workshop technology

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WORKSHOP TECHNOLOGY

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2018

Chapter One

Industrial Safety

Industrial Safety

1.1 Introduction

A safety programme should always include engineering safety at the design and equipment installation stage, education of employees in safe practices, concerns the attitude of employees and management. It should motivate all the industrial employees in accident prevention and safety consciousness. It must provide all safety instructions and training essential for the employees to think, act and work safely so that the number of accidents can be minimized. Safety education must give knowledge about safe and unsafe mechanical conditions and personal practices. Safety training must involve induction and orientation of new recruits to safety rules and practices, explaining safety function, during their initial job training through efforts made by the first level supervisors. Formulating employee's safety committees, holding of employee's safety meeting, display of charts, posters, film etc. are very much essential in each industry for stressing the need to act safely. It educates employees to develop their safety consciousness.

1.2 Objectives of Industrial Safety:

The objectives of industrial safety are as follows:

1. Industrial safety is needed to check all the possible chances of accidents for preventing loss of life and permanent disability of any industrial employee, any damage to machine and material as it leads to the loss to the whole establishment.
2. It is needed to eliminate accidents causing work stoppage and production loss.
3. It is needed to prevent accidents in industry by reducing any hazard to minimum.
4. It is needed to reduce workman's compensation, insurance rate and all the cost of accidents.
5. It is required to educate all members regarding the safety principles to avoid accidents in industry.
6. It is needed to achieve better morale of the industrial employees.
7. It is required to have better human relations within the industry.
8. It is needed to increase production means to a higher standard of living.

Figure 1.1 Samples of Safety Signs

1.3 Causes of Accident

The accidents may take place due to human causes, environmental causes and mechanical causes. These causes are discussed as under.

1.3.1 Human Causes

1. Accidents may occur while working on unsafe or dangerous equipments or machineries possessing rotating, reciprocating and moving parts.
2. Accidents occur while operating machines without knowledge, without safety precautions, without authority, without safety devices.
3. Accidents generally occur while operating or working at unsafe speed.
4. Accidents may occur while working for long duration of work, shift duty etc.
5. Accidents commonly occur during use of improper tools.
6. Accidents may occur while working with mental worries, ignorance, carelessness, nervousness, dreaming etc.
7. Accidents occur because of not using personal protective devices.

1.3.2 Environmental Causes

1. Accidents may occur during working at improper temperature and humidity causes fatigue to the workers so chances of accidents increases with workers having fatigue.
2. The presence of dust fumes and smoke in the working area may causes accidents.
3. Poor housekeeping, congestion, blocked exits, bad plant layout etc. may cause accidents.
4. Accidents occur due to inadequate illumination.
5. Improper ventilation in the plant may also leads to industrial accidents.

1.3.3 Mechanical Causes

1. Continued use of old, poor maintained or unsafe equipment may result in accidents.
2. Accidents commonly occur due to use of unguarded or improper guarded machines or equipments.
3. Unsafe processes, unsafe design and unsafe construction of building structure may lead to accidents in the plant.
4. Accidents occur due to improper material handling system and improper plant layout.
5. Accidents may occur due to not using of safety devices such as helmets, goggles, gloves, masks etc.

However the other general causes of accidents in workshops are listed under:

1. Because of ignorance to work with equipments, hand tools, cutting tools and machine tools.
2. Operating machine and equipments without knowledge.
3. Extra curiosity to work without knowing.
4. Due to poor working conditions.
5. Because of speedy work.

6. Improper method to work.
7. Due to use of improper tools.
8. Because of lack of discipline.
9. Uninterested in work.
10. Due to carelessness.
11. Due to over confidence.
12. Bad working environment.
13. Because of excessive over times duty by industrial workers.
14. Dangerous materials with which to work.
15. Lack of cleanliness.
16. Due to poor planning.

A large number of accidents can be avoided if proper safety measures and safety rules are adopted in manufacturing areas. Some of the important causes of accidents involve violation of safety rules, not using of safety devices, improper use of gadgets and machine controls, non-development of safety working habits, ignorance of the operation of tools, machine and equipments operation, unsafe working conditions, monotony and work-relating stresses, wear and tear of the functional components, explosive and inflammable material etc.

1.4 Common Sources of Accidents

A large number of revolving, rotating, reciprocating and moving parts of machinery can be said as the sources of danger and require guarding for protection against accidents. Extensive studies reveal that some characteristic groups of dangerous parts are acting as common sources of accidents in workshops. Many such major sources are as under.

1. Revolving parts, pulley, flywheels, worms, worm wheel, fan, gears, gear trains, gear wheels etc.
2. Projecting fasteners of revolving parts; like bolts, screws, nuts, key heads, cotters and pins etc.
3. Intermittent feed mechanisms, tool feed of planer; table feed of a shaper, ram feed of power presses and similar other applications.
4. Revolving shafts, spindles, bars, mandrels, chucks, followers and tools like drills, taps, reamers, milling cutters, and boring tool etc.
5. Rotating worms and spirals enclosed in casings, such as in conveyors and revolving cutting tool, like milling cutters, circular saw blade, saw band, circular shears and grinding wheels, etc.
6. Reciprocating tools and dies of power presses, spring hammer, drop hammers, and reciprocating presses, reciprocating knives and saw blade such bow saw, shearing and perforating machines and the cutting and trimming machine and power hacksaws etc.
7. Moving parts of various machines, like those of printing machines, paper-cutters and trimmers, etc.
8. Revolving drums and cylinders without casing, such as concrete and other mixers, tumblers and tumbling barrels, etc.
9. High speed rotating cages such as in hydro-extractors.

10. Revolving weights, such as in hydraulic accumulator or in slotting machines for counter-balance.
11. Nips between meshing racks and pinions of machine parts
12. Nips between reciprocating parts and fixed components, such as between shaper table and the fixture mounted on it or a planer table and table reversing stops, etc.
13. Nips between crank handles for machine controls and fixed parts.
14. Projecting nips between various links and mechanisms, like cranks, connecting rods, piston rods, rotating wheels and discs, etc.
15. Projecting sharp edge or nips of belt and chain drives; via belt, pulleys, chains sprockets and belt fasteners, spiked cylinders etc.
16. Nips between revolving control handles and fixed parts traverse gear handles of lathes, millers, etc.
17. Moving balance weights and dead weight, hydraulic accumulators, counter-balance weight on large slotting machines, etc.
18. Revolving drums and cylinders uncased, tumblers in the foundry, mixers, varnish mixers etc.
19. Nips between fixed and moving parts such as buckets or hoppers of conveyors against tipping bars, stops or parts of the framework.
20. Nips between revolving wheels or cylinders and pans or tables, sand mixers, crushing and incorporating mills, mortar mills, leather carrying machines, etc.
21. Cutting edges of endless band cutting machines, wood working, and log cutting metal find stone-cutting band saws, cloth-cutting band knives, etc.

1.5 General Safety Precautions while Working in a Workshop

1. One should not leave the machine ON even after the power is OFF and until it has stopped running completely. Someone else may not notice that the machine is still in motion and be injured.
2. Operator should not talk to other industrial persons when he is operating a machine.
3. One should not oil, clean, adjust or repair any machine while it is running. Stop the machine and lock the power switch in the OFF position.
4. One should not operate any machine unless authorized to do so by the authorize person in the shop.
5. Always check that work and cutting tools on any machine are clamped securely before starting.
6. The floor should be kept clean and clear of metal chips or curls and waste pieces.
7. Defective guards must be replaced or repaired immediately.
8. One should not operate any machinery when the supervisor or instructor is not in the shop.
9. All set screws should be of flush or recessed type. Projecting set screws are very dangerous because they catch on sleeves or clothing.
10. One should not try to stop the machine with hands or body.
11. Only trained operator should operate machine or switches as far as possible.
12. Always take help for handling long or heavy pieces of material.
13. Always follow safe lifting practices

14. No one should run in the shop at work time.
15. Always keep your body and clothes away from moving machine parts. Get first aid immediately for any injury.
16. Never talk to anyone while operating the machine, nor allow anyone to come near you or the machine.
17. Stop the machine before making measurements or adjustments.
18. Operator should concentrate on the work and must not talk unnecessarily while operating the machines.
19. Never wear necktie, loose sweater, wristwatch, bangles, rings, and loose fitting clothing while working in workshop.
20. Always wear overcoat or apron.
21. Stop machines before attempting to clean it.
22. Make sure that all guards are in their place before starting to operate a machine.
23. Do not attempt to operate a machine until you have received operating instructions.
24. Be thoroughly familiar with the 'stop' button and any emergency stop buttons provided on the machines.
25. Remove burrs, chips and other unwanted materials as soon as possible.
26. Do not leave loose rags on machines.
27. Wash your hands thoroughly after working to remove oils, abrasive particles, cutting fluid, etc.
28. Report all injuries to the foreman, howsoever small. Cuts and burns should be treated immediately.
29. Keep the work area clean.
30. Keep your mind on the job, be alert, and be ready for any emergency.
31. Always work in proper lighting.
32. On should not lean against the machines.

1.6 Safety Precautions while Working with Different Hand Tools

1.6.1Screw Drivers

1. When working on electrical equipment use only a screw driver with an approved handle.
2. One should wear goggles when re-sharpening screw-driver tips.
3. Screws with burred heads are dangerous and must be replaced or the burrs removed with file or an abrasive cloth.
4. One should use the correct tip of screw drivers while screwing. Too arrow or too wide tip will damage the work.

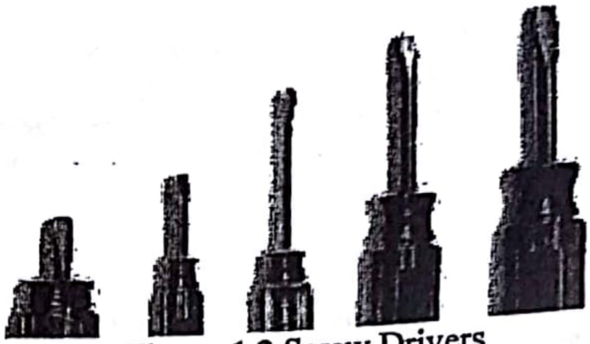


Figure 1.2 Screw Drivers

1.6.2 Wrenches

1. One should not hammer a wrench to loosen a stubborn fastener, unless the tool has been specially designed for such treatment.
2. Always pull on a wrench. One can have more control over the tool if pulling instead of pushing and there is less chance of injury.
3. It is dangerous practice to lengthen the wrench handle for, additional leverage. Use a larger wrench.
4. Choose a wrench that fit properly. A loose fitting wrench may slip and round off the corners of the bolt head and nut.
5. When using wrenches clean grease or oil from the floor in the work area. This will reduce the possibility of slipping and losing balance.

Figure 1.3 Wrenches

1.6.3 Hammers

1. One should not operate the hammer unless its head is tightly fixed to the handle.
2. Place the hammer on the bench carefully. A falling hammer can cause serious foot injuries.
3. Never strike two hammers together. The faces are very hard and the blow might cause a chip to break off.
4. Never hold the hammer too far on the handle when striking a blow.
5. Unless the blow is struck squarely, the hammer may glance of the work.

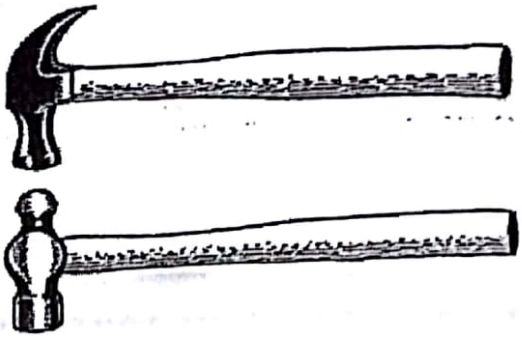


Figure 1.4 Hammers

1.7 Safety Precautions while Working with Different Cutting Tools

1.7.1 Files

1. One should always use a file card to clean the file. Never use your hand. The chips may penetrate in hand and cause a painful infection.
2. One should not use a file without a handle.
3. Short burns formed in filling may cause serious cuts. Always use a piece of cloth to wipe the surface being field.
4. Files are highly brittle and should never be used as a hammer otherwise the file will break.
5. Never hammer on a file. It may shatter and chips fly in all directions.

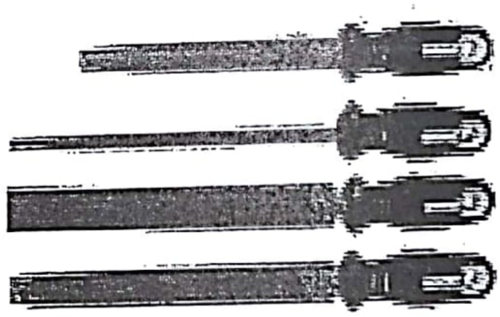


Figure 1.5 Files

1.7.2 Chisels

1. One should always hold the chisel in such a manner that the hammer blow may not miss the chisel to injure your hand.
2. Edges of metal cut with the chisel are often sharp and cause bad cuts.
3. Flying chips are dangerous. Wear transparent plastic safety goggles and use a shield, when using a chisel, to protect yourself and those working near you.
4. Sharp edges of chisels are removed by grinding or filing.
5. Mushroomed head of the chisel should be removed by grinding.

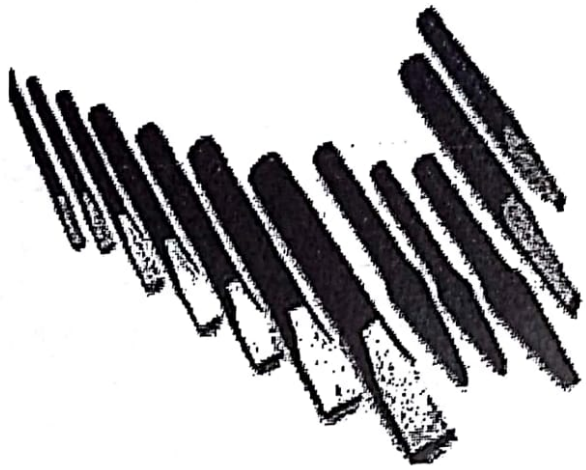


Figure 1.6 Chisels

1.7.3 Reamers

1. One should remove all bars from the reamed holes.
2. Never use your hands to remove chips and cutting fluids from the reamer and work. One should use a piece of cotton waste.

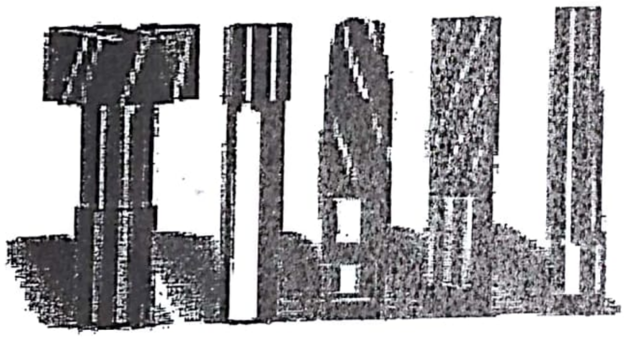


Figure 1.7 Reamers

1.7.4 Taps and Dies

1. One should use a brush to clean away chips formed by hand threading. Never use your hand.
2. One should always wear goggles if the tap, die or threaded piece is to be cleaned with compressed air.
3. Tap operator should also be careful that other person working in the area also wearing goggles.
4. Handle broken taps as you would handle broken glass. They are sharp edges and are dangerous to handle.
5. Wash your hands after using cutting fluid. Skin-rashes caused by some cutting fluids can develop into a serious skin disorder if they are left on the skin for a long period.

6. Take care of any cuts immediately. Infection may occur when injuries are not properly treated.

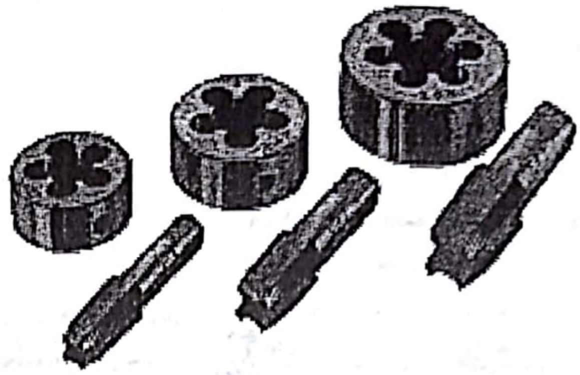


Figure 1.8 Taps and Dies

1.7.5 Abrasives

1. If the lathe is used for polishing make sure that the machine is protected from the abrasive grains that fall from the polishing wheels during polishing. They can cause rapid wear of the precision parts.
2. One should not rub fingers or hand across a piece that has just been polished by abrasive.
3. Cuts and burns should always be treated immediately by using first aid facility.
4. One should remove all abrasive particles by washing them thoroughly after the polishing operation.

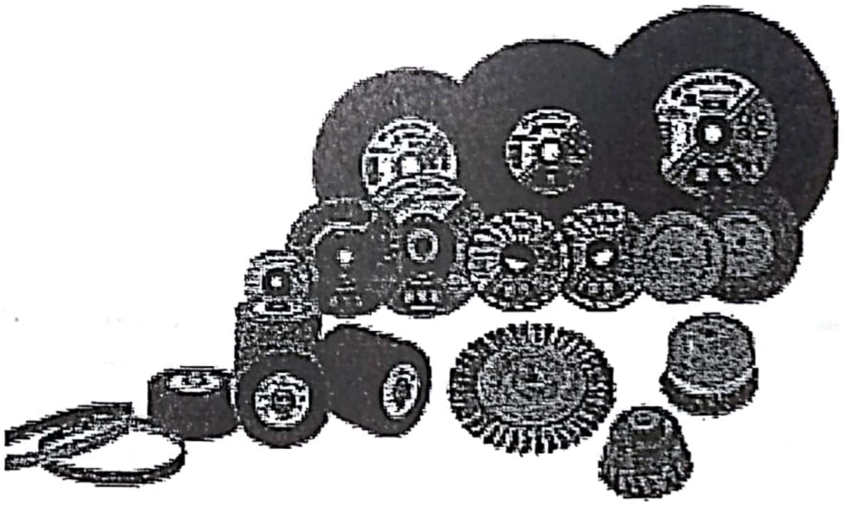


Figure 1.9 Abrasives

1.8 General Safety Precautions while Working in Machine Shop:

The following safety precautions or guidelines are generally adopted for every metal cutting or machining shop. They must be strictly followed for safety. Specific safety guidelines for some of the machine process like lathe, drilling, shaping, planning slotting, grinding, milling, and finishing operations are also described in the following sections.

1. One should use the correct tools and work holding devices recommended for the process.
2. One should hold the work piece and tool securely on the machine.
3. One should clamp the tool correctly. An overhanging tool may cause catastrophic failure of the tool, work piece or the machine tool.
4. One should not try to remove chips from the machine with your hands.
5. Never use compressed air from mouth. Use brush.
6. One should not touch a job-piece with bare hands while doing inspection or removing
7. it from the machine. Use gloves always.
8. One should operate the machine at recommended operating conditions based on work material and tool material combination and other cutting conditions specified.
9. One should use recommended coolant depending upon work-tool material combination.
10. During machining ductile materials, use chip breakers and chip guards.
11. One should re-sharp the tools immediately when it starts producing rough surfaces on the job-piece or produces chatter.
12. One should not run the machines at speed higher than recommended. It may produce vibrations and chatter and damage job-piece, tool, or both.
13. Provide sufficient approach and over travel distances wherever necessary.
14. In case of power failures, switch off the machine and retrieve tool from the workpiece.
15. One should wear goggles to protect eyes from flying chips.
16. Machines are governed by the old clinch garbage input, garbage output. The skill of the operator is often the limiting factor for the machining operation.
17. Stop machine before attempting to clean, removing tool or workpiece.

1.9 FIRST AID

In case of fatal injury first aid provider should call the doctor as soon as possible or to arrange the ambulance for taking the victim to the hospital. He should deal the victim with full sympathy and make early arrangement to call the family member or some responsible member so that adequate arrangements can be made in hospital for the due care of the victim. If breathing has stopped, he or she should be provided artificial respiration immediately. For first aid services, a first-aid box containing the following items is always kept ready during working hours in the shops or nearby working places where there are chances accidents to occur.

Questions	
Note : Support your answer by neat sketches	
Q1	Explain briefly the following: 1. Human Causes of accidents, 2. Environmental Causes of accidents, 3. Mechanical Causes of accidents, 4. Safety Precautions,
Q2	What are the main causes of accidents?
Q3	List the types of common accidents.
Q4	What are the main objectives of industrial safety?
Q5	**Which of the following Statement is Correct?** 1. A large number of accidents can be avoided if proper safety measures and safety rules are adopted in manufacturing areas. 2. Unsafe processes, unsafe design and unsafe construction of building structure may lead to accidents in the plant. 3. The presence of dust fumes and smoke in the working area may causes accidents. 4. A large number of revolving, rotating, reciprocating and moving parts of machinery can be said as the sources of danger and require guarding for protection against accidents. 5. A suitable layout and proper working conditions play an important role in preventing accidents which would have otherwise occurred. 6. In safety plan ,moving path or passage ways should be clearly marked and never be obstructed. 7. Accidents occur because of not using personal protective devices. 8. Accidents commonly occur during use of improper tools. 9. Eyes can be damaged by intense light. Workshops should be ventilated to remove any fumes.

Chapter Two

Materials and Their Properties

Materials and Their Properties

2.1 Introduction:

Materials are an important aspect of engineering design and analysis. The importance of materials science and engineering can be noted from the fact that historical ages have been named after materials. In the customer driven competitive business environment, the product quality is of paramount importance. The product quality has been found to be influenced by the engineering design, type of materials selected and the processing technology employed. Therefore, the importance of materials and their processing techniques cannot be undervalued in today's world. Materials form the stuff of any engineering application or product. It has been found that the engineers do not give adequate attention to this important subject. Moreover, it has not been adequately represented in the course curriculum of various universities. Therefore, it becomes imperative to highlight the importance of engineering materials for all engineers related to the various aspects of engineering applications.

2.2 Classification of Materials:

The first module deals with the classification of the engineering materials and their processing techniques. The engineering materials can broadly be classified as:

a) Metals

b) Polymers.

c) Ceramics.

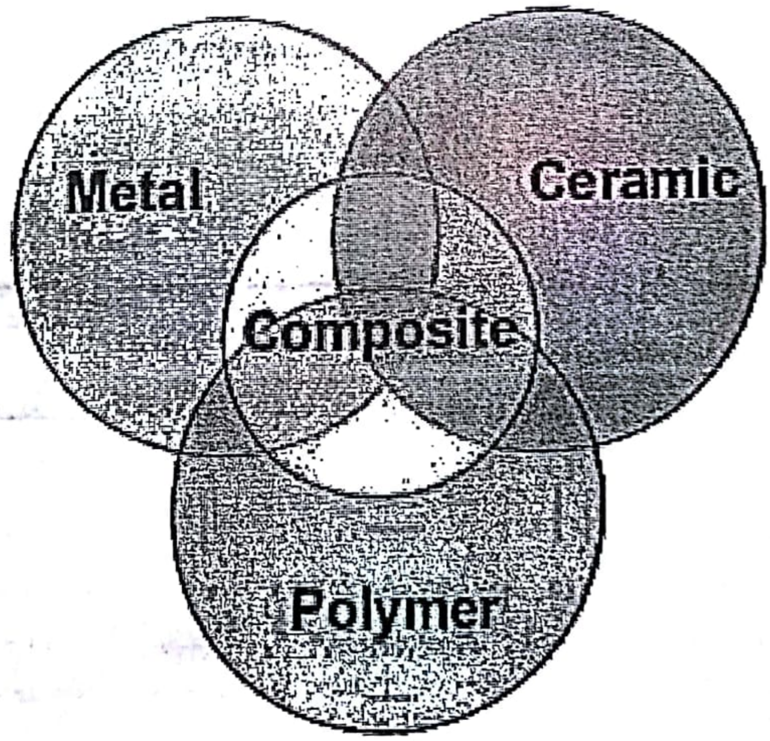


Figure 2.1 Classifications of Engineering materials

2.2.1 Metallic Materials

These materials are inorganic substances which are composed of one or more metallic element and may also contain some non-metallic elements. Examples of **metallic elements** are steel, copper, aluminum and iron. **Non-metallic elements** such as carbon, nitrogen and oxygen may also be contained in metallic materials. **Metals** have a crystalline structure in which the atoms are arranged in an orderly manner. **Metals** are extremely good conductors of electricity and heat and are not transparent to visible light; a polished metal surface a lustrous appearance. Many metals are relatively strong and ductile at room temperature, and many maintain good strength even at high temperature.

2.2.2 Polymeric Materials

Most polymeric materials consist of organic long molecular chains or networks. Structurally, most polymeric materials are non-crystalline but some consist of mixtures of crystalline and non-crystalline regions. The strength and ductility of polymeric materials vary greatly. Because of the nature of their internal structure, most polymeric materials are poor conductors of electricity. Some of these materials are good insulators and are used for electrical isolative applications.

Figure 2.2. Plastic materials

2.2.3 Ceramics Materials

Ceramics materials are inorganic materials which consist of metallic and non-metallic elements chemically bonded together. **Ceramics materials** can be crystalline, non-crystalline, or mixture of both. Most ceramics materials have high hardness and high-temperature strength but tend to have mechanical brittleness. Lately, new ceramics materials have been developed for engine applications. **Advantages of ceramic** materials for engine applications are light weight, high strength and hardness, good heat and wear resistance, reduced friction, and insulative properties.

The insulative property along with high heat and wear resistance of many ceramics make them useful for furnace lining for high-temperature liquid metals such as steel. Important space applications for ceramics are the ceramics tiles for the space shuttle. Silica, Glasses, Concrete, Cement, Ferrites, Granite etc., are ceramics.

2.2.4 Composite Materials

Composite materials are mixtures of two or more materials. Fiber glass is a familiar example, in which glass fibers are embedded within a polymeric material. A composite is designed to display a combination of the best characteristics of each of the component materials. Fiber glass acquires strength from the glass and flexibility from the polymer. Another example of the use of composites is glass-reinforced polyphenylene sulfide (PPS) for oil field fitting. This application utilizes the excellent corrosion resistance of this material.

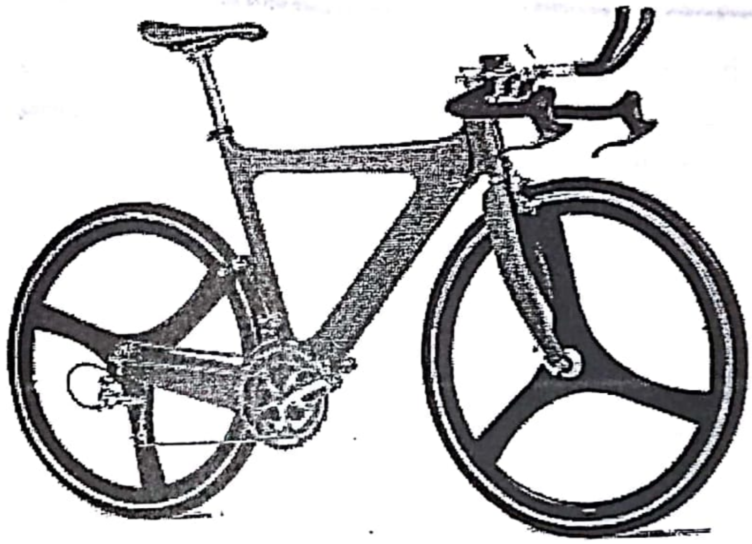


Figure 2.3 Example for Composite material

Characteristic Properties of major Classes		
Metals	**polymers**	**Ceramics**
Hard but malleable Shiny Little color Intermediate melting temp. Conduct electricity High density Difficult to burn	Stiff or flexible Dull Colorless Low melting temp. Nonconductive Low density Flammable	Hard but brittle Shiny if glazed Many colors Highest melting temp. Nonconductive Intermediate density Not flammable

2.3 General Properties of Engineering Materials

The principle properties of materials which are of importance to the engineer in selecting materials. These can be broadly divided into:

2.3.1 MECHANICAL PROPERTIES:

Under the action of various kinds of forces, the behavior of the material is studied that measures the strength and lasting characteristic of a material in service. The mechanical properties of materials are of great industrial importance in the design of tools, machines and structures. Theses properties are structure sensitive in the sense that they depend upon the crystal structure and its bonding forces, and especially upon the nature and behavior of the imperfections which- exist within the crystal itself or at the grain boundaries.

The mechanical properties of the metals are those which are associated with the ability of the material to resist mechanical forces and load. The main mechanical properties of the metal are strength, stiffness, elasticity, plasticity, ductility, malleability, toughness, brittleness, hardness, formability, castability and weldability. These properties can be well understood with help of tensile test and stress strain diagram. The few important and useful mechanical properties are explained below.

2.3.1.1 Elasticity

It is defined as the property of a material to regain its original shape after deformation when the external forces are removed. It can also be referred as the power of material to come back to its original position after deformation when the stress or load is removed. It is also called as the tensile property of the material.

2.3.1.2 Strength

Strength is defined as the ability of a material to resist the externally applied forces with breakdown or yielding. The internal resistance offered by a material to an externally applied force is called stress. The capacity of bearing load by metal and to withstand destruction under the action of external loads is known as strength. The stronger the material the greater the load it can withstand. This property of material therefore determines the ability to withstand stress without failure. Strength varies according to the type of loading. It is always possible to assess tensile, compressive, shearing and torsional strengths. The maximum stress that any material can withstand before destruction is called its ultimate strength. The tenacity of the material is its ultimate strength in tension.

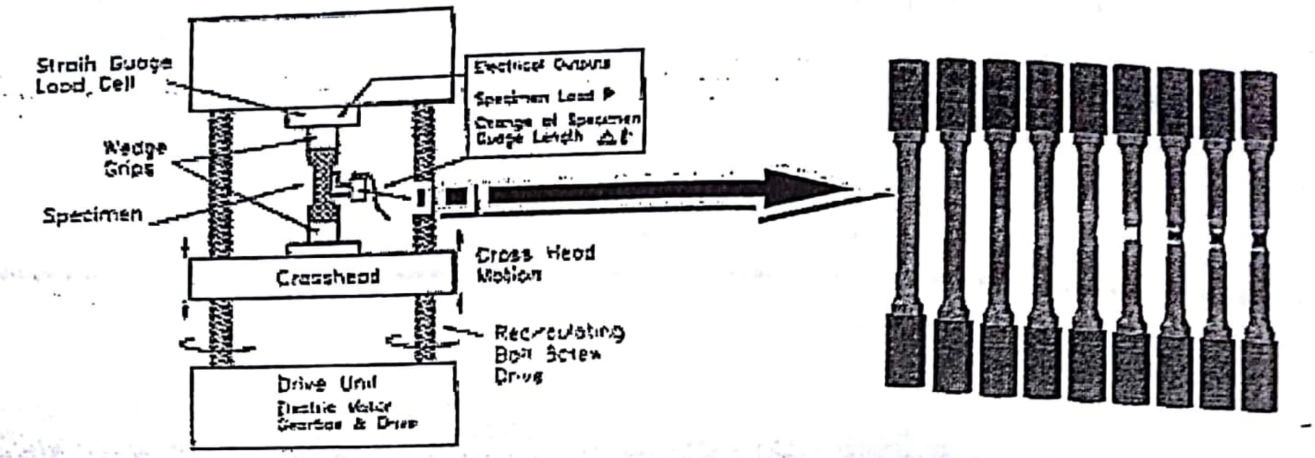


Figure 2.4 Tensile test

2.3.1.3Plasticity

Plasticity is defined the mechanical property of a material which retains the deformation produced under load permanently. Plastic deformation takes place only after the elastic range of material has been exceeded. Such property of material is important in forming, shaping, extruding and many other hot or cold working processes. Materials such as clay, lead, etc. are plastic at room temperature and steel is plastic at forging temperature. This property generally increases with increase in temperature of materials.

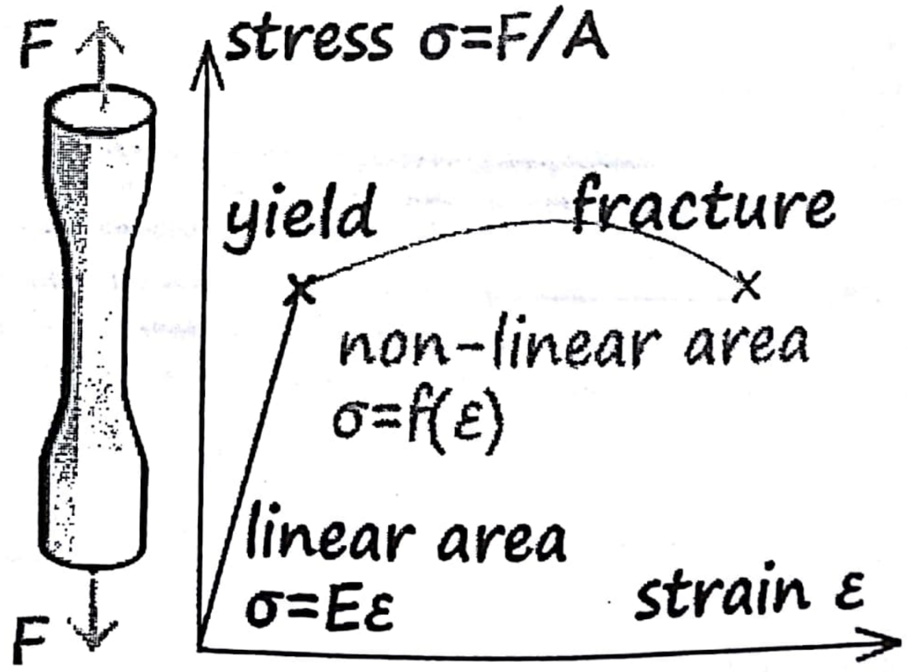


Figure 2.5 Material behaviors under the Tension Load

2.3.1.4 Ductility

Ductility is termed as the property of a material enabling it to be drawn into wire with the application of tensile load. A ductile material must be strong and plastic. The ductility is usually measured by the terms, percentage elongation and percent reduction in area which is often used as empirical measures of ductility. The materials those possess more than 5% elongation are called as ductile materials. The ductile material commonly used in engineering practice in order of diminishing ductility are mild steel, copper, aluminum, nickel, zinc, tin and lead.

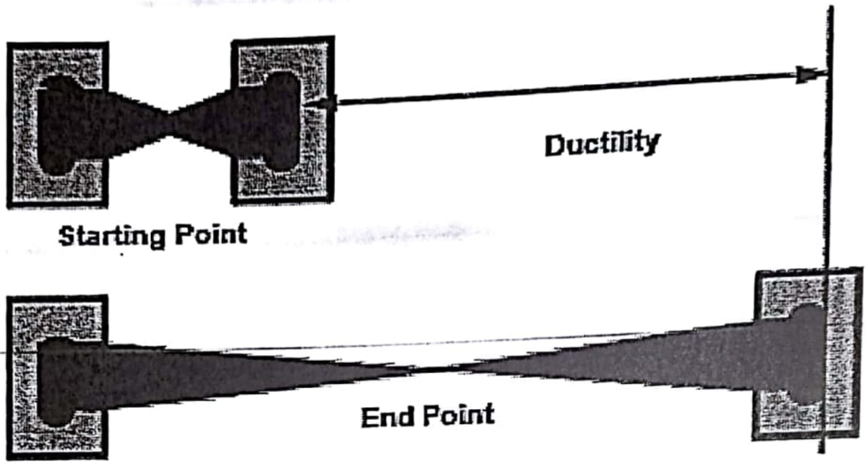


Figure 2.6 Ductility of Materials

2.3.1.5 Malleability

Malleability is the ability of the material to be flattened into thin sheets unde applications of heavy compressive forces without cracking by hot or cold working means. I is a special case of ductility which permits materials to be rolled or hammered into thi sheets. A malleable material should be plastic but it is not essential to be so strong. Th malleable materials commonly used in engineering practice in order of diminishin malleability are lead, soft steel, wrought iron, copper and aluminum. Aluminum, copper, tin lead, steel, etc. are recognized as highly malleable metals.

Figure 2.7 Malleability of Materials

2.3.1.6 Hardness

Hardness is defined as the ability of a metal to cut another metal. A harder metal can always cut or put impression to the softer metals by virtue of its hardness. It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc.

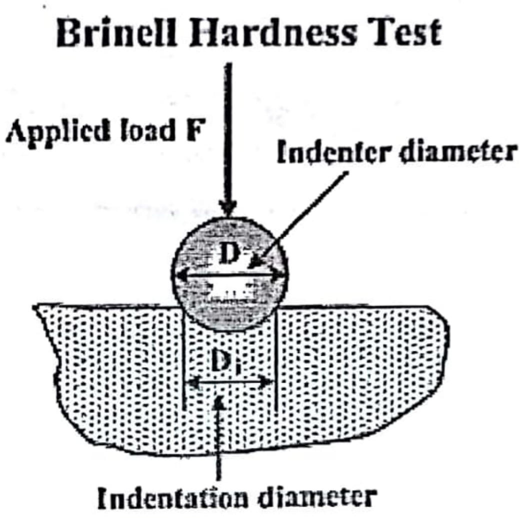


Figure 2.8 Hardness Test

2.3.1.7 Creep

When a metal part when is subjected to a high constant stress at high temperature for a longer period of time, it will undergo a slow and permanent deformation (in form of a crack which may further propagate further towards creep failure) called creep.

2.3.1.8 Formability

It is the property of metals which denotes the ease in its forming in to various shapes and sizes. The different factors that affect the formability are crystal structure of metal, grain size of metal hot and cold working, alloying element present in the parent metal. Metals with small grain size are suitable for shallow forming while metal with size are suitable for heavy forming. Hot working increases formability. Low carbon steel possesses good formability.

2.3.1.9 Brittleness

Brittleness is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. The materials having less than 5% elongation under loading behavior are said to be brittle materials. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Glass, cast iron, brass and ceramics are considered as brittle material.

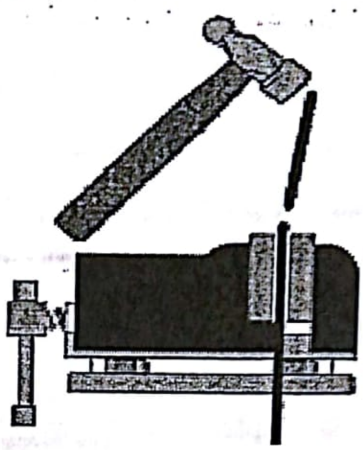


Figure 2.9 Brittleness of Materials

2.3.1.10 Toughness

It is the ability of the materials to withstand bending.

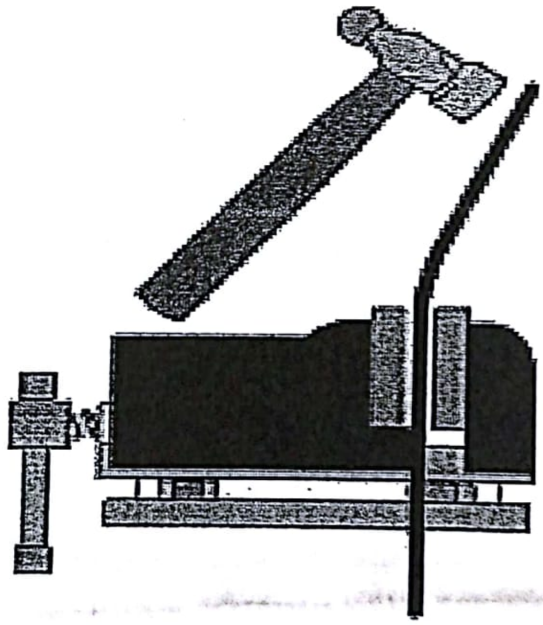


Figure 2.10 Toughness of Materials

2.3.1.11 Castability

. Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. Cast iron, aluminum and brass are possessing good castability.

2.3.1.12 Weldability

Weldability is defined as the property of a metal which indicates the two similar or dissimilar metals are joined by fusion with or without the application of pressure and with or without the use of filler metal (welding) efficiently. Metals having weldability in the descending order are iron, steel, cast steels and stainless steels.

2.3.2 PHYSICAL PROPERTIES

The important physical properties of the metals are density, color, size and shape (dimensions),
specific gravity, porosity, luster etc. Some of them are defined as under.

2.3.2.1 Density

Mass per unit volume is called as density. In metric system its unit is kg/mm3. Because of very low density, aluminum and magnesium are preferred in aeronautic and transportation applications.

$$density\ (\rho) = \frac{mass\ (m)}{volume\ (V)}$$

$$\text{Relative density (d)} = \frac{\text{Density of the material}}{\text{Density of pure water at } 4^{\circ}\text{C}}$$

2.3.2.2 Color

It deals the quality of light reflected from the surface of metal. Many metals have specific colors that distinguish them from others. For example, brass and gold are yellow, silver is white, copper is reddish brown, aluminum is white, Tin is silvery white. Grey Cast Iron is grayish black.

Luster: It is the ability of a metal to reflect light when finely polished. It is also known as brightness of surface. Lusters of some metals/alloys are as under:

Aluminum, Antimony, Zinc, Gold ------------------ Bright
Silver, Stainless Steel, Chromium --------------------- Shining
Tin, cobalt, manganese ---------------------------------- Metallic
Copper, Chilled cast iron -------------------------------- Bright Metallic
Grey cast iron -- Dull

2.3.2.3 Size and shape

Dimensions of any metal reflect the size and shape of the material. Length, width, height, depth, curvature diameter etc. determines the size. Shape specifies the rectangular, square, circular or any other section.

2.3.2.4 Specific Gravity

Specific gravity of any metal is the ratio of the mass of a given volume of the metal to the mass of the same volume of water at a specified temperature.

2.3.2.5 Porosity

A material is called as porous or permeable if it has pores within it.

2.3.2.6 Melting Point (M.P.)

Melting point of metal is that temperature at which a solid material is changed into liquid. Pure metal possess a specific value of melting point. Low melting point metals are used in safety devices like fuse plug, fuse wires, boiler safety devices etc.

Melting Point of some common metals			
Tin	=232 °C	Nickel	= 1452 °C
Lead	= 327 °C	Cobalt	= 1480 °C
Aluminum	= 659 °C	Iron	= 1535 °C
Silver	= 960 °C	Chromium	= 1615 °C
Copper	= 1083 °C	Tungsten	= 3410 °C

2.3.3 Chemical Properties

The study of chemical properties of materials is necessary because most of the engineering materials, when they come in contact with other substances with which they can react, suffer
from chemical deterioration of the surface of the metal. Some of the chemical properties of the metals are corrosion resistance, chemical composition and acidity or alkalinity. Corrosion is the gradual deterioration of material by chemical reaction with its environment.

2.3.4 Thermal Properties

The study of thermal properties is essential in order to know the response of metal to thermal changes i.e. lowering or raising of temperature. Different thermal properties are thermal conductivity, thermal expansion, specific heat, melting point, thermal diffusivity.

2.3.5 Electrical Properties

The various electrical properties of materials are conductivity, temperature coefficient of resistance, dielectric strength, resistivity, and thermoelectricity. These properties are defined as under.

2.3.5.1Conductivity

Conductivity is defined as the ability of the material to pass electric current through it easily i.e. the material which is conductive will provide an easy path for the flow of electricity through it.

2.3.5.2 Temperature Coefficient of Resistance

It is generally termed as to specify the variation of resistivity with temperature.

2.3.5.3 Dielectric Strength

It means insulating capacity of material at high voltage. A material having high dielectric strength can withstand for longer time for high voltage across it before it conducts the current through it.

2.3.5.4 Resistivity

It is the property of a material by which it resists the flow of electricity through it.

2.3.5.5 Thermoelectricity

If two dissimilar metals are joined and then this junction is heated, a small voltage (in the milli-volt range) is produced, and this is known as thermoelectric effect. It is the base of the thermocouple. Thermo -couples are prepared using the properties of metals.

2.3.6 Magnetic Properties

Magnetic properties of materials arise from the spin of the electrons and the orbital motion of electrons around the atomic nuclei. In certain atoms, the opposite spins neutralize one another, but when there is an excess of electrons spinning in one direction, magnetic field is produced. Many materials except ferromagnetic material which can form permanent magnet, exhibit magnetic affects only when subjected to an external electro-magnetic field. Magnetic properties of materials specify many aspects of the structure and behavior of the matter. Various magnetic properties of the materials are magnetic hysteresis, coercive force and absolute permeability which are defined as under.

Questions	
Note : Support your answer by neat sketches	
Q1	Explain briefly the following: 1. Elasticity. 2. Plasticity. 3. Brittleness. 4. Toughness.
Q2	What are the-main classes of engineering materials?
Q3	Define a composite material. Give an example of a composite material.
Q4	Define polymeric materials. Give examples of polymeric materials.
Q5	Which of the following Statement is Correct? 1. Elasticity: It is the ability of a material to deform under load and return to its original size and shape when the load is removed. 2. Plasticity: This property is the exact opposite to elasticity, while the ductility and malleability are particular cases of the property of the plasticity. 3. Brittleness: It is the property of a material that shows little or no plastic deformation before fracture when a force is applied. 4. Toughness: It is the ability of the materials to withstand bending. 5. The melting temperatures and the recrystallisation temperatures have a great effect on the materials and the alloys of the materials properties and as a result on its applications. 6. Luster: It is the ability of a metal to reflect light when finely polished. 7. Castability is defined as the property of metal, which indicates the ease with it can be casted into different shapes and sizes. 8. A ductile material must be strong and plastic. 9. Composite materials are mixtures of two or more materials. 10. Formability: It is the property of metals which denotes the ease in its forming in to various shapes and sizes.

Casting

Casting

3.1 Introduction

Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. The solidified object is taken out from the mold either by breaking or taking the mold apart. The solidified object is called casting and the technique followed in method is known as casting process.

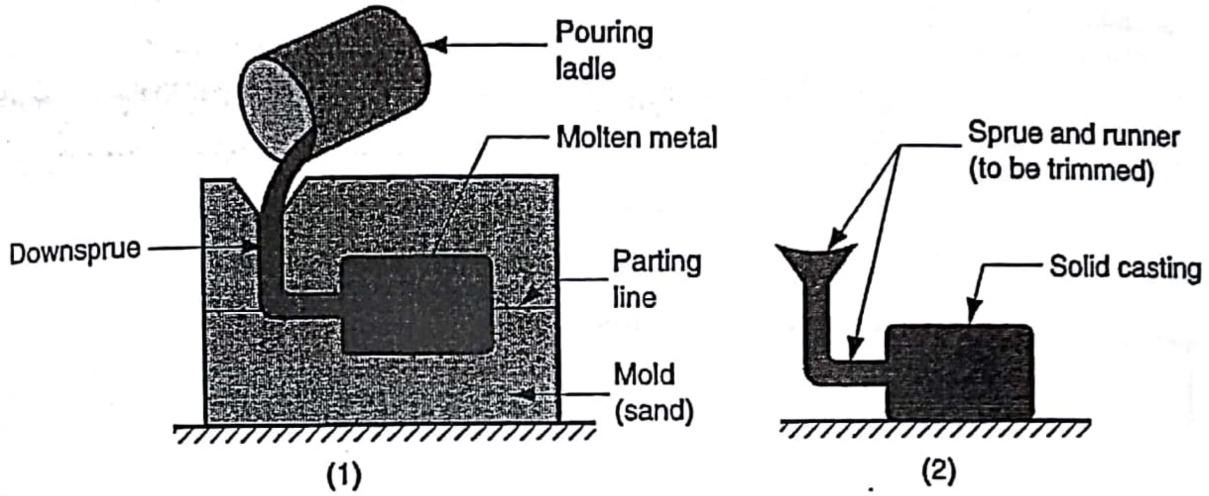


Figure 7.1 Sand Casting

A mold is formed into the geometric shape of a desired part. Molten metal is then poured into the mold; the mold holds this material in shape as it solidifies. A metal casting is created.

Although this seems rather simple, the manufacturing process of metal casting is both a science and an art. Let's begin our study of metal casting with the mold. First, molds can be classified as either open or closed. A closed mold is a container, like a cup, that has only the shape of the desired part. The molten material is poured directly into the mold cavity which is exposed to the open environment as shown in figure 7.2.

This type of mold is rarely used in manufacturing production, particularly for metal castings of any level of quality. The other type of mold is a closed mold; it contains a delivery system for the molten material to reach the mold cavity where the part will harden within the mold. A very simple closed mold is shown in figure 7.3. The closed mold is by far, more important in manufacturing metal casting operations.

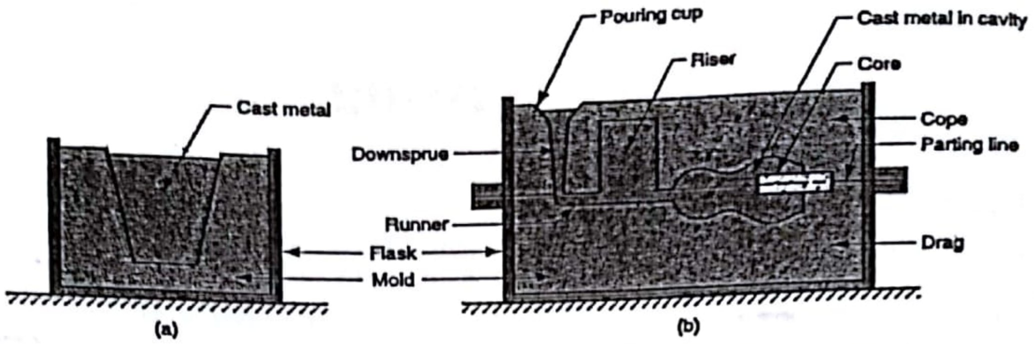


Figure7.2 Open mold **Figure 7.3** Closed mold

There is expendable mold casting and permanent mold casting. As the name implies expendable molds are used for only one metal casting while permanent molds are used for many. When considering manufacturing processes there are advantages and disadvantages to both.

Expendable Mold	**Permanent Mold**
1. Can produce one metal casting only 2. Made of sand, plaster, or other similar material. Binders used to help material hold its form. 3. Mold that metal solidifies in must be destroyed to remove casting 4. More intricate geometries are possible for casting	1. Can manufacture many metal castings 2. Usually made of metal or sometimes a refractory ceramic 3. Mold has sections that can open or close permitting removal of the casting 4. Need to open mold limits part shapes

3.2 Patterns

Expendable molds require some sort of pattern. The interior cavities of the mold in which the molten metal will solidify are formed by the impression of this pattern. Pattern design is crucial to success in manufacture by expendable mold metal casting. The pattern is a geometric replica of the metal casting to be produced. It is made slightly oversize to compensate for the shrinkage that will occur in the metal during the casting's solidification, and whatever amount of material that will be machined off the cast part afterwards. Although machining will add an extra process to the manufacture of a part; machining can improve surface finish and part dimensions considerably. Also increasing the machine finish allowance will help compensate for unknown variables in shrinkage, and reduce trouble from areas of the metal casting that may have been originally too thin or intricate.

3.2.1 Pattern Material

The material from which the pattern is made is dependent upon the type of mold and metal casting process, the casting's geometry and size, the dimensional accuracy required, and the number of metal castings to be manufactured using the pattern. Patterns can be made from wood, like softwood, or hardwood, various plastics, or metal like aluminum, cast iron, or steel. In most manufacturing operations, patterns will be coated with a parting agent to ease their removal from the mold.

3.3 Cores

For metal castings with internal geometry cores are used. A core is a replica, (actually an inverse), of the internal features of the part to be cast. Like a pattern the size of the core is designed to accommodate for shrinkage during the metal casting operation, and machine allowance. Unlike a pattern a core remains in the mold while the metal is being poured. Hence a core is usually made of a similar material as the mold. Once the metal casting has hardened the core is broken up and removed much like the mold. Depending upon the location and geometry of the core within the casting, it may require that it is supported during the operation to prevent it from moving or shifting. Structural supports that hold the core in place are called chaplets. The chaplets are made of a material with a higher melting temperature than the casting's material,

When manufacturing by metal casting consideration of the mold is essential. The pattern is placed in the mold and the mold material is packed around it. The mold contains two parts, the drag (bottom), and the cope (top). The parting line between the cope and drag allows for the mold to be opened and the pattern to be removed once the impression has been made.

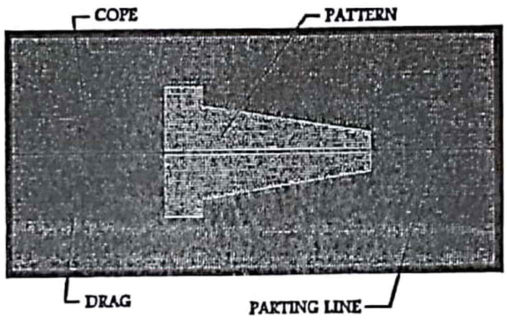


Figure 7.4 The pattern

The core is placed in the metal casting after the removal of the pattern. Figure 7.5 shows the pattern impression with the core in place.

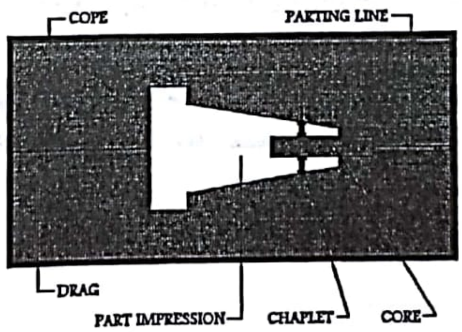


Figure 7.5 The pattern impression

Now the impression in the mold contains all the geometry of the part to be cast. This metal casting setup, however, is not complete. In order for this mold to be functional to manufacture a casting, in addition to the impression of the part, the mold cavity will also need to include a gating system. Sometimes the gating system will be cut by hand or in more adept manufacturing procedures the gating system will be incorporated into the pattern along with the part. Basically a gating system functions during the metal casting operation to facilitate the flow of the molten material into the mold cavity.

3.4 Elements of a Gating System

Fig. 7.7 shows a mold with all its features, ready for metal casting.

3.4.1 Pouring Basin: This is where the molten metal employed to manufacture the part enters the mold. The pouring basin should have a projection with a radius around it to reduce turbulence.

3.4.2 Down Sprue: From the pouring basin the molten metal for the casting travels through the down sprue. This should be tapered so its cross-section is reduced as it goes downward.

3.4.3 Sprue Base: The down sprue ends at the sprue base. It is here that the casting's inner cavity begins.

3.4.4 Ingate/Choke Area: Once at the sprue base the molten material must pass through the ingate in order to enter the inner area of the mold. The ingate is very important in flow regulation during the metal casting operation.

3.4.5 Runners: Runners are passages that distribute the liquid metal to the different areas inside the mold.

3.4.5 Main Cavity: The impression of the actual part to be cast is often referred to as the main cavity.

3.4.6 Vents: Vents help to assist in the escape of gases that are expelled from the molten metal during the solidification phase of the metal casting process.

3.4.7 Risers: Risers are reservoirs of molten material. They feed this material to sections of the mold to compensate for shrinkage as the casting solidifies.

There are different classifications for risers.

a. Top Risers: Risers that feed the metal casting from the top.
b. Side Risers: Risers that feed the metal casting from the side.
c. Blind Risers: Risers that are completely contained within the mold.
d. Open Risers: Risers that are open at the top to the outside environment.
Figure 7.6 illustrates the difference between top risers and side risers.

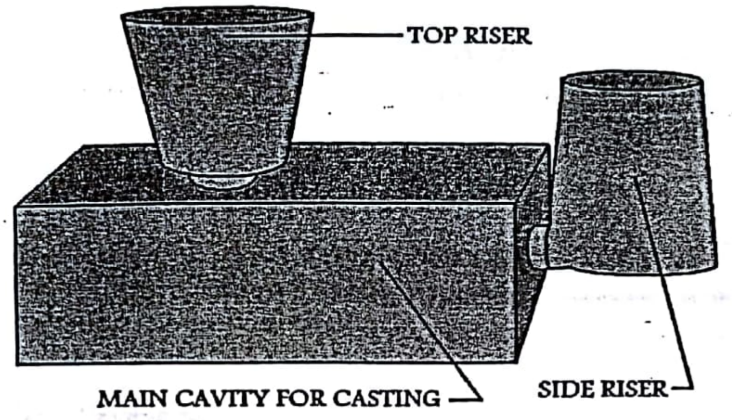


Figure 7.6 Difference between top and side risers

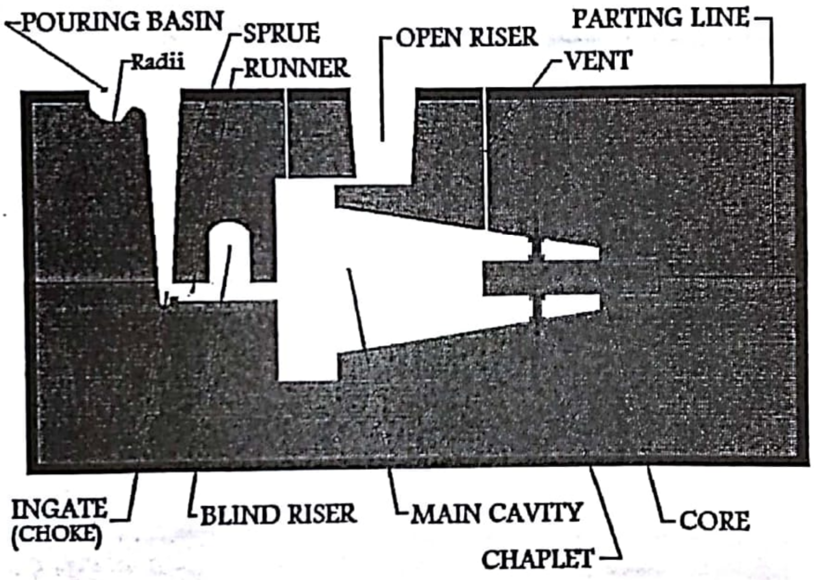


Figure 7.7 Gating system For Casting

3.5 Pouring of the Metal:

When manufacturing by metal casting, pouring refers to the process by which the molten metal is delivered into the mold. It involves its flow through the gating system and into the main cavity (casting itself).

Goal: Metal must flow into all regions of the mold, particularly the casting's main cavity, before solidifying.

3.5.1 Factors of Pouring

3.5.1.1 Pouring Temperature: Pouring temperature refers to the initial temperature of the molten metal used for the casting as it is poured into the mold. This temperature will obviously be higher than the solidification temperature of the metal.

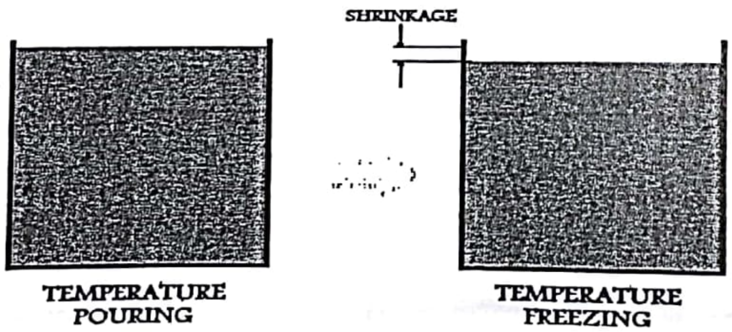
3.5.1.2 Pouring Rate: Volumetric rate in which the liquid metal is introduced into the mold. Pouring rate needs to be carefully controlled during the metal casting operation, since it has certain effects on the manufacture of the part. If the pouring rate it too fast then turbulence can result. If it is too slow the metal may begin to solidify before filling the mold.

3.5.1.3Turbulence: Turbulences is inconsistent and irregular variations in the speed and direction of flow throughout the liquid metal as it travels though the casting.

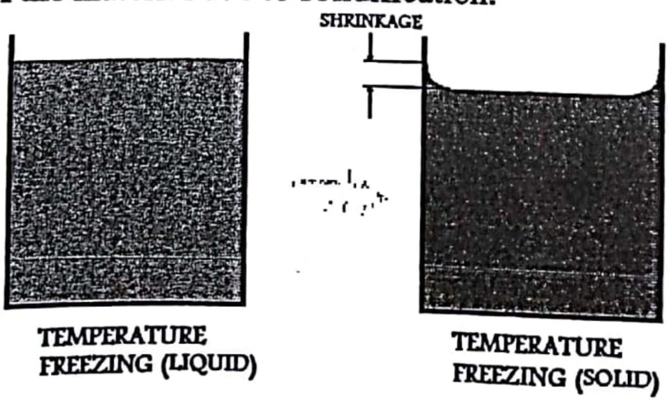
3.5.1.4 Fluidity: Since pouring is a key element in the manufacturing process of metal casting, and the main goal of pouring is to get metal to flow in to all regions of the mold before solidifying.

3.5.1.5Shrinkage: Most materials are less dense in their liquid state than in their solid state, and more dense at lower temperatures in general. Due to this nature a metal casting undergoing solidification will tend to decrease in volume, during the manufacture of a part by casting this decrease in volume is termed shrinkage. Shrinkage of the casting metal occurs in three stages:

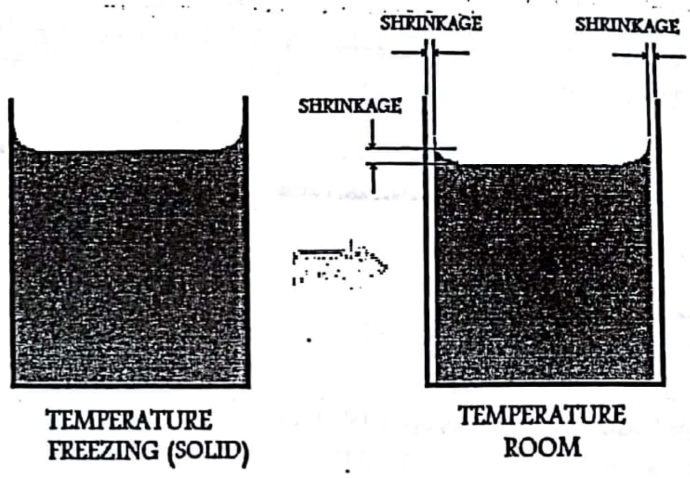
a. Decreased volume of the liquid as it goes from the pouring temperature to the freezing temperature.



b. Decreased volume of the material due to solidification.



c. Decreased volume of the material as it goes from freezing temperature to room temperature.



3.6 Porosity

One of the biggest problems caused by shrinkage, in the manufacture of a cast part, is porosity. It happens in at different sites within the material, when liquid metal can't reach sections of the metal casting where solidification is occurring. As the isolated liquid metal shrinks a porous or vacant region develops.

3.7Cavities

Any cavities in the material, angular or rounded, internal or exposed fit into this category. Cavities as a defect of casting shrinkage would be included here.

3.8 Discontinuities

Cracks, tearing, and cold shuts in the part qualify as discontinuities. Tearing occurs when the casting is unable to shrink naturally and a point of high tensile stress is formed. This could occur, for example, in a thin wall connecting two heavy sections. Cold shuts happen when two relatively cold streams of molten metal meet in the pouring of the casting. The surface at the location where they meet does not fuse together completely resulting in a cold shut.

3.9 Defective Surface:

Defects affecting the surface of the manufactured part. Blows, scabs, laps, folds, scars, blisters, ect.

3.9.1 Incomplete Casting:

Sections of the metal casting did not form. In a manufacturing process causes for incomplete metal castings could be; insufficient amount of material poured, loss of metal from mold, insufficient fluidity in molten material, cross section within casting's mold cavity is too small, pouring was done too slowly, pouring temperature was too low.

3.9.2 Incorrect Dimensions or Shape:

The metal casting is geometrically incorrect. This could be due to unpredicted contractions in the part during solidification. A warped casting. Shrinkage of the casting may have been miscalculated. There may have been problems with the manufacture of the pattern.

3.9.3 Inclusions

Unwanted particles contained within the material act as stress raisers compromising the casting's strength. During the manufacturing process, interaction of the molten metal with the environment including the atmosphere, (chemical reactions with oxygen in particular), and the mold itself can cause inclusions within a metal casting. As with most defects good mold maintenance is important in their control casting.

3.10The Effect of Gases, and Material Selection in Metal Casting

3.10.1 Gases during the Manufacture of a Casting

The molten metal used during the casting process may trap and contain gases. There are various reasons that gases are absorbed into the metal melt during manufacture. Turbulent flow of the casting material through the system may cause it to trap gas from the air. Gases may trapped from material or atmosphere in the crucible when the melt is being prepared. Gases may be trapped from the reaction between the molten metal and the mold material.

Since liquid metal has a much higher solubility than solid metal, as the casting solidifies these gases are expelled. If they cannot escape the casting, they may form vacancies in the material; increasing the casting's porosity.

3.11 Sand

Sand: Product of the disintegration of rocks over long periods of time. Most sand casting operations use silica sand (SiO_2). A great advantage of sand in manufacturing applications is that sand is inexpensive. Another advantage of sand to manufacture products by metal casting processes is that sand is very resistant to elevated temperatures. In fact sand casting is one of the few processes that can be used for metals with high melting temperatures such as steels, nickel, and titanium. Usually sand used to manufacture a mold for the casting process is held together by a mixture of water and clay. A typical mixture by volume could be 89% sand, 4% water, 7% clay. Control of all aspects of the properties of sand is crucial when manufacturing parts by sand casting, therefore a sand laboratory is usually attached to the foundry.

3.12 Requirements of Good Moulding Sand:

1. It must allow the free passage of air and gases generated when in contact with molten metal.
2. When rammed it must retain the shape given to it and resist the pressure of the molten metal.
3. It must be able to withstand high temperature without fusing.

3.13 Inspections of Casting

Following methods are employed to inspect the casting.

1. Destructive inspection method. In this type of inspection the casting sample is destroyed during inspection. This method is used to test mechanical properties, e.g., tensile strength, hardness etc. These tests are performed on the test bars or pieces cut from the casting sample.
2. Nondestructive inspection method.

Following are the various methods of non-destructive inspection:

a) Visual inspection.
b) Dimensional inspection.
c) Pressure testing.
d) Radiographic inspection.
e) Magnetic particle inspection.
f) Fluorescent penetrate.
g) Eddy current inspection.

3.14 Types of Casting

1. Sand casting: Commonly used method involves pouring molten metal into a cavity in a mass of packed sand.
2. Shell mould casting:
3. Precision investment casting: It employs techniques that enable very smooth, highly accurate casting to be made from both ferrous and non ferrous metal.
4. Plaster mould casting:
5. Permanent mould casting:
6. Die casting:
7. Centrifugal casting:

3.14.1 Centrifugal Casting

The manufacturing process of centrifugal casting is a metal casting technique that uses the forces generated by centripetal acceleration to distribute the molten material in the mold. Centrifugal casting has many applications in manufacturing industry today. The process has several very specific advantages. Cast parts manufactured in industry include various pipes and tubes, such as sewage pipes, gas pipes, and water supply lines, also bushings, rings, the liner for engine cylinders, brake drums, and street lamp posts. The molds used in true centrifugal casting manufacture are round, and are typically made of iron, steel, or graphite.

Some sort of refractory lining or sand may be used for the inner surface of the mold. Centrifugal casting. In this case, several casting cavities are located around the outer portion of a mould, and metal is fed to these cavities by radial gates from the centre, either single or stack can be used. The mould cavities are filled under pressure from the centrifugal force of the metal as the mould is rotated.

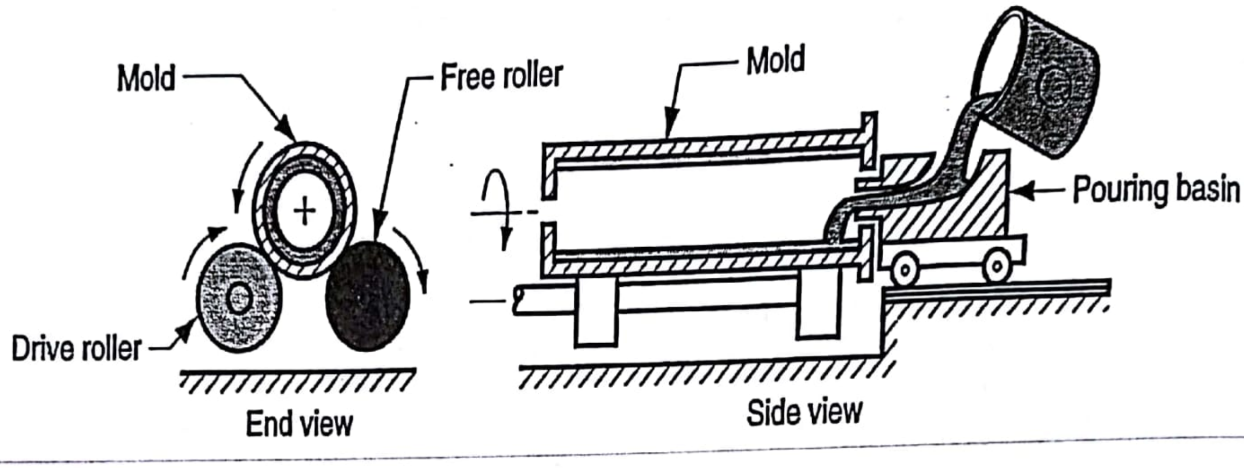


Figure 7.9 Centrifugal casting unit

The casting will harden as the mold continues to rotate.

It can be seen that this casting process is very well suited for the manufacture of hollow cylindrical tubes. The forces used in this technique guarantee good adhesion of the casting material to the surface of the mold. Thickness of the cast part can be determined by the amount of material poured. The outer surface does not need to be round, square or different polygonal and other shapes can be cast.

3.15 The Recommended tests for the sand casting:

1. Fineness test or Sand grain size test.
2. Permeability test.
3. Strength test.
4. Moisture content test.
5. Clay content test.
6. Mould hardness test.

3.15.1 Fineness test. This test determines the size of grains and the distribution of grains of different sizes in the moulding sand.

3.15.2 Permeability test. Permeability (or porosity of the moulding sand) is the measure of its ability to permit air to flow through it.

3.15.3 Strength test: The strength of moulding sands can be carried out on the universal sand strength testing machine. The strength can be measured in compression, shear and tension.

3.15.4 Moisture content test. Moisture content may be determined by loss of weight, after evaporation.

Dry-Sand Molds:
Dry-Sand molds are baked in an oven, (at 300F - 650F for 8-48 hours), prior to the casting operation, in order to dry the mold. Dry-Sand molds are manufactured using organic binders rather than clay.

3.16The Pattern

In sand casting a few different types of patterns may be used in the process.

3.16.1 Solid Pattern

This is a one piece pattern representing the geometry of the casting. It is an easy pattern to manufacture, but determining the parting line between cope and drag is more difficult for the foundry worker.

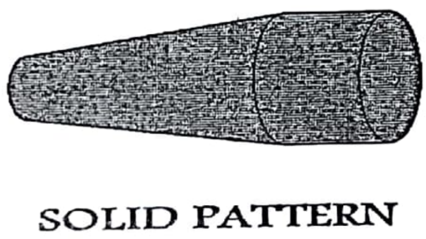


Figure 7.10 Sold pattern

3.16.2 Split Pattern

The split pattern is comprised of two separate parts that when put together will represent the geometry of the casting. When placed in the mold properly the plane a which the two parts are assembled should coincide with the parting line of the mold. This makes it easier to manufacture a pattern with more complicated geometry. Also mold setup is easier since the patterns placement relative to the parting line of the mold is predetermined.

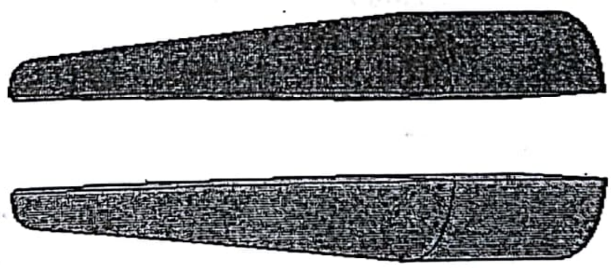


Figure 7.11 Split pattern

3.17 Cope and Drag Pattern

The cope and drag pattern is also typical in casting manufacture for high production industry runs. The cope and drag pattern is the same as the match plate pattern in that it is a two piece pattern representing the casting and divided at the parting line. Each of the two halves are mounted on a plate for easy alignment of the pattern and mold. The difference between the cope and drag pattern and the match plate pattern is that in the match plate pattern the two halves are mounted together, where as in the cope and drag pattern the two halves are separate. The cope and drag pattern enables the cope section of the mold, and the drag section of the mold to be created separately and latter assembled before the pouring of the casting.

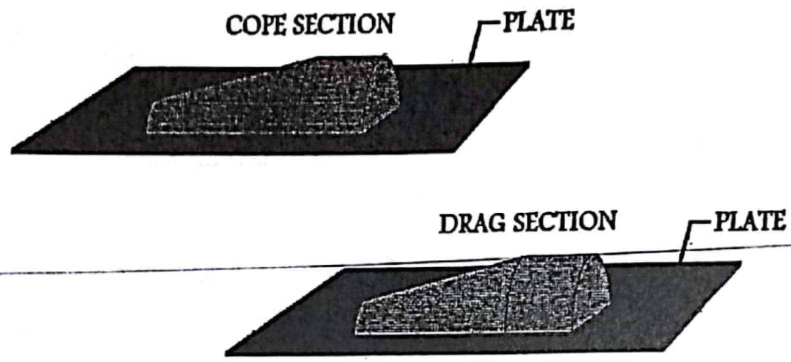


Figure 7.12 Cope and Drag pattern

In manufacturing industry a gating system (not shown) is often incorporated as part of the pattern particularly for a cope and drag pattern. Patterns can be made of different materials, and the geometry of the pattern must be adjusted for shrinkage, machine finish, and distortion. Pattern basics are covered in detail in the patterns section.

3.18 Cores

Cores form the internal geometry of a casting. Cores are placed in the mold, and remain there during the pouring phase of the manufacturing process. The metal casting will solidify around the core. Core basics are covered in detail in the cores section. Cores are made of the highest quality sand and are subject to extreme conditions during the casting operation. Cores must be strong and permeable; also, since the metal casting will shrink onto the core, cores must have sufficient collapsibility.

3.19 The Sand Casting Operation

The sand casting operation involves the pouring of the molten metal into the sand mold, the solidification of the casting within the mold, and the removal of the casting. The casting operation is covered in detail on the Metal Casting Operation page.

Of specific interest to sand casting would be; the effect and dissipation of heat through the particular sand mold mixture during the casting's solidification, the effect of the flow of liquid metal on the integrity of the mold, (mold sand mixture properties and binder issues), and the escape of gases through the mixture. Sand usually has the ability to withstand extremely high temperature levels, and generally allows the escape of gases quite well. Manufacturing with sand casting allows the creation of castings with complex geometry. Sand casting manufacture, however, only imparts a fair amount of dimensional accuracy to the cast part.

After the sand casting is removed from the sand mold it is shaken out, all the sand is otherwise removed from the casting, and the gating system is cut off the part. The part may then undergo further manufacturing processes such as heat treatment, machining, and or shaping. Inspection is always carried out on the finished part to evaluate the effectiveness and satisfaction of its manufacture.

3.20 Melting Equipment

The main types of furnaces used in foundries for melting various varieties of ferrous and non-ferrous metals and alloys are:

1- Crucible furnace:

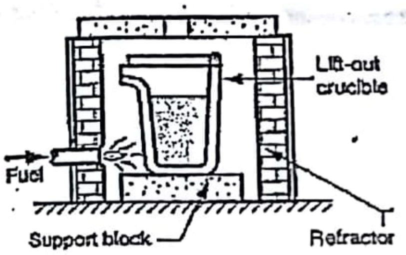


Figure 7.13 Lift-out-crucible

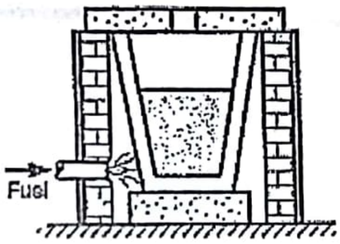


Figure 7.14 Stationary pot

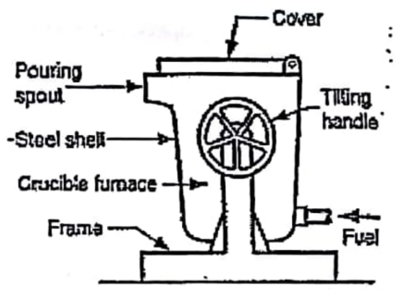


Figure 7.15 Tilting pot

2- Induction furnace:

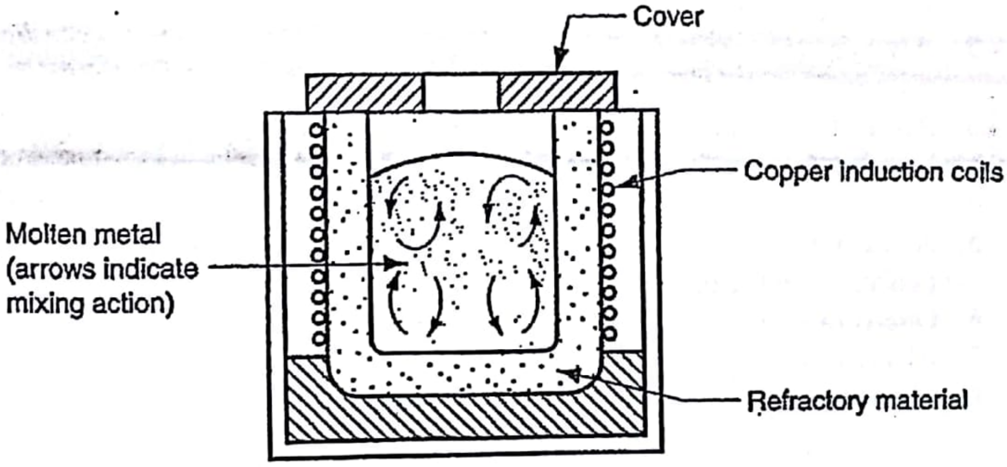


Figure 7.16 Induction furnace

3- Arc furnace.
4- Open hearth furnace.
5- Cupola.

3.21ADVANTAGES AND DISADVANTAGES OF CASTING PROCESSES:

3.21.1 Advantages:

1. Cheapest method of fabrication.
2. Objects of large size can be produced easily.
3. The objects having complex and complicated shapes, which cannot be produced by another method of production, can usually be cast.
4. Castings with wide range of properties can be produced by adding various alloying elements.
5. By proper selection the type of moulding and casting process, required dimensional accuracy in casting can be achieved.
6. Almost all the metals and alloys and some plastics can be cast.
7. The number of castings can vary from very few to several thousands.

3.21.2 Disadvantages

1. The time required for the process of making casting is quite long.
2. Metal casting involves melting of metal which is a high energy consuming process.
3. The working conditions in foundries are quite bad due to heat, fume etc., compared to other processes.
4. Metal casting is still highly labor -intensive compared to other processes.
5. The productivity is less than other automatic processes.

3.22 Safety Precautions while Working in Casting shop

. Similar to other manufacturing processes, the following safety precautions need to be taken in the casting shop also.

1. One should use mask to avoid excessive inhalation of the dust, which may cause serious problem to health.
2. Always wear protective clothes to keep safe from the heat radiating from the melting process.
3. All foundry men should wear protective clothes, glasses, shoes, and gloves while handling molten metal for casting process.
4. One should be alert as severe burn injury can result from spillage of the molten metal.
5. Always use proper ventilation to protect from molten metal fumes and gases that evolve from the mould during pouring.
6. One should not touch hot moulds and castings.
7. Always use earplugs to safeguard against the heavy noise.
8. One should always keep clean the work area.

Questions	
Note: Support your answer by neat sketches	
Q1:	List the various methods of non-destructive inspection.
Q2:	What are the main requirements of good sand moulding?
Q3:	List the main advantages and disadvantages of casting processes.
Q4:	Explain briefly the following: 1.Expendable Mold, 2. Permanent Mold, 3. Open Mold, 4.Close mold, 5. Centrifugal casting, 6. Patterns, 7.Core, 8. Chaplets, 9. Shrinkage, 10.G.F.N, 11. Split pattern,
Q4	Which of the following Statement is Correct? 1. Casting process is one of the earliest metal shaping techniques known to human being. It means pouring molten metal into a refractory mold cavity and allows it to solidify. 2. The pattern is a geometric replica of the metal casting to be produced. 3. Patterns will be coated with a parting agent to ease their removal from the mold. 4. A core is a replica, (actually an inverse), of the internal features of the part to be cast. 5. If the pouring rate it too fast then turbulence can result. If it is too slow the metal may begin to solidify before filling the mold. 6. The objects having complex and complicated shapes, which cannot be produced by another method of production, can usually be cast. 7. The time required for the process of making casting is quite long. 8. Metal casting is still highly labor -intensive compared to other manufacturing processes.

Forging

Forging

4.1 Introduction

Forging is an oldest shaping process used for the producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammers. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers, small power hammers, die, press or upsetting machine. It consists essentially of changing or altering the shape and section of metal by hammering at a temperature of about 980°C, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith's shop. A metal such as steel can be shaped in a cold state but the application of heat lowers the yield point and makes permanent deformation easier. Forging operation can be accomplished by hand or by a machine hammer. Forging processes may be classified into hot forging and cold forgings and each of them possesses their specific characteristics, merits, demerits and applications.

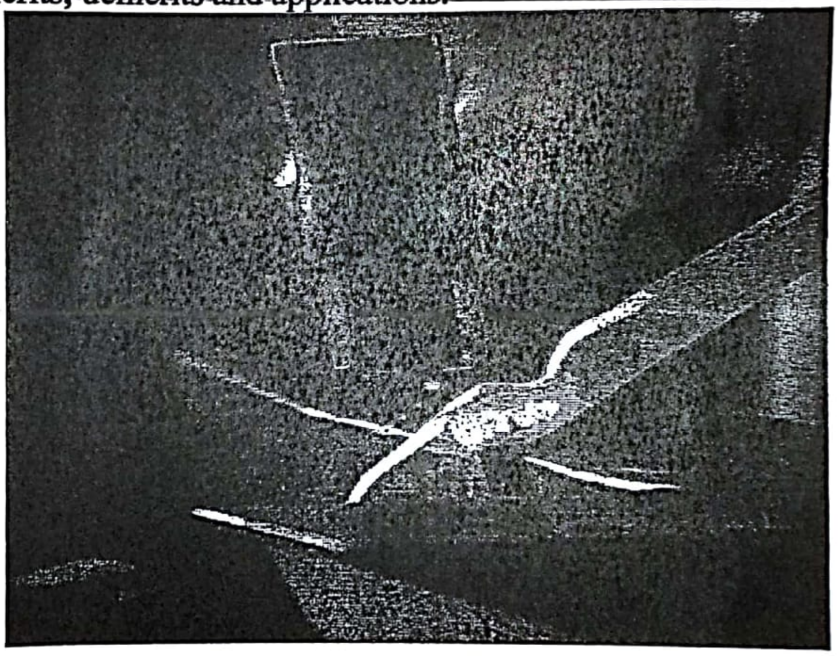


Figure 5.1 Hand Forging

Hand forging process is also known as black-smithy work which is commonly employed for production of small articles using hammers on heated jobs. It is a manual controlled process even though some machinery such as power hammers can also be sometimes used. Black-smithy is, therefore, a process by which metal may be heated and shaped to its requirements by the use of blacksmith tools either by hand or power hammer.

Forging by machine involves the use of forging dies and is generally employed for mass production of accurate articles. In drop forging, closed impression dies are used and there is drastic flow of metal in the dies due to repeated blow or impact which compels the plastic metal to conform to the shape of the dies. The final shape of the product from raw material is achieved in a number of steps. There are some advantages, disadvantages and applications of forging operations which are given as under.

4.2 Cold and Hot Working

4.2.1. Cold Working

When plastic deformation of metal is carried out at temperature below the recrystallisation temperature the processes performed on metals are termed as cold working. The various cold working processes are:

4.2.1.1 Advantages of cold working

1. Handling of material is easy.
2. Good surface finish and better dimensional accuracy.
3. Energy saving since heating is not required.
4. Strength, fatigue and wear properties are improved.
5. Minimum contamination because of low working temperature.
6. No possibility of de-carbonization of the surface.
7. Economical for smaller sizes.
8. Highly suitable for mass production and automation, because of low working temperatures.
9. The physical properties of metals that do not respond to heat treatment can be improved by cold working.
10. Thin gauge sheet can be produced.

4.2.1.2 Disadvantages

1. Ductility of metal is reduced.
2. Deformation energy required is high, so more powerful equipment is required, thus cost is high.
3. Severe stresses are set up, this requires stress relieving, which increases the cost
4. Owing to limited ductility at room temperature, the complexity of shapes that can be readily produced is limited.
5. Cold working, for large deformation, requires several stages with inter stage annealing, which increases the production cost.

Components each as shaft components, flanged components, finished gears and bearing, etc.

4.2.2. Hot Working

When plastic deformation of metal is carried out at temperature above the recrystallisation temperature the processes performed on metals are termed as hot working.

4.2.2.1Recrystallisation

It is a process by which distorted grains of cold worked metal are replaced by new strain free grains during heating above a specific m num temperature called recrystallisation temperature.

1. Recrystallisation temperature is a function of particular metal.
2. Purity of metal: Soluble impurities raise the recrystallisation temperature.
3. Metal/Alloys: Recrystallisation usually occurs at a temperature of about 0.3 T_m in pure metals and about 0.5 T_m, in alloys, where T_m is the melting temperature.

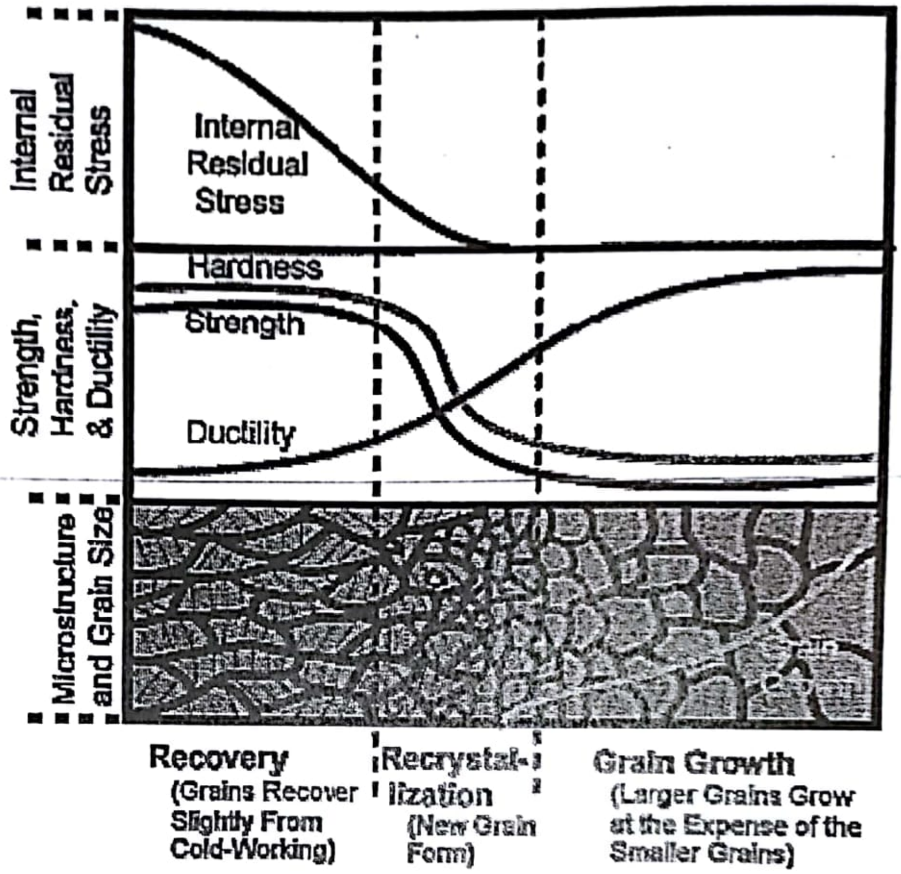


Figure 5.2 Recovery, recrystallisation and grain growth

4. Amount of prior deformation.
5. Annealing time: The longer annealing time decreases required temperature for recrystallisation.
6. Grain size: The final grain size of cold worked metal depends on recrystallisation temperature.

4.2.2.2 Advantages of hot working

1. High production rate (since the process is faster).
2. Very high reduction is possible without fear of fracture.
3. Deformation energy required is low, hence, less powerful equipments are required.
4. Structure can be altered to improve the final properties.
5. The process does not change hardness or ductility of the metal since distorted grains soon change into new undeformed grains.
6. Annealing and stress relieving are not required.

4.2.2.3 Disadvantages

1. Handling of material is not so easy.
2. Heat resistant tools required (which are expensive).
3. High temperature may promote undesirable reactions.
4. Close tolerances cannot be held because of non-uniform cooling and thermal contraction.
5. Surface finish is poor because of scale formation.
6. Metallurgical structure may be non-uniform because of cooling after deformation.

4.3 Forgeable Materials

Forgeable metals are purchased as hot-rolled bars or billets with round or rectangular cross the sections. Forgeable materials should possess the required ductility and proper strength. Some forgeable metals are given as under in order of increasing forging difficulty.

Some Forgeable Materials

1. Aluminum alloys
2. Magnesium alloys
3. Copper alloys.
4. Carbon and low alloy steels
5. Martensitic stainless steels
6. Austenitic stainless steels
8. Titanium alloys
9. Columbium alloys
10. Tantalum alloys
11. Molybdenum alloys
12. Tungsten alloys
13. Beryllium.

4.4 Heating Devices

Forgeable metals are heated either in a hearth or in a furnace. The hearths are widely used for heating the metals for carrying out hand forging operations. Furnaces are also commonly used for heating metals for heavy forging. The forging job is always heated to the correct forging temperature in a hearth or in a furnace located near the forging arrangements. Gas, oil or electric-resistance furnaces or induction heating classified as open or closed hearths can be used. Gas and oil are economical, easily controlled and mostly used as fuels. Electric heating is the most modern answer to tackle scaling and it heats the stock more uniformly also. In some cases, coal and anthracite, charcoal containing no sulphur and practically no ash are the chief solid fuels used in forging furnaces. Forge furnaces are built raise temperatures up to 1350°C in their working chambers.

4.4.1 Rotary-hearth furnaces

These are set to rotate slowly so that the stock is red to the correct temperature during one rotation. These can be operated by gas or oil fuels.

4.4.2 Continuous or conveyor furnaces

These furnaces are of several types and are preferred for larger stock. They have an air or oil-operated cylinder to push stock end-to-end through a narrow furnace. The pieces are charged at one end, conveyed through the furnace and moved at other end at the correct temperature for the forging work.

4.4.3 Induction furnaces

These furnaces are very popular because induction greatly decreases scale formation and can often be operated by one person. The furnace requires less maintenance than oil or gas-fired furnaces. In induction furnaces the stocks are passed through induction coils in the furnaces. Delivery to forging machine operator can be effected by slides or automatic handling equipment

4.4.4 Box or batch type furnaces

These furnaces are the least expensive furnaces widely used in forging shops for heating small and medium size stock. There is a great variety of design of box-type furnaces, each differing in their location of their charging doors, firing devices and method, employed for .charging their products. These furnaces are usually constructed of a rectangular steel frame, lined with insulating and refractory bricks. One or more burners for gas or oil can be provided on the sides. The job-pieces are placed side by side in the furnace using a slot through a suitable tong. It is therefore sometimes called slot type furnace.

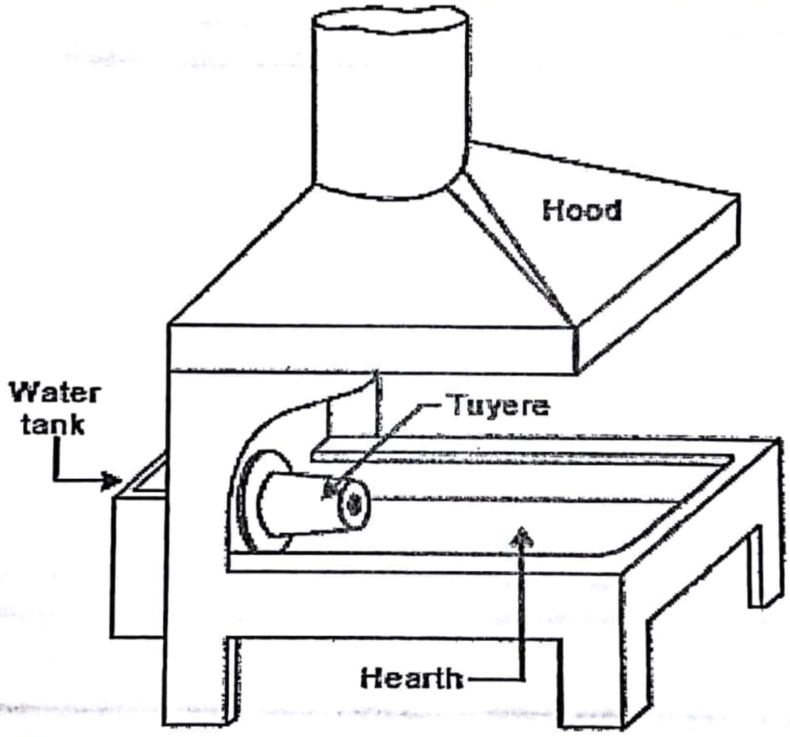


Figure 5.3 Typical hearth

4.4.5 Resistance furnaces

These furnaces are faster than induction furnaces, and can be automated easily. In resistance heating furnace, the stock is connected to the circuit of a step-down transformer. Fixtures are also equipped along with furnace for holding different length, shape, and diameter of stock. However, the fixtures are often quite simple and can be adjusted to handle a family of parts.

4.4.6. Open fire and stock fire furnace

The fire itself plays an important part on the efficient heating of stock and it must be kept clean, free from excess dust or clinkers. Work which is laid on top of the fire will get hot underneath and remain colder on the top use it is exposed to the atmosphere, and uneven heating will result.

4.5COMMON HAND FORGING TOOLS:

For carrying out forging operations manually, certain common hand forging tools are employed. These are also called blacksmith's tools, for a blacksmith is one who works on the forging of metals in their hot state. The main hand forging tools are as under.

1. Tongs. 2. Flatter 3. Swage. 4. Fuller. 5. Punch. 6. Rivet header
7. Hot chisel. 8. Hammers. 9. Anvil. 10. Swage block. 11. Drift. 12. Set-hammer
14. Brass scale. 15. Brass. 16. Black smith's gauge. 17. Heading tool.

Some of the hand forging tool and their applications are described as under.

1. **Tongs:** The tongs are generally used for holding work while doing a forging operation.

2. **Flatter:** Is shown below .It is commonly used in forging shop to give smoothness and accuracy to articles which have already been shaped by fullers and swages.

3. **Swage:** Swage is used for forging work which has to be reduced or finished to round, square or hexagonal form.

4. **Fuller:** is used in forging shop for necking down a forgeable job. It is made in top and bottom tools as in the case of swages.

5. **Punch:** Punch is used in forging shop for making holes in metal part when it is at forging heat.

6. **Rivet header:** Rivet header is used in forging shop for producing rivets heads on parts.

7. **Chisels:** Chisels are used for cutting metals and for nicking prior to breaking. They may be hot or cold depending on whether the metal to be cut is hot or cold.

8. **Hand hammers:** There are two major kinds of hammers are used in hand forging: (1) the hand hammer used by the smith himself and (2) the sledge hammer used by the striker. Hand hammers may further be classified as (a) ball peen hammer, (b)

straight peen hammer, and (c) cross peen hammer. Sledge hammers may further be classified as (a) Double face hammer, (b) straight peen hammer, and (c) cross peen hammer. Hammer heads are made of cast steel and, their ends are hardened and tempered. The striking face is made slightly convex. The weight of a hand hammer varies from about 0.5 to 2 kg where as the weight of a sledge hammer varies from 4 to 10 kg.

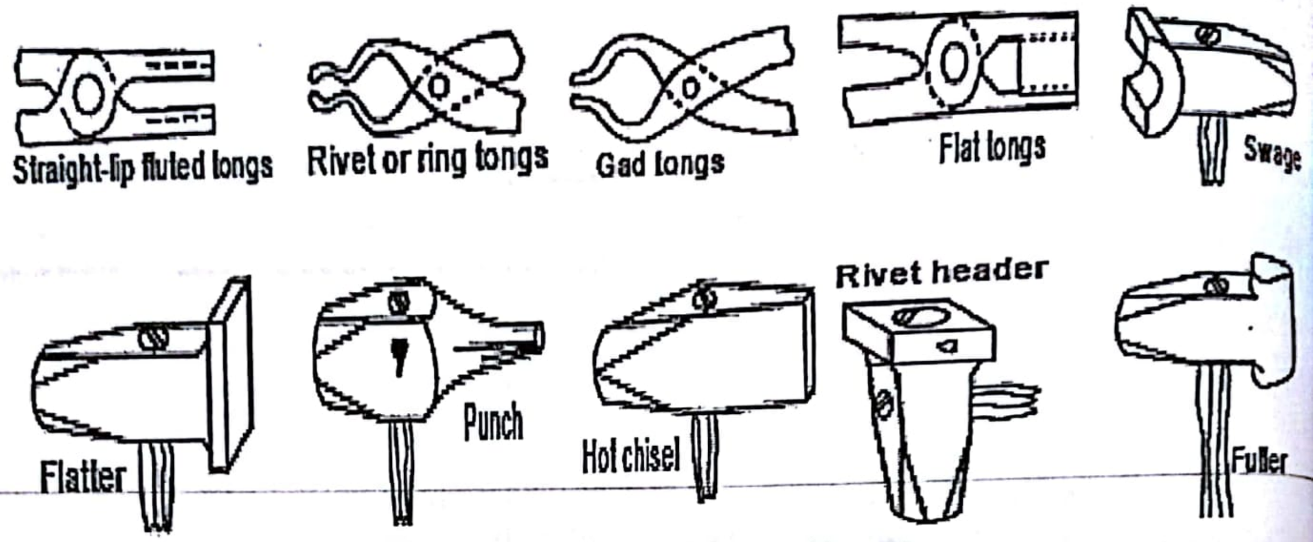


Figure 5.4 Hand forging tools

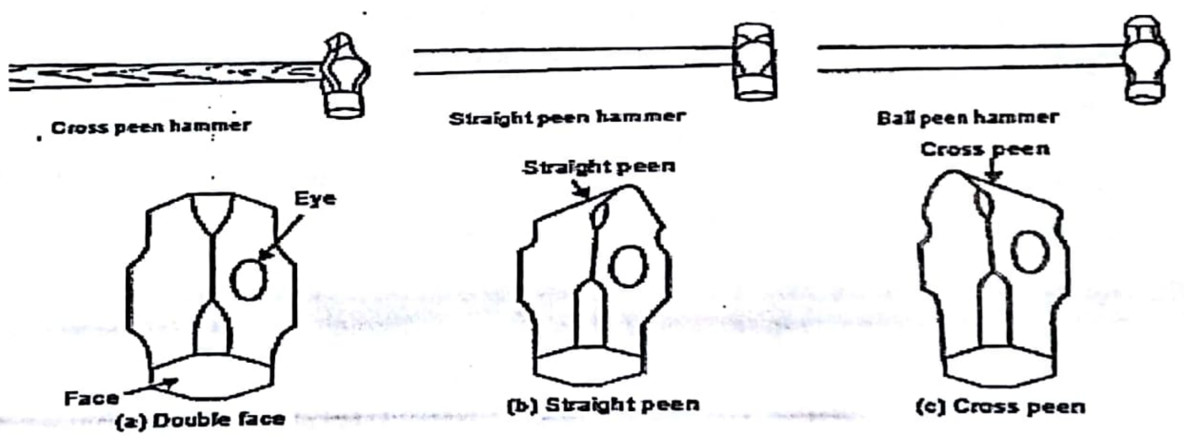


Figure 5.5 Types of hammers

9. **Anvil:** An anvil is a most commonly tool used in forging shop .It acts as a support for blacksmith's work during hammering. The body of the anvil is made of mild steel with a tool steel face welded on the body, but the beak or horn used for bending curves is not steel faced. The round hole in the anvil called pritchel hole is generally used for bending rods of small diameter, and as a die for hot punching operations. The

square hole is used for holding square shanks of various fittings. Anvils in forging shop may vary up to about 100 to 150 kg and they should always stand with the top face about 0.75 m. from the floor. This height may be attained by resting the anvil on a wooden or cast iron base in the forging shop.

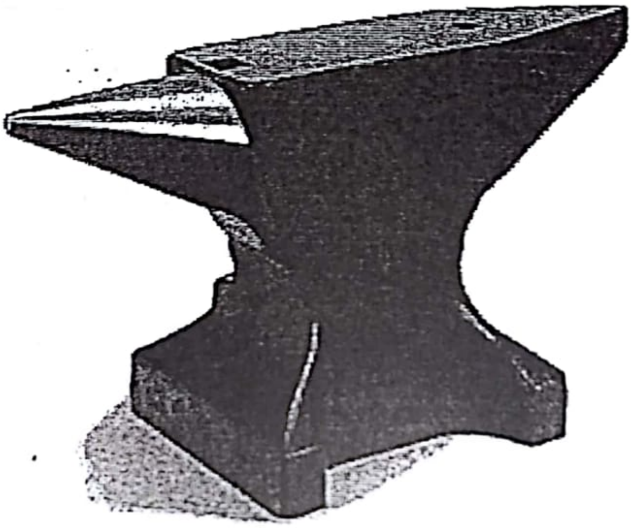


Figure 5.6 Anvil

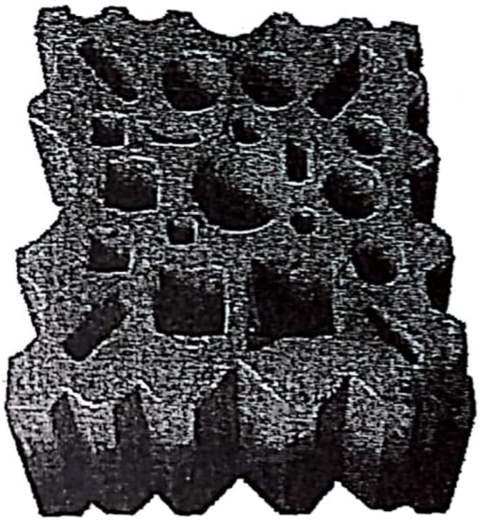


Figure 5.7 Swage block

4.6 Forging Operations:

The hand forging operations are:

1. Upsetting. 2. Bending. 3. Drawing down. 4. Cutting. 5. Setting down. 6. Punching. 7. Flattening. 8. Fullering. 9. Forge Welding. 10. Swaging.

4.7 Drop Hammers:

Drop hammers are operated hydraulically and are widely used for shaping parts by drop hammering a heated bar or billet into a die cavity. A drop forging raises a massive weight and allows it to fall under gravity on close dies in which forge component is allowed to be compressed.

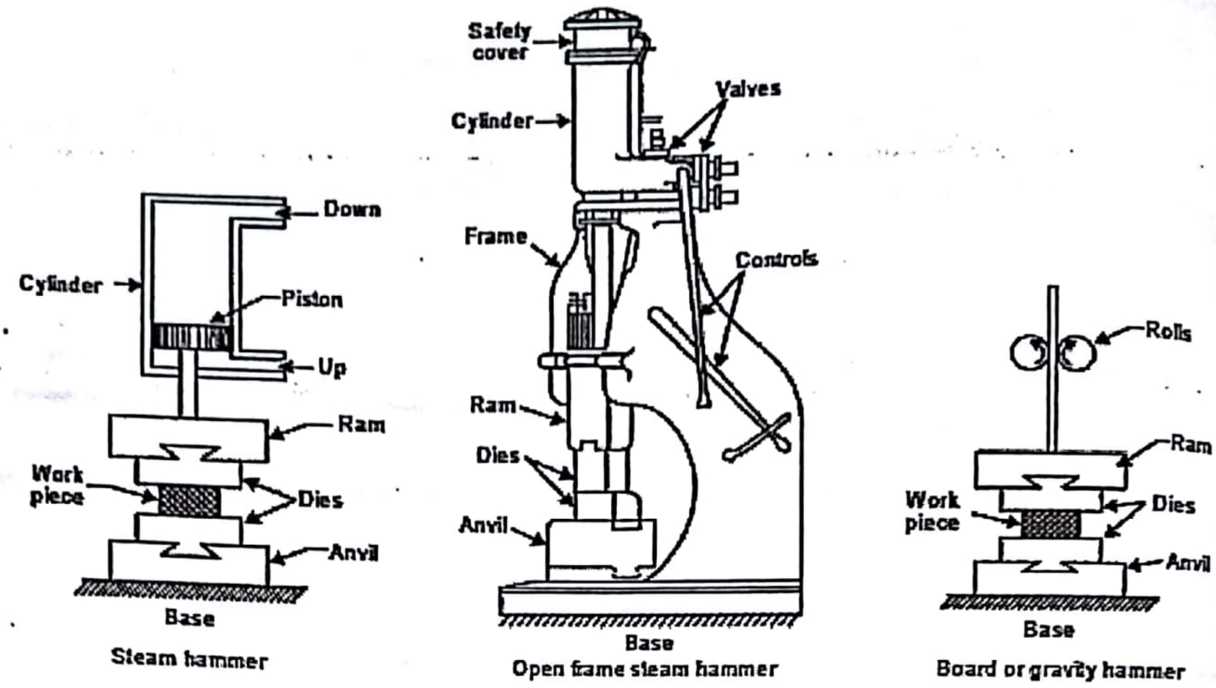


Fig. 5.8 Hammers

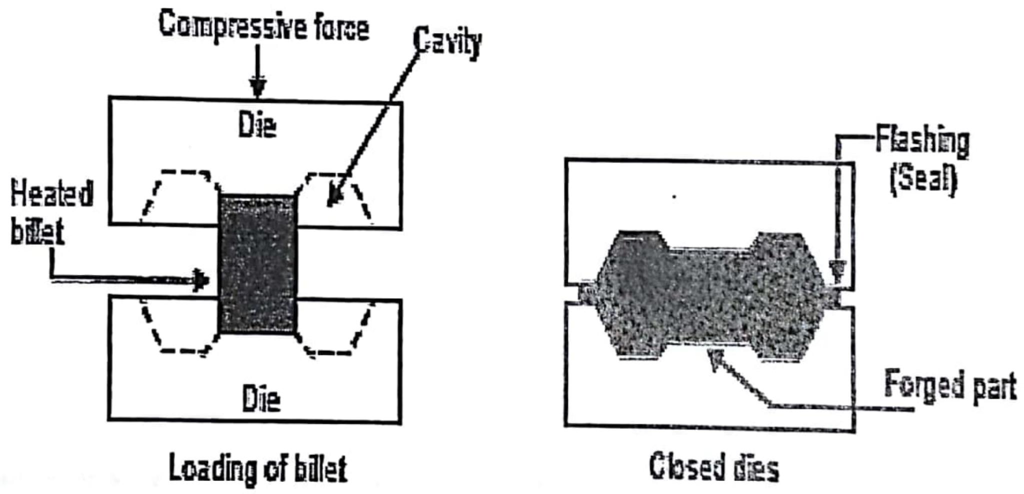


Figure 5.9 Close dies forging.

4.8 Advantages of forging:

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.
2. Forging refines the structure of the metal.
3. It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it.

4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.
5. Because of intense working, flaws are rarely found, so have good reliability.
6. The reasonable degree of accuracy may be obtained in forging operation.
7. The forged parts can be easily welded.

4.9 Disadvantages of forging:

Few disadvantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.
2. The close tolerances in forging operations are difficult to maintain.
3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.
4. Some materials are not readily worked by forging.
5. The initial cost of forging dies and the cost of their maintenance is high.
6. The metals gets cracked or distorted if worked below a specified temperature limit.
7. The maintenance cost of forging dies is also very high.

4.10 Applications of forging:

Almost all metals and alloys can be forged. The low and medium carbon steels are readily hot forged without difficulty, but the high carbon and alloy steels are more difficult to forge and require greater care. Forging is generally carried out on carbon alloy steels, wrought iron, copper-base alloys, aluminum alloys, and magnesium alloys. Stainless steels, nickel based super-alloys, and titanium are forged especially for aerospace uses. Producing of crank shaft of alloy steel is a good example which is produced by forging. Forging processes are among the most important manufacturing techniques utilized widely in manufacturing of small tools, rail-road equipments, automobiles and trucks and components of an airplane industries. These processes are also extensively used in the manufacturing of the parts of tractors, shipbuilding cycle industries, railroad components, agricultural machinery etc.

4.11 Defects in Forged Parts:

Defects commonly found in forged parts that have been subjected to plastic deformation are as follows:

1. Defects resulting from the melting practice such as dirt, slag and blow holes.
2. Ingot defects such as pikes, cracks scabs, poor surface and segregation.
3. Defect due to faulty forging design.
4. Defects of mismatched forging because of improper placement of the metal in the die.
5. Defects due to faulty design drop forging die.
6. Defects resulting from improper forging such as seams cracks laps, etc.
7. Defects resulting from improper heating and cooling of the forging part such as burnt metal and decarburized steel.

4.12 SAFETY PRECAUTIONS:

Some safety precautions generally followed while working in forging shop are given as under:

1. Always avoid the use of damaged hammers.
2. Never strike a hardened surface with a hardened tool.
3. No person should be allowed to stand in line with the flying objects.
4. Always use the proper tongs according to the type of work.
5. The anvil should always be free from moisture and grease while in use.
6. Always wear proper clothes, foot-wears and goggles.
7. The handle of the hammer should always be tightly fitted in the head of the hammer.
8. Always put out the fire in the forge before leaving the forge shop.
9. Always keep the working space clean.
10. Proper safety guards should be provided on all revolving parts.
11. Head of the chisel should be free from burrs and should never be allowed to spread.
12. During machine forging, always observe the safety rules prescribed for each machine.
13. One must have the thorough knowledge of the working of the forging machine before operating it.

Questions	
Note : Support your answer by neat sketches	
Q1	Explain briefly the following: 1. Forging, 2. Tongs, 3. Flatter, 4. Swage, 5.Anvil.
Q2	What are the main advantages of Cold & Hot Working?
Q3	Compare between Hot & Cold working.
Q4	Explain in brief the defects in forging?
Q5	Which of the following Statement is Correct? 1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads. 2. Forging refines the structure of the metal. 3. It results in considerable saving in time, labor and material as compared to the production of similar item by cutting from a solid stock and then shaping it. 4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains. 5. The close tolerances in forging operations are difficult to maintain. 6. Forging is limited to simple shapes and has limitation for parts having undercuts etc. 7. Some materials are not readily worked by forging.

Chapter Five

Measuring Devices

Measuring Devices

5.1 Introduction

Measurement techniques have been of immense importance ever since the start of human civilization, when measurements were first needed to regulate the transfer of goods in barter trade to ensure that exchanges were fair. The industrial revolution during the nineteenth century brought about a rapid development of new instruments and measurement techniques to satisfy the needs of industrialized production techniques. Since that time, there has been a large and rapid growth in new industrial technology. This has been particularly evident during the last part of the twentieth century, encouraged by developments in electronics in general and computers in particular. This, in turn, has required a parallel growth in new instruments and measurement techniques.

5.2 Systems of measurement

The main two systems of measurements are:
1. The **METRIC** system: The basic unit of length in the metric system is the meter.
2. The **IMPERIAL** system: The basic unit of length in the Imperial system is the yard.

The METRIC system nowadays is used in most countries.

5.2.1 Steel Rules

Most metric rules are divided into millimeter or half millimeter graduations.
They are numbered every 10 mm as shown in Fig. 3.1.
The measurement is determined by counting the number of millimeters.

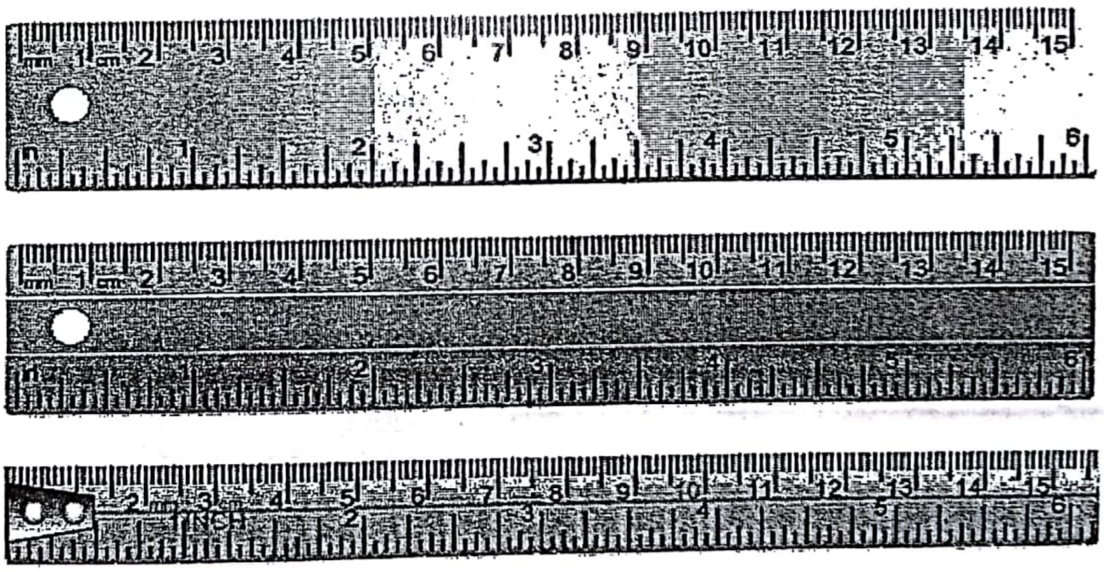


Figure 3.1 Metric rules

Using the steel rule

Always look straight down at 90° to the rule. Using the datum edge to help you measure correctly. If you look from the side, you can get inaccurate measurements.

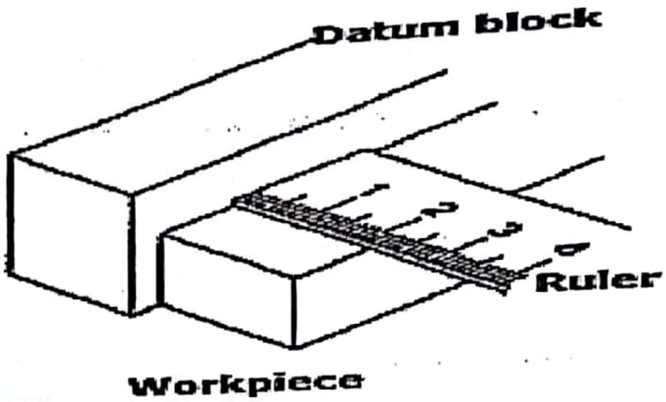


Figure 3.2 Using the steel ruler

Other uses of steel rule

The edge of the rule is ground flat. You can use the edge of the rule to check that the workpieces edges are flat.

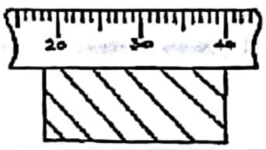


Figure 3.3 No gap between the workpiece and
Rule means the workpiece edge is
FLAT

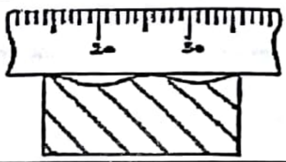


Figure 3.4 Gap between the workpiece and the
Rule means the workpiece edge is NOT
FLAT

Care of the steel rule

The steel rule is an accurate instrument, treat it with care.

1. Keep the rule clean and lightly oiled.
2. Protect it from damage.
3. Never use it as a screwdriver.
4. Never use the end as a scraper.
5. Never bend or twist a steel ruler.

5.2.2 Vernier Calipers

The Vernier caliper is a measuring instrument with a sliding scale used to carry out accurate measurements of inside, outside, and depth dimensions.

5.2.2.1 The main parts of the Vernier Caliper

The Vernier caliper has 6 parts: as illustrated in fig. 3.5 :

1. Outside jaws: used to measure external lengths.

2. Inside jaws: used to measure internal lengths.
3. Stem: used to measure depths .A
4. Main scale,
5. Vernier scale
6. Screw clamp: used to block the movable jaw to allow the easy transferring a measurement.

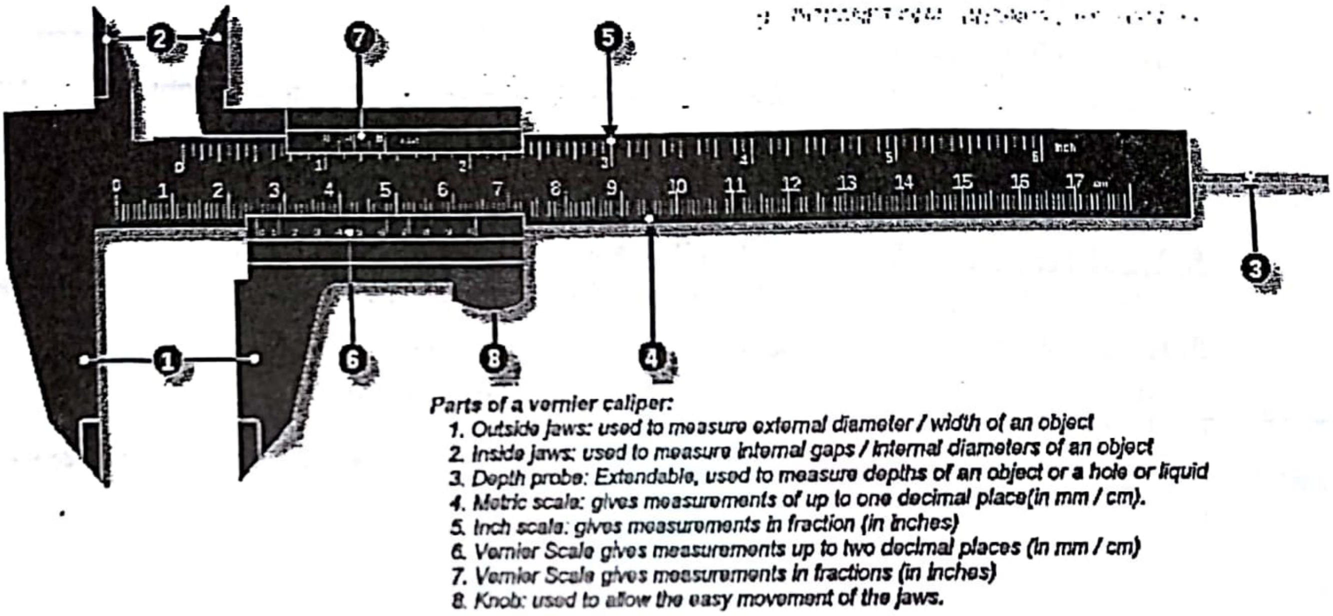


Figure 3.5 The main parts of Vernier caliper

Types of Vernier calipers:

A - **Standard** Vernier caliper.	
B - **Dial** Vernier caliper.	
C - **Digital** Vernier caliper which is easier to read than the other two types.	

5.2.2.2 The accuracy of Vernier calipers

The Vernier consists of a main scale engraved on a fixed ruler and a Vernier scale engraved on a movable jaw. The movable Vernier scale is free to slide along the length of the fixed ruler. This main scale is presented in centimeters with the smallest division in millimeters. The actual length of the Vernier scale is 9 mm. The 9 mm are divided into 10 divisions.

According to the number of divisions the accuracy values are determined.

1. The Vernier caliper with 10 divisions in Vernier scale is accurate to (1/10) ±0.1 mm.
2. The Vernier caliper with 20 divisions in Vernier scale is accurate to (1/20) ±0.05 mm.
3. The Vernier caliper with 50 divisions in Vernier scale is accurate to (1/50) ±0.02 mm.

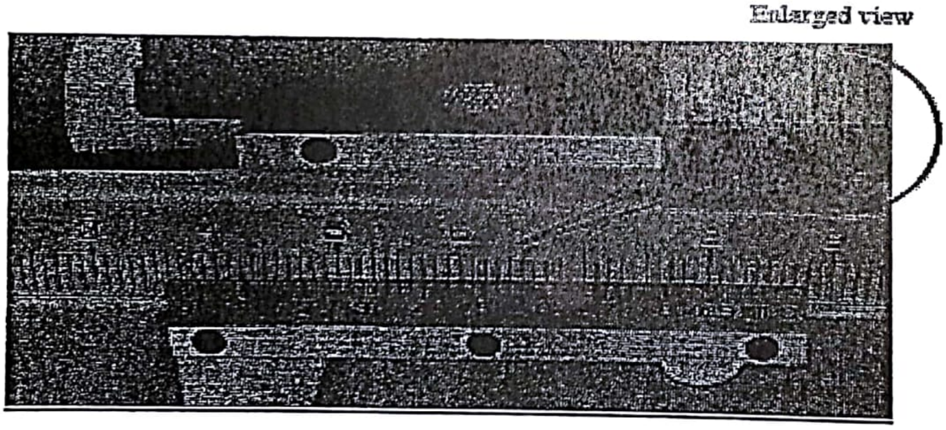
5.2.2.3 Using Vernier Calipers

Vernier calipers can be used to measure:

1. The outside diameter or width of an object.
2. The inside diameter or width of an object.
3. The depth of an object.

5.2.2.4 Reading Vernier Calipers

In Fig. shown below, the Vernier scale (below) is divided into 10 equal divisions and thus the least count of the instrument is 0.1 mm. Both the main scale and the Vernier scale readings are taken into account when measuring. The main scale reading is the first reading on the main scale immediately to the left of the zero of the Vernier scale (3 mm), while the Vernier scale reading is the mark on the Vernier scale, which exactly coincides, with a mark on the main scale (0.7 mm). The reading is therefore 3.7 mm.



The reading is: 37 mm + 0.46 mm = 37.46 mm.

Figure 3.6 The reading of Vernier

5.2.3 Micrometers

The micrometer screw gauge is used to measure even smaller dimensions than the Vernier calipers. The micrometer screw gauge also uses an auxiliary scale (measuring hundredths of a millimeter) which is marked on a rotary thimble. It is a screw with an accurately constant pitch. The micrometers in our laboratory have a pitch of 0.50 mm (two full turns are required to close the jaws by 1.00 mm). The rotating thimble is subdivided into 50 equal divisions. The thimble must be rotated through two revolutions to open the jaws by 1 mm.

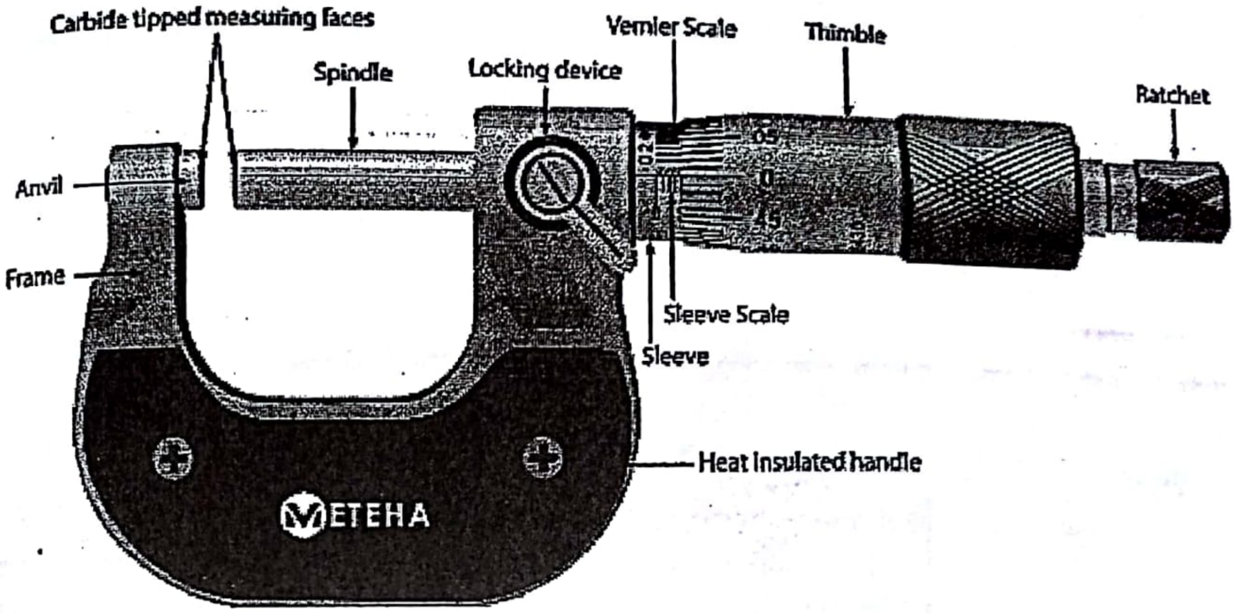
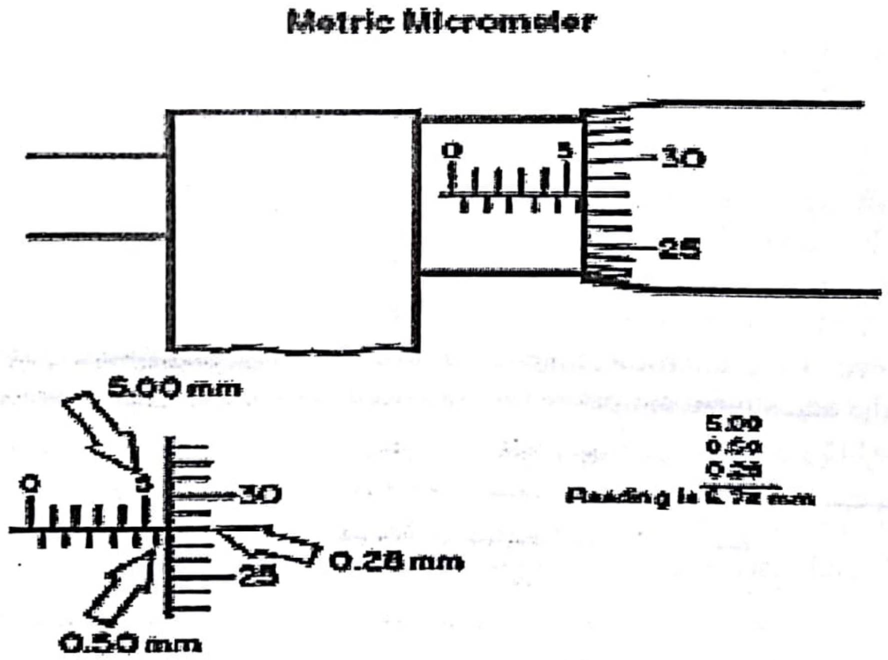


Figure 3.7 Micrometer

3.2.3.1 Reading the micrometer



Fig

Figure 3.8 Reading the micrometer

An inside micrometer reads like an outside micrometer however the scales are just the opposite and reads left to right.
Parts of an Inside Micrometer

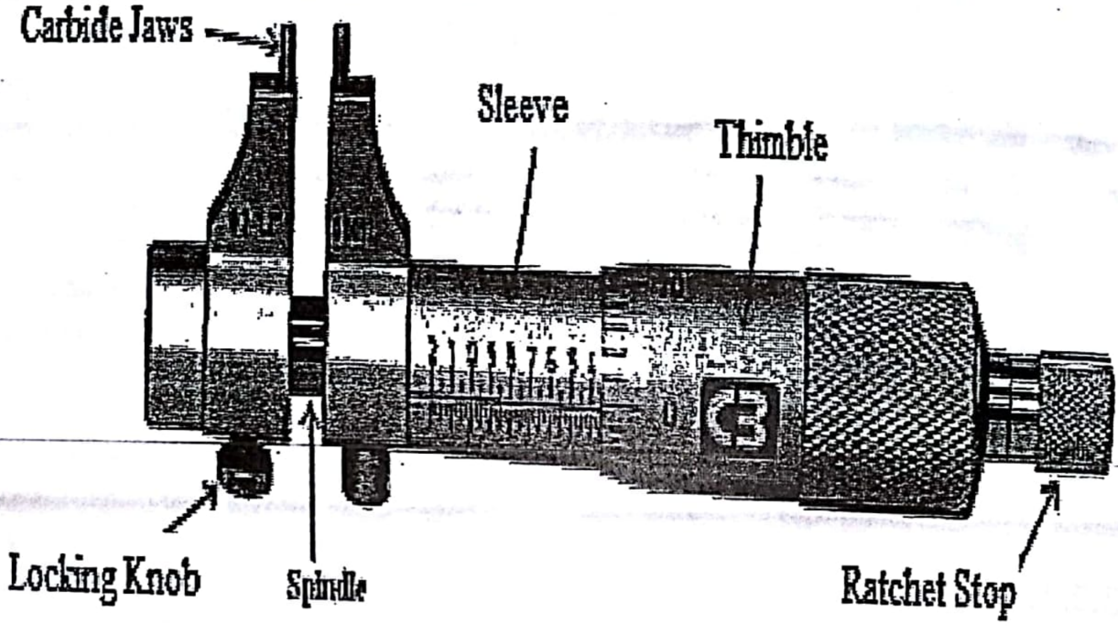
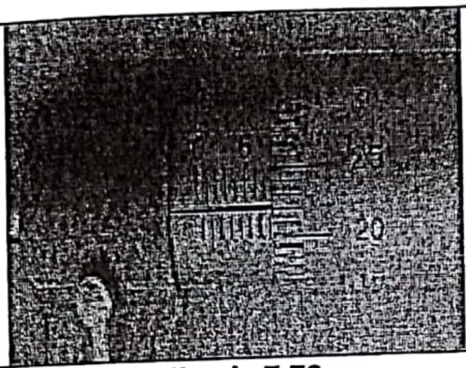


Figure 3.9 Inside Micrometer

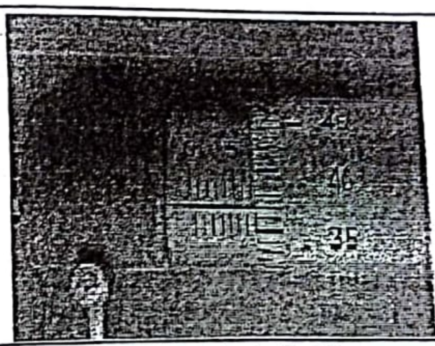
When a micrometer is at its minimum reading (.200) the horizontal line on the sleeve should line up with the '0' on the thimble. To see if this is the case you must use the standard that is supplied with the micrometer.

If the 0 does not line up then it will be necessary to calibrate the micrometer by rotating the sleeve. Each micrometer comes with a half moon adjusting wrench for this purpose. To make the adjustment simply puzzle the wrench to the side of the spindle and insert the small tip into the leverage hole. If the 0 does not line up then it will be necessary to calibrate the micrometer by rotating the sleeve. Each micrometer comes with a half moon adjusting wrench for this purpose. To make the adjustment simply puzzle the wrench to the side of the spindle and insert the small tip into the leverage hole.

5.2.3.2 Examples of micrometer reading:



The reading is **7.72 mm.**



The reading in is **7.38mm.**

5.2.4 Caliper

Calipers are generally of two types inside and outside to make internal or external measurements. They do not have direct scale reading. They transfer the measurement from jobs to scale or vice versa. Fig. 3.10 shows a simple outside caliper. The caliper is held in a rule as shown in Fig. 3.11 to read the size. It is used to make external measurement such as thickness of plates, diameter of sphere and cylinders. Fig. 3.12 shows the standard spring joint outside caliper.

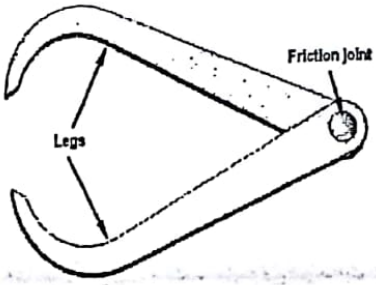


Figure 3.10 A simple outside caliper

Figure 3.11 Inside caliper

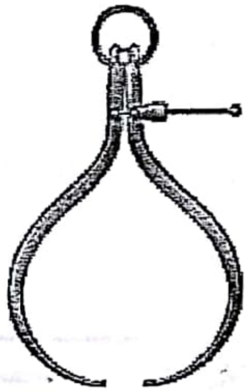


Figure 3.12A standard spring joint caliper

5.2.5 Dial Indicators

The dial indicators are also known as dial gauges and are shown in Fig. 3.13. It is generally used for testing flatness of surfaces and parallelism of bars and rods. They are also used for testing the machine tools. They are available in both metric as well as in inches units. Inches dial indicator of 0.001" measuring accuracy is in commonly used but they are also available up to an accuracy of 0.0001". The commonly used metric dial indicator has an accuracy of 0.01 mm. Those having 0.001 mm accuracy are also available; however they are used in highly precision measurement work.

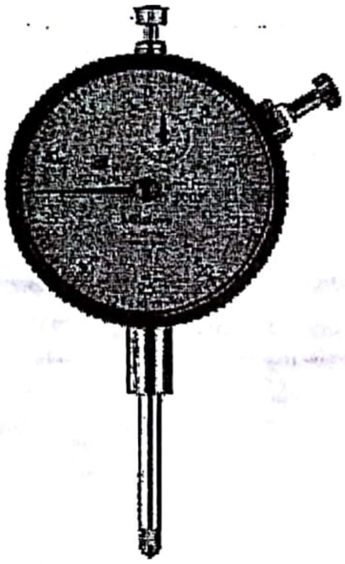


Figure 3.13 Dial indicators

5.2.6 Feeler gauge

The set of feeler gauges and the gauges themselves need not conform to the illustration; only the dimensions specified must be complied with. This standard contains feeler gauges and sets of feeler gauges which are met with most frequently in practice and commerce. Other lengths, widths and summary of sets are also available commercially for special purposes, but which are not included in this Standard on account of their variety. Only a tolerance quality was standardized, since in the case of larger permissible variations than are specified in this Standard, overlapping can occur in the lower range of nominal thickness.

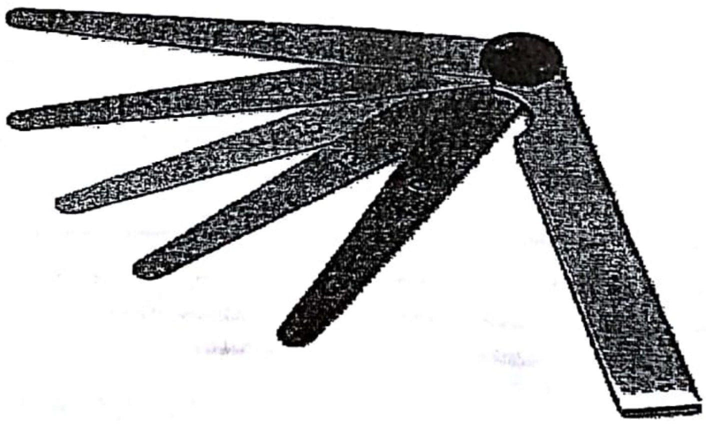


Figure 3.14 A feeler gauge

Questions	
Q1	Explain briefly: 1- Vernier Calipers, 2- Micrometers, 3- Calipers , 4- Dial gauge
Q2	What are the main parts which Consist the (Vernier/Micrometer)?
Q3	What are the types of (Vernier/ Micrometer)?
Q4	Explain briefly: The proper use of: 1- Rulers. 2- Vernier, 3- Micrometer

Chapter Six

Welding

Welding

6.1 Definition:

•A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting. Filler material is typically added to strengthen the joint.

•**Welding** is a dependable, efficient and economic method for permanently joining similar metals. In other words, you can weld steel to steel or aluminum to aluminum, but you cannot weld steel to aluminum using traditional welding processes.

•**Welding** is used extensively in all sectors or manufacturing, from earth moving equipment to the aerospace industry.

6.2 CLASSIFICATION OF WELDING AND ALLIED PROCESSES:

There are different welding, brazing and soldering methods are being used in industries today. There are various ways of classifying the welding and allied processes.

Welding Processes:

1. Oxy-Fuel Gas Welding Processes

a. Air-acetylene welding
b. Oxy-acetylene welding
c. Oxy-hydrogen welding
d. Pressure gas welding

2. Arc Welding Processes

a: Carbon Arc Welding.
b. Shielded Metal Arc Welding.
c. Submerged Arc Welding.
d. Gas Tungsten Arc Welding.
e. Gas Metal Arc Welding.
f. Plasma Arc Welding.
g. Atomic Hydrogen Welding.
h. Electro-slag Welding.
i. Stud Arc Welding.
j. Electro-gas Welding.

3. Resistance Welding

a. Spot Welding.
b. Seam Welding.
c. Projection Welding.
d. Resistance Butt Welding.
e. Flash Butt Welding.
f. Percussion Welding.
g. High Frequency Resistance Welding.
h. High Frequency Induction Welding.

4. **Solid-State Welding Processes**
   a. Forge Welding.
   b. Cold Pressure Welding.
   c. Friction Welding.
   d. Explosive Welding.
   e. Diffusion Welding.
   f. Cold Pressure Welding.
   g. Thermo-compression Welding.

5. **Thermit Welding Processes**
   a. Thermit Welding.
   b. Pressure Thermit Welding.

6. **Radiant Energy Welding Processes**
   a. Laser Welding
   b. Electron Beam Welding

6.3 Welding Processes

Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction. During some type of welding processes, pressure may also be employed, but this is not an essential requirement for all welding processes. Welding provides a permanent joint but it normally affects the metallurgy of the components.

6.4 Edge preparations

For welding the edges of joining surfaces of metals are prepared first. Different edge preparations may be used for welding butt joints, which are given in Fig 8.1.

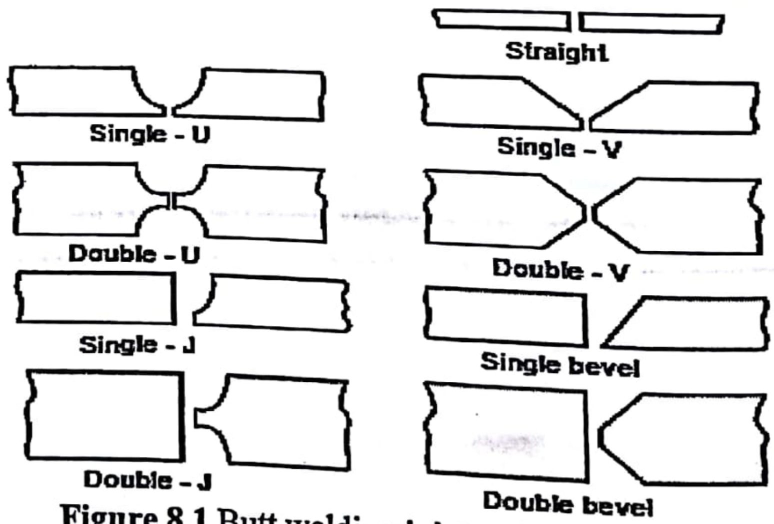


Figure 8.1 Butt welding joints edge preparations

6.5 Welding joints: Some common welding joints are shown below. Welding joints are of generally of two major kinds namely lap joint and butt joint. The main types are described as under.

1. Lap weld joint:

Single-Lap Joint

This joint, made by overlapping the edges of the plate, is not recommended for most work. The single lap has very little resistance to bending. It can be used satisfactorily for joining two cylinders that fit inside one another.

Double-Lap Joint

This is stronger than the single-lap joint but has the disadvantage that it requires twice as much welding.

2. Tee Fillet Weld

This type of joint, although widely used, should not be employed if an alternative design is possible.

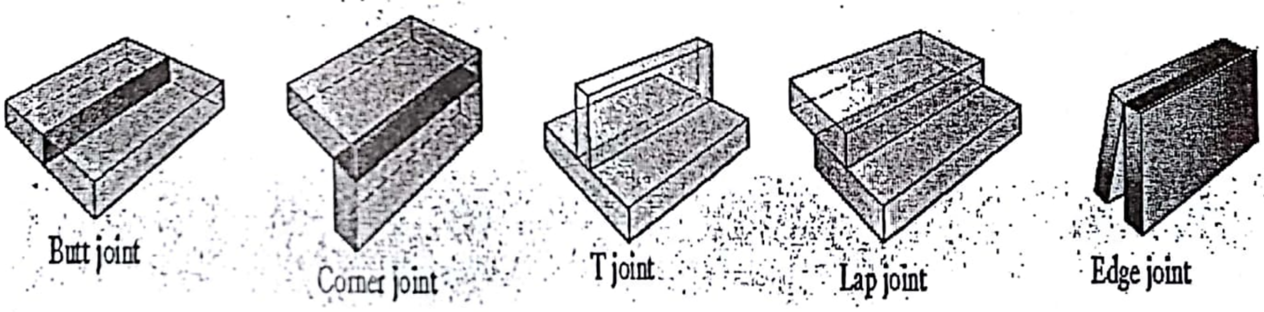


Figure 8.2 Five basic types of weld joint designs.

3. Single-V Butt Weld

It is used for plates up to 15.8 mm thick. The angle of the vee depends upon the technique being used, the plates being spaced approximately 3.2 mm.

4. Double-V Butt Weld

It is used for plates over 13 mm thick when the welding can be performed on both sides of the plate. The top v angle is either 60° or 80°, while the bottom angle is 80°, depending on the technique being used.

6.6 Welding Electrodes

An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between electrode and workpiece. Welding electrodes are classified into following types:

(1) Consumable Electrodes

(a) Bare Electrodes

(b) Coated Electrodes

Consumable electrode is made of different metals and their alloys. The end of this electrode starts melting when arc is struck between the electrode and workpiece. Thus consumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloy wire without any flux coating on them. Coated electrodes have flux coating which starts melting as soon as an electric arc is struck. This coating on melting performs many functions like prevention of joint from atmospheric contamination, arc stabilizers etc.

(2) Non-consumable Electrodes
(a) Carbon or Graphite Electrodes
(b) Tungsten Electrodes

Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc. These electrodes do not melt away during welding. But practically, the electrode length goes on decreasing with the passage of time, because of oxidation and vaporization of the electrode material during welding.

6.7 Welding Positions
There are four types of welding positions, which are given as:
1. Flat or down hand position.
2. Horizontal position.
3. Vertical position.
4. Overhead position.

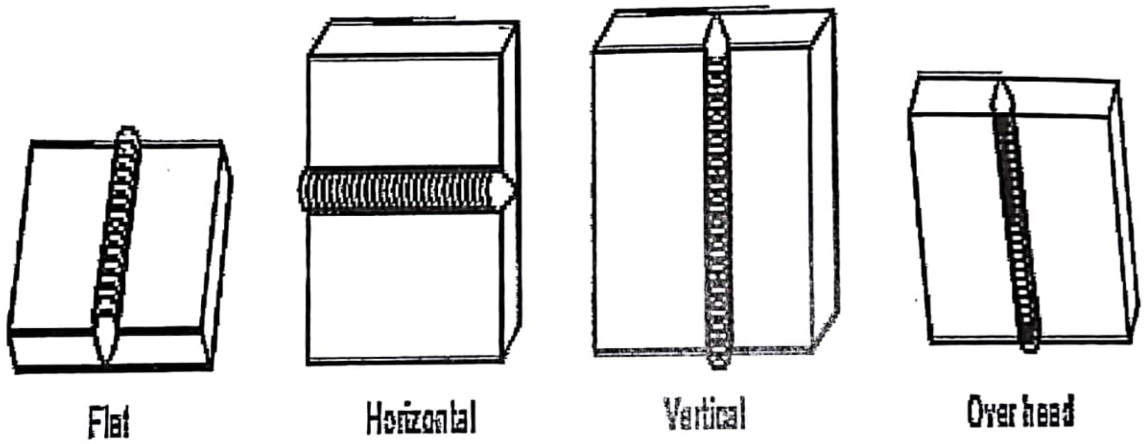


Figure 8.3 Welding positions.

1. Flat or Down-hand Welding Position: The flat position or down hand position is one in which the welding is performed from the upper side of the joint and the face of the weld is approximately horizontal. This is the simplest and the most convenient position for welding. Using this technique, excellent welded joints at a fast speed with minimum risk of fatigue to the welders can be obtained.

2. Horizontal Welding Position: In horizontal position, the plane of the workpiece is vertical and the deposited weld head is horizontal. The metal deposition rate in horizontal welding is next to that achieved in flat or down-hand welding position. This position of welding is most commonly used in welding vessels and reservoirs.

3. Vertical Welding Position: In vertical position, the plane of the workpiece is vertical and the weld is deposited upon a vertical surface. It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal. The welder must constantly control the metal so that it does not run or drop from the weld.

4. Overhead Welding Position: The overhead position is probably even more difficult to weld than the vertical position. Here the pull of gravity against the molten metal is much greater. The force of the flame against the weld serves to counteract the pull of gravity. In overhead position, the plane of the workpiece is horizontal. But the welding is carried out from the underside.

6.8 Main Components of Electric Arc Welding

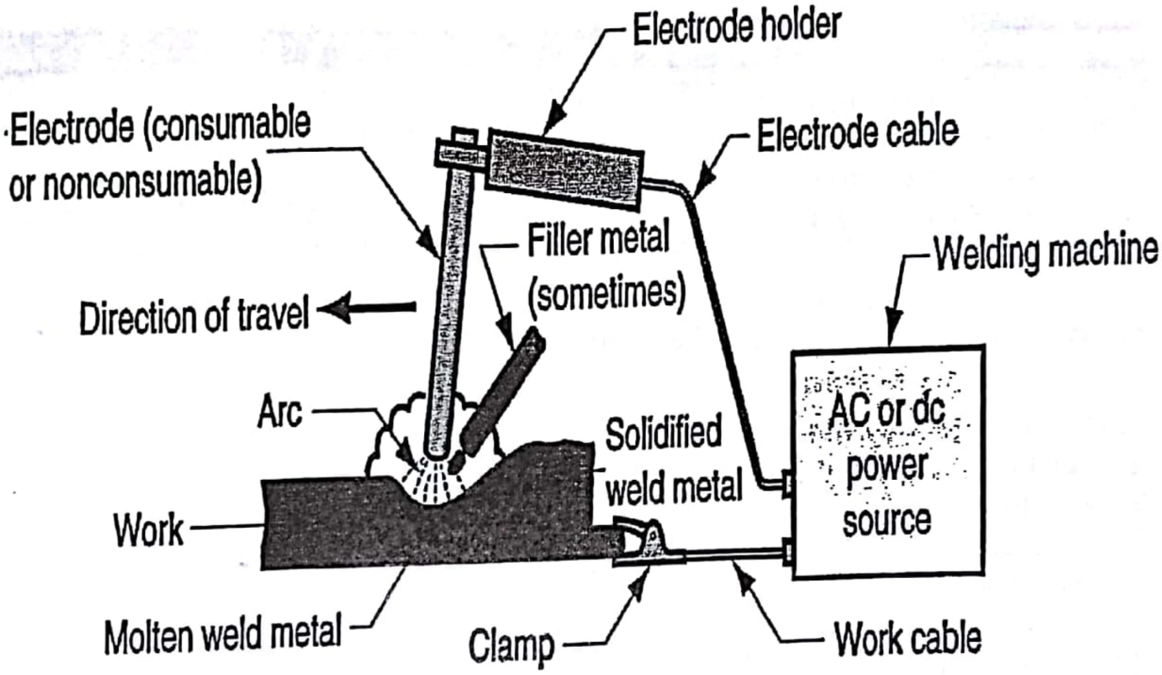


Figure8.4 Electric Arc Welding Components

1. Transformers: The transformers type of welding machine produces A.C current and is considered to be the least expensive. It takes power directly from power supply line and transforms it to the voltage required for welding. Transformers are available in single phase and three phases in the market.

Motor generators: These are D.C generators sets, in which electric motor and alternator are mounted on the same shaft to produce D.C power as pert the requirement for welding. These are designed to produce D.C current in either straight or reversed polarity. The polarity selected for welding depends upon the kind of electrode used and the material to be welded.

Rectifiers: These are essentially transformers, containing an electrical device which changes A.C into D.C by virtue of which the operator can use both types of power (A.C or D.C, but only one at a time).In addition to the welding machine, certain accessories are needed for carrying out the welding work.

2. Welding cables: Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the workpiece and back to the welding power source. These are insulated copper or aluminum cables.

3. Electrode holder: Electrode holder is used for holding the electrode manually and conducting current to it. These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder. Electrode holders are available in sizes that range from 150 to 500 Amps.

5. Hand Screen: Hand screen used for protection of eyes and supervision of weld bead.
6. Chipping hammer: Chipping Hammer is used to remove the slag by striking.
7. Wire brush: Wire brush is used to clean the surface to be weld.
8. Protective clothing: Operator wears the protective clothing such as apron to keep away the exposure of direct heat to the body.

6.8.1 Advantages:

1. Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
2. Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
3. Large number of metals and alloys both similar and dissimilar can be joined by welding.
4. General welding equipment is not very costly.
5. Portable welding equipments can be easily made available.
6. Welding permits considerable freedom in design.

6.8.2 Disadvantages:

1. It results in residual stresses and distortion of the workpieces.
2. Welded joint needs stress relieving and heat treatment.
3. Welding gives out harmful radiations (light), fumes and spatter.
4. Edges preparation of the welding jobs is required before welding
5. Skilled welder is required for production of good welding
6. Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

6.9 GAS WELDING PROCESSES:

A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen propane or butane) mixture is usually referred as 'gas welding'. The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal. The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature. Oxy-acetylene flame is the most versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases. Other gases such as Hydrogen, Propane, Butane, Natural gas etc., may be used for some welding and brazing applications.

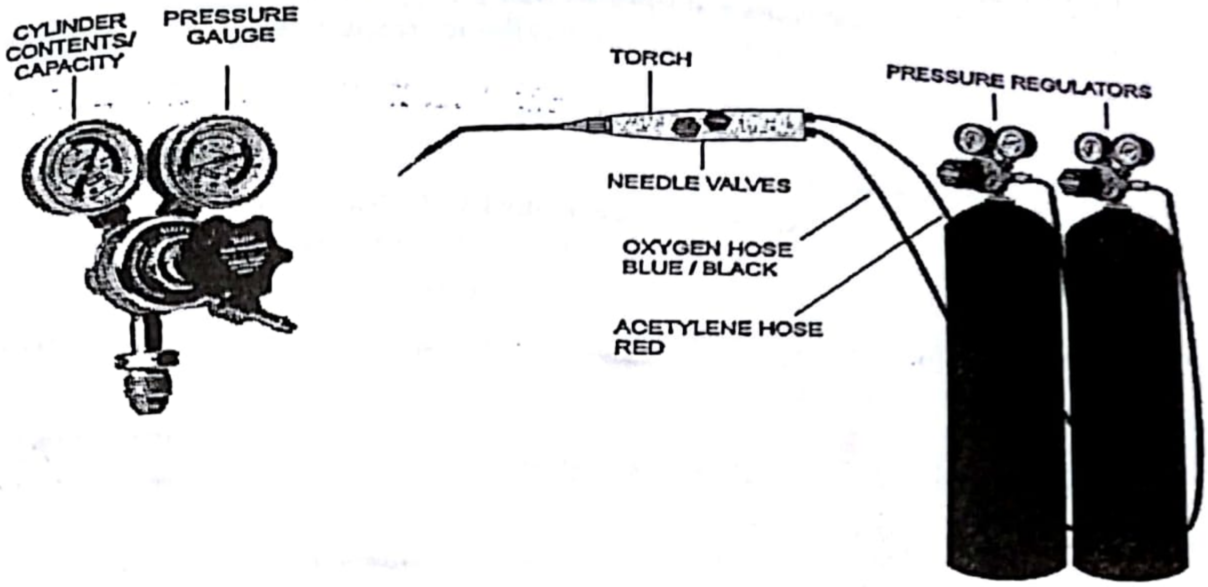


Figure 8.5 Schematic sketches of oxyacetylene welding torch and gas supply

6.9.1.1Torch tips: It is the portion of the welding apparatus through which the gases pass just prior to their ignition and burning. A great variety of interchangeable welding tips differing in size, shape and construction are available commercially. The tip sizes are identified by the diameter of the opening. The diameter of the tip opening used for welding depends upon the type of metal to be welded.

6.9.1.2 Hose pipes: The hose pipes are used for the supply of gases from the pressure regulators. The most common method of hose pipe fitting both oxygen and acetylene gas is the reinforced rubber hose pipe. Green is the standard color for oxygen hose, red for acetylene, and black hose for other industrially available welding gases.

6.9.1.3 Goggles: These are fitted with colored lenses and are used to protect the eyes from harmful heat and ultraviolet and infrared rays.

6.9.1.4 Gloves: These are required to protect the hands from any injury due to the heat of welding process.

6.9.1.5 Spark-lighter: It is used for frequent igniting the welding torch.

6.9.1.6 Filler rods: Gas welding can be done with or without using filler rod. When welding with the filler rod, it should be held at approximately 900 to the welding tip. Filler rods have the same or nearly the same chemical composition as the base metal. Metallurgical properties of the weld deposit can be controlled by the optimum choice of filler rod. Most of the filler rods for gas welding also contain deoxidizers to control the oxygen content of weld pool.

6.9.1.7 **Fluxes:** Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface. These are usually employed for gas welding of aluminum, stainless steel, cast iron, brass and silicon bronze. They are available in the market in the form of dry powder, paste, or thick solutions.

6.9.2 Types of Welding Flames:

In oxy-acetylene welding, flame is the most important means to control the welding joint and the welding process. The correct type of flame is essential for the production of satisfactory welds. The flame must be of the proper size, shape and condition in order to operate with maximum efficiency. There are three basic types of oxy-acetylene flames.

1. Neutral welding flame (Acetylene and oxygen in equal proportions).
2. Carburizing welding flame or reducing (excess of acetylene).
3. Oxidizing welding flame (excess of oxygen).

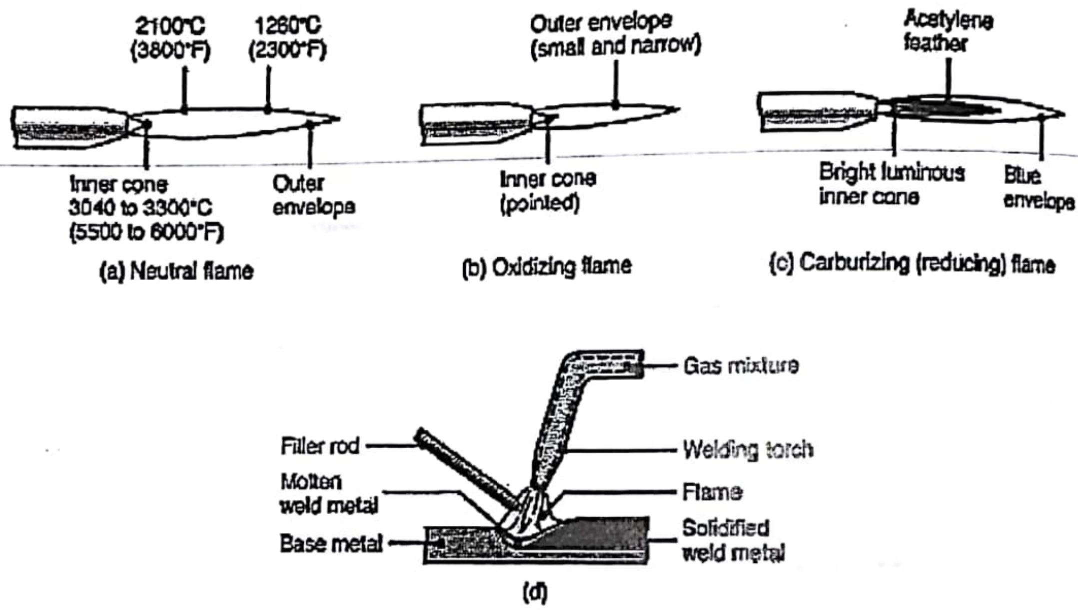


Figure 8.6 Three types of flames in oxyacetylene welding

6.9.3 Advantages and Disadvantages of Gas Welding:

6.9.3.1 Advantages:

1-The oxy-acetylene torch is versatile. It can be used for brazing, bronze welding, soldering, heating, heat treatment, metal cutting, metal cleaning, etc.

2-It is portable and can be moved almost everywhere for repair of fabrication work.

3-The oxy-acetylene flame is easily controlled and not as piercing as metallic arc welding, hence, extensively used for sheet metal fabrication work.

4-Welder has considerable control over the temperature of the metal in the weld zone. When the rate of heat input from the flame is properly coordinated with the speed of welding, the size,. viscosity and surface tension of the weld puddle can be controlled, permitting the pressure of the flame to be used to aid in positioning and shaping the weld.

5-The cost and maintenance of the gas welding equipment is low when compared to that of some other welding processes.

6-The rate of heating and cooling is relatively low. In some cases, this is an advantage.
7-Good weld quality.

6.9.3.2 Disadvantages:

1-As compared to arc welding, it takes considerably longer time for the metal to heat up.
2-Owing to prolonged heating harmful thermal effects are aggravated which results is a larger heat affected area, increased grain growth, distortion and less of corrosion resistance.
3-Oxygen and acetylene gases are expensive.
4-Flux applications and the shielding provided by the oxy-acetylene flame are not so positive as those supplied by the inert gas in TIG, MIG or C02 welding.
5-The handling and storing of gas necessitate lot of safety precautions.
6-Heavy sections cannot be joined economically.
7-Flame temperature is less than the temperature of the arc.
8-Skilled operator required.
9- Difficult to prevent contamination.
10- Large heat affected zone.

6.9.4 Applications of Gas Welding

Following are the applications of gas welding:

1. To join most ferrous and non-ferrous metals, e.g., carbon steels, alloy steels, cast iron, aluminum, copper, nickel, magnesium and its alloys, etc.
2. To join thin materials.
3. To join materials in whose case excessively high temperatures would cause certain elements in the metal to escape into the atmosphere.
4. To join materials in whose case excessively high temperatures or rapid heating and cooling of the job would produce unwanted or harmful changes in the metal.
5. Automotive and Aircraft industries.
6. Sheet metal fabricating plants.

6.10 RESISTANCE ELECTRIC WELDING:

It is the method of uniting two pieces of metal by the passage of a heavy electric current while the surfaces are pressed together. The fusing temperature is obtained by placing the surfaces to be joined in contact with one another, and passing a current of two to eight volts, at a high amperage through them. The heat is developed around the point to which they touch, forcing them together (by pressure mechanically applied), and at the same time switching off the current, completes the weld.

6.10.1 Resistance Spot Welding:

Spot welding is the simplest and most commonly used resistance-welding process. Is carried out by overlapping the edges of two sheets of metal and fusing them together between copper electrode tips at suitably spaced intervals by means of a heavy electrical current. The resistance offered to current as it passes through the metal raises the temperature of the metal between the electrodes to welding heat. The current is cut-off and mechanical pressure is then applied by the electrodes to forge the welds. Finally the electrodes open.

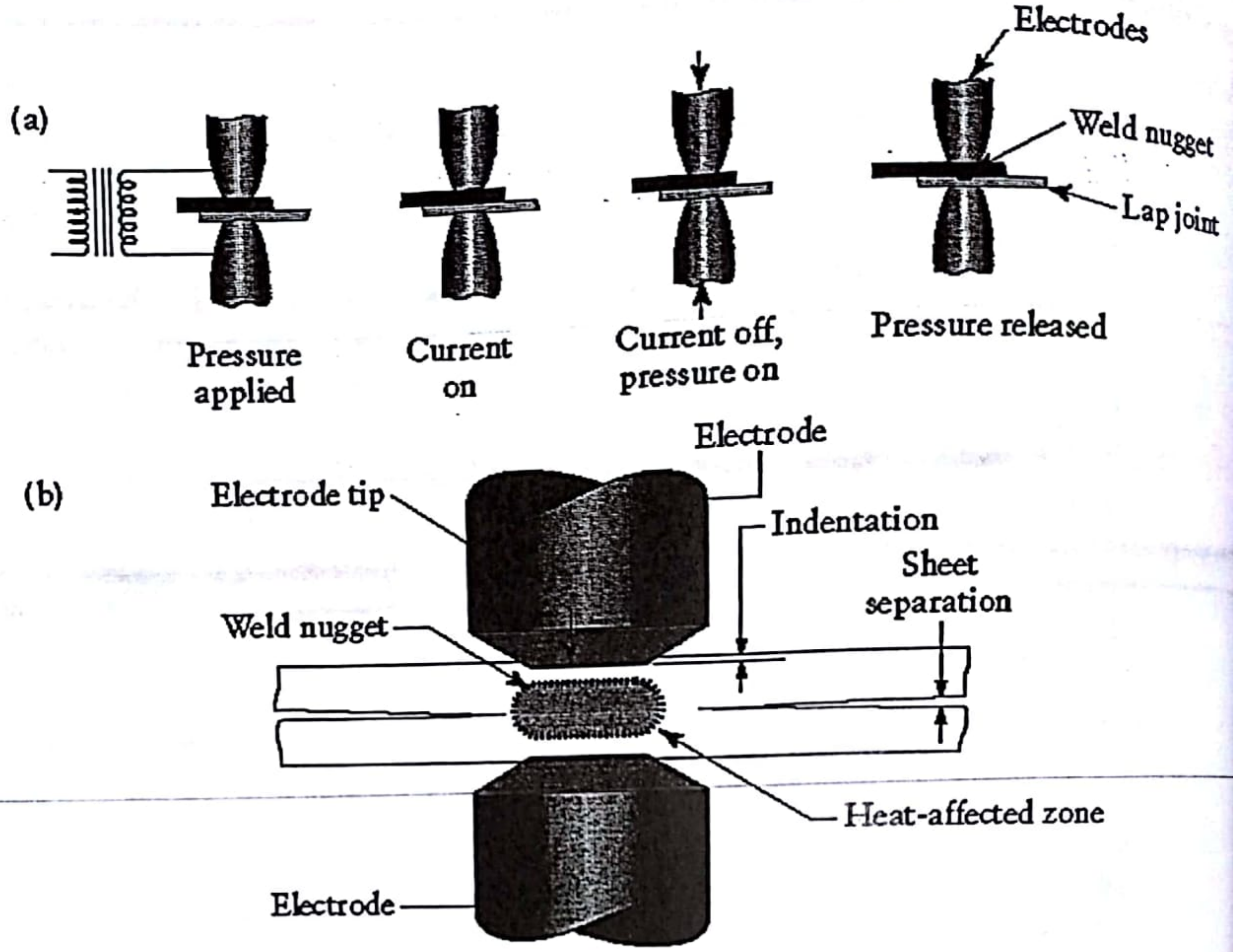


Figure 8.6 Resistance Spot Welding

When sheets of unequal thickness are joined, the current and pressure setting for the thinner sheets are used. Similarly four thickness may be welded, using the same settings as for two thickness

6.10.1.1 Applications:

Spot welding is widely used for fabricating sheet-metal products. Examples of its applications range from attaching handles to stainless-steel cookware to rapid spot welding of automobile bodies, using multiple electrodes.

6.10.1.2 Advantages:

1..High production rate.
2. Very economical process.
3. High skill not required.
4. Most suitable for welding sheet metals.
5. Dissimilar metals can be welded.
6. No edge preparation is needed.
7. Operation may be made automatic or semi-automatic.
8. Dependability.
9. Small heat affected area.

10. More general elimination of warping or distortion of parts.

6.10.1.3 Limitations:

1. Suitable for thin sheets only.
2. High equipment cost.

A special feature of resistance welding is the rapid heating of the surface being welded (in hundredths of a second) due to application of currents of high amperage.

6.10.1.5 The various resistance welding processes are:

1. Resistance spot welding.
2. Resistance seam welding.
3. Resistance projection welding.
4. Resistance butt welding.

6.11 Friction Welding

In this welding process, often termed as "inertia welding", the two surfaces to be welded are rotated relative to each other under light normal pressure. When the interface temperature increases due to frictional rubbing and when it reaches the required welding temperature, sufficient normal pressure is applied and maintained until the two pieces get welded.

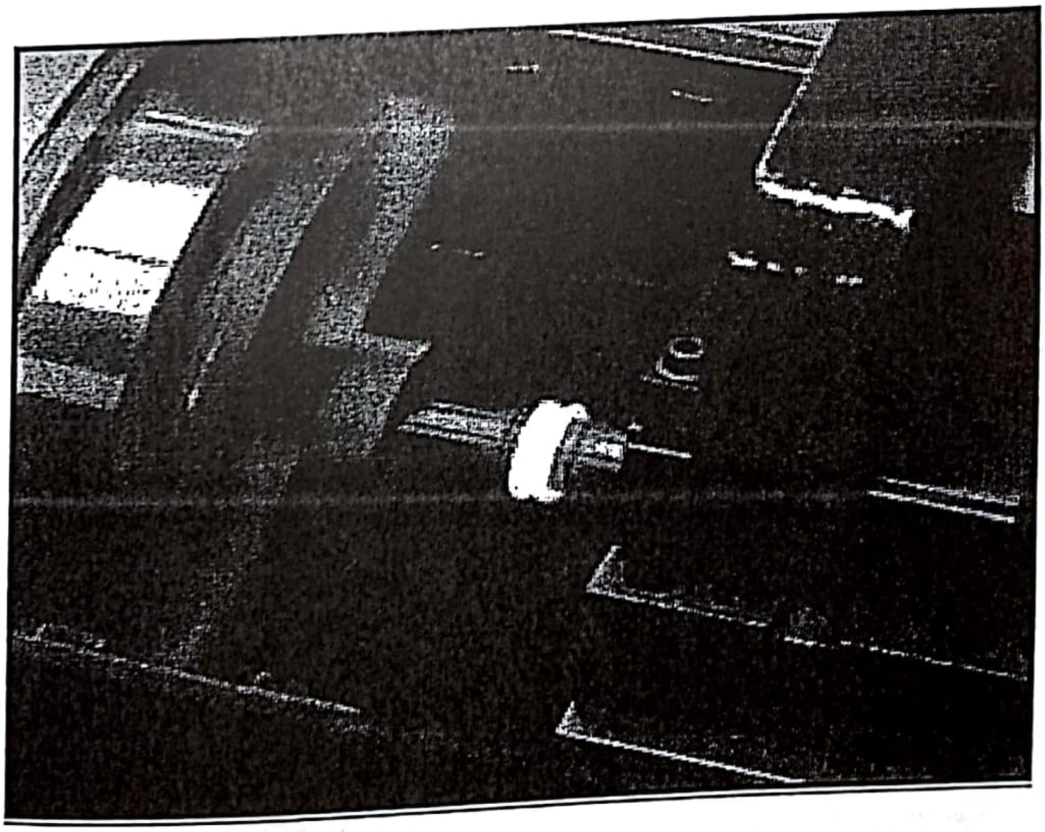


Figure 8.7 Friction Welding

- A wide variety of metals and metal combinations can be welded by this process. Filler metals, fluxes, or shielding gases are not required, and welds can be made with a minimum of joint preparation.
- The method is most suitable for circular parts, that is, butt welding of round bars or tubes.

6.12 TUNGSTEN INERT-GAS (TIG) WELDING

This welding process is also called Gas Tungsten Arc Welding (GTAW) as shown below. In this process the heat necessary to melt the metal is provided by a very intense electric arc which is struck between a virtually non-consumable tungsten electrode and metal workpiece. The electrode does not melt and become a part of the weld. On joints where filler metal is required, a welding rod is fed into the weld zone and melted with base metal in the same manner as that used with oxyacetylene welding. The weld zone is shielded from the atmosphere by an inert-gas (a gas which does not combine chemically with the metal being welded) which is ducted directly to the weld zone where it surrounds the tungsten.

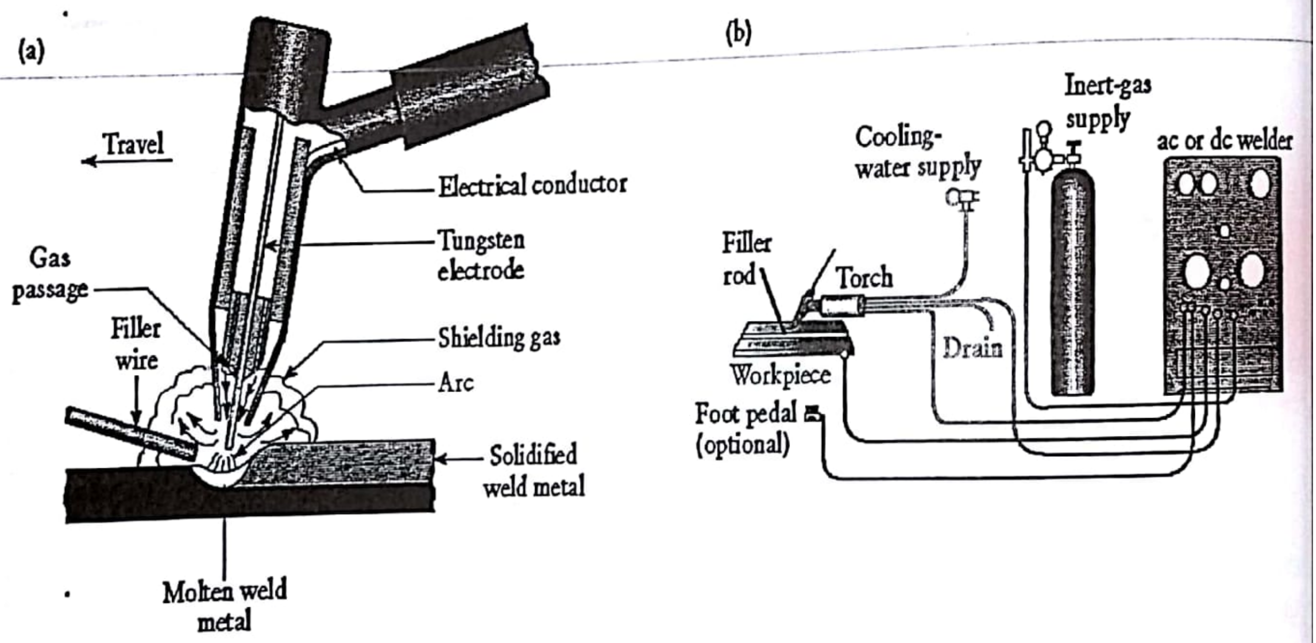


Figure 8.8 Tungsten inert-gas (TIG) welding

The major inert gases that are used are argon and helium.

6.12.1TIG process offers the following advantages

a. TIG welds are stronger, more ductile and more corrosion resistant than welds made with ordinary shield arc welding.
b. Since no granular flux is required, it is possible to use a wide variety of joint designs than in conventional shield arc welding or stick electrode welding.
c. There is little weld metal splatter or weld sparks that damage the surface of the base metal as in traditional shield arc welding.

6.12.2 Applications

1. The TIG process lends itself ably to the fusion welding of aluminum and its alloys, stainless steel, magnesium alloys, nickel base alloys, copper base alloys, carbon steel and low alloy steels.
2. TIG welding can also be used for the combining of dissimilar metals, hard facing, and the surfacing of metals.

6.13 METAL INERT-GAS (MIG) WELDING

The inert-gas consumable electrode process, or the MIG process is a refinement of the TIG process, however, in this process, the tungsten electrode has been replaced with a consumable electrode. The electrode is driven through the same type of collect that holds a tungsten electrode by a set of drive wheels. The consumable electrode in MIG process acts as a source for the arc column as well as the supply for the filler material.

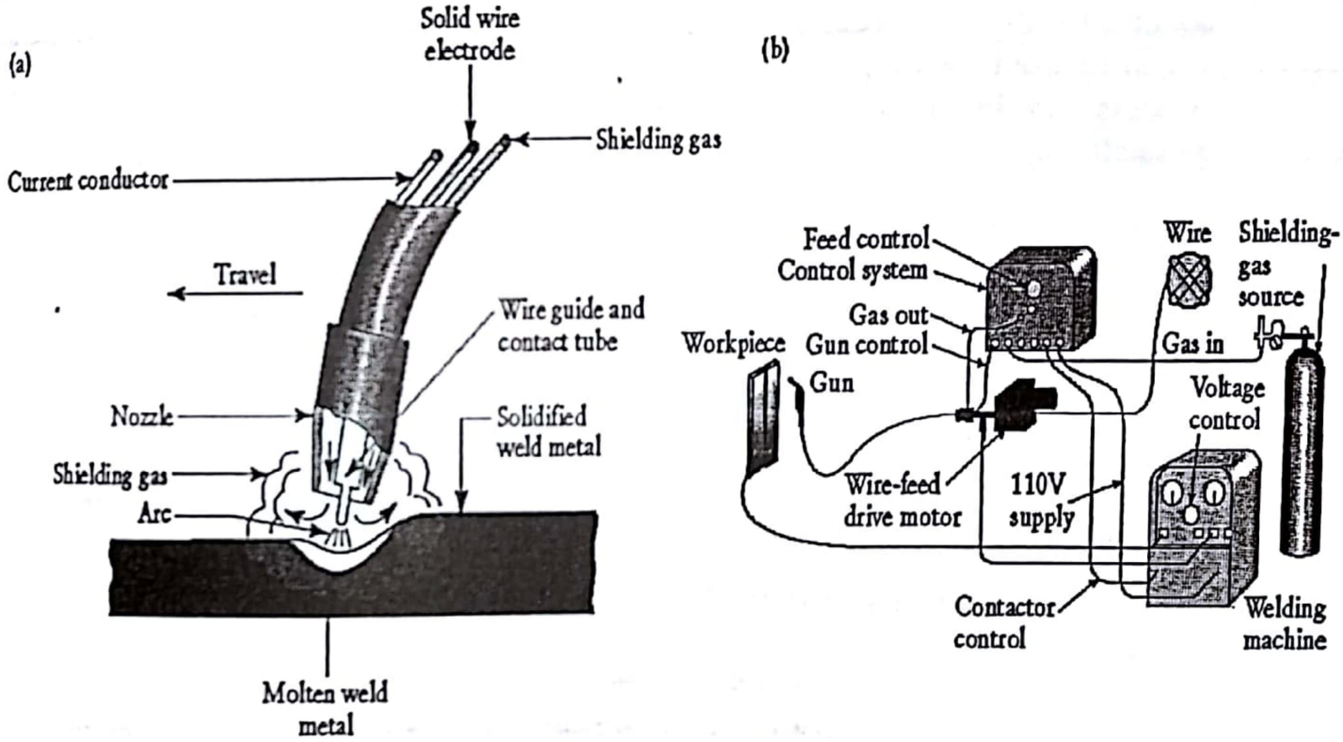


Figure 8.12 Metal inert-gas welding (MIG)

MIG welding employs the following three basic processes.

1. Bare-wire electrode process
2. Magnetic flux process
3. Flux-cored electrode process.

- **Driving wheels**
  a. Power source
  b. Shielding \ gas
  c. Puddle
  d. Base metal

e. Consumable electrodes
f. Arc
g. column

6.13.1 Advantages

1-It provides higher deposition rate.
2-It is faster than shielded metal-arc welding due to continuous feeding of filler metal.
3-Welds produced arc of better quality.
4-There is no slag formation.
5-Deeper penetration is possible.
6-The weld metal carries low hydrogen content.
7- More suitable for welding of thin sheets.

6.13.3 Applications

1. Practically all commercially available metals can be welded by this method.
2. It can be used for deep groove welding of plates and castings, just as the submerged arc process can, but it is more advantageous on light gauge metals where high speeds are possible.

6.14 CHARACTERISTICS OF GOOD WELD

1. The weld should not crack in the bend test.
2. It should not contain scum or slag imbedded in the well.
3. Its appearance should be ripple like and not spongy.
4. It should not have cavities, and the grain size should be uniform.
5. The contour of the weld should be even.
6. The weld should have even width.
7. Over current tries to dissolve scum in the weld while undercurrent tries to give cracks in the weld.
8. If electrode distance from the weld is varying this will cause the unevenness of the weld.

6.15 Safety Precautions while Working in Welding shop

6.15.1 Gas welding

1. One should not use a leaking gas cylinder.
2. One should not handle oxygen cylinders, valves, regulators, hoses or fittings with oily hands.
3. Welder should not mix the gases in one cylinder.
4. No one should transfer the gas from one cylinder to another.
5. One should clearly mention on the cylinders the type of gas in it (i.e. oxygen, acetylene, etc.).
6. One should use nose masks where the local exhaust ventilation is not practicable. Insist the safety officer to provide proper ventilation system.

7. Always avoid skin contact with fluxes, which contain fluorides. If they will penetrate the skin, they produce severe irritation.
8. No one should weld the parts, which are coated with toxic material such as lead, cadmium, zinc, mercury, or paint containing toxic before materials. Any such coatings must be removed prior to welding.
9. Acetylene gas should not be brought in contact with the unalloyed copper directly (except in torch) which may result in a violent explosion.

6.15.2 Arc welding

1. One should use protective clothing and eye protection devices while performing arc welding operation, otherwise radiation from electric arc will damage the retina of eyes. One has to be sure that other people standing nearby also uses eye-protection devices from ultraviolet rays.
2. Always use ear protection devices such as muffler because excessive noise caused during the process of arc welding may cause temporary or permanent hearing loss.
3. Welder should keep clothing and gloves dry.
4. Always keep welding cables free of grease and oil.
5. One should prevent the non-insulated portion of the electrode holder from touching the welding ground or job-piece when the current is on.
6. Always keep the body insulated from both the work and the metal electrode holder.
7. One should carry out the welding process by standing on the insulating material like dry wood rather than on a grounded metal structure.
8. It is easier and safer to establish an arc on a clean surface than on a dirty or rusty one.
9. Always turn the welding machine off when it is not in use.
10. One should not change the polarity switch when the machine is under use. This will burn the surface of the switch and the resulting arc can cause injury to the welder.
11. Always avoid using electrode holders with defective jaws or poor insulation.

Questions	
Q1	What are the types of welding flames?
Q2	List the various resistance welding processes.
Q3	What are the main types of welding electrodes?
Q4	What are the main applications of Gas welding ?
Q5	Explain briefly the following: 1. Consumable Electrodes, 2. Non-consumable Electrodes, 3. Welding, 4. Electrode holder, 5. Wire brush, 6. Goggles, 7. Flux, 8. Spot welding,
Q5	Which of the following Statements is Correct? 1.A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting. 2.Filler material is typically added to strengthen the joint. 3.Welding is used extensively in all sectors or manufacturing, from earth moving equipment to the aerospace industry. 4.Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations. 5.Welded joint needs stress relieving and heat treatment. 6.Welding gives out harmful radiations (light), fumes and spatter. 7.Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal 8.Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface. 9.The rate of heating and cooling is relatively low. In some cases, this is an advantage for the gas welding. 10. Gas welding used to join most ferrous and non-ferrous metals. 11. Friction welding *is* most suitable for circular parts, that is, butt welding of round bars or tubes. 12. The resistance welding is possible to weld dissimilar metals as well as metal plates of different thicknesses. 13. In the resistance welding: Heating of workpiece is confined to a very small part which results in less distortion.

Machining Operations

1.10.2 Safety Precautions while Working on Lathe Machine

1. One should always be sure that all guards are in place before running the machine.
2. Always clamp the work and tool properly with correct size of work and tool holding device.
3. Always keep the machine clear of tools.
4. Machine should be stopped before making measurements or adjustments.
5. Wear an apron or a properly fitted shop coat. Goggles should also be used.
6. One should remove necktie, wrist watch and jewellery while working.
7. One should not operate the lathe until he knows the proper procedure.
8. One should check the work frequently when it is being machined.
9. One should check the face-plate or chuck by hand to be sure that there is no danger of the work striking any part of the lathe.
10. Stop the machine and remove chips with pliers. One should not remove the chips by hand.

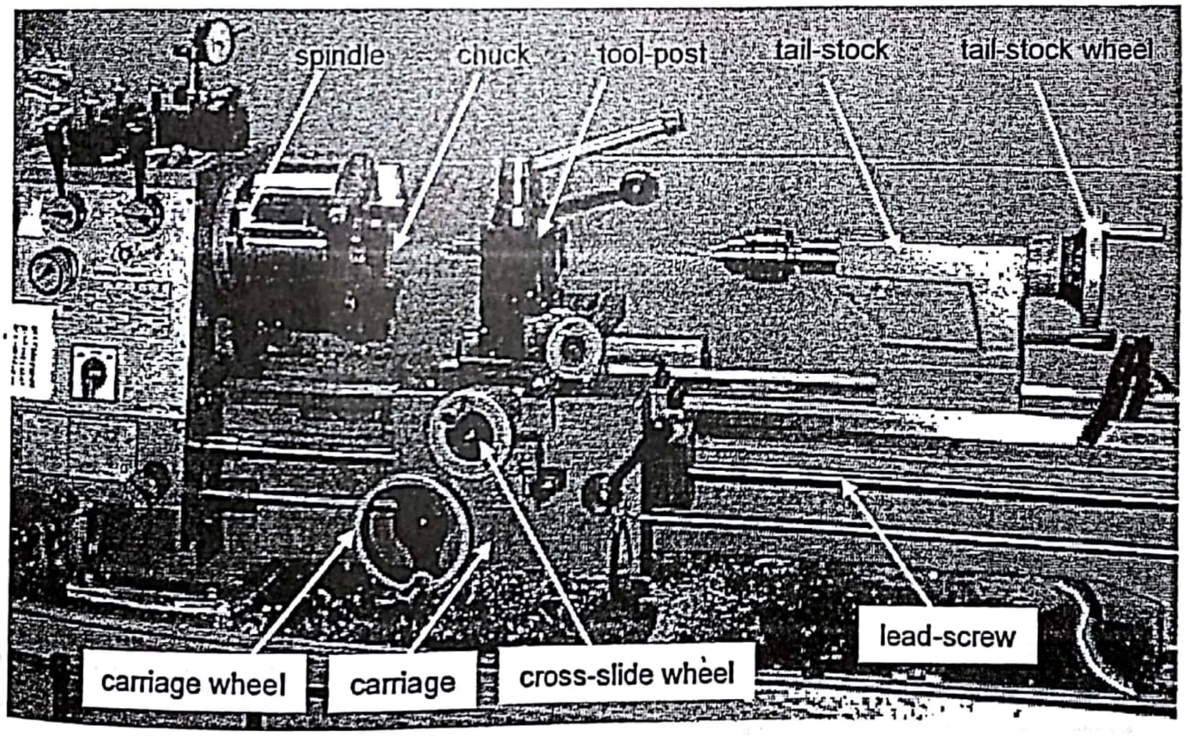


Figure 9. 1 Lathe Machine

9.1 Lathe Machine

The lathe is a machine tool used principally for shaping articles of metal, wood, or other material. All lathes, except the vertical turret type, have one thing in common for all usual machining operations; the workpiece is held and rotated around a horizontal axis while being formed to size and shape by a cutting tool. The cutter bit is held either by hand or by a mechanical holder, and then applied to the workpiece. Principal capabilities of the lathe are forming straight, tapered, or irregularly outlined cylinders, facing or radial turning cylindrical sections, cutting screw threads, and boring or enlarging internal diameters. The typical lathe provides a variety of rotating speeds and suitable manual and automatic controls for moving the cutting tool.

9.2 Types of Lathes

Lathes can be conveniently **classified** as **engine lathes, turret lathes,** and **special purpose lathes.** All engine lathes and most turret and special purpose lathes have horizontal spindles and, for that reason, are sometimes referred to as horizontal lathes. The smaller lathes in all classes may **be classified** as **bench lathes** or floor or pedestal lathes, the reference in this case being to the means of support.

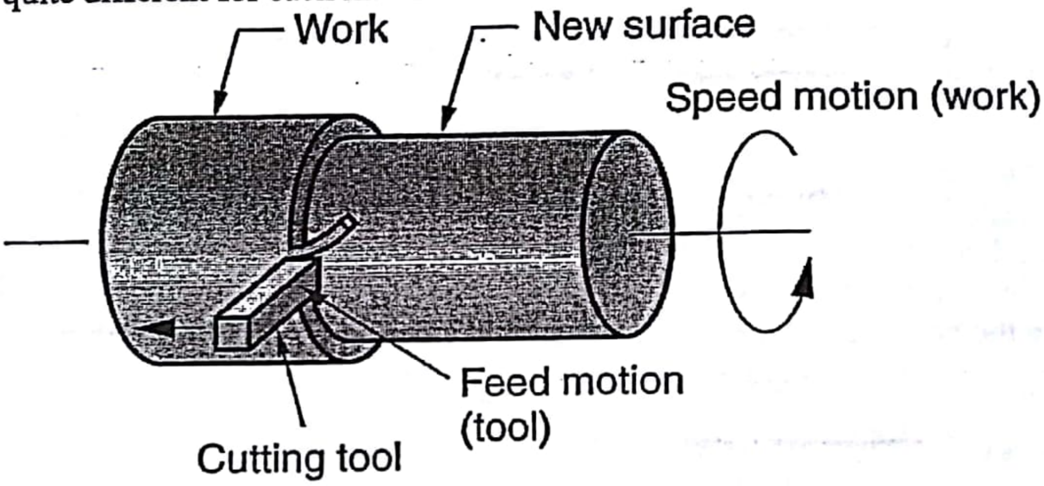
- **SPINDLE LOCK KNOB:** For keeping the spindle from rotation when tightening or loosening collets.
- **TAILSTOCK:** For accurately holding the tailstock spindle.
- **TAILSTOCK HAND WHEEL:** For moving the tailstock spindle toward or away from the workpiece.
- **TAILSTOCK SPINDLE:** For holding drill chucks or lathe centers in the tailstock.
- **SPINDLE SPEED DISPLAY:** Shows the spindle speed in Rotations per Minute (RPMs).
- **SPINDLE SPEED KNOB:** For adjusting the speed of the lathe spindle.
- **CARRIAGE:** Moves the tool post, cross slide toward or away from the chuck.
- **EMERGENCY STOP SWITCH:** For shutting off the spindle rotation and feeds in case of an emergency.

- **COLLET CHUCK:** For holding small diameter work pieces in the spindle of the lathe.
- **TOOL POST:** For holding and quickly changing between different Tool Holders.
- **TOOL HOLDER:** For holding lathe bits and other lathe cutting tools.
- **COMPOUND SLIDE HAND WHEEL:** For manually feeding cutting tools at an angle to the spindle.
- **CROSS SLIDE HAND WHEEL:** For manually feeding cutting tools across the spindle (the X axis).
- **CARRIAGE HAND WHEEL:** For manually feeding cutting tools in line with the spindle (the Z axis).
- **CROSS SLIDE FEED LEVER:** For turning the auto feed for the cross slide on and off.
- **CARRIAGE FEED LEVER:** For turning the auto feed for the carriage on and off.
- **SPINDLE ON/OFF & DIR. LEVER:** For turning the spindle on or off and for setting the rotation direction.
- **FEED DIRECTION KNOB:** To determine the direction of the carriage or cross

slide auto feed.

9.3 Three important elements

In order to get an efficient process, good surface finish and correct geometry on the lathe, it is important to adjust the rotating speed (RPM), a cutting depth and a feed speed. Please note that these important elements cannot be decided easily, because these suitable values are quite different for each material.



(a)

1. **ROTATION SPEED:** It is the number of rotations per minute (rpm) of the chuck. When the rotating speed is high, higher removal rates are possible. But when too high, too much friction could be generated. However, since a little operation mistakes may lead to the serious accident, it is better to set lower rotating speed at the first stage.
2. **CUTTING DEPTH:** The cutting depth of the tool affects to the processing speed and the roughness of surface. When the cutting depth is big, the processing speed becomes quick, but the surface temperature becomes high, and it has rough surface. Taking off too much material can break the tool or your workpiece. If you do not know a suitable cutting depth, it is better to set to small value. Always remove a very small amount of material on your final pass to assure a good surface finish.
3. **FEED SPEED:** The feed speed of the tool also affects to the processing speed and the roughness of surface. When the feed is high, you can remove a lot of material quickly. When the feed is low, the surface improves. There are automatic feeds on these machines that can move the feed handles for you at a very accurate feed. These auto feeds maintain a consultant speed and result in nicer finishes. A beginner must always use the manual mode, until they have enough experience. A user should hold the handle of the automatic feed until the operation is complete and never walk away. Serious accidents may occur if the tool bit or any part of the post or the cross slides touch the chuck!

9.4 Cutting Speed

Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting. Too slow cutting speeds reduce productivity and increase manufacturing costs whereas too high cutting speeds result in overheating of the tool and premature failure of the cutting edge of the tool. The following factors affect the cutting speed:

Calculation of cutting speed Cs, in meters per minute

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

Where

D is diameter of job in mm.

N is in RPM

9.5 FEED

Feed is defined as the distance that a tool advances into the work during one revolution of the headstock spindle. It is usually given as a linear movement per revolution of the spindle or job. During turning a job on the center lathe, the saddle and the tool post move along the bed of the lathe for a particular feed for cutting along the length of the rotating job.

IF	THEN
You increase the feedrate too much	You risk taking too big a "bite" and will break the cutter.
You decrease the feedrate too much	You risk "rubbing" (not cutting) and will wear out the cutter.
You increase the spindle speed too much	You will not cut, but instead burn up the tool with friction.
You decrease the spindle speed too much	Your cut will be very slow.

9.8 Lathe Operations

(a)**Facing:** The tool is fed radially into the rotating work on one end to create a flat surface on the end.

(b)**Taper turning:** Instead of feeding the tool parallel to the axis of rotation of the work, the tool is fed at an angle, thus creating a tapered cylinder or conical shape.

(c)**Contour turning:** Instead of feeding the tool along a straight line parallel to the axis of rotation as in turning, the tool follows a contour that is other than straight, thus creating a contoured form in the turned part.

(d)**Form turning:** In this operation, sometimes called **forming**, the tool has a shape that is imparted to the work by plunging the tool radially into the work.

(e)**Chamfering:** The cutting edge of the tool is used to cut an angle on the corner of the cylinder, forming what is called a "chamfer."

(f) **Cutoff:** The tool is fed radially into the rotating work at some location along its length to cut off the end of the part. This operation is sometimes referred to as **parting.**

(g)***Threading:*** A pointed tool is fed linearly across the outside surface of the rotating workpart in a direction parallel to the axis of rotation at a large effective feed rate, thus creating threads in the cylinder. -

(h)***Boring:*** A single-point tool is fed linearly, parallel to the axis of rotation, on the inside diameter of an existing hole in the part.

(i) **Drilling:** Drilling can be performed on a lathe by feeding the drill into the rotating work along its axis. **Reaming** can be performed in a similar way.

(j) **Knurling:** This is not a machining operation because it does not involve cutting of material. Instead, it is a metal forming operation used to produce a regular cross- hatched pattern in the work surface

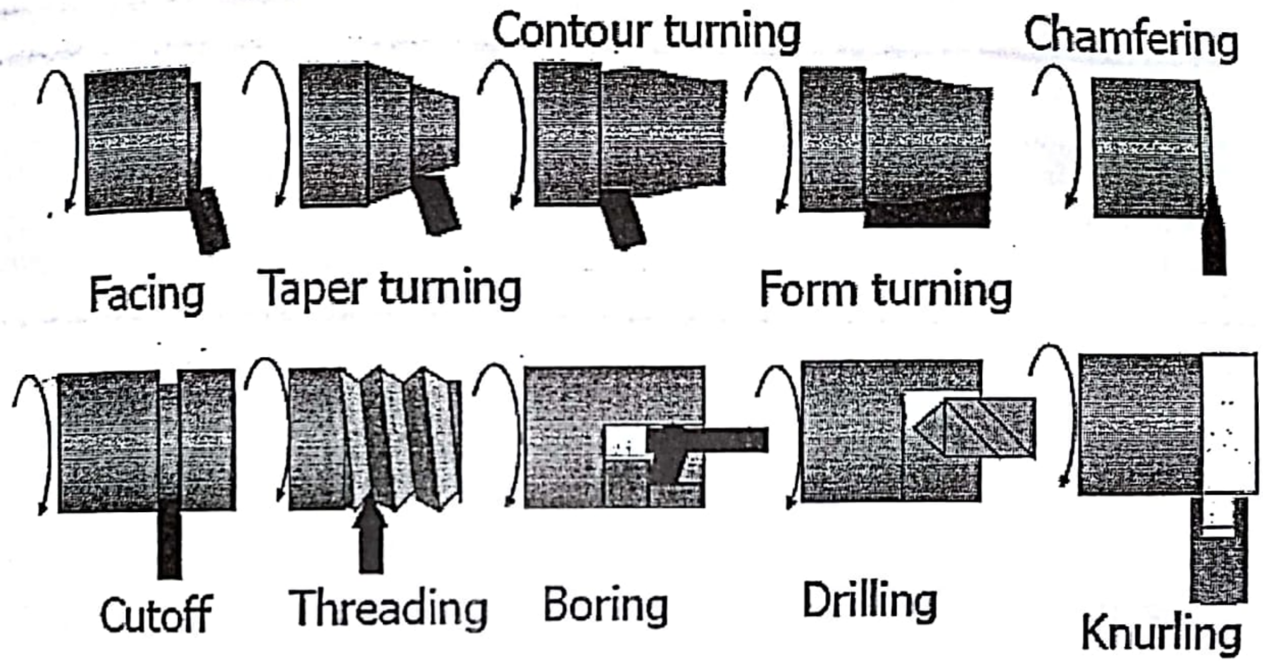


Figure 9.2 Lathe operations

The main factors which influence the selection of a proper cutting speed are:

1. Material of the cutting tool.
2. Hardness and machinability of the metal to be machined.
3. Quality of heat treatment, if it is a H.S.S. steel tool.
4. Whether machining is to be done with or without the use of a coolant.
5. Rigidity of the tool and the work.
6. Tool shape.
7. Depth of cut.
8. Feed to be given to the tool.
9. Rigidity of the machine.

- Feed may be defined as the distance that a tool advances into the work during one revolution of the headstock spindle. Feed is expressed in mm/revolution.
- Larger feeds reduce machining time, but the tool life is reduced.

The values of speed, feed and depth of cut, in general, depend upon the following factors:

1-Type of workpiece material;

2-Type of tool material;

3-Type of surface finish required.

4- Material Removal Rate (MRR).

10.1 SHAPING MACHINE (SHAPER)

Shaper is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line. The basic components of shaper are shown in Fig. 10.1. It is intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical, or inclined. In general, the shaper can produce any surface composed of straight-line elements. A shaper is used to generate flat (plane) surfaces by means of a single point cutting tool similar to a lathe tool.

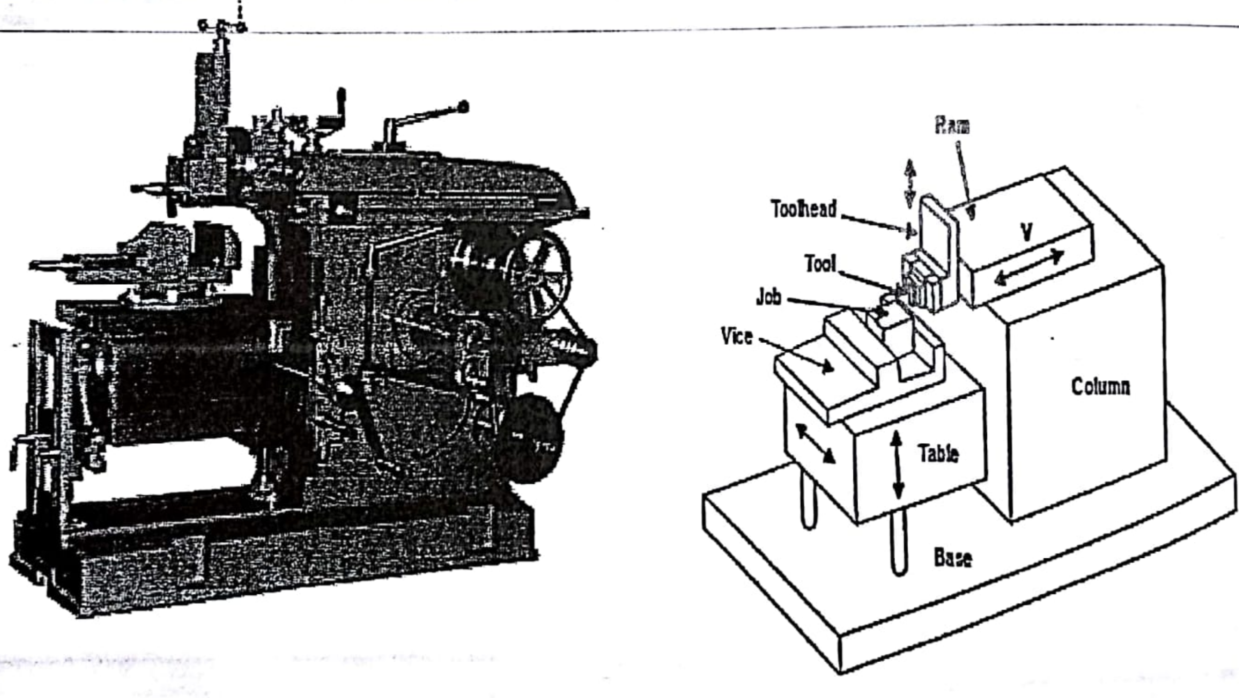


Figure 10.1 Principal components of a shaper

A shaper is a reciprocating type of machine tool intended primarily to produce horizontal, vertical or inclined flat surfaces (up to 1000 mm long).

10.2 Principle of working

In the shaper, the cutting tool has a reciprocating motion, and it cuts only during the forward stroke only. The work is held in a vice bolted to the work table. The regular feed is obtained by moving the worktable automatically at right angles to the direction of the cutting tool and the tool head gives downward feed at right angles to the regular feed or any other angle as desired.

Most shaping machines usually work with one cutting tool, and cutting is done in the forward stroke only, but the exceptions exist where more than one tool is used for simultaneous cutting or cutting on both (forward and return) strokes.

10.3 Specification of A Sharper

The size of a shaper is specified by the maximum length of stroke or cut it can make. Usually the size of shaper ranges from 175 to 900 mm. Besides the length of stroke, other particulars, such as the type of drive (belt drive or individual motor drive), floor space required, weight of the machine, cutting to return stroke ratio, number and amount of feed, power input etc. are also sometimes required for complete specification of a shaper.

10.4 Surfaces Produced on Shaper

1. Horizontal plain surface.
2. Vertical plain surface.
3. Inclined surface.
4. Grooved surface.
5. Slotted surface.
6. Stepped surface.

10.5 Advantages, Limitations, and Applications of Shapers:

10.5.1 Advantages:

1. The set up of shaper is very quick and easy and can be readily changed from one job to another.
2. The work can be held easily.
3. The single point tools can be easily grounded to any desired shape.
4. Lower first cost.
5. The cutting stroke has a definite stopping point.
6. Because of lower cutting forces, thin and fragile jobs can be conveniently machined on shapers.

10.5.2 Limitations:

1-A shaper, by nature, is a slow machine, because of its straight line, forward and return (idle) stroke. The single point tool requires several strokes to complete a work.

2-The cutting speeds are not usually very high since difficulties are encountered in designing machine tools with high speeds of reciprocating motion due to high inertia forces developed in the motion of the units and components of the machine. Owing to these reasons the shaper does not find ready adaptability for assembly and production line.

- **Cutting speed:** is defined as the average linear speed of the tool during the cutting stroke in m/min, which depends on the number of ram strokes (or ram cycles) per minute and the length of the stroke.

11.1 Drilling Machine

Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill. A drill is a rotary end-cutting tool with one or more cutting lips and usually one or more flutes for the passage of chips and the admission of cutting fluid. A drilling machine as shown in fig. 11.1 is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter- boring, countersinking, honing, reaming, lapping, sanding etc.

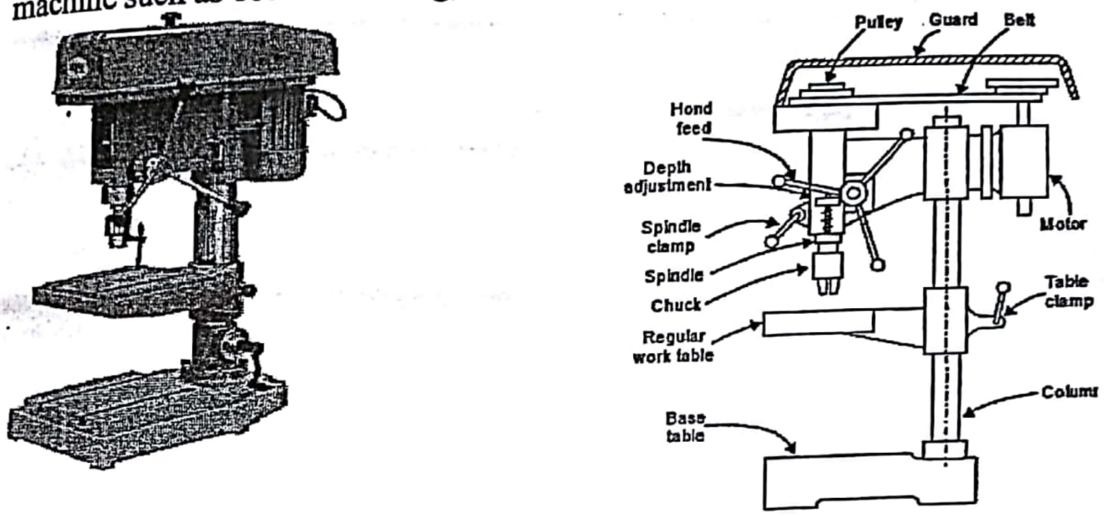
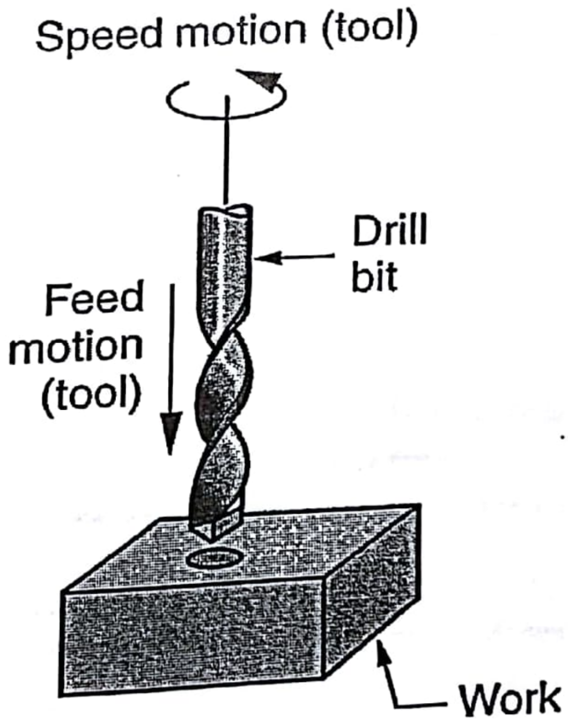


Figure11.1 Construction of drilling machine



(b)

Figure11.2 Drilling operation

11.2 SIZE OF A DRILLING MACHINE

Different parameters are being considered for different types of drilling machines to determine their size. The size of a portable drilling machine is decided by the maximum diameter of the drill that it can hold. The sensitive and upright drilling machines are specified by the diameter of the largest workpiece which can be centered under the drill machine spindle. A radial drilling machine is specified by the length of the arm and the diameter of the column. To specify a drilling machine completely, following other parameters may also be needed:

1. Table diameter
2. Number of spindle speeds and feeds available
3. Maximum spindle travel
4. Morse taper number of the drill spindle
5. Power input
6. Net weight of the machine
7. Floor space required, etc.

11.3 Cutting Speed

The cutting speed in a drilling operation refers to the peripheral speed of a point on the surface of the drill in contact with the work. It is usually expressed in meters/min. The cutting speed (Cs) may be calculated as:

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

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

11.4 Feed

The feed of a drill is the distance the drill moves into the job at each revolution of the spindle. It is expressed in millimeter. 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. The feed per minute may be calculated as:

$F = Fr \times N$

Where, F = Feed per minute in mm.
Fr = Feed per revolution in mm.
N = R.P.M. of the drill.

Drilling is a process of making hole or enlarging a hole in an object by forcing a rotating tool called "Drill".

The **drill** is generally called as **'twist drill'**, since it has a sharp twisted edges formed around a cylindrical tool provided with a helical groove along its length to allow the cut material to escape through it. The sharp edges of the conical surfaces ground at the lower end of the rotating twist drill cut the material by peeling it circularly layer by layer when forced against a workpiece. The removed material chips get curled and escape through the helical grooves provided in the drill. A liquid coolant is generally used while drilling to remove the heat of friction and obtain a better finish for the hole.

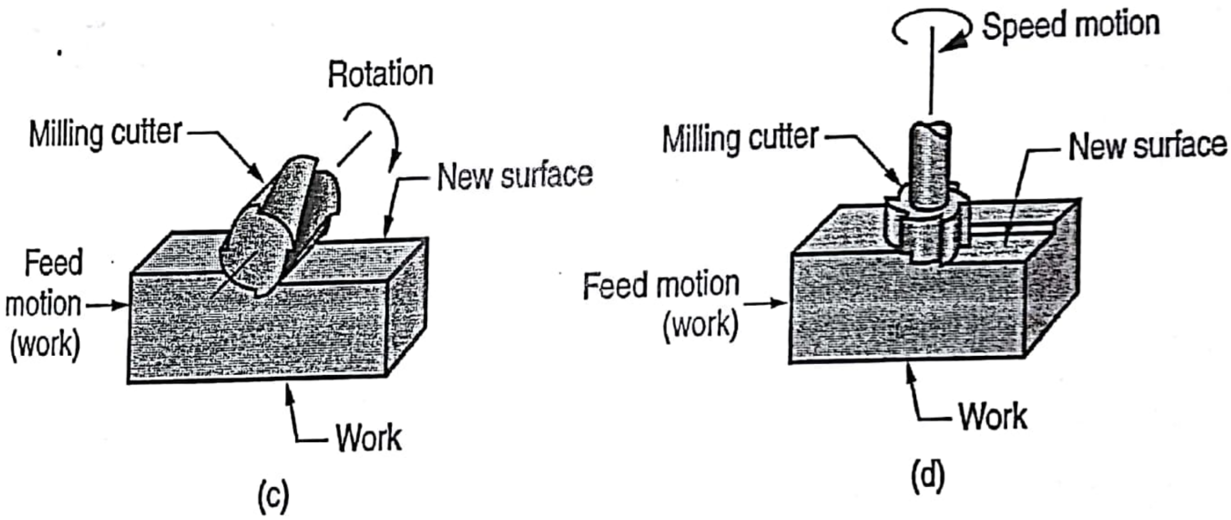
11.5 Specifications of a Drilling Machine

A drilling machine is specified as follows:

1. Size of the drilling machine table.
2. Largest bit the machine can hold.
3. Maximum size of the hole that can be drilled.
4. Maximum size of the workpiece that can be held.
5. Power of the motor, spindle speed or feed.

12.1 Milling Machines

A Milling Machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine. This is the reason that a milling machine finds wide application in production work.



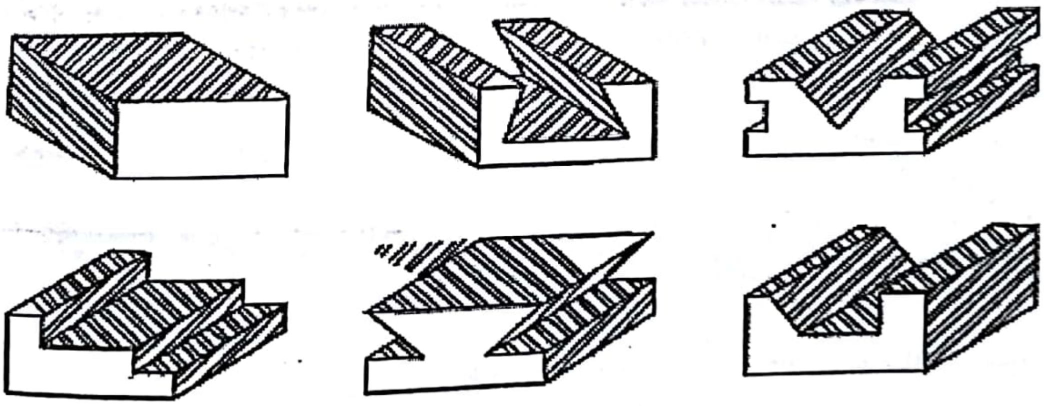
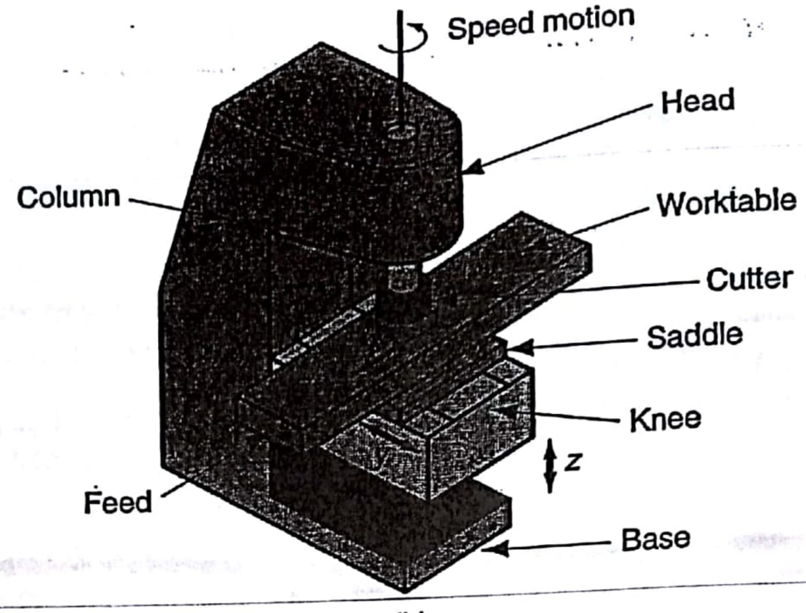


Figure 12.1 Job surfaces generated by milling machine



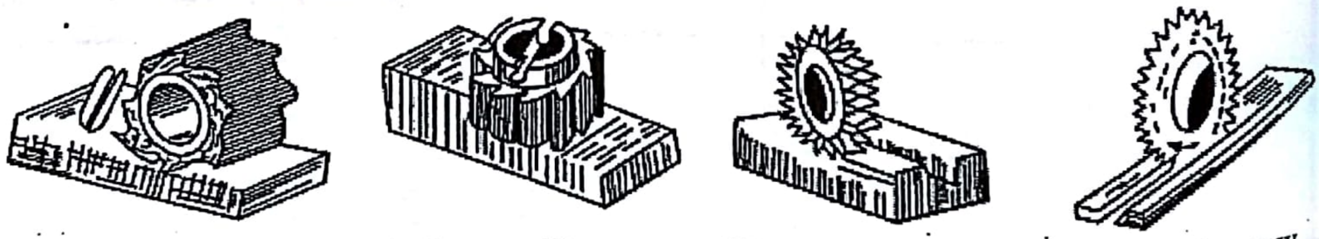
(b)

12.2 TYPES OF MILLING CUTTERS

Fig. 12.2 illustrates some types of milling cutters along with workpieces. Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

1. Plain milling cutters,
2. Side milling cutters,
3. Face milling cutter,
4. Angle milling cutters,
5. End milling cutter,
6. Fly cutter,
7. T-slot milling cutter,
8. Formed cutters,
9. Metal slitting saw.

Milling cutters may have teeth on the periphery or ends only, or on both the periphery and ends. Peripheral teeth may be straight or parallel to the cutter axis, or they may be helical, sometimes referred as spiral teeth.



Plain milling cutter Shell end mill Side milling cutter Metal- slitting saw

Angle milling cutter   Form milling   End milling

Figure12.2 Types of milling cutters

12.3 Milling machine

Milling Machine is a machine tool in which metal is removed by means of a revolving cutter with many teeth, each tooth having a cutting edge which removes metal from a workpiece. In a milling machine the work is supported by various methods on the workable, and may be fed to the cutter longitudinally, transversely or vertically.

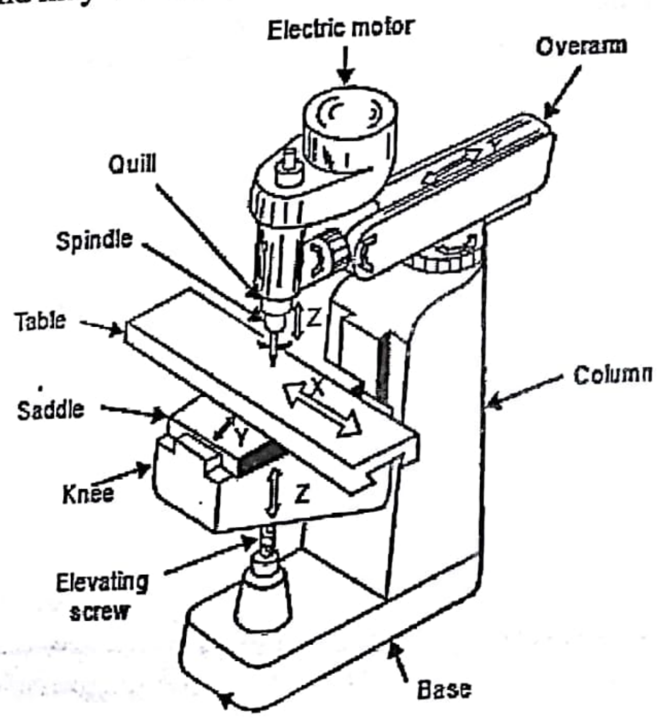


Figure 12.4 Vertical column and knee type milling machine

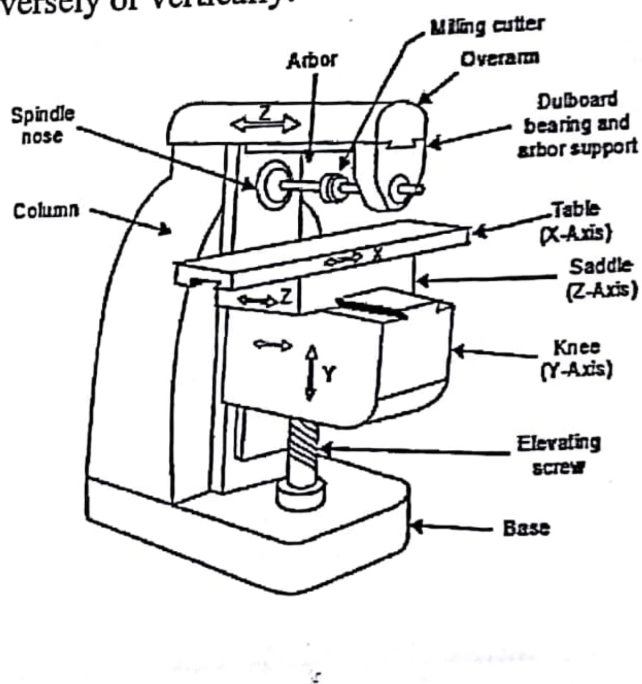


Fig. 12.3 Horizontal Milling Machine

12.4 Size of Milling Machine

The size of the column and knee type milling machine is specified by:

(1) The dimensions of the working surface of the table, and

(2) Its maximum length of longitudinal, cross and vertical travel of the table.

12.5 Indexing and dividing heads

Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. In cutting spur gear equal spacing of teeth on the gear blank is performed by indexing. Indexing is accomplished by using a special attachment known as dividing head or index head as shown in Fig. 12.5. The dividing heads are of three types:

(1) Plain or simple dividing head,
(2) Universal dividing head and
(3) Optical dividing head.

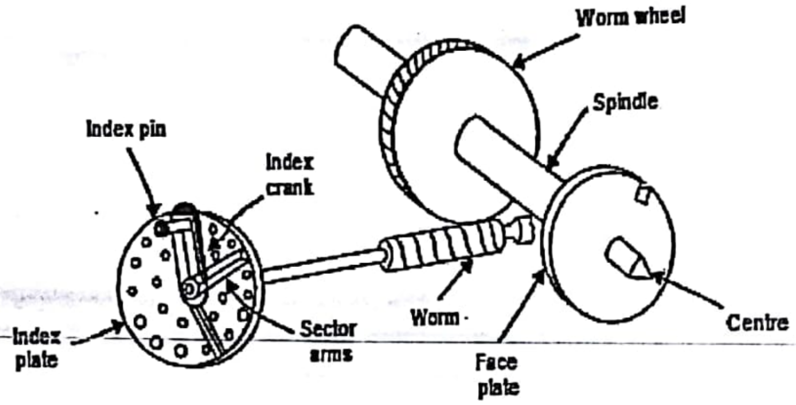
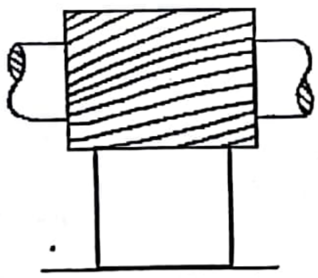
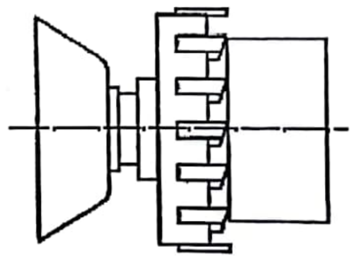


Figure 12.5 Dividing head

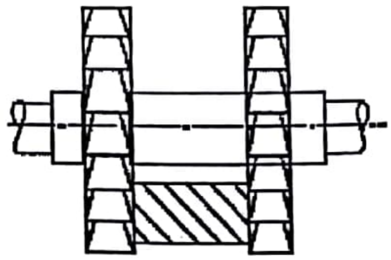
12.6 Operations Performed on Milling Machine:



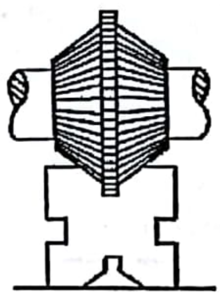
Plane Milling



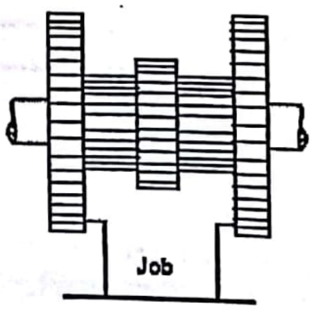
Face Milling



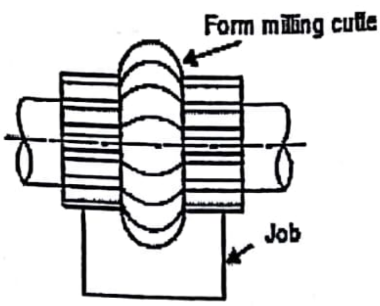
Side Milling



Angular Milling



Gang Milling



Form Milling

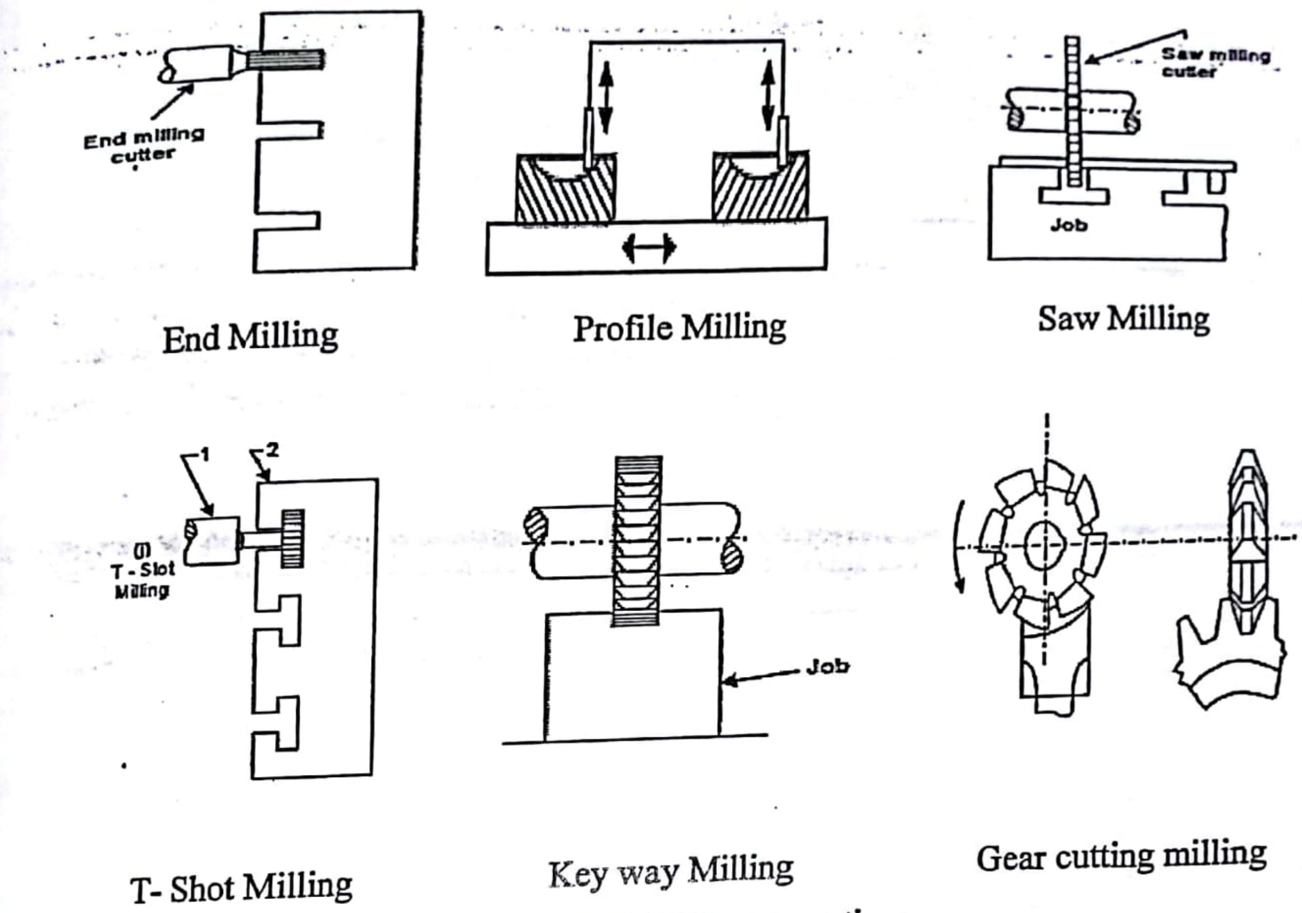


Figure12.6 Milling operations

12.7 Generally there are two types of milling processes:

1. Up milling (or conventional milling) process
2. Down milling (or climb milling) process.

12.8 Classification of Milling Machines:

The milling machines are broadly *classified* as follows:

1- Column and knee type :
2- Horizontal milling machine.
3- Vertical milling machine.
4- Universal milling machine.
5- Manufacturing or fixed bed type :
6- Simplex milling machine.
7- Duplex milling machine.
8- Triplex milling machine.
9- Planer type :

12.9 Types of Milling Cutters are:

a. Plain milling cutters.
b. Side milling cutters.

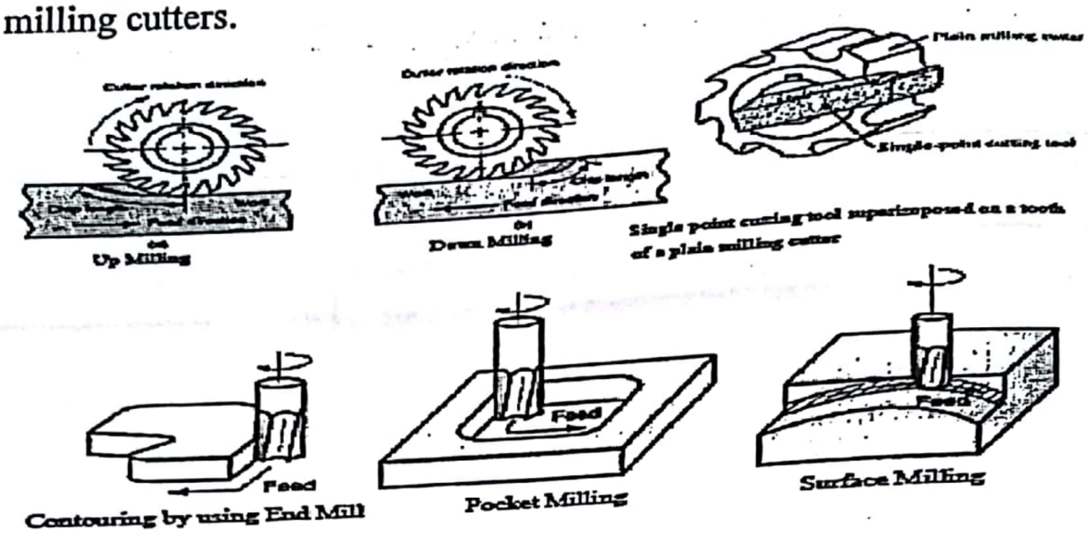


Figure 12.7 Types of Milling

12.10 Advantages of a planer as compared to shapers and millers:

1. Can take much heavier cuts.
2. Larger work can be handled.
3. The work is mounted on a table which is supported throughout its entire movement, so a maximum support is obtained.
4. No work or tool deflection or distortion (since there are no overhanging parts such as a ram).

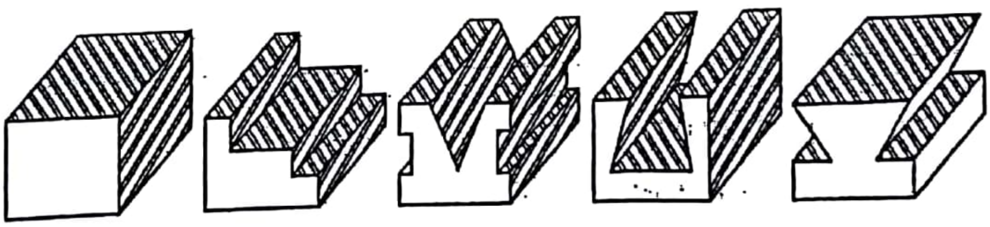


Figure 12.8 Components manufactured by planning/shaping processes

1.13.1 General Safety Guidelines while Working on Grinding Machines

1. Grinding wheels badly worn or cracked should be replaced.
2. The grinding wheel should be properly balanced while mounting.
3. One should ensure that no combustible or flammable materials are nearby that could be ignited by sparks generated by grinding wheels during grinding operations.
4. One should allow the grinding wheel to reach full speed before stepping it into the grinding position. Faulty wheels usually break at the start of an operation.
5. Always use the face of the grinding wheel that is meant for grinding.
6. One should slowly move job-pieces across the face of wheel in a uniform manner. This will keep the wheel sound.
7. Grinding wheels should be checked properly timely for soundness. Suspend the wheel on a string and tap it. If the wheel rings, it is probably sound.

8. One should not use a grinding wheel that has been dropped or dealt with a heavy blow, even if there is no apparent damage.
9. Before using a new grinding wheel, let it run for a few seconds at the full speed to check and make sure that it is perfectly balanced.
10. One should not operate the grinding wheel beyond its bursting speed.
11. Follow the manufacturer's instructions for the correct use of the grinding wheels.
12. Always wear goggles during grinding or allied processes.

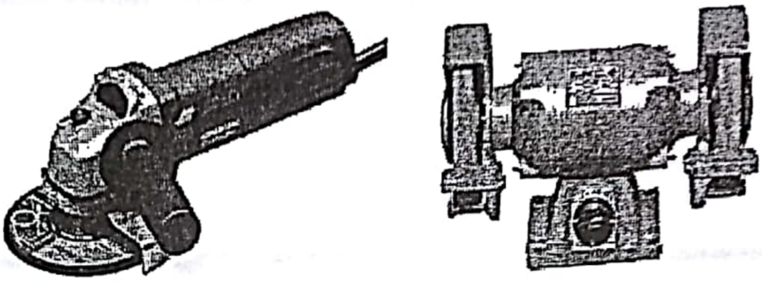
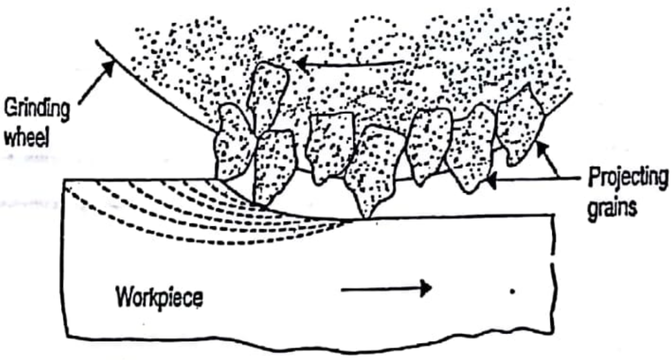


Figure 13.1 Grinding Machines

13.1 GRINDING AND FINISHING PROCESSES

Grinding is a metal cutting operation performed by means of a rotating abrasive tool, called "grinding wheel". Such wheels are made of fine grains of abrasive materials held together by a bonding material, called a "bond'. Each individual and irregularly shaped grain acts as a cutting element (a single point cutting tool).

– A magnified view of a grinding wheel and its cutting operation is shown below. The projecting grains of the abrasive material are held firmly by the board. The grains during rotation of the wheel remove very thin chips whose cross-section is similar to that obtained in milling. For this operation high wheel speeds are normally employed (up to 75 m/s). As the section of the chip removed during the process is small, and high cutting speeds are involved, this operation results into very good finish and high accuracy.



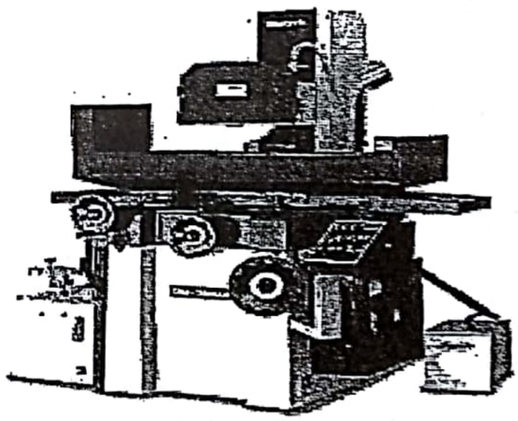


Figure13.2 Grinding

-The '*grinding* and 'finishing processes are used for final finish *and* super finish. The most common one is surface grinding. This process is accompanied by a certain amount of metal removal. This process can give a surface finish in a range of 1.25 µm to 0.25 µm.

-**For many applications,** grinding cannot meet the accuracy and surface finish requirements. For such applications workpieces are subjected to final operations. Two such operations are **honing and lapping.**

-**Grinding** is done on surfaces of almost all conceivable shapes and materials of all kinds. The grinding operation can be : (i) Rough (or non-precision) grinding and (ii) Precision grinding.

a. **"Rough grinding"** is a commonly used method ±or removing excess material from castings, forgings and welding etc.

b. **"Precision grinding"** is the principal production method of cutting materials that are too hard to be machined by other conventional tools or for producing surfaces on parts to higher dimensional accuracy and a finer finish as compared to other manufacturing methods.

13.2 Classification of grinding machine,

In accordance with the type of surface to the ground, is classified as:

1. External cylindrical grinding.
2. Internal cylindrical grinding.
3. Surface grinding.
4. Form grinding.

a. **External cylindrical** grinding. It produces a straight or tapered surface on a workpiece. The workpiece must be rotated about its own axis between centers as it passes lengthwise across the face of a revolving grinding wheel.

b. **Internal cylindrical** grinding. It produces internal cylindrical holes and tapers. The workpieces are chucked and precisely rotated about their own axes. The grinding wheel or, in the case of small bore holes, the cylinder wheel rotates against the sense of rotation of the workpiece.

c. **Surface grinding.** It produces flat surface. The work may be ground by either the periphery or by the end face of the grinding wheel. The workpiece is reciprocated at a constant speed below or on the end face of the grinding wheel.

d. **Form grinding.** This operation is done with specially shaped grinding wheels that grind the formed surface as in grinding gear teeth, threads, splined shafts, holes etc.

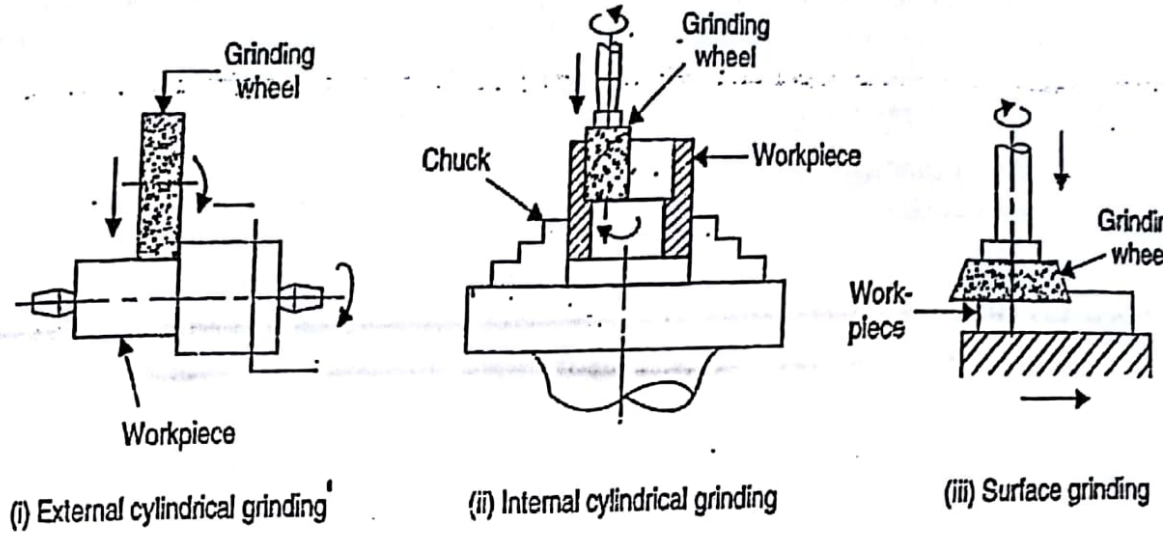


Figure13.3 Three basic kinds of precision grinding

13.3 Advantages of Grinding Process Over Other Cutting Processes:

1. It is possible to achieve very accurate dimensions and smoother surface finish in a very short time.
2. It is the only method of removing material from materials after hardening.
3. Owing-to large number of cutting edges on the grinding wheel it is possible to produce extremely smooth surface desirable at contact and bearing surfaces by grinding operation.
4. Complex profiles can be produced accurately with relatively inexpensive turning/templates.
5. Grinding unlike conventional machining need not cut through the hard skin of forgings etc.
6. Since the grinding wheel has considerable width therefore no marks as a result of feeding are there.
7. In this process little pressure is required, thus permitting its use on very, light work that would otherwise tend to spring away from the tool. This characteristic permits the use of magnetic cluck for holding the work in many grinding operations.

13.4 Following are the special features of grinding process:

1. The grinding operation is intermittent in nature, and produces discontinuous chips.
2. The grinding wheel has a self sharpening character *(i.e.,* the dull or worn out grains of the grinding wheel during the operation are removed either by fracture or tearing of the bond, thus exposing fresh new grains).
3. The load acting on individual cutting grains is non-uniform.

4. The geometry of the grain is highly random and the time of contact between the chip and an abrasive grain is very small.
5. The grinding action depends strongly upon the characteristics of the grinding wheel.
6. High temperatures to the tune of 1000°C to 1400°C are usually encountered in grinding resulting into rapid grain wear and high induced surface in the workpiece.
7. The effective rake angle of abrasive grains is highly negative.

8.Grinding is associated with high specific cutting energy as compared to that encountered in conventional cutting operations.

13.5 Grinding Machines:

The grinding machines are classified as follows:

A. According to the quality of surface finish :
1. Roughing or non-precision grinders :

a- Bench, pedestal or floor grinders.
b- Swing frame grinders.
c- Portable and flexible shaft grinders.
d- Belt grinders.

2. Precision grinders.

B. According to the type of he surface generated or work done :
1. Cylindrical grinders :
   a. Plain cylindrical grinders.
   b. Universal cylindrical grinders.
   c. Centerless internal grinders.
   d. Universal internal grinders,
   e. Planetary internal grinders

2. Internal grinders :
   a. Plain internal grinders.
   b. Chucking internal grinders.
   c. Centerless internal grinders.

3. Surface grinders :
(i) Reciprocating table :
   a. Horizontal spindle,
   b. Vertical spindle.

(ii) Rotating table :
   (a) Horizontal spindle,
   (b) Vertical spindle.

4. **Tool and cutter grinders :**
   a. Universal
   b. Special.

Surface grinders

Surface grinding is the method of grinding designed to carry out the removal of metal from a part or parts less expensively and with greater precision than could be achieved by machining processes with cutting tools of steel, or by hand or machine filing.

14.1 Sawing

Sawing is a process in which a narrow slit is cut into the work by a tool consisting of a series of narrowly spaced teeth. Sawing is normally used to separate a workpart into two pieces, or to cut off an unwanted portion of a part. These operations are often referred to as *cutoff* operations. Since many factories require cutoff operations at some point in the production sequence, sawing is an important manufacturing process.

Saws

1. One should not test the sharpness of the blade by a running a finger across the teeth.
2. One should not brush away the chips with your hand.
3. All hard blades can shatter and produce flying chips. Wear your toggles.
4. One should be sure that the blade is properly tensioned.
5. Store the saw so that you will not accidentally reach into the teeth when you pick it up.
6. If the blade breaks while you are on cutting stroke, your hand may strike the works and cause an injury. Therefore saw operator should work carefully.

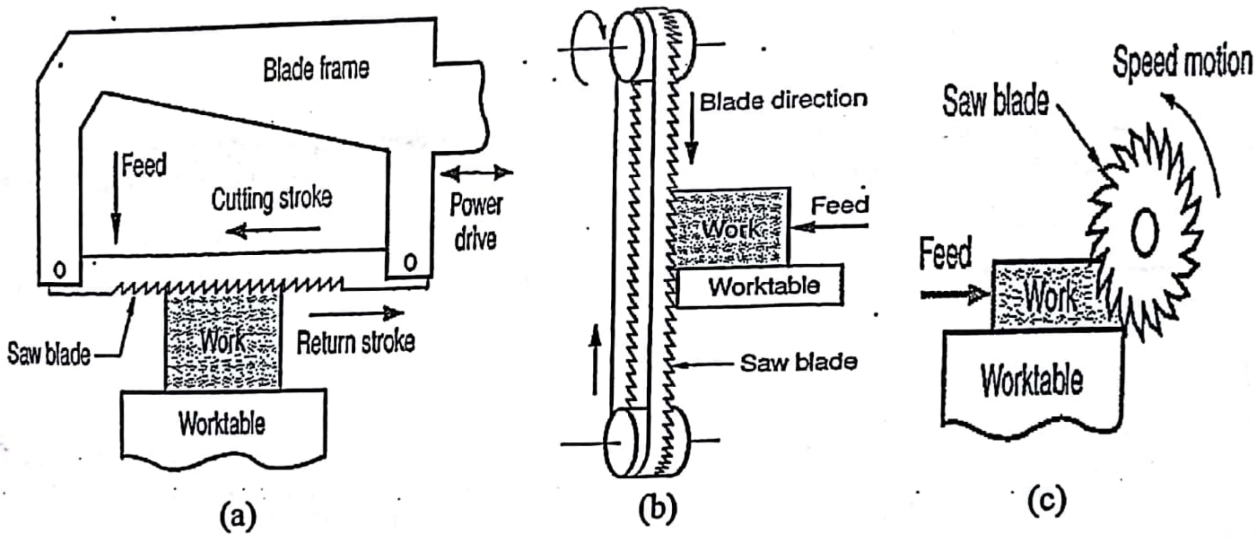


Figure 14.1 There are three basic types of sawing, shown according to the type of blade motion involved: (a) hack sawing, (b) band sawing, and (c) circular sawing.

14.1.1 Hack sawing: Involves a linear reciprocating motion of the saw against the work. This method of sawing is often used in cutoff operations. Cutting is accomplished only on the forward stroke of the saw blade. Because of this intermittent cutting action, hack sawing is inherently less efficient than the other sawing methods, both of which are continuous. The hacksaw blade is a thin straight tool with cutting teeth on one edge. Hack sawing can be done either manually or with a power hacksaw. A power hacksaw provides a drive mechanism to operate the saw blade at a desired speed; it also applies a given feed rate or sawing pressure.

14.1.2 Band sawing : involves a linear continuous motion, using a band saw blade made in the form of an endless flexible loop with teeth on one edge. The sawing machine is a band saw, which provides a pulley-like drive mechanism to continuously move and guide the band saw blade past the work. Band saws are classified as vertical or horizontal. The designation refers to the direction of saw blade motion during cutting. Vertical band saws are used for cutoff as well as other operations such as contouring and slotting.

14.1.3 Circular sawing: uses a rotating saw blade to provide a continuous motion of the tool past the work. Circular sawing is often used to cut long bars, tubes, and similar shapes to specified length. The cutting action is similar to a slot milling operation, except that the saw blade is thinner and contains many more cutting teeth than a slot milling cutter. Circular sawing machines have powered spindles to rotate the saw blade and a feeding mechanism to drive the rotating blade into the work.

	Questions
	Note : Support your answer by neat sketches
Q1	**Explain briefly the following:** 1-Turning, 2-Grinding, 3 - Milling, 4- Shaping, 5-Sawing
Q2	Which of the following statement is (correct/ incorrect)? 1. The cutting depth of the tool affects to the processing speed and the roughness of surface. 2. When the cutting depth is big, the processing speed becomes quick, but the surface temperature becomes high, and it has rough surface. 3. The feed speed of the tool also affects to the processing speed and the roughness of surface. 4. When the feed is high, you can remove a lot of material quickly. When the feed is low, the surface improves. 5. Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. 6. Machining at a correct cutting speed is highly important for good tool life and efficient cutting. 7. Too slow cutting speeds reduce productivity and increase manufacturing costs 8. Too high cutting speeds result in overheating of the tool and premature failure of the cutting edge of the tool. 9. Feed is defined as the distance that a tool advances into the work during one revolution of the headstock spindle. 10. When the tool is fed radially into the rotating work on one end to create a flat surface on the end the process called Facing. 11. When the tool is fed at an angle to create a tapered cylinder or conical shape, the process called *Taper turning*. 12. *Contour turning:* the tool follows a contour that is other than straight, thus creating a contoured form in the turned part. 13. The cutting edge of the tool is used to cut an angle on the corner of the cylinder, forming what is called a "chamfer." 14. When the tool is fed radially into the rotating work at some location along its length to cut off the end of the part. This operation is sometimes referred to as parting *or cutoff.* 15. *Boring:* A single-point tool is fed linearly, parallel to the axis of rotation, on the inside diameter of an existing hole in the part. 16. *Knurling* is not a machining operation because it does not involve cutting of material. Instead, it is a metal forming operation used to produce a regular cross-hatched pattern in the work surface 17. Larger feeds reduce machining time, but the tool life is reduced. 18. Shaper is a reciprocating type of machine tool in which the ram moves the cutting tool backwards and forwards in a straight line.

	19. In the shaper, the cutting tool has a reciprocating motion, and it cuts only during the forward stroke only. 20. The size of a shaper is specified by the maximum length of stroke or cut it can make. 21. The set up of shaper is very quick and easy and can be readily changed from one job to another. 22. Because of lower cutting forces, thin and fragile jobs can be conveniently machined on shapers. 23. A shaper, by nature, is a slow machine, because of its straight line, forward and return (idle) stroke. The single point tool requires several strokes to complete a work. 24. Drilling is an operation of making a circular hole by removing a volume of metal from the job by cutting tool called drill. 25. Feed of a drill is the distance the drill moves into the job at each revolution of the spindle. 26. A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. 27. Indexing is the operation of dividing the periphery of a piece of work into any number of equal parts. 28. Grinding is a metal cutting operation performed by means of a rotating abrasive tool, called "grinding wheel". 29. Grinding operation is the only method of removing material from materials after hardening. 30. The grinding operation is intermittent in nature, and produces discontinuous chips.
Q3	Classify Grinding machines.
Q4	What are the special features of grinding process?