✓ **Plain milling**

Steps for Performing Plain Milling Operations:

Step 1: **Preparation** of tools and milling machine**:** choose right milling cutter and ensure the milling machine is clean and in good codition

Step 2: Workpiece Setup: Use a vise or clamps to firmly hold the workpiece Use a vise or clamps to firmly hold the workpiece position the workpiece so that the cutter will engage the material at the desired location

Step 3: Machine Settings: Adjust the spindle speed and feed rate according to the material type and cutter specifications and determine the depth of cut based on the material and cutter capabilities.

Step 4: Safety Checks: Wear Personal Protective Equipment (PPE)

Step 5: Performing the Milling Operation: Turn on the milling machine and allow it to reach the set speed and slowly lower the cutter into the workpiece, ensuring a smooth and controlled entry.

Then Keep an eye on the operation, watching for any signs of excessive vibration, noise, or overheating.

Step 6: Finishing the Cut:

- Withdraw the Cutter: Once the desired depth and length of cut are achieved, raise the cutter from the workpiece.
- Turn Off the Machine: After completing the milling operation, turn off the machine and allow it to come to a complete stop.

Step 7: Post-Operation

- Inspect the Workpiece: Check the finished part for accuracy and surface finish.
- Clean the Work Area: Remove any chips and debris from the machine and surrounding area.
- Store Tools Properly: Clean and store the milling cutter and any other tools used during the operation.

✓ Keyway milling

Keyway milling is a specific milling operation used to cut a keyway (a slot or groove) into a workpiece, typically on shafts, pulleys, gears, or couplings. The keyway allows for the insertion of a key that secures the rotation of the parts and prevents slipping between connected components.

Steps for Performing Keyway Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: A vertical or horizontal milling machine is often used for keyway milling. For shafts, a horizontal milling machine may be preferred.
- **Install the workpiece**: Secure the workpiece, such as a shaft, onto the machine table or in a fixture (e.g., a V-block for cylindrical shafts). Ensure it is stable and aligned.
- **Choose the milling cutter**: A keyway milling cutter, such as an end mill or a slot cutter, is typically used. The cutter diameter should match the required keyway size.
- **Set machine parameters:** Determine the cutting speed, feed rate, and depth of cut based on the workpiece material and the cutter's specifications.

Step 2: Align the Workpiece:

- Position the workpiece to ensure the keyway will be milled in the correct location.
- For cylindrical parts, the center of the shaft must be accurately aligned with the cutter. Use a dial indicator or edge finder to ensure proper alignment.

Step 3: Position the Cutter:

- Set the depth of the cut by adjusting the vertical or horizontal movement of the milling cutter.
- Position the cutter so that it will engage the workpiece at the desired starting point for the keyway.

Step 4: Perform the Keyway Milling:

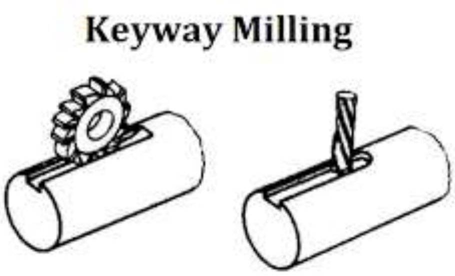
- Start the milling machine and engage the feed mechanism.
- Slowly feed the cutter into the workpiece along the length of the keyway. The keyway should have parallel sides and a flat bottom.
- Make successive passes if the keyway requires a greater depth, increasing the cut depth incrementally until the final depth is reached.

Step 5: Finishing:

- After the desired depth and width of the keyway are achieved, check the dimensions using a key or calipers**.**
- Make any final finishing passes to ensure the keyway is smooth and dimensionally accurate.

Step 6: Shut Down and Inspect:

- **Turn off the machine and remove the workpiece.**
- **Inspect the keyway for proper width, depth, and alignment, and check for burrs, which** may need to be deburred.



✓ Face milling

Face milling is a milling operation where the cutter's axis is perpendicular to the surface being machined. It is primarily used to produce flat surfaces and is one of the most common types of milling operations.

Steps for Performing Face Milling Operations:

Step 1: Preparation and Setup:

- Select the machine: Face milling can be performed on either vertical or horizontal milling machines, although vertical mills are more common.
- Install the workpiece: Secure the workpiece on the machine’s table using a vise, clamps, or fixtures. Ensure the workpiece is stable and won't move during machining.
- Choose the face mill cutter: A face mill cutter is used, which typically has multiple inserts to improve material removal efficiency. The cutter

diameter should be large enough to cover the surface area being milled.

- Adjust machine settings: Set the spindle speed, feed rate, and depth of cut based on the material being machined and the face mill cutter's size and type.

Step 2: Align the Workpiece:

- Ensure the workpiece is aligned so that the face mill will remove material uniformly across the surface.
- Use a dial indicator or other alignment tools to ensure the workpiece is parallel to the machine table.

Step 3: Position the Cutter:

- Move the milling table to position the workpiece under the face mill cutter.
- Set the initial depth of cut by adjusting the vertical position of the cutter.

Step4: Perform the Face Milling:

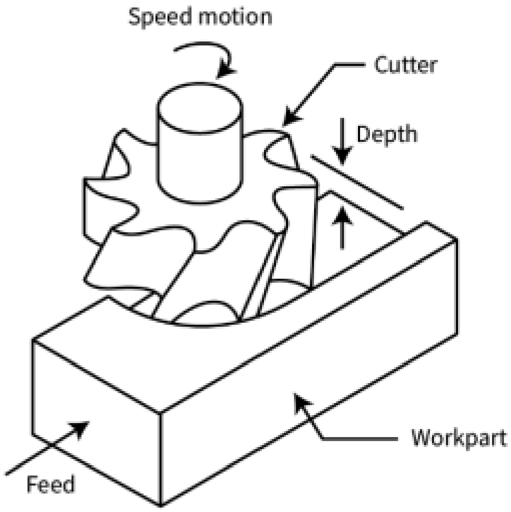
- Start the machine and engage the feed mechanism to move the table.
- The face mill cutter should engage the workpiece evenly. As the cutter rotates, it removes material from the surface, producing a flat finish.
- Multiple passes may be needed to achieve the desired surface finish or remove more material.

Step 5: Finishing:

- For better surface finish, reduce the feed rate or depth of cut on the final pass.
- Inspect the flatness and surface quality of the milled surface.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the flatness, surface finish, and overall dimensional accuracy of the face-milled surface.
- Deburr any sharp edges if necessary



✓ Side milling

Side milling is a milling operation in which the sides of a workpiece are machined using the peripheral cutting edges of the milling cutter. It is typically used for creating vertical or angled surfaces, grooves, or shoulders along the side of a workpiece.

Steps for Performing Side Milling Operations:

Step1: Preparation and Setup:

- **Select the machine**: Side milling is typically done on a horizontal milling machine, but can also be performed on a vertical machine using appropriate cutters.
- **Install the workpiece**: Secure the workpiece on the machine's table using a vise, clamps, or fixtures, ensuring that the side to be milled is accessible and aligned properly.
- **Choose the milling cutter**: A side milling cutter (either a plain side mill, an end mill, or a staggered-tooth cutter) is used. The cutter's diameter and width should match the requirements of the operation.
- **Adjust machine settings**: Set the spindle speed, feed rate, and depth of cut according to the material being machined and the dimensions of the cutter.

Step 2: Align the Workpiece:

- Ensure that the workpiece is properly aligned and that the side to be milled is perpendicular to the cutter.

- Use alignment tools like dial indicators to ensure precision.

Step 3: Position the Cutter:

- Position the cutter so it is aligned with the side of the workpiece where material needs to be removed.
- Set the initial depth of cut by adjusting the vertical position of the milling table or spindle, depending on the machine type.

Step 4: Perform the Side Milling:

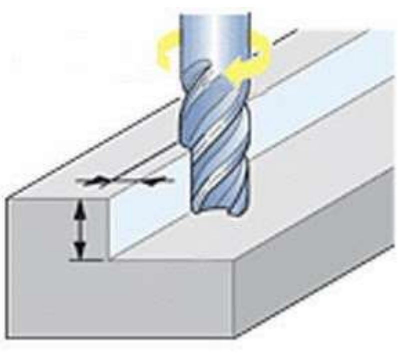
- Start the milling machine and engage the feed.
- Slowly feed the cutter into the side of the workpiece, ensuring consistent movement.
- The cutter removes material along the side of the workpiece, leaving a flat or angled surface.
- Multiple passes may be required for deeper cuts or to achieve the final dimensions.

Step 5: Finishing:

- After achieving the desired side profile, reduce the feed rate or depth of cut for a finishing pass to improve the surface finish.
- Check the dimensions and surface quality of the milled side.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the side surface for flatness, dimensional accuracy, and surface finish.
- Deburr any sharp edges or burrs that may have formed during machining.



✓ Straddle milling

Straddle milling is a special form of side milling where two cutters are mounted on an arbor to machine two parallel surfaces on opposite sides of the workpiece simultaneously. It is commonly used to produce symmetrical features such as grooves or shoulders on either side of a workpiece.

Steps for Performing Straddle Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Straddle milling is typically performed on a horizontal milling machine, which allows mounting two cutters on an arbor.
- **Install the workpiece**: Secure the workpiece firmly on the machine table using a vise, clamps, or fixtures. The workpiece should be centered so that the two cutters will cut both sides evenly.
- **Select the cutters**: Two side milling cutters are mounted on the same arbor, spaced apart to match the required distance between the two cuts. The cutter's diameter and width should correspond to the dimensions of the features being machined.
- **Adjust the machine settings**: Set the spindle speed, feed rate, and depth of cut according to the material and cutter specifications.

Step 2: Align the Workpiece:

- Proper alignment is crucial to ensure that the two parallel cuts are equidistant from the center of the workpiece.
- Use alignment tools such as a dial indicator to position the workpiece precisely relative to the cutters.

Step 3: Position the Cutters:

- Mount the two cutters on the arbor with spacers in between to set the required distance between the cuts.
- Position the cutters so that they are aligned with the sides of the workpiece where the material needs to be removed.

Step 4: Perform the Straddle Milling:

- Start the machine and engage the feed mechanism.
- Feed the workpiece under the cutters, allowing both cutters to remove material simultaneously from the two opposite sides.

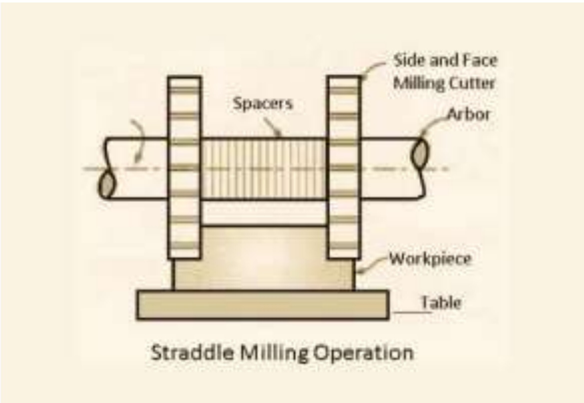
- Maintain a consistent feed rate to ensure uniform cutting on both sides of the workpiece.
- For deeper cuts, multiple passes may be needed, gradually increasing the depth of cut.

Step 5: Finishing:

- After machining both sides, check the dimensions and surface finish.
- Perform finishing passes with reduced depth of cut and feed rate if necessary to improve surface quality and dimensional accuracy.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Measure the distance between the two machined surfaces, ensuring the cuts are parallel and symmetrical.
- Deburr any sharp edges and check for any signs of tool marks or imperfections.



✓ Angular milling

Angular milling is a milling operation where the axis of the milling cutter is set at an angle other than 90° to the surface of the workpiece. This technique is used to machine angular surfaces, chamfers, grooves, or V-shaped profiles on a workpiece.

Steps for Performing Angular Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Angular milling can be done on both vertical and horizontal milling machines, depending on the orientation of the surface to be machined.
- **Install the workpiece**: Secure the workpiece on the machine table using a vise, clamps, or specialized fixtures, ensuring it's stable and won't move during the operation.
- **Choose the milling cutter**: Select a cutter suitable for angular cuts, such as an angular milling cutter, single-angle or double-angle cutter. The cutter angle should correspond to the desired angle of the machined surface.
- **Adjust the machine settings**: Set the spindle speed, feed rate, and depth of cut based on the material of the workpiece and the cutter specifications.

Step 2: Align the Workpiece:

- Position and align the workpiece so that the cutter will engage at the correct angle. You can tilt the workpiece on the milling table or adjust the milling head to the desired angle.
- Use an angular protractor, sine bar, or other alignment tools to ensure precise angular positioning.

Step 3: Position the Cutter:

- Move the milling table or head to position the cutter in the correct starting location.
- Set the depth of cut to match the amount of material to be removed from the workpiece at the desired angle.

Step 4: Perform the Angular Milling:

- Start the machine and engage the feed.
- Feed the cutter into the workpiece, ensuring consistent contact between the cutter and the angled surface.
- If necessary, perform multiple passes, gradually increasing the depth of cut until the desired profile or angle is achieved.

Step 5: Finishing:

- For better surface finish and higher precision, reduce the feed rate and depth of cut on the final pass.

- Check the workpiece for the correct angle, surface finish, and dimensional accuracy.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the angular surface using tools such as an angle gauge, protractor, or sine bar to verify the accuracy of the angle.
- Deburr the edges to remove any sharp or rough material left by the milling process.

Key Considerations:

- **Angle Accuracy**: Proper setup is critical to ensure the correct angle is achieved. Use precision tools like sine bars, angle plates, or protractors to set and verify the angle.
- **Tool Selection**: Select a milling cutter that corresponds to the angle of the cut. Single-angle or double-angle milling cutters are commonly used for angular milling operations.
- **Cutting Speed and Feed**: Adjust these parameters based on the material being machined and the cutter type to avoid tool wear and ensure a smooth cut.
- **Coolant**: Use coolant or lubrication to minimize heat buildup, improve the cutter's life, and achieve a smoother surface finish.

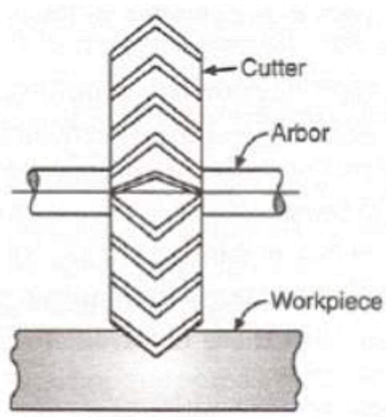
Types of Angular Milling:

- **Single-Angle Milling**: The cutter has one angular cutting edge, often used for creating chamfers or angular grooves.
- **Double-Angle Milling**: The cutter has two angular cutting edges, used for creating V-shaped profiles or grooves.
- **Compound Angle Milling**: Involves setting the workpiece and the cutter at different angles for machining complex surfaces.

Applications:

- **Chamfers and Bevels**: Angular milling is often used to machine chamfers, bevels, or tapered edges on parts.
- **Grooves and Slots**: Useful for creating angled grooves, V-grooves, or dovetail profiles.
- **Angular Surfaces on Complex Parts**: Used in the production of gears, molds, and precision components that require angular features.

• **Die and Toolmaking**: Frequently used in making cutting tools, dies, and jigs that require precise angles.



Angular milling

✓ Flute milling

Flute milling is a specialized milling operation used to machine helical grooves or flutes into cylindrical or tapered workpieces, such as drill bits, taps, reamers, or end mills. These flutes serve as channels for chip removal and coolant flow during cutting operations.

Steps for Performing Flute Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Flute milling is usually performed on a vertical or horizontal milling machine with a rotary attachment or dividing head to rotate the workpiece during milling.
- **Install the workpiece**: Secure the cylindrical or tapered workpiece, such as a drill blank or tool shaft, in a rotary fixture or indexing head, which allows precise rotation of the workpiece while milling.
- **Choose the milling cutter**: A cylindrical or helical end mill cutter is used. The cutter diameter should match the size and shape of the flute being machined. For straight or helical flutes, special flute milling cutters may also be employed.
- **Set machine parameters**: Determine the spindle speed, feed rate, and depth of cut based on the material being machined and the desired flute dimensions.

Step 2: Align the Workpiece:

- Align the workpiece to ensure that the flutes are positioned symmetrically and that the cutter will engage the workpiece at the correct point.
- Use an indexing head to rotate the workpiece at precise angles for each flute, ensuring even spacing around the circumference.

Step 3: Position the Cutter:

- Move the cutter into the correct position relative to the workpiece to begin machining the first flute.
- Set the depth of cut to match the desired depth of the flute. Multiple passes may be required to reach the final depth, especially in hard materials.

Step 4: Perform the Flute Milling:

  - Start the machine and engage the rotary attachment or dividing head to rotate the workpiece while feeding the cutter along the length of the workpiece.
  - The cutter will machine a helical or straight flute, depending on the setup.
  - After completing the first flute, index the workpiece to the next position and repeat the process to mill additional flutes.

- Adjust the depth and width of the cut in successive passes as necessary.

Step 5: Finishing:

- Once the flutes are machined, perform a finishing pass with reduced depth of cut and slower feed rate to improve surface finish and accuracy.
- Check the dimensions of the flutes, including width, depth, and helix angle, if applicable.

Step 6: shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the machined flutes for dimensional accuracy, surface finish, and uniformity.
- Deburr the edges to remove any burrs or sharp edges from the flutes.

Key Considerations:

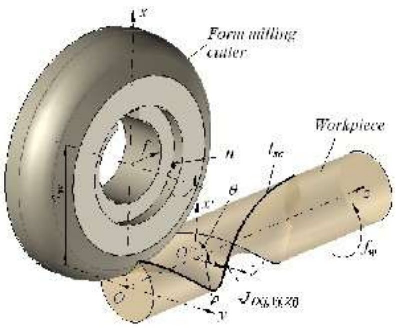
•**Cutter Selection**: The cutter must match the desired flute profile, whether straight or helical. Special flute cutters are used for manufacturing tools like drills or reamers.
•**Indexing**: Accurate indexing and rotation of the workpiece are crucial for even flute spacing around the circumference.
•**Cutting Speed and Feed**: These must be carefully controlled to avoid tool wear, especially when machining hard materials like tool steel.
•**Coolant**: Apply coolant to reduce heat buildup, improve surface finish, and prolong tool life, especially during deeper flute cuts.

Types of Flute Milling:

•**Straight Flute Milling**: Involves cutting straight grooves parallel to the axis of the workpiece. This is common for reamers and taps.
•**Helical Flute Milling**: Creates spiral or helical grooves, often used in cutting tools like drill bits and end mills. The helix angle determines the spiral's slope.
•**Tapered Flute Milling**: Machining flutes on tapered workpieces, such as tapered reamers or tapered end mills.

Applications:

•**Manufacturing Cutting Tools**: The most common application of flute milling is in the production of cutting tools such as drills, reamers, taps, and end mills. The flutes serve as channels for chip removal and coolant flow.
•**Screw Threads**: Helical flutes are also used in the production of taps and screws.
•**Machining Helical Grooves**: Used for creating grooves in components like shafts or screws where a spiral profile is required.



✓ **Gang milling**

Gang milling is a milling technique where multiple cutters are mounted on the same arbor or spindle and used simultaneously to perform multiple machining operations on a workpiece in a single pass. This method is highly efficient for mass production or when multiple surfaces need to be machined in a single setup.

Steps for Performing Gang Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Gang milling is typically performed on a horizontal milling machine that can accommodate multiple cutters on a single arbor.
- **Install the workpiece**: Secure the workpiece on the machine table using a vise, clamps, or specialized fixtures. Ensure it is stable and correctly positioned for all cutting operations.
- **Choose the cutters**: Select multiple milling cutters with different profiles, such as plain, side, and angular cutters, depending on the features to be machined. The cutters are spaced along the arbor to correspond with the specific surfaces or grooves to be machined.
- **Set machine parameters**: Determine the spindle speed, feed rate, and depth of cut based on the material of the workpiece and the types of cutters used.

Step 2: Align the Workpiece:

- Proper alignment is critical in gang milling because all cutters must engage the workpiece at the correct points simultaneously.
- Use alignment tools such as dial indicators to position the workpiece so that all surfaces to be machined are aligned with their respective cutters.

Step 3: Position the Cutters:

- Install the cutters on the arbor, spacing them with appropriate spacers and shims to match the distance between the surfaces or features to be machined.
- Ensure that each cutter is aligned with its corresponding feature on the workpiece.

Step 4: Perform the Gang Milling:

- Start the milling machine and engage the feed mechanism.
- The workpiece is fed beneath the cutters, and multiple surfaces are machined simultaneously. For example, one cutter could machine a flat

surface while another cutter simultaneously machines a groove or shoulder.

- Ensure a steady feed rate to allow smooth engagement of all cutters with the workpiece.
- For larger or deeper cuts, multiple passes may be required.

Step 5: Finishing:

- After completing the initial cuts, a finishing pass can be made with a reduced depth of cut to improve the surface finish.
- Check the accuracy of each machined surface and make any necessary adjustments for finishing.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect all machined surfaces, grooves, and features for dimensional accuracy, surface finish, and alignment.
- Deburr any sharp edges left from the milling process.

Key Considerations:

- **Cutter Selection**: The cutters must be chosen carefully based on the specific features to be machined. They should be spaced appropriately on the arbor to ensure proper engagement with the workpiece.
- **Arbor Setup**: Use correct spacers and shims between the cutters to ensure the proper distance between the machined features.
- **Cutting Speed and Feed**: These parameters should be optimized based on the material being machined and the combination of cutters to ensure smooth operation and to prevent tool wear or breakage.
- **Coolant**: Coolant is important to reduce heat buildup during gang milling, especially when multiple cutters are engaged at once.

Advantages of Gang Milling:

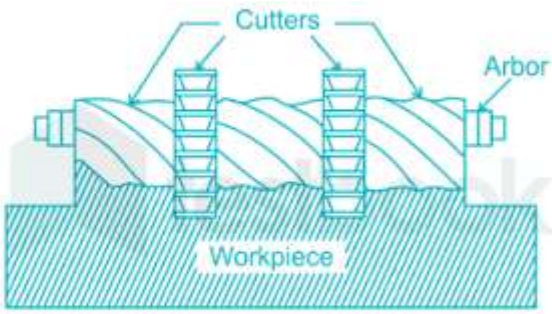
- **High Efficiency**: Multiple operations are performed simultaneously, reducing machining time and increasing production efficiency.
- **Consistency**: Machining multiple surfaces at once ensures consistency and parallelism between machined features.
- **Cost-Effective**: Gang milling reduces the need for multiple setups, making it more cost-effective for mass production.

Applications:

• **Production Environments**: Gang milling is commonly used in industries like automotive, aerospace, and machinery manufacturing, where mass production and efficiency are critical.
• **Complex Parts**: This method is ideal for machining complex parts with multiple surfaces, such as engine components or machine parts that require precise and simultaneous milling operations.
• **Simultaneous Slotting, Surfacing, and Grooving**: Gang milling can be used to machine multiple slots, grooves, and surfaces in a single pass, especially in parts that have repetitive or parallel features.

Types of Gang Milling:

• **Plain Gang Milling**: Involves the use of several plain cutters on a single arbor to machine flat surfaces.
• **Profile Gang Milling**: Combines various cutters to machine different profiles, such as T-slots or complex shapes, in one pass.
• **Combination Gang Milling**: Utilizes cutters with different shapes (plain, side, angular) to machine multiple surfaces with different geometries simultaneously.



Gang milling

✓ Cam milling

Cam milling is a specialized milling process used to machine cams, which are mechanical components used to convert rotary motion into linear motion or vice versa. Cams are commonly used in engines, automated machinery, and various mechanical systems to control movement.

Steps for Performing Cam Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Cam milling is often performed on a horizontal milling machine, but it can also be done on a vertical machine depending on the type of cam being produced.
- **Install the workpiece**: Secure the workpiece (the cam blank) on the machine table or a dividing head. A cam profile fixture or special attachment is used to hold the blank and rotate it as needed.
- **Choose the milling cutter**: A profile milling cutter or an end mill is typically used to cut the cam profile. The cutter size and shape must match the contour of the cam profile.
- **Adjust machine settings**: Set the spindle speed, feed rate, and depth of cut according to the material of the cam blank and the cutter specifications.

Step 2: Align the Workpiece:

- The cam blank should be positioned so that the milling cutter will follow the desired cam profile. Proper alignment is crucial for accurate cam geometry.
- Use a rotary fixture or cam milling attachment to position the workpiece correctly for each pass of the cutter.

Step 3: Position the Cutter:

- Move the cutter to the starting point of the cam profile. For a radial cam, this may be the outermost point of the cam's lobe.
- Set the depth of cut for the first pass, which will gradually shape the cam profile.

Step 4: Perform the Cam Milling:

- Start the machine and engage the feed.
- The rotary fixture or dividing head will rotate the cam blank while the cutter moves along the profile, removing material and shaping the cam lobe.

- Multiple passes may be required to complete the profile, especially for more complex cam shapes.
- Carefully follow the cam's designed contour, ensuring the milling operation produces the correct motion curve.

Step 5: Finishing:

- Once the cam profile is machined, perform a finishing pass with reduced depth of cut to refine the surface finish and ensure precision.
- For high-precision applications, further processes like grinding may be needed after milling to achieve the required surface quality and accuracy.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the cam blank.
- Inspect the cam profile using measurement tools like micrometers, calipers, or a profile projector to verify that the cam shape matches the design specifications.
- Deburr any sharp edges or burrs left from the milling process.

Key Considerations:

- **Profile Accuracy**: The cam profile must be milled with high precision, as even small deviations can affect the cam's performance. Proper fixture setup and accurate cutter path control are essential.
- **Cutter Selection**: The cutter must be chosen based on the type of cam and the material. Special profile cutters may be required for non-standard cam shapes.
- **Rotary Fixture**: The use of a rotary attachment or dividing head is essential to control the rotation of the cam blank and to ensure the cutter follows the cam profile precisely.
- **Cutting Speed and Feed**: These parameters should be optimized based on the material being machined and the cutter size to ensure a smooth finish and avoid tool wear.

Types of Cams Milled:

- **Radial (Disc) Cams**: These cams have a profile cut into the perimeter of a disc. The follower moves in a straight line as the cam rotates.
- **Cylindrical Cams**: These have a profile machined into the surface of a cylinder. The follower moves along the axis of the cylinder as it rotates.

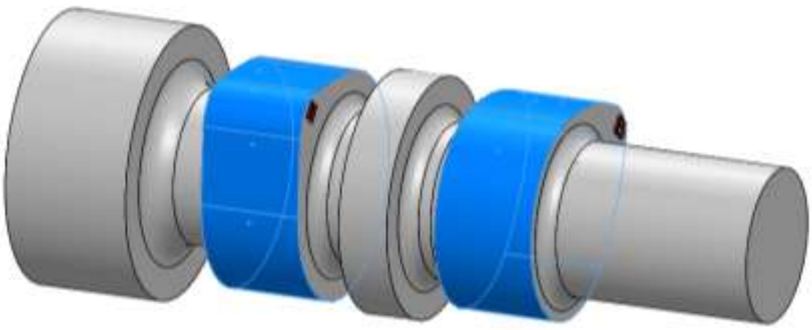
- **Plate (Flat) Cams**: These cams have a profile milled onto a flat surface, often used in linear motion applications.

Applications:

- **Automotive Engines**: Cams are essential components in internal combustion engines, where they control valve timing.
- **Automation and Robotics**: Cams are used to precisely control mechanical movements in automated systems and machinery.
- **Textile Machinery**: Cams are often used in textile machines to control needle or shuttle movement.
- **Press Tools and Punching Machines**: Used in applications where cyclic movement is required, such as in punch presses.

Advantages of Cam Milling:

- **Precision**: Cam milling allows for the accurate creation of cam profiles, which are crucial for controlling mechanical motion in machines.
- **Customization**: Complex cam profiles, including non-standard shapes, can be machined to meet specific design requirements.
- **Efficiency**: Multiple cams can be milled simultaneously with gang milling setups or specialized cam milling machines, improving productivity.



✓ **Form milling**

Form milling is a milling process used to create intricate or complex shapes and contours on a workpiece by using a specially shaped milling cutter. The cutter has a profile that corresponds to the desired contour, allowing the machine to produce curved surfaces, concave or convex shapes, and intricate profiles in a single pass.

Steps for Performing Form Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Form milling can be performed on both horizontal and vertical milling machines, but horizontal machines are more commonly used due to the flexibility of using various shaped cutters on the arbor.
- **Install the workpiece**: Secure the workpiece on the machine table using a vise, clamps, or fixtures, ensuring it's positioned for the milling cutter to engage the workpiece in the desired location.
- **Select the form cutter**: Choose a milling cutter with a specific form or profile that matches the shape you need to machine. Form cutters include concave, convex, gear cutters, and other specialized profiles.
- **Set machine parameters**: Adjust the spindle speed, feed rate, and depth of cut based on the material of the workpiece and the cutter specifications.

Step 2: Align the Workpiece:

- Ensure the workpiece is properly aligned so that the cutter can engage the surface in the correct position. This is critical for maintaining the accuracy of the desired form.
- Use precision tools like dial indicators to align the workpiece before machining.

Step 3: Position the Cutter:

- Mount the form cutter on the milling machine's arbor or spindle. The cutter should be positioned so that the profile cuts into the workpiece in the correct orientation.
- Set the depth of cut, which may vary depending on whether you're rough cutting or finishing the surface.

Step 4: Perform the Form Milling:

- Start the machine and engage the feed.
- Move the cutter along the workpiece, carefully following the contour or profile to be machined. For complex profiles, you may need to use multiple passes to achieve the final shape.

- Control the feed rate to ensure the cutter accurately follows the shape of the workpiece without creating unwanted deviations.

Step 5: Finishing:

- Once the form profile has been machined, perform a finishing pass to improve the surface quality. This typically involves reducing the depth of cut and slowing down the feed rate for a smoother finish.
- Inspect the form to ensure it meets the required dimensions and specifications.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the machined form using tools such as calipers, micrometers, or profile gauges to verify that the profile matches the design requirements.
- Deburr any sharp edges or clean up the surface as needed.

Applications of Form Milling:

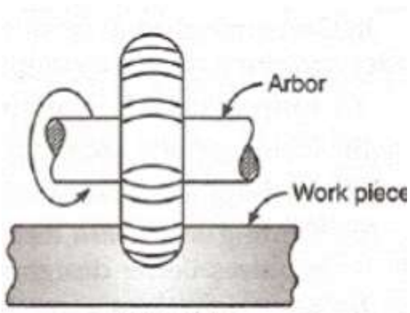
- **Gear Cutting**: Form milling is commonly used to cut gears by using form cutters with tooth profiles that correspond to the gear being produced.
- **Molds and Dies**: Used for machining molds, dies, and other parts that require complex or non-standard shapes.
- **Cams and Grooves**: Machining cam profiles or special grooves with precision.
- **Concave and Convex Surfaces**: Creating circular contours, either concave or convex, on a part.

Types of Form Cutters:

- Concave and Convex Cutters: These cutters are designed to machine concave or convex shapes into a workpiece.
- Gear Cutters: Specially designed to machine gear teeth with specific profiles.
- Chamfer Cutters: Used to mill angled edges or chamfers on parts.
- Special Profile Cutters: Customized cutters made to machine specific non-standard shapes.

Advantages of Form Milling:

• **High Precision**: Form milling allows for the accurate reproduction of intricate shapes and profiles.
• **Efficiency**: Complex profiles can be machined in a single pass, reducing the need for multiple setups.
• **Customization**: Special form cutters can be designed to match specific part profiles, making it ideal for custom or complex parts.



✓ Thread milling

Thread milling is a machining process used to create internal or external threads on a workpiece using a rotating cutter. This technique is especially useful for producing threads in materials that are difficult to tap, for achieving high precision, and for larger diameter threads. Thread milling can also be used for creating threads with varying pitches and profiles.

Steps for Performing Thread Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Thread milling is typically performed on a CNC milling machine. The machine should have the capability to control the movement of the cutter and workpiece accurately.
- **Install the workpiece**: Secure the workpiece on the machine table or in a vise, ensuring it is held firmly and aligned correctly for the threading operation.
- **Choose the thread mill cutter**: Select a thread mill cutter that matches the thread specifications (size, pitch, and profile) you need to create. Thread mills can have various designs, including single-form and multi-form options.

- **Set machine parameters**: Input the spindle speed, feed rate, and depth of cut based on the material of the workpiece and the specifications of the thread.

Step 2: Determine Thread Specifications:

- Define the desired thread specifications, including the thread type (e.g., metric, imperial), pitch, diameter, and depth.
- Ensure that the chosen cutter matches the thread specifications to achieve accurate threading.

Step 3: Align the Workpiece:

- Properly align the workpiece to ensure that the cutter engages the correct starting point for the threading operation. Use precision measuring tools if necessary.

Step 4: Perform the Thread Milling:

- Start the machine and engage the spindle.
- The thread milling process typically involves a helical motion, where the cutter moves in a circular path while simultaneously advancing along the axis of the hole or workpiece to create the thread profile.
- For multi-form cutters, multiple passes may be required to achieve the desired depth and profile, while single-form cutters may need to be repositioned for each pass.
- Monitor the operation to ensure the cutter maintains proper engagement with the material throughout the milling process.

Step 5: Finishing:

- After the initial threading is completed, perform any necessary finishing passes to achieve the desired thread quality and surface finish. This might include adjusting the feed rate or depth of cut to refine the thread.
- Inspect the threads visually and measure them with calipers or thread gauges to ensure they meet specifications.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the machined threads for dimensional accuracy, profile, and surface finish using appropriate measuring tools.

- Deburr any sharp edges or clean up the surface if needed.

Key Considerations:

- **Cutter Selection**: Choosing the correct thread mill cutter is critical. The cutter must match the desired thread type, diameter, and pitch.
- **Thread Pitch**: Understand the difference between fine and coarse pitches, as this will affect the cutter selection and machining parameters.
- **Cutting Parameters**: Optimize spindle speed, feed rate, and depth of cut based on the workpiece material to ensure efficient and precise threading.
- **Coolant**: Use cutting fluid or coolant to reduce heat and improve surface finish, especially when machining harder materials.

Types of Thread Mills:

- **Single-Form Cutters**: These create threads by moving in a helical path. They typically require a repositioning of the cutter for each pass.
- **Multi-Form Cutters**: These can create threads in one pass and are designed to produce multiple thread forms simultaneously, increasing efficiency.
- **Tapered Thread Mills**: Used for creating tapered threads, commonly found in pipe threads and certain mechanical applications.

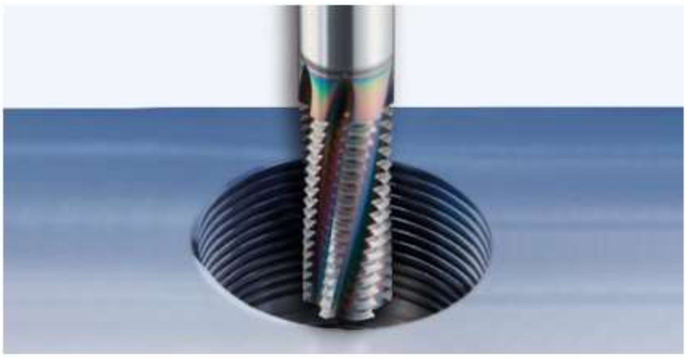
Applications:

- **Automotive and Aerospace**: Thread milling is used for creating precision threads in critical components such as engine parts and landing gear.
- **Tooling and Fixtures**: Used in the production of custom tooling and fixtures where specific thread dimensions are required.
- **General Manufacturing**: Suitable for producing threads in various industrial applications, including fasteners and connectors.

Advantages of Thread Milling:

- **Versatility**: Thread milling can create a wide variety of thread types and sizes, including both internal and external threads.
- **Precision**: Offers high accuracy and control, especially for threads with tight tolerances or unique profiles.
- **Material Compatibility**: Particularly effective for machining difficult materials, including hard metals and composites.
- **Reduced Tool Wear**: Thread mills tend to have longer tool life compared to taps, especially when working with challenging materials.

External thread milling operation



Internal Thread milling operation

✓ **Drilling & reaming**

Drilling and reaming are two common machining operations used to create holes in a workpiece. While both processes involve removing material to form holes, they serve different purposes and utilize different tools. Here's an overview of each process, along with the steps involved.

Drilling is the process of creating a cylindrical hole in a workpiece using a rotating drill bit. It is often the first step in creating a hole and can produce holes of various diameters and depths.

Steps for Performing Drilling Operations:

Step 1: **Preparation and Setup**:

- **Select the machine**: Drilling is typically performed on a drill press, milling machine, or CNC machine.
- **Install the workpiece**: Secure the workpiece in a vise or fixture, ensuring it is aligned correctly for the drilling operation.
- **Choose the drill bit**: Select a drill bit that matches the desired hole diameter and depth. Drill bits come in various types, such as twist bits, spade bits, and flat bits.

Step 2: **Determine Hole Specifications**:

- Define the hole diameter, depth, and position on the workpiece.
- Mark the center point of the hole using layout tools or center punches to guide the drill bit.

Step 3: Align the Workpiece: Ensure the workpiece is properly aligned to facilitate accurate drilling. Use measuring tools to double-check positioning.

Step 4: Perform the Drilling:

- Start the drilling machine and engage the drill bit.
- Slowly feed the drill bit into the workpiece while maintaining pressure to keep the bit cutting efficiently.
- Monitor the drilling operation to ensure the bit is cutting straight and that there are no issues, such as binding or excessive heat.

Step 5: Finishing the Drilling:

- Once the hole is drilled to the desired depth, withdraw the drill bit from the hole carefully.
- Remove any chips or debris from the hole and surrounding area.

Step 6: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the drilled hole for diameter, depth, and surface finish. Use calipers or gauges to verify the dimensions.

Key Considerations for Drilling:

- **Cutting Speed and Feed Rate**: Adjust these parameters based on the material being drilled and the drill bit size.
- **Coolant**: Use cutting fluid to reduce heat and improve the surface finish, especially when drilling hard materials.
- **Drill Bit Wear**: Monitor drill bit condition, as worn bits can lead to inaccurate holes and poor surface finishes.

✓ **Reaming**

Reaming is a finishing operation that enlarges and refines the diameter of an already drilled hole. It improves the hole's accuracy, surface finish, and ensures a tighter tolerance.

Steps for Performing Reaming Operations:

Step 1: Preparation and Setup:

- **Select the machine**: Reaming is typically performed on a drill press, milling machine, or CNC machine.
- **Install the workpiece**: The workpiece must be securely clamped, just as with drilling. Ensure it is positioned for easy access to the drilled hole.
- **Choose the reamer**: Select a reamer that matches the desired final hole diameter and type (e.g., straight, tapered, or adjustable).

Step 2: Check Drilled Holes: Ensure the drilled hole is within the acceptable tolerance range for reaming. The hole should be slightly smaller than the reamer's diameter for effective material removal.

Step 3: Align the Workpiece: Confirm that the workpiece is aligned correctly so the reamer will enter the hole straight, which is essential for achieving accurate dimensions.

Step 4: Perform the Reaming:

- Start the machine and engage the reamer.
- Slowly feed the reamer into the hole. Unlike drilling, reaming typically uses a slower feed rate and higher spindle speed to create a smooth surface finish.
- Maintain consistent pressure, allowing the reamer to cut smoothly without excessive force.

Step 6: Finishing the Reaming:

- Withdraw the reamer carefully once the desired depth and finish are achieved.
- Remove any chips or debris from the hole.

Step 7: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the reamed hole for diameter, surface finish, and accuracy. Use appropriate measuring tools to verify dimensions.

Key Considerations for Reaming:

- **Reamer Selection**: Ensure the reamer matches the required hole specifications and is suitable for the material being machined.
- **Cutting Speed and Feed Rate**: Use lower feed rates compared to drilling to prevent chatter and ensure a smooth finish.

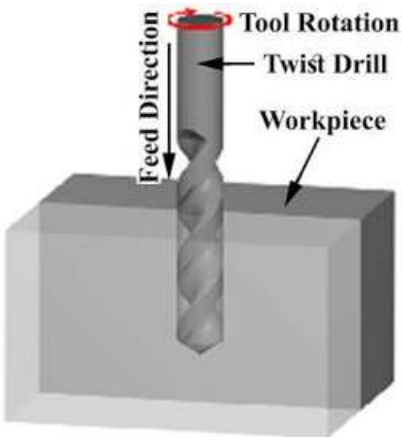
- **Lubrication**: Applying cutting fluid can help reduce friction and improve surface finish during reaming.

Applications of Drilling and Reaming:

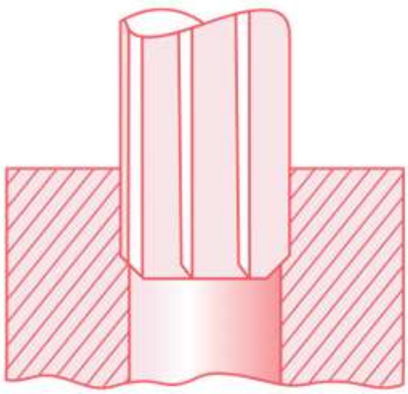
- **Manufacturing**: Used extensively in machining processes for creating holes in parts for assembly, such as fasteners and connections.
- **Automotive**: Drilling and reaming operations are vital in engine component manufacturing and assembly.
- **Aerospace**: Precision holes are often required in aircraft components for weight reduction and performance.
- **General Engineering**: Commonly used for creating holes in various materials, including metals, plastics, and composites.

Advantages of Drilling and Reaming:

- **Precision**: Reaming allows for tight tolerances and improved surface finish, while drilling provides efficient material removal.
- **Versatility**: Both processes can be used on various materials and in different applications.
- **Efficiency**: Drilling is an efficient way to create holes quickly, while reaming enhances the accuracy and quality of the hole.



Drilling Operation



Reaming operation

✓ **End milling**

End milling is a machining process that uses a rotating cutter called an end mill to remove material from the surface of a workpiece. This technique is versatile and widely used for various milling operations, including creating flat surfaces, slots, profiles, and complex geometries. End mills can cut in both the axial and radial directions, making them suitable for a range of applications.

Steps for Performing End Milling Operations:

Step 1: Preparation and Setup:

- **Select the machine**: End milling is commonly performed on vertical milling machines or CNC milling machines.
- **Install the workpiece**: Secure the workpiece onto the machine table using a vise, clamps, or fixtures, ensuring it is held firmly and correctly aligned for the milling operation.
- **Choose the end mill**: Select an end mill based on the desired cutting action (e.g., square end, ball end, or corner radius) and the material being machined. The diameter of the end mill should match the required features on the workpiece.

Step 2: Determine Milling Specifications: Define the desired features to be machined, including dimensions, shapes, and tolerances. And mark reference points on the workpiece if necessary to guide the milling operation.

Step 3: Align the Workpiece: Ensure the workpiece is aligned correctly to achieve the desired cutting path. Use precision measuring tools, such as dial indicators, to verify alignment.

Step 4: Set Cutting Parameters:

- Input the spindle speed, feed rate, and depth of cut based on the material of the workpiece and the specifications of the end mill.
- Typically, a slower feed rate is used for harder materials, while a faster rate can be used for softer materials.

Step 5: Perform the End Milling:

- Start the milling machine and engage the end mill.
- Move the end mill into the workpiece, following the programmed or planned path to remove material. The cutter can be fed horizontally, vertically, or at angles, depending on the desired profile.
- Monitor the operation to ensure the cutter is engaged correctly and that there are no issues, such as excessive vibration or tool wear.

Step 6: Finishing:

- After the initial milling is completed, perform any finishing passes if required. Adjust the feed rate or depth of cut for finishing to achieve the desired surface quality.
- Inspect the machined features to ensure they meet the required dimensions and tolerances.

Step 7: Shut Down and Inspect:

- Turn off the machine and remove the workpiece.
- Inspect the machined features using measuring tools like calipers or micrometers to verify accuracy and surface finish.
- Clean any chips or debris from the workpiece and machine area.

Key Considerations:

- **Cutter Selection**: The end mill type (e.g., standard, ball end, or corner radius) should be chosen based on the desired shape and finish of the workpiece.
- **Cutting Speed and Feed Rate**: Adjust these parameters based on the material being machined and the end mill specifications for optimal performance and tool life.
- **Coolant Use**: Utilize cutting fluids or coolants to reduce heat and improve surface finish, particularly when machining harder materials.

Types of End Mills:

- **Square End Mills**: Used for producing flat surfaces and sharp corners.
- **Ball End Mills**: Ideal for creating curved surfaces and complex shapes.
- **Corner Radius End Mills**: Combine the features of square and ball end mills, allowing for slightly rounded corners.
- **Tapered End Mills**: Used for machining angled surfaces and features.
- **Multi-Flute End Mills**: Typically have more cutting edges, allowing for faster material removal and better surface finishes.

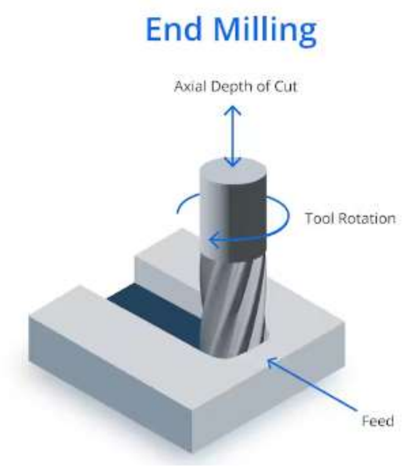
Applications:

- **Machining**: Used for milling operations in various industries, including automotive, aerospace, and general manufacturing.
- **Tool and Die Making**: Commonly used for creating molds, dies, and tooling components.

- **Fabrication**: Suitable for producing custom parts and components with precise dimensions.

Advantages of End Milling:

- **Versatility**: Capable of performing a wide range of milling operations, including contouring, slotting, and profiling.
- **Precision**: Provides high accuracy and surface finish, especially with finishing cuts.
- **Tool Life**: End mills can be reused multiple times with proper maintenance and cutting conditions.



✓ **Gear cutting**

Gear cutting is a specialized machining process used to produce gears, which are mechanical components that transfer motion and torque between machines. There are several methods for cutting gears, with the most common being **hobbing**, **shaping**, **milling**, and **grinding**. Each method is suited for different types of gears and applications.

Methods of Gear Cutting

- **Gear Hobbing**:

  - **Process**: Gear hobbing involves using a specialized cutting tool called a hob, which has a series of teeth that cut the gear profile as it rotates. The hob and workpiece are fed together, allowing for continuous cutting.

Applications: Commonly used for creating spur gears, helical gears, and worm gears. It's suitable for high-volume production due to its efficiency.

Advantages:

- Fast production rates.
- Can produce complex gear shapes.
- Capable of cutting multiple gears in one setup.

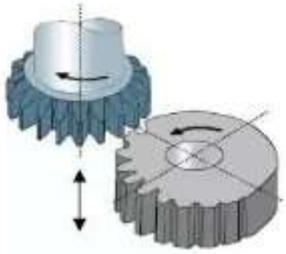
- **Gear Shaping**:

Process: Gear shaping uses a reciprocating cutter that moves in a linear motion, cutting the gear teeth as it shapes the workpiece. The cutter is usually mounted on a vertical spindle, and the workpiece is rotated incrementally to cut each tooth.

Applications: Ideal for internal gears and complex profiles, such as those found in planetary gear systems.

Advantages:

- Can cut internal gears and splines.
- Provides a high degree of accuracy and finish.
- Suitable for a wide range of gear sizes.



GEAR SHAPING PROCESS

- **Gear Milling**:

Process: In gear milling, a rotating cutter removes material from the workpiece to form gear teeth. This method can involve various types of milling machines and tools, including end mills and specialized gear cutters.

Applications: Used for producing gears with less complex shapes, such as spur gears and bevel gears.

Advantages:

- Versatile; can produce various gear types and profiles.
- Allows for detailed control over the cutting process.

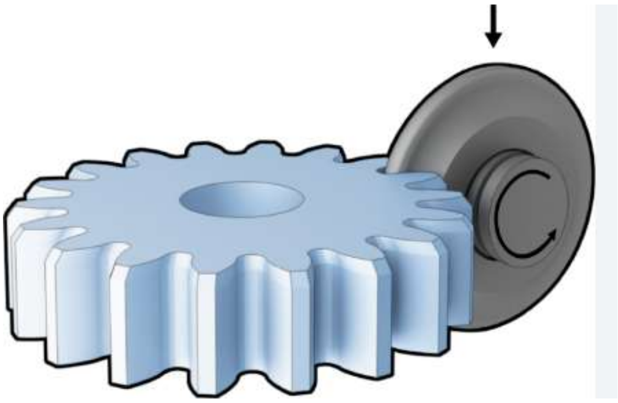
- **Gear Grinding**:

Process: Gear grinding involves using a grinding wheel to refine the gear teeth after they have been cut by other methods. This process improves the surface finish and accuracy of the gear.

Applications: Often used for high-precision gears, such as those in aerospace and automotive applications, where tolerances are critical.

Advantages:

- Produces very smooth surfaces and tight tolerances.
- Ideal for hard materials and finished gears.



Steps for Gear Cutting (Hobbing Example)

Step 1: Preparation and Setup:

- Select the machine: Choose a gear hobbing machine capable of handling the gear size and specifications.
- Install the workpiece: Secure the workpiece (gear blank) on the machine's work table using appropriate fixtures.
- Choose the hob: Select a hob that matches the gear specifications, including the number of teeth, pitch, and tooth profile**.**

Step 2: Set Machine Parameters: Input the correct spindle speed, feed rate, and depth of cut based on the material and gear specifications. And ensure the machine is calibrated and properly aligned to avoid inaccuracies.

Step 3: Start the Cutting Process

Begin the machine operation and engage the hob with the workpiece. And feed the workpiece and hob together, allowing the hob to cut the gear teeth progressively.

Step 4: Monitor the Process: watch for signs of tool wear or abnormalities during cutting.

And adjust machine settings if necessary to maintain cutting quality.

Step 5: Finishing and Inspection: After the gear is cut, check the surface finish and dimensions to ensure they meet specifications. And remove any burrs or sharp edges, and inspect the gear for any defects.

Step 6: Shut Down and Clean: Turn off the machine and remove the finished gear. And Clean the work area and inspect the machine for maintenance needs.

✓ **Boring**

A **boring operation** on a **milling machine** involves enlarging an existing hole with a single-point cutting tool. Unlike drilling, which creates a hole, boring refines or enlarges a hole to achieve precise diameters and tight tolerances. This operation can be used to correct errors in drilled holes, such as misalignment or size inaccuracy, or to create specific internal contours.

Key Aspects of Boring **on a Milling Machine:**

- **Tooling**:
  - A **boring head** or **boring bar** is used, typically held in the spindle of the milling machine.
  - The cutting tool, usually a single-point tool, is adjustable to achieve the desired diameter.
- **Workpiece**:
  - The workpiece is usually clamped to the machine's table.
  - The hole to be bored must already exist (either drilled or cast).
- **Precision**:
  - Boring is known for its precision. It's commonly used when tight tolerances and accurate hole geometry are required.
  - The operator can adjust the boring tool incrementally to get the exact diameter.
- **Boring Types**:
  - **Line Boring**: Creating or enlarging holes in multiple parts along a straight axis.

- **Back Boring**: Boring in reverse to access areas where traditional boring might not be possible.
- **Depth Control**:
  - The depth of the cut is controlled by the vertical movement of the milling machine's spindle.
- **Applications**:
  - Engine cylinder boring.
  - Precision hole enlargement in molds and fixtures.
  - Refining or resizing holes after casting or drilling.

Points to Remember

- It is necessary to know that, the specific details of each step may vary depending on the workpiece, machining operation, and the milling machine being used.
- Always prioritize safety, precision, and adherence to the machining requirements.

Application of learning 3.1.

Go to the manufacturing workshop and perform at least 4 different operations (plain milling , keyway milling, side milling and end milling)on milling.

Indicative content 3.2: Inspecting Milled Parts.

Duration: 20hrs

Practical Activity 3.2.1: Checking the accuracy of the milled part

Task:

1: You are requested to go to the manufacturing workshop check the accuracy of the milled part by applying milled parts inspection methods according to the work to performed

2: Select and Wear appropriate PPEs related to the task.

3: check the accuracy of the milled part by applying milled parts inspection methods.

5: Present your work to the trainer and your classmates

6: Read the key readings 3.2.1

7: Perform the task provided in application of learning 3.2

Key readings 3.2.1: Checking the accuracy of the milled part

- **Check the accuracy of the milled part**
  Inspecting milled parts is a critical process to ensure that they meet the required specifications, tolerances, and overall quality. Here's a breakdown of each aspect, the accuracy of a milled part refers to how closely it matches the design specifications. This includes both dimensions and geometric tolerances. To verify this, precision measuring tools and instruments are commonly used.

  ✓ **Surface finish**

  The surface finish measures the texture of the part's surface and is important for both functional and aesthetic reasons.

  It can be inspected by:

  - **Surface Roughness Tester**: This device measures the roughness (Ra value), which should be within the specified range.

- **Visual Inspection**: For surface defects such as scratches, burrs, or tool marks.
- **Tactile Inspection**: Feeling the part for any irregularities.

✓ **Dimensions**

Dimensional accuracy ensures that the part conforms to its design size specifications. To check dimensions:

- Varnier calipers and micrometers: For precise measurements of thickness, width, and length.
- Height Gauges: For vertical measurements.
- Coordinate Measuring Machine (CMM): This is used for highly precise 3D measurements to inspect complex shapes and profiles.

✓ **Tolerance**

Tolerances indicate the allowable deviation from the nominal dimensions. Precision measuring instruments are used to check whether the part falls within the upper and lower limits of these tolerances.

- **Go/No-Go Gauges**: These can be used for quick tolerance verification.
- **CMM or Laser Scanners**: For parts with very tight tolerances.

✓ **Geometry**

The geometric tolerances refer to the form, orientation, and location of features on the part. Inspection tools and methods include:

- **CMM**: To check for geometric parameters like flatness, roundness, perpendicularity, and parallelism.
- **Optical Comparators**: For inspecting contours and geometrical profiles.
- **Profile Projectors**: Used for assessing complex shapes and angles.

✓ **Feature Alignment**

Feature alignment checks whether critical features (such as holes, slots, or protrusions) are correctly positioned in relation to each other. For this:

- **CMM** or **optical measurement systems**: These can check for positional accuracy and alignment of features with high precision.
- **Dial Indicators**: For checking alignment and straightness.

- ✓ **Edge Quality**

Edge quality ensures that there are no unwanted burrs, sharp edges, or imperfections that could affect functionality or safety. Techniques include:

- **Visual Inspection**: Using magnifying tools or microscopes.
- **Finger Test**: Feeling the edges to detect burrs.
- **Deburring Tools**: Sometimes used post-inspection to remove minor defects.

- **Apply milled parts inspection methods.**

Applying milled parts inspection methods involves a series of checks to ensure that the parts meet the required specifications and quality standards. Here's how you can approach each method:

- ✓ **Conduct Visual inspection**

Visual inspection is a method of quality control in which the surface and appearance of a product, part, or material are examined with the naked eye or using basic magnification tools to identify defects, irregularities, or deviations from standards. It is one of the simplest and most cost-effective inspection methods, often serving as the first line of defense in detecting problems during manufacturing, construction, or maintenance processes.

Visual inspection has objective of Identify any surface defects, cracks, scratches, or other visible issues.

Tools and equipment: Naked eye or magnifying equipment such as magnifying glasses, borescopes, or microscopes.

Steps for conducting visual inspection:

- Inspect the entire surface of the milled part for scratches, cracks, dents, or material inconsistencies.
- Look for signs of incorrect machining, such as burrs or sharp edges that may need further finishing.
- Ensure that there are no obvious defects like chips or corrosion.

- ✓ **Dimensional inspection**

Verify that the part meets specified dimensions within tolerance.

Tools: Calipers, micrometers, height gauges, coordinate measuring machines (CMM), or optical comparators.

Steps for dimensional inspection:

- Measure all critical dimensions as per the engineering drawing.
- Compare measured values to the tolerances specified on the blueprint or design documentation.
- Record results for quality control purposes and check for consistency across multiple parts.

✓ **Geometric Dimensioning and Tolerance (GD&T) Inspection**

The objective is to ensure the part conforms to the geometric constraints specified by GD&T symbols on the drawing.

Tools: CMMs, height gauges, and other precision measuring instruments.

Steps for Geometric Dimensioning and Tolerance (GD&T) Inspection:

- Check geometric features like flatness, roundness, perpendicularity, parallelism, and position.
- Use the GD&T symbols on the engineering drawings to determine how each feature needs to be inspected.
- Measure the actual position and orientation of features like holes, slots, or surfaces, and ensure they meet the specified tolerances.

✓ **Surface Finish Inspection**

The objective is to assess the roughness and quality of the surface finish to meet the required specifications.

Tools: Surface roughness testers, profilometers, or tactile sensors.

Steps for Surface Finish Inspection:

- Measure the surface roughness using a roughness tester (often in terms of Ra, Rz, etc.).
- Compare the surface finish to the required specifications, which are often listed in micrometers or microinches.
- Visual inspection can also identify areas that appear to have inconsistent surface textures or finishes.

✓ **Functionality Testing**

The objective is to confirm the part performs as intended in its application.

Tools: Depends on the part's function, but could include jigs, fixtures, or simulation tools.

Steps for functionality testing:

- Test the part in a fixture or assembly to ensure it fits and functions as expected.
- Simulate real-world conditions, if possible, to assess the part's functionality under load or movement.

Evaluate the part for wear resistance, durability, or other specific performance requirements based on the end-use.

Points to Remember

- After milling machine operation, it is necessary to make the inspections methods of milled because is crucial to ensure that it meets the required specifications and functionality test.
- It is necessary to check the accuracy of a milled part because is crucial to ensure that it meets the required specifications and tolerances.

Application of learning 3.2

In the study visit organized by your trainer to local machining area where there are milled parts, you are requested to perform the following :

1. Check the accuracy of milled parts
2. Applyling milled parts inspection methods

Indicative content 3.3: Finishing the Milled Part.

Duration: 10hrs

Theoretical Activity 3.3.1: Identification of selection factors of surface finishing

Tasks:

1: Answer the following questions related to finishing techniques.

I. What are the factors to consider when choosing surface finishing methods?

2. Provide the answer for the asked questions and write them on papers.
3. Present the findings/answers to the whole class
4. For more clarification, read the key readings 3.3.1. and ask questions where necessary
5. Perform the task provided in application of learning 3.3

Key readings 3.3.1.: Identify selection factors of surface finishing techniques.

- **Several factors influence the selection of surface finishing techniques. Some of the key selection factors include**

✓ **Material type**

- **Metal**: Aluminum, steel, titanium, etc., each has specific finishing techniques that work best. For example, anodizing is commonly used for aluminum, while electroplating is often used for steel.
- **Plastic**: Plastics may require finishing techniques like polishing or coating for improved aesthetics and performance.
- **Hardness**: Harder materials may require more abrasive finishing methods, like grinding or sandblasting.

✓ **Desired Surface Finish**

- **Roughness**: The required level of smoothness (measured in Ra, for example) will influence whether you use polishing, grinding, or other techniques.
- **Aesthetic**: If the part needs a high-quality visual finish, techniques like buffing, painting, or plating may be preferred.

- **Texture**: Some parts require a specific texture, whether rough or smooth, which could be achieved using processes like sandblasting or bead blasting.

  - ✓ **Part function and application**

- **Mechanical Properties**: Surface treatments may be chosen to improve mechanical properties like hardness, wear resistance, or friction reduction (e.g., case hardening or nitriding for steel).
- **Corrosion Resistance**: If the part will be exposed to harsh environments, techniques like anodizing, galvanizing, or powder coating can protect against corrosion.
- **Electrical Conductivity**: Some finishes (e.g., gold plating) are used to enhance electrical conductivity, important for electrical components.
- **Chemical Resistance**: Parts exposed to chemicals may require finishing techniques that provide resistance, such as chemical coatings or plating.

  - ✓ **Dimensional Tolerance**

- **Post-Finishing Tolerance**: Some finishing processes remove material (e.g., grinding, polishing), which can affect dimensional tolerances. Consider whether the finishing process will alter critical dimensions.
- **Precision Requirements**: If the part has tight tolerances, processes like electropolishing or chemical polishing might be better suited than abrasive techniques.

  - ✓ **Production Volume**

- **Mass Production**: For large-scale production, cost-effective and quick processes like vibratory finishing or tumbling may be chosen.
- **Prototyping/Low Volume**: For small production runs, more precise or labor-intensive techniques such as manual polishing or selective coating might be used.

  - ✓ **Environmental and safety considerations**

- **Environmental Impact**: Some finishing processes, like electroplating, may involve hazardous chemicals, which could be restricted by environmental regulations.
- **Health and Safety**: Processes like sandblasting can generate harmful dust or fumes, requiring special safety measures.

  - ✓ **Time Constraints**

- **Process Time**: Certain finishing techniques take longer than others. For example, anodizing and plating may require more time due to multiple steps, while mechanical polishing or grinding might be faster.
- **Lead Time**: Consider the turnaround time for outsourced finishing processes, which could affect production schedules.

  ✓ **Surface Hardening (if needed)**

Wear Resistance**:** Processes like carburizing, nitriding, or hard chrome plating are chosen when wear resistance is critical for part longevity.

  ✓ Coating Adhesion and Compatibility

- **Adhesion**: Ensure that the finishing technique adheres well to the material. For example, anodizing works well with aluminum but not with steel.
- **Coating Compatibility**: If multiple coatings are applied (e.g., primer, paint, or sealant), compatibility between layers must be considered.

Practical Activity 3.3.1: Applying surface Finishing techniques

Task:

1: You are requested to go in manufacturing workshop and apply surface finishing techniques after milling operations

2: Select and Wear appropriate PPE related to the task.

3: Apply surface finishing techniques after milling operations

5: Present your work to the trainer and your classmates

6: Read the key readings 3.3.1

7: Perform the task provided in application of learning 3.3

Key readings 3.3.2: Applying surface Finishing techniques

- **Finishing the milled part**

✓ **Apply surface Finishing techniques**

- **Deburring**

Deburring is the process of removing burrs, which are small, unwanted projections or sharp edges left on a material after machining processes like milling, drilling, or cutting. Burrs can affect the functionality, safety, and aesthetics of a part, making deburring a crucial step in finishing.

Common Deburring Methods:

1. **Manual Deburring**
   - **Tools**: Files, deburring blades, sandpaper, or abrasive pads.
   - **Process**: Operators manually remove burrs using hand tools to smoothen rough edges or surfaces.
   - **Advantages**: Simple, inexpensive, and effective for small batches or complex parts.
   - **Disadvantages**: Time-consuming, inconsistent results, and requires skilled labor.
2. **Mechanical Deburring**
   - **Tumbling/Vibratory Finishing**: Parts are placed in a barrel with abrasive media that polishes the edges through vibration or rotation.
     - **Advantages**: Suitable for large batches and complex shapes.
     - **Disadvantages**: Less precise and may not reach deep or fine areas.
   - **Grinding/Sanding**: Abrasive wheels, belts, or discs are used to grind off burrs.
     - **Advantages**: Fast and efficient for removing large burrs.
     - **Disadvantages**: May be too aggressive for delicate parts.
3. **Thermal Deburring**
   - **Process**: Parts are exposed to a controlled burst of heat or combustion, which vaporizes the burrs without affecting the part itself.

- **Advantages**: Efficient for small, internal burrs that are difficult to reach.
- **Disadvantages**: Expensive and requires specialized equipment.

4. **Electrochemical Deburring (ECD)**
   - **Process**: A cathode tool is placed near the burrs, and a small electrical current is passed through an electrolyte solution, dissolving the burrs.
   - **Advantages**: Precise and excellent for removing burrs in hard-to-reach areas.
   - **Disadvantages**: Expensive and used primarily for high-precision applications.
5. **Cryogenic Deburring**
   - **Process**: Parts are exposed to extremely cold temperatures using liquid nitrogen, making the burrs brittle and easy to remove with light mechanical action.
   - **Advantages**: Ideal for removing burrs from soft materials like plastic or rubber.
   - **Disadvantages**: Specialized equipment and high cost.
6. **Brush Deburring**
   - **Process**: Abrasive brushes are used to scrub away burrs, often in automated systems.
   - **Advantages**: Gentle, suitable for delicate parts, and offers good control over the deburring process.
   - **Disadvantages**: May not be effective for large or tough burrs.

Factors for Selecting a Deburring Method:

1. **Material Type**: Different materials (e.g., metals, plastics) require different deburring methods.
2. **Size and Shape of Burrs**: Large, thick burrs may need grinding, while small, internal burrs may be better suited for thermal or electrochemical deburring.
3. **Complexity of the Part**: Intricate or fragile parts may need more controlled and precise deburring methods, like electrochemical or cryogenic deburring.
4. **Batch Size**: For high-volume production, automated processes like tumbling or vibratory finishing are more efficient, while manual deburring is better suited for low volumes.

5. **Precision Requirements**: If dimensional accuracy is critical, precise methods like electrochemical or brush deburring are preferable.

Fig: Deburring

✓ **Polishing**

Polishing is the process of smoothing and improving the surface finish of a material to achieve a glossy, reflective, or uniform appearance. It typically involves the use of abrasive materials or compounds to remove surface imperfections like scratches, oxidation, or rough textures. Polishing is widely used to enhance both the aesthetic and functional properties of parts in various industries.

- **Polishing Process:**

1. **Initial Surface Preparation**:
   - Parts are prepared by removing large burrs, rough edges, or significant surface imperfections.
   - Sanding or grinding may be used to achieve a uniform surface before polishing.
2. **Abrasive Polishing**:
   - Abrasive materials (such as sandpaper or polishing compounds) are applied to progressively smoothen the surface.
   - Polishing often begins with coarse abrasives and then moves to finer abrasives in several stages.
   - Different grades of abrasives (coarse to fine) are used depending on the desired surface finish.
3. **Buffing (Final Stage)**:

- **Buffing wheels** (typically soft, cloth-based wheels) are used along with fine polishing compounds to achieve a mirror-like finish.
- This step is usually the final phase in polishing, especially when high-gloss finishes are required.

Factors Influencing Polishing:

1. **Material Type**:
    - **Metals**: Metals like aluminum, stainless steel, and brass are commonly polished for a shiny, reflective finish.
    - **Plastics**: Polishing is used to remove scratches and improve clarity, especially for acrylic and polycarbonate.
    - **Ceramics and Glass**: Special abrasive materials are used to polish ceramics and glass for a smooth, non-porous finish.
2. **Surface Condition**:
    - **Pre-existing Surface Roughness**: Rougher surfaces may require more aggressive polishing steps to achieve a smooth finish.
    - **Hardness of Material**: Harder materials may require more time and specific polishing techniques or abrasives.
3. **Desired Finish**:
    - **High Gloss/Mirror Finish**: Requires finer abrasives and more steps in the polishing process.
    - **Matte or Satin Finish**: Can be achieved by stopping the polishing process before the final buffing stage or using specific compounds.
4. **Precision**:

In applications where dimensional accuracy is critical, the polishing process must be carefully controlled to avoid excessive material removal.

Fig: Plishing

✓ **Brushing**

Brushing is a surface finishing process in which a material is treated with an abrasive brush to create a uniform, textured finish. Unlike polishing, which aims for a shiny, reflective surface, brushing gives the material a satin or matte appearance with visible, fine lines that follow the brushing direction. It's commonly used for aesthetic purposes and to improve the durability of the surface by removing imperfections.

- **Brushing Process:**

1. **Abrasive Brushes**: Abrasive brushes or pads are used, which contain abrasive particles that scrape away small amounts of material from the surface.
2. **Manual or Machine Brushing**: The brushing process can be done manually with hand-held brushes or using automated machines where the part is passed through rotating brush heads.
3. **Linear Motion**: The brushing action typically follows a linear or consistent motion in one direction to create fine lines on the surface.
4. **Abrasive Selection**: Different types of abrasive materials can be used depending on the desired texture and the material being brushed (e.g., wire brushes, nylon brushes with embedded abrasives).

- **Factors for Selecting Brushing:**

1. **Material Type**:
    - **Metals**: Stainless steel, aluminum, brass, and copper are commonly brushed to give them a uniform, matte finish.
    - **Plastics**: Certain types of plastics can be brushed, though care must be taken to avoid damaging softer materials.
    - **Wood**: Brushing is sometimes used to give wood a distressed or textured appearance.
2. **Surface Condition**:
    - **Pre-existing Surface**: Brushing can be used to remove minor scratches, imperfections, or oxidation. It can also be applied to surfaces that have been previously machined or polished.
    - **Desired Texture**: Brushing is chosen when a non-reflective, matte finish with fine lines is preferred. The texture can vary depending on the abrasiveness of the brush.

3. **Finish Consistency**:

   - **Directionality**: Brushed finishes typically have a consistent direction. For applications where appearance is important, it is essential to ensure the brushing lines are uniform and follow a defined pattern.
   - **Line Fineness**: The coarseness of the brush determines the fineness of the lines left on the material, with coarser brushes creating more prominent textures and finer brushes producing smoother results.

4. **Part Geometry**:

   - **Flat or Curved Surfaces**: Brushing works best on flat surfaces but can also be used on curved parts if applied carefully.
   - **Complex Shapes**: For intricate parts with detailed features, manual brushing may be required to ensure even coverage.

Fig: Brushing

✓ **Smoothing**

Smoothing is a surface finishing process used to create a uniform, even, and refined surface by eliminating roughness, imperfections, or uneven textures. Unlike polishing, which focuses on achieving a shiny, reflective finish, smoothing is more concerned with removing surface irregularities to create a consistent and clean surface. Smoothing is often a precursor to other finishing techniques like polishing, painting, or coating.

✓ **Smoothing Process:**

1. **Initial Surface Cleanup**:

   - **Deburring**: Removing burrs or sharp edges left over from machining processes to make the surface safer and more uniform.
   - **Grinding/Sanding**: Rougher surfaces are smoothed by using coarse abrasives to level out imperfections or surface marks.

2. **Abrasive Smoothing**:

- **Tools**: Abrasive pads, sandpaper, grinding wheels, or sanding belts are used to progressively smooth the surface.
- **Abrasive Grit Selection**: Coarse abrasives are used initially, followed by finer grits as the process moves towards the desired surface finish.
- **Hand or Machine Application**: Smoothing can be done manually with handheld tools or through automated machines, depending on the scale and precision required.

3. **Finishing Touches**:

After the coarse abrasives have done their job, finer abrasives or buffing compounds may be applied to achieve the desired level of smoothness.

Factors for Selecting a Smoothing Technique:

1. **Material Type**:
   - **Metals**: Smoothing techniques like grinding, sanding, and tumbling are commonly used for metals like steel, aluminum, and brass.
   - **Plastics**: Softer materials like plastics may require less aggressive smoothing methods such as fine sanding or buffing.
   - **Wood**: Sanding is typically used to smooth wood surfaces before painting or varnishing.
2. **Surface Condition**:
   - **Surface Roughness**: Parts with high roughness may require more aggressive smoothing techniques, while those with minor imperfections can be treated with fine abrasives.
   - **Machined vs. Cast Parts**: Machined parts often need less intensive smoothing than cast or molded parts, which may have more pronounced imperfections.
3. **Part Geometry**:
   - **Flat Surfaces**: Easier to smooth with sanding or grinding tools.
   - **Complex Shapes**: Intricate or detailed parts may require more specialized techniques such as manual smoothing or electrochemical methods to ensure uniform results.

4. **Desired Finish**:

   - **Smoothness Level**: The required level of smoothness depends on the final application. Some parts may need a very fine finish (e.g., in medical or precision instruments), while others may only need to be moderately smooth.
   - **Subsequent Processes**: If the part will be painted, coated, or polished, the smoothing process may stop at an intermediate stage, as the final finish will be applied later.

5. **Production Volume**:

   - **Low-Volume**: Manual smoothing or small-scale mechanical processes are suitable.
   - **High-Volume**: Automated or mass smoothing techniques, such as tumbling or vibratory finishing, are more efficient for larger production runs.

Fig: Smoothing

✓ **Painting**

Painting is a surface finishing process in which a protective or decorative coating is applied to a part or material. The primary purpose of painting is to enhance the appearance of the surface, provide protection against environmental factors (such as corrosion, UV radiation, or moisture), and improve the durability of the material. Painting is used across various industries and can be done manually or with automated systems, depending on the application and scale.

Painting Process:

1. **Surface Preparation**:

   - **Cleaning**: The surface must be cleaned of dirt, grease, and dust. This is typically done using solvents, detergents, or sandblasting to ensure the paint adheres properly.

- **Sanding/Grinding**: For smooth surfaces, light sanding or grinding may be performed to create a slightly rough texture for better paint adhesion.
- **Priming**: A primer coat is often applied to enhance paint adhesion and improve the finish. Primers also provide corrosion resistance and fill minor surface imperfections.

2. **Application of Paint**:
   - **Brush or Roller**: Paint is applied manually using brushes or rollers. This method is typically used for small surfaces or touch-ups.
   - **Spray Painting**: A more common method for larger or more complex parts, paint is atomized and sprayed onto the surface in fine droplets, creating an even coat.
   - **Powder Coating**: A dry powder is electrostatically applied to the part and then cured in an oven to form a hard, protective coating. This is widely used for metals.
   - **Dipping**: The part is submerged in a tank of paint, allowing the entire surface to be evenly coated. This is useful for complex shapes or large-scale production.
3. **Curing and Drying**:
   - **Air Drying**: Some paints dry naturally in the air, though this can take time depending on environmental conditions.
   - **Oven Curing**: For certain paints (e.g., powder coatings or industrial finishes), the part is placed in an oven to accelerate curing, creating a harder, more durable finish.
4. **Finishing**:
   - **Additional Coats**: Depending on the desired result, multiple coats of paint may be applied, with each coat allowed to dry before the next is added.
   - **Clear Coating**: A clear topcoat can be applied for additional protection and to give the surface a glossy or matte finish.

✓ **Factors Influencing Paint Selection:**

1. **Material Type**:
   - **Metals**: Solvent-based paints, powder coatings, and primers are often used to prevent corrosion and provide durability.

- **Plastics**: Certain types of paints and primers are specifically designed for plastics to ensure proper adhesion and flexibility.
- **Wood**: Water-based or oil-based paints are commonly used on wood, depending on the desired finish and durability.

2. **Environmental Conditions**:
   - **Outdoor Applications**: For outdoor use, paints must be resistant to UV rays, moisture, and temperature changes. Solvent-based and powder coatings are popular for their weather resistance.
   - **Indoor Applications**: Water-based paints are typically sufficient for indoor use and are preferred for their low toxicity and ease of application.
3. **Desired Appearance**:
   - **Gloss Level**: Paint finishes range from matte to high-gloss. High-gloss paints offer a reflective, shiny finish, while matte paints have no sheen and can hide surface imperfections.
   - **Color Options**: Modern paints offer virtually unlimited color options, allowing for customization to meet aesthetic or branding requirements.
4. **Durability Requirements**:
   - **Wear and Tear**: In areas with high traffic or frequent handling, durable paints like epoxy or powder coatings are preferred.
   - **Corrosion Resistance**: In environments where parts are exposed to moisture, chemicals, or corrosive elements, paints with protective additives or primers are essential.
5. **Ease of Application**:
   - **Manual Application**: Some paints are easier to apply with a brush or roller, making them suitable for small-scale or DIY projects.
   - **Spray Application**: For large-scale or high-volume production, spray painting offers a more efficient and uniform application.

Fig: Painting

✓ **Powder Coating**

Powder coating is a finishing process in which a dry powder is applied to a surface and then cured under heat to form a hard, durable finish. It is widely used for coating metal parts and products due to its excellent performance characteristics, environmental benefits, and aesthetic options.

✓ **Factors Influencing Powder Coating Selection:**

1. **Material Type**:
   - **Metal**: Most commonly coated with powder, including aluminum, steel, and other alloys.
   - **Plastic**: Certain types of plastic can also be powder coated, though they may require special powders or pretreatment.
2. **Environmental Conditions**:
   - **Outdoor vs. Indoor Use**: For outdoor applications, select powders that offer UV resistance and weatherability.
   - **Chemical Exposure**: Consider powders with specific chemical resistance for parts exposed to harsh environments.
3. **Desired Finish**:
   - **Gloss Level**: Available in various finishes, including matte, satin, and high-gloss.
   - **Texture**: Options include smooth, wrinkled, or textured finishes to meet design requirements.
4. **Part Complexity**:

Shape and Size: Powder coating is suitable for a variety of shapes and sizes, but the complexity may influence application methods and curing requirements.

5. **Production Volume**:

   - **High-Volume Runs**: Powder coating is cost-effective for high-volume production due to efficient application and reduced waste.

   - **Low-Volume Runs**: While still viable, smaller runs may have higher per-unit costs compared to traditional liquid coatings.

Fig: Powder coating

Points to Remember

- It is necessary to know the selection of surface finishing methods because it is crucial in manufacturing, and help us to achieve the desired surface properties.
- While applying surface finishing techniques to milled parts, it's essential to consider the specific requirements of the parts and the according to the desired outcomes

Application of learning 3.3

With referring to the theoretical Activity 3.3.1 and 3.3.2, you are requested go to manufacturing to perform surface finishing techniques on different milled parts
N.B : Do not apply all surface finishing techniques on one milled part.

Learning outcome 3 end assessment

Written assessment

Q1. The following are statements used in milling machine operations, answer by ''**True''** if the statement is correct or ''**False''** if the statement is wrong.

a) Drilling is a finishing operation that enlarges and refines the diameter of an already drilled hole. It improves the hole's accuracy, surface finish, and ensures a tighter tolerance.

b) Reaming is a finishing operation that enlarges and refines the diameter of an already drilled hole. It improves the hole's accuracy, surface finish, and ensures a tighter tolerance.

c) Flute milling is a machining process used to create internal or external threads on a workpiece using a rotating cutter.

d) Thread milling is a specialized milling operation used to machine helical grooves or flutes into cylindrical or tapered workpieces, such as drill bits, taps, reamers, or end mills.

e) Angular milling is a milling operation where the axis of the milling cutter is set at an angle other than 90° to the surface of the workpiece**.**

Q2: Ready the following statetment and choose the correct answer by writing the letter corresponding to the answer.

I. The following are steps for performing plain milling operations on milling machine Except:

   a) Preparation and Setup:
   b) Align the Workpiece:
   c) Position the Cutter:
   d) Positioning tools

II. The following are types of milling machine, choose one which is generally used for plain milling by writing the letter which corresponding to the answer?

   i. Vertical milling machine
   ii. Horizontal milling machine
   iii. Universal milling machine
   iv. CNC milling machine

III. The following are goals of milling machine, choose goals which is reflecting on the main goal of plain milling machine writing the letter which is corresponding to those goal?

   a) To create a cylindrical surface
   b) To remove material in a parallel direction to the axis of rotation
   c) To cut a keyway
   d) To drill holes

IV. One of the following is not importance of importance of painting during milling machine operations choose the letter corresponding to the statement which is not importance of painting.

a) Aesthetic Appeal
b) Corrosion Resistance
c) Weather Protection
d) Decreasing length of product

Q3. Match the following milling operations in column **B** with their corresponding meaning in the column **A** and give the answers in provided column of answers

Answers	**Meaning (A)**	**Milling operation (B)**
………	1. is a fundamental milling operation where the surface is machined parallel to the axis of rotation of the cutter.	A. Taper turning
………	2. milling operation where the axis of the milling cutter is set at an angle other than 90° to the surface of the workpiece.	B. Side milling
………	3. milling operation in which the sides of a workpiece are machined using the peripheral cutting edges of the milling cutter.	C. Angular milling
………	4. a special form of side milling where two cutters are mounted on an arbor to machine two parallel surfaces on opposite sides of the workpiece simultaneously.	D. Gang milling
………	5. milling technique where multiple cutters are mounted on the same arbor or spindle	E. Straddle milling
		F. Rolling
		G. Plain milling

Q4. Ready the following statement related to the types of paints and coatings and filling the gaps by using words which are in bracket **(chemical ,solvents ,water, Soap, Gas, glossy ,electrostatically**).

I. Water-based paints are made with ______ as the solvent, making them environmentally friendly and easy to clean up.
II. Solvent-based paints use organic _______, such as turpentine or acetone, to carry the paint pigments.
III. Powder coating is a dry, powder-like substance that is ______ applied and cured in an oven to form a hard finish.
IV. Epoxy paint consists of a resin and a hardener, forming a hard, ______-resistant coating suitable for industrial environments.
V. Enamel paint is a solvent-based paint that creates a hard, ______ finish, commonly used for metal surfaces and outdoor furniture.

Practical assessment

RMCT Machining Company has received a tender from Car Furniture Company Ltd to manufacture Worm gear for replacing the damaged one. You are requested to produce the new worm gear to replace the damaged one by using milling machine.

All needed tools, materials, attachment, accessories and equipment are available in workshop of RMCT Machining Company.

Note: respect the following worm gear specifications and dimension

		Worm
1	Material	Mild steel
2	Normal module	2.178206
3	N° of teeth	3
4	Normal pressure angle	14^{o}
5	Helix angle	18^{o}
6	Hand	Right
7	Tip diameter	19.1mm
8	Pitch circle diameter	14.1mm
9	Base circle diameter	10.97mm
10	Flank surface roughness	0.15µmRa

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