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WORKSHOP TECHNOLOGY & TUTORIAL

MECHANICAL ENGINEERING DEPARTMENT

SUFAIRUZ BINTI SAAD

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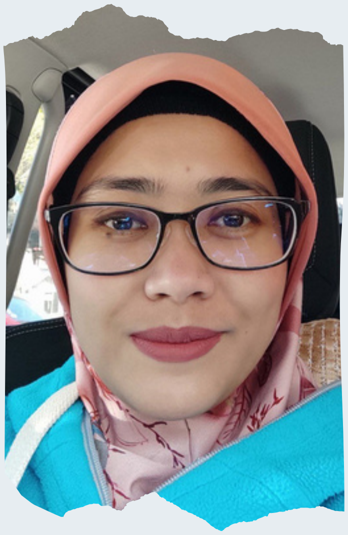

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ACKNOWLEDGMENTS

Being an engineering student makes related book equally important in helping students have good grasp of basic mechanical engineering. For the author, this book act as a compilation of sample question related to topic discussed throughout the syllabus and aims to motivate the author to write more. The goal is to provide a comprehensive yet simple book and is intended to encourage student to develop sufficient knowledge in workshop practices.

The authors wish to thanks all the lecturers, husband, family, friends, colleagues and most importantly PTSB in making this possible. Alhamdulillah, truly grateful in every assistance the author gets throughout the process.

Thank you again.

INTRODUCTION

WORKSHOP TECHNOLOGY provides exposure and knowledge in using hand tools, machine operation such as drilling, lathe, milling and computer numerical control. It also covers on gear measurement and inspection welding process in Oxy Acetylene (OAW), Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW) and Gas Metal Arc Welding (GMAW).

WORKSHOP SAFETY

WORKSHOP SAFETY

BASIC INFORMATION AND PRECAUTIONS

Safety in the workshop may be divided into the following:

i. Workshop grooming
ii. Safe work practices
iii. Housekeeping

WORKSHOP GROOMING

- Always wear proper garments when entering workshop. Never wear loose clothing to avoid getting caught in rotating parts.
- Always wear safety glasses/ goggles in any area of machine shops.
- Keep all jewellery such as watches, rings and bracelets when attending machines.
- Long hair must be properly secured.
- Wear apron when necessary.
- Safety shoes must be worn at all times in the machine shop.

Safety in the workshop may be divided into the following:

i. Workshop grooming

ii. Safe work practices

iii. Housekeeping

SAFE WORK PRACTICES

- Do a safety checklist before operating a machine. Make it a habit.
- Never leave a machine unattended.
- Use a brush to remove chips from the machine.
- Gloves must not be worn around a moving machine. Keep your hands from moving parts. Always stop a machine before measuring, cleaning or making adjustments.
- If your workshop has noise level more than 115 dB, ear protection must be worn.
- No horse playing or scuffling in the workshop.

Safety in the workshop may be divided into the following:

i. Workshop grooming
ii. Safe work practices
iii. Housekeeping

SAFE WORK PRACTICES

- Always implement buddy system when lifting heavy parts. Heavy stock, even if it is short, should be carried by two people.
- Using a compressed air to clear chips from machine or your cloth is not a good practice as chips and particles will fling at high velocity and resulting in injury.
- Knows where to look for the first aid box in the workshop.
- Always inform the supervisor if injuries happen.
- Know the location of all fire extinguishers.

Safety in the workshop may be divided into the following:

i. Workshop grooming
ii. Safe work practices
iii. Housekeeping

HOUSEKEEPING

-Always stop the machine before attempting cleaning.

-Keep the floor clear of stock and unwanted tools.

-Clean up spillage (oil/ grease/ water/ detergent) to avoid tripping.

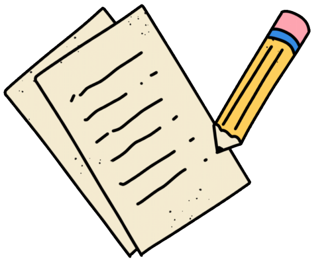
-Sweep the metal chips frequently as they are embedded to the shoes.

-Never place any tools on the machine work table.

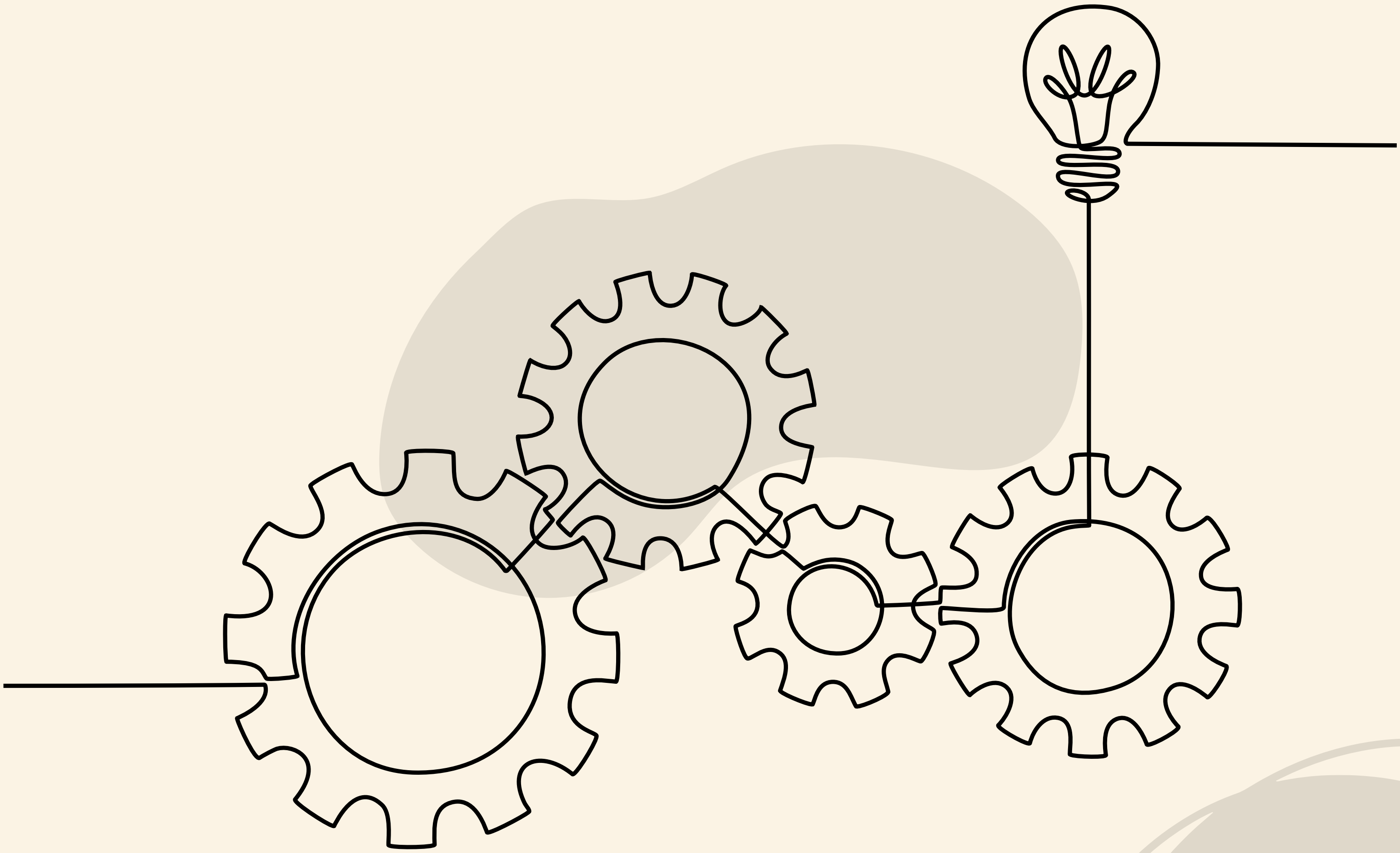
-Return every tool to its storage rack/ box.

-Return stock to the storage rack after cutting off the required length.

-Always keep the machine and hand tools clean.



HAND TOOLS



INTRODUCTION

HAND TOOLS

1. Hand tools are needed in workmanship activity. Although machine helps get things in shape, the importance of hand tool operations should not be overlooked. A good machinist should be able to use all hand tools skillfully.

2. Some of the works involve are holding, striking, assembling, cutting, thread cutting, finishing, taking measurement, marking, layout and inspection.

3. As for basic measurement, it can be taken by use of a rule or any other non-precision measuring tool (inch/ metric standard system). One of the important reason of taking measurement is when one needed to transfer measurement for work.

OBJECTIVES

Apply the knowledge of basic mechanical components and equipment, hand tools and measuring equipment in workshop technology.

Marking/ Layout

Accuracy is needed as it represents how close a measurement come to its true value. Whereas, precision is how close measurements of the same item are to each other. The accuracy of a layout entails the proper and careful use of all layout tools.

Layout Tables & Surface Plates

A work may be performed on a layout table or a surface plate for stability & accuracy. There are different types of table which is made from granite or cast iron. Both come with its own advantages.

Along with the table, there are other hand tool used, such as, scriber, dividers, squares, steel rules, surface gage, prick punch, center punch & layout accessories which come in handy in layout (angle plate, parallels, v-blocks & keyseat rules).

Granite surface Plate

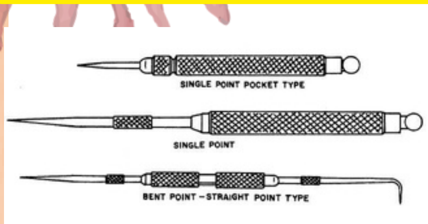
Cast Iron surface Plate

Caution !!!
Never hammer or punch any layout on a surface plate & always keep the working surface clean & cover it when not in use.

All the above mentioned hand tool equipment are common to be found in machine shop and the figures can be seen in the next page.

Hand Tools & Accessories

Pocket & Double End Scriber



Scriber when combine with rule, square is used to draw straight lines

Angle Plate

To hold the workpiece so that lines are accurately positioned

Surface Gauge

To scribe layout lines on a workpiece

Keyseat Rule with clamp

Keyseat Rule is used to scribe lines parallel to the axis of a cylinder

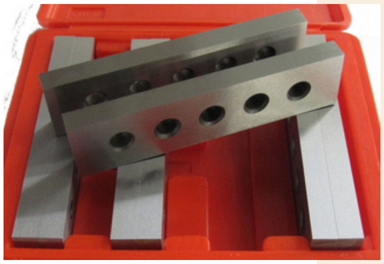
Prick Punches & Center Punches

Punches are used in layout work such as permanent mark (dented)

Steel Rule

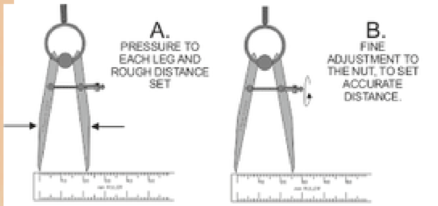
Steel rule is usually used to take measurements, surface level checks & help to make straight lines

Parallels

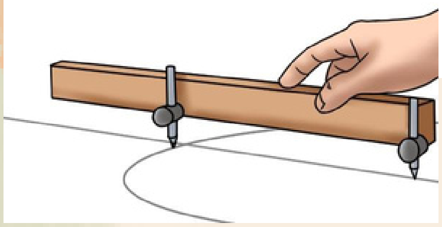


Parallels keep the bottom surface of the workpiece parallel with the surface plate

Dividers & Trammels



Dividers are used for scribing arcs and circles on a layout & for transferring measuremenst



Trammel consists of a beam on which two sliding/ adjustable heads with scriber points are mounted.

L-Square

L Square is used for inspection purposes

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Caution !!!

1. Never use a hammer with a greasy handle.
2. Be sure to use a solid handle not cracked one.
3. Never strike two hammer faces together as it may chip off and causes injury.
4. Make sure the head is not loose.

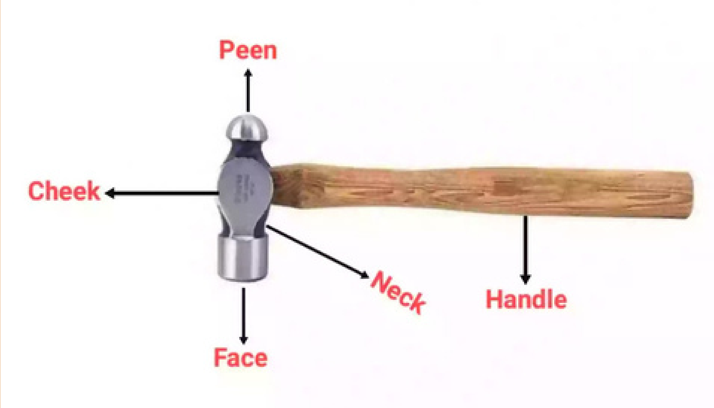
Hammer

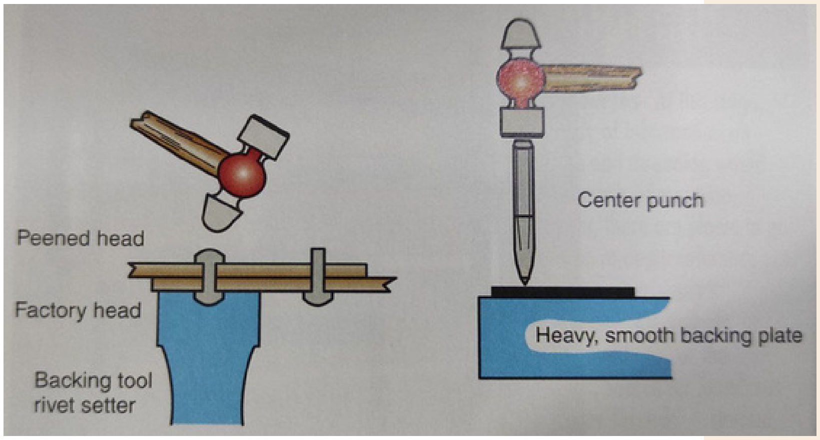
The most common used hammer is called ball-peen hammer. It is made in variety of sizes (Ranges: 55-1400 g).

The smaller sizes are used for layout work while the larger ones for general work.

Always grasp the hammer at the end of the handle to provide better balance & a greater striking force.

Ball Peen Hammer





Some of the uses of ball-peen hammer

Hammers are classified as either soft or hard. Hammers are specified based on its head weight. It is used as a striking tool in the workshop

Ball-peen hammers have a sharp impact but are accurate.

Soft-faced hammers are less hard, but may be light or heavy.

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Hacksaw

Hacksaw is considered on of the cutting tool. It is divided into few main parts; the frame, handle & blade.

The frame can either be adjustable/ solid. The solid is more rigid & will accommodate blades of only one specific length. While, the adjustable frame is commonly used and has a wide range of blade length (250-300 mm).

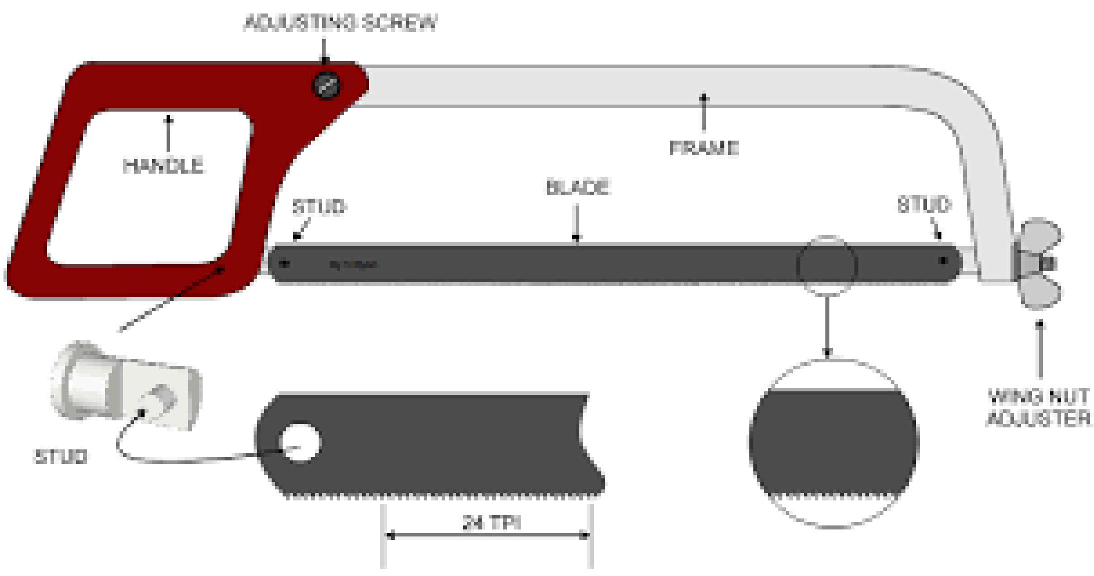
A wing nut helps in adjusting the blade tensioning.

In general, a coarser blade will cut faster. The y can be used for heavy cuts or for softer metal.

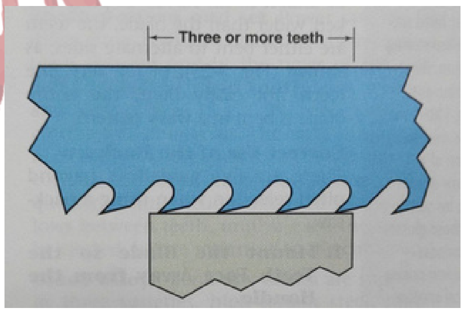
However, there is a limit for coarseness both safety and for tool life.

Correct Use of a Hacksaw:

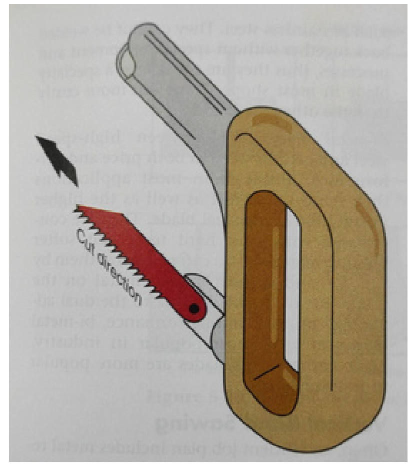
1. Mount the blade so that the teeth face away from the handle
2. Do not force the cut
3. Apply pressure on the forward stroke
4. For hard material, slow your stroke rate



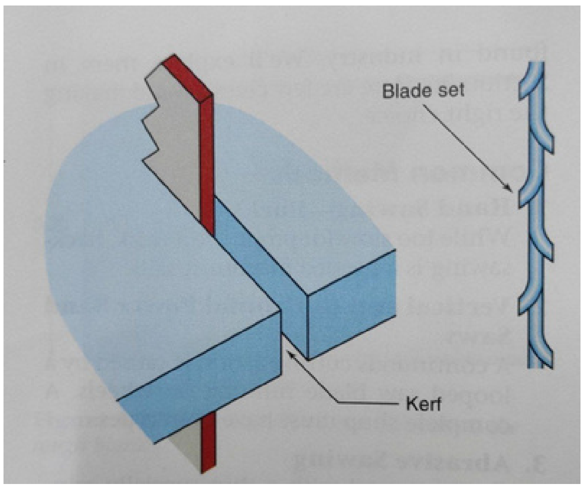
Hacksaw



Too coarse teeth can be stripped. Select blade pitch such that three or more teeth are in contact with the work.



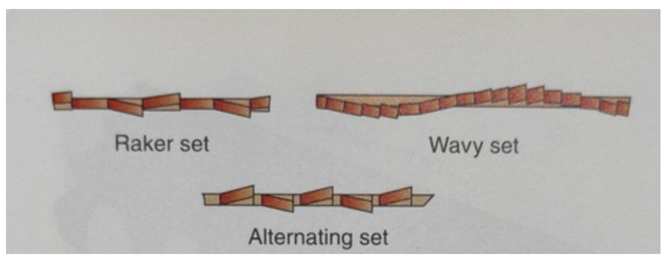
A hacksaw is correctly mounted when the teeth cut on the forward stroke.

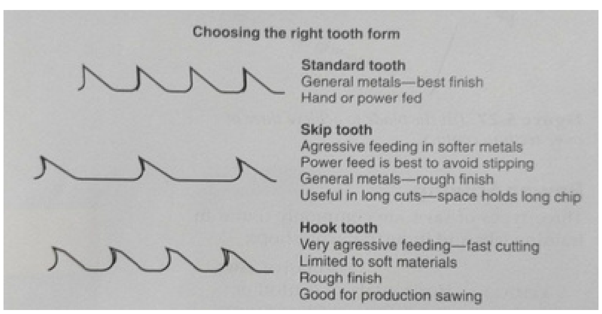


The kerf is a term of which a small groove created through a saw cuts. It provides clearance for the rest of the blade to stop it binding.

The width of kerf has to allowed for when cutting materials of length and width. It means that we need to cut on a waste side of a line.

Blade set creates a kerf wider than the blade to prevent rubbing and allow curved cuts.





Correct tooth must be chosed based on the sawing method, its material hardness & cut sizes. Choose coarser blades for longer cut surfaces or softer metals.

Caution !!!

If a saw blade breaks or become dull in a partly finished cut, replace the blade and rotate the work one-half turn so that the old cut is at the bottom. This is done to avoid new blade quickly ruin.

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Files

Files are too considered as cutting tools. They are often used to put the finishing touches on a machined workpiece, remove burrs or sharp edges or as a final fitting operations.

A file is made of high carbon steel, having a series of teeth cut on its body by parallel chisel cuts. It comes with a variety of of types and shapes and function.

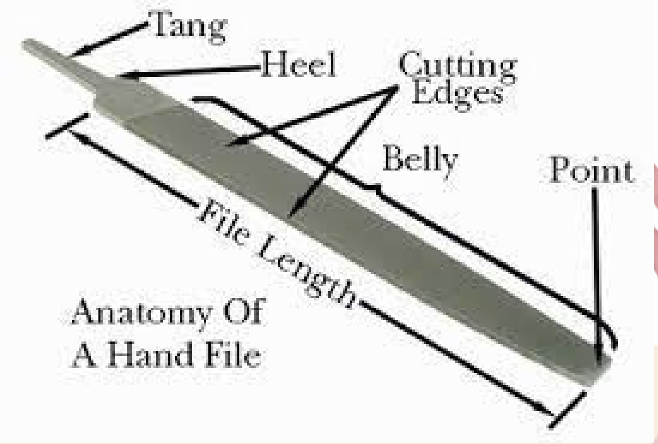
They are: **Single Cut & Double Cut files**

- Single cut files have a single row of parallel teeth running diagonally across the face. it is used for making smooth finish or when hard materials are to be finished.
- Double cut files have two intersecting teeth. The first row is usually coarser, called overcut. The other row is called the upcut. This file is used for fast metal removal & easy chips clearing.

Caution !!!

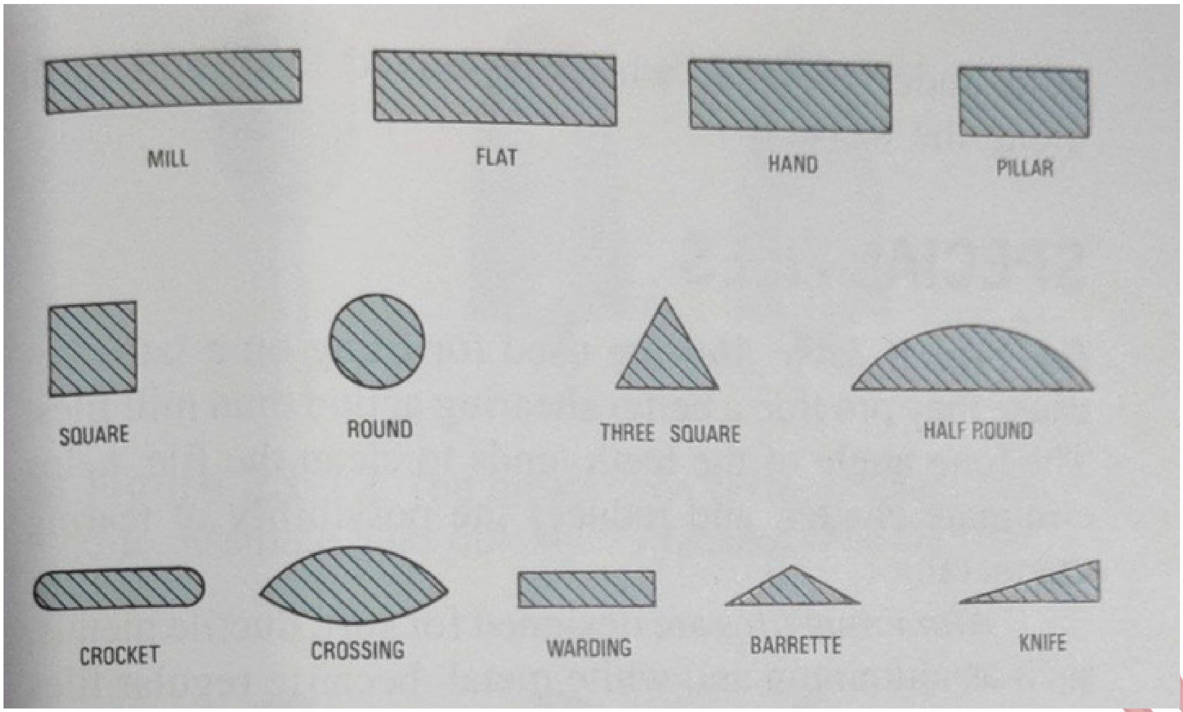
1. Never use a file without its handle. Serious hand injury may result, should the file slip.
2. Apply pressure only on the forward stroke. Pressure on the return stroke will dull the the file.
3. Never use a file as a pry or a hammer. It can easily snap and causing small pieces fly and end up injuring the eye.
4. Store file separately.
5. Always use a file card or brush to clean the face.

Parts of a file



Files

Types of files



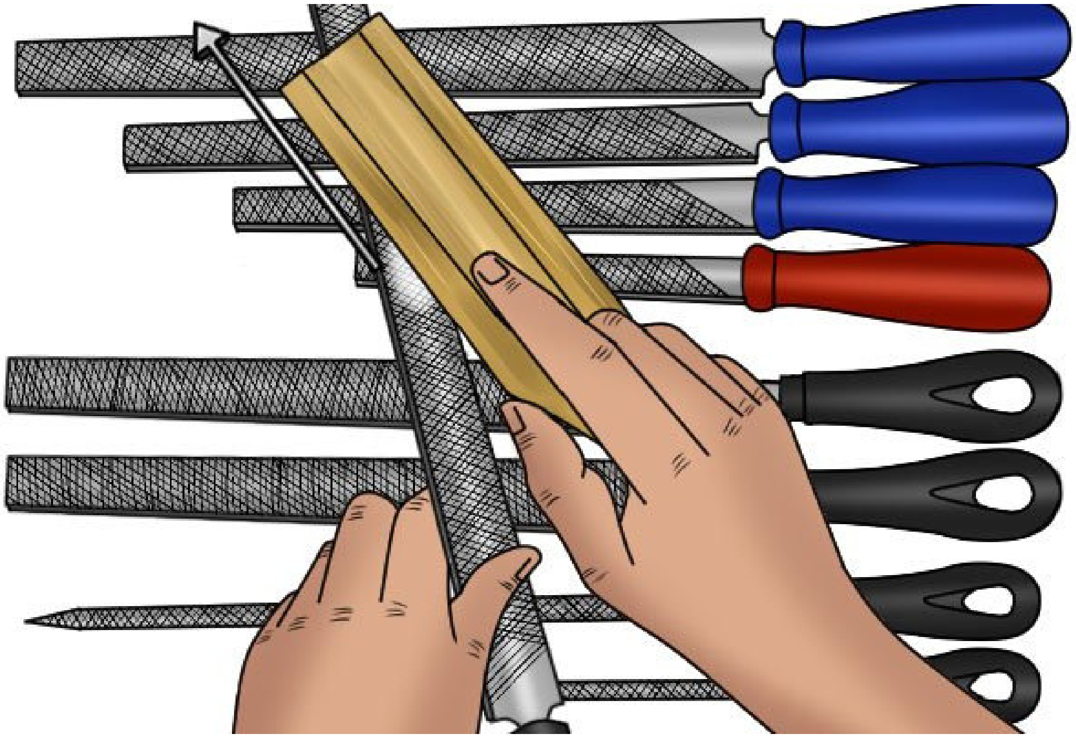
Cross sectional views of files

Files

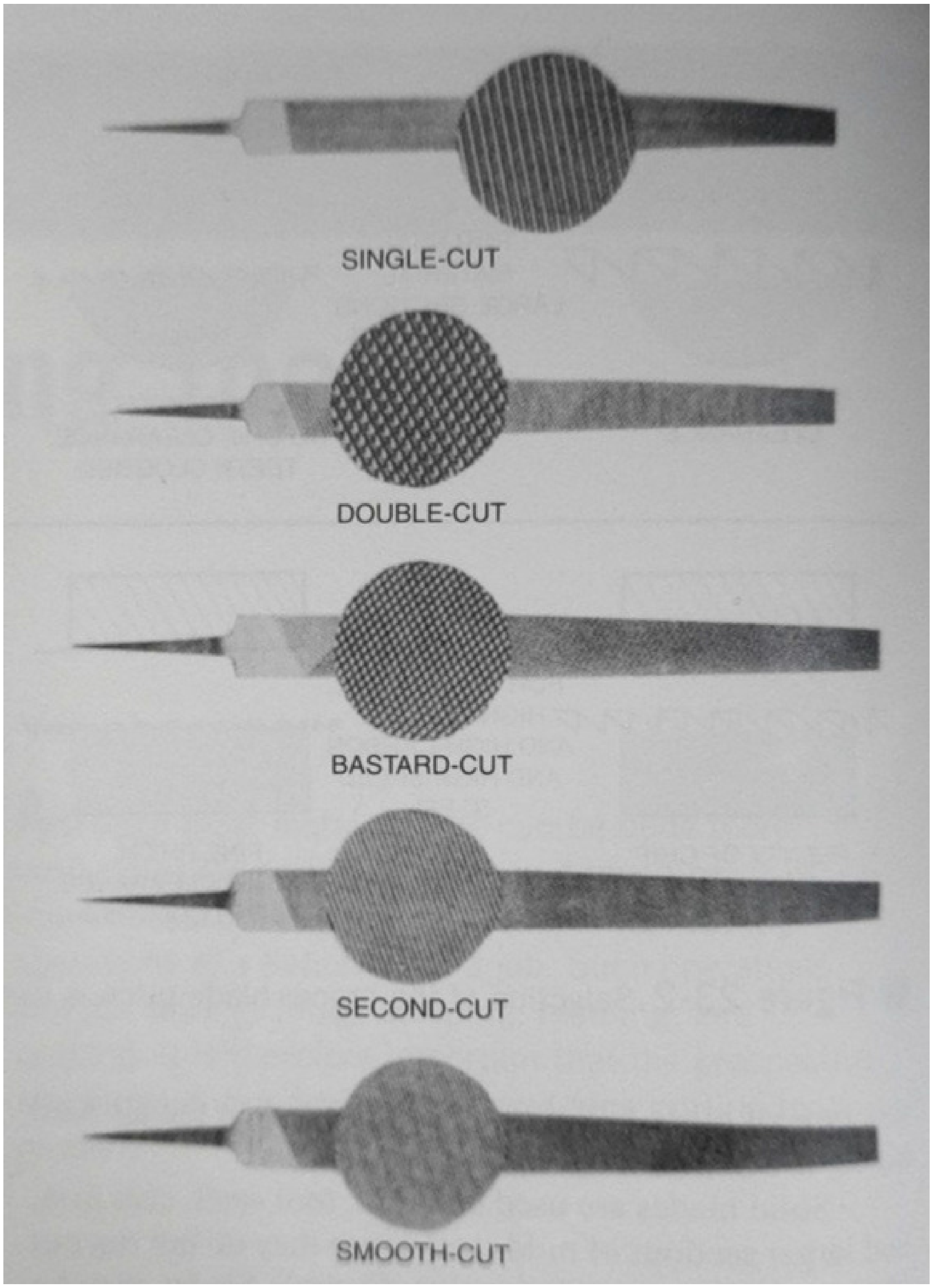
Proper filing position

Draw filing

Cleaning a file using file card/ brush



Files



File classification - Degrees of coarseness

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Chisels

Chisels are used in the workshop along with hammer. It is used:

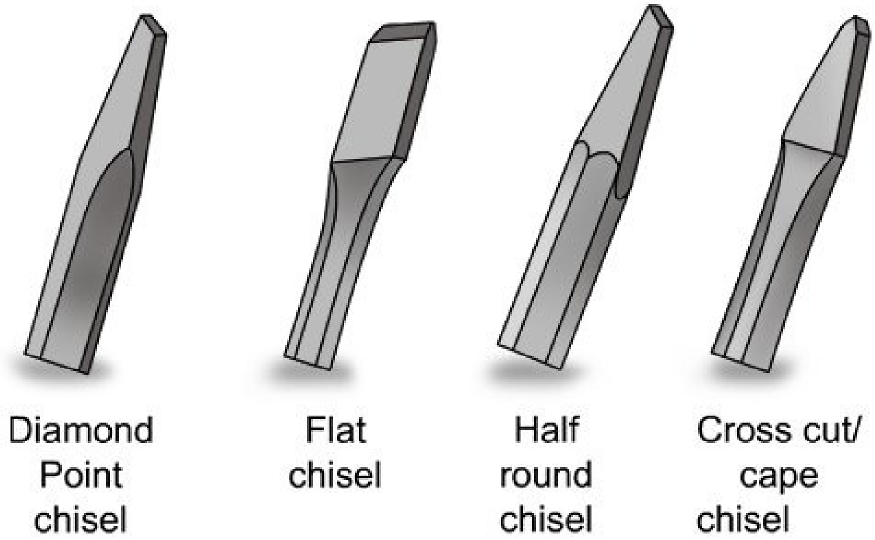
- Cut flat, round or angle iron and metal sheet.
- To remove unwanted metal from the work surface known as chipping.

Chisels are used both on hot and cold metals.

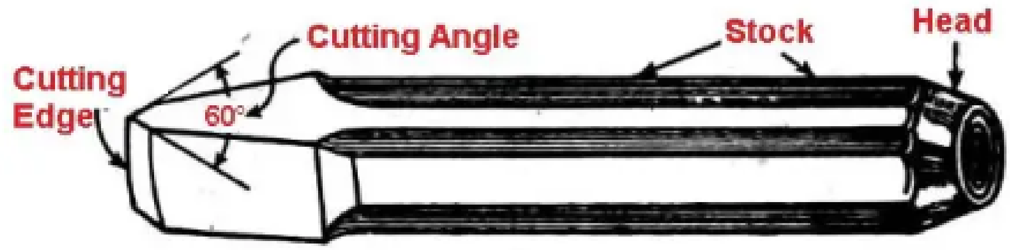
a) Hot Chisel - Used for cutting hot metals in blacksmith's workshop. There is a hole in a chisel in which a wooden handle is fixed. Their cutting edge is made at an angle of 30°. While using this part, it is frequently dipped into water for making it cold so that its edges remain intact.

b) Cold Chisel - usually used in sheet metal work and done in cold condition. It is available in 4 sides, 6 sides or 8 sides. They are made of high carbon steel, which contains 0.75% to 1.00% of carbon. Generally, chisel, of 150 mm length is used. Practically, chisels measurement is known from the width of chisels cutting edge.

Types of chisel



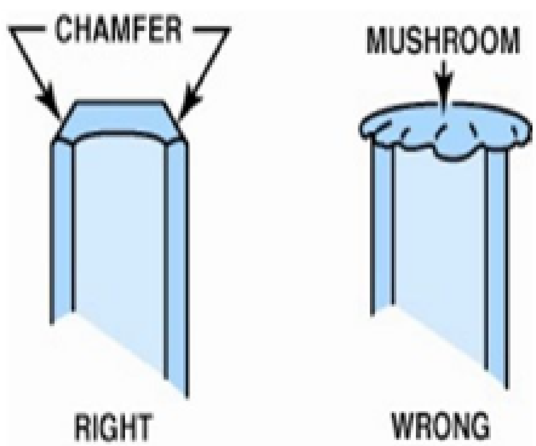
Chisels



Parts of a Chisel

Chisels Care

Use a grinder or a file to remove the mushroom material on the end of a punch or chisel.



The angle at which a cutting edge of chisel is grinded is known as its cutting angle. For cutting hard metal, the cutting angle is more and for cutting soft metals the cutting angle is less. While grinding chisels for cutting various kinds of metals their angles should be as under:

- Mild steel – 55 °
- Cast iron – 60 °
- Tool steel – 65 ° to 70 °
- Copper – 45 °
- Aluminum – 30 °
- Brass – 50 °

Chisels

Methods of Using Chisel

Chisel is used for cutting and chipping a thin metal sheet, plate, round rod and such other material. In fig cutting of a metal plate has been illustrated. The following points should be kept in mind while using a chisel:

1. Accurate marking should be done on the metal to be cut.
2. Always hold the chisel properly with your left hand and the hammer in your right hand.
3. Set the chisel properly on the marked line then strike the hammer on its head. Before striking the second blow on the chisel, it should be set again.
4. While cutting with a chisel we should concentrate on its cutting edge.
5. Strike the hammer blow at the centre of the head of the chisel.

Caution !!!

At the time of chipping, we must always use safety goggles.

Keep your face towards the wall, while chipping.

If someone is working in your front, you should fix chipping guard at the rear of the vice so that chips do not hit him.

The mushroom head chisel should never be used for chipping.

There should not be any greasy substance on the chisel head and face of the hammer being used for chipping.

An extraordinarily long chisel should not be used for chipping.

While chipping we should keep on applying grease on the edge of the chisel.

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Tap and Dies

Taps are cutting tools used to cut internal threads in holes.

They are made of high quality tool steel, hardened and ground.

Another characteristics of taps is the amount of chamfer at the cutting end of the tap. It has three sets of tap:

- Taper
- Plug
- Bottoming

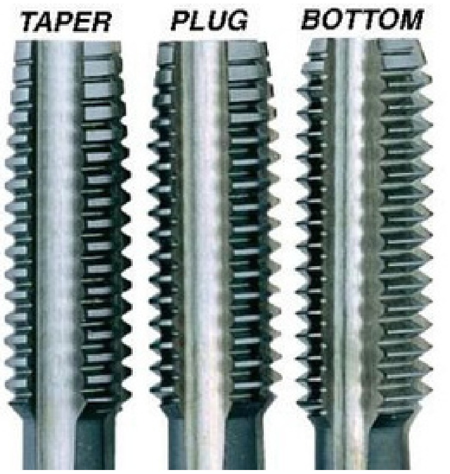
Taper - Used at starting a tapped thread square with the part.

Plug - The most commonly used tap, both in hand and machine tapping

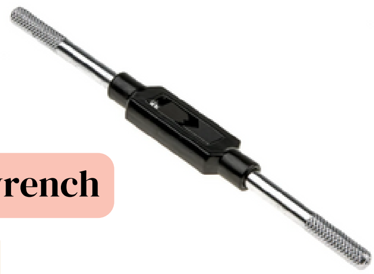
Bottoming - Used to produce threads that extend almost to the bottom of a blind hole. A blind hole is one that is not drilled entirely through a part.

A tap wrench is used to provide driving torque while hand tapping.

Taps



Using a tap



Tap wrench

Other Hand Tools

Some of other hand tools to be discussed are; Hacksaw, files, hammer, chisel, tap & dies.

Threading Dies

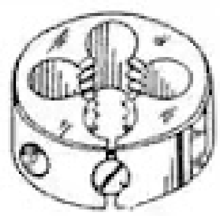
A die is used to manually cut external threads on the surface of a bolt or rod.
Dies are used to cut external threads on around materials.
The most common threading dies are:

- The solid
- The adjustable split
- The adjustable screw plate die

Solid - Used for chasing or re-cutting damaged threads & may be driven by a suitable wrench. It is fixed.
Adjustable split - It has an adjusting screw that permits an adjustment over or under the standard thread depth. It fits into the die stock.
Adjustable screw plate die - More efficient die as it provides greater adjustment than the split die.

Caution !!!

1. When cutting a long thread, keep the arms and hands clear of the sharp threads coming through the die.
2. Always stand aside when cleaning out holes with compressed air. Wear goggles.
3. Apply cutting fluid when threading.
4. To break packed chips, reverse the wrench a revolution.



Die

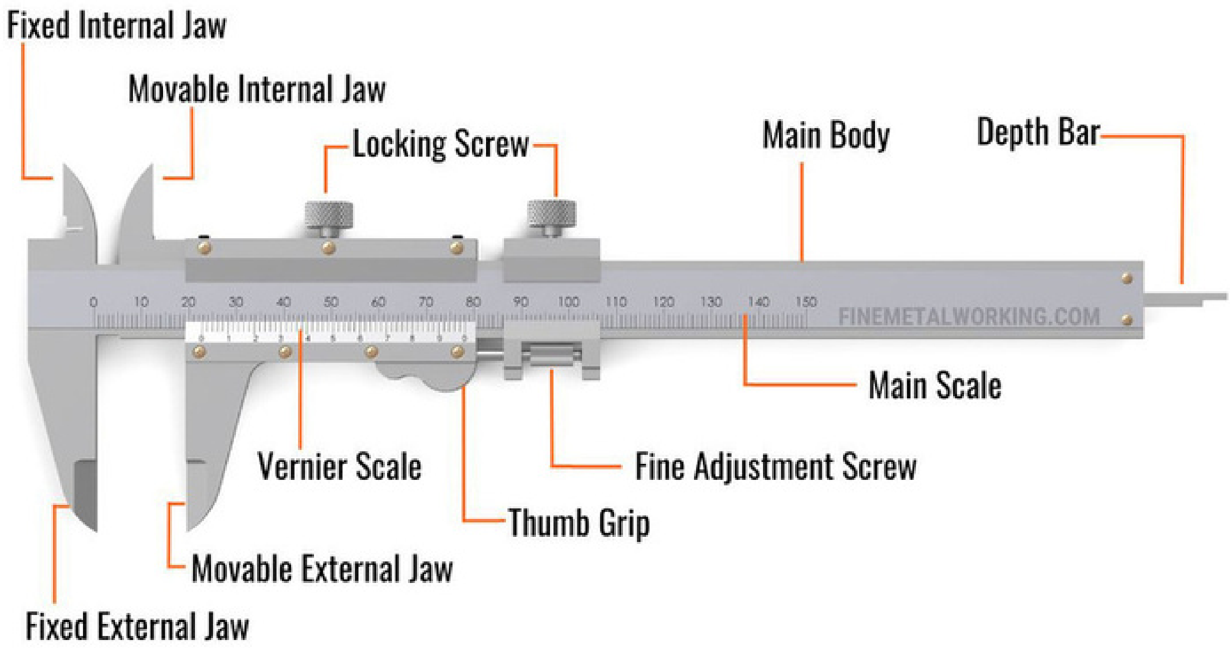
Die & Stock

Die Stock

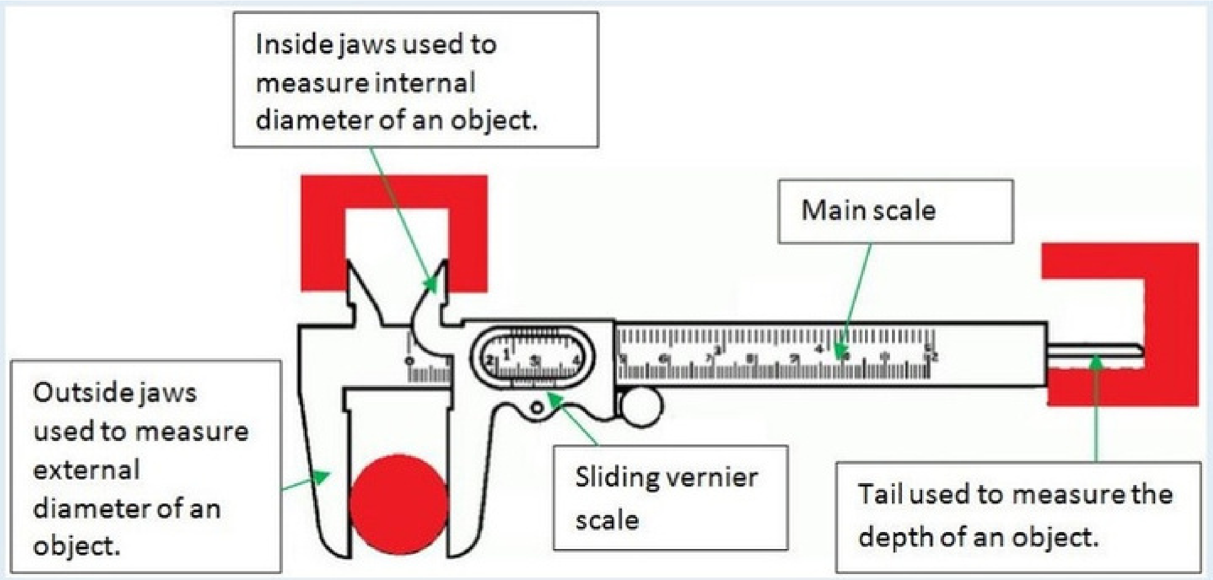
Using Threading Die

Measuring Devices

Vernier Caliper

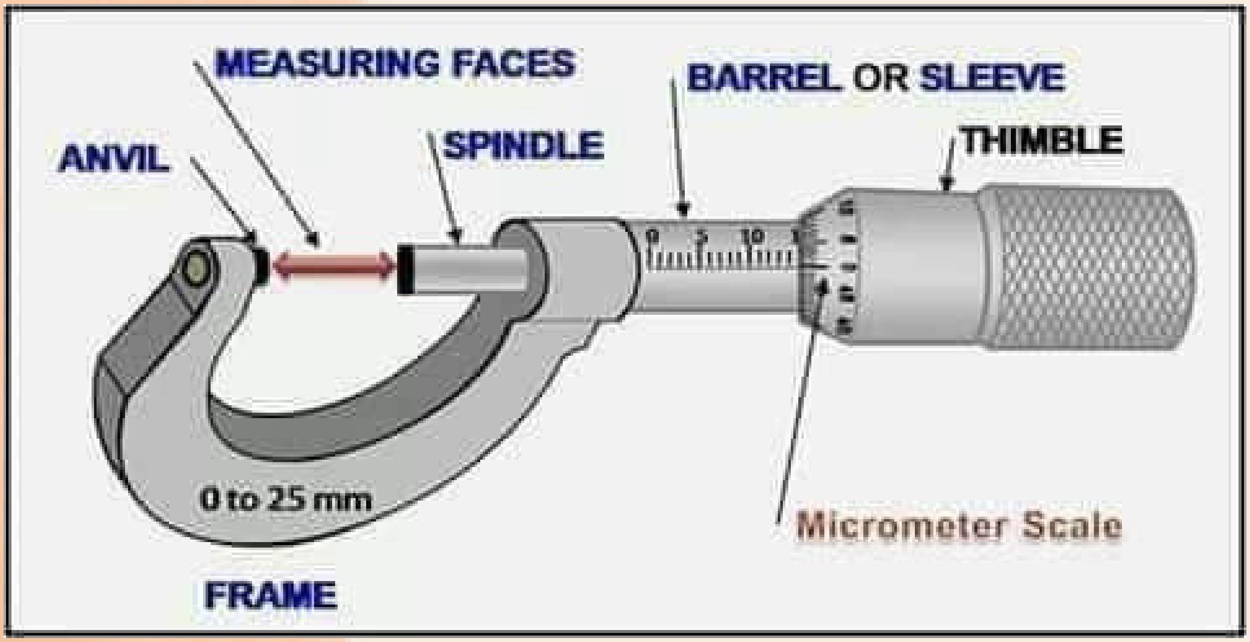


What Can Vernier Caliper Measure?



Measuring Devices

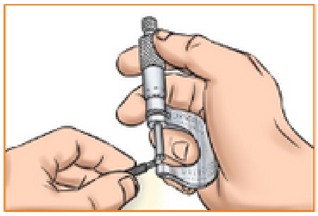
Micrometer



Learn More About Vernier Caliper & Micrometer

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

Using Micrometer



Step 1 – Position object to be measured

Hold the object you are measuring in your non-dominant hand and the micrometer in your dominant hand with the frame in your palm.

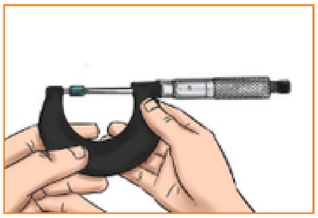
Position the object on the anvil, that is, the fixed measuring face of the micrometer.

Step 2 – Clamp object between anvil and spindle

Rotate the thimble using the ratchet speeder until the spindle is close to the object.

Carefully turn the ratchet as you approach the surface to be measured and continue until the spindle stops rotating.

The ratchet will keep turning, applying the correct amount of force for an accurate measurement. Using the micrometer thimble alone requires a degree of skill and practice to achieve the correct "feel".



Step 3 – Read the measurement

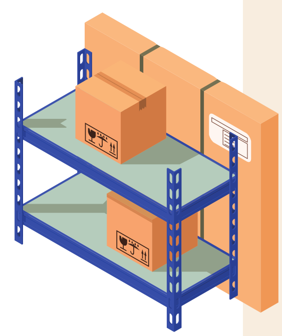
Read the measurement indicated on the scale.

If you need to remove the object (or the micrometer), first secure the spindle by turning the locking device, remove object and then take your reading.

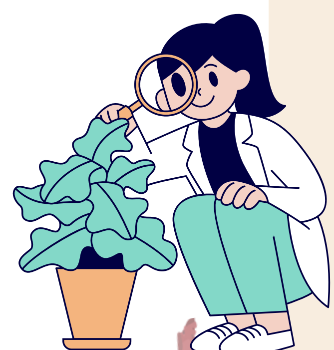
MAINTENANCE & CARE FOR HAND TOOLS

Regular Cleaning: Hand tools should be cleaned regularly to remove dirt, dust, and debris. Wiping them with a clean cloth, and if necessary, using a mild solvent, helps maintain their performance.

Lubrication: Applying appropriate lubrication, such as oil or grease, to moving parts of hand tools prevents rusting and ensures smooth operation. Lubrication should be done as per the manufacturer's recommendations.



Storage: Hand tools should be stored in a clean, dry, and organized manner. Using toolboxes, racks, or pegboards ensures easy accessibility and prevents damage or loss.



Inspection: Regularly inspecting hand tools for any signs of wear, damage, or malfunction is crucial. Damaged tools should be repaired or replaced promptly to ensure safety and maintain efficiency.

Proper Use: Lastly, using hand tools correctly and as intended is vital for their longevity. Applying excessive force or using a tool for a task it is not designed for can lead to tool failure, potential injury, or damage to workpieces.

TRAINING & SAFETY CONSIDERATION

Proper Training: Mechanical engineers should receive adequate training on the safe and efficient use of hand tools. Training programs should cover the correct handling, operation, and maintenance of tools, as well as safety guidelines and procedures.

Personal Protective Equipment (PPE): When using hand tools, mechanical engineers should wear appropriate PPE, such as safety glasses, gloves, and hearing protection. PPE safeguards against potential hazards and reduces the risk of injury.

Hazard Assessment: Before using hand tools, mechanical engineers should perform a hazard assessment of the work area. Identifying potential hazards, such as proximity to electrical sources or unstable work surfaces, allows for appropriate precautions to be taken.

Work Area Organization: Keeping the work area clean and organized minimizes the risk of accidents caused by tripping or falling objects. Mechanical engineers should ensure proper storage and organization of tools to maintain a safe work environment.

Collaborative Safety Culture: Promoting a collaborative safety culture among mechanical engineering teams encourages open communication about safety concerns and fosters a proactive approach to identifying and mitigating potential risks.

TUTORIAL

1.State **TWO (2)** functions of a hacksaw.

....

....

....

2. Describe the most common hammer used in the workshop.

....

3. Give **THREE (3)** reasons for broken taps.

....

....

....

4. Explain the basic principles of the Vernier caliper.

....

....

....

....

....

....

....

....

....

5. Choose between double-cut files and single-cut files, which one is suitable when a smooth finish is desired or when hard materials are to be finished?

....

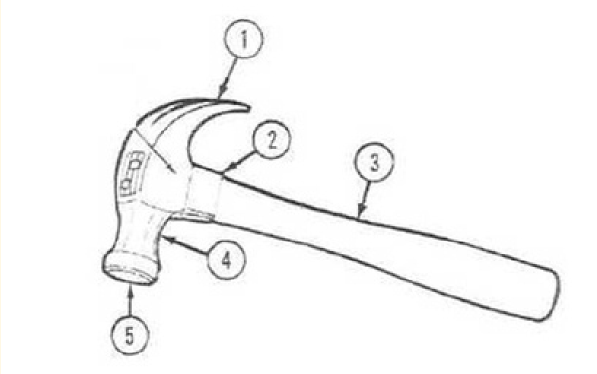


Figure 1: Claw type hammer

6. Label **FIVE (5)** parts of claw type hammer accordingly.

No.	**Name of Parts**
1	
2	
3	
4	
5	

7. Draw and label **SIX (6)** main parts of a standard micrometer.

8. Identify the function of hand tools.

....

....

....

9. Thread cutting taps are supplied in sets of three. Write the name of each taps.

....

....

....

10. Match **SEVEN (7)** tools according to their category or activity.

Tools		Category/activity
Surface gauge		Striking
Vernier caliper		Fixing
Files		Threading
Surface plate		Measuring
Dies		Testing/ Checking
Hammer		Marking out
Screw drivers		Cutting

11. State a solution for correcting a tap that has not started squarely.

....

....

....

12. Name **ONE (1)** reason why should a handle be used on a file?

....

13. What is a die?

....

....

14. Complete the label of the micrometer in Figure 2 using the hints given.

Hint:

Ratchet stop	Lock	Anvil	Frame	Thimble

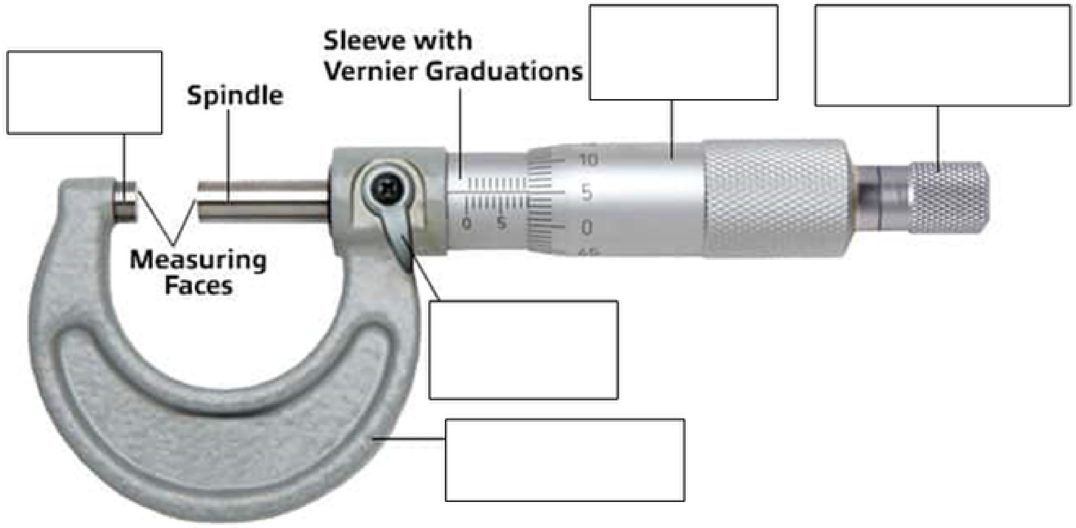
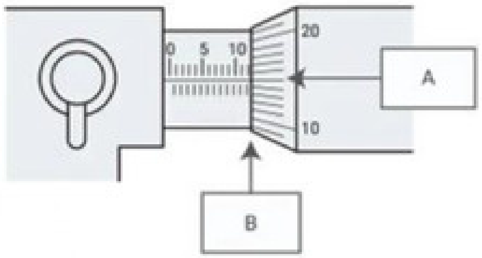
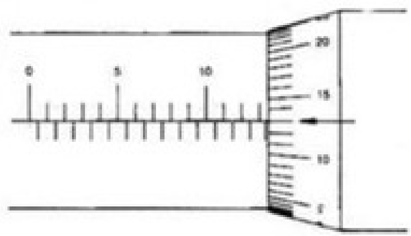
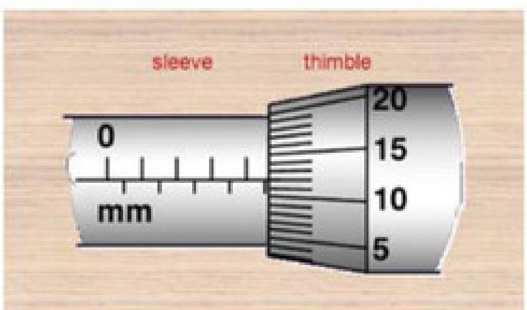


Figure 2: External micrometer

15. State the micrometer and vernier caliper readings.







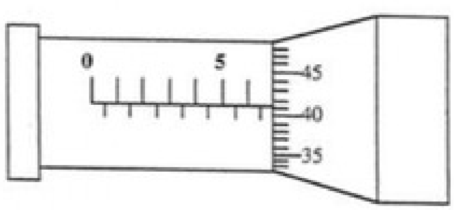
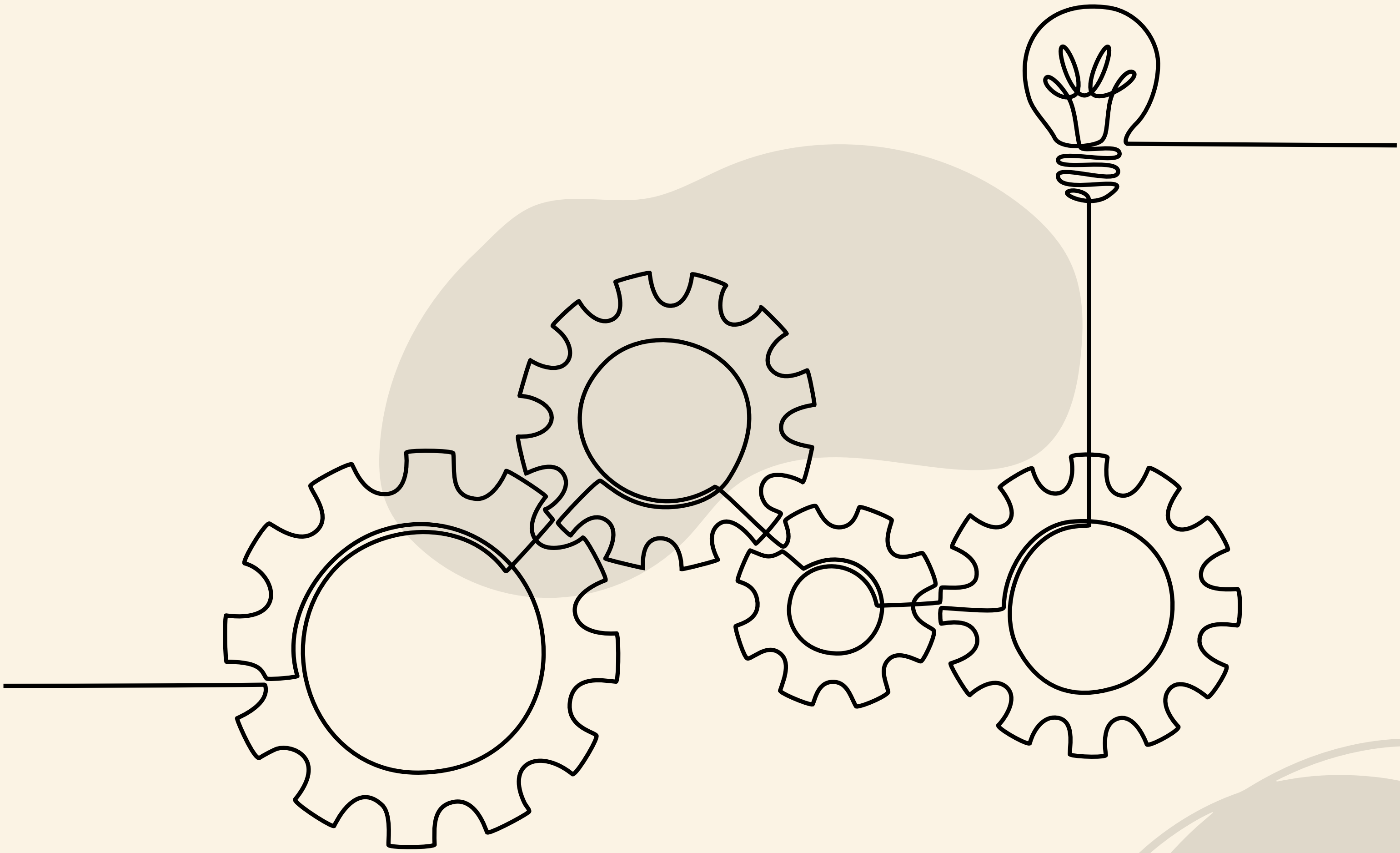


Figure 3: Micrometer and vernier caliper sample readings

DRILLING



INTRODUCTION

DRILLING

1. A drilling machine tool, called a drill press, is used to produce holes into or through workpiece material. Drill is held in the drilling machine by a chuck or Morse taper and is rotated and fed into the workpiece at variable speeds.

2. It can perform various machining operations: Drilling, boring, core drilling, step drilling, counter sinking, boring, counter boring, spot facing, reaming and tapping.

3. Drilling Machine is the simplest, moderate, and most accurate machine tool used in almost all the production shops and tool rooms. Drilling is basically a single-purpose machine tool as its main purpose is to make holes in the workpiece. Drilling operations can also be performed on lathe machines.

OBJECTIVES

Apply the knowledge of basic mechanical components and equipment, hand tools and measuring equipment in workshop technology.

Introduction to Drilling Machines:

A drilling machine is a versatile tool used in various industries for creating holes in different materials such as metal, wood, plastic, and more. It can perform a wide range of drilling operations, ranging from simple holes to complex patterns. Drilling machines are commonly used in construction sites, workshops, manufacturing plants, and maintenance facilities.

Types of Drilling Machines:

Bench Drill Press: This type of drilling machine is mounted on a workbench or table and is commonly used for lighter drilling tasks. It offers precise drilling capabilities and is often preferred for small-scale projects or hobbyists.

Pillar Drill Press: Also known as a column drill, this type of drilling machine is floor-mounted and provides stability, power, and accuracy. It is widely used in workshops and industrial settings for heavy-duty drilling tasks.

Radial Arm Drill: This drilling machine features a movable arm that can be adjusted to different positions. It offers versatility and is commonly used for large-scale drilling operations, such as drilling in large workpieces or multiple holes in a single setup.

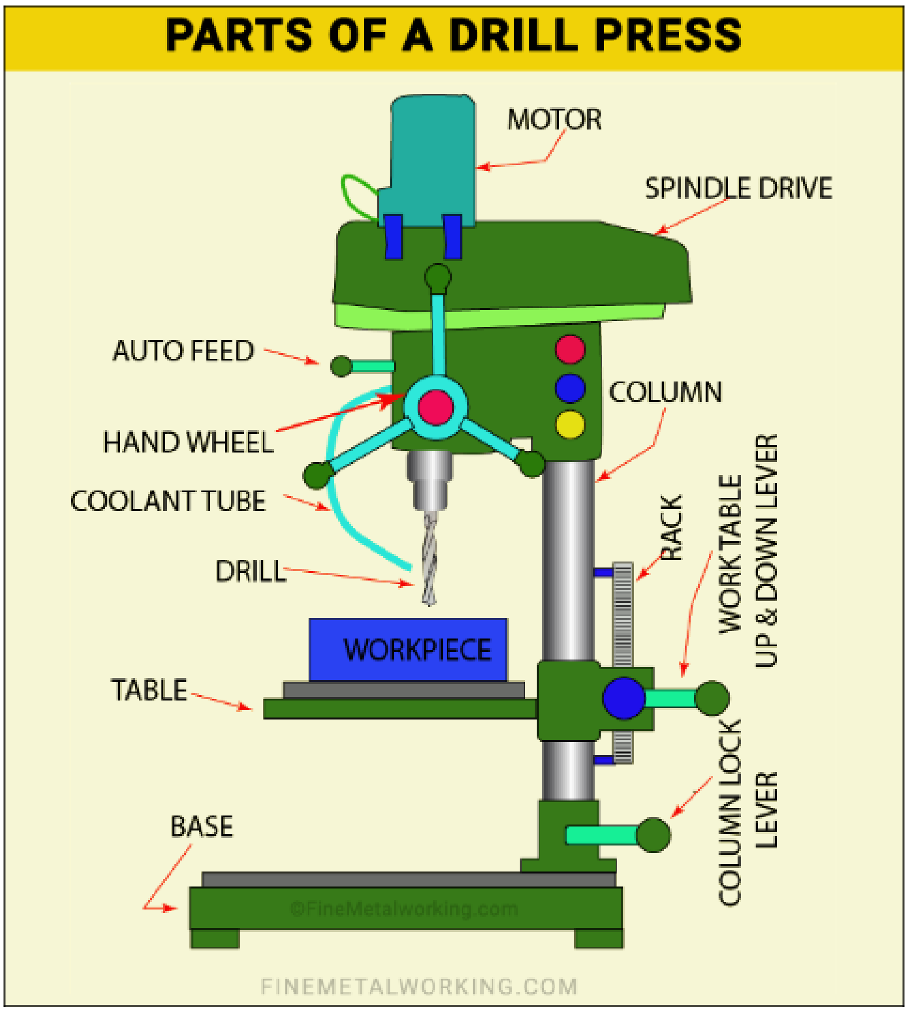
Portable Magnetic Drill: As the name suggests, this drilling machine is portable and uses a magnetic base to attach to the workpiece. It is commonly used in metal fabrication industries, offering flexibility and easy maneuverability in tight spaces or on vertical surfaces.

Cordless Drill: This handheld drilling machine is powered by rechargeable batteries, allowing for cord-free operation. It offers convenience, especially for on-the-go drilling tasks or situations where power outlets are not easily accessible.

Key Features and Considerations:

When selecting a drilling machine, it's important to consider various features and factors based on your specific requirements. Here are some key considerations:

- **Power and Speed:** Look for a drilling machine with sufficient power and variable speed options. Higher power ensures efficient drilling through different materials, while variable speed allows for versatility in handling various drilling tasks.
- **Chuck Size and Type:** The chuck is the part that holds the drill bit. Different chuck sizes and types accommodate various drill bit sizes and shank types. Ensure the drilling machine you choose can handle the range of drill bits you intend to use.
- **Depth Stop and Depth Gauge:** These features allow you to accurately control and measure the depth of the holes you drill, ensuring consistent results across multiple workpieces.
- **Adjustability and Stability:** Consider the adjustability and stability offered by the drilling machine. Look for features such as adjustable table height, arm position, and a solid base to ensure precise drilling and minimize vibrations.



Important parts:

- Base
- Column
- Spindle
- Sleeve (quill)
- Head
- Worktable

Drilling Important Parts

HEAD

The head of drill press is composed of the sleeve, spindle, electric motor and feed mechanism.

The head is connected to the column.

COLUMN

The column of most drill machines is circular and built rugged and solid.

The column supports the head and the sleeve or quill assembly.

BASE

The base supports the entire machine.

It should be bolted to the floor.

The top of the base is similar to a worktable and maybe equipped with T-slots for mounting workpiece too large for the table.

Drilling Important Parts

SLEEVE (QUILL)

The sleeve (quill) does not revolve but may slide in its bearing in a direction parallel to its axis.

When the sleeve carrying the spindle with a cutting tool is lowered, the cutting tool is fed into the workpiece.

When it is moved upward, the cutting tool is withdrawn from the workpiece.

Feed pressure applied to the sleeve by hand or power causes the revolving drill to cut its way into the workpiece.

WORKTABLE

The worktable is supported on an arm mounted to the column.

The worktable can be adjusted vertically to accommodate different heights of workpiece.

It may be swung completely out of the way.

SPINDLE

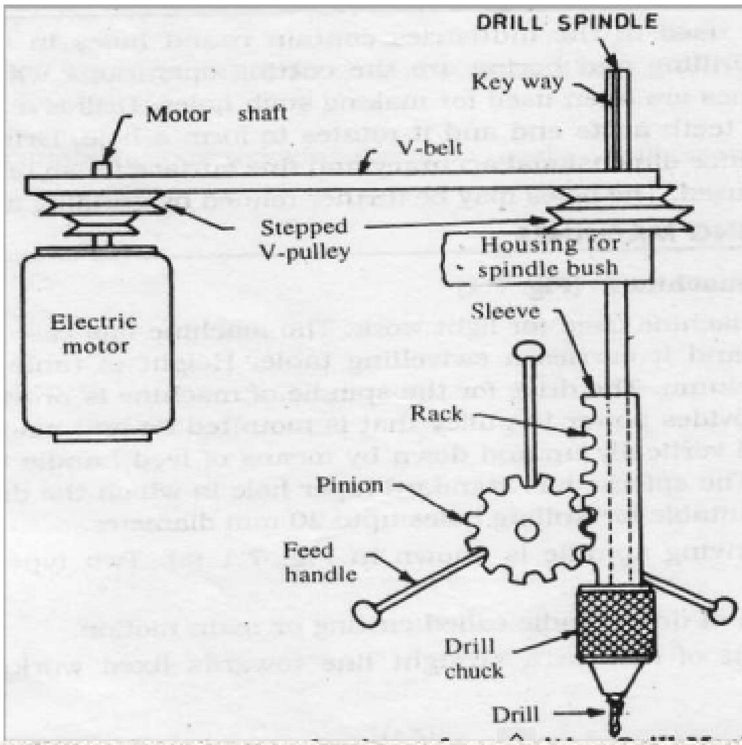
The spindle holds the drill (cutting tool) and revolves in a fixed position in a sleeve.

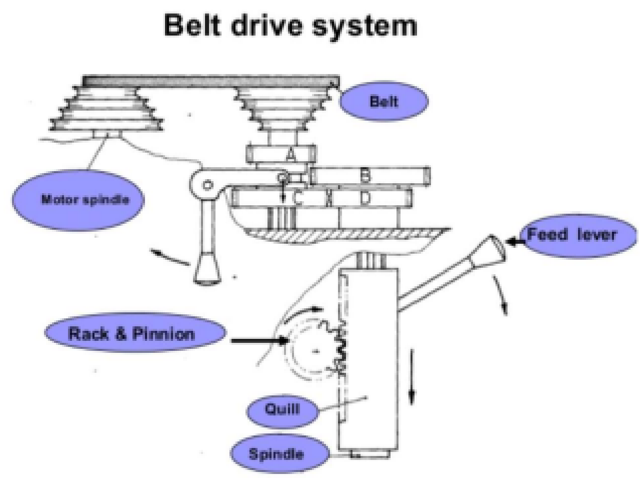
In most drilling machines, the spindle is vertical and work is supported on a horizontal table.

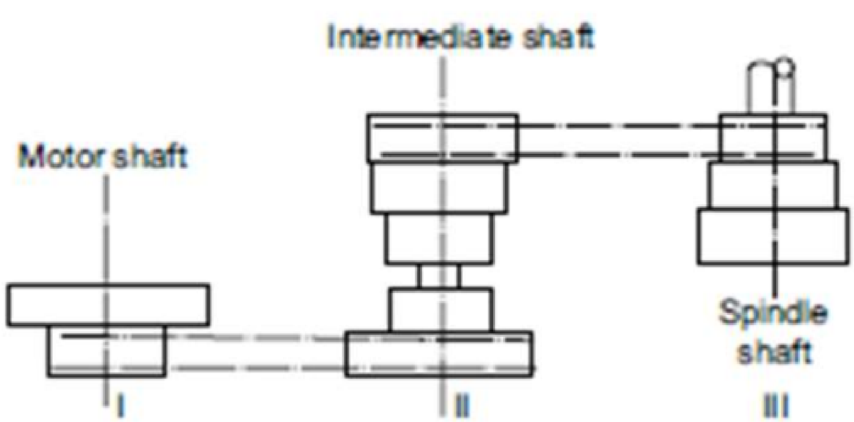
Drilling Driving Mechanisms

Stepped type driving mechanisms are widely used.

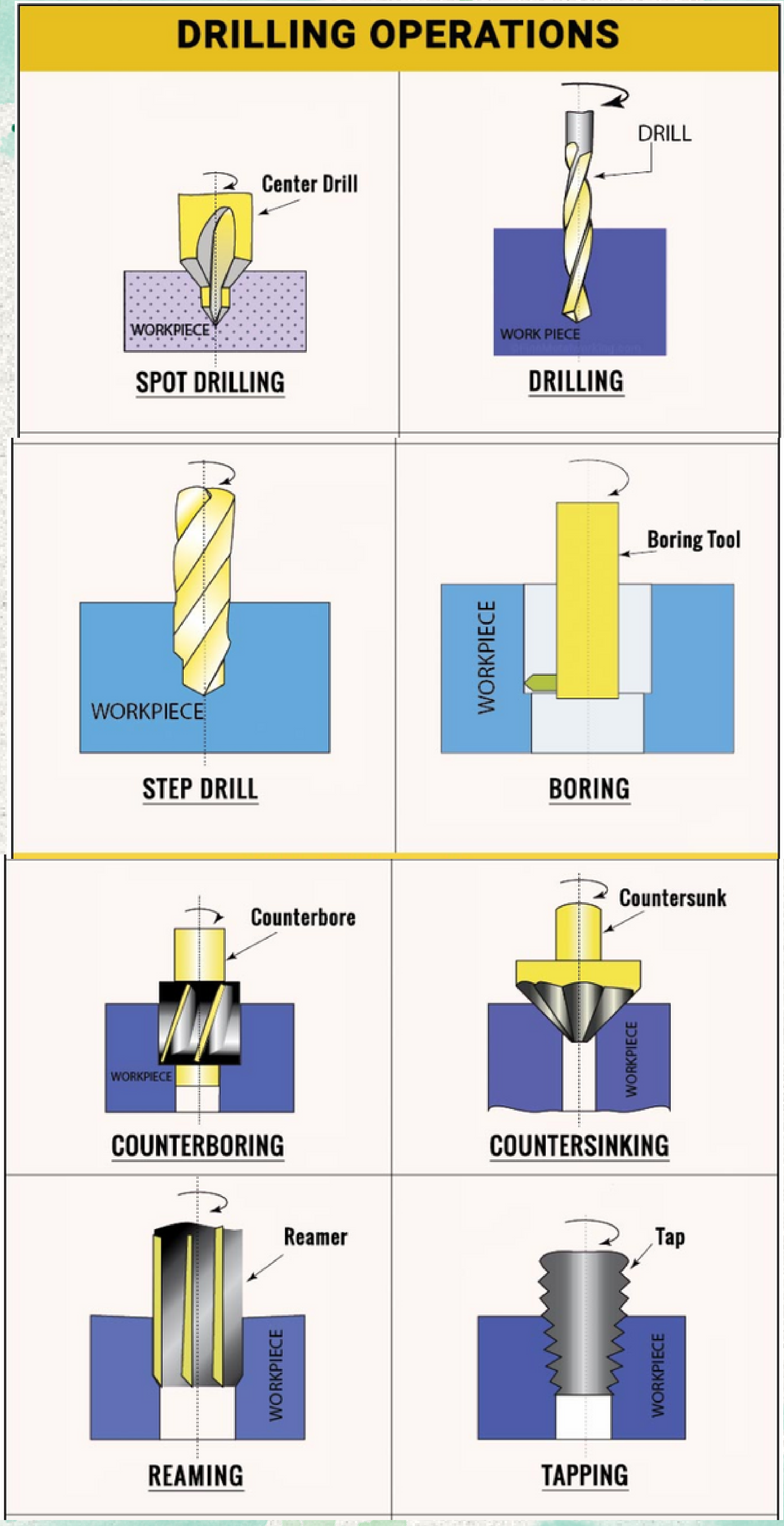
Stepless type driving mechanisms have found limited application according to drilling machine type (automatic feed mechanism)







Belt Transmission


DRILLING OPERATIONS
Center Drill
WORKPIECE
SPOT DRILLING
DRILL
WORK PIECE
DRILLING
WORKPIECE
STEP DRILL
Boring Tool
WORKPIECE
BORING
Counterbore
WORKPIECE
COUNTERBORING
Countersunk
WORKPIECE
COUNTERSINKING
Reamer
WORKPIECE
REAMING
Tap
WORKPIECE
TAPPING

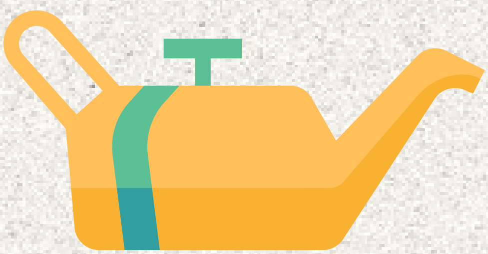
What is the purpose of a drilling machine?

You can do the drilling operation on any machine which has provision for rotating the work-piece or the tool, like a lathe or milling machine. However, a dedicated machine for drilling will make the work faster and accurate.

You can drill a workpiece in the following steps: center marking → center punch → center drill → drilling to the required size in one or more steps.

For doing tapping or reaming, you need to predrill a hole of the recommended size.

Drilling Machine has based upon the principle that the rotating edge of the tool exerts a large force on the workpiece and holes are being created in the workpiece. The material is removed from the workpiece by the shearing and extrusion process.



Coolant System

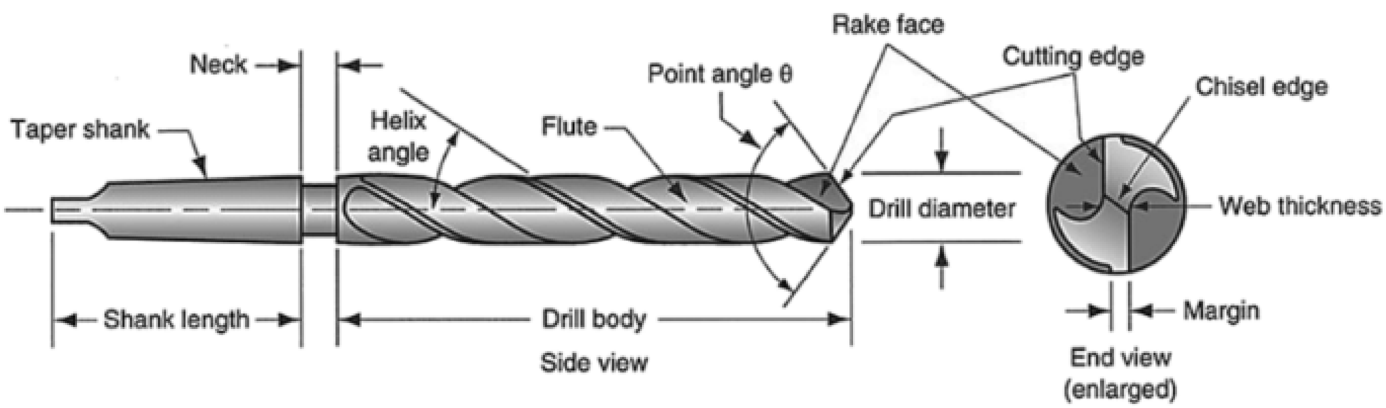
Like the other machines, the drilling machine also needs a cooling system to cool the cutting area. Normally all drilling machines will have a cooling system consisting of a coolant tank, coolant pump, connecting hose, and a filter to separate the chips. In small machines that do not have a cooling system, you need to spray a cooling oil manually to the cutting area.

Easier chip removal	Help dissipate heat	Wash away the chips
Permit greater cutting speeds	Improve surface finsh	Providing for maximum tool life

Tool Bit

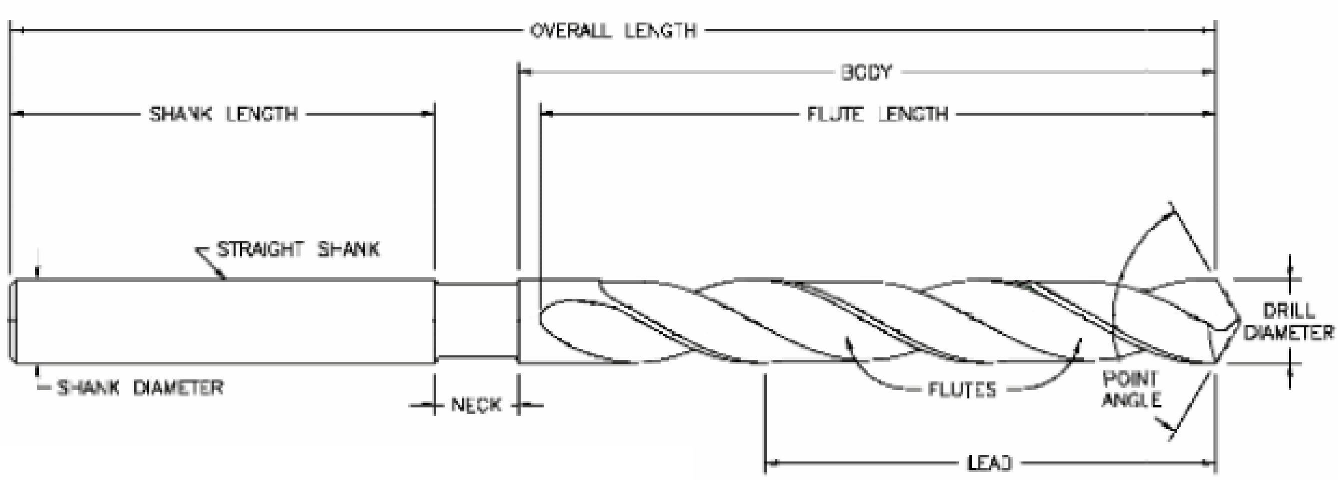
What Is A Twist Drill Bit?

A Twist drill bit is a cutting tool used with a drill machine to create cylindrical holes in various materials, such as wood, metal, or plastic. It is typically a cylindrical or conical-shaped metal piece with spiral grooves called flutes along its length. The flutes help to remove debris and chips from the hole as the drill bit rotates.



Straight Shank Twist Drill

Anatomy of a drill bit:



Terminologies

- **Body:** The primary and central cylindrical portion of the drill bit that extends from the shank to the drilling end. It provides structural integrity and stability to the overall design of the drill bit, ensuring precise and controlled drilling.

- **Shank:** The non-cutting end of the drill bit, usually a cylindrical section with a specific diameter, that is inserted into the drill chuck. It acts as a secure connection point between the drill bit and the drilling machine, allowing for efficient power transmission during drilling operations.

- **Point:** The sharpened and tapering tip of the drill bit that initiates the drilling action by piercing the material being drilled. It features a carefully crafted geometry to facilitate easy penetration and reduce the amount of force required for drilling.

- **Lips:** The precise and keen cutting edges formed by the intersection of the two flutes at the drilling end of the drill bit. These edges exhibit exceptional sharpness and hardness to effectively shear and remove material during the drilling process.

- **Body Clearance:** The strategically relieved area situated behind the cutting edges or lips. It offers ample space for efficient chip removal, preventing chip congestion and ensuring the drill bit operates smoothly, reducing heat buildup and prolonging the bit's lifespan.

- **Chisel Edge:** The straight and refined edge formed at the center of the drill bit where the two lips meet. It aids in the initial guidance and stability of the drill bit during the early stages of drilling, facilitating precise hole placement.

Terminologies

- **Chisel Edge Corner:** The sharply defined corner formed at the intersection of the chisel edges at the center of the drill bit. It assists in accurate positioning and centering of the drill bit, enhancing drilling precision and minimising the risk of wandering.
- **Face:** The flat and meticulously machined surface located behind the lips, extending from the dead center to the chisel edge. It provides consistent support to the lips and plays a crucial role in facilitating efficient chip evacuation and maintaining cutting performance.

- **Flank:** The smoothly contoured and structurally integral surface of the drill bit that connects the face to the body. It ensures stability and strength during drilling operations, minimizing vibration and deflection for enhanced drilling accuracy.
- **Flutes:** The precisely formed and carefully spaced spiral or helical grooves that extend along the length of the drill bit. These flutes act as pathways for the swift and effective removal of chips and debris, preventing clogging and promoting efficient chip evacuation.

- **Heel:** The terminating end of the drill bit situated behind the cutting edges and flutes. It contributes to the overall robustness and stability of the drill bit, maintaining alignment and preventing unnecessary deflection during drilling.
- **Neck:** The skill-fully tapered or reduced diameter section connecting the body to the shank. It serves as a transition zone, smoothly blending the larger body to the narrower shank, optimizing strength and reducing the risk of breakage during demanding drilling tasks.
- **Tang:** A specifically designed flat or tapered section located on the shank of certain drill bits. The tang provides a reliable means of securely gripping the drill bit in compatible drill chucks, ensuring firm attachment and minimizsng any potential slippage during drilling operations.

Types of Twist Drill Bit

HSS Reduced Shank Turbo Max Twist Drill Bit

Best HSS Drill Bit for Metal Fully Ground

Bright Surface HSS Drill Bit for Metal Drilling

HSS 135 Degree Twist Drill Bits for Metal Drilling

Best Hss Fully Ground Twist Drill Bits

Best Black and Gold HSS Twist Drill Bits

Straight Shank HSS Titanium Drill Bits

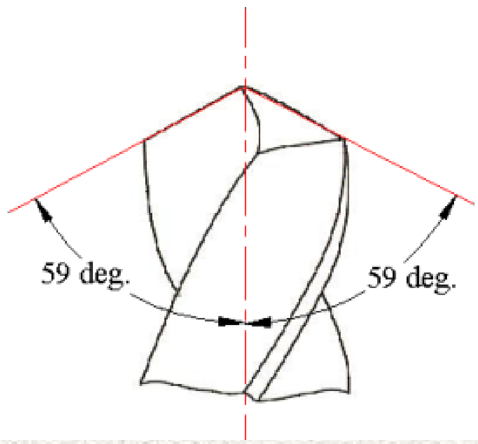
Metal Drilling HSS Metal Drill Bit Black Oxide

1. Taper-shank Drills
2. Cobalt Highspeed Steel
3. Straight shank drills, taper length
4. Straight shank drills, jobber's length
5. Heavy-duty drills
6. Cotter pin drills
7. Straight fluted drill
8. Half-round drills
9. Multi-cut drill
10. Deep Hole Drill
11. Shell-type core drill and
12. Carbide Drills

Drilling Angle

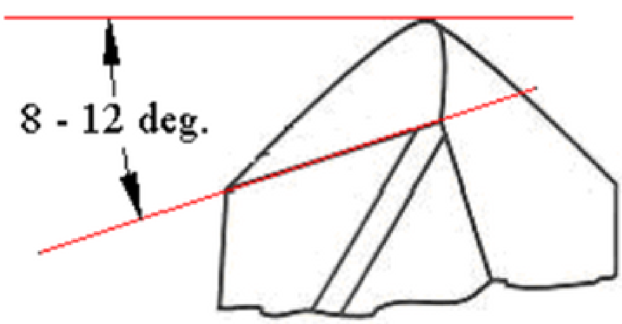
Point angle:

The point angle on a conventional drill is 118° for drilling medium carbon steel.



The lip clearance angle

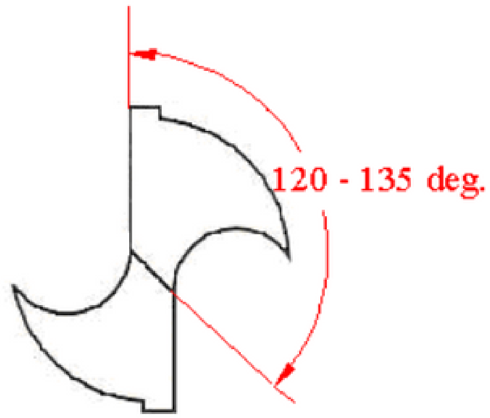
The lip clearance angle vary according to the drilled material, for hard material the range is 6 – 9° and for soft materials up to 15°.



Drilling Angle

The chisel edge angle

The chisel edge angle is also vary according to the drilled materials, for hard material it should be 120º and for soft materials 135º.



Drilling Procedures

How to Drill a Hole?

Step 1: Measure and Mark. Measure the location of the hole. Use a scriber to draw intersection line.

Step 2: Center Punch. A center punch makes a small dent in the surface of the material that prevents the drill from wandering when it first contacts the surface.

Step 3: Set Up the drilling machine. Use clamps to secure the workpiece to the worktable.

Step 4: Drill the workpiece.

Step 5: Clean Up the Hole (De-burr)

Step 6: Clean Up the work area.

DRILL BIT MATERIALS

- High-Speed Steel (HSS): High-speed steel is a popular choice for drill bits due to its excellent balance of hardness, toughness, and heat resistance. It is an alloy of steel with elements like tungsten, molybdenum, chromium, and vanadium. HSS drill bits are versatile and can effectively drill in materials such as wood, metal, plastic, and composites.
- Cobalt Steel: Cobalt steel drill bits are made by alloying high-speed steel with cobalt. The addition of cobalt enhances the hardness, heat resistance, and durability of the drill bit. Cobalt drill bits are particularly well-suited for drilling in hard materials like stainless steel, cast iron, and high-temperature alloys.
- Carbide-Tipped: Carbide-tipped drill bits feature a cutting edge made of carbide, which is a very hard and wear-resistant material. The carbide tip is brazed or welded onto a steel body. Carbide-tipped bits are known for their ability to drill in tough materials, including concrete, masonry, and ceramics.
- Solid Carbide: Solid carbide drill bits are made entirely of carbide material. Carbide is extremely hard and can withstand high temperatures, making these bits highly suitable for drilling in hard and abrasive materials like hardened steel, cast iron, and composites. Solid carbide bits are commonly used in machining and high-precision drilling applications.
- Diamond-Coated: Diamond-coated drill bits have a thin layer of diamond particles deposited onto the cutting edge. Diamond is the hardest known material, making these bits exceptionally effective for drilling in very hard materials like glass, ceramics, and stone.
- Titanium Nitride (TiN) Coated: TiN-coated drill bits have a thin layer of titanium nitride applied to the surface. The coating enhances the hardness, lubricity, and wear resistance of the drill bit. TiN-coated bits are commonly used in metalworking applications, providing extended tool life and reduced friction during drilling.

DRILL BIT MATERIALS

- **Black Oxide Coated: Black oxide-coated drill bits undergo a surface treatment that provides corrosion resistance and improved lubricity. The black oxide coating helps reduce friction and heat during drilling. These bits are commonly used for general-purpose drilling in materials like wood, metal, and plastic.**
- **The choice of drill bit material depends on factors such as the type of material being drilled, the desired hole size and quality, and the specific requirements of the drilling application. Selecting the appropriate drill bit material ensures optimal performance and longevity of the tool.**

Twist Drill Angle

The twist drill angle refers to the angle formed by the cutting lips of a twist drill bit. The two primary angles associated with a twist drill are the point angle and the helix angle:

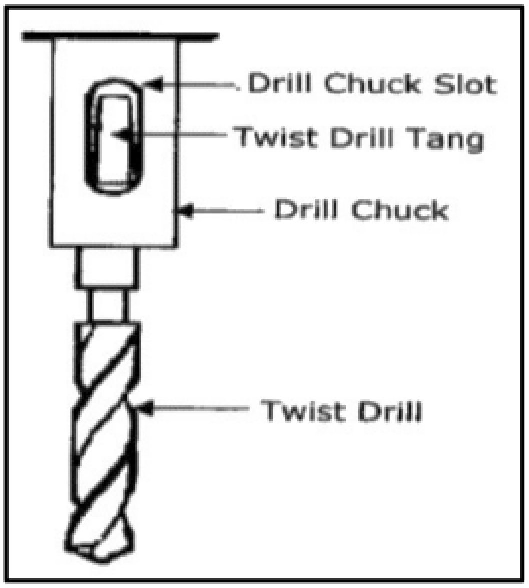
1. Point Angle: The point angle is the angle formed between the cutting edges at the tip of the drill bit. It determines the aggressiveness and efficiency of the cutting action. The most common point angle for twist drills is 118 degrees or 135 degrees. The 118-degree angle is commonly used for general-purpose drilling in materials like wood, metal, and plastic. The 135-degree angle is often preferred for drilling in harder materials such as stainless steel and cast iron.
2. Helix Angle: The helix angle refers to the angle formed between the leading edge of the flute and a plane perpendicular to the drill axis. It determines the rate at which the drill bit advances into the material and affects chip evacuation. The helix angle can vary depending on the application and material being drilled. Typically, twist drills have helix angles ranging from 20 degrees to 40 degrees. Steeper helix angles are used for softer materials, while shallower angles are used for harder materials.

The twist drill angle plays a significant role in the cutting performance, chip evacuation, and overall efficiency of the drill bit. It is essential to select the appropriate drill bit with the correct twist drill angle for the specific drilling application and material to achieve optimal results.

Tool Holding Devices

- By directly fitting in the spindle hole
- By using drill sleeve
- By using drill chuck

By directly fitting in the spindle hole



By using drill sleeve

Where a cutting tool or Chuck has a Morse taper smaller than that of the spindle, the difference is made up by using a **sleeve**.

Tool Holding Devices

By using drill chuck

Drills and similar tools with parallel shanks are held in a **drill chuck**.

By rotating the outer sleeve, the jaws can be opened and closed.

To ensure maximum grip, the chuck should be tightened using the correct size of chuck key. This prevents the drill from spinning during use and chewing up the drill shank.

Drill Socket

Drill sockets and drill sleeves are such adapters, used in order to add to or substract from the Morse taper so that the drill bit fits into the chuck spindle.

Work Holding Devices

The work should be held firmly on the machine table before performing any operation on it. As the drill exerts very high quantity of torque while rotating, the work should not be held by hand. If the workpiece is not held by a proper holding device, it will start rotating along with the tool causing injuries to the operator and damage to the machine.

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

- Drill vise
- ‘T’ - bolts and clamps
- Step block
- V - block
- Angle plate
- Drill jigs

Drill Vise

Vise is one of the important devices used for holding workpiece on a drilling machine table. The work is clamped in a vise between a fixed jaw and a movable jaw.

Parallel blocks are placed below the work so that the drill may completely pass through the work without damaging the table. Different types of vises are used for holding different types of work and for performing different operations.

The different types of vises are
Plain vise
Swivel vise
Tilting vise
Universal vise

Drill Vise

T-Bolt

The workpieces can be held directly on the machine table by means of 'T' - bolts and clamps. The top of the machine table has 'T' - slots into which 'T' - bolts may be fitted. The bolts of diameter 15 to 20mm are used.

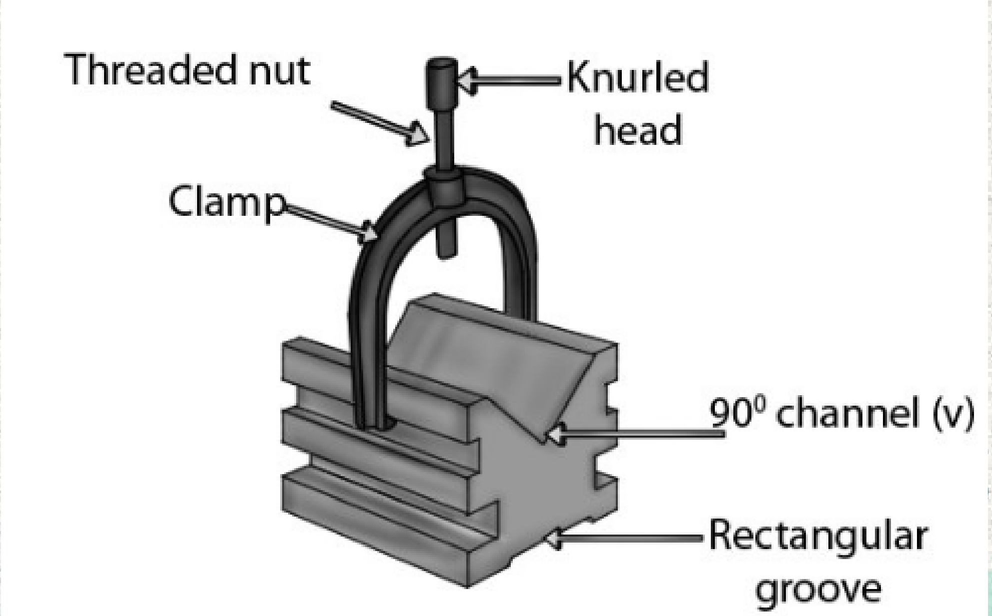
The clamps are made of mild steel. 'T' - bolts pass through a central hole on the clamp. The clamp is made to rest horizontally on the work surface by placing a suitable step block at the other end of the work.

Step Block

The step blocks are used in combination with 'T' - bolts and clamps for holding the work directly on the table. The step block supports the other end of the clamp. Workpieces of different heights are held by leveling the clamp on different steps of the step block

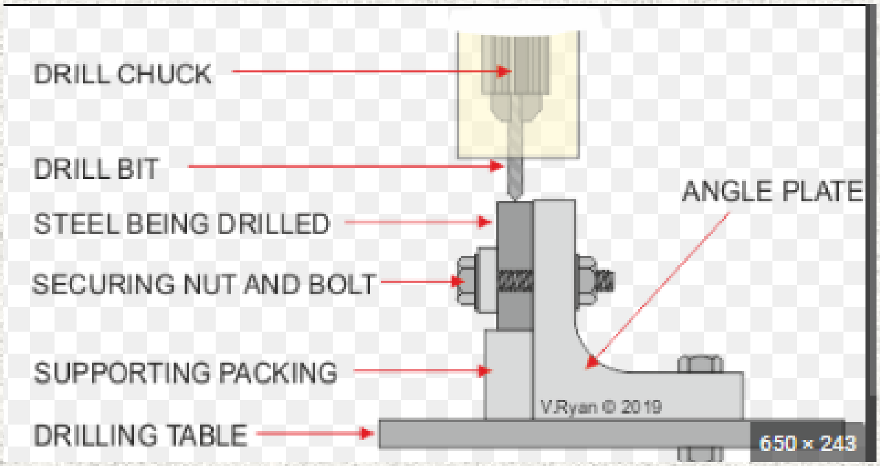
V Block

V- blocks are used for holding cylindrical workpieces. The work may be supported on two or three 'V' - blocks according to the length of the work. The work is held on the 'V' groove and is clamped by straps and bolts. They are made of cast iron or steel and are accurately machined



Angle Plate

Angle plates have two faces at right angle to each other and are made of cast iron. It resembles the English alphabet 'L'. All the sides of a angle plate are machined accurately. Slots and holes are provided on both the faces of the angle plate. Work is clamped on one of its faces by means of bolts and nuts.

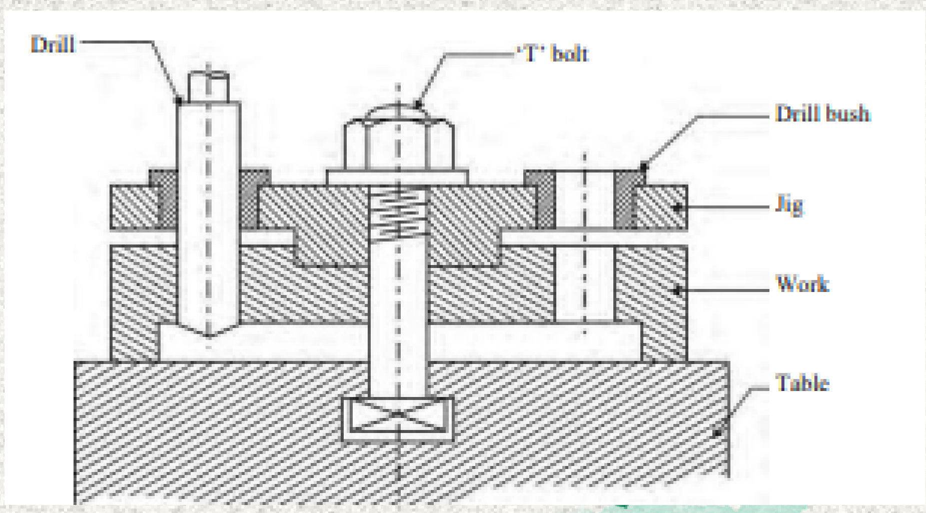


Drill Jig

Drill jigs are used in mass production process. A jig is specially designed to hold the work securely and to guide the tool at any desired position. Holes may be drilled at the same relative positions on each of the identical workpieces.

The work is clamped and removed easily. The cost of making a drill jig is more but a low order of skill is sufficient to work with a drill jig.

Different types of drill jigs are
1. Plate jig 4.Box jig
2. Channel jig 5.Indexing jig.
3. Diameter jig



Advantages & Disadvantages

Various advantages of the drilling machine are:

- High speed
- High output
- Easy to operate
- High flexibility
- Low maintenance and lower cost.

The various trouble experienced during drilling along with their remedies are as follows:

- Limited size workpiece
- Rough hole
- Chipped cutting lips
- Oversized holes
- Breaking of drill

Applications of Twist Drill

- Metalworking: Twist drill bits are extensively used in metalworking applications. They can drill holes in materials like steel, aluminum, brass, and other metals. Whether it's for general fabrication, construction, automotive, or aerospace industries, twist drill bits are essential tools for creating holes in metal components.

- Woodworking: Twist drill bits are also commonly used in woodworking applications. They can drill holes in wooden materials, including solid wood, plywood, and MDF (Medium-Density Fiberboard). Woodworkers use twist drill bits for tasks such as creating dowel holes, pilot holes for screws, and general hole drilling in woodworking projects.

- Plastic and Composite Materials: Twist drill bits are suitable for drilling holes in various plastic materials, such as acrylic, PVC, and ABS. They are also used for drilling holes in composite materials like fiberglass, carbon fiber, and laminates.

- DIY and Home Improvement: Twist drill bits are widely used in DIY projects and home improvement tasks. Whether it's drilling holes to install shelves, hooks, or assembling furniture, twist drill bits are essential tools for many household applications.

- Electrical and Plumbing: Electricians and plumbers often use twist drill bits to create holes for running wires, cables, and pipes through walls, floors, or ceilings. Twist drill bits allow them to efficiently and accurately drill holes in different materials encountered in electrical and plumbing installations.

- Metal Fabrication: In metal fabrication processes such as machining, drilling precise holes is a common requirement. Twist drill bits are used in milling machines, lathes, and other machining equipment to create holes for bolts, dowels, and other fasteners.

Drilling Recommendations

- The speed is the *surface speed* of the drill at its periphery

General Recommendations for Speeds and Feeds in Drilling

		Drill diameter			
		Feed, mm/rev		Speed, rpm	
Workpiece material	Surface speed m/min	1.5 mm	12.5 mm	1.5 mm	12.5 mm
Aluminum alloys	30–120	0.025	0.30	6400–25,000	800–3000
Magnesium alloys	45–120	0.025	0.30	9600–25,000	1100–3000
Copper alloys	15–60	0.025	0.25	3200–12,000	400–1500
Steels	20–30	0.025	0.30	4300–6400	500–800
Stainless steels	10–20	0.025	0.18	2100–4300	250–500
Titanium alloys	6–20	0.010	0.15	1300–4300	150–500
Cast irons	20–60	0.025	0.30	4300–12,000	500–1500
Thermoplastics	30–60	0.025	0.13	6400–12,000	800–1500
Thermosets	20–60	0.025	0.10	4300–12,000	500–1500

Note: As hole depth increases, speeds and feeds should be reduced. The selection of speeds and feeds also depends on the specific surface finish required.

Drilling Recommendations

- The *feed* in drilling is the distance the drill travels into the workpiece per revolution
- *Chip removal* during drilling can be difficult for deep holes in soft and ductile workpiece materials

General Troubleshooting Guide for Drilling Operations

Problem	Probable causes
Drill breakage	Dull drill, drill seizing in hole because of chips clogging flutes, feed too high, lip relief angle too small
Excessive drill wear	Cutting speed too high, ineffective cutting fluid, rake angle too high, drill burned and strength lost when drill was sharpened
Tapered hole	Drill misaligned or bent, lips not equal, web not central
Oversize hole	Same as previous entry, machine spindle loose, chisel edge not central, side force on workpiece
Poor hole surface finish	Dull drill, ineffective cutting fluid, welding of workpiece material on drill margin, improperly ground drill, improper alignment

Drill Reconditioning

- Drills are reconditioned by grinding them either manually or with special fixtures
- Hand grinding is difficult and requires considerable skill in order to produce symmetric cutting edges
- Grinding on fixtures is accurate and is done on special computer controlled grinders

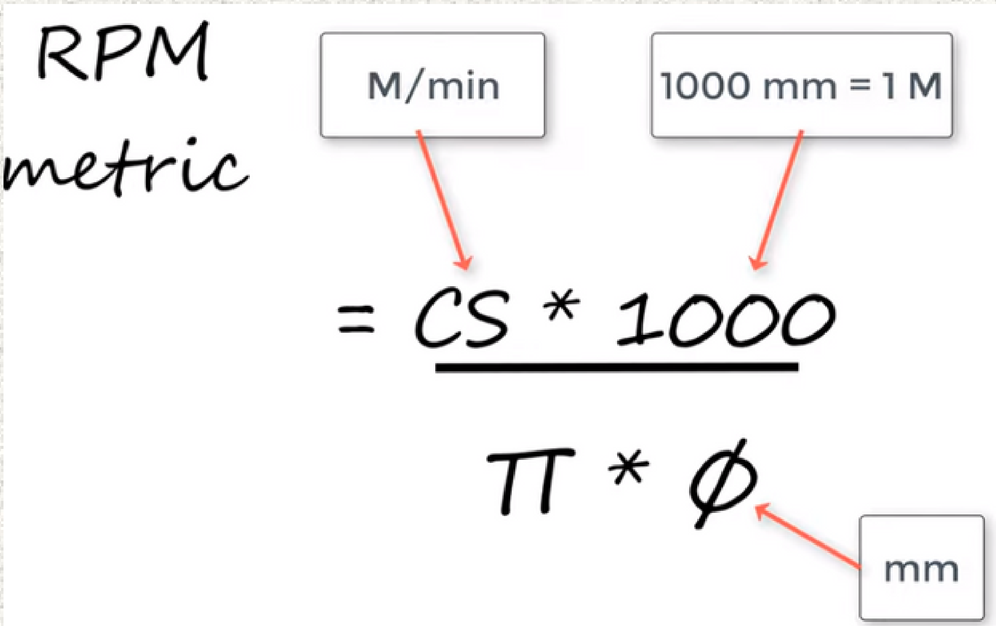
Measuring Drill Life

- Drill life is measured by the number of holes drilled before they become dull and need to be re-worked or replaced
- *Drill life* is defined as the number of holes drilled until this transition begins

FEEDS	
Use lower feed range for:	Use higher feed range for:
Fine tooth cutters Fragile and small cutters Light and finishing cuts Deep slots Hard-to-machine materials Flexible workpiece or setup	Coarse tooth cutters Rugged cutters Heavy roughing cuts Abrasive materials Easy-to-machine materials Rigid setups
SPEEDS	
Use lower speed range for:	Use higher speed range for:
Heavy cuts Hard materials Tough materials Abrasive materials Maximum cutter life Minimum tool wear Flexible workpiece or setup	Light cuts Softer materials Non-metallics Maximum production rates Better finishes Hand feed operations Higher tool rake angles

Drilling Calculation

Revolution Per Minute (RPM)



Also known as (aka) spindle speed. The RPM setting for drilling depends on the cutting speed of the material and the size of the drill bit. The RPM setting will change with the size of the bit. As the drill bit gets smaller, the RPM must increase to maintain the recommended surface footage. Take the case of the wheel. Think of the drill bit as a wheel and the cutting speed as a distance. A larger wheel (drill bit) will need to turn less revolutions to cover the same distance in the same amount of time than a smaller wheel (drill bit). Therefore, to maintain the recommended cutting speed, larger drills must be run at slower speeds than smaller drills.

Unit: rpm @ rev/min

Drilling Calculation

Cutting Speed (CS)

CS is the rate at which the tool passes over the surface of the metal (or how fast the cutting tool is spinning)

Cutting speed is the speed at the outside edge of the tool as it is cutting. This is also known as surface speed. Surface speed, surface footage, and surface area are all directly related. If two tools of different sizes are turning at the same revolutions per minute (RPM), the larger tool has a greater surface speed.

Unit: m/min

Feed (F)

The feed of a drill is the distance the drill moves into the work at each revolution of the spindle. It is expressed in millimeters. The feed may also be expressed as feed per minute. The feed per minute may be defined as the axial distance moved by the drill into the work per minute. Feed depends upon factors like the material to be drilled, the rigidity of the machine, power, depth of the hole and the type of finish required.

Unit: mm

Depth of Cut (DoC)

The depth of cut in drilling is equal to one half of the drill diameter. If 'd' is the diameter of the drill, the depth of cut (t) $t = d/2$ mm.

Drilling Calculation

1. If a 15 mm twist drill is to cut a medium carbon steel using cutting speed of 21.4 m/min. Find the RPM.

$$RPM = \frac{CS \times 1000}{\pi \times D}$$

$$= \frac{21.4 \times 1000}{\pi \times 15}$$

$$RPM = 454.12 \text{ rev/min}$$

2. Find the CS of a 10 mm diameter drill with a spindle of 178 rev/ min.

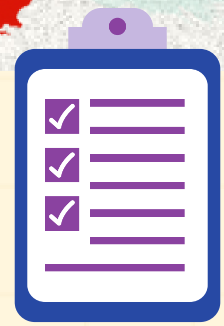
$$RPM = \frac{CS \times 1000}{\pi \times D}$$

$$CS = \frac{RPM \times \pi \times D}{1000}$$

$$= \frac{178 \times \pi \times 10}{1000}$$

$$= 5.59 \text{ m/min}$$

SAFETY & MAINTENANCE

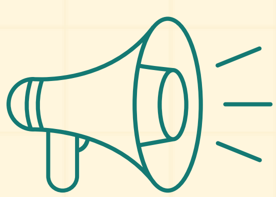


Safety should be a top priority when working with drilling machines. Here are some essential safety precautions to follow:

- Always wear appropriate personal protective equipment, including safety goggles, gloves, and ear protection.
- Make sure the workpiece is securely clamped or fixed in place to prevent movement during drilling.
- Avoid wearing loose clothing or jewelry that could get caught in the drilling machine.
- Switch off the machine and unplug it when not in use or during maintenance.
- Familiarize yourself with the specific safety guidelines outlined in the drilling machine's user manual.

Proper maintenance and care help prolong the lifespan and ensure optimal performance of a drilling machine. Here are some maintenance tips:

- Regularly clean the drilling machine and remove any debris or dust buildup from the motor, chuck, and other components.
- Lubricate moving parts as recommended by the manufacturer to prevent friction and ensure smooth operation.
- Inspect the power cord and plugs for any signs of damage, and replace them if necessary.
- Check and adjust the belt tension if applicable to maintain proper power transmission.
- Store the drilling machine in a clean and dry environment, away from moisture or extreme temperatures.



Remember to always refer to the manufacturer's instructions and guidelines for specific details about the drilling machine you are using, as different models may have unique features or requirements. Stay safe and enjoy the benefits of using a drilling machine for your projects.

TUTORIAL

1.Describe **TWO (2)** ways of checking a drill size.

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2. Name **TWO (2)** methods of holding a drill bit.

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3. Discuss the consequences of drilling with a drill bit that has not been sharpened properly.

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4. Write **FOUR (4)** types of work holding devices suitable for drilling operation.

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5. Solve the problem of finding revolutions per minute (N) required to drill the following holes using a high-speed drill:

i. A 5 mm hole in tool steel (Given: CS18 m/min)

Answer:

ii. A 20 mm hole in machine steel (Given: CS30 m/min)

Answer:

6. Illustrate a twist drill and label the common parts.

7. Calculate the revolutions per minute (N) required to drill the following holes using a high-speed drill:

i. A 9 mm hole in a steel casting (Given: CS12 m/min)

Answer:

ii. A 20 mm hole in cast iron (Given: CS24 m/min)

Answer:

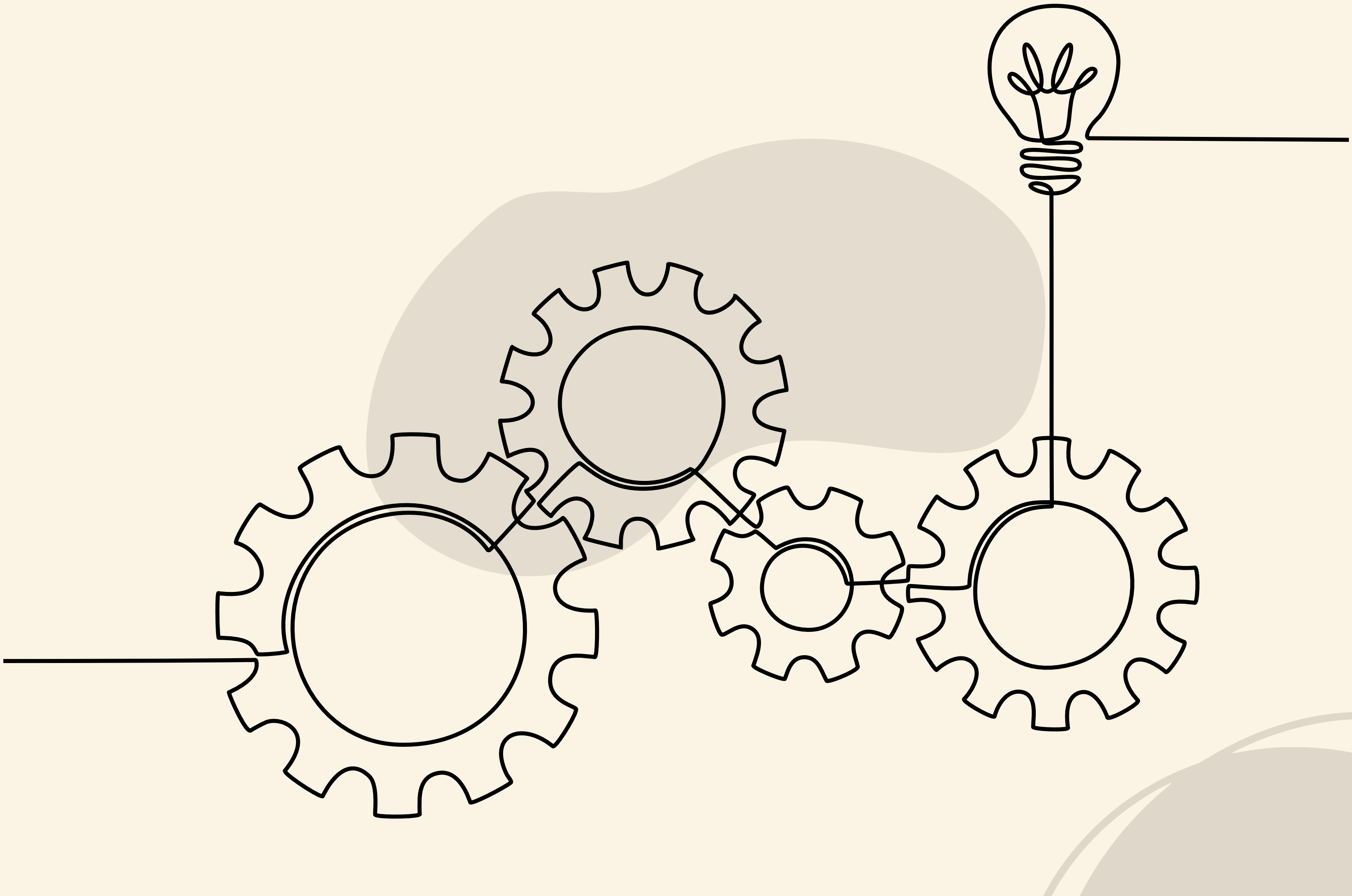
8. Name and draw **TWO (2)** work-holding devices on drilling machine.

9. State **FOUR (4)** coolant functions in drilling process.

10. Explain the procedure for clamping a workpiece properly.

11. Identify **THREE (3)** criteria of good cutting fluid.

LATHE



INTRODUCTION

LATHE

1. Lathe machining can be considered the forerunner of all machine tools. The work is held & rotated on its axis while the cutting tool is fed along the lines of a desired cut.

2. With the suitable attachments, lathe can be used for turning, boring, drilling, threading, reaming, grinding, facing, tapering, polishing etc. Cutting operations are performed using cutting tool fed either at the right angles or parallel to the work axis.

3. In ordinary turning, metal is removed using a single-point tool and the tool itself must be harder than the workpiece. Chips formed from the cutting process slide across the tool face.

OBJECTIVES

Apply the knowledge of basic mechanical components and equipment, hand tools and measuring equipment in workshop technology.

NOTES

Lathe is a machining tool used for shaping wood or metal by rotating the workpiece around a stationary cutting tool.

Lathe is done by removing the excess material (called chips).

CHUCKS

CUTTING PROCESS

During the process, the workpiece is mounted on the chuck/ face plate while the cutting tool is placed on the tool post.

TYPES OF LATHES

➢ **Engine Lathe or center lathe**

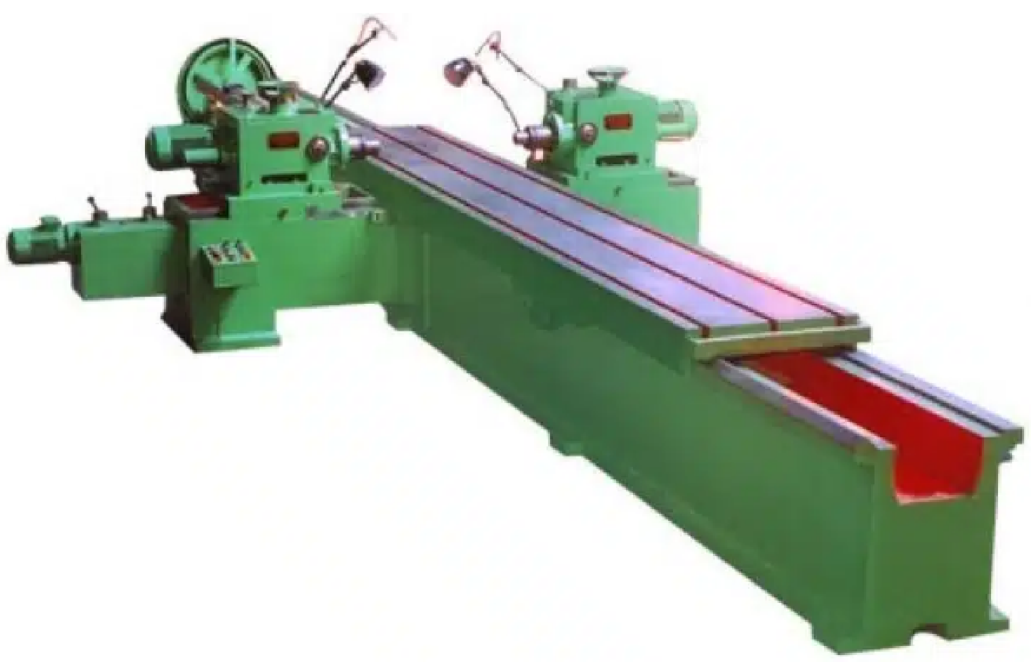
- It is most common type of lathe and is widely used in workshop.
- The speed of the spindle can be widely varied as desired which is not possible in a speed lathe.

➢ **Bench Lathe**

- Small lathe which can mounted on the work bench
- It is used to make small precision and light jobs.

➢ **Speed lathe**

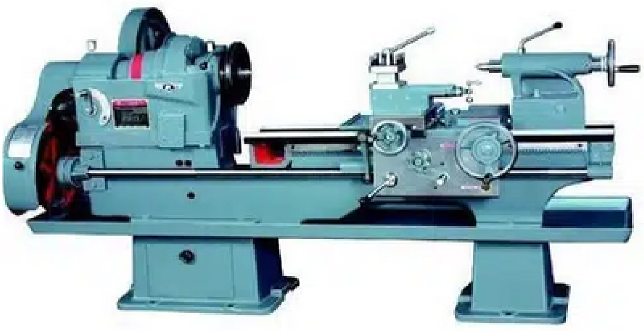
- It is named because of the very high speed of the head stock spindle.
- Consists head stock, a tail stock and tool post. it has no gear box.
- Applicable in wood turning, metal spinning and operations.



Special Purpose Lathe Machine

TYPES OF LATHE

- **Tool room lathe :**
  - It is similar to an engine lathe, designed for obtaining accuracy.
  - It is used for manufacturing precision components, dies, tools, jigs etc. and hence it is called as tool room lathe.
- **Special purpose lathes :**
  - Gap lathe
  - Instrument lathe
  - Facing lathe
  - Flow turning lathe
  - Heavy duty lathe



Automatic Lathe Machine

- **Automatic Lathe**
  - A lathe in which the work piece is automatically fed and removed without use of an operator.
  - It requires very less attention after the setup has been made and the machine loaded.
- **Turret Lathe**
  - Turret lathe is the adaptation of the engine lathe where the tail stock is replaced by a turret slide(cylindrical or hexagonal).
  - Tool post of the engine lathe is replaced by a cross slide which can hold number of tools.
- **Capstan lathe**
  - These are similar to turrent lathe with the difference that turret is not fixed but moves on an auxiliary slide. these are used for fast production of small parts.

Engine Lathe Machine

Tool Room Lathe Machine

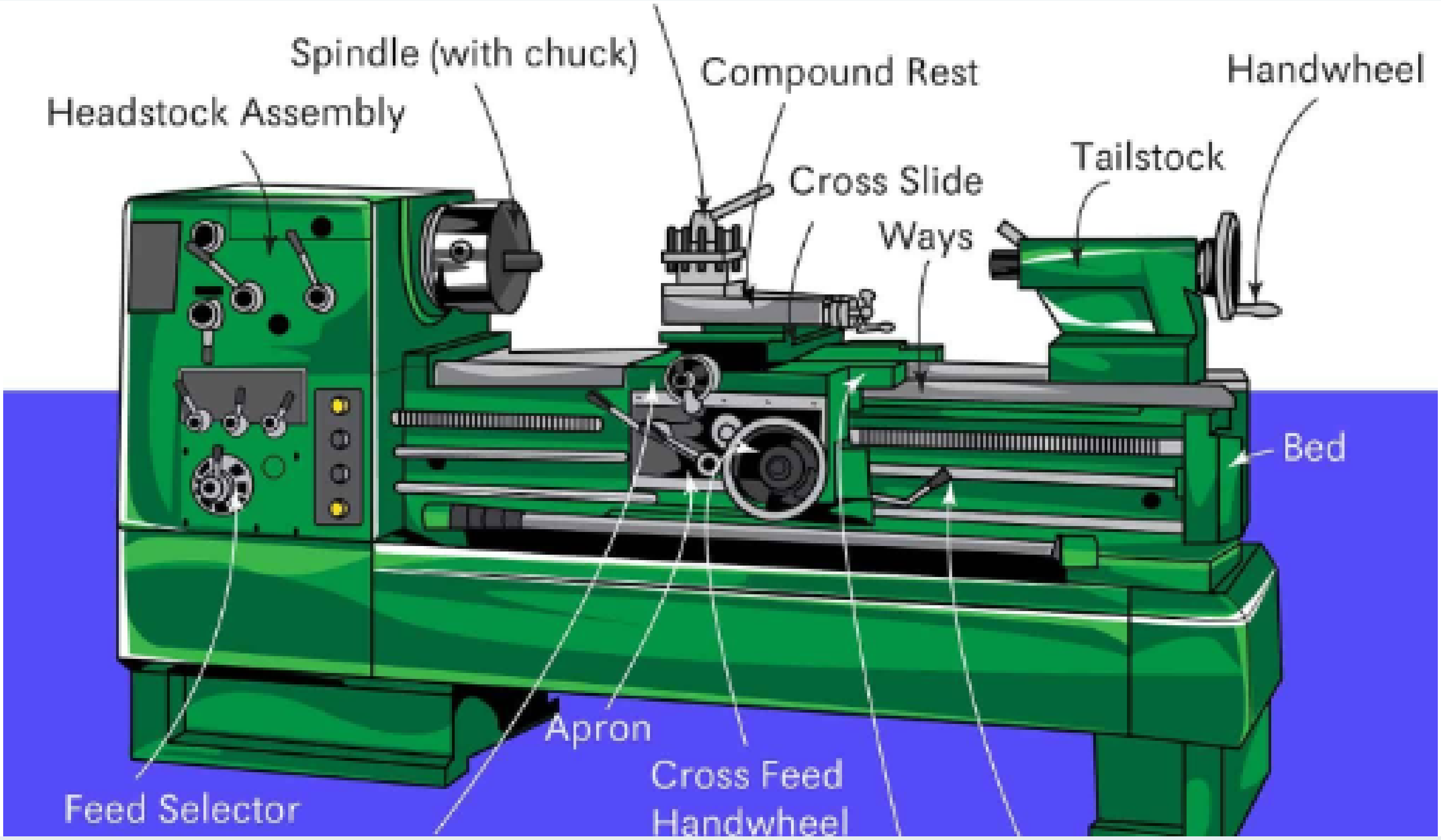
Speed Lathe Machine

Bench Lathe Machine

Turret Lathe Machine

CNC Lathe Machine

LATHE MACHINE & PARTS



LATHE MAIN PARTS

1. Headstock
2. Tailstock
3. Carriage
4. Bed
5. Quick change gear box

LATHE PARTS

Here we will introduce some important parts of the Lathe Machine.

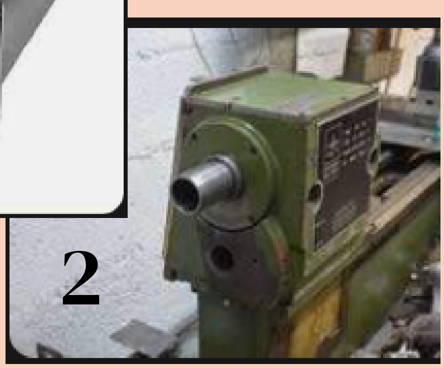
1.Bed. The bed is also known as the tray, It is the main part of the lathe machine and the main guiding part for accurate machining works. The bed must be rigid enough to withstand the forces created from the operation process and able to handle the weight of the workpiece. All the parts of the lathe machine are mounted on it such as the tailstock, headstock, carriage, and other parts. High-grade special cast iron is normally used as the material of the bed as it is rigid and has high damping quality which able to absorb the vibrations produced during the machining.

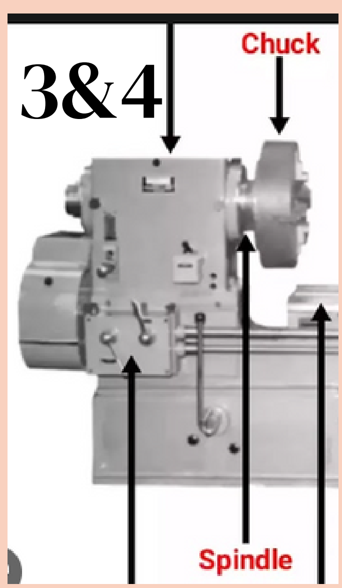
2.Headstock is installed on the left side of the lathe machine. It acts as a housing to keep some parts of the machine such as the main spindle, chuck, gear train, gear speed control levers, and feed controllers. These transmission systems are used together to monitor and change the speed of the spindle.

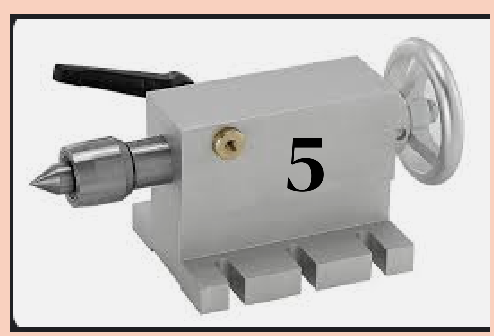
3.Chuck: This is a device that bolted on the spindle of the headstock and used to hold the workpiece at one end. It rotates with the spindle and so the workpiece. There are generally using two types of chunks which are three-jaw and four-jaw chuck. The three-jaw chuck (self-centering) is designed to move simultaneously whereas the four-jaw chuck is moving independently.

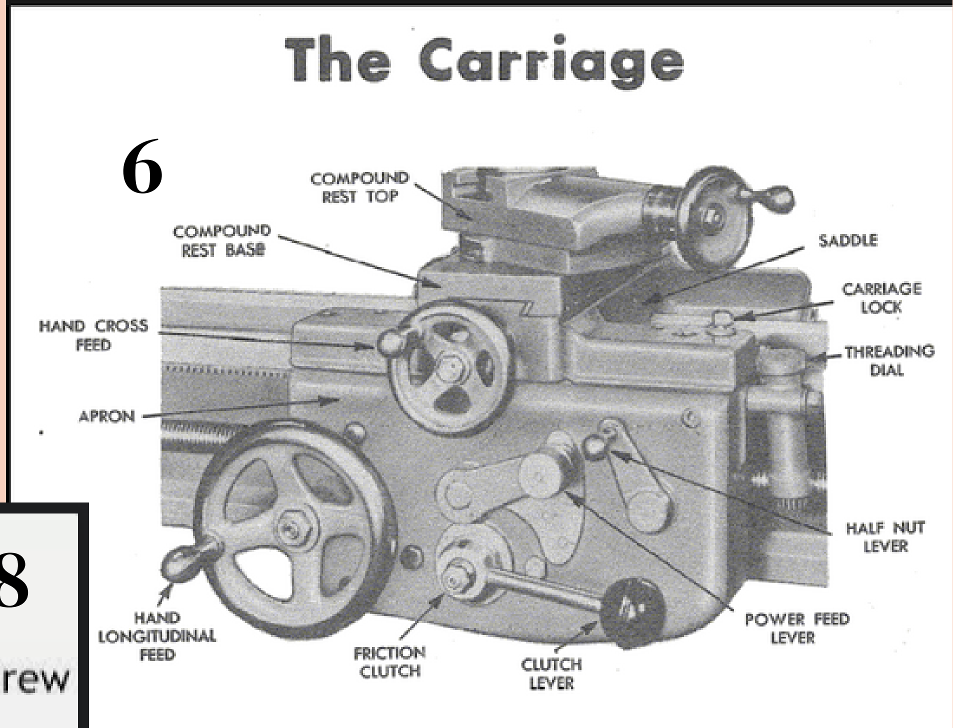
4.Main Spindle is a hollow shaft and the chunk is mounted on it. This is used to hold and rotate the chuck and its hollow design allows long bars to pass through.

5.Tailstock is movable and located on the right side of the lathe. The two main purposes of the tailstock are to provide support to the workpiece from the right end when it is being machined and to hold tools for performing several operations such as tapping, drilling, etc. It is good for centering the job when a long work is tied on the chuck and provide support to damp the vibration.









LATHE PARTS

6.Carriage is located in between the headstock and tailstock. It can be moved manually or with power feed in the outer ways. The carriage consists of 5 main parts which are the Saddle, Apron, Cross slide, Tool post, and compound rest. It provides three movements to the tools which are longitudinal feed, cross feed, and angular feed. Five main parts in the carriage including

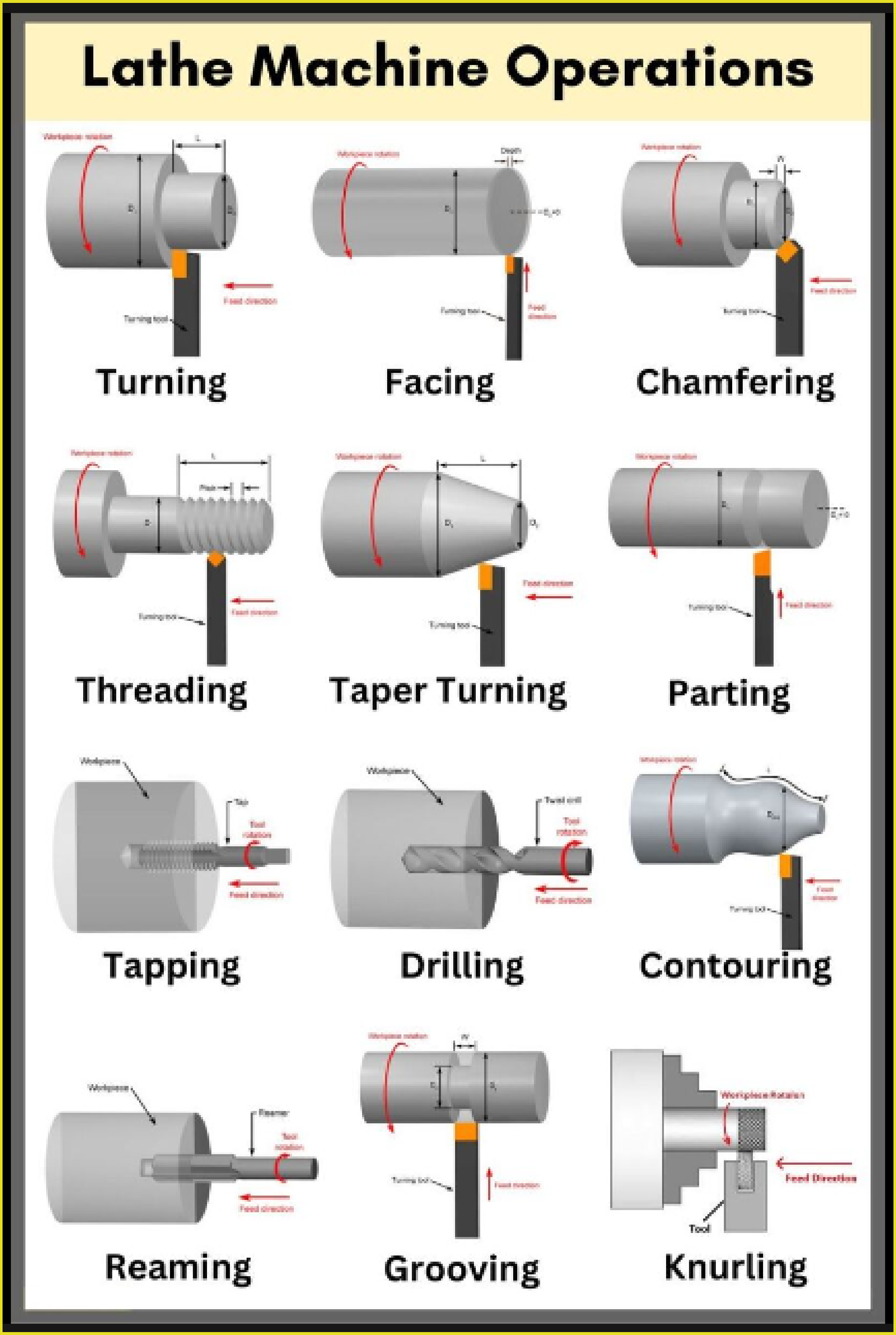
a) Saddle: Located at the top portion of the carriage.
b) Apron: Located at the front portion of the carriage. It includes all the mechanisms of moving and controlling the carriage.
c) Cross slide: To provide cutting motion of the tool. It can be operated manually or by the cross feed equipment.
d) Tool post: It is mounted at the top of the carriage and possesses a T-slot used for holding various tools.
e) Compound rest: It is mounted to the cross slide and used to support the tool post or cutting tools in multiple positions for taper turning and other operations.

7.Lead Screw is located below the feed rod and used to move the carriage longitudinally during thread cutting operation.

8.Feed Rod is used to moving the carriage horizontally from left to right and vice versa. The movement of the feed rood is mandatory during the turning operation.

9.Hand Wheel is operated manually by hand to move the carriage, cross slide, tailstock, and other parts that equipped with the handwheel.

LATHE MACHINE OPERATIONS



Lathe Machine Operations

LATHE OPERATIONS

- **Turning**: to remove material from the outside diameter of a workpiece to obtain a finished surface.
- **Facing**: to produce a flat surface at the end of the workpiece or for making face grooves.
- **Boring**: to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves.
- **Drilling**: to produce a hole on the work piece.
- **Reaming**: to finishing the drilled hole.
- **Threading**: to produce external or internal threads on the work piece.
- **Knurling**: to produce a regularly shaped roughness on the workpiece.

MATERIAL USED FOR MAKING TOOL BIT

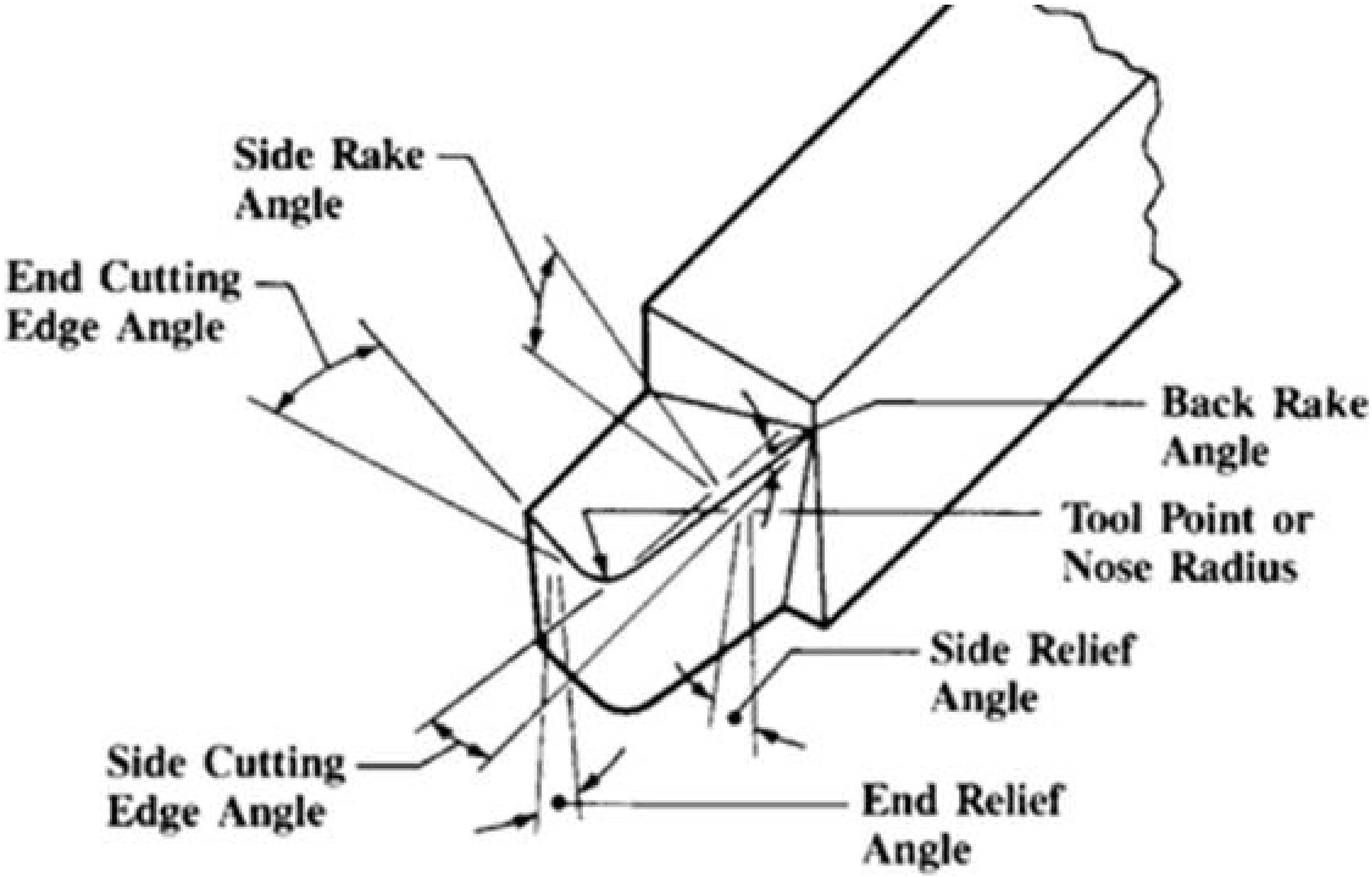
1. High Speed Steel (HSS)
2. Cobalt
3. Carbide
4. Tungsten
5. Molybdenum
6. Chromium
7. Vanadium
8. Carbon
9. Diamond

TYPES OF TOOL FOR LATHE

TOOL BIT- SEVEN ANGLES

Components Of A Lathe Cutting Tool

Although lathe machine tools have different designs for their functions and applications, they all have specific parts in common. Below are the parts commons to every type of lathe cutting tool.



TOOL BIT- SEVEN ANGLES

1. Rake angle - to control direction of chips flow & the strength of the tool bit.

2. Side rake angle - to control flow chip direction. Angle is typically about 5 degree.

3. Cutting edge angle - this angle affects chip formation , tool strength & cutting force to various degree. Angle is typically about 15 degree.

4. Relief angle - control interference & rubbing at the tool & workpiece.

DIFFERENTIATE 3 & 4 JAW CHUCKS

3 JAW CHUCK

- Setting up of work is easy
- Has less gripping power
- Depth of cut is comparatively less
- Heavier jobs cannot be turned
- Workpieces cannot be set for eccentric turning

4 JAW CHUCK

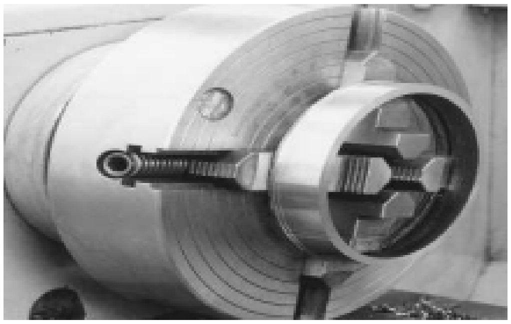
- Setting up of work is difficult
- More gripping power
- More depth of cut can be given
- Heavier jobs can be turned
- Workpieces can be set for eccentric turning

TYPES OF CHUCK

Three jaw chuck

- For holding cylindrical stock centered.
- For facing/center drilling,etc.

Four-Jaw Chuck



- This is independent chuck generally has four jaws , which are adjusted individually on the chuck face by means of adjusting screws

Collet Chuck

Collet chuck is used to hold small workpieces

Magnetic Chuck

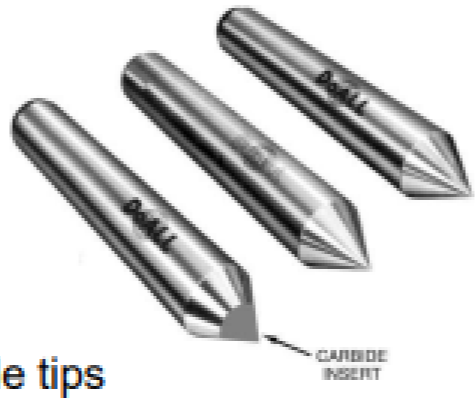
Thin jobs can be held by means of magnetic chucks.

WORKHOLDING DEVICES

Lathe Centers

- Work to be turned between centers must have center hole drilled in each end
  - Provides bearing surface
- Support during cutting
- Most common have solid Morse taper shank

  60º centers, steel with carbide tips
- Care to adjust and lubricate occasionally



Mandrels

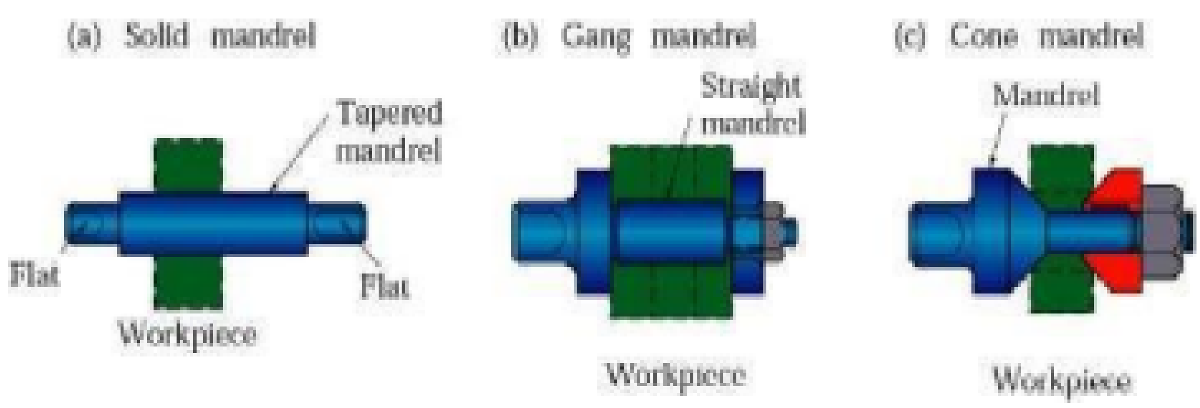


Fig : Various types of mandrels to hold work pieces for turning. These mandrels are usually mounted between centers on a lathe. Note that in (a) both the cylindrical and the end faces of the workpiece can be machined, whereas in (b) and (c) only the cylindrical surfaces can be machined.

Types of Lathe Dogs

- Standard bent-tail lathe dog
  - Most commonly used for round workpieces
  - Available with square-head setscrews of headless setscrews
- Straight-tail lathe dog
  - Driven by stud in drive plate
  - Used in precision turning

46-54

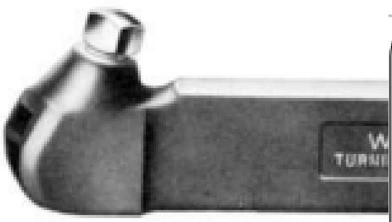
Types of Lathe Dogs

- Safety clamp lathe dog
  - Used to hold variety of work
  - Wide range of adjustment
- Clamp lathe dog
  - Wider range than others
  - Used on all shapes

LATHE TOOL HOLDER

Straight Toolholder

- General-purpose type
- Used for taking cuts in either direction and for general machining operations
- Designated by letter S



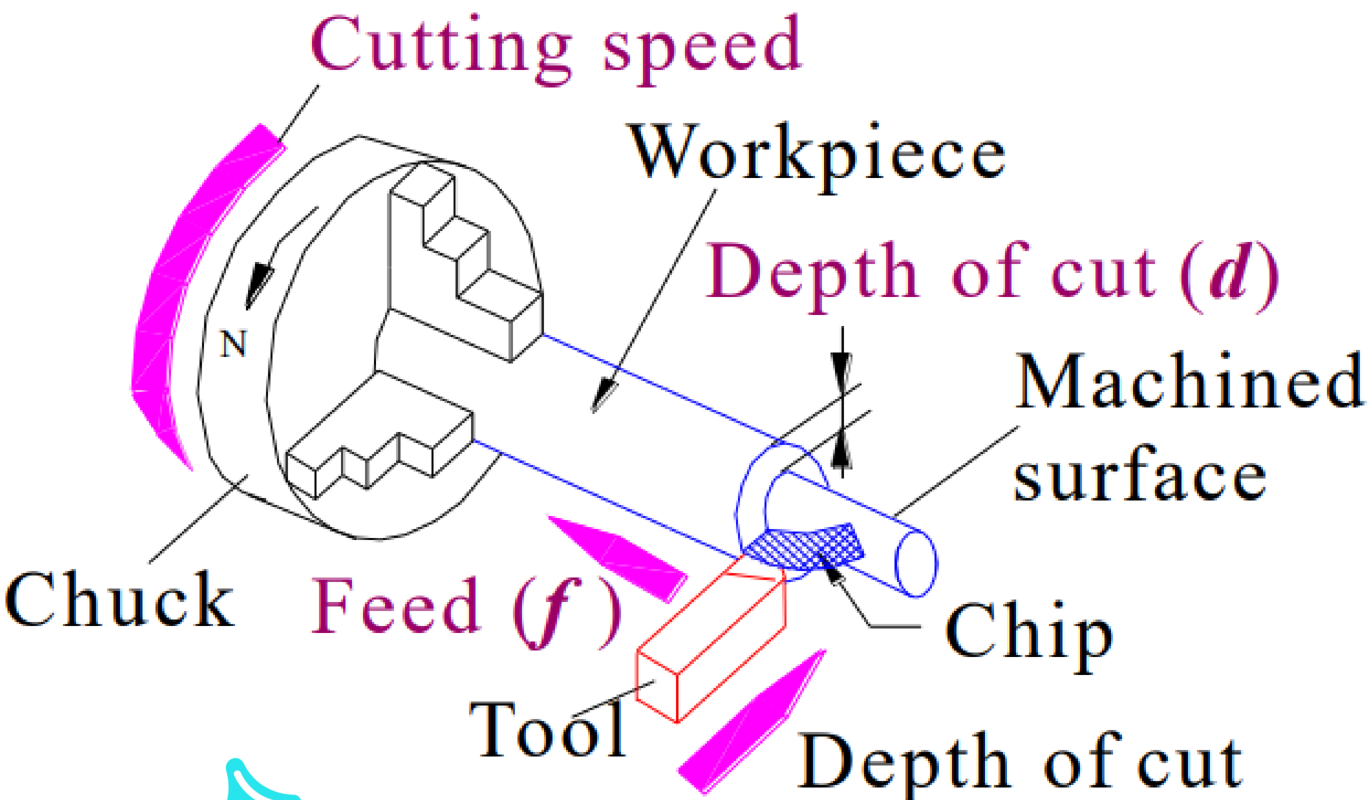
Right-Hand Offset Toolholder

- Offset to the left
- Designed for machining work close to the tailstock and cutting left to right
    - Also for facing operations
- Designated by letter R

Left-Hand Offset Toolholder

- Offset to the right
- Designed for machining work close to chuck or faceplate and cutting right to left
- Designated by letter L

Operating Conditions



CUTTING SPEED, FEED & DEPTH OF CUT

CUTTING SPEED

- aka CS
- It is defined as the rate in meters per minute at which the surface of the job moves past the cutting tool.

$$Cutting\ Speed = \frac{\pi\, dn}{1000}\ m/min$$

n also refer to RPM

FEED

- Defined as the distance for a tool advances into the work during one revolution of the headstock spindle.

DEPTH OF CUT

- Defined as the perpendicular distance measured from the machined surface to the uncut surface of the workpiece.

$$Depth\ Of\ Cut = \frac{d_1 - d_2}{2}$$

Where,

- d1 – diameter of the workpiece surface before machining.
- d2 – diameter of the machined surface.

SUGGESTED CUTTING SPEED

Average cutting speed expressed in meter per minute for different operations in a lathe using an H.S.S. tool

AVERAGE CUTTING SPEED EXPRESSED IN m. PER MINUTE FOR DIFFERENT OPERATIONS IN A LATHE USING A H.S.S. TOOL

Material	Turning	Thread Cutting	Drilling	Reaming
Cast Iron	15 – 19	7 – 8	22 – 31	6 – 8
Mild Steel	25 – 31	9 – 10	28 – 35	10 – 15
Brass	60 – 90	20 – 25	60 – 90	25 – 30
Aluminium	120	25 – 30	60 – 90	20 – 30

Average cutting speed, feed and depth of cut for different tool materials:

AVERAGE CUTTING SPEED, FEED AND DEPTH OF CUT FOR DIFFERENT TOOL MATERIALS

Material	H.S.S v.m.p.m.	Stellite v.m.p.m.	Cemented Carbide v.m.p.m.	Feed Mm/rev	Depth of Cut mm
Cast Iron	15 – 19	30	63	0.2 to 0.8	0.5 to 1 for finishing operations 2 to 5 for roughing operation
Mild Steel	25 – 31	55	810		
Brass	60 – 90	120	180		
Aluminium	120	300	360		

LATHE APPLICATIONS

Metalworking: Lathe machines are widely used for turning, facing, threading, and tapering operations on metal parts. They are crucial in the production of shafts, bolts, nuts, and other precision components.

Woodworking: Lathe machines are utilized for shaping, grooving, and carving wooden workpieces, resulting in furniture components, decorative objects, musical instruments, and more.

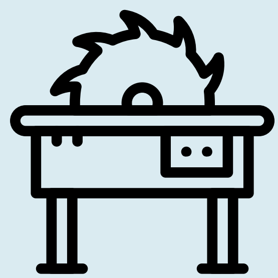
Plastics Industry: Lathe machines are employed for machining plastic materials, producing items like pipes, fittings, automotive parts, and household products.

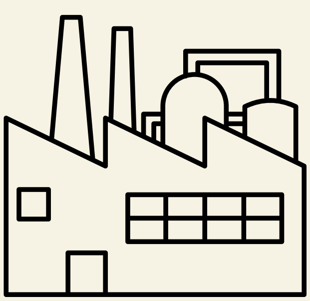
Prototyping and Research: Lathe machines facilitate the creation of prototypes and experimental models in various fields, enabling researchers and designers to test and refine their concepts efficiently.

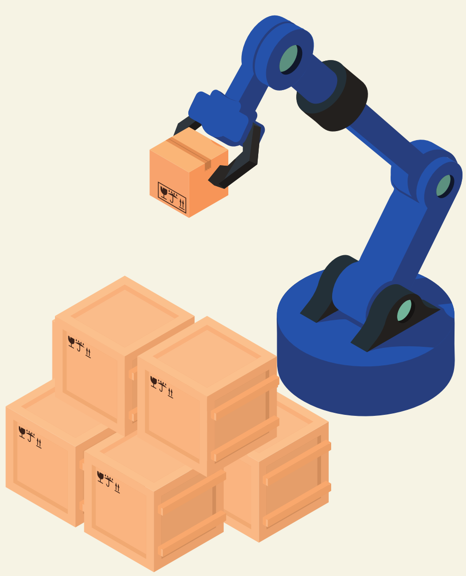
Education and Skill Development: Lathe machines play a crucial role in vocational training and educational institutions. They help in imparting practical knowledge and skills related to machining and manufacturing processes.

LATHE APPLICATIONS

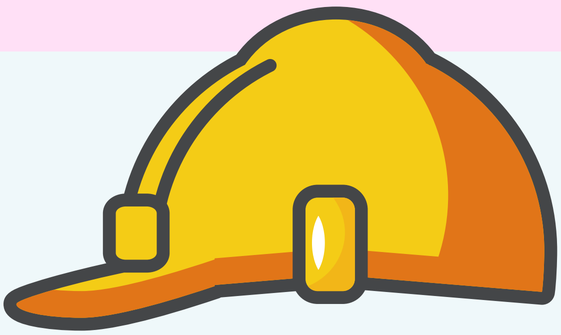
- Textile
- Power generation
- Medical
- Aerospace
- Automotive
- Wood industry
- Defense
- Arts
- Plastic
- Automobile industry







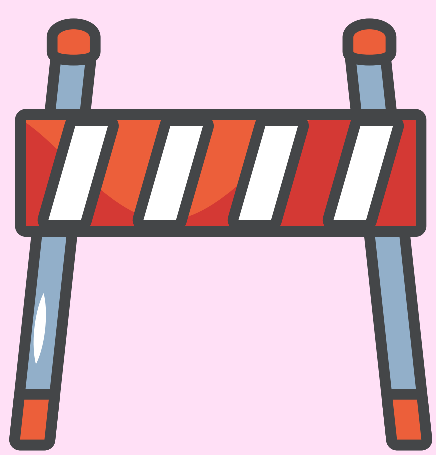
SAFETY PRECAUTIONS WHILE USING LATHE MACHINE



When operating a lathe machine, it is essential to follow safety guidelines to prevent accidents and injuries. Some important precautions to consider are:

- **Protective Clothing:** Always wear appropriate protective gear, such as safety glasses, gloves, and closed-toe footwear, to protect against flying chips, heat, and other hazards.
- **Machine Guarding:** Ensure the lathe machine has proper guards in place to protect operators from moving parts and flying debris.
- **Correct Tool Selection:** Use the right cutting tools for the specific machining task. Dull or inappropriate tools can cause accidents or damage the workpiece.
- **Secure Workpiece:** Securely clamp the workpiece in the lathe to prevent it from moving or flying out during machining.
- **Emergency Stop:** Familiarize yourself with the emergency stop feature of the lathe machine and know how to use it effectively in case of any mishaps or emergencies.

By following these safety precautions and acquiring proper training, one can operate a lathe machine efficiently and reduce the risk of accidents.



TUTORIAL

1. Describe the function of the below parts:

i. Bed

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ii. Tailstock

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iii. Base

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iv. Headstock

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2. Draw and labels **SEVEN (7)** parts of a lathe machine.

3. List **SEVEN (7)** operations that can be performed on a lathe.

4. Describe an insert in the lathe process.

5. Differentiate by an illustration of three-jaw universal chuck and four-jaw independent chuck.

6. Identify the part of the lathe that serves as housing for the driving pulleys and back gears. Three jaw chuck and four jaw chuck are the most commonly used for holding or clamping the workpiece for cutting and attaching to it.

7. Define these terms:

i. Cutting speed

....

....

ii. Feed

....

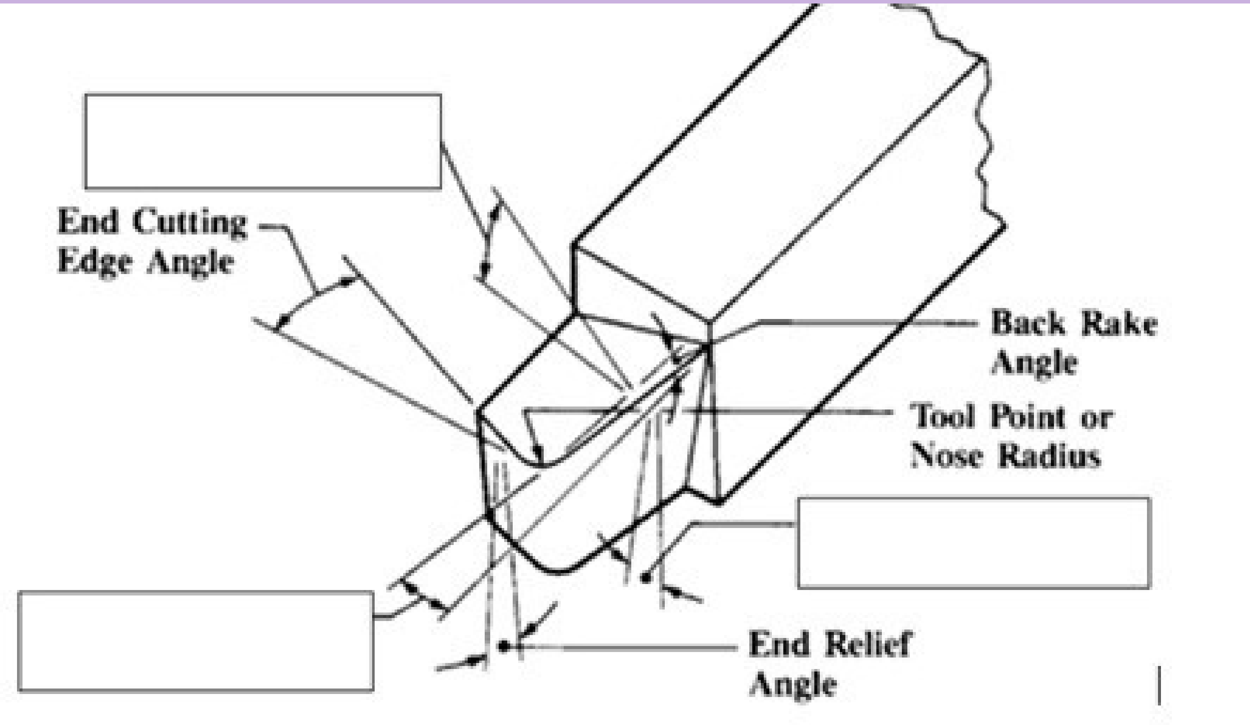
....

iii. Depth of cut

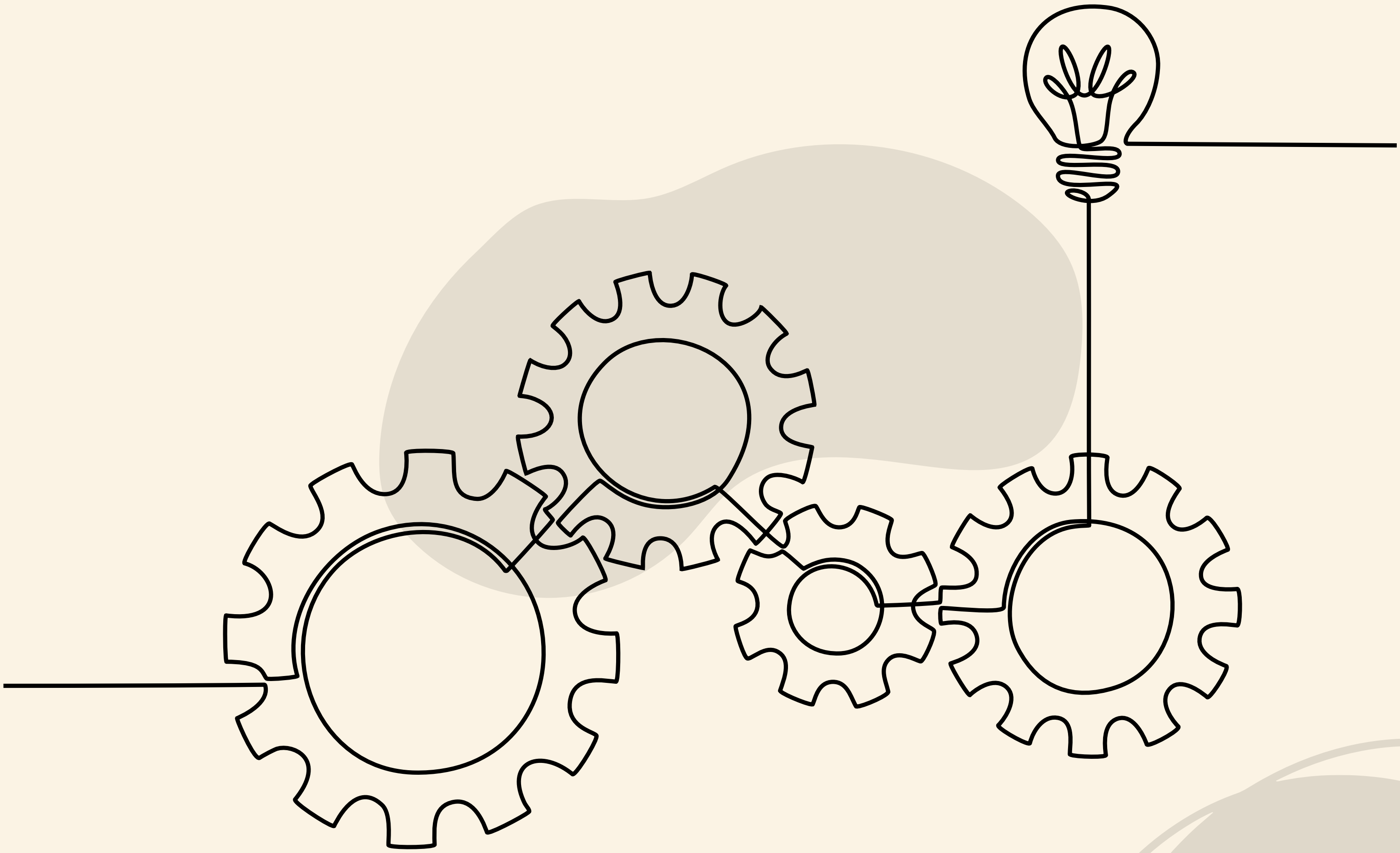
....

....

8. Fill up the names of unlabeled angle parts for the lathe tool bit.



MILLING



INTRODUCTION

MILLING

1. The milling machine works by feeding the workpiece fixed on the bed of the machine against a revolving milling cutter that removes material from the work to create flat, curved and or complex 3D surfaces. Depending on the type of machine, this is achieved by either moving the bed, ram, or a combination of the two. You can also use a milling machine to drill holes, boring, reaming, thread cutting etc.

2. On a simple conventional machine the ram is fixed and the movement of the Z-axis is usually to give depth of cut. During the actual milling process only the X-axis and Y-axis moves. The exception would be in a hole making process such as drilling or boring where the X and Y-axes movements are paused and the Z-axis moves up and down.

OBJECTIVES

Apply the knowledge of basic mechanical components and equipment, hand tools and measuring equipment in workshop technology.

Introduction to Milling Machines:

- Milling machines are versatile machining tools used to remove material from a workpiece to create complex shapes and features.
- They are widely used in industries such as manufacturing, automotive, aerospace, and more.
- Milling machines can perform various operations like drilling, cutting, shaping, and finishing.

Advantages of Milling machine

- Versatility: Can perform a wide range of operations, reducing the need for multiple machines.
- Precision: Deliver accurate and consistent results, especially when using CNC machines.
- Efficiency: Can process multiple workpieces simultaneously, improving productivity.
- Flexibility: Able to work with various materials, including metals, plastics, and composites.
- Customization: Offers the ability to create complex shapes and unique designs.

Components of Milling Machine

- **Base:** lower part of the machine that arrangement is to provide support to the system.
- **Column:** Vertical part fixed on to the machine.
- **Knee:** that is elevating screw which moves it up & down.
- **Saddle:** mounted on the knee to support & provide the cross feed mechanism to the worktable.
- **Spindle:** Hollow shaft driven by motor to rotate milling cutter.
- **Arbor:** In horizontal milling to hold & rotate milling cutter.

Essential part of a milling machine

- Spindle: Rotating part that holds and drives the cutting tool.
- Cutter: Removes material from the workpiece.
- Table: Platform where the workpiece is secured.
- Power Feed: Mechanism that moves the workpiece or cutter automatically.
- Control Panel: Allows operators to adjust settings and control machine movements.

Vertical Milling Machine

Horizontal Milling Machine

- **Vertical Milling Machine:**
  - The spindle axis is vertical, allowing the cutter to move up and down the workpiece.
  - Ideal for tasks that require drilling or tapping vertically.
- **Horizontal Milling Machine:**
  - The spindle axis is horizontal, allowing the cutter to move horizontally across the workpiece.
  - Suitable for tasks that require multiple cutters or machining grooves.

Item	Vertical Milling	Horizontal Milling
Characteristic	Most common and versatile machine tools	Versatile machine tool
Operation	To machine horizontal, vertical and angular surfaces, grooves, slots and keyways plus a wide variety of other machining operations	It is not only suitable for milling flat and irregularly shaped surfaces but also for gear and thread cutting, drilling, boring, reaming & slotting operations.
Types of Cutter	End-mill/ shell mill/ T-slot cutter/ fly cutter, drill chucks, boring heads & other tools etc.	Milling cutters (formed/ side/ single angle/ double angle/ face mill/ plain mill, gear tooth, slitting saw/ keyseat cutter)
Machine Setup	The cutter is mounted in a collet and attach to the spindle, vertically	The cutter is mounted between arbor & spacer bushing or arbor assembly, horizontally

Types of Milling Machines and Their uses

Here is a list of different types of milling machines that are commonly used in metalworking.

01	Bench Top Milling Machine	09	Triplex Milling Machine
02	Column and Knee Type Milling Machine	10	Turret Mill
03	Horizontal Milling Machine	11	Rotary Table Milling Machine
04	Vertical Milling Machine	12	Planer Type Milling Machine
05	Ram-Type Milling Machine	13	Tracer Milling and Pantograph
	a) Universal Ram-Type Milling Machine	14	Tracer-Controlled Milling Machine
	b) Swivel Cutter Head Ram-Type Milling Machine	15	3-Axes CNC Milling Machine
06	Fixed Bed Type Milling Machine	a)	Horizontal Machining Centers
07	Simplex Milling Machine	b)	Vertical Machining Centers
08	Duplex Milling Machine	16	5-Axes CNC Milling Machine / Machining Center

Column and Knee Type Milling Machine

Your Column and Knee Type Milling machine has the following major parts.

The **base** of your machine acts as a foundation, and the complete machine structure is built on it.

The hollow **column** of your machine is mounted vertically on the base and supports the knee, saddle and table; it houses the spindle and all its drive mechanism and provides movement to the knee, saddle, table, spindle, etc.

The **knee** of your machine is mounted on the column guide-ways and can be moved vertically, up and down.

The **saddle** of your machine is mounted on the guide-ways of the knee and has transverse movement.

The **table** of your machine is mounted on the saddle and can move to and fro longitudinally. You can clamp the workpiece directly on the table using the T-slots or with the help of a machine vice.

The **overarm and brace** of your machine is mounted on the top of the column and supports the arbor (fitted into the spindle as an extension). You have the overarm and brace arrangement only in Horizontal Column and Knee Type Milling Machine.

Your Column and Knee Type Milling Machine has a pressurized cooling system consisting of a coolant tank filled with coolant, coolant pump, and piping to direct the flow of coolant on the cutting area.

With the above arrangement, you can move the table up and down, longitudinally (left and right) and transversely (back and forth).

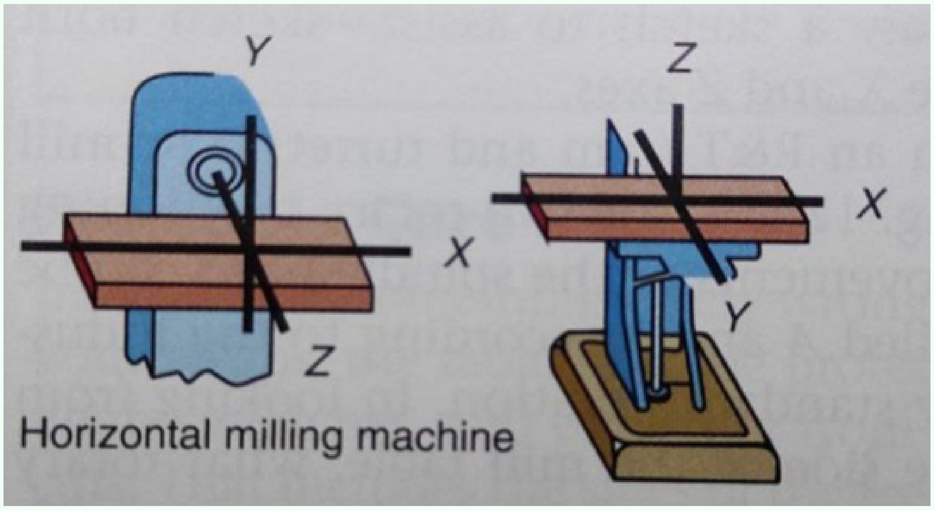
Horizontal Milling Machine

Your Horizontal Milling Machine has all the features of a Column and Knee Type Milling Machine and comes with a horizontal spindle. Your Machine is generally bigger than vertical Milling Machine and comparatively heavy and larger work-pieces can be machined.

You can directly mount a face milling cutter and do face milling of work-pieces clamped on the table.

You can also use an arbor for mounting one or more cutters and do plain milling, slab milling, straddle milling, slotting, etc. You need to support the other end of the arbor using the overarm arrangement.

Your Horizontal Milling machine is classified as a universal type, if you are able to swivel the table in the horizontal plane, normally up to 45 degrees to your left or right.



Standard axis between vertical and horizontal milling machine

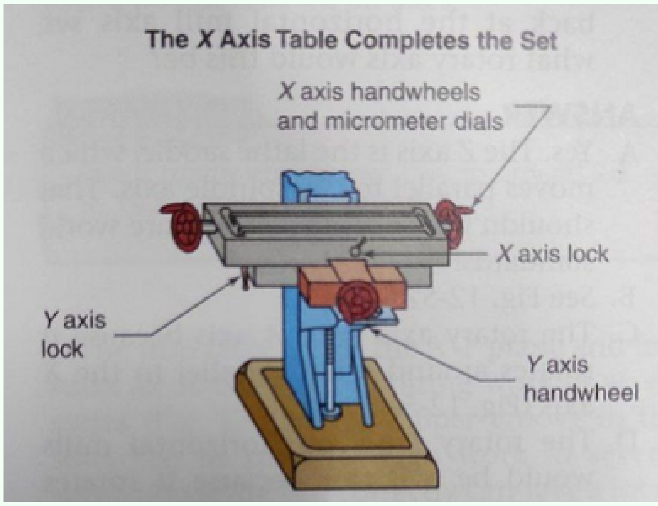
Vertical Milling Machine

Your Vertical Milling machine is a Column and knee type Milling Machine minus the overarm arrangement and has a vertical spindle head at the top of the column. The milling head of your Vertical Milling Machine may be the fixed head, sliding head or swiveling head, or a combination of swiveling and sliding head. You can move the quill of the spindle up and down.

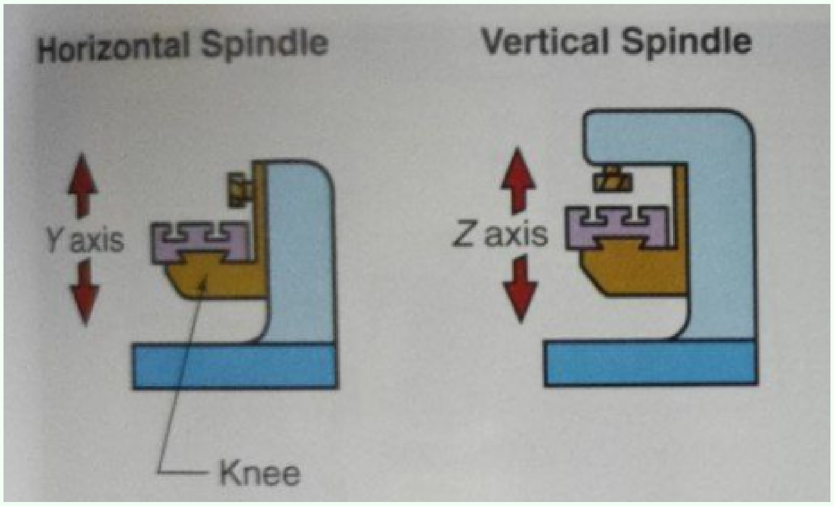
Your Vertical Milling machine is suitable for milling operations like face milling, slotting, keyway milling, and form-milling using a form cutter.

You can mount the work-piece on a rotary-table (mounted on a machine table) and cut circular slots or slots at equal angular locations.

You can mount indexing head arrangement on the machine table and do operations such as gear cutting, keyways etc.



Vertical milling machine table slide



Vertical & horizontal milling machine spindle axis

Milling Operations

1. Face Milling

The most basic operation of all is a face cut. The cutter is lowered below the surface of the work to the depth of cut (DoC), then set to engage the work at a given portion of its diameter called radial engagement (RE).

End milling cutters are also used to face cut because they have cutting teeth both on their end and sides. It can also plunge straight down into the work, similar to drilling. It can produced a medium fine finish and when facing, remove metal at a relatively slow rate, compared to face mill cutters.

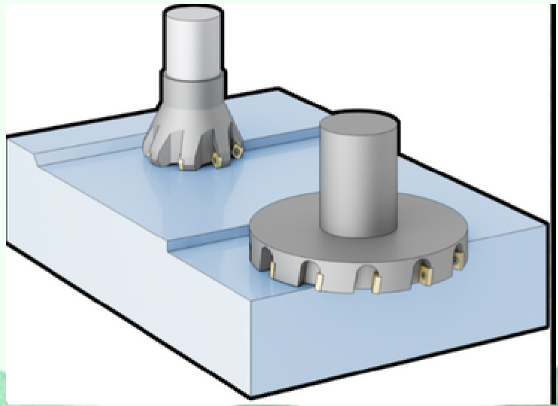
Fly cutters are a single tooth, facing cutter, used more in tooling work than production due to very slow cutting.

A face mill aims to clean up a surface, and sometimes, they have no vertical sides when inserted.

During face milling operation, the edges of the cutter grind away at the surface of the workpiece, resulting in material removal. It means that the cutting edges present on the periphery of the cutter perform the cutting action.

Depending on the type of face milling operation, the cutting tool can remove the material from the face or the edges of the stock, with the final result being a smooth and flat surface workpiece. A significant advantage of face milling is its ability to machine large objects and surfaces in minimal time, using a small-sized cutter.

Face milling flat surface



Milling Operations

1. Face Milling

There are mainly six different types of face-milling operations.

Type of Milling	Diameter of cutter	Applications
Conventional	Greater than the workpiece width	Roughing and finishing cuts
Partial	Slightly smaller than the workpiece width	Roughing and finishing cuts
End	Smaller relative to workpiece width	Machining slots in the workpiece
Profile	Smaller relative to workpiece width	Machining/smoothening the periphery of a flat workpiece
Pocket	Smaller relative to workpiece width	Machining shallow pockets into the workpiece
Surface Contouring	Smaller relative to workpiece width	Machining contours on the surface of the workpiece

How to Select Tool for Face Milling?

The finish type required on the stock is an important factor in selecting the appropriate face mill.

It can either be roughing or finishing, depending on your requirement.

Roughing is performed for quick and high material removal, whereas finishing is more time-consuming and removes lesser material but produces a higher quality finish.

Generally, shell mills are used for roughing, whereas fly cutters are used for finishing operations.

End mills, on the other hand, are ideal for roughing and finishing operations.

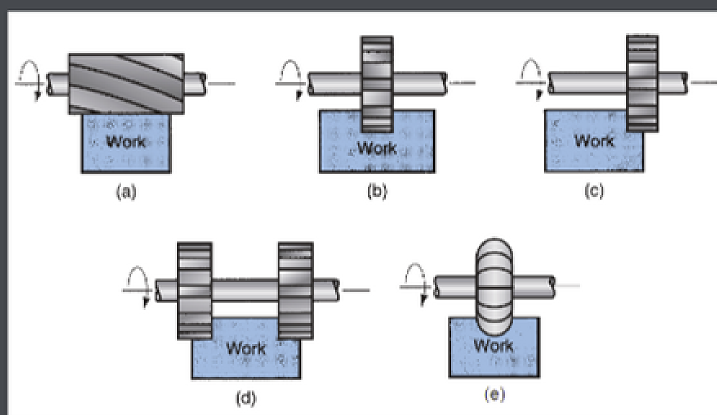
Milling Operations

2. Peripheral Milling

Also called profiling means cutting around the outside or inside of a part using the side teeth of the cutter. Usually used cutter is the end mill.

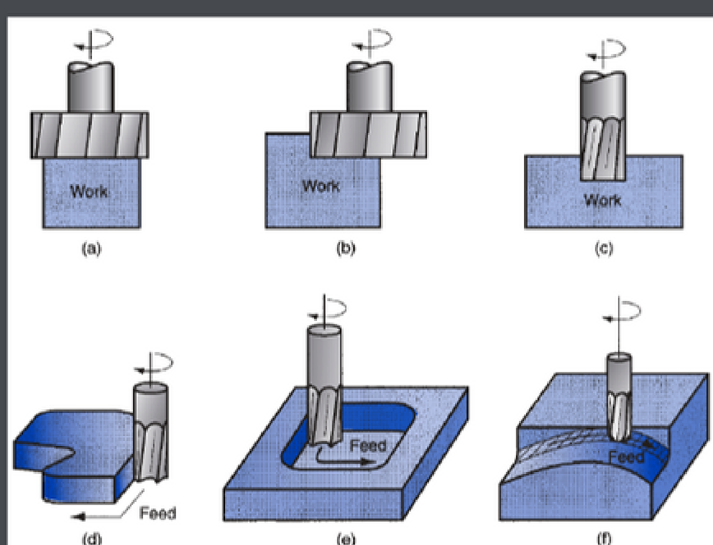
In peripheral milling, also called plain milling, the axis of the tool is parallel to the surface being machined, and the operation is performed by cutting edges on the outside periphery of the cutter. Several types of peripheral milling can be performed:

- **Slab milling** – The basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides;
- **Slotting** – Also called slot milling, in which the width of the cutter is less than the workpiece width, creating a slot in the work (when the cutter is very thin, this operation can be used to mill narrow slots or cut a workpart in two, called saw milling);
- **Side milling** – Cutter machines the side of the workpiece;
- **Straddle milling** – The same as side milling, only cutting takes place on both sides of the work;
- **Form milling** – The milling teeth have a special profile that determines the shape of the slot that is cut in the work.



Peripheral milling operations: (a) slab milling, (b) slotting, (c) side milling, (d) straddle milling, and (e) form milling.

In peripheral milling, the direction of cutter rotation distinguishes two forms of milling: up milling and down milling. In up milling, also called **conventional milling**, the direction of motion of the cutter teeth is opposite the feed direction when the teeth cut into the work. In down milling, also called **climb milling**, the direction of cutter motion is the same as the feed direction when the teeth cut the work.



Two forms of peripheral milling operation: (a) conventional milling, and (b) climb milling.

Milling Operations

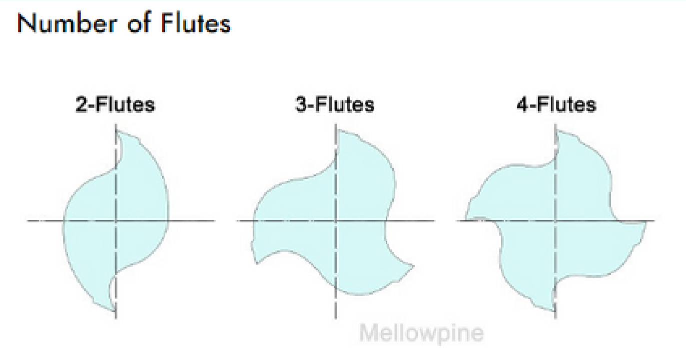
2. Peripheral Milling

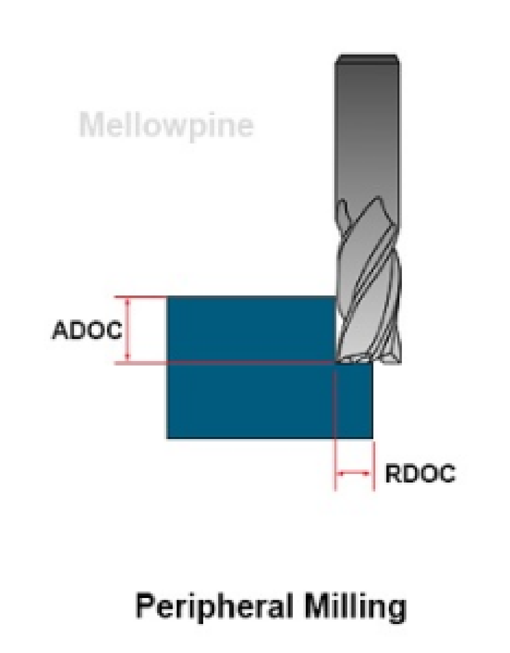
The number of flutes of the cutting edges dictates the construction type of the face mill. It mainly varies with the cutter diameter and milling material.

Flutes are the deep spiral-shaped grooves in the mill that facilitate the movement of chips out from the material during the milling operation.

Two-flute face mills are common for ductile materials that produce long chips during milling.

Peripheral milling





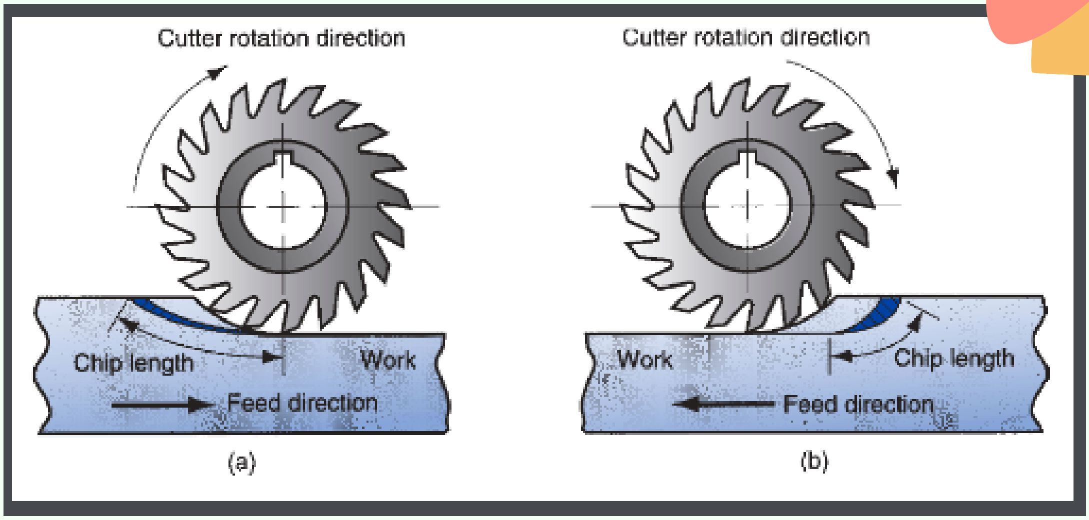
A peripheral milling operation also constitutes end milling. Before feeding the tool into and around the workpiece, it should first be positioned at a predetermined depth at the Z-axis.

There are notable differences between face milling and peripheral milling.

Parameter	Face Milling	Peripheral Milling
Teeth location	On the periphery and the face of the cutter	On the periphery of the cutter
Stock surface position	At right angles to the cutter axis of rotation	Parallel with the cutter axis of rotation
Spindle type	Both horizontal and vertical spindles	Horizontal spindle
Material removed	Relatively smaller volume	Large volume
Cutting source	Both the periphery and face	Only the periphery
Depth of cut	More along the radial axis	More along the axial/vertical axis

What Are the Two Types of Peripheral Milling?

The two types of peripheral milling are **conventional milling and climb milling**.



Conventional/ Up Milling

As its name suggests, the conventional milling process is the traditional approach where the cutting tool rotation is against the movement of the workpiece. In this case, the cut is in the upwards direction, that's why this milling technique is also called up milling.

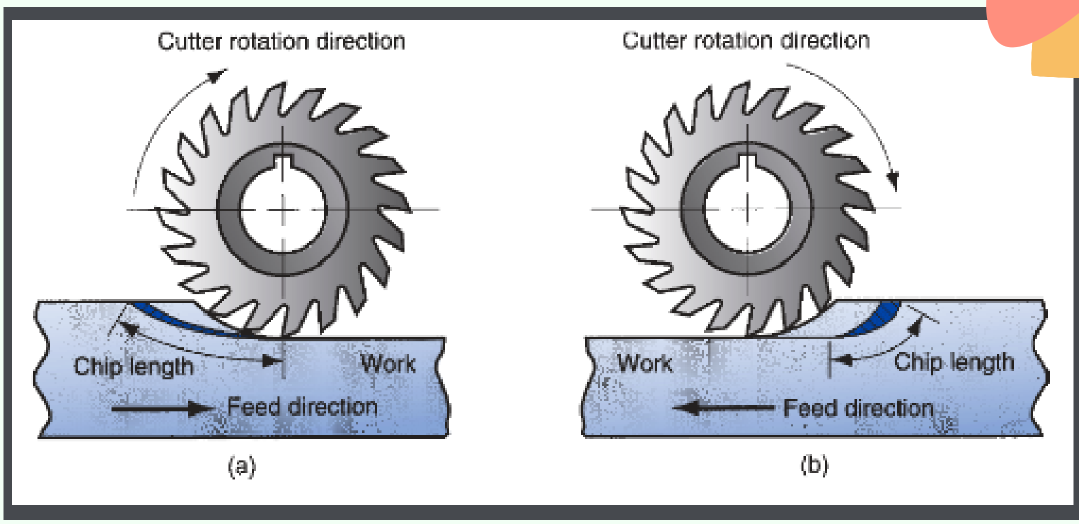
The conventional milling process is entirely the opposite of climb milling. In this case, the chip width starts from virtually zero and gradually increases. Furthermore, the chips evacuate in the path of the cutter because of its rotation, and the workpiece experiences an uplifting force because of the cutting action.

Climb/ Down Milling

Climb milling or down milling is a process where the cutting tool rotates in the same direction as the workpiece. The name comes from the fact that the cutting tool's teeth climb onto the workpiece surface and deposit the chips behind the cutter, which eliminates the chances of recutting. Some other properties that make climb milling different are the downward forces requiring lower holding requirements, chip width which decreases during the process, and the shear plane specifications.

What Are the Two Types of Peripheral Milling?

The two types of peripheral milling are **conventional milling and climb milling**.

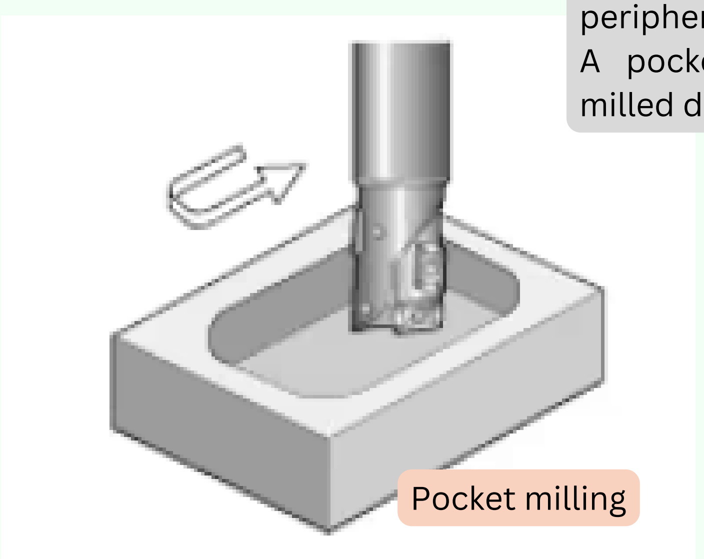


Conventional/ Up Milling	Climb/ Down Milling
Workpiece fed against cutter direction	Workpiece fed in the same cutter direction
Produce progressively thicker chips	Produce progressively thinner chips
Give poor surface finish, since chips gets accumulated at the cutting zone	Give good surface finish, since chips are thrown away during cutting process
Suitable for machining harder materials	Used for soft materials and finishing operations
Strong clamping is required since the cutting force is directed upwards & tends to lift the workpiece	Strong clamping is not reuired since the cutting force is directed downwards & keep the workpiece pressed to the work table

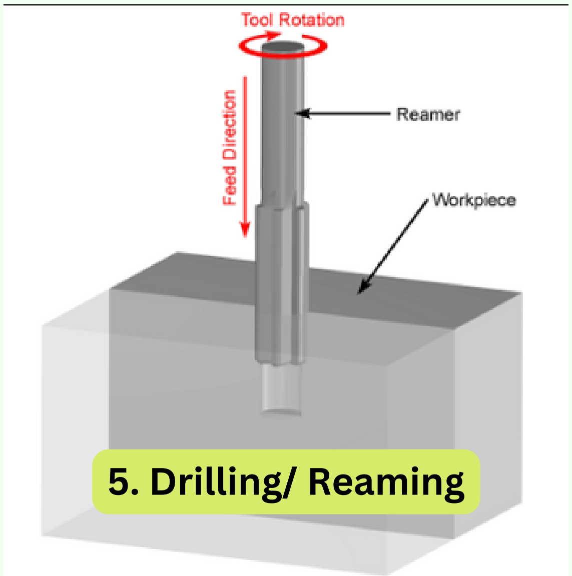
Milling Operations

3. Step & Pocket Milling

Often a combination of face and peripheral milling is required in one cut. A pocket, is a depression or cavity milled down into the metal.



Pocket milling

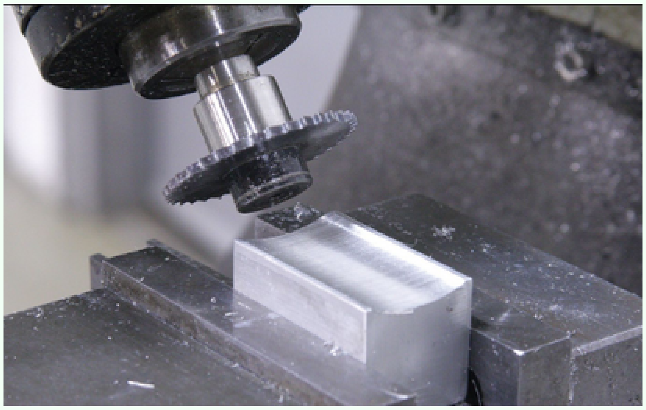


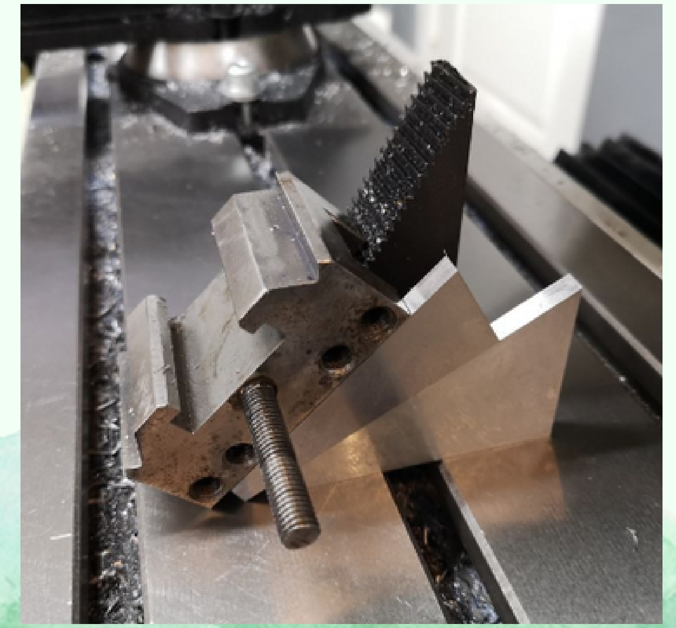
5. Drilling/ Reaming

4. Angle Cutting

On manual mills, angular cuts can be set up several different ways, by either tilting the cutter or tilting and rotating the parts.

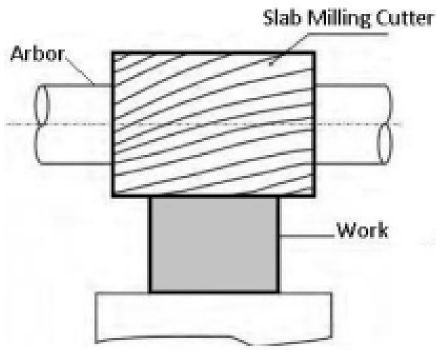
Angles can also be cut using form ground cutters.





Other Milling Operations

8 Plain Milling



Plain Milling Operation

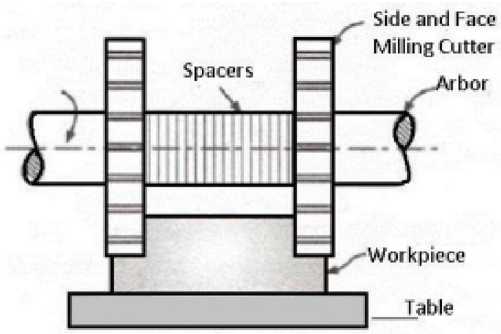
- The plain milling is the most common types of milling machine operations.
- Plain milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.
- To perform the operation, the work and the cutter are secured properly on the machine.
- The depth of cut is set by rotating the vertical feed screw of the table. And the machine is started after selecting the right speed and feed.

Other Milling Operations

9 **Side Milling**

- The side milling is the operation of producing a flat vertical surface on the side of a workpiece by using a side milling cutter.
- The depth of cut is set by rotating the vertical feed screw of the table.

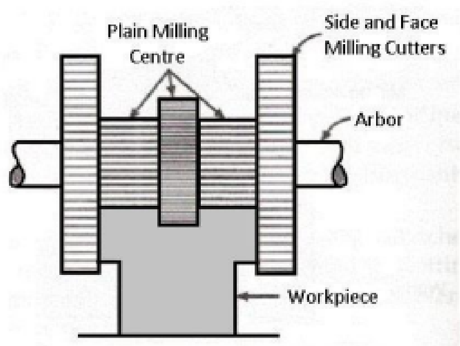
10 **Straddle Milling**



Straddle Milling Operation

- The straddle milling is the operation of producing a flat vertical surface on both sides of a workpiece by using two side milling cutters mounted on the same arbor.
- Distance between the two cutters is adjusted by using suitable spacing collars.
- The straddle milling is commonly used to design a square or hexagonal surfaces.

11 **Gang Milling**

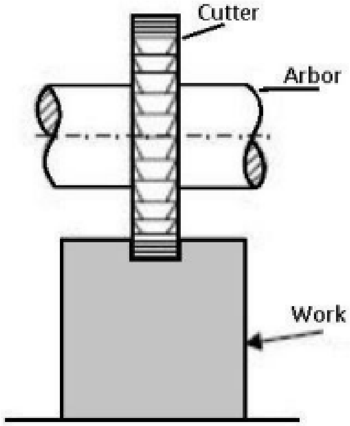


Gang Milling Operation

- The gang milling is the operation of machining several surfaces of a workpiece simultaneously by feeding the table against a number of cutters having the same or different diameters mounted on the arbor of the machine.
- The method saves much of machining time and is widely used in repetitive work.
- Cutting speed of a gang of cutters is calculated from the cutter of the largest diameter.

Other Milling Operations

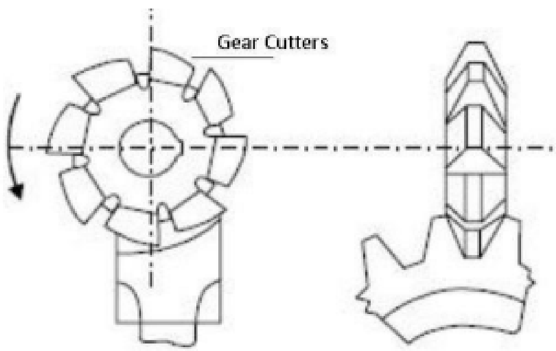
12 **Milling Keyways, Grooves and Slots**



Keyway Milling Operation

- The operation of producing of keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.
- It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.
- The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using endmills.

13 **Gear Cutting**

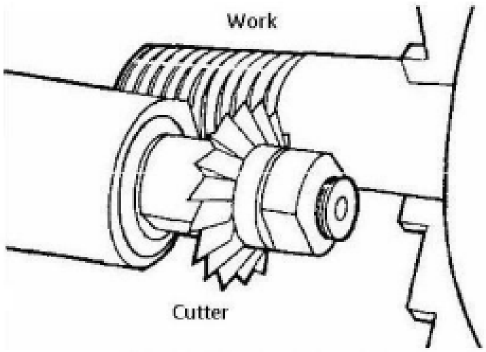


Gear Cutting Milling Operation

- The gear cutting operation is performed in a milling machine by using a form-relieved cutter. The cutter may be a cylindrical type or end mill type.
- The cutter profile fits exactly with the tooth space of the gear.
- Equally spaced gear teeth are cut on a gear blank by holding the work on a universal diving head and then indexing it.

Other Milling Operations

14 **Helical Milling**



Helical Milling Operation

- The helical milling is the operation of producing helical flutes or grooves around the periphery of a cylindrical or conical workpiece.
- The operation is performed by rotating the table to the required helix angle. And then by rotating and feeding the workpiece against rotary cutting edges of a milling cutter.
- Production of the helical milling cutter, helical gears, cutting helical grooves or flutes on a drill blank or a reamer.

Milling can be performed on workpieces in variety of materials, including most metals and plastics. Common materials that are used in milling include the following:

- **Aluminum**
- **Brass**
- **Magnesium**
- **Nickel**
- **Steel**
- **Thermoset plastics**
- **Titanium**
- **Zinc**

When selecting a material, several factors must be considered, including the cost, strength, resistance to wear, and machinability. The machinability of a material is difficult to quantify, but can be said to posses the following characteristics:

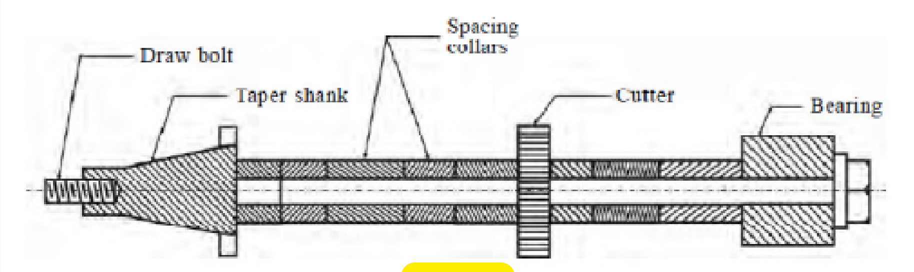
- **Results in a good surface finish**
- **Promotes long tool life**
- **Requires low force and power to mill**
- **Provides easy collection of chips**

Types of Milling Cutter

Methods of Holding Cutter

Depending on the design of the cutter, there are several methods of supporting milling cutters on the machine spindle.

1) Arbor
2) Collet
3) Adapter
4) Screwed on cutters
5. Sleeves



Arbor

Collet

Adapter

Screwed on cutters

Sleeve

Work Holding Device

For effective machining operations, the workpieces need to be properly and securely held on the machine table. The following are the usual methods of holding work on the table :

1. Vises :
   i. Plain vise
   ii. Swivel Vise
   iii. Universal Vise
2. V- Block
3. Clamps, T bolts
4. Angle Plate

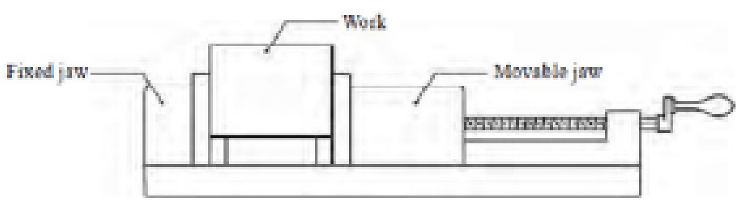


Fig 5.6 Plain vise

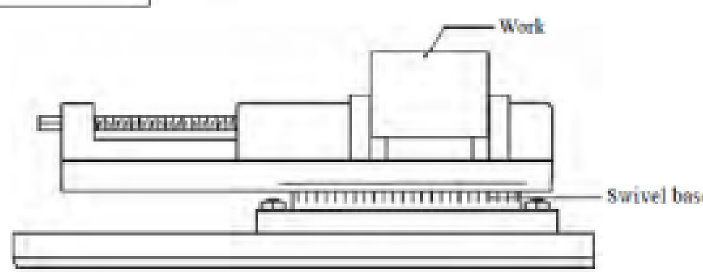


Fig 5.7 Swivel vise

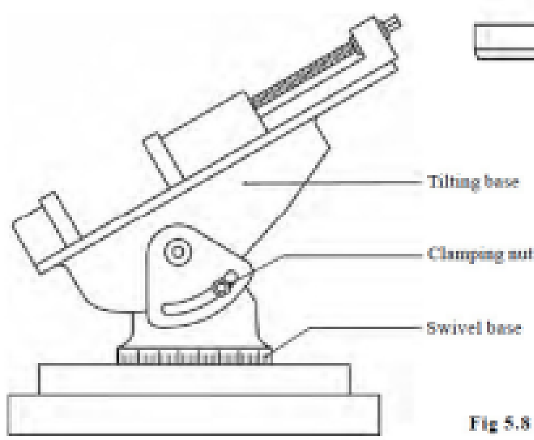


Fig 5.8 Universal vise

Milling Parameters

•Cutting action is carried out by feeding the workpiece against the rotating cutter. Thus, the spindle speed, the table feed, the depth of cut, and the rotating direction of the cutter become the main parameters of the process. Good results can only be achieved with a well balanced settings of these parameters.

Spindle Speed

•Spindle speed in revolution per minute (R.P.M.) for the cutter can be calculated from the equation

$$N = \frac{CS \times 1000}{\pi d}$$

:- where --

N = R.P.M. of the cutter,

CS = Linear Cutting Speed of the material in m/min.

d = Diameter of cutter in mm

Feed Rate

Feed rate (F) is defined as the rate of travel of the workpiece in mm/min. But most tool suppliers recommend it as the movement per tooth of the cutter (f). Thus,

$$F = f \cdot u \cdot N$$

Where , F = table feed in mm/min, f = movement per tooth of cutter in mm, u = number of teeth of cutter N = R.P.M. of the cutter where,

C.S. and feed rate for some common material :- Tool

Tool Material	High Speed Steel		Carbide	
Material	Cutting Speed	Feed (f)	Cutting Speed	Feed (f)
Mild Steel	25	0.08	100	0.15
Aluminium	100	0.15	500	0.3
Hardened Steel	---	---	50	0.1

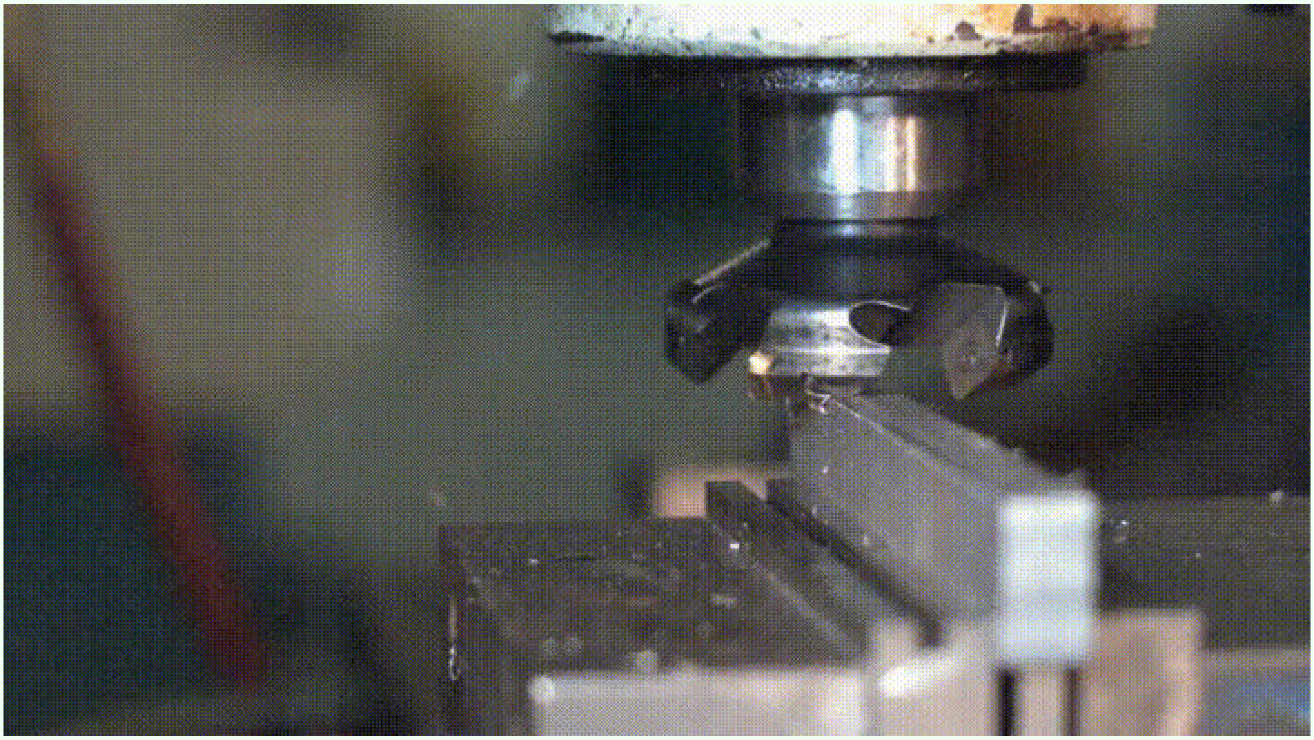
Milling Parameters

Feed can also be described as follows:

$$F = RPM \times CPT \times N$$

Machining Time

$$t = Length / Feed$$



Milling Calculation

Find the feed rate in mm/min for a six-tooth helical carbide milling cutter with a diameter of 75 mm for machining a cast iron workpiece. Using CS value of 60 m/min and Chip per tooth (CPT) of 0.25 mm/tooth.

F = RPM x CPT x N

$$RPM = \frac{60 \times 1000}{\pi \times 75}$$

$$= 254 \text{ rev/min}$$

$$F = N \times CPT \times RPM$$

$$= 6 \times 0.25 \times 254$$

$$= 381 \text{ mm/min}$$

Milling Safety

Safety Precautions While Using Milling Machines:

Wear appropriate personal protective equipment (PPE), such as safety glasses, gloves, and ear protection.

Securely clamp the workpiece to prevent it from shifting during machining.

Check and adjust cutting speed, feed rate, and depth of cut according to the material being machined.

Regularly inspect and maintain the machine to ensure proper functioning and reduce the risk of accidents.

Provide training to operators on safe operating procedures and emergency protocols.

Note: Remember to follow general safety guidelines, consult official sources, and use accurate and reliable information when using milling machines.

TUTORIAL

1. Describe the difference between up milling and down milling by statement and sketches.

UP MILLING	DOWN MILLING
Description:	Description:
Sketches:	Sketches:

2. State THREE (3) examples of work-holding equipment in the milling machine.

....

....

....

....

3. List **SEVEN (7)** safety procedures while using milling machine.

....

....

....

....

....

....

4. Express the feed in millimeters per minute for machining using a 50 mm- diameter of high-speed helical milling machine with 12 teeth cutting at 0.08 mm per tooth (CPT) and a cutting speed of 33 meters per minute.

Revolution per minute (N)	**Feed rate (F)**

5. State **FOUR (4)** advantages of climb milling.

....

....

....

....

....

....

6. Calculate the feed in mm/min for a 75 mm diameter, six-tooth helical carbide milling cutter when machining a cast-iron workpiece. Note that, CPT = 0.25 mm and CS = 60 m/min.

Revolution per minute (N)	Feed rate (F)

7. Name **SIX (6)** operations that can be performed on a milling machine.

....

....

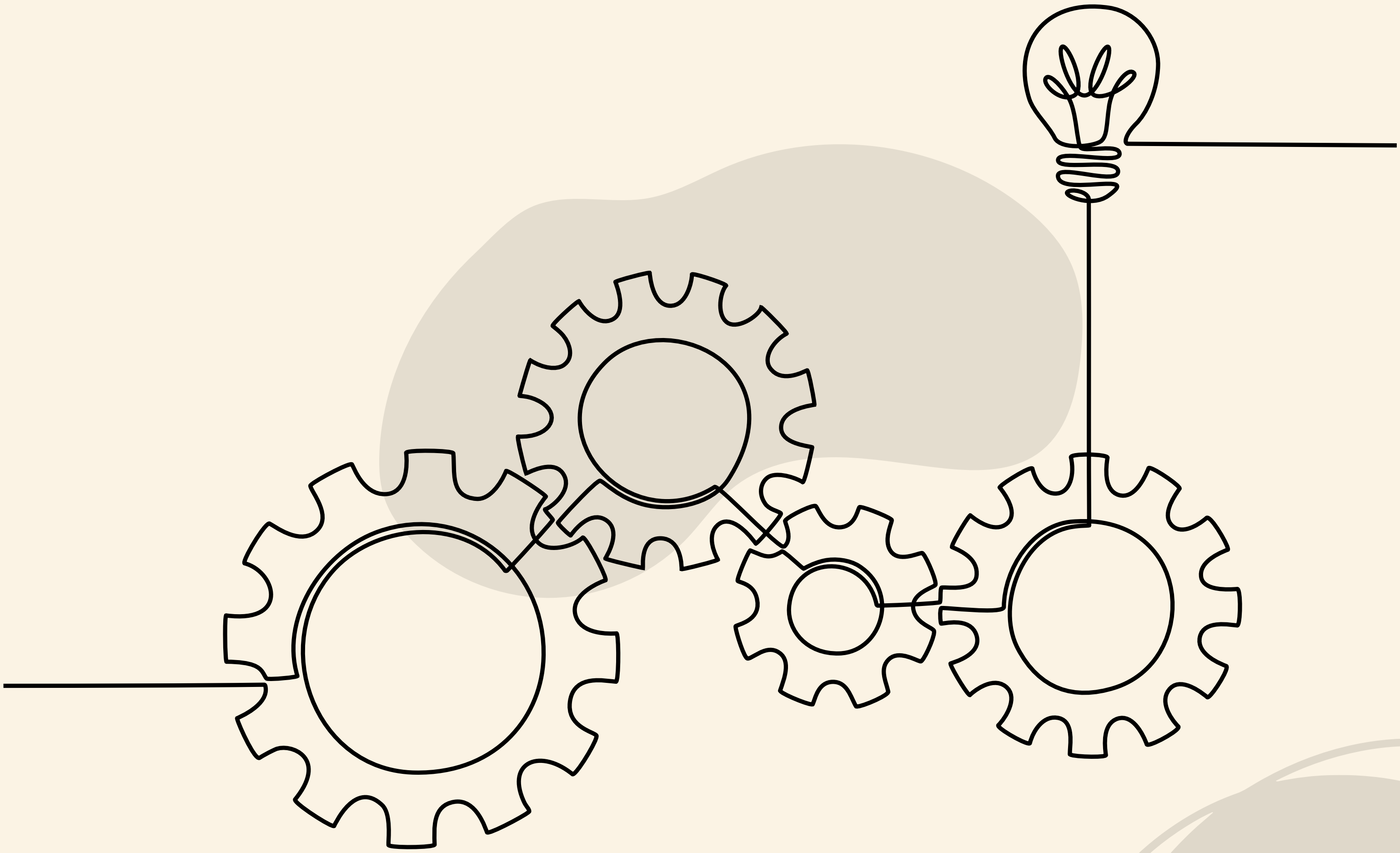
....

8. Draw and label the horizontal milling machine.

9. Show the features of the:

i. Plain vise	
ii. Swivel base vise	
iii. Universal vise	

GEAR



INTRODUCTION

GEAR

1. Gear making is the process of creating mechanical devices that transmit power and motion between rotating shafts. Gears are typically made by cutting, forming, or molding a variety of materials, including metal, plastic, and composites.

2. The most common method for producing gears is through gear cutting. Gear cutting involves the removal of material from a blank to create teeth on the gear. The process can be done using a variety of tools, including gear hobbing machines, gear shaping machines, and gear grinding machines. Each of these machines uses a different method to create the gear teeth, and the choice of machine depends on the specific requirements of the gear.

OBJECTIVES

Apply standard practice in operating mechanical tools and component

3. Another method of producing gears is through casting or molding. This involves pouring molten metal or plastic into a mold in the shape of the desired gear. Once the material has solidified, the gear can be removed from the mold and finished to the desired specifications.

4. Gear making can also involve assembly of individual gear components. For example, a planetary gear system consists of several individual gears that are assembled together to form a complex gear system

5. Basic function of gear:
   - To transmit power
   - To change speed
   - To change direction
   - To change the plane direction
   - To give positive drive

6. Regardless of the specific method used, gear making is a precise and complex process that requires specialized knowledge and equipment to ensure the finished product is of high quality and functions properly.

7. Gear applies in lots of these industries:
   1. **Automotive:** Gears are used in cars, trucks, and other vehicles to transmit power from the engine to the wheels. They are used in the transmission, differential, and other parts of the drivetrain.
   2. **Manufacturing:** Gears are used in manufacturing machines to transmit power and motion between different components. They are also used in machines that cut, shape, and grind materials.

3. Robotics: Gears are used in robotics to transmit power and motion between different parts of the robot. They are used in robotic arms, grippers, and other mechanisms.

4. Aerospace: Gears are used in airplanes, helicopters, and other aircraft to transmit power between different parts of the aircraft. They are also used in the landing gear and other mechanical systems.

5. Watches and clocks: Gears are used in watches and clocks to control the movement of the hands and keep accurate time.

6. Medical equipment: Gears are used in medical equipment such as MRI machines and X-ray machines to control the movement of different parts of the equipment.

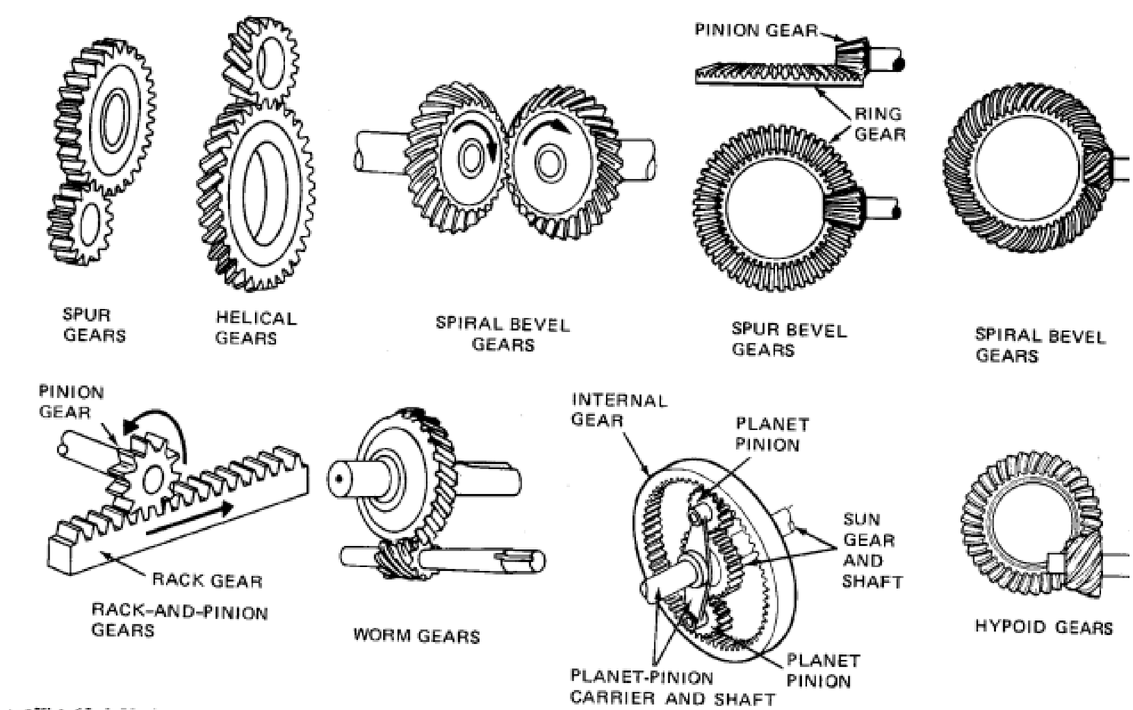
8. GEAR INSPECTION

Gear inspection is an essential part of the manufacturing process, as it ensures that the gears meet the required specifications and are free of defects. Here are some reasons why gear inspection is needed after manufacturing:

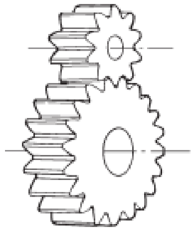
- Quality control: Gear inspection is necessary to ensure that the gears meet the required quality standards. This includes checking the dimensions, surface finish, and material properties of the gears.
- Preventing defects: Gear inspection can help identify any defects or flaws in the gears that could cause problems in their operation. This can include cracks, chips, or other damage that may have occurred during the manufacturing process.

- Conformance to specifications: Gear inspection ensures that the gears conform to the required specifications, such as tooth profile, pitch, and runout. This is essential for ensuring that the gears will work correctly in the intended application.
- Improved reliability: By inspecting gears after manufacturing, manufacturers can identify any potential issues before the gears are put into service. This can help improve the reliability and durability of the gears, reducing the risk of unexpected failures.
- Cost savings: Gear inspection can help identify any defects or issues early on in the manufacturing process, reducing the need for rework or scrap. This can result in cost savings for manufacturers, as they can avoid the costs associated with remanufacturing or replacing defective gears.

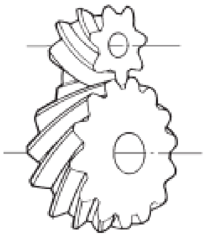
In summary, gear inspection is critical to ensuring that gears meet the required quality standards, conform to specifications, and are free of defects. It can help improve the reliability of gears, reduce the risk of unexpected failures, and result in cost savings for manufacturers.



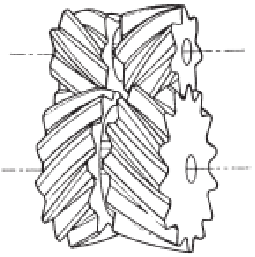
Types of Gear



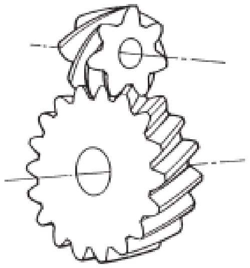
1. Spur Gear
This is a cylindrical shaped gear in which the teeth are parallel to the axis. It has the largest applications and, also, it is the easiest to manufacture.



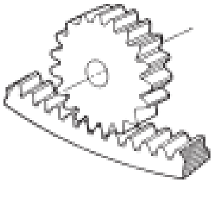
2. Helical Gear
This is a cylindrical shaped gear with helicoid teeth. Helical gears can bear more load than spur gears, and work more quietly. They are widely used in industry. A disadvantage is the axial thrust force the helix form causes.



3. Double Helical Gear
This is a gear with both left-hand and right-hand helical teeth. The double helical form balances the inherent thrust forces.

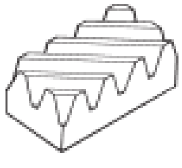


4. Screw Gear (Crossed Helical Gear)
Two helical gears of opposite helix angle will mesh if their axes are crossed. As separate gear components, they are merely conventional helical gears. Installation on crossed axes converts them to screw gears. They offer a simple means of gearing skew axes at any angle. Because they have point contact, their load carrying capacity is very limited.



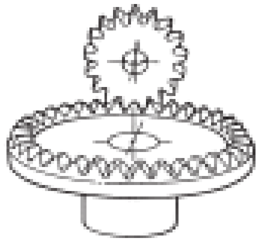
5. Internal Gear
This is a cylindrical shaped gear but with the teeth inside the circular ring. It can mesh with a spur gear. Internal gears are often used in planetary gear systems.

6. Spur Rack
This is a linear shaped gear which can mesh with a spur gear with any number of teeth. The spur rack is a portion of a spur gear with an infinite radius.



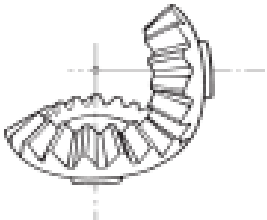
7. Helical Rack
This is a linear shaped gear which meshes with a helical gear. Again, it can be regarded as a portion of a helical gear with infinite radius.

Types of Gear



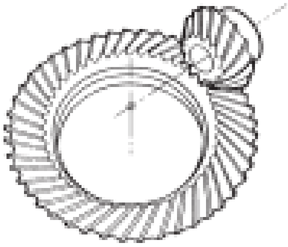
8. Face Gear

This is a pseudobevel gear that is limited to 90° intersecting axes. The face gear is a circular disc with a ring of teeth cut in its side face; hence the name face gear. Tooth elements are tapered towards its center. The mate is an ordinary spur gear. It offers no advantages over the standard bevel gear, except that it can be fabricated on an ordinary shaper gear generating machine.



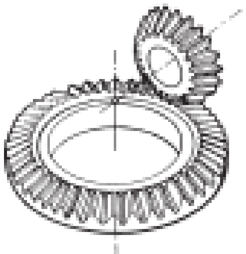
9. Straight Bevel Gear

This is a gear in which the teeth have tapered conical elements that have the same direction as the pitch cone base line (generatrix). The straight bevel gear is both the simplest to produce and the most widely applied in the bevel gear family.



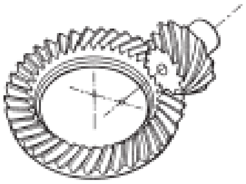
10. Spiral Bevel Gear

This is a bevel gear with a helical angle of spiral teeth. It is much more complex to manufacture, but offers a higher strength and lower noise.



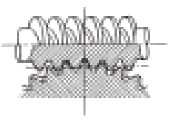
13. Zerol Gear

Zerol gear is a special case of spiral bevel gear. It is a spiral bevel with zero degree of spiral angle tooth advance. It has the characteristics of both the straight and spiral bevel gears. The forces acting upon the tooth are the same as for a straight bevel gear.



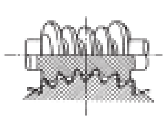
14. Hypoid Gear

This is a deviation from a bevel gear that originated as a special development for the automobile industry. This permitted the drive to the rear axle to be nonintersecting, and thus allowed the auto body to be lowered. It looks very much like the spiral bevel gear. However, it is complicated to design and is the most difficult to produce on a bevel gear generator.



11. Worm And Worm Gear

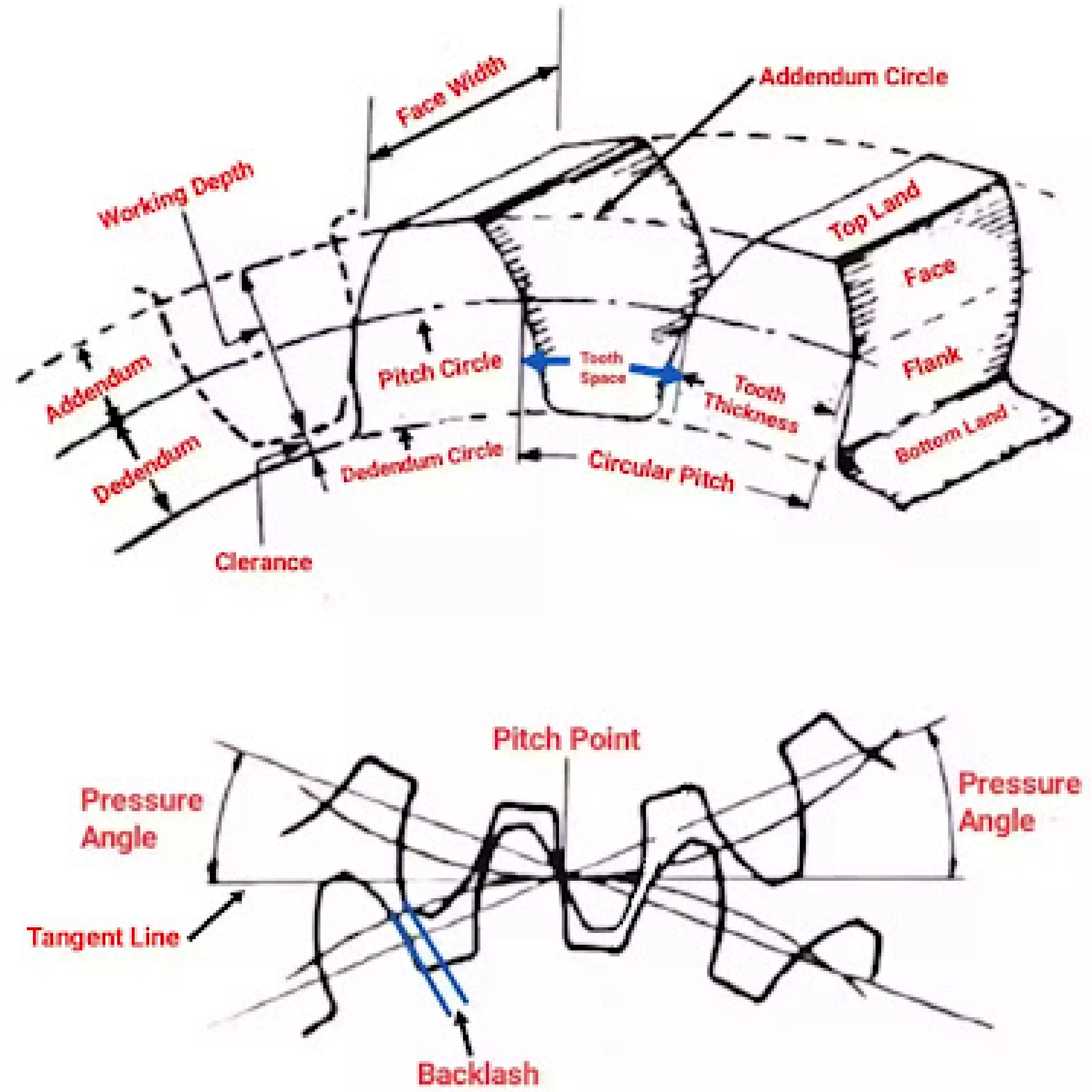
Worm set is the name for a meshed worm and worm gear. The worm resembles a screw thread; and the mating worm gear a helical gear, except that it is made to envelope the worm as seen along the worm's axis. The outstanding feature is that the worm offers a very large gear ratio in a single mesh. However, transmission efficiency is very poor due to a great amount of sliding as the worm tooth engages with its mating worm gear tooth and forces rotation by pushing and sliding. With proper choices of materials and lubrication, wear can be contained and noise is reduced.



12. Double Enveloping Worm Gear

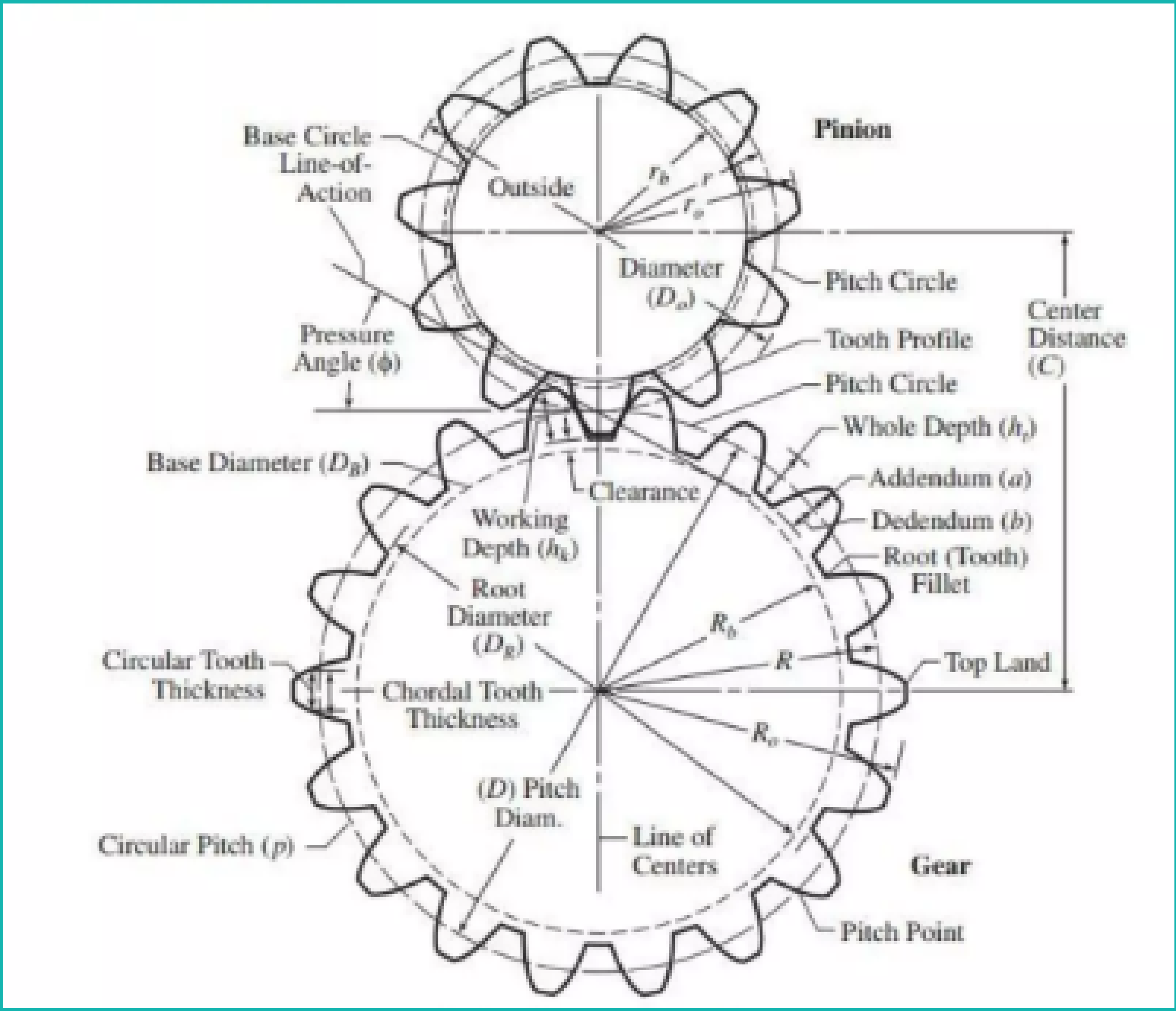
This worm set uses a special worm shape in that it partially envelops the worm gear as viewed in the direction of the worm gear axis. Its big advantage over the standard worm is much higher load capacity. However, the worm gear is very complicated to design and produce, and sources for manufacture are few.

GEAR TERMINOLOGIES



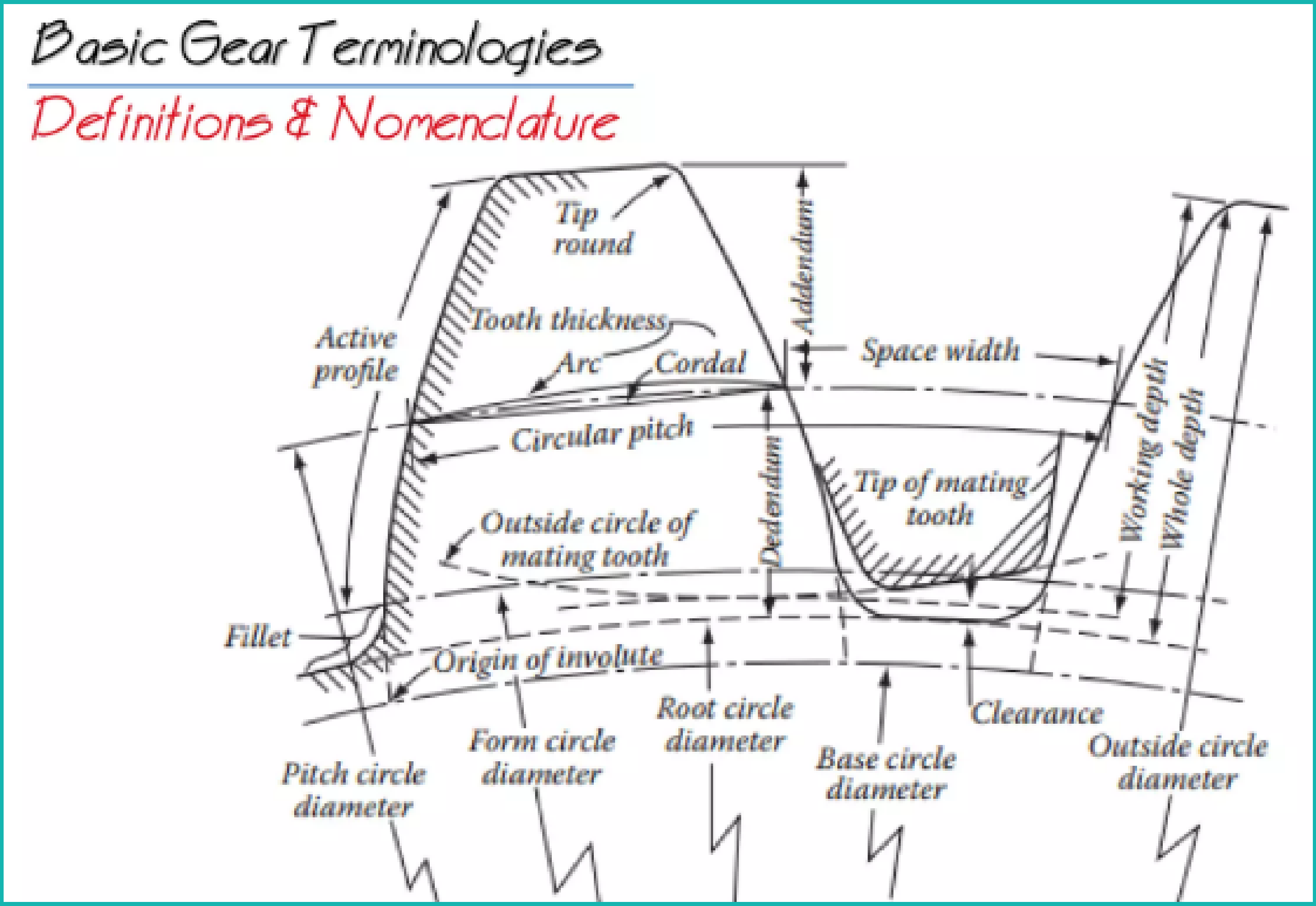
Terminology of Spur Gear

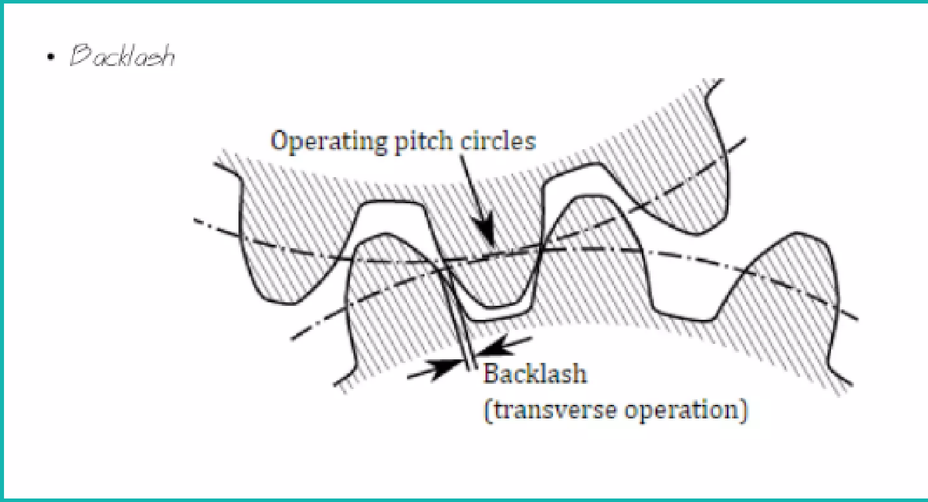
GEAR TERMINOLOGIES



- Chordal Thickness
  - It is the length of the chord subtended by the circular thickness arc. The dimension obtained when a gear tooth caliper is used to measure the tooth thickness at the pitch circle.

GEAR TERMINOLOGIES





Gear Terminologies

Top Land

The top most surface of the gear tooth is called top land.

Bottom Land

The bottom most surface of the gear tooth is called bottom land.

Pitch Circle

When two gears have meshed together, then the point on which one gear tooth is in contact with the tooth of the other gear is called the contact point.

And the imaginary circle that passes through this contact point is called the pitch circle.

The perpendicular drawn at the point of contact in a pair of teeth must pass through the point of pitch. This is called the law of gearing.

Pitch Circle Diameter (PCD)

As the name indicate it is the diameter of the pitch circle.

It can be denoted by the PCD.

Module

A module is defined as the ratio of pitch circle diameter in mm to the total no of teeth.

Gear Terminologies

Circular Pitch

The distance between a point of the tooth, measured at the same point in the adjacent teeth, is known as the circular pitch along the circumference of the pitch circle.

Addendum

When the radial distance between the pitch circle and the addendum circle is measured, it is called the addendum.

Addendum can be denoted by the capital letter A.

Since we know that, Addendum is equal to the module.

Addendum Circle

The circle that passes from the top of the tooth is called the addendum circle.

It is also called the outside circle which surrounds the outer ends of the teeth.

In external gears, the addendum circle is on the outer cylinder while in the internal gears the addendum circle is on the inner cylinder.

Clearance

When two gears meshed together, then the gap between the addendum circle of the top tooth and the dedendum circle of the other tooth is called the clearance.

Clearance can be denoted by the capital letter C.

Gear Terminologies

Dedendum

When the radial distance between the pitch circle and the dedendum circle is measured, it is called the dedendum.

It can be denoted by the capital letter D.

Dedendum circle

The circle that passes from the bottom of the tooth is called the dedendum circle.

It is also called the root circle which surrounds the bottom of teeth.

Tooth Thickness

Tooth thickness is the distance that is measured along the pitch circle of two attached teeth.

Tooth thickness is also called circular thickness.

It is denoted by the capital letter T.

Total Depth

Total depth is the sum of addendum and Dedendum.

Face of Tooth

Above the pitch circle, the surface of the tooth is called the face of the tooth.

Face Width

Face width is the width of the tooth.

Working Depth

This is the distance of the arrangement of two teeth which is expressed as '2A'.

Formula - Metric Gear

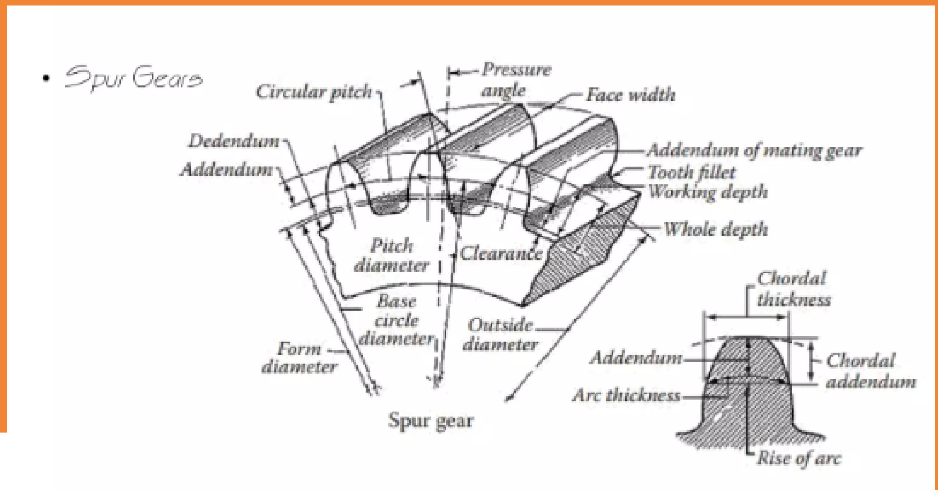
To Obtain	Knowing	Rule	Formula
Addendum (A)	Normal Module	Addendum equals module	A = M
Circular pitch (CP)	Module	Multiply module by π	CP = M x 3.1416
	Pitch diameter and number of teeth	Multiply pitch diameter by π and divide by number of teeth	CP = PD x $\frac{3.1416}{N}$
	Outside diameter and number of teeth	Multiply outside diameter by π and divide by number of teeth minus 2	CP = $\frac{OD \times 3.1416}{(N+2)}$
Chordal thickness (CT)	Module and outside diameter	Divide 90 by number of teeth. Find the sine of this angle and multiply by the pitch diameter.	CT = PD x sin$\left[\frac{90}{N}\right]$
	Module	Multiply module by π and divide by 2	CT = $\frac{M \times 3.1416}{2}$
	Circular pitch	Divide circle pitch by 2	CT = $\frac{CP}{2}$
Clearance (CL)	Module	Multiply module 0.166 mm	CL = M x 0.166
Dedendum (D)	Module	Multiply module 1.166 mm	D = M x 1.166
Module (M)	Pitch diameter and number of teeth	Divide pitch diameter by the module	M = $\frac{PD}{N}$
	Circular pitch	Divide circular pitch by π	M = $\frac{CP}{3.1416}$
	Outside diameter and number of teeth	Divide outside diameter by number of teeth	M = $\frac{OD}{N+2}$
Number of teeth (N)	Pitch diameter and module	Divide pitch diameter by the module	N = $\frac{PD}{M}$
	Pitch diameter and circular pitch	Multiply pitch diameter by π and divide product by circular pitch	N = $\frac{PD \times 3.1416}{CP}$
Outside diameter (OD)	Number of teeth and module	Add 2 to the number of teeth and multiply sum of module	OD = (N + 2) x M
	Pitch diameter and module	Add 2 modules to pitch diameter	OD = PD + 2M
Pitch diameter (PD)	Module and number of teeth	Multiply module by number of teeth	PD = M x N
	Outside diameter and module	Subtract 2 modules from outside diameter	PD = OD – 2M
	Number of teeth and outside diameter	Multiply number of teeth by outside diameter and divide product by number of teeth plus 2	PD = $\frac{N \times OD}{N+2}$
Whole depth (WD)	Module	Multiply module by 2.166 mm	WD = M x 2.166
Centre-to-centre distance(CD)	Pitch diameters	Divide the sum of the pitch diameters by 2	CD = $\frac{PD_1 + PD_2}{2}$

Figure 5.1.4: Table of Formula calculating metric gear

Spur Gear Calculation

A spur gear has a Pitch Diameter (PD) of 60 mm and 20 teeth. Compute the following:

1. Module
2. Circular Pitch
3. Addendum
4. Outside Diameter
5. Dedendum
6. Whole Depth
7. Cutter Number



Solution

1. $M = \frac{PD}{N}$

$= \frac{60}{20}$

$= 3$ mm

2. $CP = M \times \pi$

$= 3 \times 3.1416$

$= 9.425$ mm

3. $A = M$

$= 3$ mm

4. $OD = (N + 2) \times M$

$= 22 \times 3$

$= 66$ mm

Module Size (mm)		Milling Cutter Numbers: Cutter No.	For Cutting
0.5	3.5		
0.75	3.75	1	12 to 13 teeth
1	4	2	14 to 16 teeth
1.25	4.5	3	17 to 20 teeth
1.5	5	4	21 to 25 teeth
1.75	5.5	5	26 to 34 teeth
2	6	6	35 to 54 teeth
2.25	6.5	7	55 to 134 teeth
2.5	7	8	135 teeth to rack
2.75	8		
3	9		
3.25	10		

5. $D = M \times 1.166$

$= 3 \times 1.166$

$= 3.498$ mm

6. $WD = M \times 2.166$

$= 3 \times 2.166$

$= 6.498$ mm

7. Cutter number (see Table 70.3) = 3

Spur Gear Calculation

Two identical gears in mesh have a centre-to-centre distance (CD) of 120 mm. Each gear has 24 teeth. Find below terms:

i. Pitch Diameter
ii. Module
iii. Outside Diameter
iv. Whole Depth
v. Circular Pitch
vi. Chordal thickness

i. PD $= \dfrac{2 \times CD}{2}$ (equal gears)

$= \dfrac{2 \times 120}{2}$

$= \dfrac{240}{2}$

$= \underline{120 \text{ mm}}$

ii M $= \dfrac{PD}{N}$

$= \dfrac{120}{24}$

$= \underline{5 \text{ mm}}$

iii. OD $= (N + 2) \times M$

$= 26 \times 5$

$= \underline{130 \text{ mm}}$

iv WD $= M \times 2.166$

$= 5 \times 2.166$

$= \underline{10.83 \text{ mm}}$

v. CP $= M \times \Pi$

$= 5 \times 3.1416$

$= \underline{15.708 \text{ mm}}$

vi. CT $= \dfrac{M \times \Pi}{2}$

$= \dfrac{5 \times 3.1416}{2}$

$= \underline{7.85 \text{ mm}}$

Gear Inspection

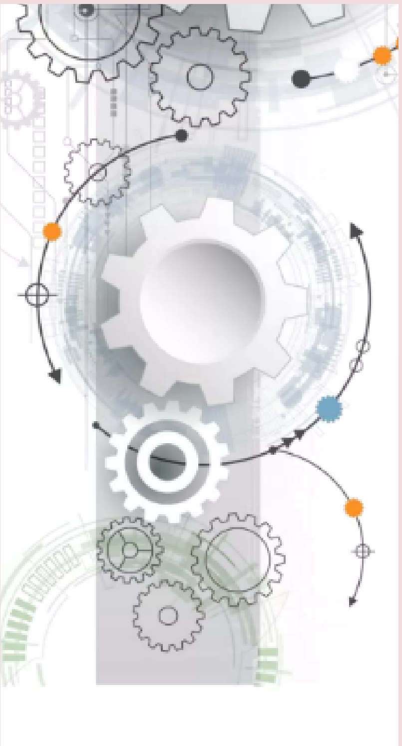
The purpose of gear inspection is to:

- Assure required accuracy and quality,
- Lower overall cost of manufacture by controlling rejects and scrap.
- Control machines and machining practices and maintain produced accuracy as machines and tools wear,
- Determine heat treat distortions to make necessary corrections

A gear's tooth thickness can be checked in many ways. The most common method is to measure over balls or pins positioned in diametrically opposite tooth spaces on *external gears*. Internal *gears* are measure between balls or pins. Balls are usually used for helical gears.

Tooth thickness can also be measured by determining the center distance when in tight mesh (no backlash) with a master gear. Tooth thickness determined by a master gear is usually called "functional tooth thickness," as it will include other variables, such as lead, involute, spacing, and runout errors.

All of the analytical and functional inspection measurement (lead, involute, spacing, tooth thickness, runout, composite error,etc.) can now be analyzed by computers. It is no longer necessary for an inspector to judge if the part is in tolerance or not, as the computer will judge. Data storage is also accomplished so that the history of a given part can be stored for years and recalled at moment's notice.■



Gear Tooth Measurements

MEASUREMENT OF GEAR TOOTH PARAMETERS USING GEAR TOOTH VERNIER

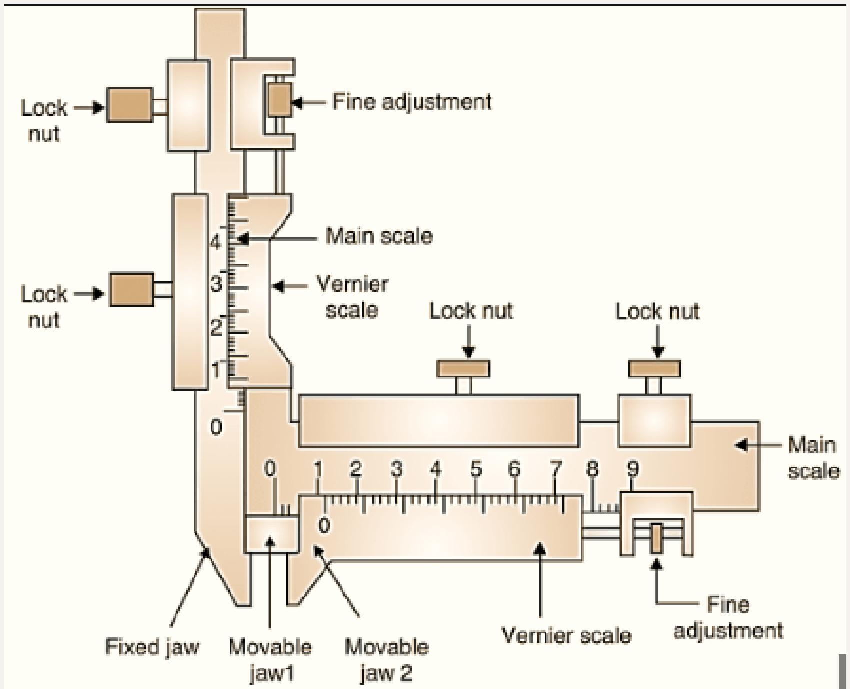


Figure 1 - Gear tooth vernier caliper

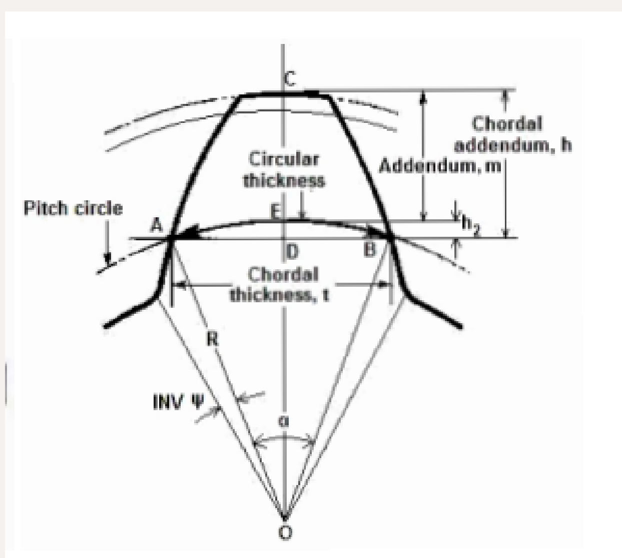


Figure B - Gear tooth geometry

MEASUREMENT OF GEAR TOOTH PARAMETERS USING GEAR TOOTH VERNIER

- Multiple thickness measurement
  - The chordal tooth thickness and associated addendum depth for several positions on a tooth may be computed for a gear tooth caliper. Comparison with computed values indicate profile accuracy

Tooth thickness is measured by the gear tooth vernier. The vernier shown in Fig. A consists of two vernier calipers set at 90º to each other. Since the gear tooth thickness varies from the root to the tip, the vernier must be capable of measuring the tooth thickness at a specified position on the tooth. The tooth thickness is measured at the pitch circle as shown in Fig. B.

The thickness of the tooth at pitch line and the addendum is measured by an adjustable tongue, each of which is adjusted independently by adjustable screws on the graduated bars. The gear tooth vernier is set with its vertical scale at a distance equal to chordal addendum so that the thin slit will be at a height ‘m’ from the tip of the jaw. Hence the gear tooth slit will sit on the top land and the tip of the jaws will measure the chordal thickness, t. “t” is the chord ADB while tooth thickness is the arc AEB. Therefore the tooth thickness thus measured is called “Chordal tooth thickness”.

$$h = (m + h_2)$$
$$t = AB = 2AD$$
$$\angle AOD = \alpha / 2 = 2\pi / 4N = \pi / 2N$$

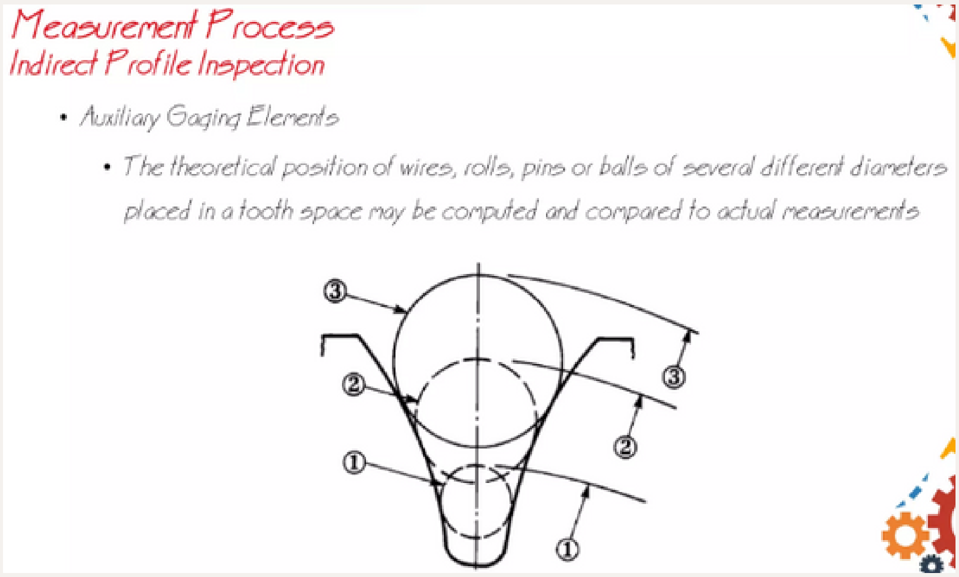
Where, R = Pitch Circle Radius = Nm/2

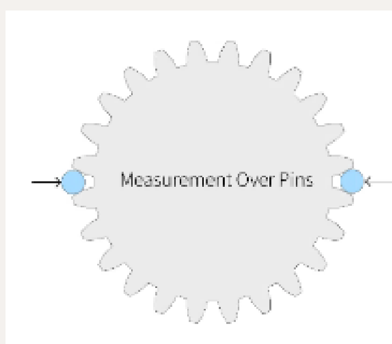
$$t = 2AO\sin(\alpha / 2) = 2R\sin(\pi / 2N)$$
$$t = Nm\sin(\pi / 2N)$$
$$h_2 = DE = R(1 - \cos(\alpha / 2)) = \frac{Nm}{2}(1 - \cos\pi / 2N)$$

Gear Tooth Measurements

Gear Measurements Using Pins or Balls

Measurement Over Pins (or Measurement Over Wires) is a method for measuring and inspecting spur gears and helical gears, with both even and odd tooth counts.





Tooth thickness measurement with pins or balls

This measuring method is similar to that used for the control of screw threads. The diameter of the pin is chosen in such a way that this is in contact with the tooth flanks at the pitch diameter and, on the other hand, is larger than the tip circle located in tooth spaces that are diametrically opposed towards each other.

Gear Tooth Measurements

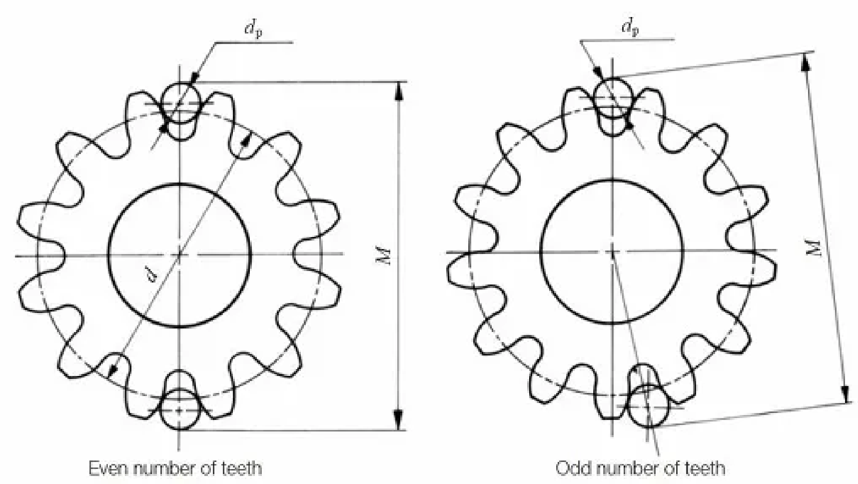
Gear Measurements Using Pins or Balls

The pin diameter can be calculated in function of the module of the gear parameters, namely: the module – pressure angle – correction – number of teeth. The calculated diameter does not always give a practical diameter as a result, therefore is then chosen for a standard pin diameter which is available. For gears with normal teeth without correction one uses usually standard pins whose diameters are located approximately on the following values:

- 1.75 m for external gears with a pressure angle of a = 20°
- 1.7. m for external gears with a pressure angle of a = 14°30′
- 1.65 m for internal gears with a pressure angle of a = 20°
- 1.6. m for internal gears with a pressure angle of a = 14°30′

Over pin (ball) measurement is a type of gear tooth thickness measurement method, along with chordal tooth thickness measurement and span measurement of teeth.

For example, in the case of spur gears, the tooth thickness is determined by inserting pins or balls into the tooth grooves facing each other when the number of teeth is even, or 180/z(°) when the number of teeth is odd, and measuring the outer dimension (or inner dimension in the case of internal gears) using a measuring instrument such as a micrometer.



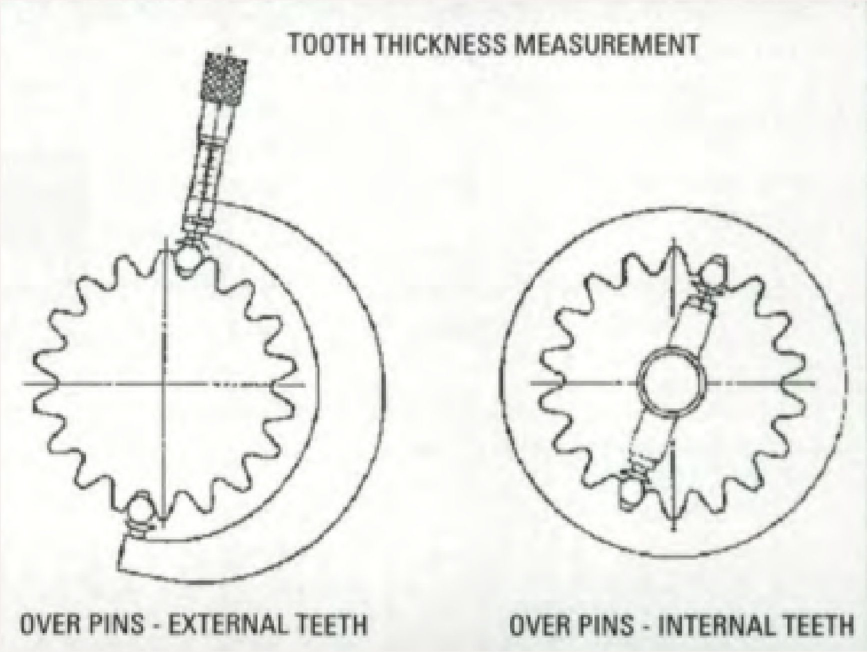
Over pin (ball) measurement

Gear Tooth Measurements

Gear Measurements Using Micrometer

When a gear inspector takes a gage and uses its anvils or pins on diametrically opposed tooth spaces, what he's actually measuring is changes in tooth thickness.

Pitch diameter is the diameter of a pitch circle. The standard (reference) pitch circle is defined as: "The circle which intersects the involute at the point where the pressure angle is equal to the profile angle of the basic rack."



Therefore, the standard pitch diameter is actually a reference dimension that doesn't change as long as the number of teeth and the diametral pitch or module don't change. The standard pitch diameter shouldn't have a tolerance and isn't measured.

When measuring thickness change, it's common practice to measure the gear over pins or anvils. This is often called a measurement over wires (MOW). As the teeth get thinner, this measurement becomes smaller.

TUTORIAL

1. What is gear?

....

2. Define indexing in gear making process.

....

....

....

3. State **FIVE (5)** functions of a gear.

....

....

....

....

4. Explain the gear terminologies stated below:

i. Addendum

....

ii. Dedendum

....

iii. Module

....

iv. Clearance

....

v. Pitch circle

....

5. Name the gear shown below.

6. Give **SIX (6)** gear applications in the industry.

....

....

....

....

....

....

7. Match these gears to their category.

Angle gear
Spur gear
Spiral gear
Herringbone gear
Bevel gear
Worm and worm gear
Internal gear
Helical gear

Gears are used to connect parallel shafts lying in the same plane
Gears are used to connect the shafts which intersect at the same angle
Gears are used to connect the shafts at an angle but lying in the same plane

8. Write the formula for each term:

i. Chordal thickness ....

ii. Addendum ....

iii. Module ....

iv. Number of teeth ....

v. Circular pitch ....

vi. Outside diameter ....

9. Share the procedure to inspect the gear tooth using gear tooth vernier caliper.

....

....

....

....

10. Sketch a complete gear terminology.

11. Find the pitch diameter, module, outside diameter, and whole depth chordal thickness of the gears if the identical gears have center-to-center distance (CD) of 240 mm and 48 teeth.

12. For a 40-tooth spur gear with 240 mm PD, find:

i. Addendum

ii. Module

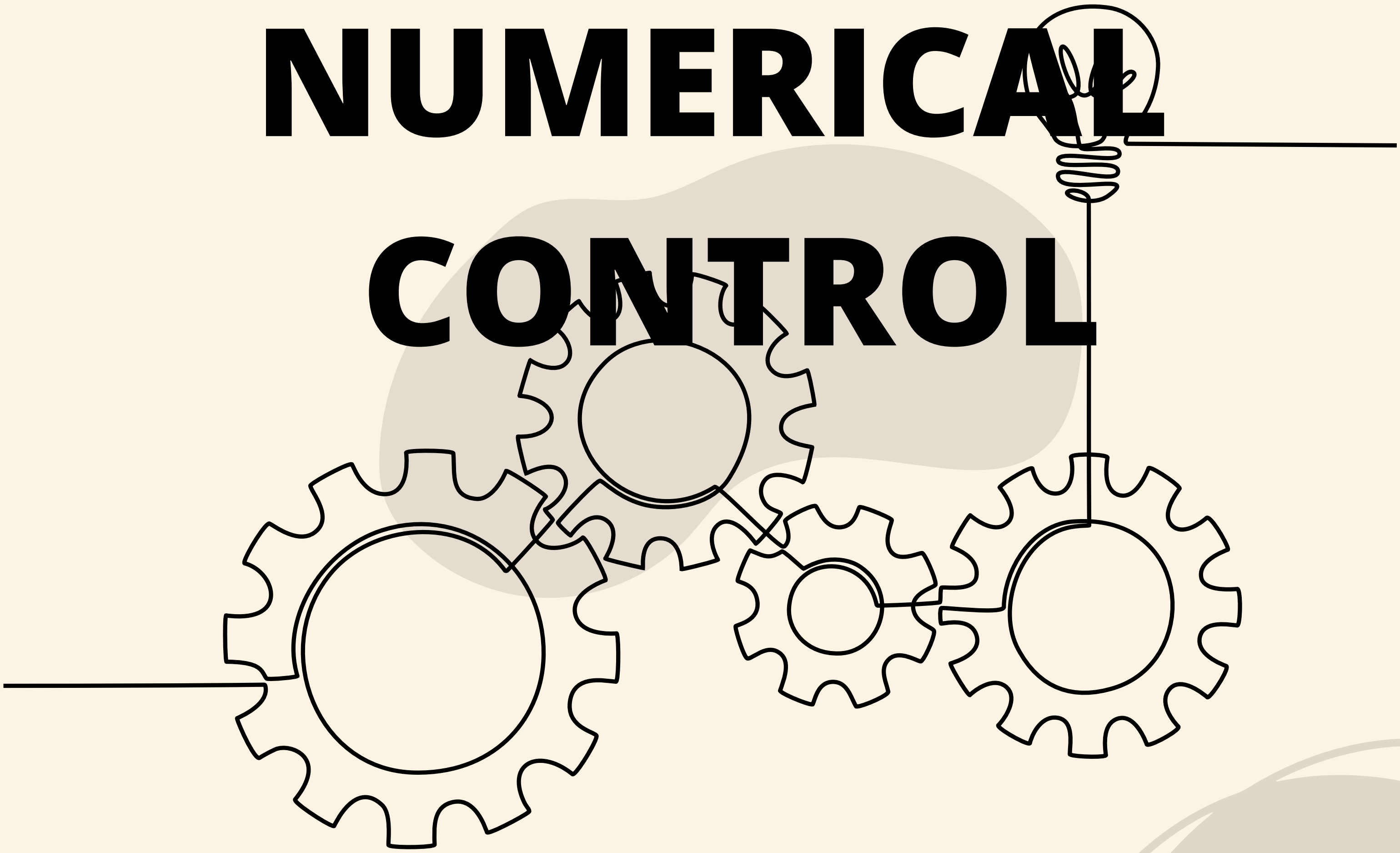
iii. CP

iv. Dedendum

v. OD

vi. Cutter Number

COMPUTER NUMERICAL CONTROL



INTRODUCTION

CNC

CNC aka Computer Numerical Control is a new method in controlling various machine tools in product making. Every numerical control machine consist of 3 components;

1) Machine control unit (MCU),
2) Machine tool and
3) Input media (program)

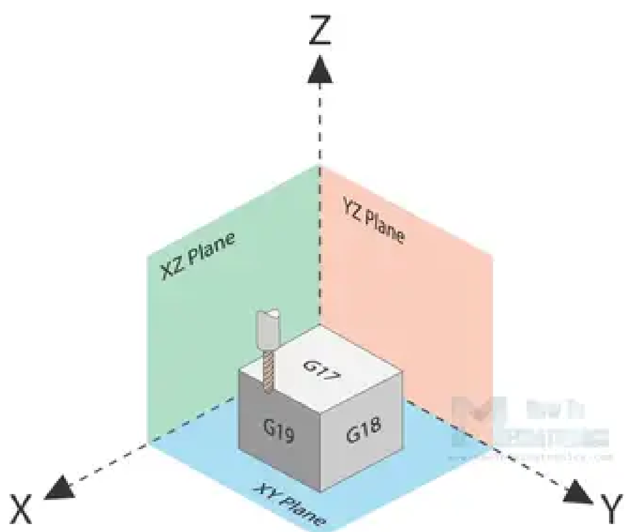
1. MCU - It is considered the heart of the CNC machine as various functions are conducted after the commands have been received.

2. Machine tool - This part resembles those used in conventional machining operations. The difference is the machine operates with computer software & normally constructed with 3-axes or even more.

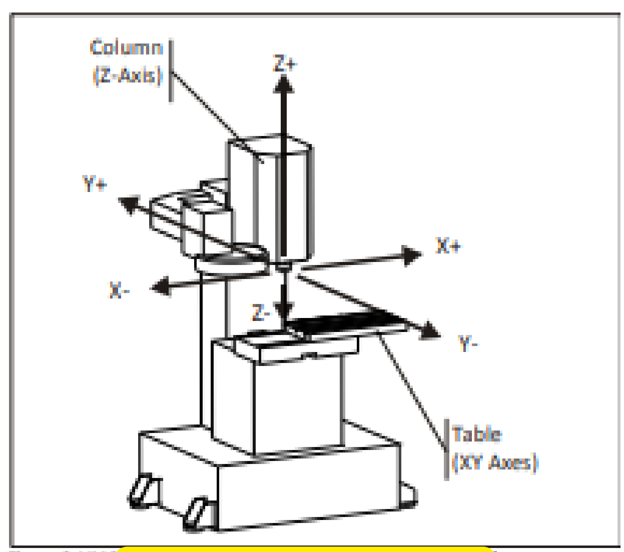
OBJECTIVES

Apply standard practice in operating mechanical tools and component

3. Input Media Program - These devices are responsible for inputting the part program into the CNC machine. There are three commonly used input devices: punch tape reader, magnetic tape reader, and computer via RS-232-C communication.



4. The concept of NC was proposed in the late 1940 s by John Parsons who recommended a method of automatic machine control that would guide a milling cutter to produce a curvilinear motion in order to generate smooth profiles on the work -pieces .



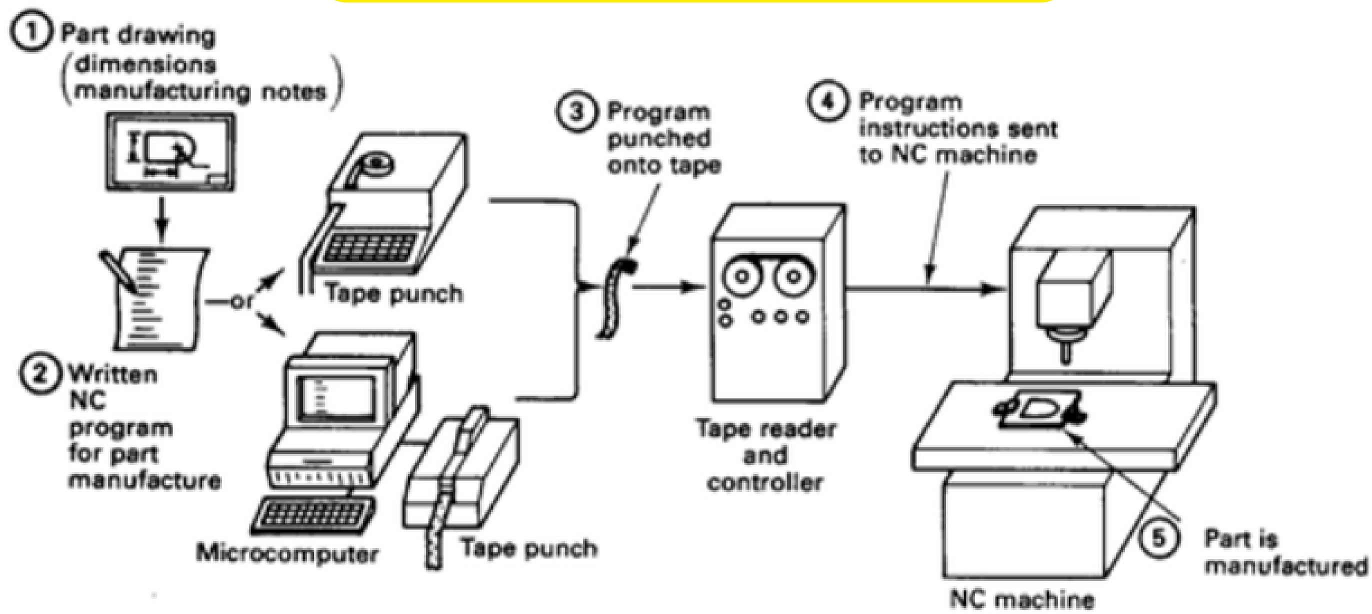
Example of axis in CNC

5. 3 primary planes

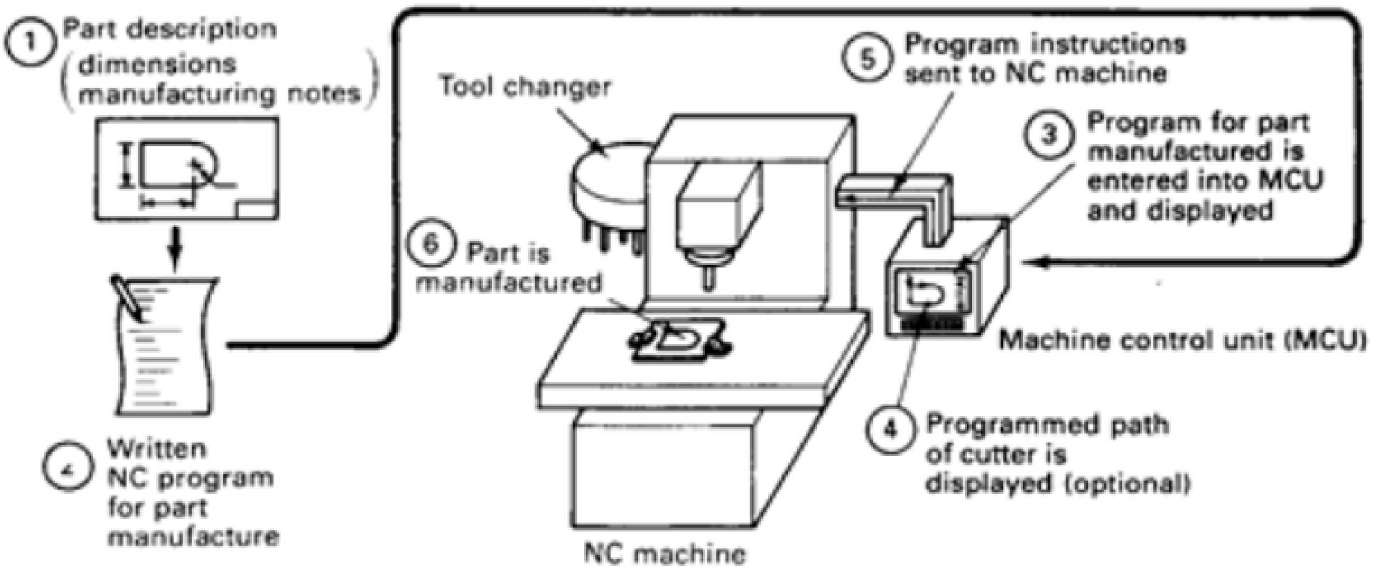
Combining any two primary axis lines defines a flat plane. There are 3 planes: X-Y, X-Z and Y-Z.

Traditional NC vs Modern CNC

Traditional NC System



CNC System



CNC Advantages

- CNC machines can be used continuously and only need to be switched off for occasional maintenance.
- These machines require less skilled people to operate unlike manual lathes/milling machines etc.
- CNC machines can be updated by improving the software used to drive the machines.
- Training for the use of CNC machines can be done through the use of “virtual software”.
- The manufacturing process can be simulated virtually and no need to make a prototype or a model. This saves time and money.
- Once programmed, these machines can be left and do not require any human intervention, except for work loading and unloading.
- These machines can manufacture several components to the required accuracy without any fatigue as in the case of manually operated machines.
- Savings in time that could be achieved with the CNC machines are quite significant.

CNC Disadvantages

- CNC machines are generally more expensive than manually operated machines.
- The CNC machine operator only needs basic training and skills, enough to supervise several machines.
- Increase in electrical maintenance, high initial investment and high per hour operating costs than the traditional systems.
- Fewer workers are required to operate CNC machines compared to manually operated machines. Investment in CNC machines can lead to unemployment.

CNC Applications

- CNC was initially applied to metal working machinery: Mills, Drills, boring machines, punch presses etc and now expanded to robotics, grinders, welding machinery, EDM's, flame cutters and also for inspection equipment etc.

Types of CNC Control Units

- ✓FANUC CONTROLL
- ✓ SIEMENS
- ✓ GSK
- ✓ MECH 3 etc

TYPES OF CNC MACHINE

There are many different types of CNC Machines used in industry, Such as:

- •Mills and Machining Centers
- •Lathes and Turning Centers
- •Drilling Machines
- •EDM Sinker and wire cut Machines
- •Flame and Laser-Cutting Machines
- •Water Jet Profilers

How Do We Input Program?

Different ways of data input are :

- •MDI : Manual Data Input
- •PROGRAM PREPARATION WITH CAD CAM
- • PROGRAM DATA TRANSFER FROM PC TO CNC M/C
- •PROGRAM DATA TRANSFER FROM PC TO DNC OPERATIONS

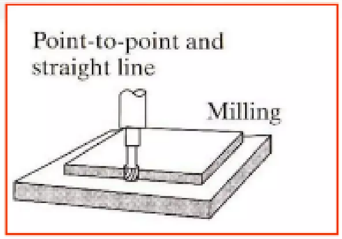
TYPES OF CNC PROGRAM SYSTEM

1	FANUC -- {SIMPLE OLD FUNCTIONE}
2	SIEMENS-- {GOOD FOR BOTH PURPOSE}
3	HAAS-- {GOOD FOR LEARNING AND PROGRAMING}
4	MAZAK-- {ADVANCE TECHANOLGY}
5	HEIDENHIEN-- {CYCLE SYSTEM EASY FOR USING}

Types of CNC Motion Control

❖ **CNC MOTION CONTROL**

- POINT TO POINT MOTION
- STRAIGHT CUT MOTION
- COUNTORING MOTION

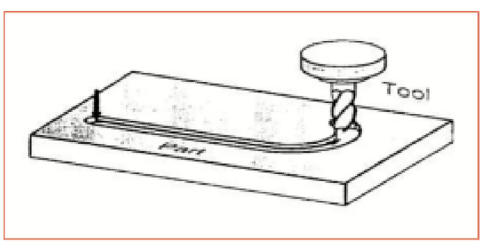


1. Point-to-point (PTP) MOTION

- ❖ The cutting tool is moved relative to the work piece (i.e. Either the cutting tool moves, or the work piece moves) until the cutting tool is at a numerically defined position and then the motion is paused.
- ❖ The cutting tool then performs an operation.
- ❖ When the operation is completed, the cutting tool moves relative to the work piece until the next point is reached, and the cycle is repeated.
- ❖ The simplest example of a PTP NC machine tool is the NC drilling machine.

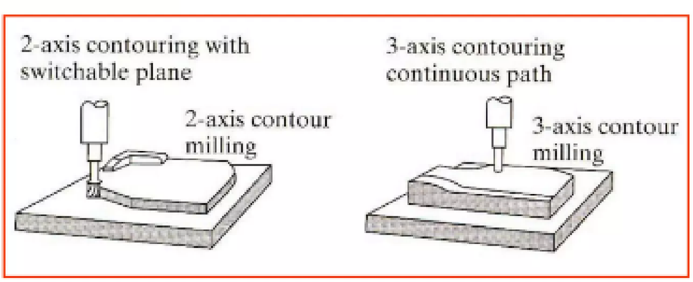
Straight-cut MOTION

- ❖ Straight-cut system are capable of moving the cutting tool parallel to one of the major axes (X-Y-Z) at a controlled rate suitable for machining.
- ❖ It is appropriate for performing milling operations to fabricate work pieces of rectangular configurations.
- ❖ Straight-cut NC systems can also perform PTP operations.



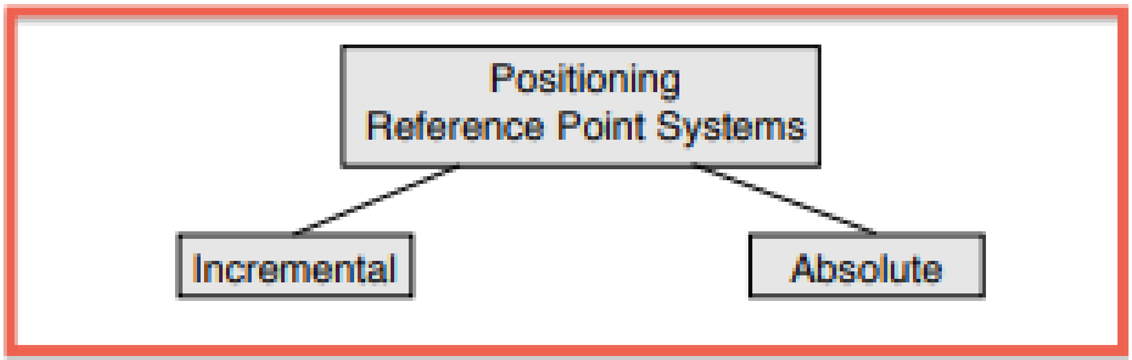
Contouring NC

- ❖ In contouring (continuous path) operations, the tool is cutting while the axes of motion are moving.
- ❖ The axes can be moved simultaneously, at different velocity.
- ❖ The path of the cutter is continuously controlled to generate the desired geometry of the work piece.

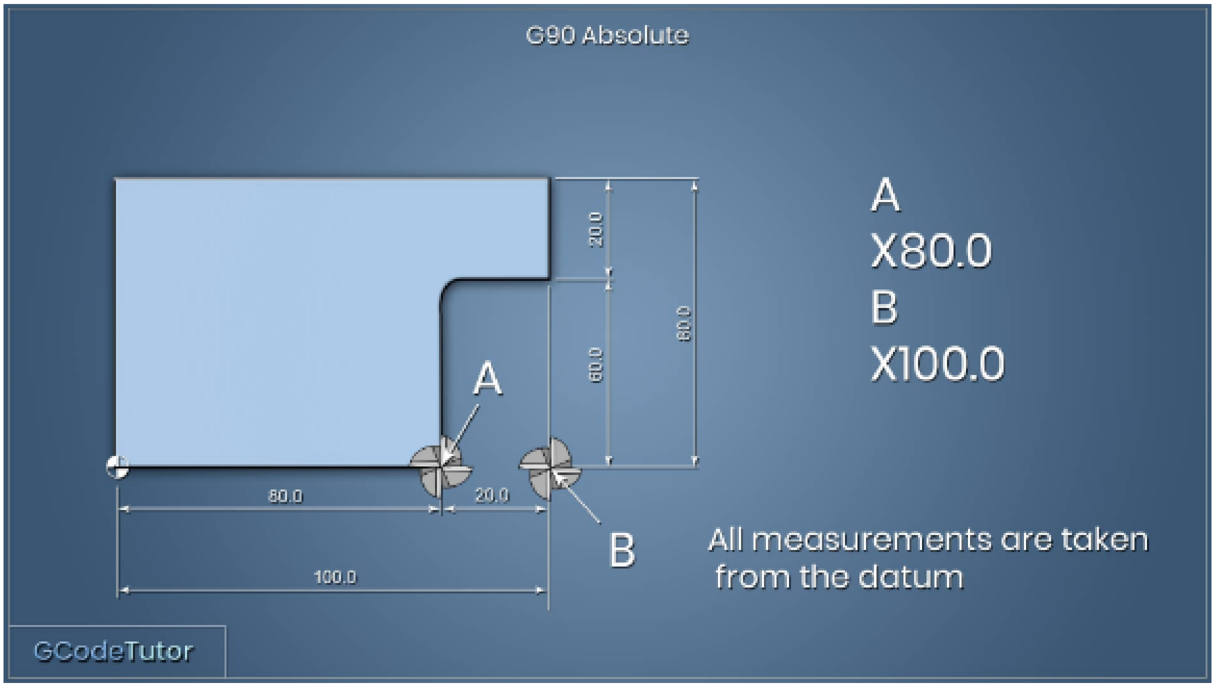


Programming Systems

Two types of programming modes, the incremental system and the absolute system, are used for CNC. Both systems have applications in CNC programming, and no system is either right or wrong all the time. Most controls on machine tools today are capable of handling either incremental or absolute programming.

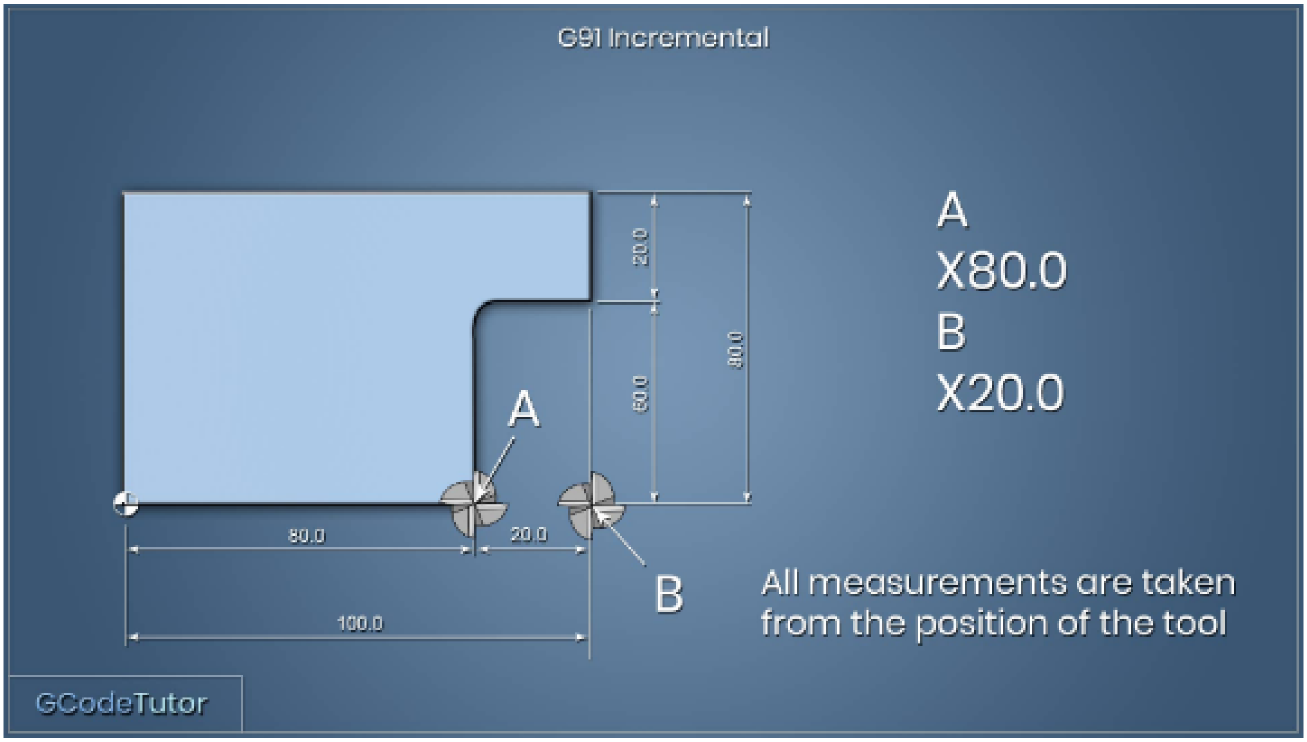


G90 Absolute positioning



The G Code G90 is used to define the absolute positioning system. When G90 is active the machine will read all dimensions and movements from the working datum position.

G91 incremental positioning



When working with G91 incremental positioning, We command the tool to move from its current position and not the datum position.

Most controls on machine tools capable of handling both by altering code between G90 (absolute) and G91 (incremental) commands.

- **Absolute Mode:**

Movement is programmed as the complete distance from a specified point, say the start point or the zero point.

- **Incremental Mode:**

In this mode the movement of the tool, slide or table is described or programmed as the distance from the end point of the previous mode and must be given the appropriate negative or positive sign.

Referenced to the Origin - Program Reference Zero (PRZ)

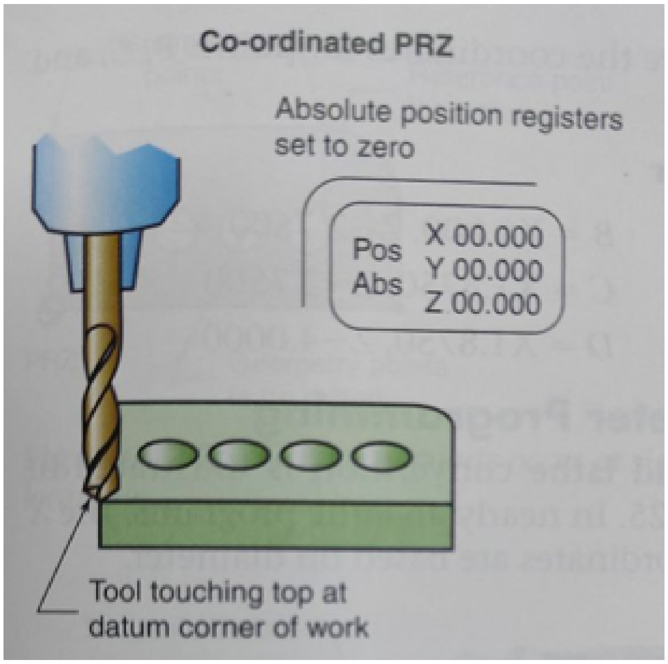
All absolute coordinates refer to a singular starting place - the origin.

In CNC work, it is called the Program Reference Zero (PRZ).

The PRZ is the reference point on which the program & the setup are based.

Setting the PRZ on the Machine:

When the machine is setup, the PRZ must be located at the same position on the physical part as it was selected for the program. This is a critical setup task on both lathe and milling machine.



Coordinating the PRZ to the physical part requires setting the axis registers to zero when the tool is at the PRZ position

Programming Systems

- **Diameter and radius program**

Some machines are designed to be programmed in diameter or radius mode. Programming for diameter is done by input of data in **diameter mode**. The values are provided for diameter at different locations as per component deg. The programming for radius is done by input of data in **radius mode** and the values are provided for radius at different locations.

One of the three types of coordinates will be found to identify most of the points on the drawing: incremental Cartesian, absolute Cartesian, or polar.

Types of motions:

Every CNC machining center has only two types of motion.

- Linear
- Circular

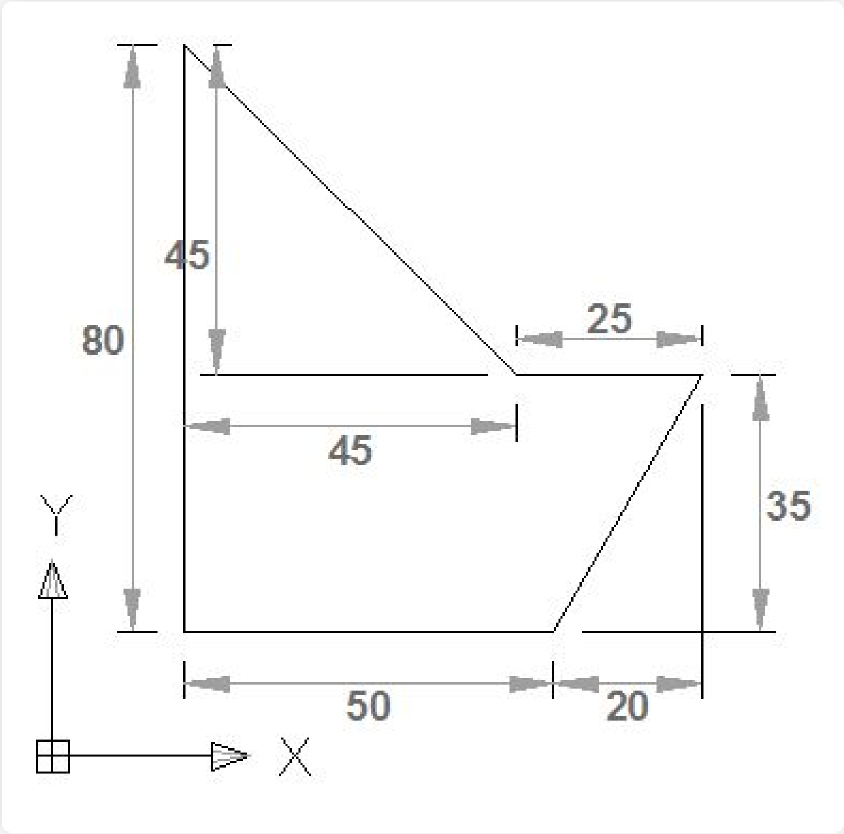
Linear motion is just as it sounds; straight line movement. These moves can be in any direction and can include all three axes. A linear move must be performed in one of two modes. Rapid or feed rate. Which mode the motion is executed is determined by a preparatory G code. G0 initiates a rapid movement and G1 is interpreted as a movement at a specified feed rate.

Rapid Linear Motion Example G0 G91 X2.0 Y2.0 Z-2.0

Feed Rate Linear Motion Example G1 F25. G91 X2.0 Y2.0 Z-2.0

The second motion type is circular. A circular motion, in contrast to a linear motion, can only be performed at a specified feed rate. A circular motion can be a full circle or it can be just a small segment of an arc. There are two event G codes used to initiate a circular motion. G2 and G3. The first, G2 tells the control that the following data should be used to create an arc in the clockwise direction. , G3 is counterclockwise.

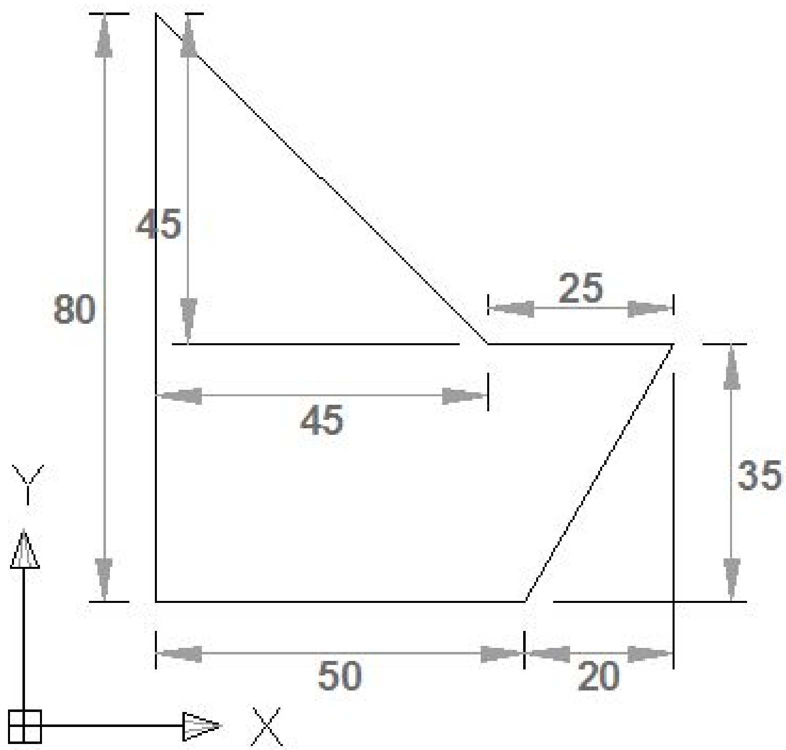
G90 Absolute Positioning



G90 Absolute Programming

```
G90 G01 X0 Y0
X50.0
X70.0 Y35.0
X45.0
X0 Y80.0
Y0
M30
```

G91 Incremental Positioning



G91 Incremental Programming

```
G91 G01 X0 Y0
X50.0
X20.0 Y35.0
X-25.0
X-45.0 Y45.0
Y-80.0
M30
```

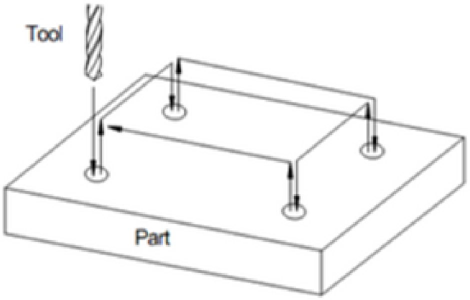
CNC Classifications

1. Classification based on the motion type.
2. Classification based on the control loops.
3. Classification based on the number of axes.
4. Classification based on the power supply.

Motion Type

Point-to-Point Systems.

1. It is used in some CNC machines such as drilling, boring and tapping machines...etc.
2. The control equipment for use with them are known as point-to-point control equipment.
3. Feed rates need not to be programmed.
4. In theses machine tools, each axis is driven separately.

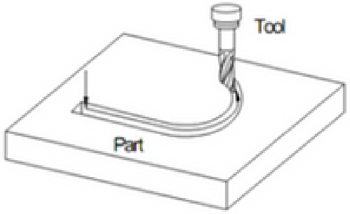


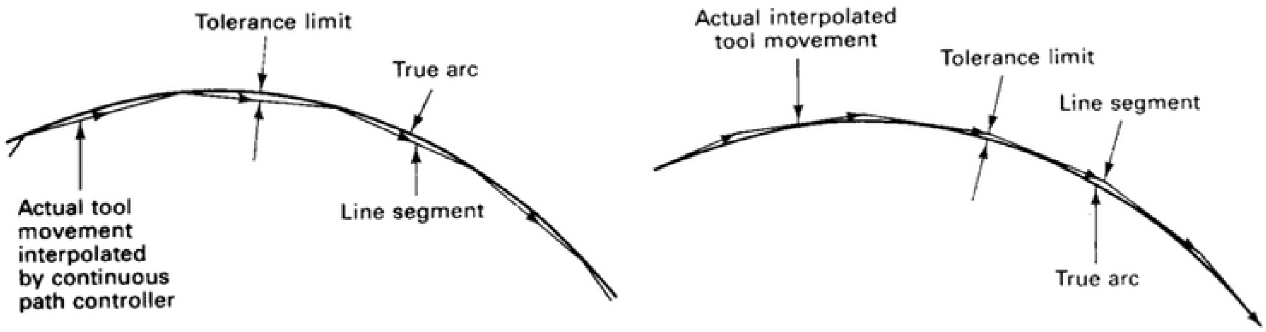
CNC Classifications

Motion Type

Contouring Systems (Continuous Path Systems)

- It is used in CNC machine tools such as milling machines.
- These machines require simultaneous control of axes.
- Contouring machines can also be used as point-to-point machines, but it will be uneconomical to use them unless the work piece also requires having a contouring operation to be performed on it.





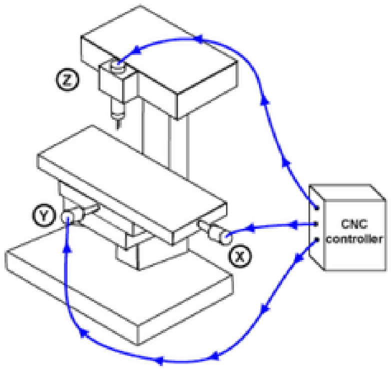
Interpolation used for continuous-path movement.

CNC Classifications

Control Loops

Open Loop Systems

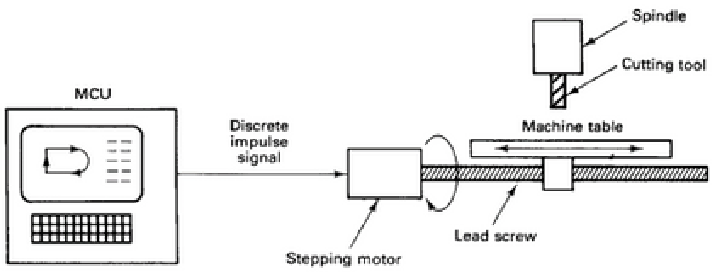
- Programmed instructions are fed into the controller through an input device.
- These instructions are then converted to electrical pulses (signals) by the controller and sent to the servo amplifier to energize the servo motors.
- The primary drawback of the open-loop system is that there is no feedback system to check whether the program position and velocity has been achieved.



Open-Loop-System

Open Loop Systems

- the open -loop system is generally used in point-to-point systems where the accuracy requirements are not critical.
- Very few continuous-path systems utilize open-loop control.



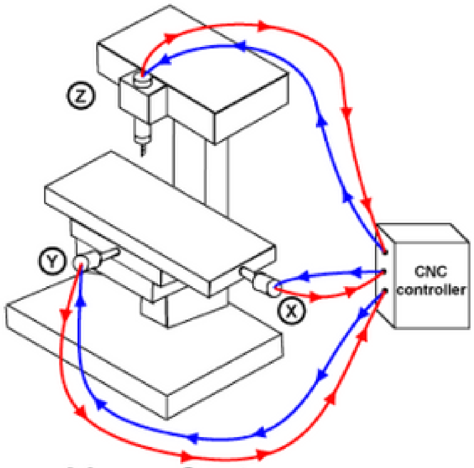
Configuration for an open loop system.

CNC Classifications

Control Loops

Closed Loop Systems

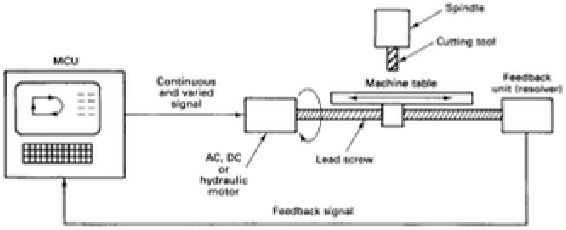
- The closed-loop system has a feedback subsystem to monitor the actual output and correct any discrepancy from the programmed input.
- These systems use position and velocity feed back.
- The feedback system could be either analog or digital.



Closed-Loop-System

Closed Loop Systems

- The analog systems measure the variation of physical variables such as position and velocity in terms of voltage levels.
- Digital systems monitor output variations by means of electrical pulses.
- Closed-loop systems are very powerful and accurate because they are capable of monitoring operating conditions through feedback subsystems and automatically compensating for any variations in real-time.



Configuration of a closed loop system.

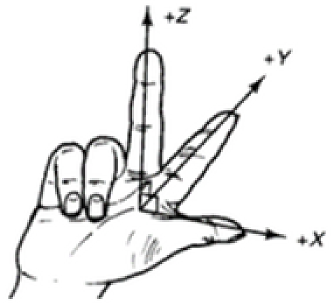
CNC Classifications

Number of Axes

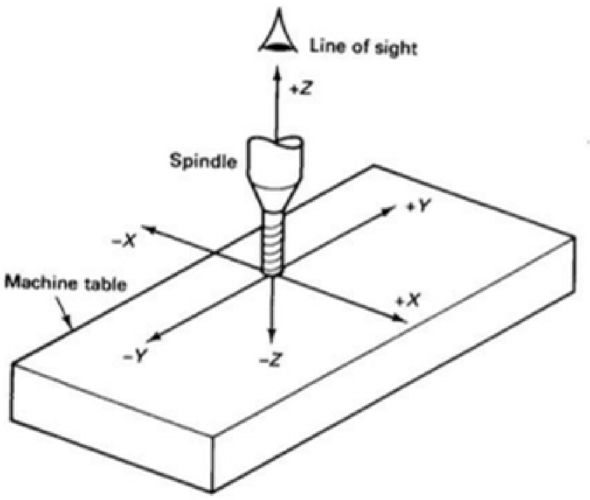
2&3 axes CNC Machines

- CNC lathes will be coming under 2 axes machines. There will be two axes along which motion takes place.
- The saddle will be moving longitudinally on the bed (Z-axis) and the cross slide moves transversely on the saddle (along X-axis).
- In 3-axes machines, there will be one more axis, perpendicular to the above two axes.
- By the simultaneous control of all the 3 axes, complex surfaces can be machined.

Rule of Thumb



The right-hand rule for linear motion.



Machine axis for a three-axis vertical CNC machine (machine axis defined as spindle movement).

CNC Classifications

Number of Axes

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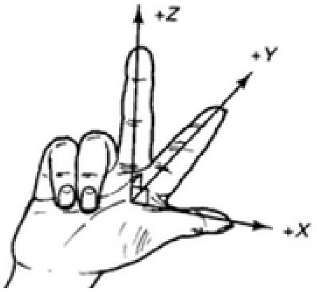
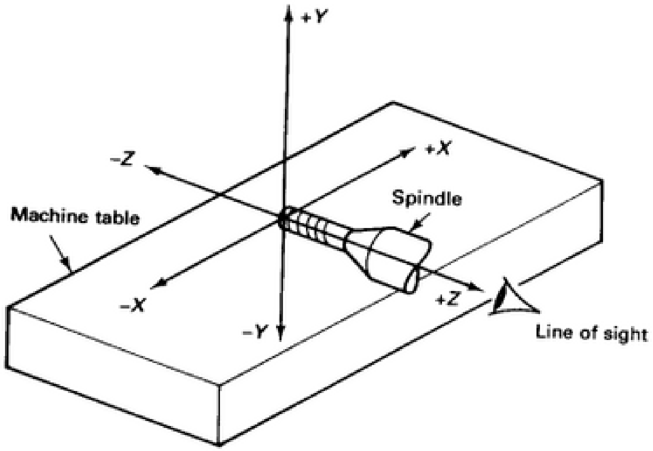
Rule of Thumb



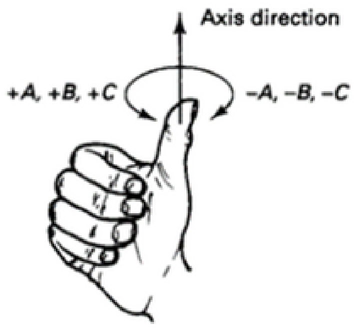
The right-hand rule for linear motion.



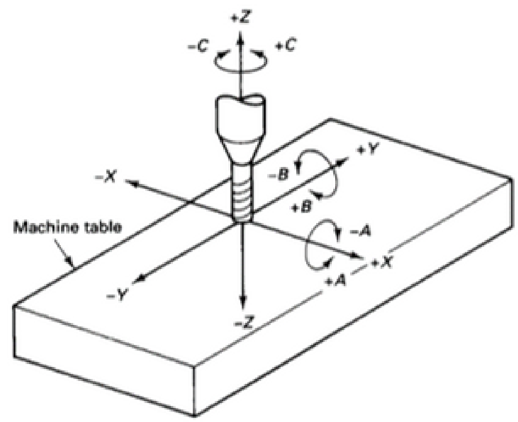
Machine axis for a three-axis horizontal CNC machine (machine axis defined as spindle movement).

CNC Classifications

Number of Axes



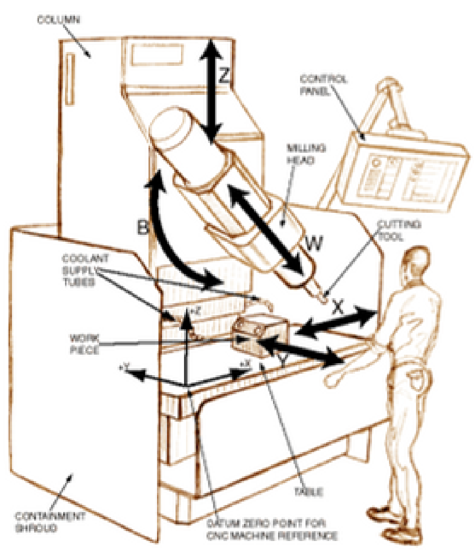
The right-hand rule for rotary motion.



Machine axes for six-axis vertical CNC machine (machine axis defined as spindle movement).

Importance of higher axes machining:

- Reduced cycle time by machining complex components using a single setup.
- In addition to time savings, improved accuracy can also be achieved as positioning errors between setups are eliminated.
- Improved surface finish and tool life by tilting the tool to maintain optimum tool to part contact all the times.



CNC Classifications

Number of Axes

Importance of higher axes machining:

- Improved access to under cuts and deep pockets. By tilting the tool, the tool can be made normal to the work surface and the errors may be reduced as the major component of cutting force will be along the tool axis.
- Higher axes machining has been widely used for machining sculptures surfaces in aerospace and automobile industry.

Power Supply

- Mechanical power unit refers to a device which transforms some form of energy to mechanical power which may be used for driving slides, saddles or gantries forming a part of machine tool.
- The input power may be of **electrical**, **hydraulic** or **pneumatic**.

AC Servo Motor for CNC Machine Tool

CNC Coordinate System

Most CNC machine tools use a language set by the Electronics Industry Association (EIA) in the 1960's. The official name of this language is RS-274D, but everyone refers it "G-code" or "G&M Code" because many of the words of this language begin with the letters G or M.

The G-code language was developed when machine controls had very little memory. It was therefore designed to be as compact as possible. While at first this language may seem arcane, the modern machine tool language is the safest and most efficient way yet devised to control machine tool motion. G&M codes, along with coordinates and other parameters, comprise what is called a **CNC program**.

CNC Language & Structure

CNC programs list instructions to be performed in the order they are written. They read like a book, left to right and top-down. Each sentence in a CNC program is written on a separate line, called a **Block**. Blocks are arranged in a specific sequence that promotes safety, predictability and readability, so it is important to adhere to a standard program structure.

Typically, blocks are arranged in the following order:

1) Program Start
2) Load Tool
3) Spindle On
4) Coolant On
5) Rapid to position above part
6) Machining operation
7) Coolant Off
8) Spindle Off
9) Move to safe position
10) End program

The steps listed above represent the simplest type of CNC program, where only one tool is used and one operation performed. Programs that use multiple tools repeat steps two through nine for each.

CNC Programming

Sample Programming

Sample program format for machining a square contour and drills a hole.

Block	Description	Purpose
%	Start of program.	Start Program
O0001 (PROJECT1)	Program number (Program Name).	
(T1 0.25 END MILL)	Tool description for operator.	
N1 G17 G20 G40 G49 G80 G90	Safety block to ensure machine is in safe mode.	
N2 T1 M6	Load Tool #1.	Change Tool
N3 S9200 M3	Spindle Speed 9200 RPM, On CW.	
N4 G54	Use Fixture Offset #1.	Move To Position
N5 M8	Coolant On.	
N6 G00 X-0.025 Y-0.275	Rapid above part.	
N7 G43 Z1. H1	Rapid to safe plane, use Tool Length Offset #1.	
N8 Z0.1	Rapid to feed plane.	
N9 G01 Z-0.1 F18.	Line move to cutting depth at 18 IPM.	
N10 G41 Y0.1 D1 F36.	CDC Left, Lead in line, Dia. Offset #1, 36 IPM.	Machine Contour
N11 Y2.025	Line move.	
N12 X2.025	Line move.	
N13 Y-0.025	Line move.	
N14 X-0.025	Line move.	
N15 G40 X-0.4	Turn CDC off with lead-out move.	
N16 G00 Z1.	Rapid to safe plane.	
N17 M5	Spindle Off.	Change Tool
N18 M9	Coolant Off.	
(T2 0.25 DRILL)	Tool description for operator.	
N19 T2 M6	Load Tool #2.	
N20 S3820 M3	Spindle Speed 3820 RPM, On CW.	
N21 M8	Coolant On.	Move To Position
N22 X1. Y1.	Rapid above hole.	
N23 G43 Z1. H2	Rapid to safe plane, use Tool Length Offset 2.	
N24 Z0.25	Rapid to feed plane.	
N25 G98 G81 Z-0.325 R0.1 F12.	Drill hole (canned) cycle, Depth Z-.325, F12.	Drill Hole
N26 G80	Cancel drill cycle.	
N27 Z1.	Rapid to safe plane.	
N28 M5	Spindle Off.	End Program
N29 M9	Coolant Off.	
N30 G91 G28 Z0	Return to machine Home position in Z.	
N31 G91 G28 X0 Y0	Return to machine Home position in XY.	
N32 G90	Reset to absolute positioning mode (for safety).	
N33 M30	Reset program to beginning.	
%	End Program.	

CNC Address Codes

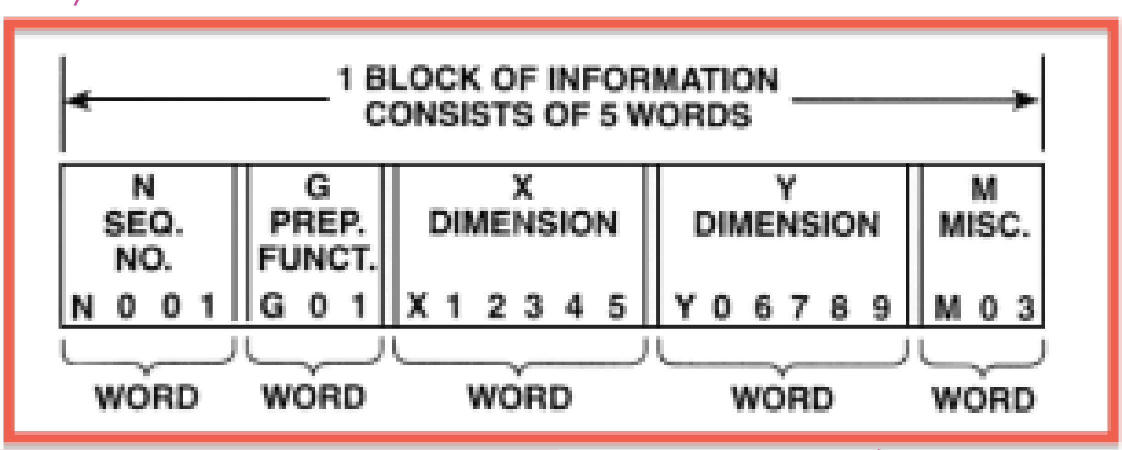
Every letter of the alphabet is used as a machine address code. In fact, some are used more than once, and their meaning changes based on which G-code appears in the same block.

Codes are either modal, which means they remain in effect until cancelled or changed, or non-modal, which means they are effective only in the current block.

The table below lists the most common address codes. A complete list is included in Appendix B, G-M Code Reference.

Code	Meaning
A	Rotation about X-axis.
B	Rotation about Y-axis.
C	Rotation about Z-axis.
D	Cutter diameter compensation (CDC) offset address.
F	Feed rate.
G	G-Code (preparatory code).
H	Tool length offset (TLO).
I	Arc center X-vector, also used in drill cycles.
J	Arc center Y-vector, also used in drill cycles.
K	Arc center Z-vector, also used in drill cycles.
M	M-Code (miscellaneous code).
N	Block Number.
O	Program Number.
P	Dwell time.
Q	Used in drill cycles.
R	Arc radius, also used in drill cycles.
S	Spindle speed in RPM.
T	Tool number.
X	X-coordinate.
Y	Y-coordinate.
Z	Z-coordinate.

A complete block of information



G & M Codes

G&M Codes make up the most of the contents of the CNC program. The definition of each class of code and specific meanings of the most important codes are covered next.

G-Codes

Codes that begin with G are called preparatory words because they prepare the machine for a certain type of motion. The most common G-codes are shown in Table 1 and a complete list and their meaning is included in Appendix B, G-M Code Reference.

Code	Meaning
G0	Rapid motion. Used to position the machine for non-milling moves.
G1	Line motion at a specified feed rate.
G2	Clockwise arc.
G3	Counterclockwise arc.
G4	Dwell.
G28	Return to machine home position.
G40	Cutter Diameter Compensation (CDC) off.
G41	Cutter Diameter Compensation (CDC) left.
G42	Cutter Diameter Compensation (CDC) right.
G43	Tool length offset (TLO).
G54	Fixture Offset #1.
G55	Fixture Offset #2.
G56	Fixture Offset #3.
G57	Fixture Offset #4.
G58	Fixture Offset #5.
G59	Fixture Offset #6.
G80	Cancel drill cycle.
G81	Simple drill cycle.
G82	Simple drill cycle with dwell.
G83	Peck drill cycle.
G84	Tap cycle.
G90	Absolute coordinate programming mode.
G91	Incremental coordinate programming mode.
G98	Drill cycle return to Initial point (R).
G99	Drill cycle return to Reference plane (last Z Height)

Table 1: Common G-Codes

G & M Codes

M-Codes

Codes that begin with M are called miscellaneous words. They control machine auxiliary options like coolant and spindle direction. Only one M-code can appear in each block of code.

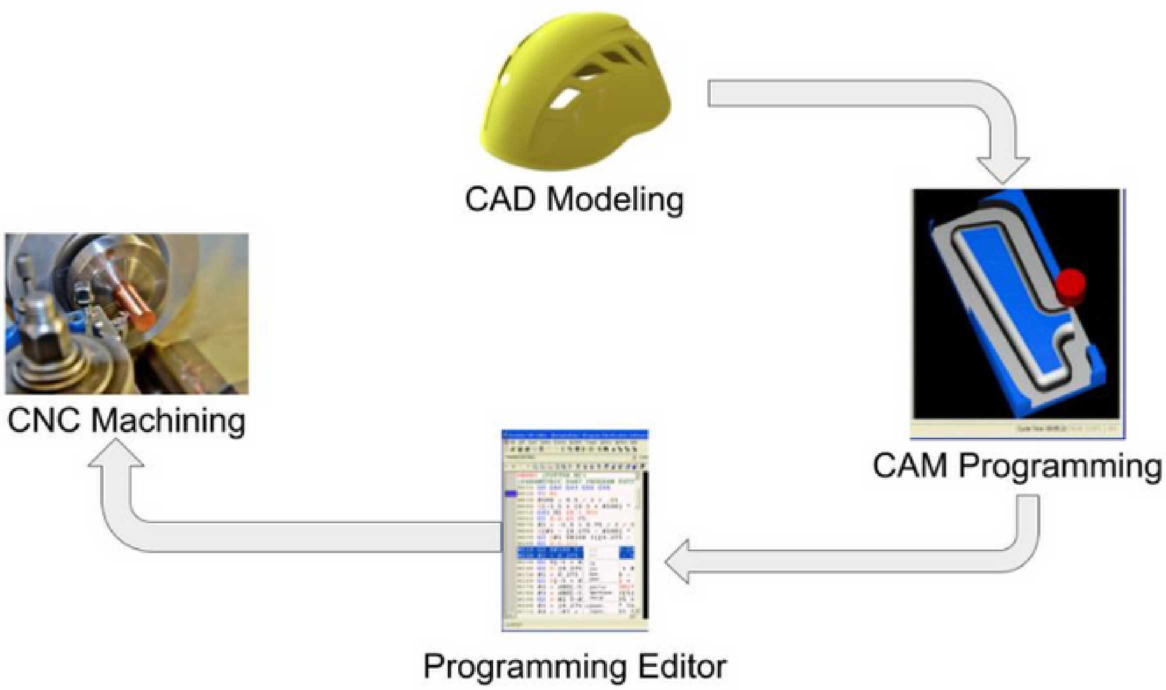
Code	Meaning
M0	Program stop. Press Cycle Start button to continue.
M1	Optional stop. Only executed if Op Stop switch on the CNC control is turned ON.
M2	End of program.
M3	Spindle on Clockwise.
M4	Spindle on Counterclockwise.
M5	Spindle stop.
M6	Change tool.
M8	Coolant on.
M9	Coolant off.
M30	End program and press Cycle Start to run it again.

Table 2: Common M-Codes

DON'T FORGET

How Does a CNC Machine Works?

CNC machines use digital instructions (such as G-Code or M-Codes) to move and tool and workpiece in a CNC machine. For machining, the Operator firstly loads digital instructions (CNC Program) and fixes the workpiece in the machine. Afterward, machines perform required machining operations automatically with minimal operator interference.



Turning Axis

Lathe

The engine lathe, one of the most productive machine tools, has always been an efficient means of producing round parts (Fig. 4). Most lathes are programmed on two axes.

- The X axis controls the cross motion of the cutting tool. Negative X (X-) moves the tool towards the spindle centerline; positive X moves the tool away from the spindle centerline.
- The Z axis controls the carriage travel toward or away from the headstock.

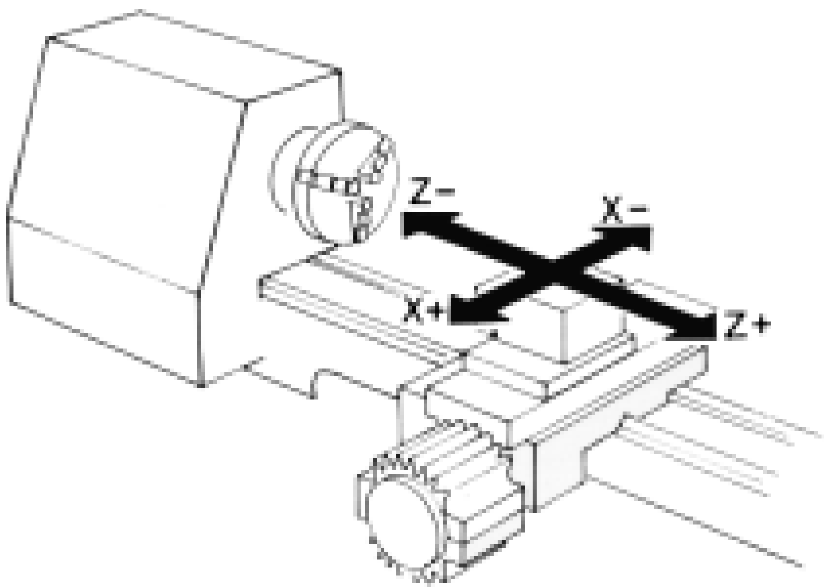
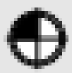


Fig. 4 The main axes of a lathe or turning center. (Emco Maier Corp)

Programming Hints

CNC Programming Hints - TURNING

 Indicates the X Z 0 (zero) location which is the starting point for programming.

 Indicates the tool-change position.

A G92 code will reset the axis register position coordinates to this position.

For a program to run on a machine, it must contain the following codes:

M03	To start the spindle/cutter revolving.
Sxxx	The spindle speed code to set the r/min.
Fxx	The feedrate code to move the cutting tool or workpiece to the desired position.

TAPERS/BEVELS/ANGLES

- The X Z coordinates of the small diameter, the large diameter, and a feedrate must be programmed.
- Z moves the cutting tool longitudinally away from the end of the workpiece.
- Z- moves the cutting tool along the length of the workpiece towards the chuck (headstock).
- X moves the cutting tool away from the work diameter.
- X- moves the cutting tool into the work diameter.

Milling Axis

Milling Machine

The milling machine has always been one of the most versatile machine tools used in industry (Fig. 5). Operations such as milling, contouring, gear cutting, drilling, boring, and reaming are only a few of the many operations which can be performed on a milling machine. The milling machine can be programmed on three axes:

- The X axis controls the table movement left or right.
- The Y axis controls the table movement toward or away from the column.
- The Z axis controls the vertical (up or down) movement of the knee or spindle.

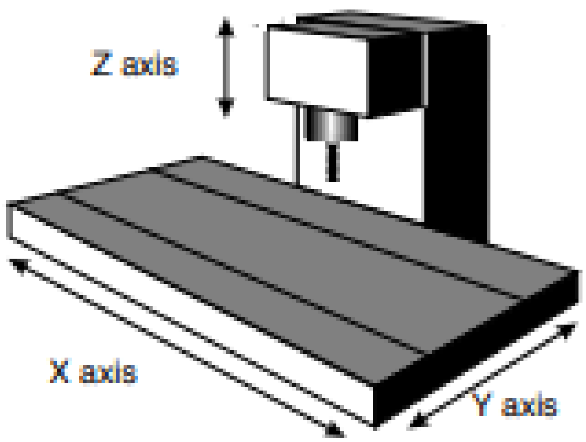


Fig. 5 The main axes of a vertical machining center. (Denford Inc.)

Programming Hints

CNC Programming Hints - MILLING

Machine reference point (maximum travel of machine)

Machine X Y zero point (could be tool change point)

Part X Y zero point (programming start point)

Indicates the tool change position. A G92 code will reset the axis register position coordinates to this position.

For a program to run on a machine, it must contain the following codes:

M03	To start the spindle/cutter revolving.
Sxxx	The spindle speed code to set the r/min.
Fxx	The feed rate code to move the cutting tool or workpiece to the desired position.

ANGLES:

The X Y coordinates of the start point and end point of the angular surface plus a feed rate (F) are required.

Z CODES:

- A Z dimension raises the cutter above the work surface.
- A Z- dimension feeds the cutter into the work surface.
- Z.100 is the recommended retract distance above the work surface before a rapid move (G00) is made to another location.

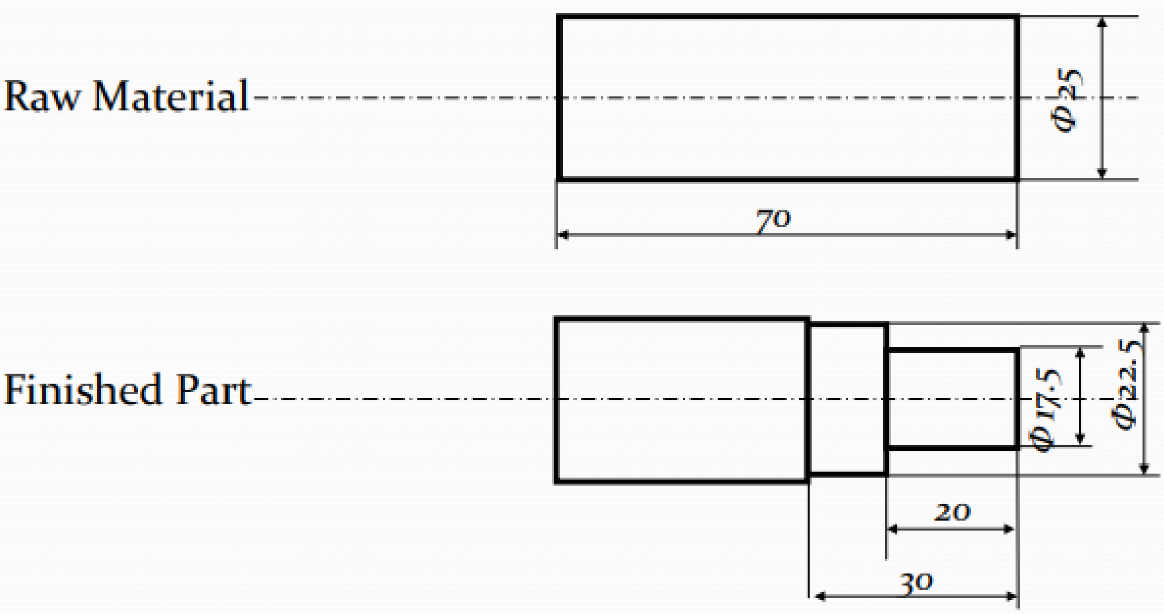
RADII / CONTOUR Requirements:

- The *start* point of the arc (XY coordinates)
- The *direction* of cutter travel (G02 or G03)
- The *end* point of the arc (XY coordinates)
- The *center* point of the arc (IJ coordinates) or the arc radius)

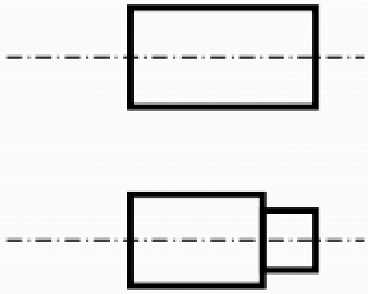
Programming

Programming Example

Cylindrical Part



Programming Example (*Cylindrical Part*)

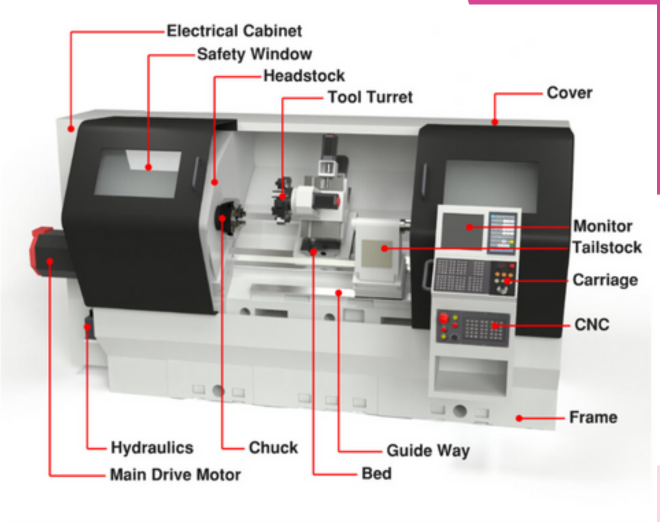


```
O0077

N0005  G28 U0.0 W0.0;
N0010  T0202;
N0020  G97 S1500 M03;
N0030  G00 X50.0 Z1.0 ;
N0040  G71 U1.0 R2.0;
N0050  G71 P0060 Q00 U0.5 W0.2 F0.2;
N0060  G01 X13.0;
N0070  X15.0 Z-1.0;
N0080  Z-30.0
N0090  X23.0
N0100  X25.0 Z-50.0;
N0110  X50.0;
N0120  G70 P0060 Q0110 S2500 F0.1;
N0130  G28 U0.0 W0.0,

N0140   M30
```

CNC LATHE



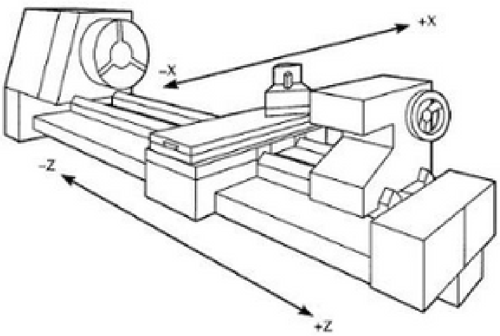
A diagram of a CNC lathe machine

What are the Parts of a CNC lathe?

- **Machine Bed**: The CNC Lathe or CNC Turning Center bed is the main base on which its components are mounted.
- **Main Spindle**: The main spindle consists of the spindle assembly and the spindle drive system. Many of the moving parts of the CNC lathe are in the main spindle, including motors, gears, and the chuck. The C-axis drive that assists in positioning the material is also assembled with the spindle.
- **Sub-Spindle** or **Second Spindle**: Although not part of the main spindle, the optional sub-spindle works in concert with the main spindle to complete primary and secondary cutting operations, improving efficiency and production.
- **Chuck**: The lathe chuck is comparable to the vise on a milling machine since it holds the workpiece to allow safe and accurate machining. The chuck size determines the size of the work a CNC lathe can handle.
- **Guide Way**: The guideway enables the cutting tool to move horizontally and vertically and complete a smooth cutting process.
- **Headstock**: The headstock contains the main motor and the main spindle mounted on the chuck.
- **Tailstock**: The tailstock is located on the end opposite the headstock. The tailstock provides support when machining long workpieces such as shafts.
- **Tool Turret**: The turret provides the ability to change the cutting tools as required. The number and size of the cutting tools will determine the turret's size.

CNC LATHE

What are the Primary Axes on a CNC Lathe?



An axis defines all the movements of a CNC Lathe, and there is a definition and purpose for each of them:

- **X-Axis:** The movement perpendicular to the spindle.
- **Z-Axis:** The longitudinal movement of the turret.
- **Y-Axis:** Vertical direction for milling/drilling operations.
- **C-Axis:** The axis that positions the part in the chuck by using the spindle.
- **B-Axis:** The rotation of the lathe's milling head enables the head to perform work from various angles.

Some of CNC Lathe Applications

- Aerospace parts
- Automotive parts (crankshafts, camshafts, pistons, etc.)
- Train parts
- Electric motor parts
- Nuts & bolts
- Baseball bats
- Gun barrels
- Cue sticks
- Candlestick holders

CNC MILLING

CNC milling, or computer numerical control milling, is a machining process which employs computerized controls and rotating multi-point cutting tools to progressively remove material from the workpiece and produce a custom-designed part or product. This process is suitable for machining a wide range of materials, such as metal, plastic, glass, and wood, and producing a variety of custom-designed parts and products.

CNC milling is a mechanical machining process along with drilling, turning, and a variety of other machining processes, meaning that material is removed from the workpiece via mechanical means, such as the actions of the milling machine's cutting tools.

The CNC milling process begins with the creation of a 2D or 3D CAD part design. Then the completed design is exported to a CNC-compatible file format and converted by CAM software into a CNC machine program which dictates the actions of the machine and the movements of the tooling across the workpiece. Before the operator runs the CNC program, they prepare the CNC milling machine by affixing the workpiece to the machine's work surface (i.e., worktable) or workholding device (e.g., vise), and attaching the milling tools to the machine spindle. The CNC milling process employs horizontal or vertical CNC-enabled milling machines—depending on the specifications and requirements of the milling application—and rotating multi-point (i.e., multi-toothed) cutting tools, such as mills and drills. When the machine is ready, the operator launches the program via the machine interface prompting the machine to execute the milling operation.

CNC MILLING

Once the CNC milling process is initiated, the machine begins rotating the cutting tool at speeds reaching up to thousands of RPM. Depending on the type of milling machine employed and the requirements of the milling application, as the tool cuts into the workpiece, the machine will perform one of the following actions to produce the necessary cuts on the workpiece:

- Slowly feed the workpiece into the stationary, rotating tool
- Move the tool across the stationary workpiece
- Move both the tool and workpiece in relation to each other

CNC milling is a machining process suitable for producing high accuracy, high tolerance parts in prototype, one-off, and small to medium production runs. While parts are typically produced with tolerances ranging between +/- 0.001 in. to +/- 0.005 in., some milling machines can achieve tolerances of up to and greater than +/- 0.0005 in. The versatility of the milling process allows it to be used in a wide range of industries and for a variety of part features and designs, including slots, chamfers, threads, and pockets. The most common CNC milling operations include:

- Face milling
- Plain milling
- Angular milling
- Form milling

CNC Milling Equipment and Components

The CNC milling process employs a variety of software applications, machine tools, and milling machinery depending on the milling operation being performed.

CNC Mill Support Software

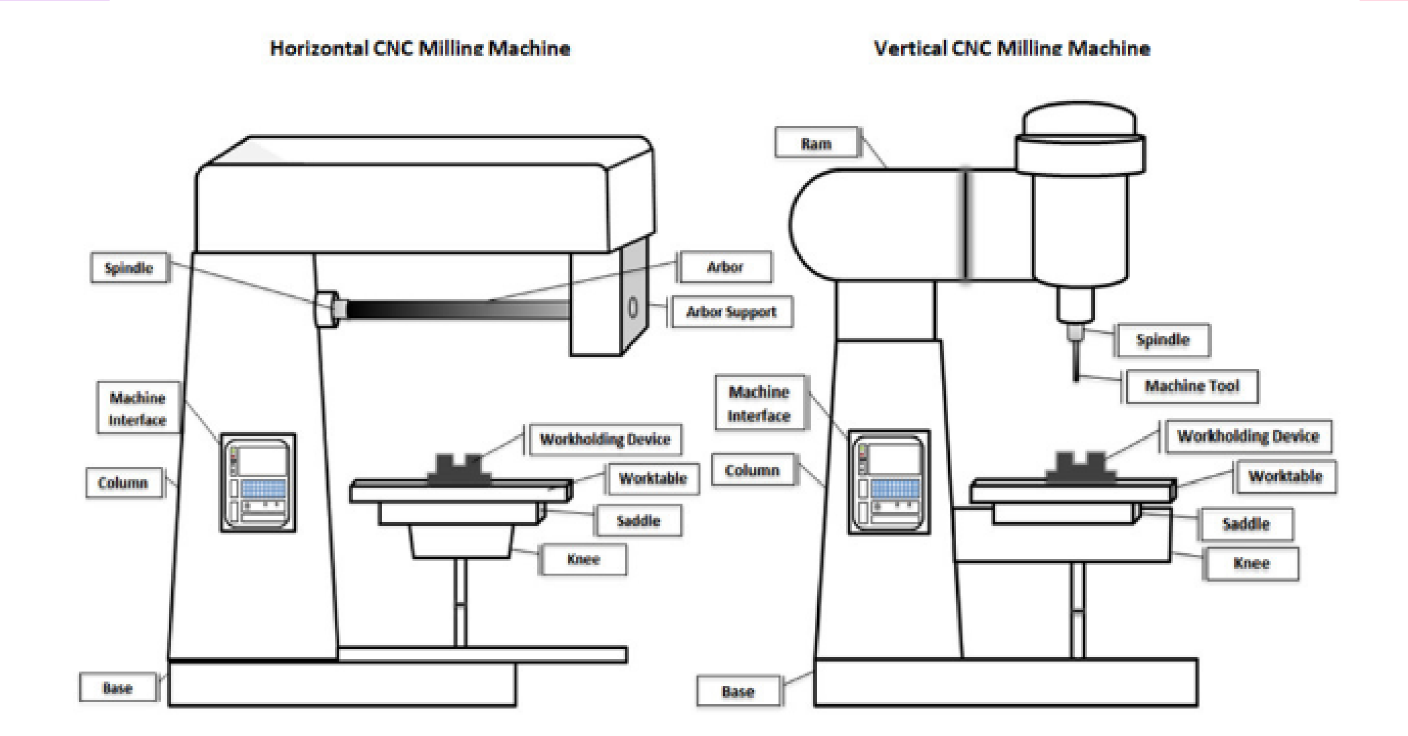
Like most CNC machining processes, the CNC milling process uses CAD software to produce the initial part design and CAM software to generate the CNC program which provides the machining instructions to produce the part. The CNC program is then loaded to the CNC machine of choice to initiate and execute the milling process.

CNC MILLING

CNC Milling Machine Components
Despite the wide range of milling machines available, most machines largely share the same basic components. These shared machine parts include the:

- Machine interface
- Column
- Knee
- Saddle
- Worktable
- Spindle
- Arbor
- Ram
- Machine tool

CNC Milling Machine Configurations and Components



CNC MILLING

Most CNC milling machines are available with 3 to 5 axes— typically providing performance along the XYZ axes and, if applicable, around rotational axes. The X-axis and Y-axis designate horizontal movement (side-to-side and forward-and-back, respectively, on a flat plane), while the Z-axis represents vertical movement (up-and-down) and the W-axis represents diagonal movement across a vertical plane. In basic CNC milling machines, horizontal movement is possible in two axes (XY), while newer models allow for the additional axes of motion, such as 3, 4, and 5-axis CNC machines.

Table 1 – Characteristics of Milling Machines by Axes of Motion

Number of Axes	Characteristics
3	• Capable of managing most machining needs • Capable of producing the same products as machines with more axes • Suitable for automatic or interactive operation, cutting sharp edges, drilling holes, milling slots, etc. • Simplest machine setup (A) • Only requires one workstation (A) • Higher knowledge requirements for operators (D) • Lower levels of efficiency and quality (D)
4	• Capable of operating on materials ranging from aluminum and composite board to foam, PCB, and wood • Suitable for advertising design, art creating, medical equipment creating, technology research, hobby prototype building, and industrial applications • Greater functionality than 3-axis machines (A) • Higher levels of precision and accuracy than 3-axis machines (A) • More complex machine setup 3-axis machines (D) • More expensive than 3-axis machines (D)

5	• Multiple axes configurations available (e.g., 4+1, 3+2, or 5) • Suitable for aerospace, architectural, medical, military, oil and gas, and artistic and functional applications • Greatest functionality and capabilities (A) • Depending on config., faster operation than 3-axis and 4-axis machines (A) • Highest levels of quality and precision (A) • Depending on config., slower operation than 3-axis and 4-axis machines (D) • More expensive than 3-axis and 4-axis machines (D)

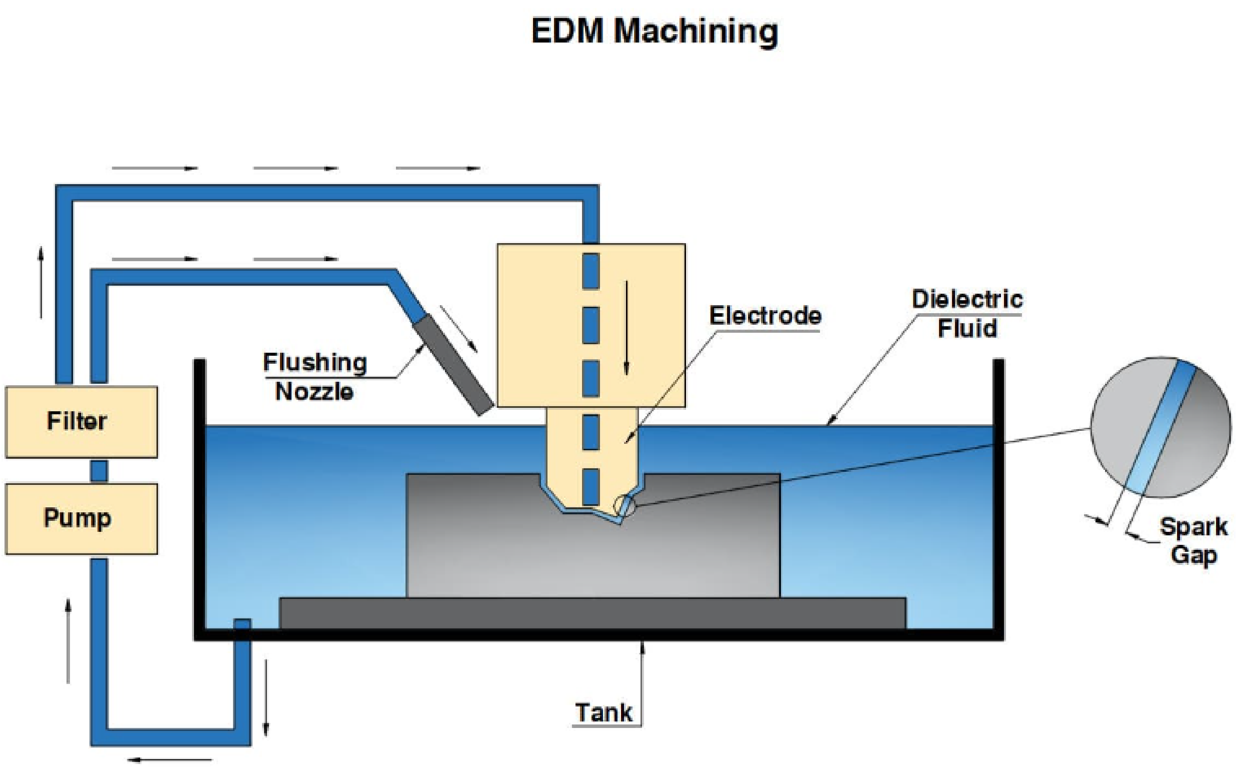
Note 1: If applicable, "A" indicates advantageous characteristics and "D" indicates disadvantageous characteristic.

Material Considerations

The CNC milling process is best suited as a secondary machining process to provide finishing features to a custom-designed part, but can also be used to produce custom designs and specialty parts from start to finish. CNC milling technology allows the process to machine parts of a wide range of materials, including:

- Metals (including alloy, exotic, heavy duty, etc.)
- Plastics (include thermosets and thermoplastics)
- Elastomers
- Ceramics
- Composites
- Glass

Electrical Discharge Machine (EDM)



Basic Working Principle of EDM

Although the principles of EDM machining are the same, there are variations in the process, especially between wired EDM working and sinker EDM working. Both processes have anodes and cathodes used to shape the workpiece to fit the parameters of the produced part. How they complete this process using electrical current is quite different.

With sinker EDM machining, an electrical potential difference is created between the tool and work material, both of which are electrically conductive and submerged in a dielectric fluid such as hydrocarbon oil or deionized water. The spark gap that separates the tool and workpiece is flooded with the dielectric fluid. The created electric field depends on the electric potential difference and the spark gap.

Electrical Discharge Machine (EDM)

Basic Working Principle of EDM

The tool takes the negative terminal while the work material takes the positive terminal of the power generator. Free electrons on the tool are subjected to electrostatic forces the moment the electric field begins. If there is less work function or smaller bonding energy of the electrons, the emission of electrons would be from the tool (assuming that it is connected to the negative terminal). This type of emission of electrons is called cold emission.

Through the dielectric medium, the cold emitted electrons are accelerated towards the work material. As they gain velocity and energy and begin moving towards the work, collisions occur between the electrons and dielectric molecules. The collisions cause the ionization of the dielectric molecules, which depends on the work function or ionization energy of the dielectric molecule and the energy of the electrons. As the electrons accelerate, positive ions and electrons are generated because of the collisions.

This cyclic process increases the electron and ion concentration in the dielectric fluid between the tool and the work material at the site of the spark gap. The concentration becomes so high that the matter in the channel is characterized as "plasma." The electric resistance of the plasma channel is very low. The large number of electrons flux from the tool to the work with ions moving suddenly from the work to the tool. This motion of electrons is known as an avalanche.

The sudden movement of electrons and ions creates the thermal energy of the spark with a heat range of 8,000°C up to 12,000°C. The rapid motion of the electrons hits the work material and the ions on the tool. The impact of the electrons and ions on the surface of the workpiece is converted into thermal energy or heat flux.

Electrical Discharge Machine (EDM)

Types of Electrical Discharge Machine

There are two types of **EDM machine** used commonly in today's world:

Sinker EDM

The Sinker EDM is also called a volume EDM or cavity EDM. This has got a work piece and an electrode present in an insulating fluid. The work piece and the electrode are connected with specific supply of power. Due to the power electrical potential is created between the two components. When the electrode reaches the work piece then the dielectric discharged is released and forms a plasma channel with slight sparks.

Applications

The sinker EDM is used when the material parts of any object requires high tolerance or corner radius. There are a lot of products and parts of those products made from Sinker EDM. Usually the production molds and dies are made with the help of this sinker EDM. It is convenient to use for making such production dies and molds.

Advantages

Sinker EDM process can do wonders for your production industry and provides durable results with high-quality finishes. Following are the advantages of Sinker EDM:

- Cuts exotic materials easily
- Tough materials are easy to cut
- Little or no polishing is required after the process is complete
- Cuts thin materials without by preventing any damage

Disadvantages

- Excessive power consumption
- Slow material removal
- No or less conductive materials produced

Electrical Discharge Machine (EDM)

Wire EDM

Introduced in 1969, the Wire EDM machining is a single-strand metal wire which is pretty thin made from brass present in the workpiece and also in dielectric fluid tank. Wire EDM is used in cutting plates thick as 300mm. Apart from this, it is also used in making dies, punches and several tools from hard metals.

Applications

Due to the flexibility of the machine the manufacturers use this to a wide range of applications. As the machine is able to cut very small pieces of materials too this is why it is a very smart choice for the production industries.

Advantages

- Cost effective
- High precision
- Best for prototype manufacturing
- Flexible machine for various cuts

Disadvantages

- Consumes high levels of energy
- Frequent change of brass, copper or other metal wire used in thermal stress

Electro-Chemical Machine (ECM)

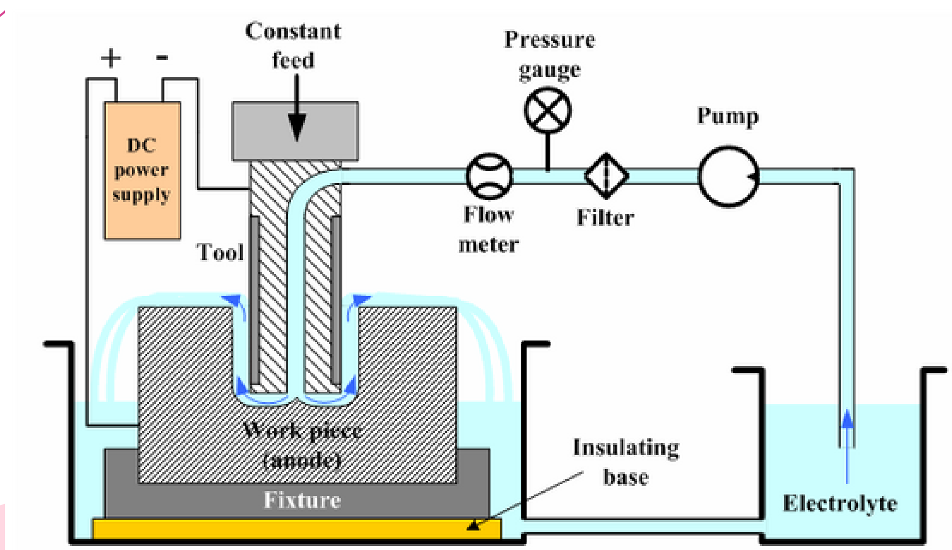
Electrochemical machining is the reverse of electroplating. An electrolyte works as a current carrier, and the high rate of electrolyte flow in the tool-workpiece gap washes metal ions from the workpiece (anode) before they have a chance to plate onto the tool (cathode).

Modification of this process are used for turning, facing, slotting, tremping, and profiling operations in which electrode becomes the cutting tools. The shaped tool is made out of brass, copper, bronze, or stainless steel.

Overall, Electrochemical Machining is a valuable manufacturing process for applications that require precise shaping of conductive materials, offering unique capabilities that complement traditional machining methods.

Electrochemical Machining (ECM) is a manufacturing process that utilises the principles of electrochemistry to remove material from a workpiece. It is a non-traditional machining method that offers unique capabilities for shaping and machining conductive materials.

Electrochemical Machining Parts



Electro-Chemical Machine (ECM)

Basic Working Principle of ECM

In **Electrochemical Machining** , an electrolyte solution is used to create an electrochemical reaction between the workpiece and a tool electrode, typically made of a conductive material like copper or brass. The workpiece and the tool electrode are connected to a power supply, forming an electrical circuit. When the circuit is established and the electrolyte flows between the electrodes, material removal occurs through a controlled dissolution process.

The electrochemical reaction takes place at the surface of the workpiece in the presence of the electrolyte. The electrolyte contains ions that participate in the electrochemical reactions, and it acts as a medium for ion transport. The applied electrical potential difference between the tool electrode and the workpiece causes the electrolyte to remove metal ions from the workpiece surface. This selective dissolution process gradually removes material from the workpiece, following the desired shape and contour defined by the tool electrode.

One of the significant advantages of ECM is its ability to machine complex shapes and profiles accurately. The process can produce intricate geometries with sharp corners, thin walls, and high aspect ratios without the need for excessive mechanical force. ECM is particularly suitable for machining materials that are difficult to process using conventional methods, such as heat-resistant alloys, titanium, and superalloys.

ECM offers several advantages, including non-contact machining, high precision, and burr-free and stress-free surface finishes. However, it also has limitations, such as limited material compatibility and the need for specialised equipment and expertise.

ECM Parts

- **Power supply: The power supply unit is responsible for providing the necessary electrical energy to drive the electrochemical reactions during Electrochemical Machining (ECM). It ensures a stable and controlled voltage or current output, which is crucial for achieving precise and accurate machining results.**

- **Electrolyte: The electrolyte solution, a vital component in ECM, acts as a conductive medium that enables the flow of ions and facilitates the electrochemical reactions. Through careful selection and composition, the electrolyte ensures optimal ion transport, ionization, and electrolytic conductivity, ensuring efficient and effective material removal.**

- **Workpiece: The workpiece, composed of a conductive material such as metal, serves as the component to be machined in ECM. It undergoes controlled material removal through the electrochemical reactions, resulting in the desired shape, dimensions, and surface characteristics. The workpiece's composition, structure, and geometry significantly influence the ECM process.**

- **Tool electrode: The tool electrode, typically constructed from copper or brass, plays a crucial role in ECM. It serves as the counterpart to the workpiece, determining the final shape and surface characteristics of the machined part. The tool electrode's design, geometry, surface finish, and material properties impact the precision and quality of the ECM process.**

- **Feed unit: The feed unit is responsible for precise control of the movement and positioning of the tool electrode and workpiece during ECM. It ensures accurate material removal by regulating parameters such as the feed rate, depth of cut, and tool-workpiece engagement. The feed unit allows for fine adjustments, enabling intricate and complex machining operations.**

Electro-Chemical Machine (ECM)

ECM Parts

- Tank: The tank houses and provides a controlled environment for the electrolyte solution used in ECM. It serves as a reservoir, maintaining a consistent volume of electrolyte and ensuring proper immersion of the workpiece and tool electrode. The tank's design and construction contribute to efficient electrolyte flow, temperature control, and containment of the ECM process.

- Workpiece holding table: The workpiece holding table securely clamps and supports the workpiece during ECM. It provides stability, precise positioning, and alignment, minimizing vibrations and maintaining workpiece integrity. The workpiece holding table's rigidity and adjustability enhance machining accuracy and repeatability.

- Pressure gauge: The pressure gauge monitors and measures the pressure of the electrolyte within the ECM system. It provides real-time feedback, ensuring optimal pressure levels for effective material removal. Accurate pressure monitoring contributes to consistent and controlled machining results.

- Flowmeter: The flowmeter precisely measures and monitors the flow rate of the electrolyte during ECM. It enables accurate control and adjustment of electrolyte circulation, ensuring a consistent and sufficient flow for effective material removal. Precise flow rate control is crucial for achieving desired machining parameters and surface finish.

- Flow control valve: The flow control valve regulates and fine-tunes the flow rate of the electrolyte. It allows for precise adjustment, optimizing the electrolyte flow to match the specific ECM requirements. By maintaining the desired flow rate, the flow control valve contributes to optimal material removal, cooling, and ion transport.

- Pressure relief valve: The pressure relief valve ensures system safety by releasing excess pressure within the ECM setup. It acts as a protective mechanism, preventing overpressure and potential damage to the components. The pressure relief valve ensures safe and reliable operation during ECM processes.

- Pump: The pump plays a critical role in ECM by facilitating the continuous circulation of the electrolyte throughout the system. It generates the necessary flow and pressure, ensuring efficient transport of dissolved ions, effective heat exchange, and consistent process conditions. The pump's reliability and performance directly impact the effectiveness and productivity of ECM.

- Reservoir tank: The reservoir tank serves as a storage unit for the electrolyte solution used in ECM. It ensures a continuous and uninterrupted supply of electrolyte to the system, allowing for prolonged machining operations without interruptions. The reservoir tank's capacity and design contribute to the efficiency and productivity of ECM processes.

Electro-Chemical Machine (ECM)

ECM Parts

- **Filters:** Filters are essential components in the ECM system as they remove impurities and contaminants from the electrolyte. They maintain the cleanliness and quality of the electrolyte, preventing clogging or damage to system components. By ensuring a clean electrolyte supply, filters enhance the longevity and performance of ECM processes.
- **Sludge container:** The sludge container collects and contains the solid waste or byproducts generated during ECM. It provides a designated space for the accumulation of sludge, making disposal or recycling easier and more efficient. Proper management of the sludge container promotes a clean and organized ECM environment.
- **Centrifuge:** The centrifuge is a valuable addition to the ECM system, allowing for the separation of suspended particles from the electrolyte. By subjecting the electrolyte to high-speed rotation, it enhances the cleanliness and effectiveness of the electrolyte, improving machining performance and prolonging the life of the electrolyte.
- **Fume extractor:** The fume extractor ensures a safe working environment by effectively removing fumes or gases generated during ECM. It captures and exhausts potentially hazardous byproducts, safeguarding the operator's health and maintaining a clean air quality. The fume extractor contributes to a comfortable and safe ECM working environment.
- **Enclosure:** The enclosure provides a protective housing for the ECM system, enclosing and safeguarding the components and subsystems. It prevents accidental contact with electrolyte, electrical components, or moving parts, ensuring operator safety during ECM operations. The enclosure also helps maintain a controlled atmosphere, providing a stable environment for precise and reliable machining.

ECM Applications

1. Medical Device Manufacturing
2. Aerospace Industry
3. Automotive Industry
4. Electronics & Microelectronics
5. Tool and Die Making
6. Jewelry Manufacturing
7. Optics Industry

Safety in CNC

CNC Machining Safety

When a CNC machine is operated properly, using the machine is a relative safe process. *This is only under the circumstances that the following rules are followed!*

Safety Rules

1. **Do not operate the machine if you are not sure of what you are doing, call for help by some who can!**
2. **Always wear safety glasses when you are near the machine!**
   A broken cutter / chip / material can shoot out of the machine during operation.
3. **Always make sure that the spindle is tightened!**
   A loose tool will cause vibrations and can be shoot away during cutting.
4. **Make sure the stock material is properly tightened!**
   The material need to be firmly secured to the table.
5. **Hit the Emergency Stop / Escape Key if something goes wrong!**
   This quickly stops the machine preventing danger.
6. **Never put your Fingers / Hand / Head near the spinning cutter!**
   Don't risk your fingers, stop the machine by Feedhold, adjust then resume.
7. **Never leave the machine unattended!**
   If something goes wrong, you need to be around to stop the machine.

TUTORIAL

1. Define CNC.

....

2. State the meaning of the axis in CNC.

....

....

3. Define the function of each address given in below.

Address	**Function**
N	
G	
M	
X,Y,Z	
I,J,K	

4. Describe **TWO (2)** differences between G90 and G91.

....

....

5. Decide True (T) or False (F) for each statement.

Statement	True/False
M09 is for Tool Change	
This character (/) is used in the program at the End of a Block	
The letter F means Feed	
Pressing the HOME button will activate JOG	
The CYCLE START button is used to start automatic operation	
All CNC operations in CNC are based on 3 axes: X, Y and Z	

6. Explain basic principle function of Electro Chemical Machine (ECM) and Electro Discharge Machine (EDM). Attach figures to support your answer.

Electro Chemical Machine (ECM)	Electro Discharge Machine (EDM)

7. Explain point-to-point machining method in computer numerical control (CNC).

....

....

8. Discuss the differences between Absolute and Incremental positioning modes.

....

....

....

9. Explain the difference between polar and rectangular coordinates.

....

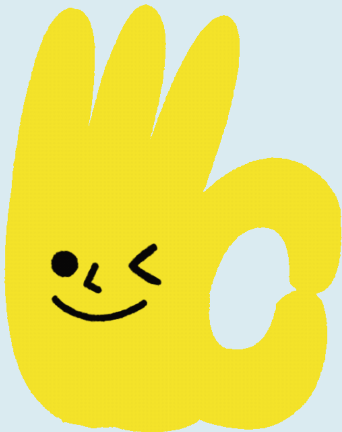
....

....

....

10. Discover which miscellaneous code should be used to:

i. Turn the spindle on clockwise : ....
ii. Turn off the coolant : ....
iii. Stop the program : ....
iv. Change tool : ....



11. State **FOUR (4)** advantages and **THREE (3)** disadvantages of CNC machining.

Advantages	**Disadvantages**

12. Name **FOUR (4)** types of advanced machining in CNC.

....

....

....

....

13. Provide a program for Figure 1 using absolute positioning.

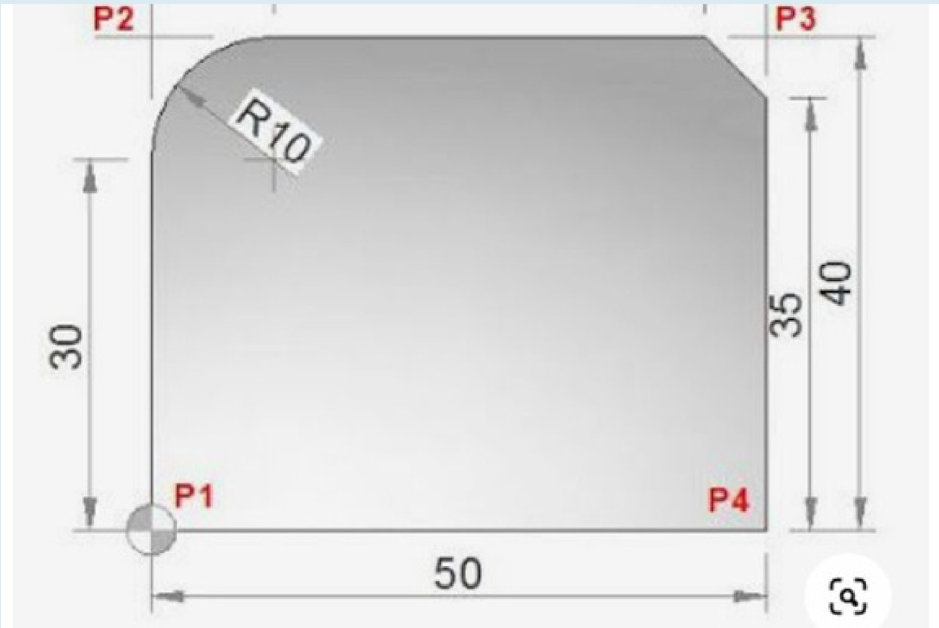


Figure 1: CNC sample

Learn More

14. Complete the program blocks for the part in Figure 2.

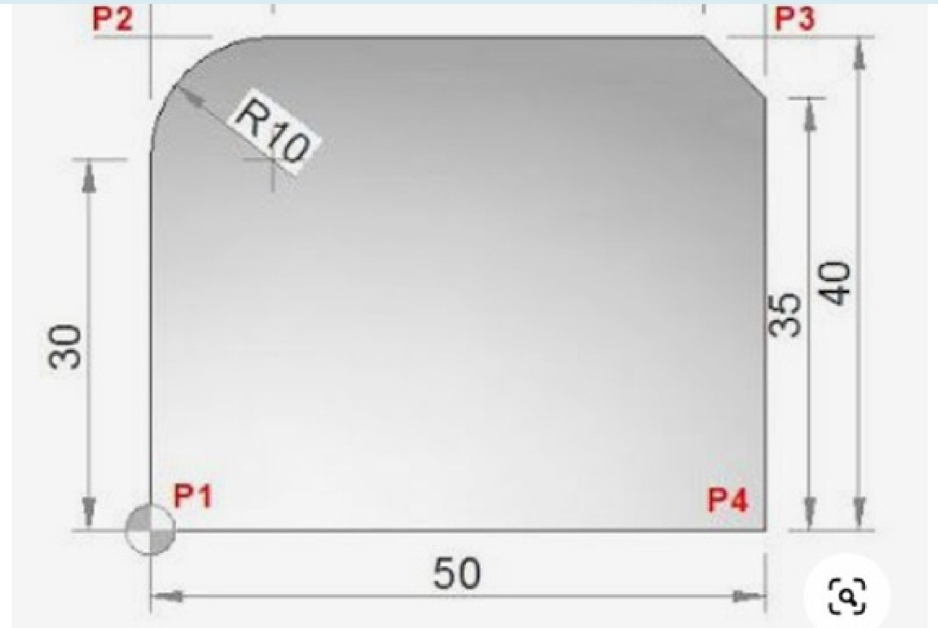
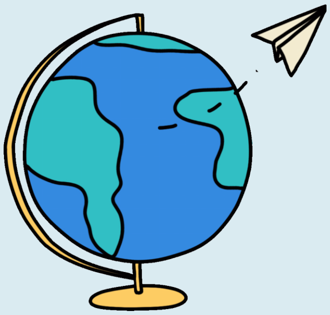
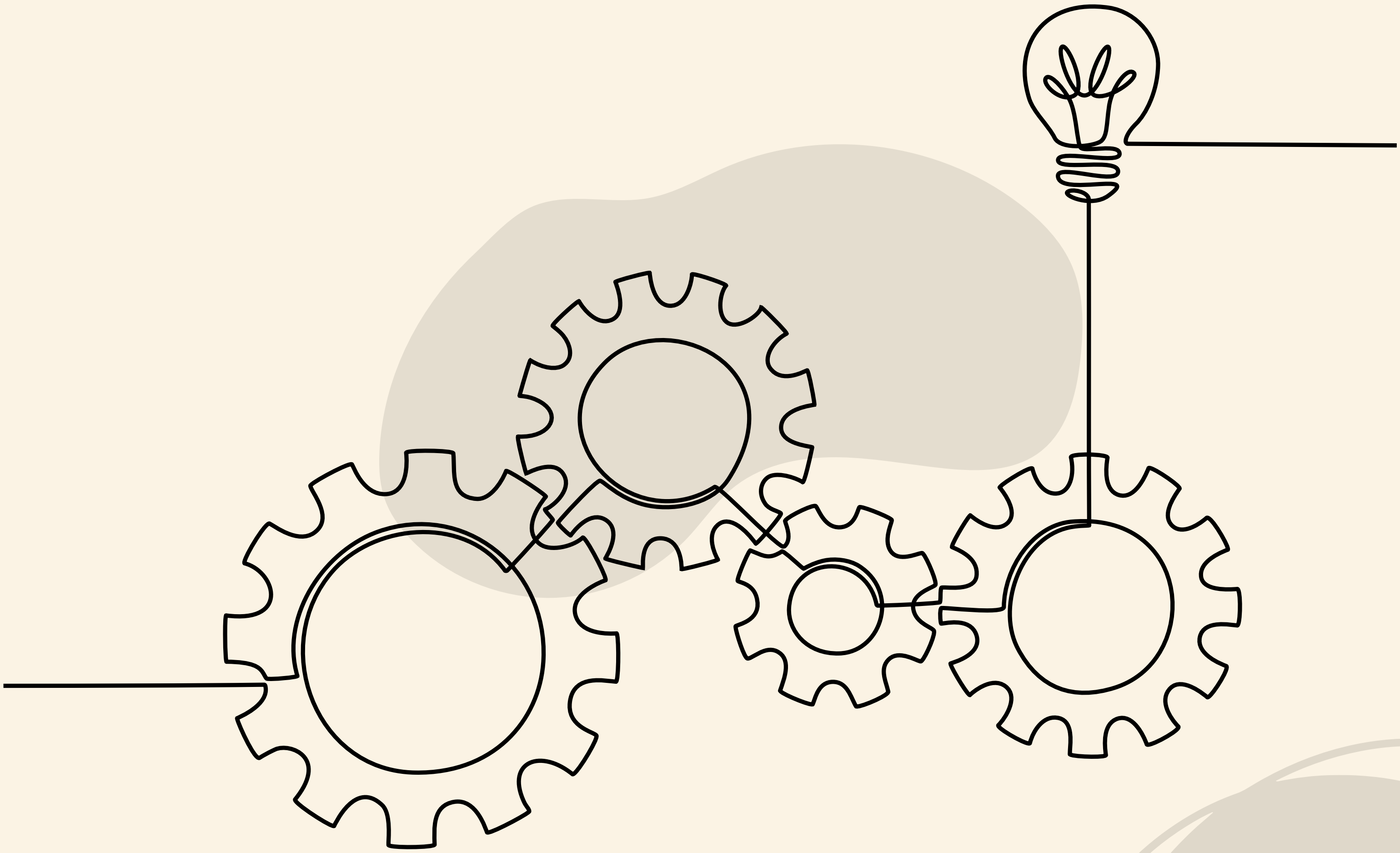


Figure 2: CNC sample



WELDING



INTRODUCTION

WELDING

1. Welding is a method of joining metals permanently. It is an ancient method, about 1500 years old. The method used in ancient days was forge or blacksmith welding.

2. One of the methods of classifying welded joints is the method used to effect the joint between metal pieces. Accordingly the methods are:
   - Fusion method without pressure/ with pressure
   - Non-fusion method

3. Welding and related processes are complex and require hands-on training, which teaches skills that are otherwise difficult to obtain.

OBJECTIVES

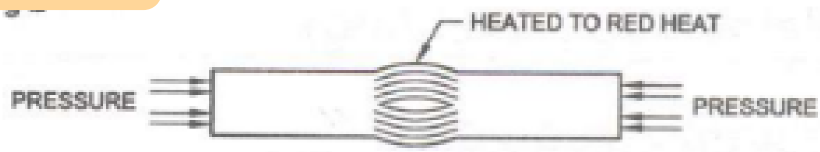
Apply standard practice in operating mechanical tools and component

Fusion welding without pressure

A method of welding in which similar and dissimilar metals are joined together by melting and fusion their joining edges with or without the addition of filler metal but without the application of any kind of pressure is known as fusion welding without pressure.

The joint made is permanent. The common heating sources are:

- arc welding
- gas welding
- chemical reaction (thermit welding)



Pressure welding

This is a method of welding in which similar metals are joined together by heating them to plastic or partially molten state and then joined by pressing or hammering without the use of filler metal.

This is fusion method of joining with pressure. Heat source may be blacksmith forge (forge welding) or electric resistance (resistance welding) or friction.

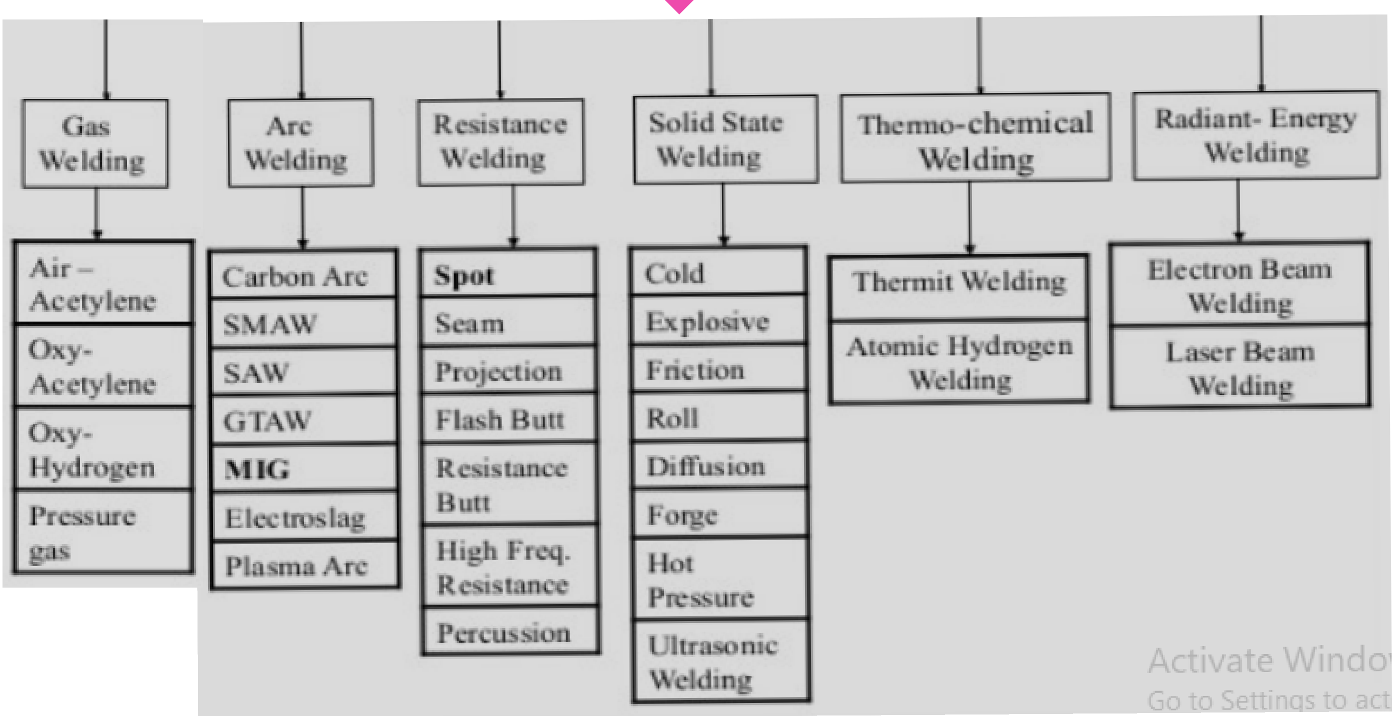
Non-fusion welding

This is a method in which similar or dissimilar metals are joined together without melting the edges of the base metal by using a low melting point filler rod but without the application of pressure. Examples of non-fusion welding include riveting, brazing, soldering, staking, clinching, adhesive bonding and mechanical fastening. Non-fusion processes require skillful application because there must be enough force applied to create a strong bond without causing damage to either metal piece being joined together.

Difference Between Fusion and Non-Fusion Welding

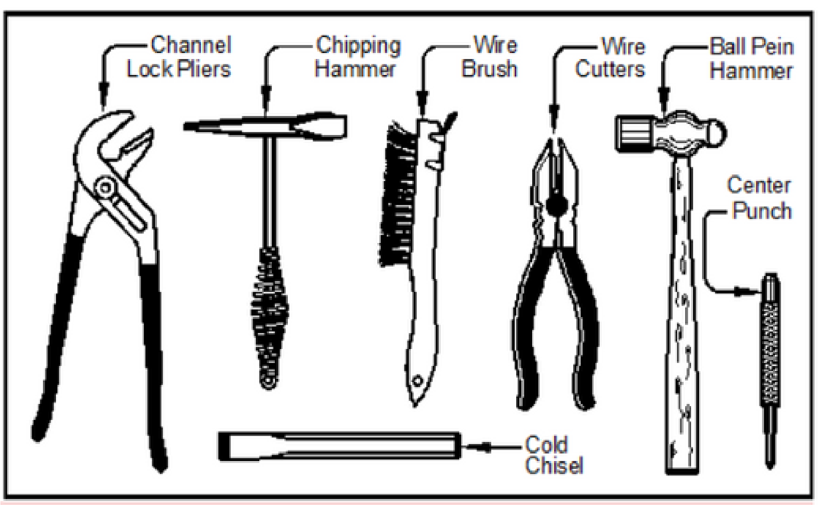
- In fusion welding, the two pieces of metal to be joined are heated until they melt.
- In non-fusion welding, the two pieces of metal to be joined are not heated until they melt.
- Fusion welding is more likely to result in a stronger joint than non-fusion welding.
- Fusion welding is more likely to result in a joint that is less likely to leak than non-fusion welding.
- Fusion welding is more expensive than non-fusion welding.
- Fusion welding is more time-consuming than non-fusion welding.

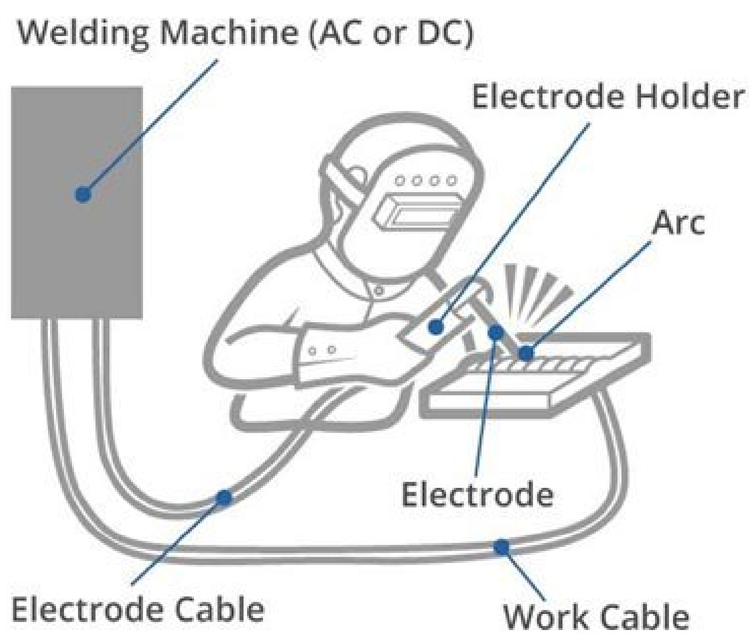
Welding Processes



Important Parts:

- Welding Torch: The welding torch is used to generate the heat required for welding and to direct the flow of filler material.
- Electrode: The electrode is a consumable filler material that is used to create the weld. It is heated and melted by the welding torch to join the base metals together.
- Power Source: The power source is responsible for supplying the necessary electrical energy for the welding process. It can be an electric arc or a gas flame.
- Welding Shield: A welding shield is used to protect the welder's eyes and face from the intense light and heat produced during welding. It is usually in the form of a protective mask or goggles.
- Ground Clamp: The ground clamp provides a secure electrical connection between the welding machine and the workpiece. It ensures proper grounding to prevent electrical hazards.





Advantages

Versatility: Welding allows for the joining of various types and thicknesses of metal, making it a versatile joining process.

Strength: Welded joints can provide high strength and durability, allowing for the construction of robust structures.

Efficiency: Welding is a relatively fast process, enabling the fabrication of products and structures in a timely manner.

Cost-effective: Welding can be a cost-effective method of joining metals, as it eliminates the need for additional joining materials or fasteners.

Joint customization: Welding allows for the creation of joints with specific shapes and sizes tailored to the requirements of the application.

Disadvantages

Complexity: Welding requires skilled operators who possess a thorough understanding of the welding process, making it a relatively complex technique.

Heat-affected zone: During welding, the surrounding metal experiences significant heating, which can lead to distortion, weakening, or changes in material properties.

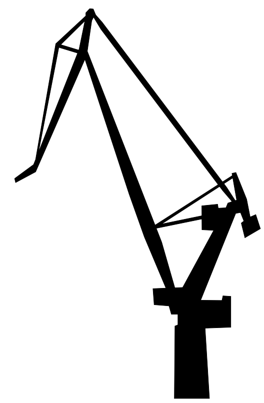
Material limitations: Certain materials, such as highly reactive metals or dissimilar metals, may pose challenges in welding due to their properties or compatibility issues.

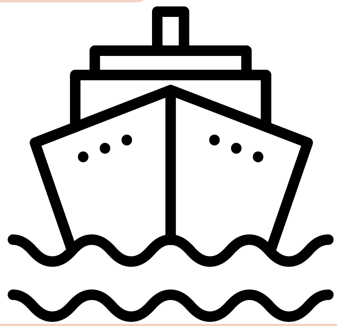
Safety hazards: Welding involves exposure to intense heat, bright light, and harmful fumes, necessitating the use of protective equipment and proper ventilation.

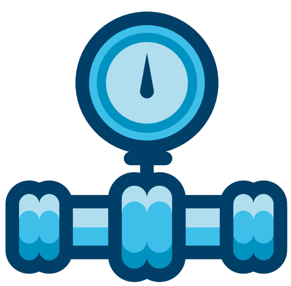
Specialized equipment: Welding often requires the use of specialized machinery and tools, which can add to the overall cost and complexity of the process.

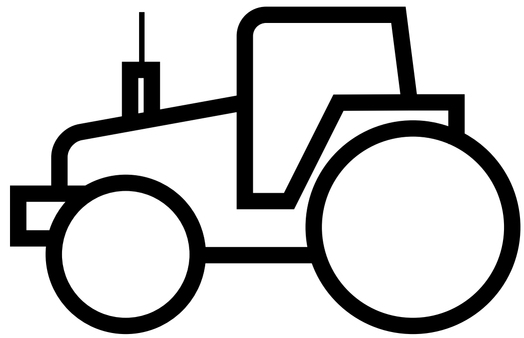
Welding Applications

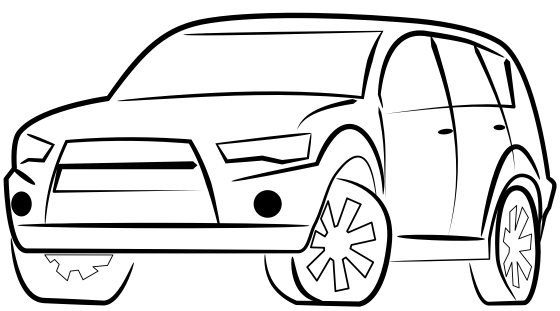
- Shipbuilding
- Fabrication of sheet metal
- Connecting ferrous and non-ferrous metals
- Automotive and aerospace industries
- Joining thin metals
- Railway coaches
- Earthmover bodies
- Doors & gates making
- Window shutters
- Pipelines
- Fabrication work of pressure vessels and steel structures
- Arts & jewelleries

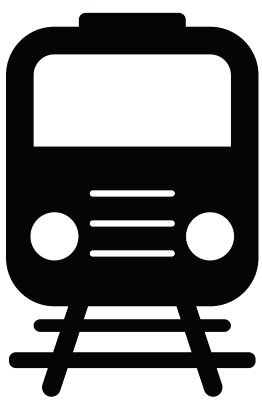


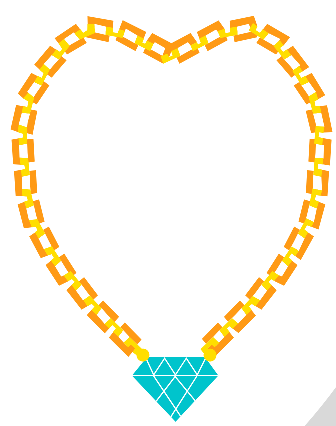


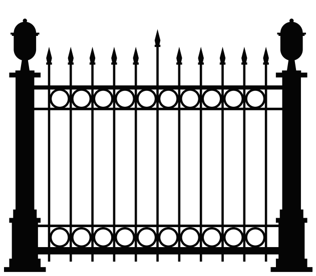




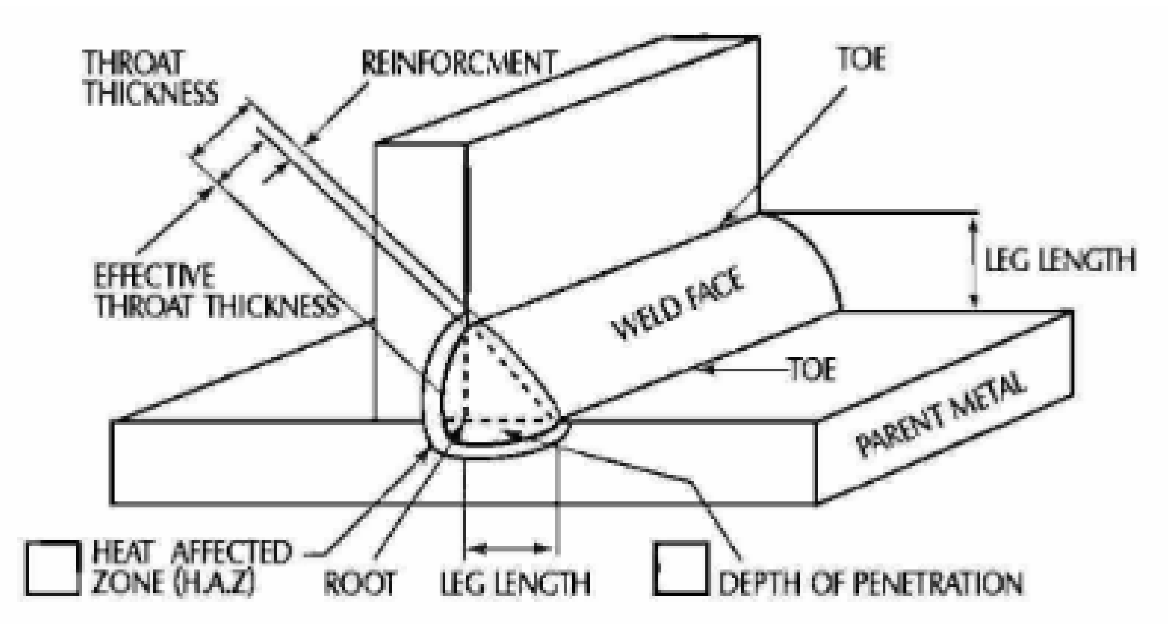








Welding Terminologies



Groove face

Face of the bevel.

Root face

Face of the root.

Root gap

The gap between the base metal. Root gap depends on thickness of weld metal.

Weld toe

The top side of weld where filler metal and base metal touches.

Weld root

The bottom side of weld where filler metal and base metal touches.

Weld reinforcement

The height of the weld protrusion on top side of weld. Excessive reinforcement is a discontinuity, as it weakens the joint at the weld toe, as sharp corner induced stress.

Weld Face

The face of the weld looking from top side of the weld.

Root reinforcement

The protrusion on bottom side of weld. Excessive reinforcement is a discontinuity, as it weakens the joint at the weld root, as sharp corner induced stress.

Weld interface

The surface on base metal where filler metal are deposited.

Heat Affected Zone

A section on the base metal parallel to the fusion zone. This section is slightly harder which increases likelihood of embrittement cracking, the reason why pre-heating and PWHT are required, to slow down the annealing(cool down) which reduces hardness.

Fusion Zone

The area where new metal is situated after welding.

Weld Leg

The distance from the weld toe to the weld root.

Fillet Weld Throat

The theoretical throat is the perpendicular distance of the weld from the hypotenuse of the largest right triangle that can be inscribed within the fillet weld cross-section (i.e., a line that connects the toe on each side of the root) to the root.

The actual throat is the distance from the root of a fillet weld to the center of its face.

Shielded Metal Arc Welding

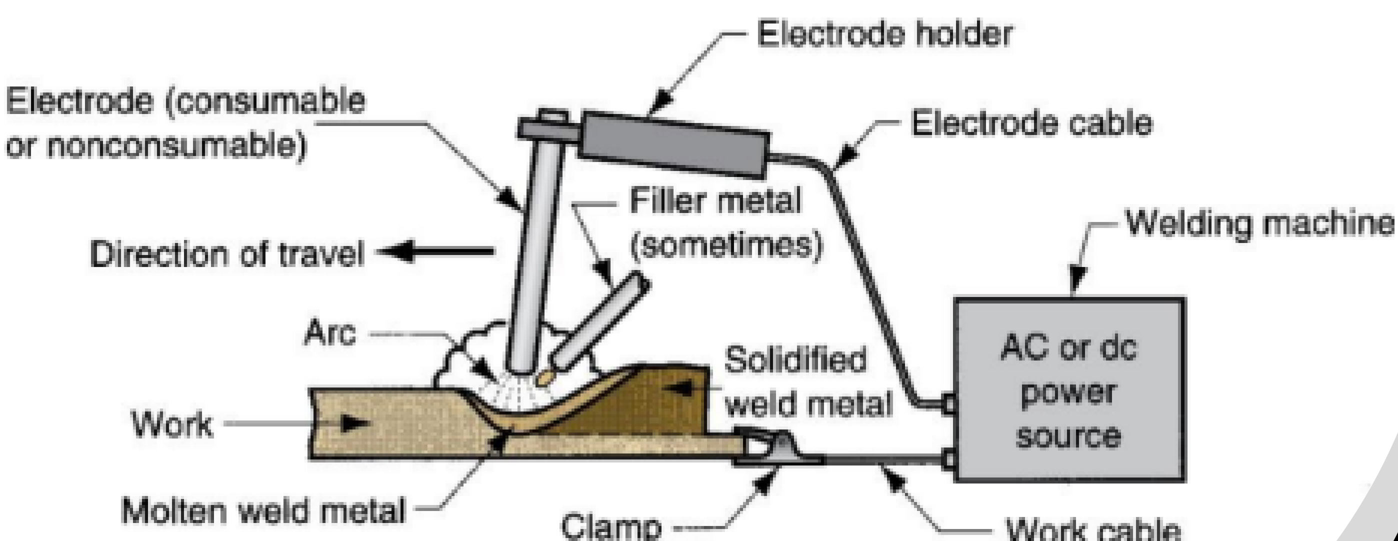
Shielded metal arc welding (SMAW) is also known as stick welding. It is an arc welding process in which the heat required for the welding comes from an electric arc.

The flux coating on the electrode also melts and provides a gaseous shield around the arc which protects the molten metal from atmospheric contamination. Hence this is called shielded metal arc welding (SMAW).

A pool of molten metal is formed near electrode tip, and as electrode is moved along joint, molten weld pool solidifies in its wake.

The electrode is generally coated with a flux which is consumable. The arc created due to the ionization of air between the electrode tip and the base metal generates an intense arc heat having a temperature between 3600°C - 4000°C.

The welding current is provided by an AC or DC machine. When the weld metal solidifies, the slag (of flux coating) gets deposited on its surface as it is lighter than the metal and the weld metal is allowed to cool gradually and slowly.



SMAW basic equipments

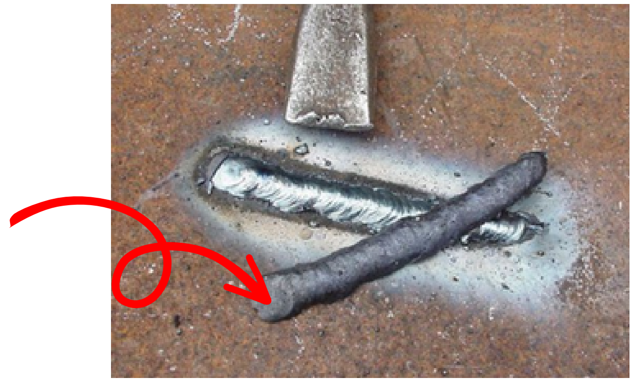
Slag & Electrode

Slag aka flux is a layer on the weldment , a byproduct of the electrode coating.

A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal.

It has these functions:

- Provides protective atmosphere for welding
- Stabilizes arc
- Reduces spattering
- Forms the weld
- Slow down the cooling rate
- Cleans metal of oxides
- Provides mechanical protection
- Keeps oxygen away
- Control the shape of the weldment



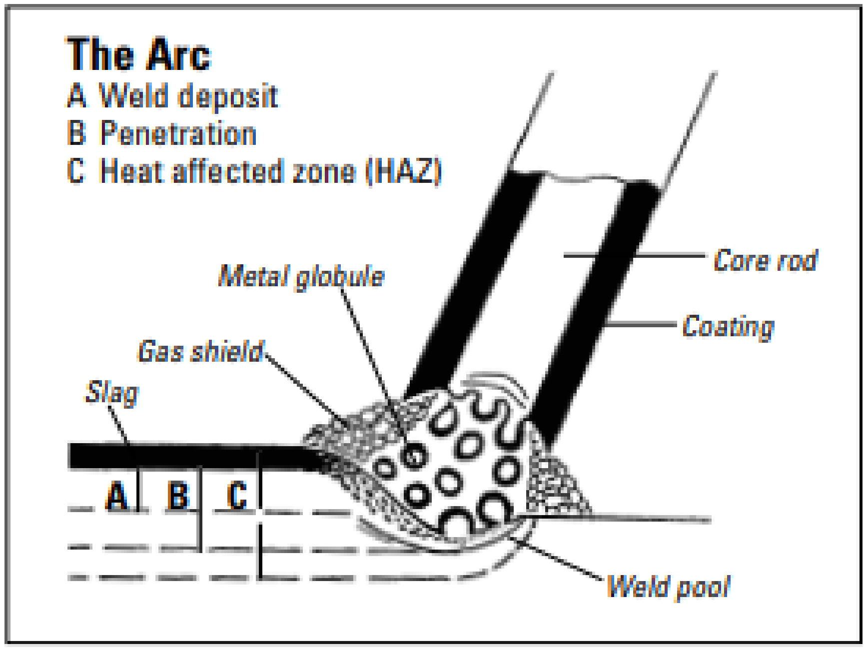
An electrode is a solid electric conductor that carries electric current into non-metallic solids, or liquids or gases or plasmas or vacuums.

The electrode size refers to the diameter of its core wire. Each electrode has a certain current range. The welding current increases with the electrode size (diameter).

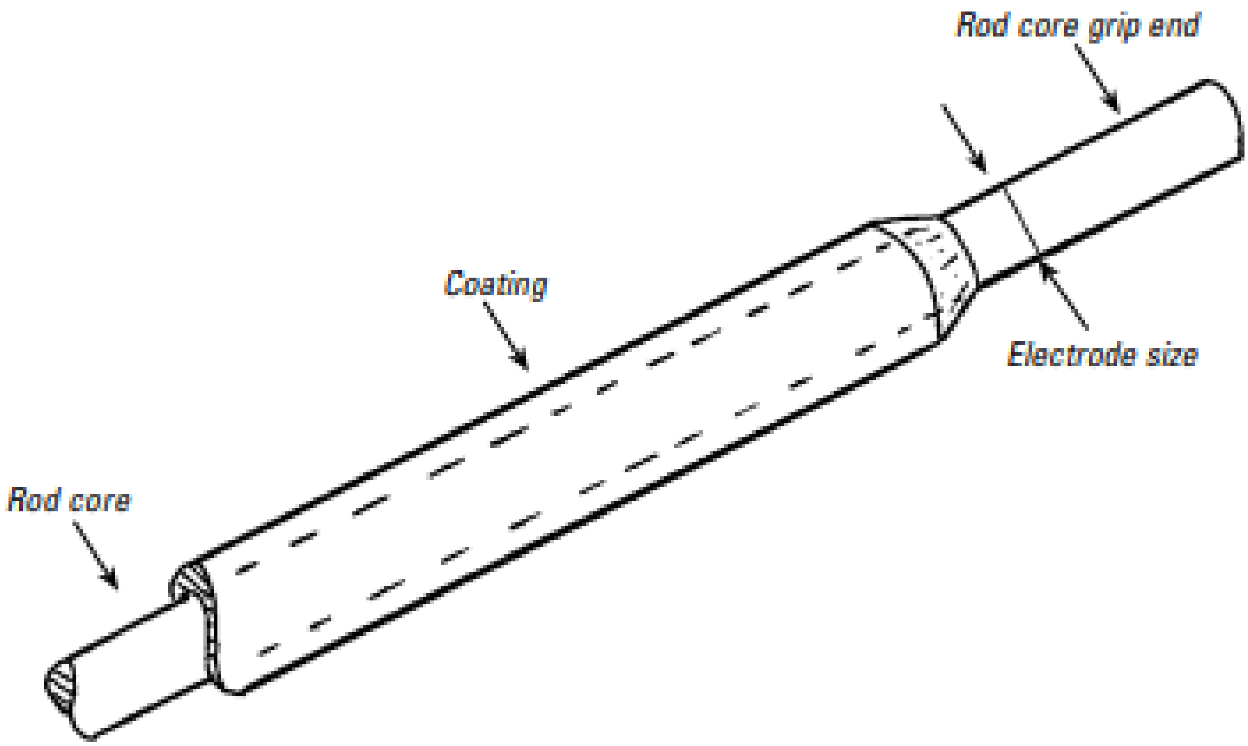
Standard length of electrodes

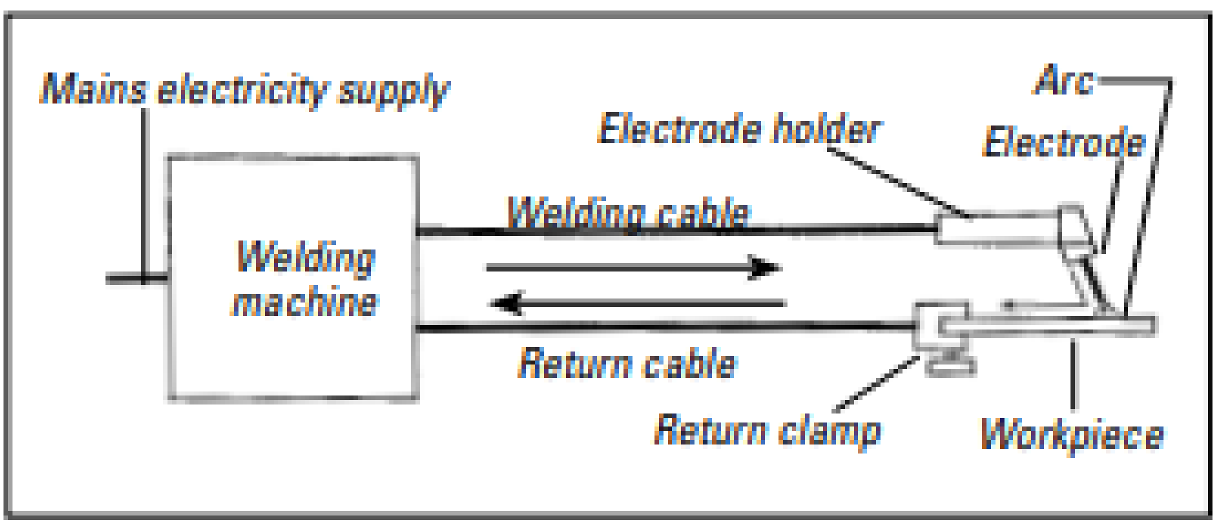
The electrodes are manufactured in two different lengths, 350 or 450mm.

Electrode size	Electrode size
1.6mm	5.0mm
2.0mm	6.0mm
2.5mm	6.3mm
3.15mm	8.0mm
4.0mm	10.0mm



The coated electrode



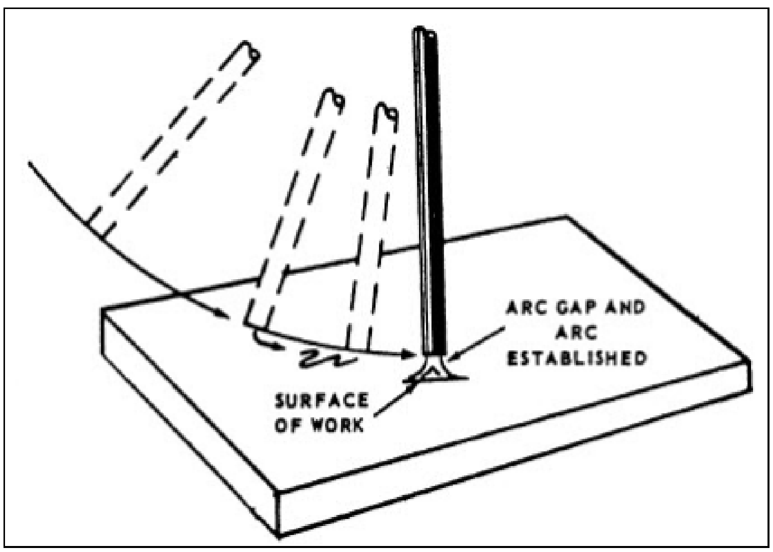


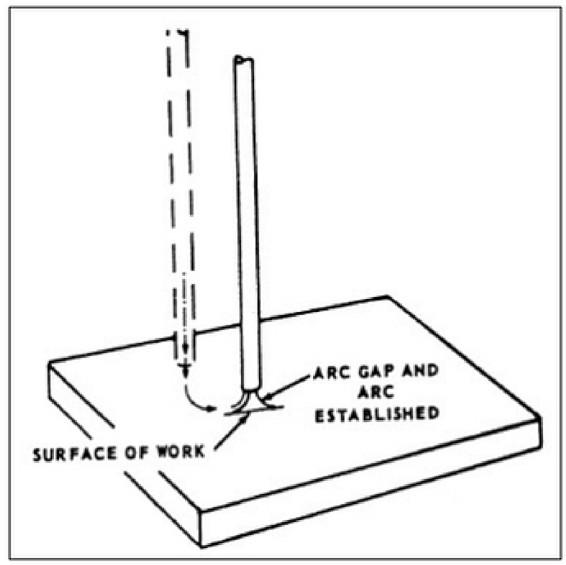
SMAW Techniques

Two techniques to perform arc welding (at the start):

Scratching

- Also known as Brushing
- Scratch the rod on the metal, and the bring the rod back to begin the molten weld puddle to start welding.





Tapping

- Hold the welding rod in a 90 degree angle to the base metal.
- Begin the arc by tapping it on the metal surface. After you tap, lift the rod to about the distance of the diameter of the welding rod.
- You can also 'bounce' the welding rod rather than tapping it.
- You'll know you have an arc when you hear the distinct stick welding sound which is a crackling sound.

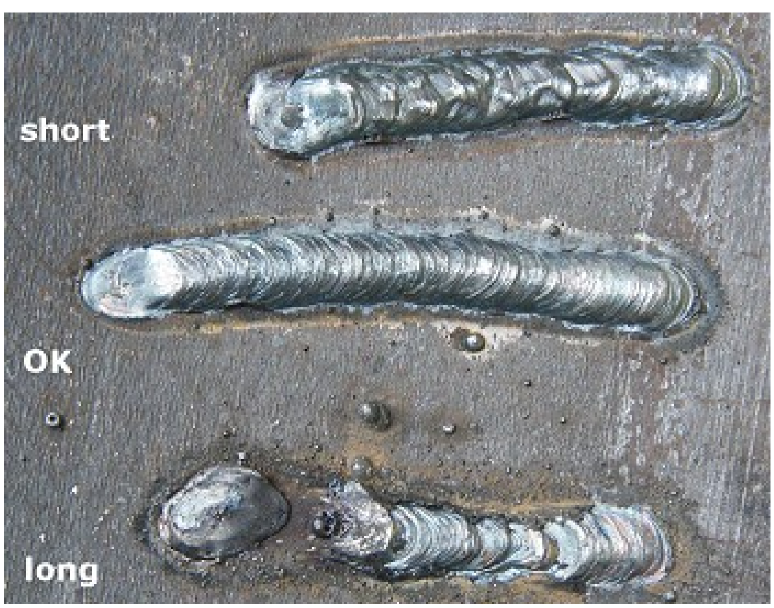
Welding Faults

Arc Length

Beginners will commonly have too long an arc length and too great a lead angle.

- **Arc Length Too Short**
  This weld was laid with the end of the rod covered by the molten slag. The surface of the weld is uneven where it has been dragged along by the rod, and the weld will be low on power and contain slag inclusions.
- **Arc Length OK**
  A normal arc weld. The weld has a consistent profile and minimal spatter.
- **Arc Length Too Long**
  Too great a distance between the rod and the work will increase the voltage resulting in a flat and wide weld with a great deal of spatter. It also makes the arc unstable, and the slag will be difficult to remove from the edges of the weld. Sectioning this weld reveals undercutting to the left side.

Arc welding is a constant current process, but the arc length has an effect on voltage. Reducing the arc length will decrease the voltage, and this reduces the heat in the weld. Increasing arc length will increase the voltage. Arc length faults can share many similarities with the current faults later on this page.



Welding Faults

Travel Speed

Beginner welders tend to move the rod too quickly, especially those who are transitioning to arc welding from another welding process.

- **Speed OK**
  The bead is fairly consistent. The ridges in the weld are semi-circular.
- **Speed Too Fast**
  Excessive speed results in a thin, weak bead. The ridges in the weld are elongated and triangular. Had the current been increased to compensate for the speed the ridges would still remain elongated.
- **Speed Too Slow**
  Welding too slowly results in a wide tall build up of weld. The shape of the weld is not consistent as the weld pool has built up and then collapsed into the crater. The poor control of the weld pool can result in cold joints and slag inclusions.

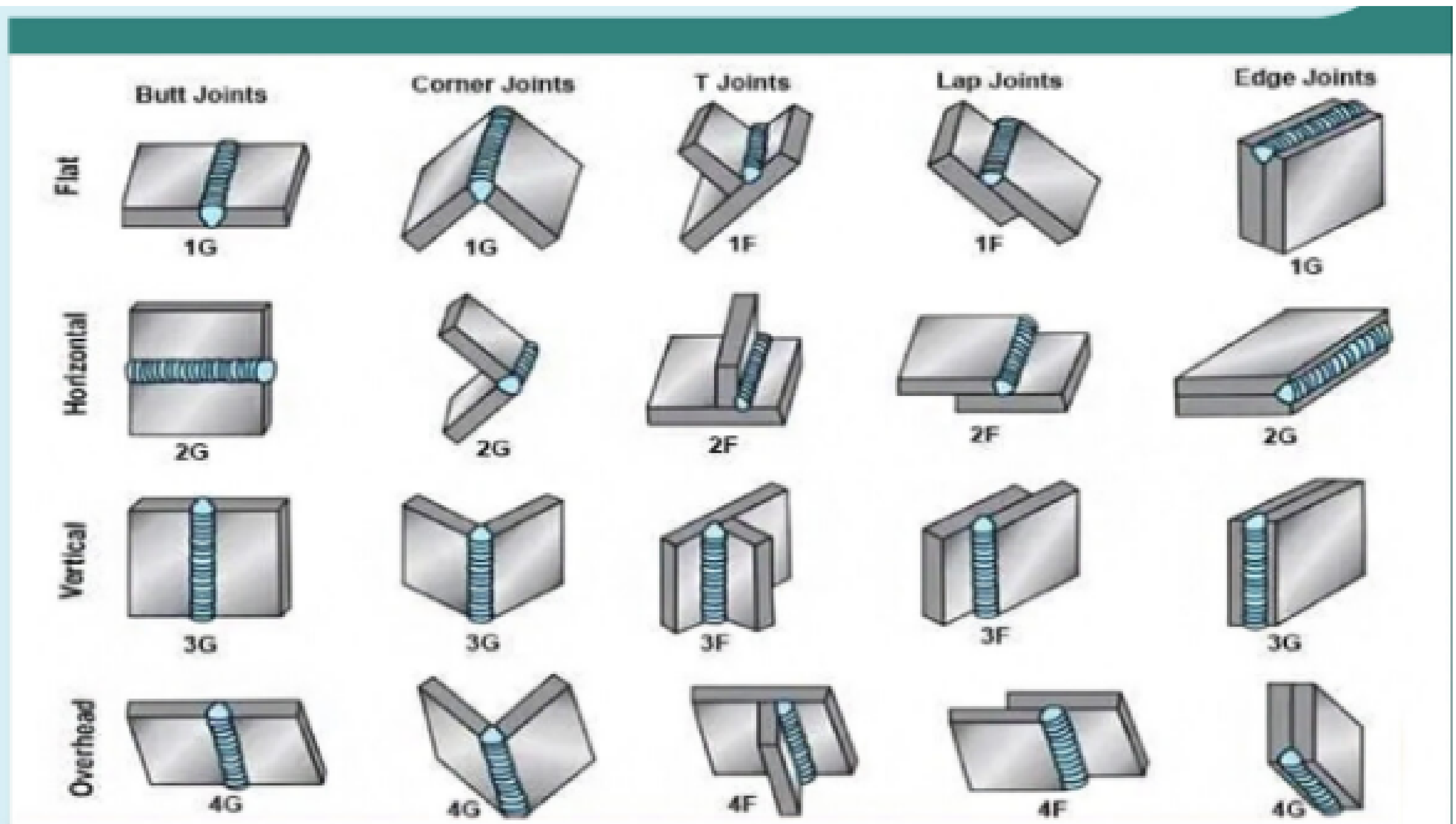
Welding Faults

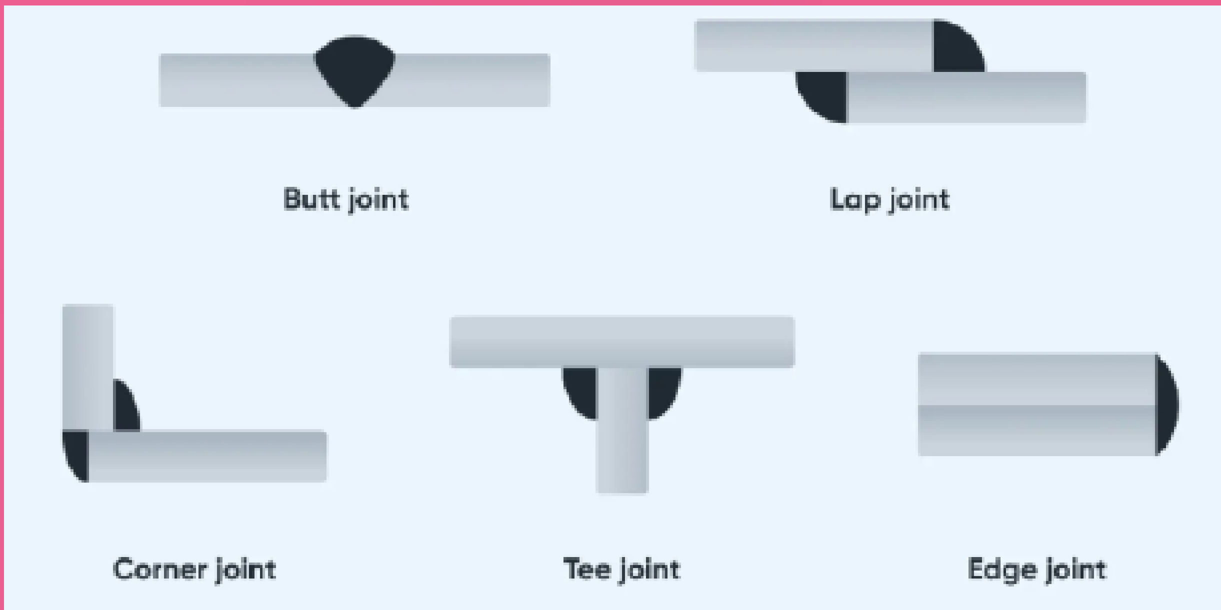
Current Setting

- **Amps too low**
  Setting the amps too low will result in a tall, narrow bead lacking in penetration. The weld will be difficult to start and the arc prone to straying towards one side of a joint in preference to the other.
- **Amps too high**
  The bead is wide, flat and irregular, and a small undercut can be seen on the right of the weld in the sectioned photo. A deep crater has formed at the end of the weld, and the slag is difficult to remove from the edges of the weld.
  Excessive current should not be compensated by excessive travel speed. This can result in slag inclusions due to rapid cooling of the weld.
- **Amps OK**
  With the amps set correctly the bead is a consistent rounded shape, and the slag is easy to remove.

Welding Positions

- Flat
- Horizontal
- Vertical
- Overhead





Types of Joint:

Butt joint: This is the most common type of joint used in welding. It involves joining two pieces of metal by placing their ends in contact and welding along the seam.

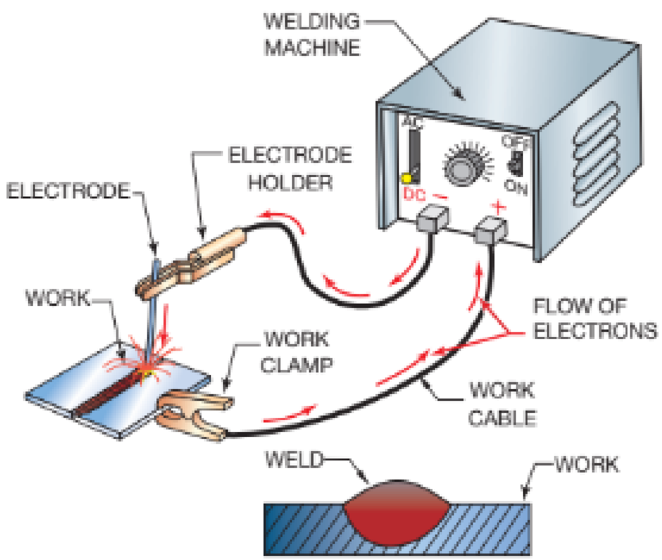
Lap joint: In this type of joint, one piece of metal overlaps with the other, and welding is applied along the overlapping area.

T-joint: A T-joint is formed when a piece of metal is joined perpendicularly to the surface of another piece, forming the shape of a "T". Welding is done along the intersection.

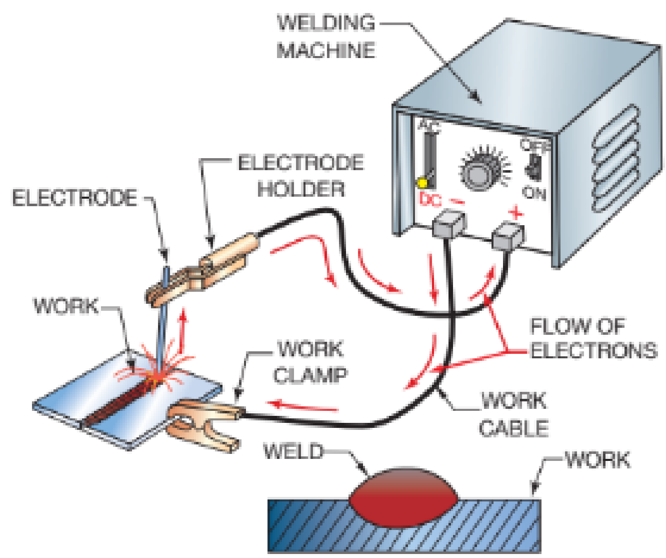
Corner joint: When two pieces of metal are joined at right angles, a corner joint is formed. Welding is applied to the corner.

Edge joint: In an edge joint, the edges of two pieces of metal are joined together. Welding is done along the edge.

Welding Polarity



Direct-current electrode negative (DCEN)



Direct-current electrode positive (DCEP)

In welding, polarity refers to the direction of electrical current flowing between the electrode (welding torch) and the workpiece:

Direct Current Electrode Positive (DCEP): Also known as reverse polarity, DCEP has the electrode connected to the positive terminal and the workpiece connected to the negative terminal. It provides deeper penetration and is commonly used for welding thick materials.

Direct Current Electrode Negative (DCEN): Also called straight polarity, DCEN has the electrode connected to the negative terminal and the workpiece connected to the positive terminal. It produces a more stable arc and is suitable for welding thin materials.

<u>Indication of wrong polarity</u>

If the electrode is used on wrong polarity it will result in:

- **Excess spatter and poor penetration**
- **Improper fusion of the electrode**
- **Heavy brownish deposition on the face of the weld metal**
- **Difficulty in manipulation of the arc**
- **Abnormal sound of the arc**
- **Poor weld bead appearance with surface defects and more spatter.**

Oxy Acetylene Welding

A method of joining metals by heating them to the melting point using a mixture of oxygen and acetylene gases.

Acetylene

A fuel gas which produces a very high temperature flame with the help of oxygen because it has more amount of carbon (92.3%) than any other fuel gas. Its chemical symbol is C_2H_2 and composed of:

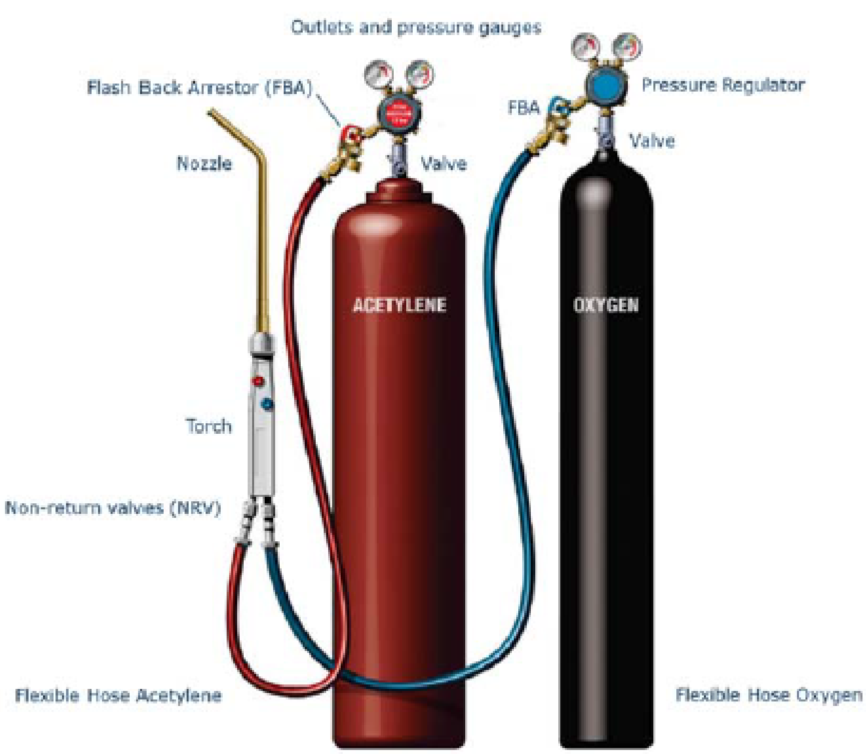
- Carbon 92.3%
- Hydrogen 7.7%

It is a colourless gas, lighter than air and highly inflammable and burns with a brilliant flame. Acetylene absorbs heat during producing and liberates heat when decomposed.

Oxygen

Oxygen is a supporter of combustion. Its chemical symbol is O_2. It is a clear, colourless, odourless and tasteless gas. It is slightly soluble in water. It does not burn itself, but supports combustion of fuels. It is industrially produced by two methods:

- by air liquefaction.
- by electrolysis of water.



Typical oxy-acetylene equipment configuration

OAW Equipment & Accessories

Acetylene Cylinders
The acetylene gas used in gas welding is stored in steel bottle shaped cylinders painted in **maroon colour**. The normal storing capacity of storing acetylene in dissolved state is 6m3 with the pressure ranging between 15-16 kg/cm2.

Acetylene Regulator
This is also used to reduce the cylinder gas pressure to the required working pressure and to control the flow of acetylene gas at a constant rate to the blowpipe. The threaded connections are **left handed**. For quickly identifying the acetylene regulator, **a groove is cut at the corners of the nut**.

There are two types of regulators
- single stage regulator
- double stage regulator

Rubber Hose Pipes & Connections
These are used to carry gas from the regulator to the blowpipe. These are made of strong canvas rubber having good flexibility. Hose-pipes which carry **oxygen are black** in colour and the **acetylene** hoses are of **maroon** colour.

Hose Protectors
At the blowpipes end of the rubber hoses hose-protectors are fitted. The hose protectors are in the shape of a connecting union and have a non-return disc fitted inside **to protect from flashback and backfire during welding.**

Oxygen Gas Cylinders
The oxygen gas required for gas welding is stored in bottle shaped cylinders. These cylinders are painted in **black colour**. Oxygen cylinders can store gas to a capacity of 7m3 with the pressure ranging between 120 to 150 kg/cm2. **Oxygen gas cylinder valves are right hand threaded.**

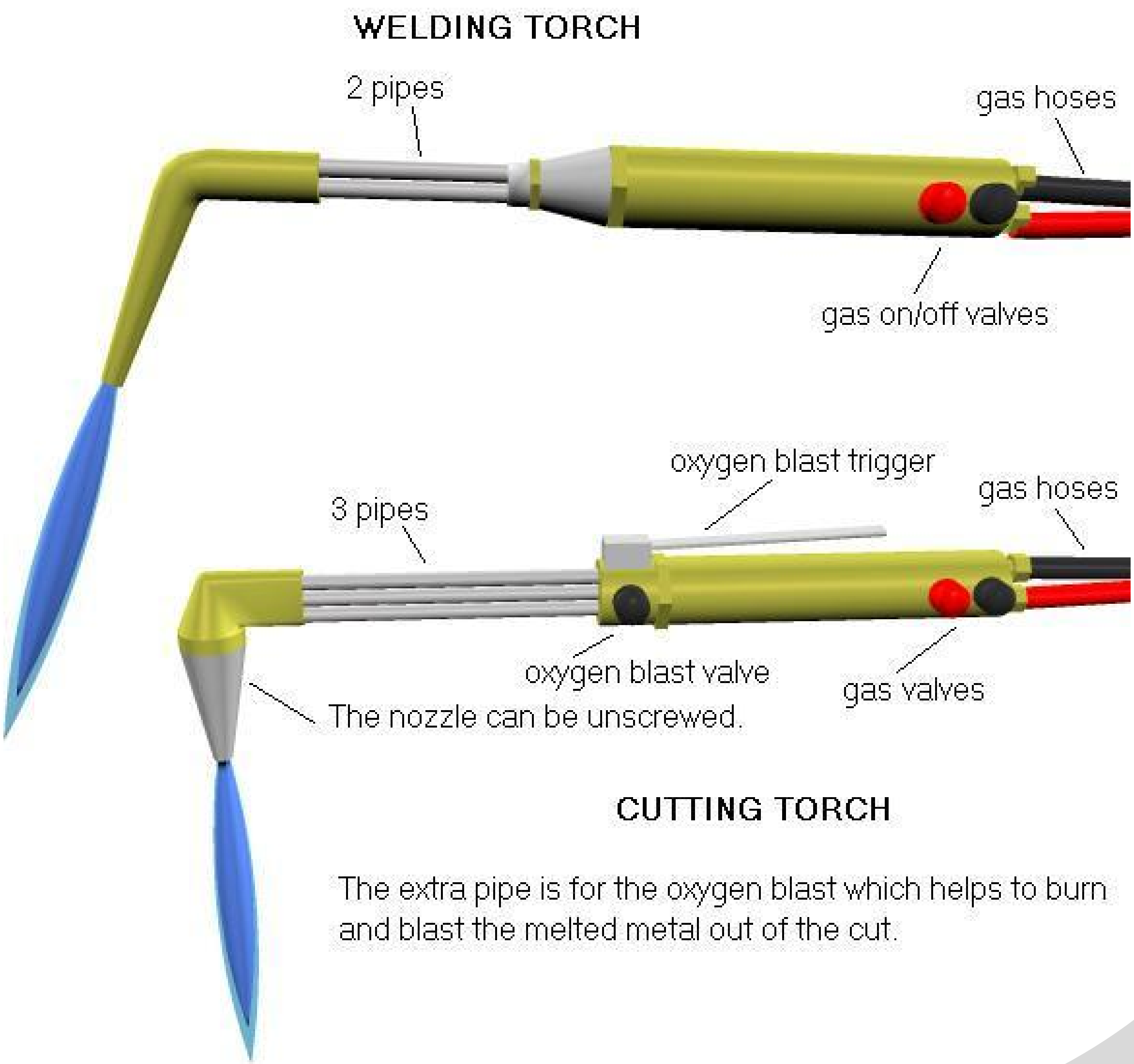
Oxygen Gas Regulator
This is used to reduce the oxygen cylinder gas pressure according to the required working pressure and to control the flow of oxygen at a constant rate to the blowpipe. The threaded connections are **right hand threaded.**

Blowpipe & Nozzle
Blowpipes are used to control and mix the oxygen and acetylene gases to the required proportion.

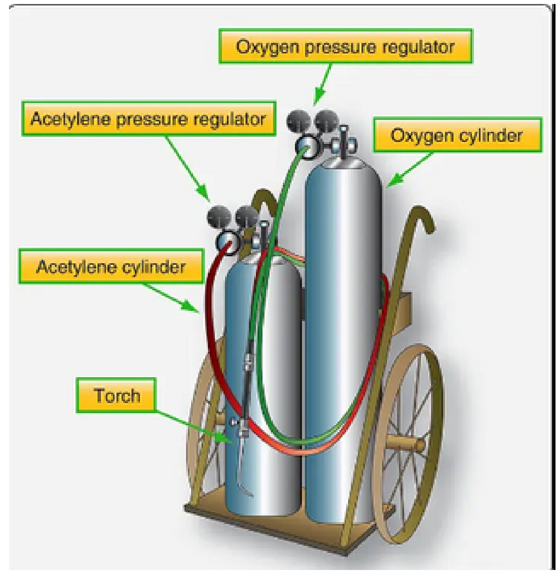
Cutting Torch
The cutting torch differs from the regular welding blowpipe in most cases. It has an additional lever for the control of the cutting oxygen used to cut the metal. The torch has the oxygen and acetylene control valves to control the oxygen and acetylene gases while preheating the metal.
The cutting tip is made with an **ORIFICE** in the centre surrounding by five smaller holes. The centre opening permits the flow of the cutting oxygen and the smaller holes are for the preheating flame. Usually different tip sizes are provided for cutting metals of different thicknesses.

Difference between cutting torch (blowpipe) and welding blowpipe

- A cutting blowpipe has two control valves (oxygen and acetylene) to control the preheating flame and one lever type control valve to control the high pressure pure oxygen for making the cut.
- A welding blowpipe has only two control vales to control the heating flame.
- The nozzle of the cutting blowpipe has one hole in the centre for cutting oxygen and a number of holes around the circle for the preheating flame.
- The nozzle of welding blowpipe has only one hole in the centre for the heating flame.
- The angle of the cutting nozzle with the body is 60°.
- The angle of the welding nozzle with the neck is 120°.
- The cutting nozzle size is given by the diameter of the cutting oxygen orifice in mm.
- The welding nozzle size is given by the volume of oxy-acetylene mixed gases coming out of the nozzle in cubic meter per hour.



Manifold System



Manifold system is a gas welding assembly in which oxygen gas cylinders and a separate acetylene gas collected between the two. Both gases will be channeled through the steel pipe to each welding station.

For manifold of single cylinder of oxygen and acetylene will be coupled together in each welding station. But, it has a security feature low and not very economical.

Whereby, a manifold system provides high security and gas savings as more stations can be operated simultaneously. Thus, each station will be spacious & comfortable.

Oxy Acetylene Flame

The Acetylene/Oxygen Flame

A correct Acetylene/Oxygen flame from a cutting nozzle or blowpipe is dependent on correct gas pressure being supplied to the torch. Inaccurate regulators or long gas hoses may result in pressure deviations that gives wrong pressure to the torch. In such cases the actual pressure at the torch connection should be checked. Too low gas pressures may give a gas flow which is slower than the flame velocity of the gas mixture. This can cause the flame to burn backwards into the nozzle opening and accelerate through the gas channels, resulting in flashback.

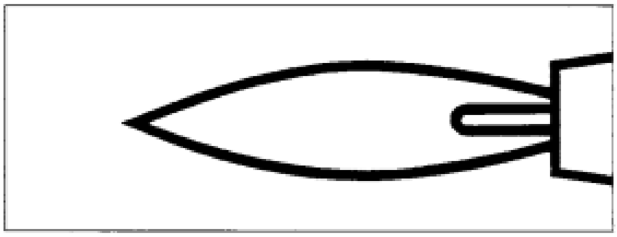
Too high gas pressures may cause the flame to leave the nozzle tip, starting at the distance from the tip where the gas flow has slowed down to match the flame velocity.

If the gas pressure is too high it may be difficult or impossible to ignite a flame.

The correct Acetylene/Oxygen flame shall be a quiet stable flame, burning close to the nozzle tip, but well away from the point where flashbacks may occur.

NOTE!

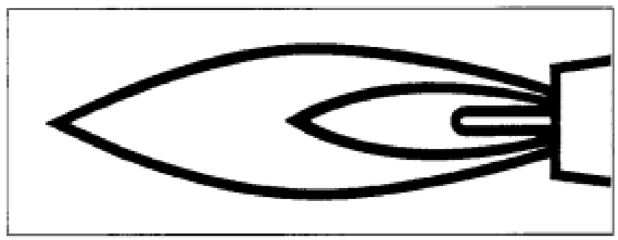
The Acetylene/Oxygen flame uses the oxygen supplied from the nozzle for the primary reaction taking place in the inner cone.
($C_2H_2+O_2 \rightarrow 2CO+H_2+$Heat).
In the flame envelope a secondary reaction takes place.
($2CO+H_2+O_2 \rightarrow +2CO_2+H_2\,O+$Heat).
This reaction needs as much Oxygen as the primary reaction, but the required Oxygen is taken from the surrounding air. Therefore always ensure proper ventilation when working with the Acetylene/Oxygen flame.



The neutral flame

Two distinct zones may be seen in the neutral flame. The inner cone of the flame has a bright blue light and extends only a short distance from the tip. Around this inner cone is the flame envelope which is darker and less intensely blue. This flame is metallurgically neutral, and is used for heating, cutting and for most steel welding work.

3 Famous Flames in OAW

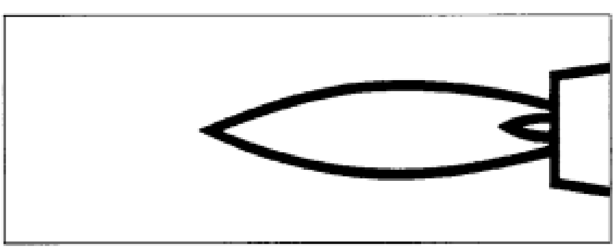


The carburizing flame

The carburizing flame has an excess of Acetylene, and is recognized by a secondary flame zone between the inner cone and the flame envelope. This zone is less bright and more white in colour than the inner cone, but is considerably brighter than the flame envelope.

When igniting an Ac/Ox torch one normally opens fully for Acetylene and only slightly for Oxygen, obtaining a strongly carburizing flame. By adding Oxygen (and if necessary reducing the Acetylene flow) the secondary zone will be reduced, and a neutral flame is obtained just as the secondary zone dissappears.

Reducing the Oxygen flow slightly again will give a carburizing flame with a small secondary flame zone, approximately twice as long as the inner cone. This soft flame (also called a reducing flame) is used for welding of Aluminium and Aluminium alloys, and for soft soldering.



The oxidizing flame

By increasing the Oxygen flow slightly beyond the point where the secondary zone disappears one will obtain an oxidizing flame (with excess Oxygen). The flame will be shorter and sharper than the neutral flame, with a shorter, more pointed inner cone. This flame is slightly hotter than the neutral flame, and is used for welding cast iron, brass, bronze and zinc alloys, and for brazing.

Flame Selection

The selection of the flame is based on the metal to be welded. The neutral flame is the most commonly used flame. Metals and flame to be used are as given below:

Metal	Types of Flame
Aluminium	Neutral
Brass	Oxidizing
Cast Iron	Neutral
Copper	Neutral
Mild Steel	Neutral
Stainless Steel	Neutral
Stellite	Carburizing

Flashback Vs Backfire

TERM	CAUSE	SOLUTION
Backfire - The flame burns back into the torch with a sharp bang. Either the flame is extinguished, or it is reignited at the nozzle opening. A flame goes out with a loud pop from the torch.	Flame is being sucked into the torch. It may be caused by: • a spark from the metal going up the tip • the pressures being too low • the tip being clogged/ dirty • Overheat the tip	• Clean the tip • Adjust the pressures • Cool down the torch
Flashback - Occur when the speed of combustion at one or more places in the flame hole becomes greater than the speed of gas flow, allowing the flame to burn back into the blowpipe. It's a sign that something is wrong the torch. When it happens, it produces a squealing noise.	This is very serious & is actually a series of explosions in the gas line usually caused by: • very unequal pressures between the two gases • clogged tips	• Be sure the equipment has flashback arrestors • Clean the tips • Adjust the pressures • Cool down the torch

Flashback can result in the hose exploding, and/or catching fire. In extreme cases, the regulator may catch fire.

Metal Inert Gas Welding

Gas Metal Arc Welding (GMAW), by definition, is an arc welding process which produces the coalescence of metals by heating them with an arc between a continuously fed filler metal electrode and the work. The process uses shielding from an externally supplied gas to protect the molten weld pool. The application of GMAW generally requires DC+ (reverse) polarity to the electrode.

GMAW is commonly known as MIG (Metal Inert Gas) welding and it is less commonly known as MAG (Metal Active Gas) welding. In either case, the GMAW process lends itself to weld a wide range of both solid carbon steel and tubular metal-cored electrodes. The alloy material range for GMAW includes: carbon steel, stainless steel, aluminum, magnesium, copper, nickel, silicon bronze and tubular metal-cored surfacing alloys. The GMAW process lends itself to semiautomatic, robotic automation and hard automation welding applications.

Advantages of GMAW

GMAW process enjoys widespread use because of its ability to provide high quality welds, for a wide range of ferrous and non-ferrous alloys, at a low price.

GMAW also has the following advantages:

- The ability to join a wide range of material types and thicknesses.
- Simple equipment components are readily available and affordable.
- GMAW has higher electrode efficiencies, usually between 93% and 98%, when compared to other welding processes.
- Higher welder efficiencies and operator factor, when compared to other open arc welding processes.
- GMAW is easily adapted for high-speed robotic, hard automation and semiautomatic welding applications.

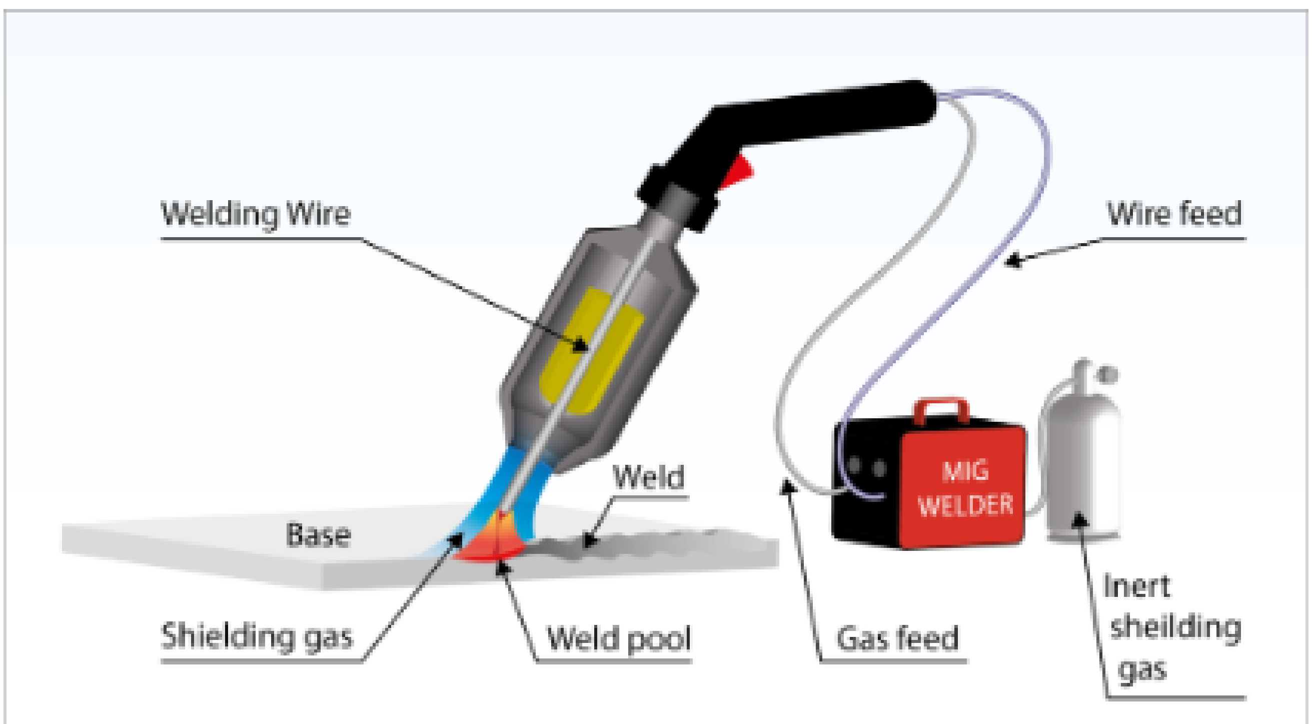
Advantages of GMAW

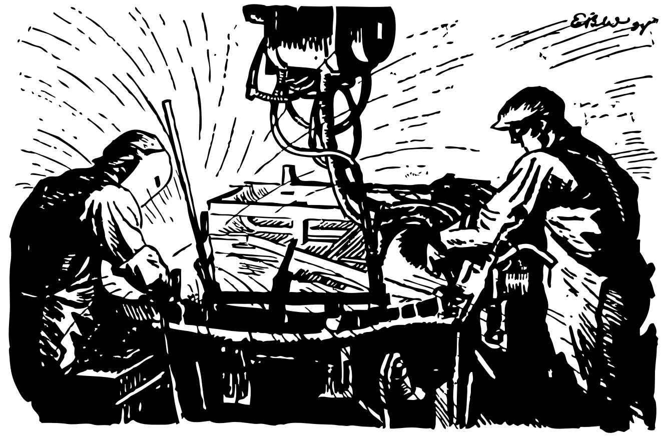
- All-position welding capability.
- Excellent weld bead appearance.
- Lower hydrogen weld deposit — generally less than 5 mL/100 g of weld metal.
- Lower heat input when compared to other welding processes.
- A minimum of weld spatter and slag makes weld clean up fast and easy.
- Less welding fumes when compared to SMAW (Shielded Metal Arc Welding) and FCAW (Flux-Cored Arc Welding) processes.

Limitations of GMAW

- The lower heat input characteristic of the short-circuiting mode of metal transfer restricts its use to thin materials.
- The higher heat input axial spray transfer generally restricts its use to thicker base materials.
- The higher heat input mode of axial spray is restricted to flat or horizontal welding positions.
- The use of argon based shielding gas for axial spray and pulsed spray transfer modes is more expensive than 100% carbon dioxide (CO_2).

MIG WELDING





How To Weld Using MIG Welding

When MIG welding, it is important to get the setup correct. The general steps are listed below:

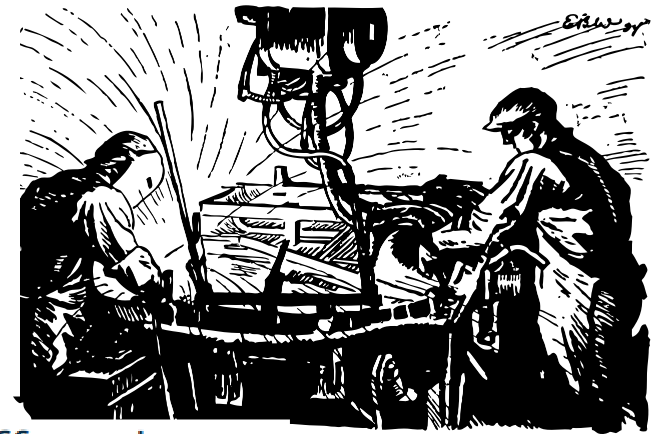
1. Connect the ground wire to the workpiece or welding table.
2. Configure the welding machine for the metal to be welded.
3. Wear the correct personal protective equipment (PPE).
4. Clamp the pieces to be welded together in place.
5. Create tack welds at either end of the joint*.
6. Weld along the joint either by pushing or pulling the weld**.

> **A tack weld is a quick spot weld meant to hold the two workpieces together for the full welding process that will follow.*
>
> ***Pushing or pulling the weld refers to the gun's positioning and direction of movement. It should be angled at 10 degrees and "pulled" so the electrode trails the gun or "pushed" so it leads the movement.*

What Are Some MIG Welding Techniques?

To create a good weld, the most important thing is to maintain a steady hand with a good gun position. The tip of the gun should be no more than 3⁄4" from the metal when welding so that the gas sufficiently covers the weld pool. The gun should be held in one hand and, where possible, rested on the index finger of the other open hand for stability. When welding two metals butted together, the gun should not angle toward one or the other. When the two metals are perpendicular, the gun should be at 45 degrees to the metal faces. Lastly, it is helpful to first rehearse running the weld without actually welding to gain a feel for the right movement.

What Industries Use MIG Welding?



MIG welding is the most common technique for repairing vehicles such as motorbikes, cars, vans, etc. Other industries that make extensive use of MIG Welding include:

1. Construction
2. Aerospace
3. High-production manufacturing
4. Shipping
5. Rail

What Are the Factors That May Affect the Quality of MIG Welding?

The most important variable that will affect the quality is the weld technique. While the setup does matter, as long as the current, gas flow, and wire feed rate are roughly correct, it shouldn't affect the final weld too much. Some of the most important variables are:

1. Distance from the gun to the weld.
2. Angle between the gun and the weld.
3. Speed of the gun movement.
4. Weld current.
5. Wire feed rate.
6. Gas flow rate.
7. The removal of contaminants from the workpiece prior to welding.

What Is the Correct Parameter Setting for MIG Welding?

There are five main parameters for MIG welding: current, length of arc, angle, manipulation, and speed. None of these parameters have a standard setting and will all vary based on what metal you're welding and the thickness of the weld. There are, however, standard charts that indicate the normal parameter settings for different welds. Generally, high current is used for welding thick metals. The shorter the arc, the hotter the weld. The gun should be held at half of the angle between the parts to be joined (i.e. the gun should be held at 90 degrees to a butt joint, 45 degrees to a T-joint, etc.). Manipulation describes whether the welder pushes or pulls the weld pool. Finally, the speed must be steady. Moving too slow will result in an oversized weld bead and possible holes in the weld joint; moving too fast may result in a lack of weld penetration.

What Are the Common Materials Used in MIG Welding?

The most common materials used in MIG welding are listed below:

1. Copper

Copper is a soft, malleable metal used in plumbing and electrical applications. MIG welding is the preferred process for welding copper. However, the heat required to weld copper is about twice that of steel where the heat temperature makes it easier and possible.

2. Aluminum

Aluminum is a soft, silvery, non-ferrous metal. Welding aluminum requires 100% pure argon gas. Aluminum welding can be difficult as the melt pool can quickly burn through the part and drip out the other side.

3. Steels

Steels are alloys made mainly of iron and carbon, usually also including sulfur and phosphorus. When welding steel, it is advised not to use 100% argon gas for shielding but rather 75% argon and 25% carbon dioxide. This is because 100% argon gas will reduce the ductility of the weld.

4. Nickel Alloys

Nickel alloys are composed of nickel and usually chromium, iron, molybdenum, and/or copper. Usually, 100% argon gas is used to weld nickel alloys. However, when more energy is required, up to 40% helium can be used.

What Is the Hardest Material to MIG Weld?

The hardest material to MIG weld is aluminum as it has a very low melting point paired with high thermal conductivity. Poor heat conductivity means that aluminum does not absorb the heat from the electrical arc well and so it is hard to keep a stable temperature throughout the process without either burning through or failing to penetrate the joint at all.

What Is the Easiest Material to MIG Weld?

The easiest material to MIG weld is mild steel. This is because of its high melting temperature, which makes mild steel very forgiving to changes in welding parameters. The lower the carbon content of mild steel, the easier it is to weld.

What Materials Cannot Be MIG Welded?

Materials such as wood, composites, and plastics cannot be MIG welded. Additionally, dissimilar metals cannot be welded together — aluminum, for instance, cannot be welded to steel or copper.

Shielding Gases for GMAW

GMAW Equipment

The basic equipment of MIG:

1. Power source
2. Welding torch
3. Wire feed unit
4. Inert gas supply/ gas cylinder
5. Electrode wire
6. Workpiece clamp

3 basic criteria are useful in understanding the properties of shielding gas:

- Ionization potential of the gas components
- Thermal conductivity of the shielding gas components
- The chemical reactivity of the shielding gas with the molten weld puddle

Shielding Gases

Argon and helium are the two inert shielding gases used for protecting the molten weld pool. The inert classification indicates that neither argon nor helium will react chemically with the molten weld pool. However, in order to become a conductive gas, that is, a plasma, the gas must be ionized. Different gases require different amounts of energy to ionize, and this is measured in terms of the ionization energy. For argon, the ionization energy is 15.7 eV. Helium, on the other hand, has an ionization energy of 24.5 eV. Thus, it is easier to ionize argon than helium. For this reason argon facilitates better arc starting than helium.

The thermal conductivity, or the ability of the gas to transfer thermal energy, is the most important consideration for selecting a shielding gas. High thermal conductivity levels result in more conduction of the thermal energy into the workpiece.

The thermal conductivity also affects the shape of the arc and the temperature distribution within the region. Argon has a lower thermal conductivity rate — about 10% of the level for both helium and hydrogen. The high thermal conductivity of helium will provide a broader penetration pattern and will reduce the depth of penetration. Gas mixtures with high percentages of argon will result in a penetration profile with a finger-like projection into the base material, and this is due to the lower thermal conductivity of argon.

Can we MIG Without Gases?

Yes. Most MIG welders can run using flux-cored wire which won't need gas. This is because the flux-core wire contains the shielding gas component within the welding wire. These wires are different to standard solid welding wire. You can't weld with solid welding wire without gas. There are also stand-alone wire feed welders that are specifically designed to run flux-core welding wires only.

Inert Shielding Gases

Argon is the most commonly used inert gas. Compared to helium its thermal conductivity is low. Its energy required to give up an electron, ionization energy, is low, and this results in the finger-like penetration profile associated with its use.

Argon supports axial spray transfer. Nickel, copper, aluminum, titanium, and magnesium alloyed base materials use 100% argon shielding. Argon, because of its lower ionization energy, assists with arc starting. It is the main component gas used in binary (two-part) or ternary (three-part) mixes for GMAW welding. It also increases the molten droplet transfer rate.

Helium is commonly added to the gas mix for stainless and aluminum applications. Its thermal conductivity is very high, resulting in the broad but less deep penetration profile. When in use, arc stability will require additions of arc voltage.

Helium additions to argon are effective in reducing the dilution of base material in corrosion resistant applications. Helium/argon blends are commonly used for welding aluminum greater than 1" (25 mm) thick.

Shielding Gas Cylinder Concerns

You must pay extra attention to the cylinder since you will need a shielding gun to use your MIG welder. First, make sure the **cylinder is always chained**. Chain it either to the machine or in a safe place in the shop to ensure it doesn't fall.

If your cylinder falls over, landing onto a regulator, the gas will try to escape, causing a cloud that might hurt nearby welders. So when you are not using the gas, remove the regulator and install a protection cap to the top of the bottle. Protecting the valve system will prevent rupture.

In addition, gas leakage may occur due to poor gas hose shape. Therefore, you should make sure you coil the hose tightly and store it properly to avoid tangling, twisting, or kinking. If you notice excessive shielding gas consumption, make sure there are no holes in your gas hose.

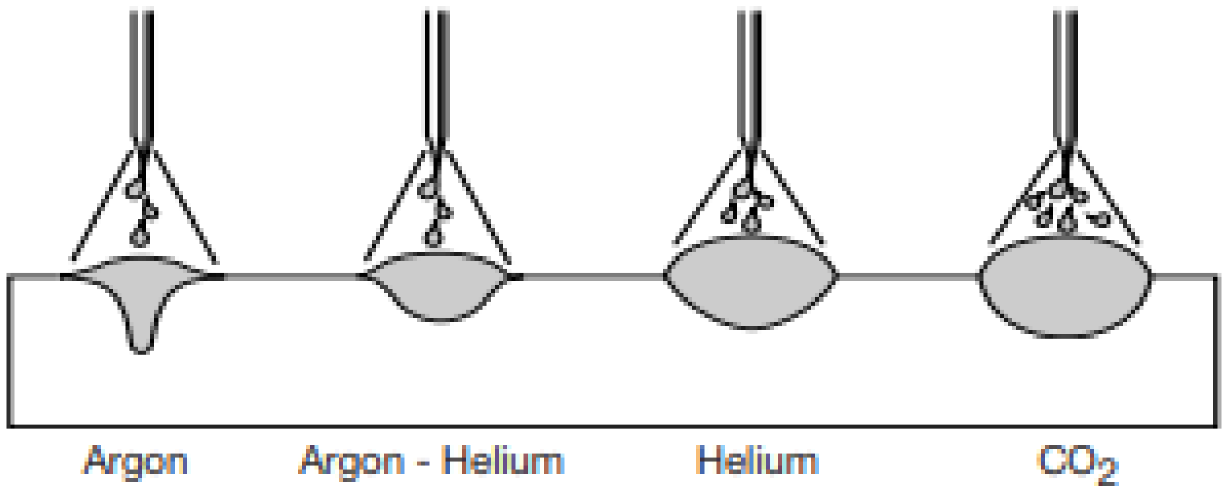
Equipment Cleaning

Clean equipment is a foundation of proper welding. You should **include cleaning into your regular maintenance schedule** for the best results. First, make sure you unplug your MIG welding machine and remove all the covers. Then use the dry air hose to remove any dirt, dust, and debris from the power supply and wire drive mechanism.

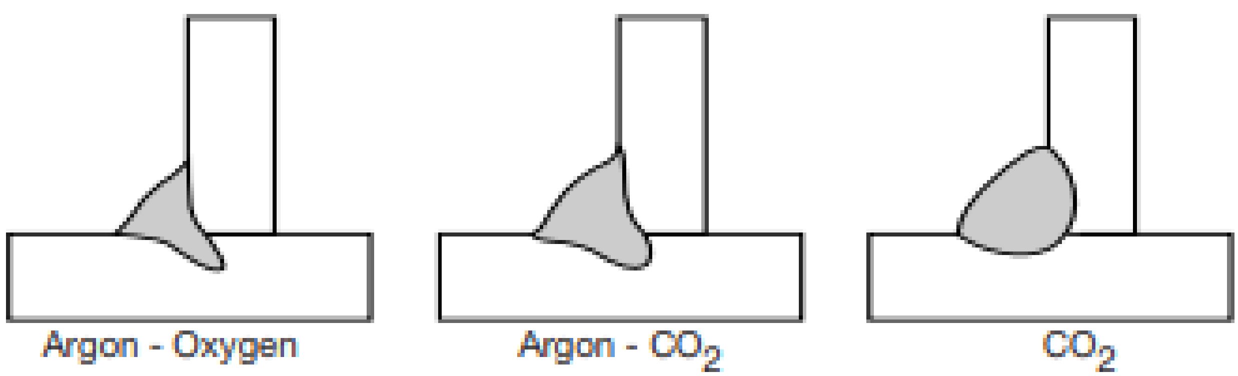
Dust and dirt may clog your cooling fans which can lead to overheating and finally malfunctioning. In addition, dirt and debris can cause wear of equipment parts, which you will have eventually to replace or repair. So, all you need to do is occasionally clean the dirt, dust, and debris, and you can be sure you don't have to spend money repairing your welder.

Reactive Shielding Gases

Oxygen, hydrogen, nitrogen, and carbon dioxide (CO2) are reactive gases. Reactive gases combine chemically with the weld pool to produce a desirable effect.



Bead contour and penetration patterns for various shielding gases



Relative effect of Oxygen versus CO2 additions to the argon shield

Wire electrode

There are several types of wire electrodes available to tackle different projects and metals. As these electrodes run through the same wire feed unit, they behave differently during the welding process and leave distinguishable results.

1. **Hard wire** is the general wire used by most MIG users as it is affordable and easy to control. This wire usually comes in large reels and can be used at different angles. Typical hardwires used are in a combination of 72/25 argon and Co2 ratio.
2. **Flux-cored wire** requires no shielding gas for the welding project as the flux is built into the wire itself. In fact, this is actually another type of welding process called flux-cored arc welding (FCAW) but this can often be performed on the same welding equipment. Portability is a great bonus with flux-cored wires as there is no need to carry a gas tank around. The absence of an additional shielding gas makes flux-core more suited to working outdoors and in windy conditions. This is extremely convenient and user-friendly but on the downside, these wires create slag during welding. Investing in a good metal brush will come in handy for the cleaning procedure.


Flux cored wire


Solid cored wire

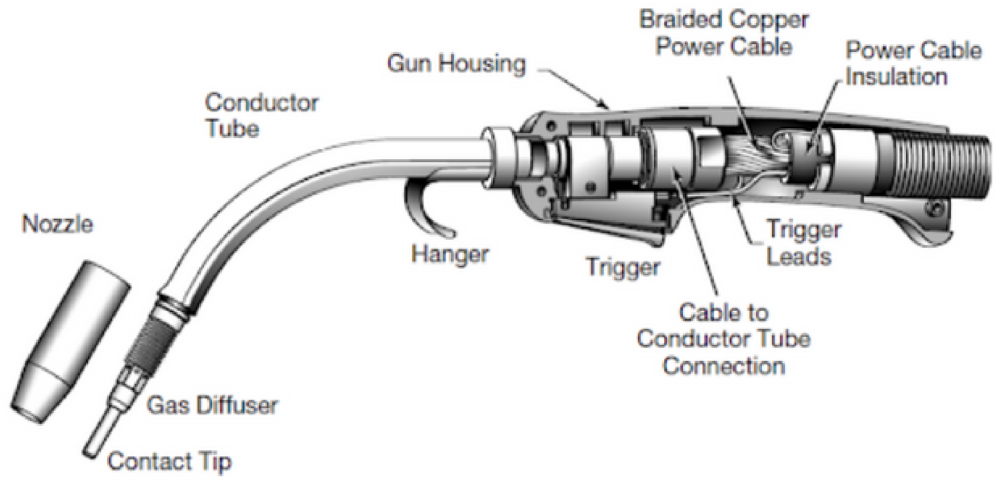
Which Wire is the Best Choice?

When comparing the flux-cored wires to the solid wires, it would be wise to note that the best choice is dependent upon the welding job and location. Both types of wires can produce sound welds with good weld bead appearances, when done correctly.

For thicker metals and outdoor jobs, the flux-cored wire electrodes work best. For thinner metals and jobs performed out of the wind, solid wire electrodes can work quite well.

Solid wire electrodes used in MIG welding are not as portable as flux-cored wires. This is due to the necessity of a shielding gas in MIGW.

Both solid wire electrodes and flux-cored wire electrodes are relatively easy to use. However, flux-cored wire electrodes are more costly.



Welding torch

A welding torch or gun is a specialised tool for fusing and melting metals. MIG torches offer versatility in their application for a variety of metal thicknesses and types of metal. Similar to TIG, MIG torches are divided into two groups:

- **Gas-cooled welding torches** are normally enough for the common welder doing minor projects. With larger projects overheating might become an issue.
- **Water-cooled welding torches** can be used at higher amperages and provide more power. They also offer smoother control over the contact tip of the nozzle. However, they cost 20-30% more than gas-cooled torches and require the welding machine to have a water-cooled system installed in the unit.

Aside from choosing the welding torch, it is important to have the correct components installed for the project at hand. One of these components is the liners in the welding gun. Liners are guides that ensure the smooth feeding of the wire during welding. Their use is rather straightforward, as they need to match the type of metal along with the wire diameter of the spool.

Take note that there are four different nozzle types used in a welding torch: recessed, flush, protruding, and adjustable. The simplest way to decide which nozzle to use is to identify the type of wire electrode used in the project.

Cables and Connections

Before you start welding, always **inspect your cables for damage**. Damaged cables can affect the arc stability; hence they will result in poor welds. In addition, make sure there are no loose connections. Loose connections can lead to a heat buildup in cables, eventually damaging your MIG gun or components.

Finally, you should **check your ground**. A bad ground will result in erratic welds, so you will have to adjust voltage constantly to achieve decent quality. Luckily, you can deal with lousy ground quickly, and the results will be satisfying.

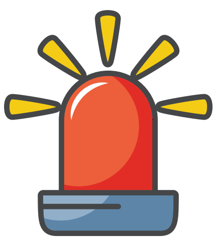
Simply inspecting the cables prior to welding will save you time trying to figure out why your arc is inconsistent or why you produce poor welds, with the settings that worked just fine yesterday.

MIG SAFE PRACTICES

Safe Handling of Shielding Gas Cylinders and Regulators. Compressed gas cylinders should be handled carefully and should be adequately secured when in use. Knocks, falls, or rough handling may damage cylinders, valves, or fuse plugs and cause leakage or accident. Valve protecting caps, when supplied, should be kept in place (handtight) until the connecting of container equipment.

Cylinder Use. The following should be observed when setting up and using cylinders of shielding gas:

1. Properly secure the cylinder.
2. Before connecting a regulator to the cylinder valve, the valve should momentarily be slightly opened and closed immediately (opening) to clear the valve of dust or dirt that otherwise might enter the regulator. The valve operator should stand to one side of the regulator gauges, never in front of them.
3. After the regulator is attached, the adjusting screw should be released by turning it counter-clockwise. The cylinder valve should then be opened slowly to prevent a too-rapid surge of high pressure gas into the regulator.
4. The source of the gas supply (i.e., the cylinder valve) should be shut off if it is to be left unattended.



Gases. The major toxic gases associated with GMAW welding are ozone, nitrogen dioxide, and carbon monoxide. Phosgene gas could also be present as a result of thermal or ultraviolet decomposition of chlorinated hydrocarbon cleaning agents located in the vicinity of welding operations, such as trichlorethylene and perchlorethylene. DEGREASING OR OTHER CLEANING OPERATIONS INVOLVING CHLORINATED HYDROCARBONS SHOULD BE SO LOCATED THAT VAPORS FROM THESE OPERATIONS CANNOT BE REACHED BY RADIATION FROM THE WELDING ARC.

Ozone. The ultraviolet light emitted by the GMAW arc acts on the oxygen in the surrounding atmosphere to produce ozone, the amount of which will depend upon the intensity and the wave length of the ultraviolet energy, the humidity, the amount of screening afforded by any welding fumes, and other factors. The ozone concentration will generally be increased with an increase in welding current, with the use of argon as the shielding gas, and when welding highly reflective metals. If the ozone cannot be reduced to a safe level by ventilation or process variations, it will be necessary to supply fresh air to the welder either with an air supplied respirator or by other means.

Nitrogen Dioxide. Some test results show that high concentra-tions of nitrogen dioxide are found only within 6 in. (152 mm) of the arc. With normal natural ventilation, these concentrations are quickly reduced to safe levels in the welder's breathing zone, so long as the welder keeps his head out of the plume of fumes (and thus out of the plume of welding-generated gases). Nitrogen dioxide is not thought to be a hazard in GMAW.

Carbon Monoxide. CO shielding used with the GMAW process will be dissociated by the heat of the arc to form carbon monoxide. Only a small amount of carbon monoxide is created by the welding process, although relatively high concentrations are formed temporarily in the plume of fumes. However, the hot carbon monoxide oxidizes to CO so that the concentrations of carbon monoxide become insignificant at distances of more than 3 or 4 in. (76 or 102 mm) from the welding plume.

Metal Fumes. The welding fumes generated by GMAW can be controlled by general ventilation, local exhaust ventilation, or if the exposure cannot be adequately controlled using ventilation, by respiratory protective equipment as described in ANSI Z49.1. The method of ventilation required to keep the level of toxic substances within the welder's breathing zone below acceptable concentrations is directly dependent upon a number of factors. Among these are the material being welded, the size of the work area, and the degree of the confinement or obstruction to normal air movement where the welding is being done. Each operation should be evaluated on an individual basis in order to determine what ventilation, exhaust or personal protective equipment will be required. Legally required exposure limits for hazardous substances are called Permissible Exposure Limits (PEL) and are established by DOSH.

Tungsten Inert Gas Welding

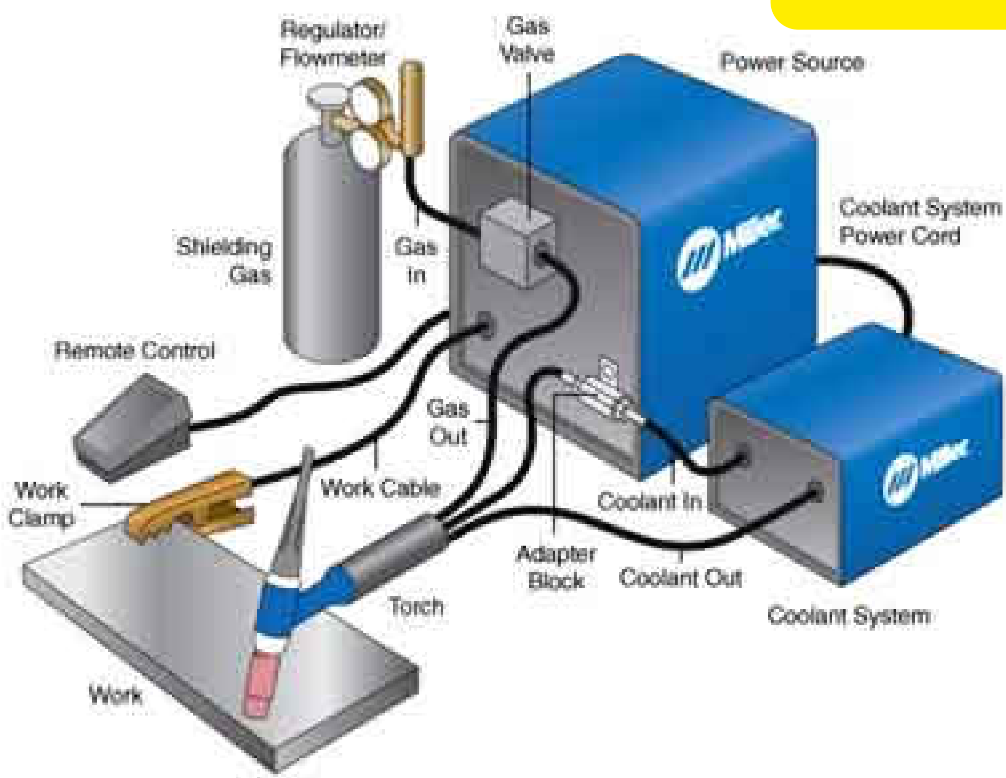
Gas Tungsten Arc Welding (GTAW) also known as Tungsten Inert Gas welding (TIG) is an electric arc welding process that produces an arc between a non-consumable electrode (tungsten which does not melt due to its high melting point) and the work piece to be welded. The weld is shielded from the atmosphere by a shielding gas that forms an envelope around the weld area. However, a filler metal is usually used in the process . The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used.

Equipments:

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a nonconsumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

1. Welding torch
2. Power supply
3. Electrode
4. Shielding gas
5. Filler Rod

TIG WELDING



Working principle:

- An arc is established between the end of a tungsten electrode and the parent metal at the joint line. The electrode is not melted and the welder keeps the arc gap constant. The current is controlled by the power-supply unit.
- A filler metal, usually available in 1 m lengths of wire, can be added to the leading edge of the pool as required. The molten pool is shielded by an inert gas which replaces the air in the arc area.
- Argon and helium are the most commonly used shielding gases.
- The process may use direct current electrode positive, direct current electrode negative or alternating current. The chart above indicates the operating characteristics of each of these current types.
- DCEN or "**straight polarity**" is used for welding most materials other than aluminium. The electrode tip geometry is generally a sharp point with a small blunted end since most of heat balance is on melting of the base material.
- DCEP or "**reverse polarity**" is rarely used since it results in low penetration. Also the constant bombardment of the tungsten electrode by electrons in the DCEP mode degrades the electrode.
- Alternating current(AC) is used primarily to weld aluminium, which has a tenacious oxide surface layer. Although the diagram above states that there is a 50% cycle from DCEN to DCEP, it is possible through solid state electronics to vary the amount of time at each polarity and also the current at each polarity.

Welding Torch:

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator.

Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

The internal metal parts of a torch are made of hard alloys of copper or brass so it can transmit current and heat effectively. The tungsten electrode must be held firmly in the center of the torch with an appropriately sized collet, and ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the diameter of the tungsten electrode they hold. The body of the torch is made of heat resistant, insulating

The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle depends upon the diameter of the electrode, the joint configuration, and the availability of access to the joint by the welder. The inside diameter of the nozzle is preferably at least three times the diameter of the electrode, but there are no hard rules. The welder judges the effectiveness of the shielding and increases the nozzle size to increase the area protected by the external gas shield as needed. The nozzle must be heat resistant and thus is normally made of alumina or a ceramic material, but fused quartz, a high purity glass, offers greater visibility. Devices can be inserted into the nozzle for special applications, such as gas lenses or valves to improve the control shielding gas flow to reduce turbulence and introduction of contaminated atmosphere into the shielded area. Hand switches to control welding current can be added to the manual GTAW torches.

Filler Rod:

Filler metals are also used in nearly all applications of GTAW, the major exception being the welding of thin materials. Filler metals are available with different diameters and are made of a variety of materials. In most cases, the filler metal in the form of a rod is added to the weld pool manually, but some applications call for an automatically fed filler metal, which often is stored on spools or coils

This filler material is a metal alloy specifically designed to withstand the high heat of welds and to fuse the two pieces of stock together as a composite. So, not surprisingly, the alloy and size of filler rods vary for the varying stock thicknesses and types of base metals people weld.

Also, be sure to determine the correct current (amperage) range for the rod. Plus, check the polarity, gas flow, cup size, torch speed, etc. before you strike an arc and start welding with a specific filler rod.

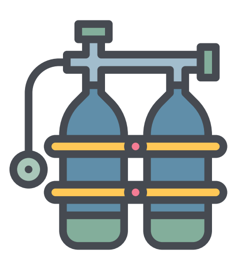
Shielding Gas

As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, argon shielding results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminum. A significant disadvantage is the difficulty of striking an arc with helium gas, and the decreased weld quality associated with a varying arc length.

Argon-helium mixtures are also frequently utilized in GTAW, since they can increase control of the heat input while maintaining the benefits of using argon. Normally, the mixtures are made with primarily helium (often about 75% or higher) and a balance of argon. These mixtures increase the speed and quality of the AC welding of aluminum, and also make it easier to strike an arc. Another shielding gas mixture, argon-hydrogen, is used in the mechanized welding of light gauge stainless steel, but because hydrogen can cause porosity, its uses are limited. Similarly, nitrogen can sometimes be added to argon to help stabilize the austenite in austenitic stainless steels and increase penetration when welding copper.

Due to porosity problems in ferritic steels and limited benefits, however, it is not a popular shielding gas additive.



Tungsten Electrode

TYPE OF TUNGSTEN	COLOR	USES AND PREFORMANCE
Pure	Green	Provides good arc stability for AC welding. Reasonably good resistance to contamination. Lowest current carrying capacity. Least expensive. Maintains a balled end.
Ceriated CeO_2 1.8% to 2.2%	Orange	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life. Possible replacement for thoriated.
Thoriated ThO_2 1.7% to 2.2%	Red	Easier arc starting. Higher current capacity. Greater arc stability. High resistance to weld pool contamination. Difficult to maintain balled end on AC.
Lanthanated La_2O_3 1.3% to 1.7%	Gold	Similar performance to thoriated tungsten. Easy arc starting, good arc stability, long life, high current capacity. Possible replacement for thoriated.
Zirconiated ZrO_2 0.15% to 0.40%	Brown	Excellent for AC welding due to favorable retention of balled end, high resistance to contamination, and good arc starting. Preferred when tungsten contamination of weld is intolerable.

Tungsten electrode types:

1. Pure tungsten electrodes -GREEN
2. Thoriated tungsten electrodes - RED
3. Ceriated tungsten electrodes - ORANGE
4. Lanthaniated tungsten electrodes – GOLD
5. Zirconiated tungsten electrodes – BROWN

The electrode used in GTAW is made of tungsten or a tungsten alloy, because tungsten has the highest melting temperature among pure metals, at 3422 °C (6192 °F). As a result, the electrode is not consumed during welding, though some erosion (called burn-off) can occur.

Electrodes can have either a clean finish or a ground finish—clean finish electrodes have been chemically cleaned, while ground finish electrodes have been ground to a uniform size and have a polished surface, making them optimal for heat conduction.

Power Supply

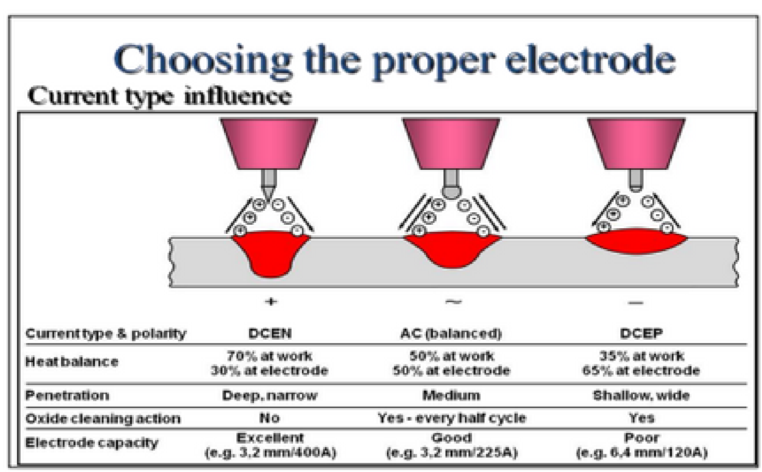
Gas tungsten arc welding (GTAW) uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch.

Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult. The preferred polarity of the GTAW system depends largely on the type of metal being welded.

Direct current with a positively charged electrode (DCEP) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures. To help it maintain its shape and prevent softening, a larger electrode is often used.

As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance.

Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTAW of aluminum or magnesium when helium is used as a shielding gas. The negatively charged electrode generates heat by emitting electrons, which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material, and this can allow oxides to build on the surface of the weld.



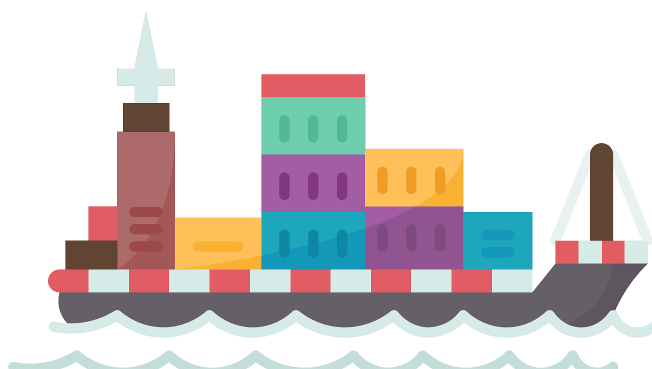
Current type & polarity	DCEN	AC (balanced)	DCEP
Heat balance	70% at work 30% at electrode	50% at work 50% at electrode	35% at work 65% at electrode
Penetration	Deep, narrow	Medium	Shallow, wide
Oxide cleaning action	No	Yes - every half cycle	Yes
Electrode capacity	Excellent (e.g. 3,2 mm/400A)	Good (e.g. 3,2 mm/225A)	Poor (e.g. 6,4 mm/120A)

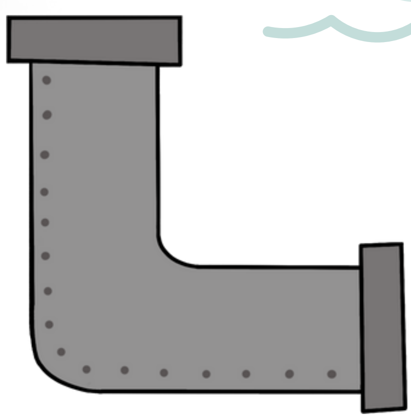
Application of TIG welding

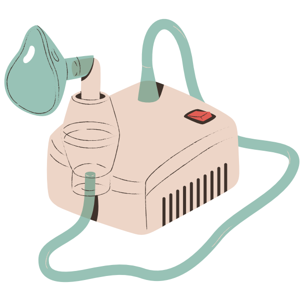
TIG welding is a versatile process that can be used in a variety of industries and applications.

- The TIG process used to join a wide range of metal. It can weld reactive metals like aluminium, magnesium, copper, nickel, titanium, etc. and their alloys.
- TIG can be used to weld in any position flat, horizontal, vertical, overhead position. TIG welding enables a wider range of joint designs in comparison to conventional shielded arc welding or stick electrode welding.
- Precision welding: TIG welding is a precise process that is well-suited for welding thin sheets of metal and creating high-quality, attractive welds.

- TIG welding is suitable for combining dissimilar metals, hard facing, and the surfacing of metals.
- It used where quality is critical. Eg. Pipes, vessels, medical equipment aerospace industry.
- Art and design: TIG welding is used in art and design to create sculptures and other decorative items.







Advantages of TIG welding

1. Non-consumable electrodes - It helps to provide flawless joints because it is not needed to stop for replacing the electrode as in consumable electrode welding. That also contributes to reducing downtime in production.
2. No flux is required because inert gas shields molten metal. So no slag and slag inclusion problems.
3. High quality and strong welding achieved by TIG.
4. Cleaner and more appealing joints. Sometimes they don't need finishing process.
5. They are suitable for welding of very thin sections.
6. The versatility of method. They can work with and without filler metal.
7. A wide range of metal can be welded. Nonferrous metals like aluminium, copper and dissimilar metal can be welded without any challenge.
8. Non-corrosive and ductile joints.
9. The minimum amount of flames and spark. Less distortion due to small heat zone.
10. Compared to welds produced through ordinary shield arc welding, TIG welds possess greater strength, ductility, and resistance to corrosion.
11. It can be done in both automatic and manual.

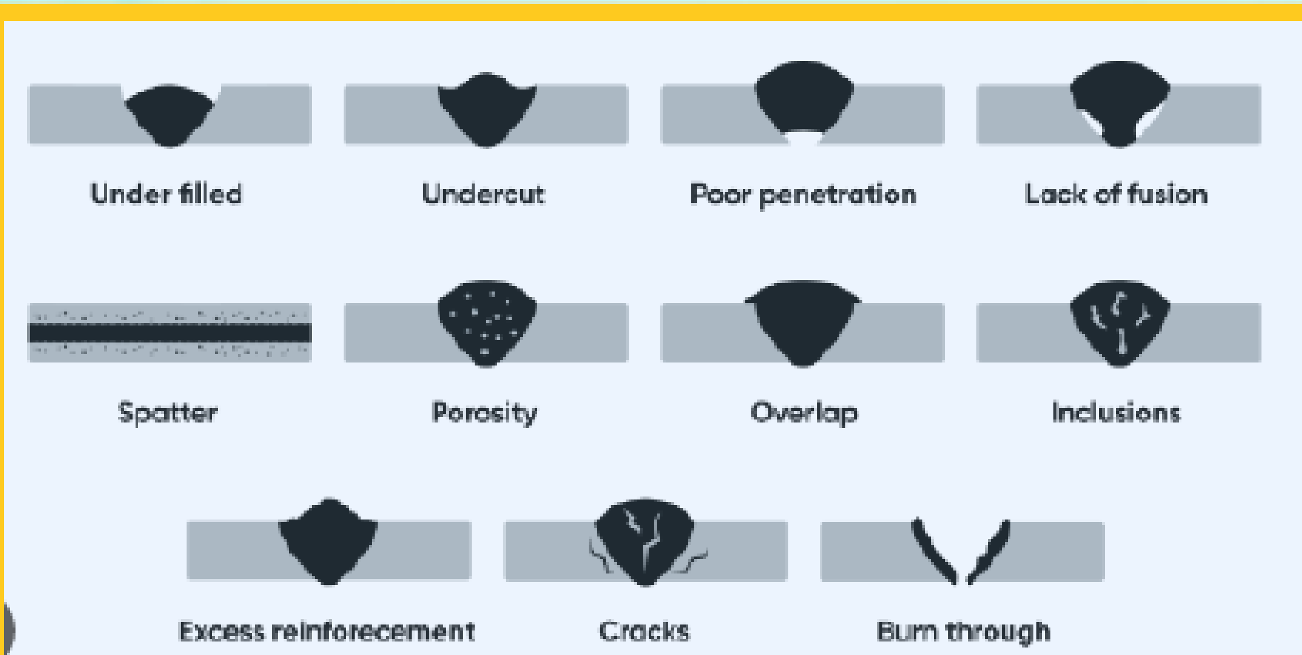
Disadvantage of TIG welding

1. TIG is a time-consuming process - They are slower than any other welding process. Lower filler deposition rate.
2. More complicated - Highly skilled and professional workers are needed to perform TIG welding.
3. Safety issue - Welders, are exposed to high intensity of light which can cause eye damage.
4. High initial cost.
5. It cannot use in thicker sheets of metal.

What Is the Difference Between MIG Welding and TIG Welding?

One of the main differences between MIG welding and TIG welding is the welding electrodes that are used to create the electric arc. TIG uses a hand-held rod as filler material and a non-consumable electrode, while MIG's consumable electrode doubles as the filler. MIG tends to do its work faster and at a lower price than TIG. MIG is also a simpler process that demands less training. TIG Welding produces a stronger weld, greater weld precision, and better aesthetics. Finally, MIG welding is better suited to thicker materials and TIG Welding is more appropriate for thinner materials.

WELDING DEFECTS



Common Welding Defects:

Porosity: Occurs when gas is trapped in the weld, resulting in small holes or voids that weaken the joint.

Lack of fusion: Refers to incomplete fusion between the weld metal and the base metal, causing a weak joint.

Cracking: Various types of cracks can occur in welds, such as longitudinal cracks, transverse cracks, or crater cracks, leading to structural integrity issues.

Undercut: A groove or depression formed along the edges of the weld due to excessive heat or improper technique, compromising joint strength.

Spatter: Excessive splattering of molten metal during welding, resulting in small droplets that can cause surface imperfections or reduce weld quality.

Wear appropriate personal protective equipment (PPE), including welding helmets, goggles, gloves, and fire-resistant clothing.

Ensure proper ventilation to minimize exposure to welding fumes and gases.

Use welding curtains or screens to protect others from UV radiation and prevent accidental flashes.

Inspect and maintain welding equipment regularly to ensure safe operation.

Follow proper electrical safety measures and disconnect power before performing any maintenance or repairs.

Safety Precautions in Welding:

Ensure proper joint preparation and fit-up before welding to minimize the risk of defects and ensure optimum weld quality.

Select the appropriate welding technique and process for the specific application, considering factors such as material compatibility, joint type, and required strength.

Monitor welding parameters, such as voltage, current, and travel speed, to maintain consistent quality and prevent defects.

Implement adequate welder training and certification programs to ensure skilled operators who can perform welding tasks safely and effectively.

Conduct regular inspections and testing of welded joints to identify any defects or potential weaknesses, allowing for timely corrective actions and quality assurance.

TUTORIAL

1. Illustrate shielded metal arc welding equipment in the box below.

2. Illustrate oxy acetylene welding equipment in the box below.

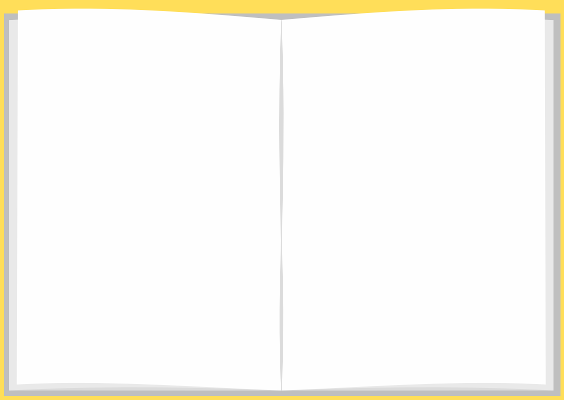
3. Illustrate metal inert gas welding equipment in the box below.

4. Illustrate gas tungsten arc welding equipment in the box below.

5. List **FIVE (5)** advantages and disadvantages of SMAW.

Advantages	**Disadvantages**

6. Differentiate between oxygen and acetylene tanks.



7. Explain the correct procedure in lighting the torch in oxy acetylene welding.

8. In oxy-acetylene welding, the proportion of oxygen and acetylene can be adjusted to produce a neutral, oxidizing or carburizing flame. Show by drawing, label and describe each three flames.

Flames drawing	Description

9. Differentiate DCEN and DCEP in SMAW.

DCEN	**DCEP**

10. Compare Alternating current (AC) to Direct current (DC).

Alternating current (AC)	**Direct current (DC)**

11. Name **TWO (2)** inert gas used in GTAW.

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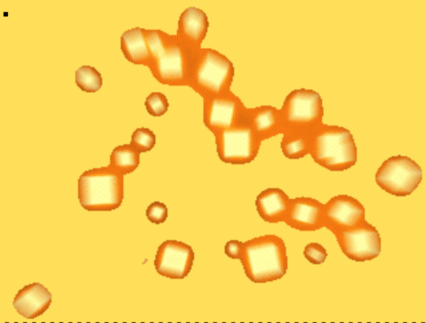

12. What are welding defects?

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13. State **NINE (9)** common defects in welding.

14. State the prevention method of distortion.

....

....

....

15. Explain the manifold system in gas welding.

....

....

....

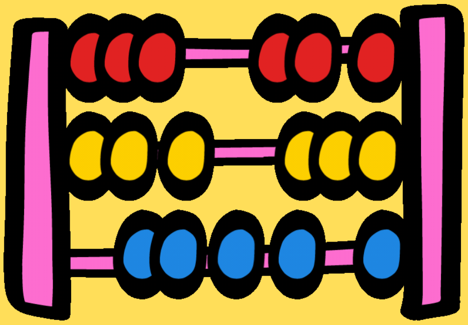
16. There are five basic types of joints; butt joint, corner joint, edge joint, lap joint and tee-joint. Characterize each joint.

WELDING JOINT	CHARACTERISTICS
1. BUTT	
2. CORNER	
3. EDGE	
4. LAP	
5. TEE	

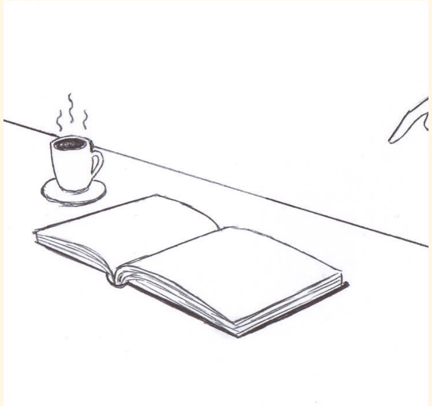
17. The problem caused by residual stresses such as cracking, distortion and buckling can be reduced by preheating the base metal or parts to be welded. Define residual stresses.

18. Seven types of famous welds are as follows. Give its descriptions in orderly manner.

Weld Types	Descriptions
1. Groove weld	
2. Fillet weld	
3. Flange weld	
4. Surfacing weld	
5. Plug weld	
6. Slot weld	
7. Tack weld	


19. Sketch welding terminologies and label the root, face, throat, toe, leg and Heat Affected Zone (HAZ).



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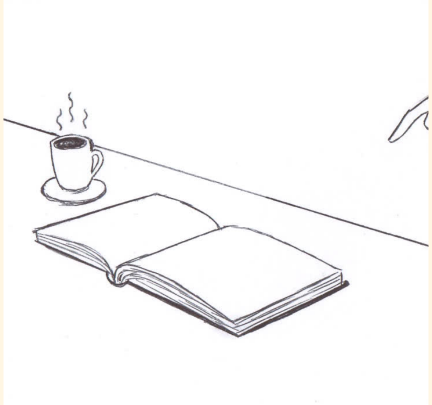

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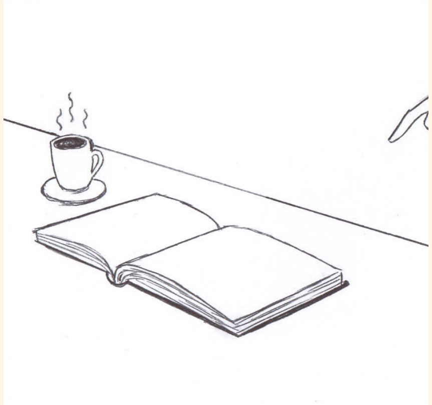

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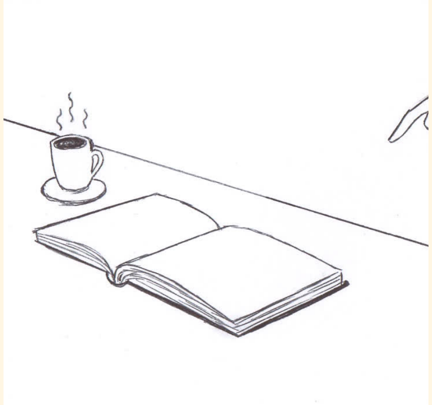

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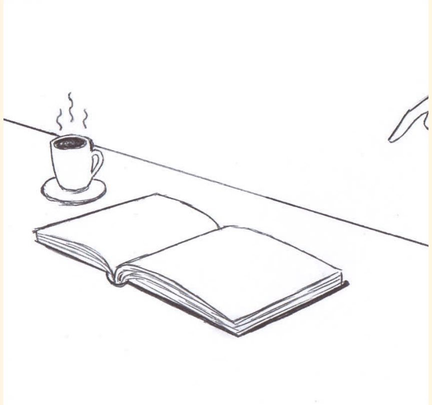

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