H.T.I

THE HIGHER TECHNOLOGICAL INSTITUTE-TENTH OF RAMADAN CITY

Principles of Production Technology & Workshop

Prepared by

Assoc. Prof. Said Hussien Zoalfakar   Dr. Abdou Abdallah Hassan

Dr. Saleh Sobhy Abdelhady   Dr. Mostafa Abd El-Galil

Course Code: ENG 005
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Introduction

Production technology is, in the purest sense, any machine that permits a company to manufacture a tangible physical good. This entails, for a small business, a workshop at the very least, with more complex processes utilizing machinery and assembly lines. It's crucial to select a production scale model that fits a company's financial capabilities; simpler workshops frequently result in lower production volumes but cost less to construct, whereas larger output operations demand more complicated and expensive machinery, which are occasionally cost prohibitive.

As a result of the numerous possibilities that are developed and assessed during the design processes for products and manufacturing technology, as well as the numerous design requirements that must be considered, a high degree of complexity must be managed. When one considers the interdependencies between product and process design, complexity increases even further. As fresh inventions are the focus of design processes, knowledge of the limitations and characteristics of recently designed goods and processes is patchy. Due to this ignorance, there are a lot of uncertainties that need to be managed. Because there are more manufacturing technologies and pertinent criteria available, design process uncertainty is continuously growing.

Many well-known product development methodologies offer guidelines for breaking down the development process into manageable subproblems. They frequently promote concretization in stages, starting with the idea for the product and ending with the precise final design. Production procedures start to matter in the product life cycle after the technical product is physically realized in accordance with design requirements as a result of the development phase.

مقدمة

تكنولوجيا الإنتاج هي، بالمعنى الدقيق للكلمة، أي آلة تسمح لشركة ما بتصنيع سلعة مادية ملموسة. وهذا يستلزم، بالنسبة للشركات الصغيرة، ورشة عمل على أقل تقدير، مع عمليات أكثر تعقيدًا تستخدم الآلات وخطوط التجميع. من الضروري اختيار نموذج حجم الإنتاج الذي يناسب القدرات المالية للشركة؛ تؤدي ورش العمل الأبسط في كثير من الأحيان إلى انخفاض حجم الإنتاج، ولكن تكلفة إنشائها أقل، في حين تتطلب عمليات الإنتاج الأكبر حجمًا آلات أكثر تعقيدًا وتكلفة، والتي تكون في بعض الأحيان باهظة التكلفة.

ونتيجة للإمكانيات العديدة التي يتم تطويرها وتقييمها أثناء عمليات تصميم المنتجات وتكنولوجيا التصنيع، بالإضافة إلى متطلبات التصميم العديدة التي يجب مراعاتها، يجب إدارة درجة عالية من التعقيد. وعندما يأخذ المرء في الاعتبار أوجه الترابط بين تصميم المنتج والعملية، فإن التعقيد يزداد بشكل أكبر.

وبما أن الاختراعات الجديدة هي محور عمليات التصميم، فإن المعرفة بالقيود والخصائص للسلع والعمليات المصممة حديثًا غير مكتملة. وبسبب هذا الجهل، هناك الكثير من الشكوك التي تحتاج إلى إدارة. نظرًا لوجود المزيد من تقنيات التصنيع والمعايير ذات الصلة المتاحة، فإن عدم اليقين في عملية التصميم يتزايد باستمرار.

تقدم العديد من منهجيات تطوير المنتجات المعروفة إرشادات لتقسيم عملية التطوير إلى مشكلات فرعية يمكن التحكم فيها. وكثيرًا ما يقومون بترويج عملية التجسيد على مراحل، بدءًا من فكرة المنتج وانتهاءً بالتصميم النهائي الدقيق. تبدأ إجراءات الإنتاج في التأثير في دورة حياة المنتج بعد أن يتم تحقيق المنتج الفني فعليًا وفقًا لمتطلبات التصميم نتيجة لمرحلة التطوير. يتم دمج تقنيات الإنتاج المناسبة وتنظيمها في سلاسل التصنيع لتحقيق ذلك. يتم تحديد متغيرات العملية ذات الصلة التي تلبي متطلبات تصميم التجسيد على أفضل وجه. تأخذ معظم منهجيات تطوير المنتج اهتمامات الإنتاج في الاعتبار في وقت مبكر من مرحلة التصميم لتلبية هذه العلاقة السببية بين الإنتاج وتطوير المنتج. ومع ذلك، تختلف درجة ونوع الشمول بشكل كبير بين الأساليب المختلفة.

CONTENTS

CHAPTER 1
INDUSTERIAL SAFETY

1.1 INTRODUCTION

Statics show that a large number of accidents occurs annually in industry, almost everyone working in a factory or a workshop has at some stage in his or her career suffered an injury requiring some kind of medical treatment or first aid. It may have been a cut finger, sometimes in permanent disablement and in many cases, fortunately, in nothing worse than a few days' or weeks' absence from work, or something more serious like sudden death. Even if an accident does not render the victim unfit for work, it makes him liable to infection, or any other of the ills, which may be contracted as the result of/injury and shock. On an average, three people are killed and 750 injured every day in industrial accidents. The cause of these accidents, may have been carelessness by victim or a colleague, defective safety equipment, not using the safety equipment supplied, or inadequate protective clothing. Statistics gathered of the accidents show, in general, that of even' three accidents which occur, two are caused by the personal element of the victim, and one by means beyond his control. To put it briefly, we may say that two out of three are the victim's own fault, and the third was his employer's fault for not making safe working conditions.

Whatever the explanation given for accident, the true cause was most likely a failure to think ahead. Apart from personal tragedies resulting from premature death or injury, the consequent loss of working hours is a serious obstacle to the nation economical progress. Thus, the governments take a very lively interest in these accidents, and, through the Factory Inspectors, exerts every means in its power to keep them as low as possible.

1.2 HAZARDS

In the case of health, the Factories Act 1961 contains basic provisions to ensure healthy working conditions. It provides for cleanliness and the maintenance of a reasonable temperature, effective ventilation, suitable lighting, proper drainage of floors, and adequate sanitary accommodation.

It is important to ensure healthy conditions in the factory, as many workers are disabled by industrial disease. Before eating, all dirt and grease should be removed from hands by washing well using soap or special cleaner and warm water. Solvents such as paraffin should never be used for this, as they may cause skin irritation. Meals should be eaten in the places provided - not in the workshop. Fig. 1.1 shows some healthy precautions.

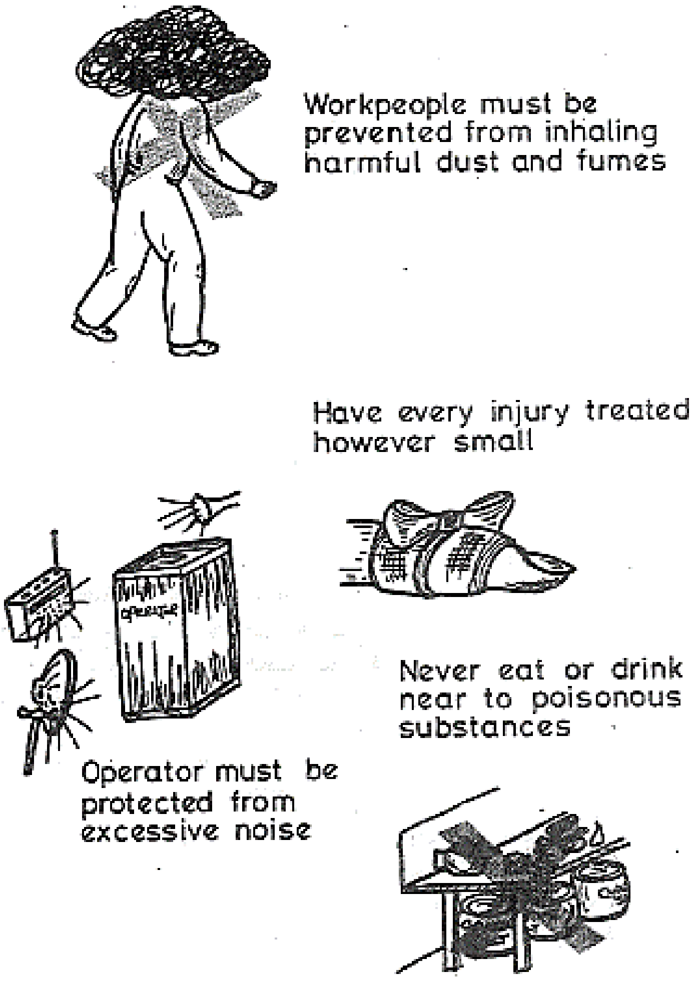


Fig.1.1: Some healthy precautions in the workplace.

1.3 SAFETY

It is essential not only to be aware of basic engineering principles but also to be aware of and therefore able to foresee the dangers that exist in the workshop.

Remember, safety is everyone's responsibility; this includes you.

You should make sure that your workplace is as safe as possible so that few dangers arise, use the appropriate protective clothing and equipment to minimize the risk of accident, and act in a safe manner at all times.

Hand tools

These are the most common tools in general use. They give rise to thousands of accidents yearly, often because they are worn, broken, or not suitable for the job concerned. Accidents caused by worn tools are predictable and can be avoided by timely tool replacement.

Precautions that should be observed are:

i. Regularly examine hand tools.

ii. Don't use them if they are found to be defective, as they can cause serious injury, particularly to the hands and eyes.

iii. Ensure that handles are securely fitted to files, scrapers, screwdrivers, and hammers and that they are not split, as shown in Fig. 1.2.

iv. Don't use hammers with chipped heads, as shown in Fig. 1.3; a piece could fly off and injure the eye or hand.

v. Use the correct spanner size as shown in Fig. 1.4; the incorrect spanner can slip and injure the hand.

vi. Don't use chisels with 'mushroomed heads as shown in Fig. 1.7; a piece could fly off and injure the eye or hand.

vii. Always keep the bench or workplace clean and tidy as shown in Fig. 1.8, and put tools in a safe place after use.

viii. Never carry loose tools in your pockets; you could slip and fall on them.

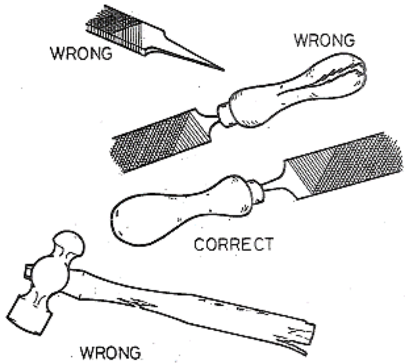


Fig. 1.2: Handles on files and hammers.

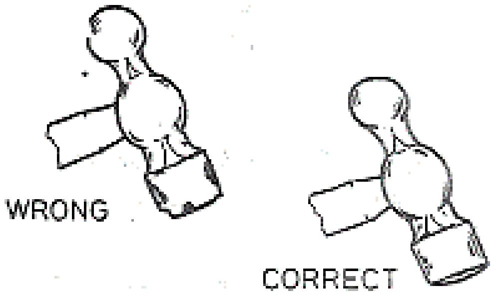


Fig. 1.3: Correct hammer head.

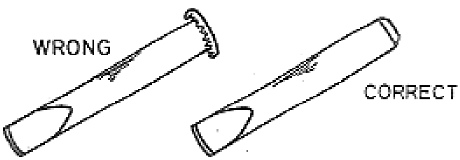


Fig. 1.4: Correct spanner.

Fig. 1.5: Correct chisel.

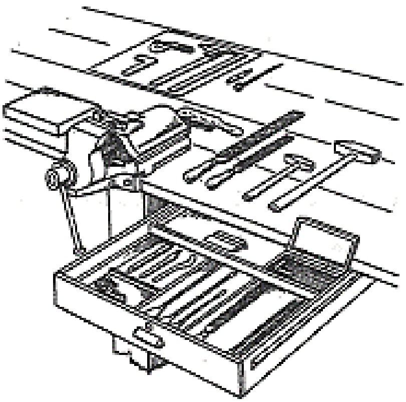


Fig. 1.6: Clean and tidy workplace.

Machinery

Equipment with moving parts is always a source of danger. It should be assumed that the unexpected would happen; for instance, an operator's attention or concentration may be affected by fatigue, especially at the end of a shift. The only safe way to prevent an accident is to guard all the dangerous parts.

Precautions that should be observed are:

i. Ensure that you know how to stop the machine before you set it in motion.

ii. Maintain your attention while machine is moving.

iii. Don't distract or startle other machine operators.

iv. Never clean a machine while it is in motion; always isolate it from the power supply first.

v. Never use compressed air to clean a machine; it may blow in your face or someone else's and cause an eye injury.

vi. Never clean away chips with bare hands; always use a suitable rake, which should be provided.

vi. Keep hair short or under a cap; it can become tangled in drills or rotating shafts.

vii. Avoid loose clothes; wear the most suitable ones.

ix. Don't wear rings or wrist watches at work.

x. Don't allow unguarded bar to protrude beyond the end of machine; in center and capstan lathes.

xi. Always ensure that all guards are correctly fitted and in position. Remember that guards are fitted on machines to protect you from accidentally coming into contact with dangerous moving parts.

CHAPTER 2
ENGINEERING MATERIALS

2.1 INTRODUCTION

Engineering materials are those engineer uses in his work. Nearly all materials existing on and under the ground are used in engineering. Some of these materials are used directly as water, sand, etc.; others need more or less treatment as iron ore, petroleum. Moreover, some materials are used alone in industry as wood, leather, etc., others are mixed together to produce other materials having specific properties as adding chromium to steel to improve its corrosion resistance.

A wide range of engineering materials is used in industry. The engineering industries, such as, automobiles, airplanes, and home appliances need wide variety of engineering materials ranging from glass to steel and from wood to rubber. The number of engineering materials is almost infinite, but it can be generally classified into metallic, non-metallic and composite as shown in Fig. 2.1. It is important to be aware of the ways in which these materials are applied and of the proper-ties, which make them suitable for these applications. Furthermore, the engineer has to learn some principles to guide him in the selection and processing of materials.

Properties of materials can be divided into two main groups; Physical and Mechanical. Physical properties are those of a material, which do not require the material to be deformed or destroyed in order to determine their values. Mechanical properties indicate a material reaction when a load is applied. These properties require deformation or destruction tests in order to determine their value. Subjecting the material to heat treatment and cold or hot working can alter the value of these properties.

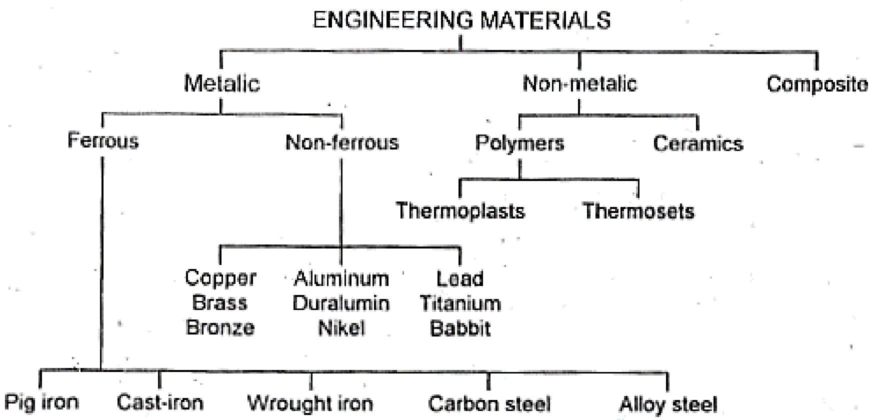


Fig. 2.1: Engineering materials classification.

2.2 CLASSIFICATION OF ENGINEERING MATERIALS

As previously stated, the engineering materials can be classified into three main groups:

A. Metallic materials,
B. Non-metallic materials, and
C. Composite materials.

2.2.1 Metallic Materials

They are those characterized mainly by their crystalline structure, high reflectivity, good electrical and thermal conductivity, strength and ability to flow before fracturing. Furthermore, they are the materials, which contain metallic elements as the main constituent. Metallic materials can be classified into two groups; ferrous metals and non-ferrous metals.

A. Ferrous Metals

They are those metals where the main constituent is iron (Fe) and hence get its name from the Latin word ***ferum***, which means iron. The route of production of ferrous metals is shown in Fig. 2.2. All ferrous metals are alloys mainly of iron and carbon. According to the percentage of carbon, ferrous metals are classified into:

Pig Iron it is obtained from iron ore by smelting in the blast furnace with the aid of coal and fluxes. It is the base for production of all other ferrous metals. It is brittle and weak because it includes large amount of carbon and impurities. It contains from 92-97% of iron, high percentage of carbon in addition to small amounts of silicon, manganese, phosphorous and sulpher. It is never used as a structural material, but used only to produce the other ferrous metals.

Cast-iron it has the same constituents as pig iron. It is produced by the further refinement of pig iron in a cupola furnace. It contains 2-5 % carbon presented as free graphite when cools slowly and has a gray appearance when it fractures, hence gets its name.

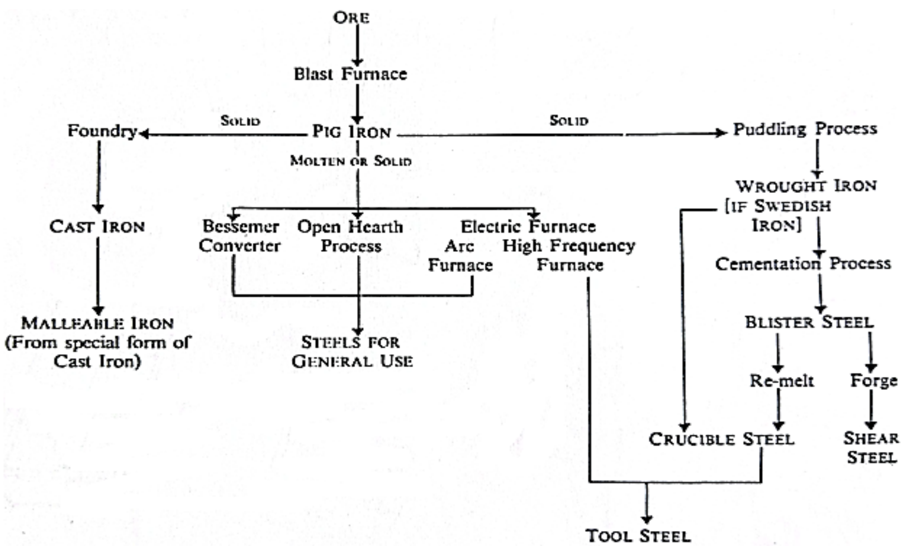


Fig. 2.2: The route of production of the ferrous metals.

The free carbon acts as a lubricant during machining operations. It is brittle, can't be forged, weak in tension but strong under compression and easy to machine. The amount of carbon gives great fluidity to the molten cast iron, which enables it for running into moulds for making castings. Intricate shapes like tool machines beds, engine bodies and their cylinder blocks, pipes, surface plates, vice bodies, are typical examples of cast iron products as shown in Fig. 2.3.

The resulting casting is extremely hard and brittle because the carbon no longer presents as free graphite but combines with the metal forming iron carbide. White cast iron is very difficult to machine. It has white appearance when it fractures, hence gets its name. It is used for rolls and balls in mills.

Wrought Iron it is almost pure iron, having a ferrite content of about 99.9%. It is pig iron, refined in the puddling furnace. It is soft, strong in tension, tough and resistant to atmospheric corrosion because it is covered with a protective oxide layer. Because it has very low carbon content, it cannot be heated into a liquid state, but it becomes pasty. This is why it is not casted but at red heat it is very soft, welds readily by hammering, making it an ideal metal for forge work. Thus, it is used for making chains and crane hooks. It is easily cold worked by rolling, twisting and bending.

Steels it is alloy of iron and carbon up to 2% C and several other elements. Carbon content determines the type of steel and its properties. Generally, as the carbon content increases, the strength and hardness increase, but the ductility decreases. They are classified into two main groups; plain carbon steels and alloys steels.

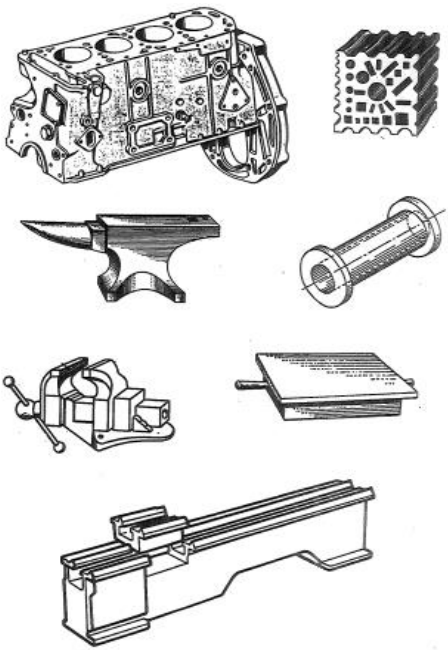


Fig. 2.3: Typical examples of Cast-iron products.

1. Plain carbon steels

Properties of plain carbon steels depend mainly on the carbon content; thus they are classified into:

Mild Steel it contains 0.06-0.25% carbon, and hence it is weak, soft and ductile which can be easily cold or hot worked. It is used for manufacture of cheap rivets, pipes, wires, angles, channels, bolts, screws, nuts, car bodies, sheets, and structures like bridges; Fig. 2.4a. It has considerable strength and ductility; it can be easily cold or hot worked, welded and machined.

Medium-Carbon Steel it has a carbon content of 0.35-0.65%. It is used for engineering components requiring higher strength and moderate hardness than mild steel such as tool holders, axles, gears, and railways rails. Typical examples are shown in Fig. 2.4b.

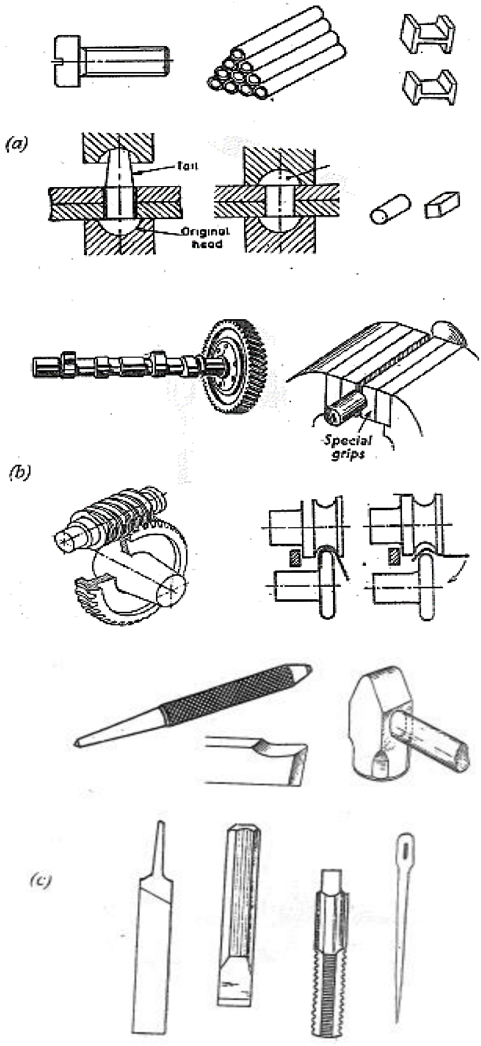


Fig. 2.4: Typical examples of carbon steel products.

High-Carbon Steel may be referred to as cast steels or tool steels. The high carbon content: 0.65-1.5% lowers their melting point, as well as increases its fluidity in the liquid state, thus, it can be casted. It is hard, strong, and brittle with little ductility and malleability. They are suitable for the manufacture of cutting tools subjected to impact such as chisels, dies and wood working tools. It can be also used for other working tools subjected to high abrasive action such as scribers, punches, files, vice jaws, cold chisels, taps drills, hammers and anvil faces as shown in Fig. 2.4c.

2. Alloy Steels

The mechanical properties of plain carbon steels are improved by adding several alloying elements. The most used alloying elements are manganese, nickel, chromium, molybdenum, silicon, vanadium, tungsten, cobalt and copper. For example, stainless steels that possess high corrosion-resistance property are obtained by adding chromium (4-22%) and nickel (0-26%) to medium carbon steels. High speed steels HSS which have the ability to keep their hardness when they are heated up to 500-600°C. HSS is used to produce cutting tools working at moderate speeds are obtained by adding 18% tungsten, 4% chromium, 1% vanadium to high carbon steels (0.7% C).

B. Non-Ferrous Metals

They are metals that do not contain iron. Pure non-ferrous metals are seldom used as structural materials since they have poor mechanical properties. For this reason, they are used in the form of alloys, except copper, aluminum and nickel that are used in pure form or alloyed. Generally, they are weaker and softer than ferrous metals, but have good corrosion resistance and attractive colors.

1. Aluminum and its Alloys; according to the volume of production, aluminum keeps the first place among the non-ferrous metals. Aluminum is used chiefly on account of its lightness; is one-third the weight of steel. It is a bluish-white color, soft and ductile, so it can be produced in the form of thin sheets, wires, tubes or solid sections.

Alloying can strengthen aluminum. Its alloys have wide applications in design and structure of transport means, in foodstuff industry (foils for packing), and in building engineering. Because its corrosion resistance, it is used for kitchen utensils and food containers. The most widely used aluminum alloy is duralumin.

Duralumin; it is one of the most important Al alloys. The composition being 95% Al, 4% Cu, 0.5% Mg, 0.5% Mn. Duralumin combines the advantages of Al and the steel strength, hence it is used for production of structural parts and in aircraft industry.

2.Copper-base alloys; copper is next to aluminum in its use as an engineering non-ferrous metal. Pure copper (99% Cu) possesses high electrical and thermal conductivities, thus it is used for electrical conductors and cables. When copper is alloyed with zinc (39-45% Zn), it is usually called brass. It is a workable material used for making cartridge cases, radiators, and sealing rings. If it is alloyed with other elements, it is often called bronze. Sometimes the other elements are specified, for example, tin bronze or phosphor bronze. There are hundreds of variations in each category.

3. Lead; it is the heaviest of the common metals. It is very soft, weak in tension, highly malleable and has blue-gray color. It can be rolled into sheets or formed into tubes, but can't be drawn into wires. It is largely used as a constituent in making bronzes fusible alloys and soft solders. It is also used for radiation shielding.

4. Nickel; it possesses high corrosion resistance and is ferromagnetic. It contains from 97.5 up to

99.5% Ni and from 0.6 up to 1.0% Co. It used for surface protection of metals, in chemical and food-stuff industry, steam seals, coins, resistance thermometers, etc.

Nickel alloys are widely used as heat resistance, and corrosion resistance metals. The well-known Ni-alloy is Monel metal. Monel metal contains usually 30% Cu. It has high corrosion resistance and good mechanical properties. It is extensive applicable in making components of chemical apparatuses, medical instruments, etc.

5. Titanium; it is characterized by its high melting point (1725°C), high strength, low specific weight and very good corrosion resistance. According to these properties, it has found wide applications in recent years as a structural material specially for high speed aircraft components.
Titanium can be alloyed with Cr, Al, Fe, Ni and certain other elements. Ti alloys may be applied as heat resistance materials in place of Al alloys and steels to reduce the weight of the construction as in rockets.

2.2.2 Non-Metallic Materials

These materials can be divided into two main groups:

1. Organic Non-Metallic Material or Polymers they are often called plastics. It may be defined as an organic material which, at some time in its history, is capable of flow, and which, upon the application of adequate heat and pressure, can be caused to flow and take up a desired shape, which will be retained after the heat and pressure are withdrawn. An organic material is one that is composed wholly, or mainly, of carbon compounds. It is convenient to classify plastics into two general categories:

a. ***thermo-softening*** or ***thermoplastic*** materials these materials can be softened and re-softened indefinitely by the application of heat and pressure, as long as the heat does not cause damage.
These materials don't melt, but flow at a suitable temperature and pressure. They are particularly suitable for injection moulding and extrusion, behave like glass when blown, and can be formed into bottle- and dome-like shapes by pressure and vacuum technique.

b) ***thermosetting*** materials or ***thermo-hardening*** materials these materials undergo a chemical change when they are subjected to heat and pressure, after which they cannot be changed by further application of heat and pressure.

These materials cure within the heated mould, so they gain rigidity before the applied pressure and temperature is removed. The melamine formaldehyde and bakelite are examples of these materials.

2. ***Inorganic Non-Metallic*** Materials are often called ceramics. The term ceramics is used to denote those products made from inorganic materials, which contain metallic and non-metallic elements. Simple examples are ionically bonded magnesia, MgO, and covalently bonded silicon carbide, SiC.

Traditional ceramic materials of interest to the engineer include stone, brick, concrete, clay, glass, vitreous enamel, and refractories. These materials are relatively hard, brittle and tend to be more resistant than other metals and plastics to high temperatures and to severe environments. They are used to produce spark plugs, floor tiles, electrical insulators, etc.

2.2.3 Composite Materials

A composite material is one composed of two (or more) distinct phases, one of which is a matrix surrounding fibers or particles of the other. There being some form of bonding at the interface between them. It is designed to provide a combination of desired properties that is not exhibited by either material on its own. Four kinds of composite materials forms are shown in Fig. 2.5.

Usually one of the materials has distinct advantages, for example it may have high strength and low density, but because it is brittle or not formable in large sections can't be used on its own. The concrete and the car tires are typical examples for composite materials. The car tire contains two or three kinds of rubber and one or more kinds of cord, plus a steel bead.

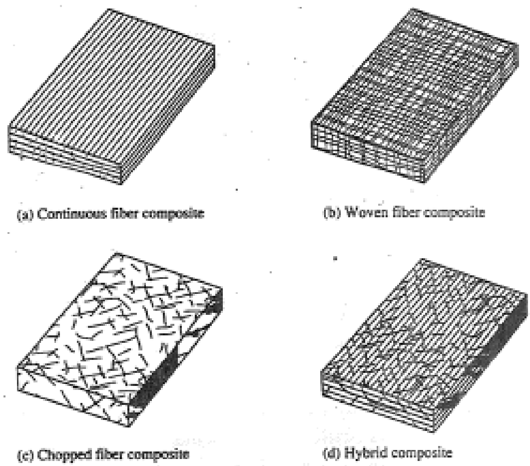


Fig. 2.5: Four kinds of composite materials forms.

2.3 PROPERTIES OF MATERIALS

The choice of a suitable material for individual components of a machine or device that working under certain conditions and have to comply with certain requirements is influenced mostly by the properties of materials.

Classification of Properties

Properties of materials can be broadly divided into the following: Physical, Chemical, Thermal, Electrical, Optical, Acoustical and Mechanical properties.

a) ***Physical properties,*** As the shape, dimensions, porosity, etc.
b) ***Chemical properties***, As the chemical composition, acidity, etc.
c) ***Thermal properties***, As the expansion, thermal conductivity, specific heat, etc.
d) ***Electrical and magnetic properties***, As the electrical resistivity and conductivity, magnetic permeability, etc.
e) ***Optical properties***, As the color, light reflection and absorption, etc.
f) ***Acoustical properties***, As the acoustic reflection and absorption, etc.
g) ***Mechanical properties***, They are the properties which determine the behavior of the material under loads, etc.

Main Mechanical Properties

Elasticity; is the ability of a material to restore its original shape or volume at once when the external force is removed. If an elastic material was loaded beyond the elastic limit point, it will not return to its original shape and will be permanently deformed when the load is removed. Leaf and helical springs shown in Fig. 2.6 are recommended to be made of elastic materials.

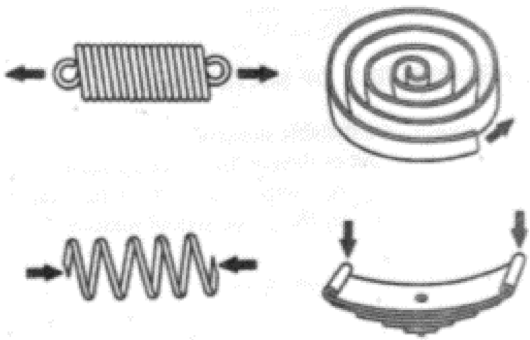


Fig. 2.6: Helical and leaf springs made of elastic material.

<u>Ductility</u>; it is the property of a material enabling it to be drawn into wires with the application of a tensile force as shown in Fig. 2.7.

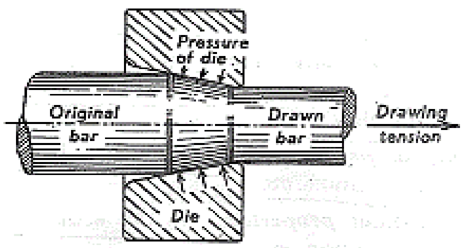


Fig. 2.7: Drawing processes for a ductile material.

A ductile material must be strong and plastic. The ductile materials commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin and lead. The ductility property is essential for bending process as shown in Fig. 2.8.

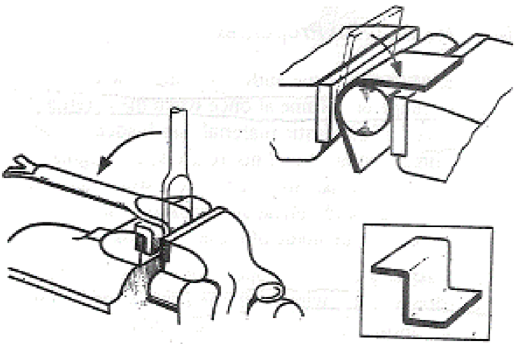


Fig. 2.8: Bending processes for a ductile material.

Hardness; it is a very important property of the metals and has a wide variety of meaning. It embraces many different properties such as resistance to wear, penetration, scratching and machining etc. It means also the ability of a metal to cut another metals. Hard metals are required for making cutting tools as saw blades as shown in Fig. 2.9, and for parts where wear must be kept to a minimum.

Strength; it is the ability of a material to resist the fracture or yielding when subjected to externally applied load. This load may be tension, compression or shear as shown in Fig. 2.10.

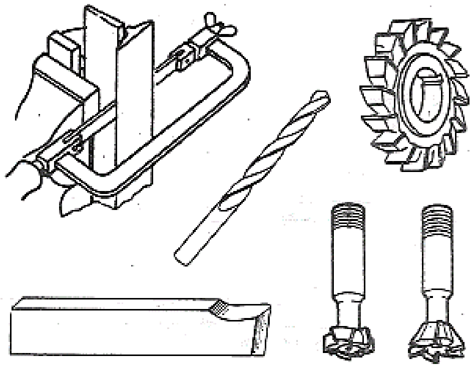


Fig. 2.9: Typical examples of hard material.

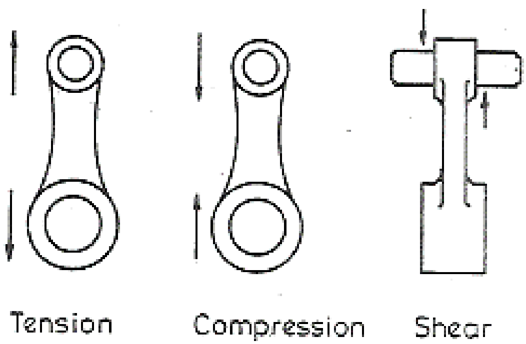


Fig. 2.10: Typical examples of strong material.

Brittlness; it is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent elongation or distortion. A brittle material will break easily when deformed or given a sudden blow. Brittleness is associated with hardness; therefore brittle materials cannot be used as forging dies. Cast iron is a typical example of a brittle material.

Toughness; it is the ability of a material to resist fracture due to high impact loads like sudden shocks. It is the opposite of brittleness. The hummer head shown in Fig. 2.11 should be tough. The toughness of a material decreases when it is heated.

Malleability; it is a special case of ductility that permits material to be rolled or hammered into thin sheet or different shape without fracturing. This property is required when forging, where hammering changes the shape of the metal. A malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice are lead, soft steel, wrought iron, copper and aluminum. Heat may be used to make a material more malleable; so, the steels should be heated before forging. There is some different between malleability and ductility, i.e., lead is a malleable material, as it can easily be shaped by hammering, but is not ductile since it is not strong enough to withstand a load if attempt to be drawn into wire.

Fusibility; it is the ability of a material to become easily a liquid when heated. It is an important property for materials that are selected to casted or welded.

Conductivity; it is the ability of a material to conduct heat or electricity. Metals have high heat and electrical conductivity, so they are considered as conductors. Wood, plastic and glass have very low heat and electrical conductivity, so they can be considered as insulators.

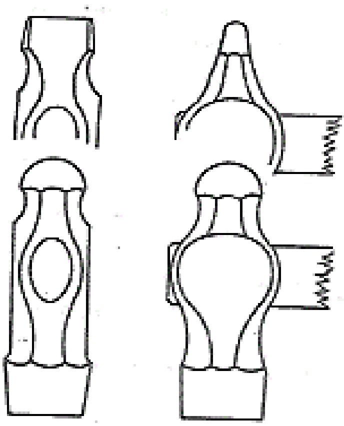


Fig. 2.11: A hammer head made of tough material.

2.4 MATERIALS SELECTION

Selecting a material for a specific component requirements depends mainly on three factors:

1. The ability to stand up to the service conditions,

2. The suitability for the process used to manufacture it,
3. The material cost and availability.

Thus, one of the main duties of the engineer is to select a material for a specific component that satisfies its service requirements. Fig. 2.12 shows a pressing device demonstrating the need of different properties.

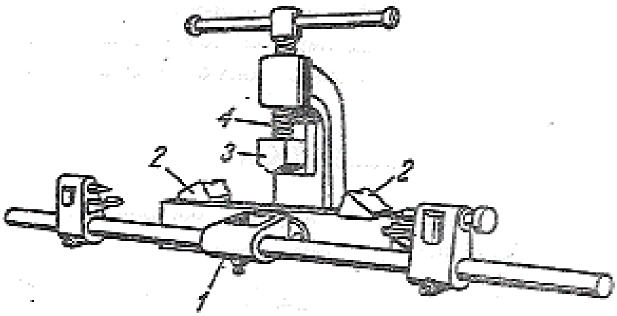


Fig. 2.11: Pressing device needs different properties.

CHAPTER 3
BENCHWORKING

3.1 INTRODUCTION

The workbench is the work carried out at the fitting bench of a workshop, tool room or general engineering shop. Here the work will include the operations of marking out, filing, sawing, chiseling, scraping, the preparation of works for machining, the repair and adjustment of machine tools, and so on. For all these operations suitable hand tools are required, and it is a wise craftsman and highly skilled nature that ensure not only that the tools are in good condition, but also that they are well cared for and kept in safe storage.

The first essential is a strong rigid workbench, free from any undue movement and provided with racks or shelves at the back for storage of articles and tools, so that the bench top may be kept tidy and clear, drawers or cupboards which can be securely locked are essential for the safe storage of the more expensive equipment.

The bench should be placed close to windows so that adequate light is available, and a source of artificial illumination is also a necessity to invite good craftsman-ship. A typical workbench carrying the important equipment is shown in Fig. 3.1

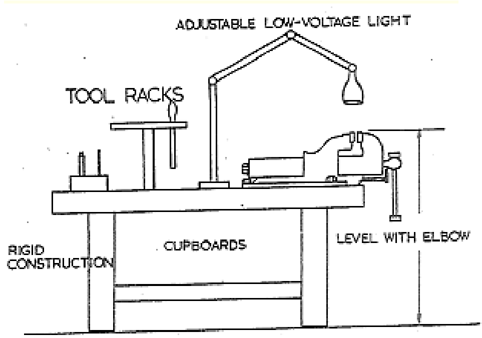


Fig. 3.1: A typical workbench carrying the important equipment.

3.2 BENCH VICE

Workpiece holding is an important aspect of all metal-removing operations . Most metals are tough and strong, and considerable force is required to file, chisel or saw them ,this means that the workpiece needs to be held with a positive grip if it is not to move under the influence of hammer blows when chiseling , or under the force of the cutting action when sawing.

A very wide range of works whilst operating on them may be held using an engineer's parallel-jaw vice (or vise) attached to the bench. It consists of an iron or steel cast body into which is fitted a square section slide formed to a jaw at its outer end. The corresponding fixed jaw is incorporated on the body of the vice, and the two jaws are faced with hardened steel jaw-pieces, screwed to the jaws and cut with teeth to help grip the work. The sliding jaw is operated by a screw and nut.

The height of the bench should be such that the top of the vice-jaws is at about the same height as the fitter's elbow when he stands normally at the bench with his upper arm hanging vertically, and forearm bent horizontally. To avoid any damaging or scratches to the surface of the finished work that can be done by the hardened jaw-pieces, it is essential to employ clamps (or clams) made of copper, brass, lead or soft steel. Fig. 3.2 shows a parallel-jaw vice.

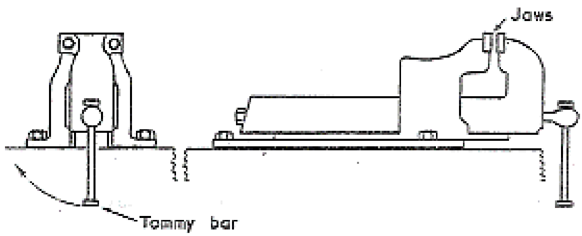


Fig. 3.2: a parallel-jaw vice.

The parallel jaw-vice is not suitable for gripping hollow round sections or pipes as shown in Fig. 3.3a that excessive pressure of the vice jaws tends to distort the thin-walled tubes. Fig. 3.3b shows a front elevation of a typical pipe-threading vice. This type of vice is very suitable for holding pipes for hack-sawing as well as for cutting a thread on the external diameter.

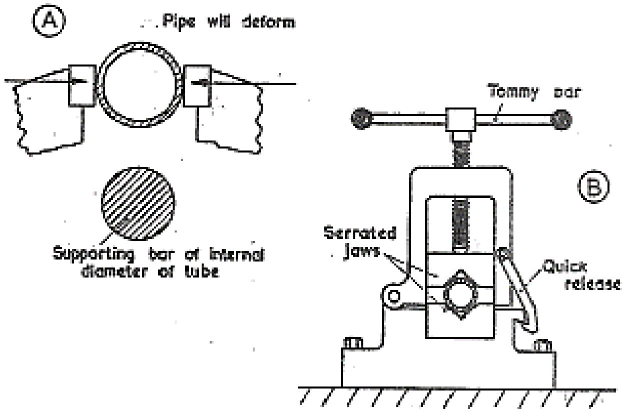


Fig. 3.3: a) Supporting bar to prevent pipe distortion, b). a typical pipe-threading vice

3.3 MARKING OUT

Marking-out is the scratching of lines on the surfaces of a workpiece, known as scribing, and is usually carried out only on a single workpiece or a small number of workpieces. The two main purposes of marking out are:

a- To indicate the workpiece out line or the position of slots or the center lines of holes, etc., by the use of scribed lines. If excess material will have to be removed a guide is given of the extent to which hacksawing or filing can be carried out.

b- To provide a guide to setting up the workpiece on a machine. The workpiece is set up relative to the marking out and is then machined.

It is important to note that the scribed lines are only a guide, and any accurate dimension must be finally checked by measuring. We therefore need marking-out tools or equipment; the following are the used tools:

Surface Table and Surface Plate; to establish the workpiece datum, a reference surface must be used. This reference surface takes the form of a large flat surface called a surface table. Fig. 3.4 shows a surface table upon which all the marking-out equipment is used.

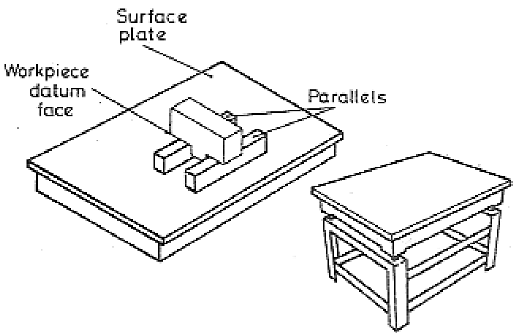


Fig. 3.4: A surface table.

Hand Scriber; to scribe lines on metal components. A sharp scriber, correctly hardened and tempered, can cut a small groove in the metal, as shown in Fig 3.5.

Scribing Blocks; two typical scribing blocks are illustrated in Fig. 3.6. Fig. 3.6a shows a relatively simple type, while Fig. 3.6b shows a better type, having provision for adjustments. The correct technique when using a scribing block is to keep the scriber horizontal and allow only the minimum length to protrude as shown in Fig. 3.6b.

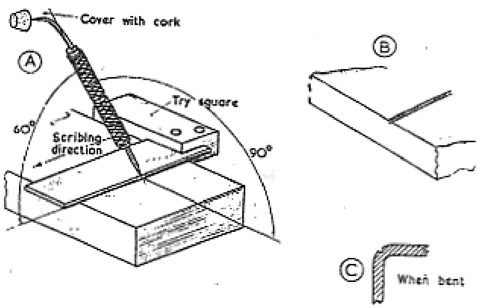


Fig. 3.5: Hand Scriber.

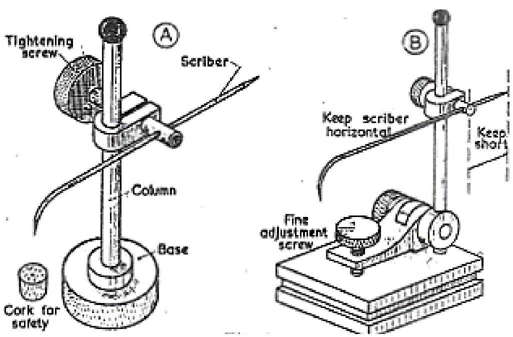


Fig. 3.6: Types of Scribing Blocks.

Engineer's Dividers; to scribe circles on metal components as shown in Fig. 3.7a with one point pivoted in a small center dot it should be necessary to scribe the circle once only.

Odd-leg Caliper; this marking out tool is a combination of scriber point and location edge. It is very suitable when a line is required to be scribed parallel to an adjacent face or datum edges as shown in Fig. 3.7b.

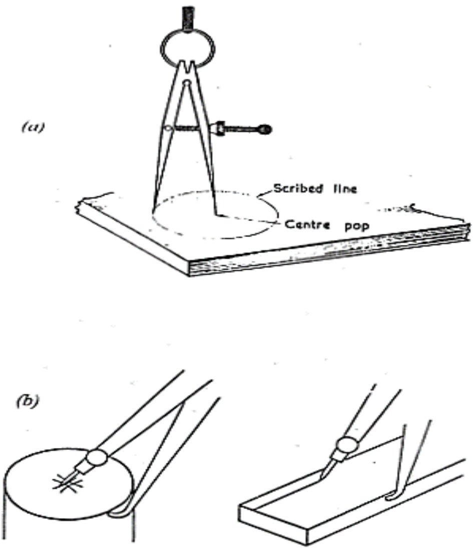


Fig. 3.7: a) Engineer´s divider, b) Odd-leg caliper.

Engineer's Steel Rule: the engineer's steel rule is perhaps the most widely used piece of marking-out equipment. It is a precision instrument and should always be treated with care and respect and kept in a nicely polished condition. Rules are available in 150, 300 and 600 mm lengths. It is used mainly in picking up dimensions. Fig. 3.8 shows the engineer's steel rule.

Center Punches; center punches serve two main purposes. The first one is to center-dot the intersection of two scribed lines when this is to form the center of a scribed circle as shown in Fig. 3.9a. It is used for the second purpose as illustrated in Fig. 3.9b to provide start for a twist drill.

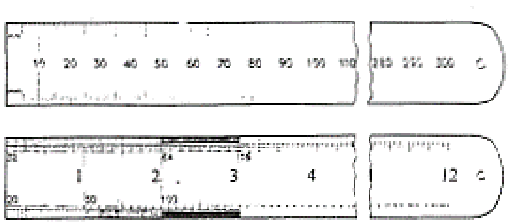


Fig. 3.8: a) Engineer´s steel rule.

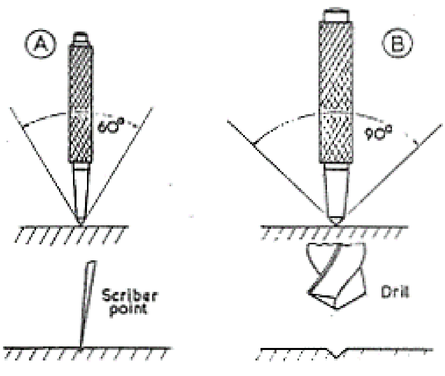


Fig. 3.9: a) Center punch.

Engineer's Square; an engineer's square is used when setting the workpiece square to the reference surface, or when scribing lines square to the workpiece datum. The square consists; as shown in Fig. 3.10; of a stock and blade made from the hardened steel and ground on all faces and edges to give a high degree of accuracy in straightness, parallelism, and squareness. It is available in a variety of blade lengths.

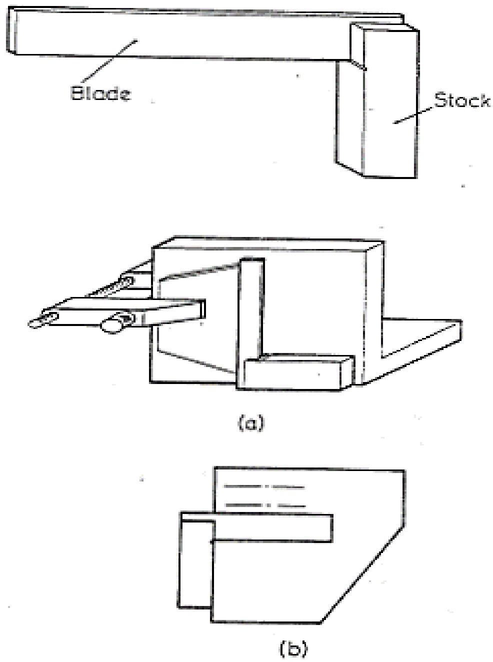


Fig. 3.10: Engineer's Square.

3.4 METAL REMOVAL AT THE BENCH

Once the outline or profile of a component has been marked-out, it is likely that the finished shape will be obtained by metal removal involving the use of hand tools at the workbench. Fig. 3.11 shows in diagrammatic form the main metal-removal techniques employed at the bench; note that the accuracy possible decreases as we move upwards.

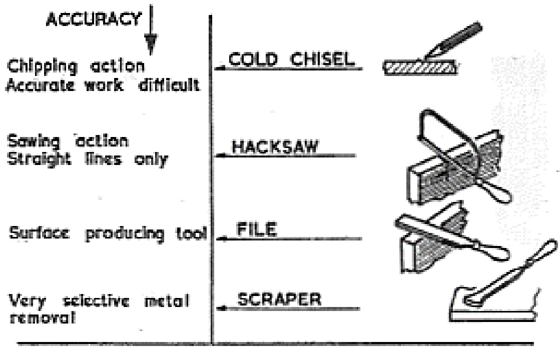


Fig. 3.11: The main metal-removal techniques.

3.4.1 Chiseling and Chipping

The cold chisel is an important cutting tool used by the fitter and engineers. The cold chisels are distinguished from other chisels by the fact that their ends not having a wooden handle. The four most important types of chisel are the flat, the cross-cut, the half round and the diamond chisel.

Chisels are made from cast tool steels of octagonal cross-section, the heaviest being made from about 20 mm material and the smaller sizes from lighter section steel down to about 10 mm.

The Flat Cold Chisel; this is perhaps the most widely used of the cold-chisel family and is the general-purpose one of the fitter. A typical flat cold chisel is illustrated in Fig. 3.12 The cold chisel is a better tool than a hacksaw for the removal of curved portions as shown in Fig. 3.12b. A flat cold chisel may also be used for producing a small flat surface as shown in Fig. 3.12 c.

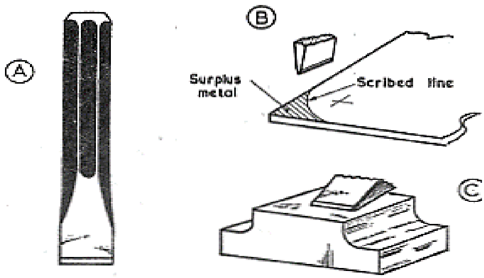


Fig. 3.12: The Flat Cold Chisel.

The Cross-Cut Chisel; the cross-cut chisel has a narrower cutting edge. The cutting end of this chisel is forged to the shape shown in Fig. 3.13, the cutting edge being 6 mm to 9 mm wide. This is to permit the body of the chisel to clear when a groove is being cut.

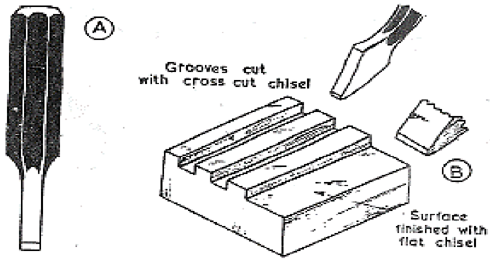


Fig. 3.13: The Cross-Cut Chisel.

Half-Round and Diamond Chisels; the half-round and diamond chisels are shown in Fig 3.14. The half-round pattern is useful for cutting grooves such as oil grooves in bearings and similar work.

The diamond chisel is often used for cutting holes in plates such as boiler plates and for grooving the start of a drilled holes to correct for an error in the starting of the drill. The diamond chisel can be used also for chiseling of letters or numbers.

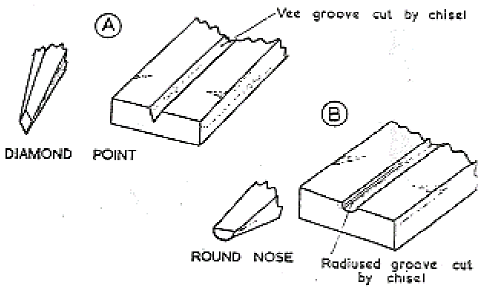


Fig. 3.14: Half-Round and Diamond Chisels.

3.4.2 The Hacksaw

The hacksaw is used to cut metal. The hacksaw is the chief tool used by the fitter for cutting-off, and for making thin cuts, preparatory to other chipping and filing operations. Where large amounts of waste metal have to be removed, this is more easily done by hacksawing away the surplus rather than by filling. A hacksaw can be used for a

wide range of work, including sawing pipes, channel and other metal sections to prescribed lengths. Hacksaw blades are available in three main types to meet the different sawing conditions:

a) All hard
b) Flexible
c) Spring back

All-hard blades are hardened throughout the whole section and cannot be bent without risk of sudden fracture. The flexible blade is hardened along the teeth only, and possesses considerable flexibility, making it very suitable for the inexperienced operator or the awkward sawing position. Straight lines are not easy to saw with a flexible blade, because of the tendency of the blade to flex or wander.

The "spring-back" blade can be considered as a compromise between the all-hard and the flexible.

The blade is fitted to the frame with the teeth pointing away from the handle, Fig. 3.15 shows a diagrammatic sketch for hacksaw.
The standard hacksaw blade is 300mm length × 13 mm width × 0.65 mm thick and is available with 14, 18, 24 and 32 teeth per 25 mm (1 inch).
A hacksaw blade should be chosen to suit the type of material being cut, whether hard or soft, and the nature of the cut, whether thick section or thin. Table 3.1 gives recommendations for the number of teeth per 25 mm on blades used for hard and soft materials of varying thickness t in mms.

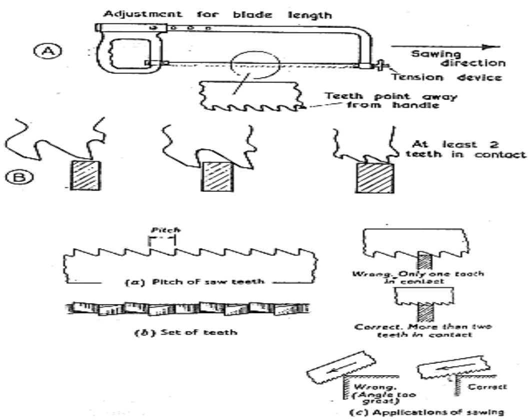


Fig. 3.15: Diagrammatic sketch for hacksaw.

Table 3.1: recommendations for the number of teeth per 25 mm on blades

Thickness (mm)	No. of teeth per 25 mm	
	Hard materials	Soft materials
up to 3	32	32
3 to 6	24	24
6 to 13	24	18
1 3 to 25	18	14

Simple Hacksawing Technique; the following hints will assist in the proper use of the hacksaw:

1- Keep the cutting lines as close as possible to the vice jaws.

2- Use a new blade when sawing non-ferrous metals such as copper, phosphor bronze or brass.

3- Apply light pressure at the start of the cut and also at the finish of the cut.

4- Make sure that a fine pitch is used when sawing thin-walled tube.

3.4.3 Filing and Engineers Files

Files are used to perform a wide variety of tasks, from simple removal of sharp edges to producing intricate shapes where the use of a machine is impracticable. Because all the surfaces produced in engineering manufacture are geometrical (typical examples consisting of plane, cylindrical, conical and spherical) it is clear that a wide range of file sections and lengths are needed . They can be obtained in lengths from 150 mm to 350 mm. When a file has a single series of teeth cut across its face it is known as single-cut file and with two sets of teeth cut across its face it is known as double cut. Fig. 3.16 shows typical examples of the more common file sections, and their applications.

The grade of cut of a file refers to the spacing of the teeth and determines the coarseness or smoothness of the file. The standard grades of cut in common use. from coarsest to smoothest are rough, bastard; second cut. smooth and dead smooth. In general, the rough and bastard cut are used for rough filing to remove the most metal in the shortest time, the second cut to bring the work close to finished size, smooth and dead smooth cut to give a good finish to the surface while removing the smallest amount of material, see Fig 3.17.

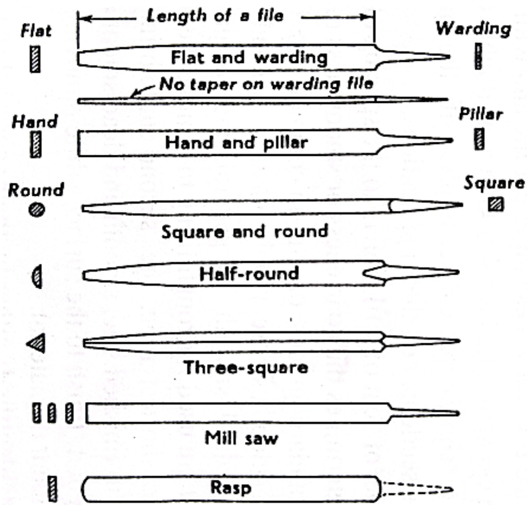


Fig. 3.16: Typical examples of the more common file sections.

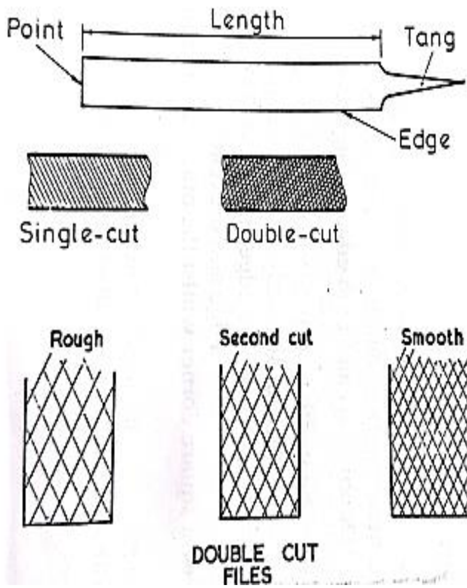


Fig. 3.17: Smooth and dead smooth cut.

Files are identified either by their general shape i.e.. hand flat or pillar or by their cross section three square, round, half-round, or knife. Fig 3.18 shows some of these files applications.

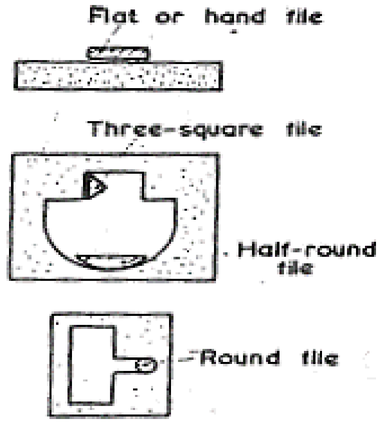


Fig. 3.18: Some of the files applications.

Flat file: this file is parallel for about two-thirds of its length and then tapers in width and thickness. It is cut on both faces (Double cut) and both edges (Single cut).

Hand file: the width of this file is parallel throughout, but its thickness tapers similarly to the flat file. Both faces are double cut. and one edge single cut. The uncut edge is called the "safe" edge and prevents cutting into one face of a square comer whilst the other face is being filed.

Both these files are used for general surfacing work. the hand file being more particularly when filing up to a step which must be straight and square. The taper in thickness enables the file to enter a slot slightly less than its full thickness.

Pillar file: nearly this file has the same section as a hand file but of a thinner section and parallel on its thickness. It is used for getting out narrow slots and keyways which the hand file would not enter.

Warding file; similar to the flat file but thinner and parallel on its thickness. Useful for getting out narrow slots.

Square file: the square file is of square cross-section, tapering towards the point. It is double-cut on all sides. This file is used for filing keyways, slots, and the smaller square or rectangular holes with go sides or fur filing comers where the hand file could not be entered.

Three-square file: the three-square or triangular file has a 60° triangular cross-section, parallel for approximately two thirds of its length, then tapering towards the point. The three faces are double-cut and the edges are sharp. This file is used for surfaces which meet at less than 90°, angular holes, and recesses.

Round file; is of circular in cross-section, tapers similar to square file. Used for opening out holes, producing rounded corners, round-ended slots, etc. Round files are usually double cut on the rough and bustard qualities over 150 mm long, whilst the rough and bastard under 150 mm together with the second-cut and smooth, are single cut.

Half-round file; the half-round file has one flat side and the rounded side is not a true half-circle, but only a portion of a circle. It is parallel for approximately two thirds of its length, then tapers in width and thickness towards the point. The flat side is double- cut and the curved side single-cut on second-cut and smooth files. This is an extremely useful double-purpose file for flat surfaces and for curved surfaces to large for the round file.

Knife file; has a wedge-shaped cross-section, the thin edge being straight while the thick edge tapers to the point in approximately the last third of its length. The sides are double-cut. This file is used in filing acute angles.

Mill file; similar to the flat file but parallel on both width and thickness. The mill saw file may have one or both edges rounded for forming the radius on saw teeth and in slots.

The rasp: the Horse Rasp is useful for filing soft metals, wood and soft non-metallic materials. The rasp tooth is cut with a pointed punch.

3.4.4 Filing

One of the greatest difficulties facing the beginner is to produce a filed surface which is flat. By carefully observing a few basic principles and carrying out a few exercises, the beginner should be able to produce a flat surface.

Filing is a two-handed operation, and the first stage is to grip the file correctly. The handle is gripped in the palm of the right hand with the thumb on top and the palm of the left hand resting at the point of the file, it is a cross filing. Having gripped the file correctly. The left foot is placed well forward to take the weight of the body on the forward stroke. The right foot is placed well back to enable the body to be pushed forward. Fig. 3.19 shows the three kinds of filing:

a- Cross-filing,
b- The light filing and,
c- Draw filing.

For lighter filing a rather lighter grip is used with the right hand and the end pressure is applied with finger and thumb. File marks may be removed, and a good finish imparted by draw filing. For this purpose, a fine-cut file with a flat face should be used.

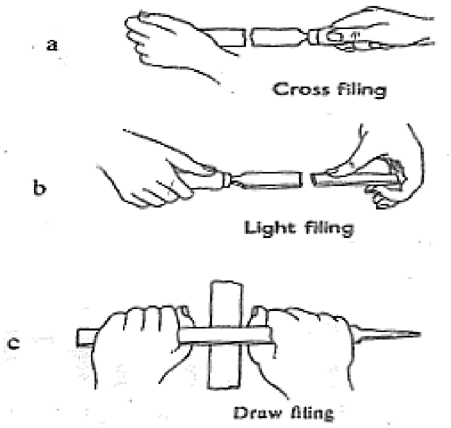


Fig. 3.19: The three kinds of filing.

3.4.5 Scraping and Scrapers

Scrapers, unlike files or chisels, are used because of their ability to remove very small amounts of metal or to correct slight irregularities from flatness. The material is removed selectivity in small amounts, usually to give a flat or for removing errors in flatness. The purpose of scraping is therefore to remove high spots to make the surface flat or circular, and at the same time to create small pockets in which lubricant can be held between the two surfaces.

Three types of scrapers may be used on flat and circular surfaces and they are shown in Fig 3.20. The flat scraper, for use on flat surfaces, resembles a hand file thinned down at the point (end), but it does not have any teeth cut on it. The point is slightly curved, and the cutting edges are kept sharp by means of an oil stone.

In many cases flat scrapers are made from old files by flattening out the end grinding and re-hardening. The scraper cuts on the forward strokes. The flatness is checked with reference to a surface plate.

For the same purpose, the half-round scraper has a slightly hollow on the underside and with a cutting edge on each side as shown in Fig. 3.20. The three-square or triangular scraper shown in the Fig., is commonly used to remove the sharp edges from curved surfaces and holes.

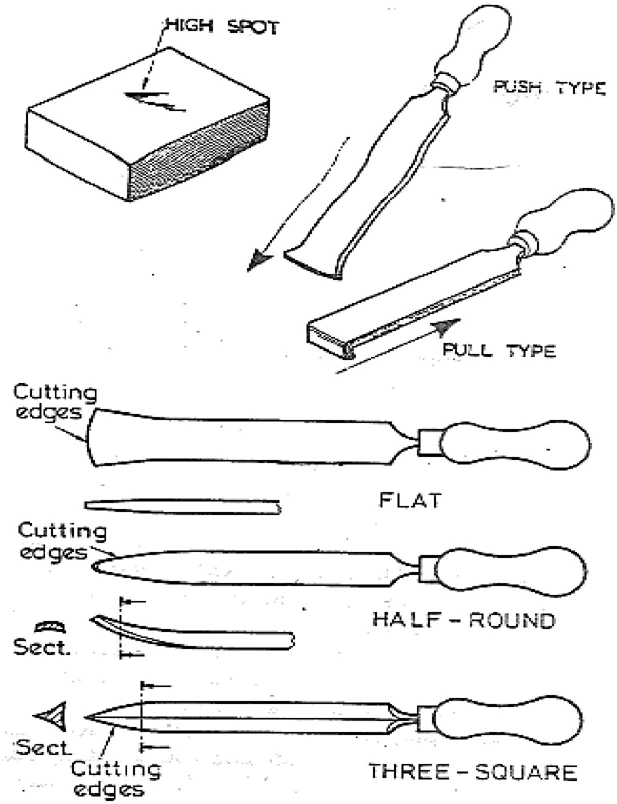


Fig. 3.20: Three types of scrapers.

3.4.6 Screw Cutting at the Bench

Screw threads are widely used in engineering for two main purposes:

i- ***transmission of motion*** ***ii- fastening***

Screw-Cutting Taps; the hand tools used to cut on internal thread are called taps, and a set of three is required if an efficient thread is to result. The first is the taper tap, the second is the semi-finishing tap and the third is the finishing tap. In this way we have divided the tapping operation into three separate stages, with small amounts of metal removed at each stage; this technique promotes a superior finish to the thread. The three taps are illustrated in Fig. 3.21, note the taper in the first tap, with a fuller thread form in the second and a full thread form in the third. It is important to ensure that the taper tap starts in correct alignment; the axis of the tap must be at 90 in all planes to the surface of the work.

The first stage in tapping is to drill a hole of the correct size. This is known as the tapping size and is normally slightly larger than the root diameter of the thread. Table 3.2 shows the tapping sizes for ISO metric threads.

Table 3.1: Tapping sizes for ISO metric threads.

Thread diameter and pitch (mm)	Drill diameter for tapping (mm)
1.6 × 0.35	1.25
2 × 0.4	1.6
2.5 × 0.45	2.05
3 × 0.5	2.5
4 × 0.7	3.3
5 × 0.8	4.2
6 × 1.0	5.0
8 × 1.25	6.8
10 × 1.5	8.5
12 × 1.75	10.2

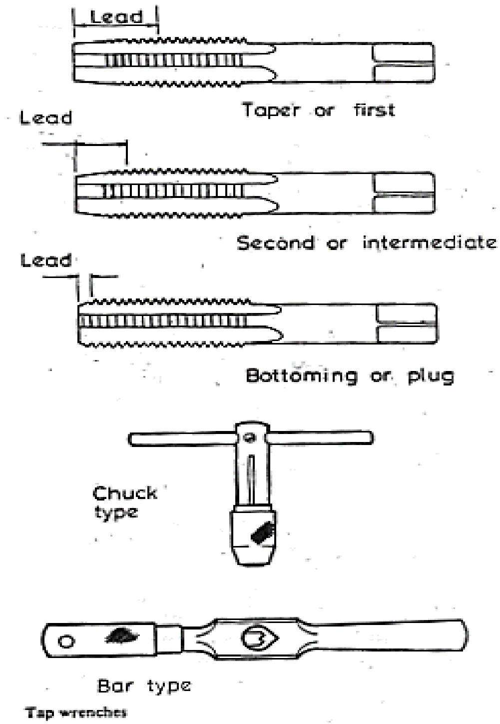


Fig. 3.21: Types of Cutting Taps.

Cutting External Threads; the tool used to cut an external thread is called a die, and the device used to hold the die and give it a turning moment or torque is called a stock. The dies are available in sizes up to approximately 36 mm thread diameter. The common type for use by hand as shown in Fig. 3.22 is the circular split die, made from high-speed steel hardened and tempered and split at one side to enable small adjustments of size to be made.

The die is held in the stock, which has a central screw for fixing and adjusting the size and two side locking screws which lock in dimples in the outside diameter of the die. Dies have led on the first two or three threads, to help start cutting, but it is usual also to have a chamfer on the end of the component. The die is placed squarely on the end of the bar and is rotated, applying downward pressure until cutting starts, ensuring that the stock is horizontal. No further pressure is required, since the die should be rotated backwards every two or three turns, to break up and clear the chips. This can be repeated until the final size is reached.

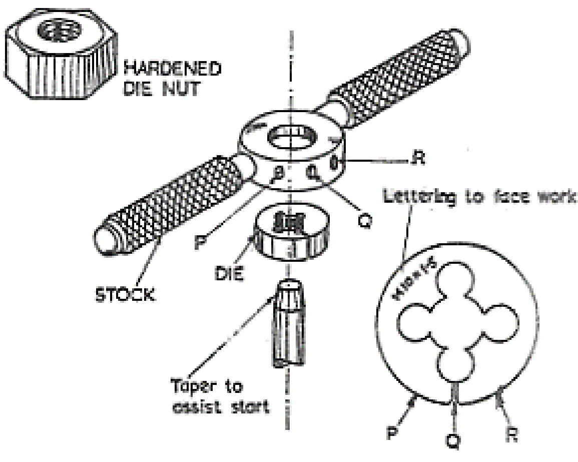


Fig. 3.22: Die used for Cutting External Threads.

CHAPTER 4
METAL CASTING

4.1 INTRODUCTION

A metal casting may be defined as a metal object produced by pouring molten metal into a mould containing a cavity which has the desired shape of the casting, and allowing the molten metal to solidify in the cavity.

The essential steps are: melting a metal charge in a furnace; pouring the melt into a previously prepared mould; extraction of heat from the melt and solidification; removal and, possibly, treatment of solidified part. The mould forms a cavity having the shape and size of the part to be casted in a material suitable for holding the molten metal until it cools. The part made by this process is called a "casting". In industry, castings are made in a foundry.

Casting processes can produce nowadays variety of products differing much in shape, size, material and accuracy. Examples of common castings are: frames of machine tools, engines parts, motors casings, pipes, steam and water valves, flywheels, large gears, toys, products made of cast iron, etc.

The main advantages of casting processes are:

1- Possibility of manufacturing parts of complex shape or intricate design.
2- Some alloys and metals cannot be formed except by casting like cast iron.
3- Possibility of producing large parts which may weight several tons.
4- Possibility of mechanizing and automating casting operations in foundries.

4.2 CASTING METHODS

The casting technique or the casting method used depends upon a number of factors, including the metal to be cast, the shape to be produced, the allowable costs and the quantity to be produced.

There are several casting techniques or methods from the technological point of view. They may be simply classified as follows:

1- Sand-Casting,
2- Die-Casting,
2- Investment-Casting
4- Continuos-Casting, and
5- Centrifugal-Casting.

If a sand mould is used, the casting is known as a sand-casting. The sand mould is produced with the aid of a wooden or metallic pattern.

If a metallic mould is used the casting is known as a die-casting. The metal mould is machined from a metallic block.

Investment-casting uses a refractory mould. It is produced using a pattern made from a low melting-point material, usually wax.

Centrifugal-casting involves the casting of metal into a rapidly rotating mould; this usually produces a denser and more homogeneous casting than is obtained when other methods are used.

Ordinary casting processes, as sand casting, will usually produce inaccurate castings. Therefore, these casting (semi-products) are further machined to obtain the required accuracy of certain surfaces. Other special casting processes, as die casting, investment casting, or centrifugal casting can produce final products with acceptable accuracy.

4.3 SAND CASTING

Sand casting is the most widely used casting process. In this method, the metal is poured into a mould or cavity that is formed in a special sand. The metal to be east is melted in a suitable furnace and brought to the mould in a ladle, from which it is poured into the mould. When the metal has solidified and cooled to a suitable temperature, the mould is broken up, and the casting removed.

Apart from the pouring technique, the main problem associated with sand-casting is the removal of the pattern from the completed mould so that the metal can be poured in. In some cases this can be overcome by making the pattern of several pieces; but as a new mould is made for each casting, the casting should, if possible, be designed so that the pattern is of one piece, so minimizing the moulding time.

The simplest mould consists of a box of sand with a depression at the top, into which the molten metal is poured; the "top" horizontal face of the casting being controlled by the quantity of metal that is poured into the mould, and the inclination of the mould relative to the "horizontal". This one-part open mould is suitable for casting billets and similar shapes.

When a more complicated and accurate casting is required, a multi-part mould consisting of two, or occasionally three sections, placed one on the other, is necessary; three-part moulds are not used as often as two-part moulds because they are more expensive to make, and consequently casting are designed with a view to using two-part moulds.

4.3.1 Sand-Casting Using Simple Two-Part Mould

Fig. 4.1 shows a bracket that can be cast using a simple two-part mould; this method can be used because the pattern will have a suitable flat face that can be placed on the moulding board at the start of the moulding operation.

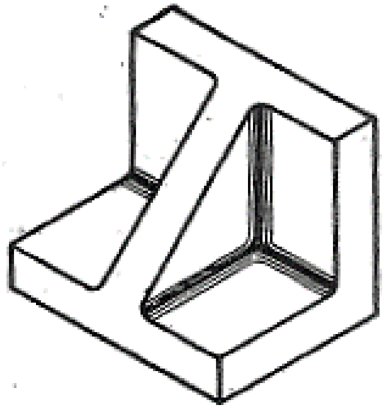


Fig. 4.1: A bracket.

The pattern used to produce the mould will be almost a replica of the casting to be produced, but it will be overall larger than the casting to allow for the contraction that will occur when the metal cools (will be explained later, under the title: Patterns).

Sand moulds are contained in metal moulding boxes (or 'flasks') that have four sides but no top or bottom; Fig. 4.2 shows a pair of moulding boxes. During the moulding operation the boxes are located together by pins so that they can be separated to remove the pattern, and replaced in the correct position before the metal is poured in; the boxes are clamped together, or the cope (top part) weighted down when pouring to prevent the cope from 'floating away' from the drag (lower part) when the mould is full of molten metal.

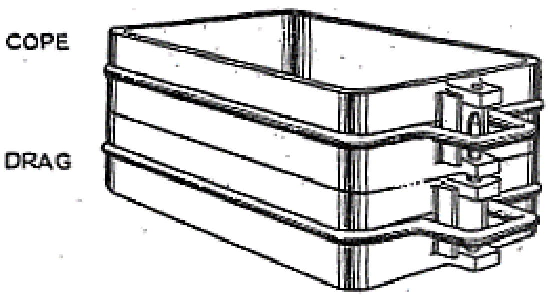


Fig. 4.2: Moulding boxes.

Fig. 4.3 illustrates the sequence when moulding the simple two-part mould to cast the bracket shown in Fig. 4. 1, applying the following steps:

Step 1 The pattern is seated on the moulding board or the foundry floor (this could not be done if the casting, and therefore the pattern also, did not have a suitable flat surface); and the lower part of moulding box (drag) is placed around it.

Step 2 The pattern is covered with facing sand, which is a specially prepared sand of good quality that can take a clean and smooth impression; resisting the heat from the molten metal that will be in contact with it.

Step 3 The facing sand is backed up with moulding sand (also called floor sand and backing sand), which is old facing sand from previous moulds.

Step 4 The moulding sand is carefully rammed up with a hand hammer so that it is fairly tight around the pattern to produce a good solid mould, yet permeable enough to allow the gases produced during casting to escape.

Mechanical ramming is used for large moulds and in high production moulding.

Step 5 The excess sand in the drag is finally leveled off with a straight bar called strike rod A bottom board is then placed on the drag.

Step 6 The drag with the pattern are then rolled over and the moulding board removed, exposing the pattern.

Step 7 The surface of the sand is smoothed over with a (rowel and lightly covered with parting sand. Parting sand has no cohesion, and will prevent the bonding of sand in the cope with that in the drag.

Step 8 The cope is located in position on the drag with the pins on either side holding it in proper position. Two or more plugs are introduced when the cope is being filled with moulding sand; the sand is then rammed up and leveled off.

The plugs will leave channels in the mould as shown in Fig. 4.3, stage 2. One channel is called spri4e (sometimes is called runner), through it the molten metal is pouring; another channel is called riser which will be filled with molten metal when the mould is completely filled. The riser is important since it first vents the air as the mould fills, and then serves as a reservoir of metal to supply and compensate the casting as it shrinks due to cooling.

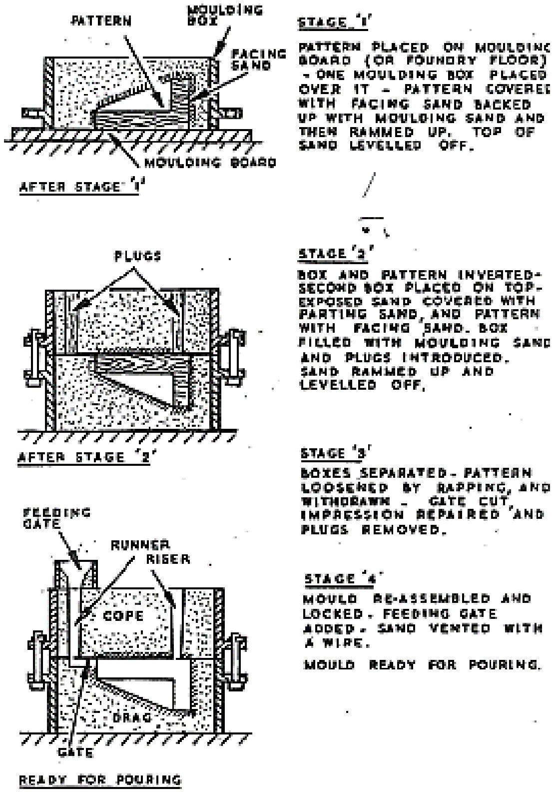


Fig. 4.3: Sequence of moulding a two-part mould.

Step 9 The cope is then carefully lifted off and set to one side. The pattern is then withdrawn from the mould by screwing a bar with a threaded end into a suitable insert in the pattern, damping the sand around the pattern, and gently rapping the bar in all direction. To facilitate the removal of the pattern without scuffing the sides of the impression, all surfaces that lie in the -direction of pattern removal are inclined slightly by a small amount (the draw angle) as shown in Fig.4.4.

Step 10 A small passage known as a gate must be cut between the cavity made by the pattern and the sprue opening, (see Fig. 4.3, stage 4). The sprue may be connected to the cavity by more than one gate. The system of connecting the sprue to the cavities is called a gating .system.

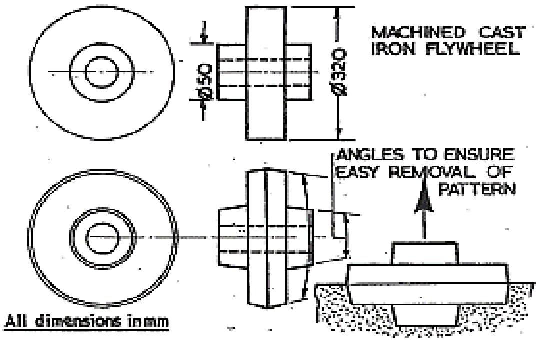


Fig. 4.4: The draft allowances.

Step 11 The two halves (sections) of the mould (cope and drag) are reassembled together, carefully locating and securing the two sections and then we get a complete mould as shown in Fig.4.3, stage 4.
The sand in the cope is vented (using a venting wire which is pushed into the sand, almost to the impression). Before the molten metal is poured, a weight should be placed on top to prevent the liquid metal from tending to float the cope and

allowing metal to run out of the mould at the parting line.

Step 12 When the metal has solidified, the sand mould is broken open to remove the casting, which will be as shown in Fig. 4.5. The runner and riser shown are produced by the metal that solidifies in the runner and riser channels. Before the casting is dispatched from the foundry it is fettled; this involves the removal of the runner and riser.

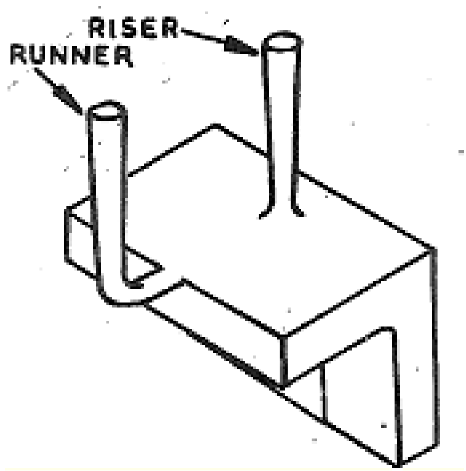


Fig. 4.5: The casted bracket.

4.3.2 Sand-Casting Using Core and Split Pattern

The hollow castings illustrated in Fig. 4.6 introduce further complications because their shapes prevent their patterns from being removed from the mould. One method of overcoming this problem is to use a split pattern. Figs. 4.7 and 4.8 show the principal stages in the production of the mould for these castings.

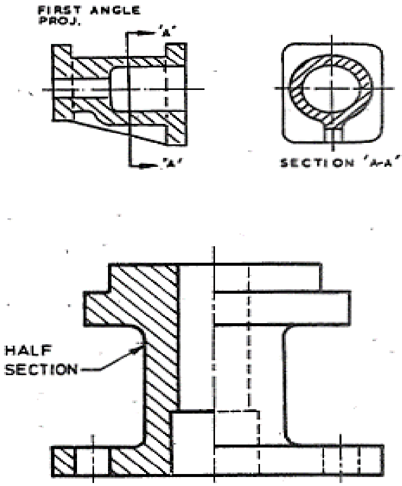


Fig. 4.6: An example of a hollow casting.

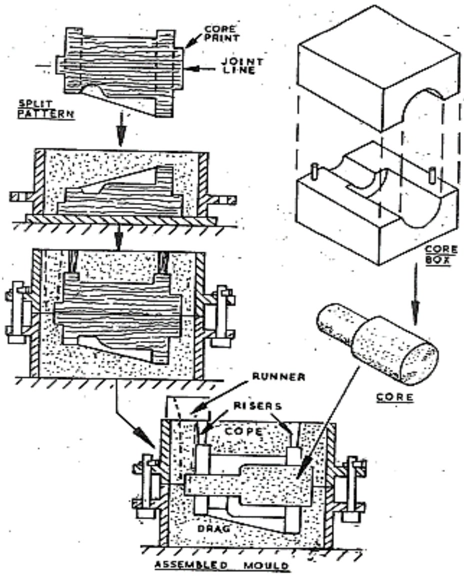


Fig. 4.7: The split pattern.

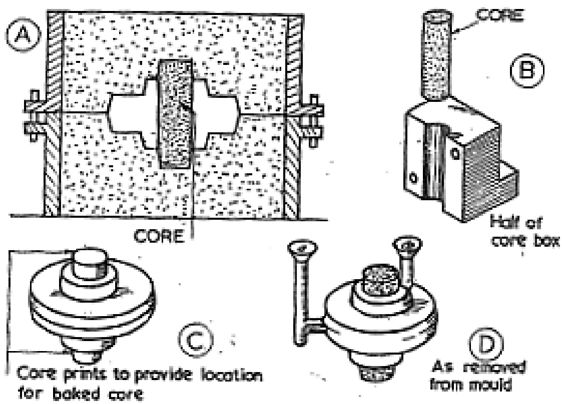


Fig. 4.8: The stages of moulding a hollow cast.

Each pattern is of two parts (the joint between them being a plane surface), located by dowels as shown in Fig. 4.9. The hollow features is produced by placing a core on the core print to restrict the molten metal.

The pattern has a projection at each end, called a core print to produce suitable location points in the mould, ready for seating the core.

At the first stage of moulding, one part of the pattern (the one without dowels) is treated like a simple pattern. When the drag has been rammed up, it is inverted, with the pattern in position. The second moulding stage is similar to that shown in Fig. 4.3, except that the other part of the pattern (the one with dowels) is put in position before the cope is rammed up. The remaining steps are the same as for simple moulding, until the mould is reassembled, after the core is introduced and seated to produce the hollow feature.

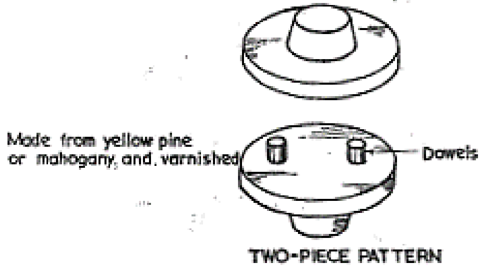


Fig. 4.9: A two-parts pattern.

4.3.3 Patterns

The first step in making a casting is to prepare a model of the required casting, known as a 'pattern' Most patterns are made of wood, which is inexpensive and can be worked easily. A wooden pattern is made by a patternmaker, a highly skilled craftsman.

Patterns are also made of aluminum, brass or plastic. If more than 500 parts are to be cast from one pattern, the pattern should be made of metal, usually aluminum. The pattern will be used to form the cavity in the sand mould.

The patternmaker must consider several items in dimensioning the pattern in addition to the original drawing dimensions.

A shrinkage allowance must be made to compensate metal shrinkage during solidification. These ranges from 10 mm/m for cast-iron, to 20 mm/m for cast steel and bronze. The pattern-makers use shrink rules which have divisions larger than that on standard scales to save the time needed to compute every dimension of the pattern.

4.3.4 Moulds Cores

Cores are needed if a casting is to have hollow portions. A core is a preformed piece of material that is put into a mould so that the metal will flow around it and leave an opening in the casting. Figs. 4.7 and 4.8 show two examples of cores and how they can be used The core must be supported in the mould, so the pattern is made with extended pieces which will leave impressions in the sand into which the core can be placed These impressions are called core prints and are shown in Figs 4.7 and 4.8.

The venting problem is acute because the core is almost surrounded by molten metal; it is therefore necessary to make it from a special sand, called core sand, that when given some further treatment becomes strong but porous. Vent holes are also provided in cores to improve permeability.

The core is made from a 40: 1 mixture of sand and oil (acting as a binder) and then is pressed into a corebox,(see Figs. 4.7 and 4.8). The core is stiffened if necessary by introducing a rod, called a core iron, on its axis.

The corebox is made of wood, metal or plastic. The core is removed from the corebox and baked in an oven for approximately 2 hours at a temperature between 1 80 to 220°C.

4.3.5 Moulding Sands

The moulding sand is a mixture of sand. clay, water and certain additives. The basic for moulding sand is clean silica sand. As this natural sand will seldom stick together, 4 to 15% of clay is added as a binder The most commonly used clays are bentonite and kaolinite (known as fire clay).

The main additives added to the mixture are cereal flours (such as com, wheat, or rye flour), coal, dust, and oil. The water content of the moulding sand is important, it is usually 3 to 4% by weight.

The essential properties of moulding sand are as follows:

Permeability The sand must allow the steam and other gases generated by the heat of casting to escape freely. If there is insufficient passage through the body of sand, then the gases will try to bubble through the solidifying metal, and will leave holes in the casting. The moulder has some control over permeability; hard ramming lowers the permeability, but this is relieved by liberal venting.

Plasticity This is the ability to take up an intricate shape, such as a Fig.d face. Fine-grained sands have better plasticity than coarse-grained, but the plasticity of a sand is chiefly a question of the content of clay, which retain moisture when the sand is damped.

Flawability This property is allied to plasticity. It is the ability of the sand to take up the desired shape. In ramming up, the blows of the rammer must be transmitted through the body of sand, which should respond readily to the packing action.

Cohesion The sand must hold together when the pattern is withdrawn, and the mould is moved about. Cohesion must be retained when molten metal enters the mould, and washes the heated mould surface; this property is often termed bond strength.

Insufficient strength may lead to a collapse in the mould during casting. The bond strength of moulding sand is affected largely by the alumina (clay) and water content.

Refractoriness The sand should resist the heat of the molten metal, without fusing. It is the silica content of the sand which has the best refractory properties, the clay being the first to fuse.

To prevent the metal from making too close contact with the sand face, up to 10% of coal dust is added to facing sand. The first effect of the molten metal is to burn this coal dust, which forms a gaseous 'blanket' between the metal and the mould face.

4.3.6 Cleaning of Castings

The next operation is cleaning, or fettling, of castings. It involves the removal of adhering sand (especially in the cast-iron and steel castings), and the gating system from the casting.

Sprues and risers, shown in Fig. 4.5 are cut off, usually using a metal band saw. Hand or rotary machine brushing is usually sufficient to clean the casting.

Sand-blasting units may be used for light, medium, and heavy castings, where sharp sand is blown against castings inside a sand blasting cabinet.

Castings may also need certain amount of chipping or grinding to remove surface and edge defects. Stand, portable, and swing-fan grinders are used for this work.

4.4 DIE CASTING

We have seen that a great disadvantage of the sand casting process is that the mould must be destroyed in order to remove the casting when it has solidified. When large quantities of very accurate castings are required, it is a better plan to make metal moulds or dies.

The advantage of these dies is that as soon as the solidified casting has been removed they can be immediately used again to produce another casting, and in this way the rate of casting production is greatly increased, resulting in a lower-cost product. This process employs a metallic mould, called a die, and so produces good accuracy and finish. There are two methods of die-casting: gravity die-casting, in which the metal is poured into a metallic mould, and pressure die-casting, in which a machine is used to inject the metal into the metallic mould.

The gravity die-casting method is now often called permanent-mould casting, and the pressure die-casting method called simply die-casting. Both methods of die-casting are suitable for low and medium melting-point metals and alloys say, aluminum alloys, zinc alloys, and brass.

Typical items made by the die-casting technique are light car parts such as carburetors and water pump cases, small motors, hand tools, and toys.

4.4.1 Gravity Die-Casting

The gravity die-casting method is very similar to sand-casting, except that the mould is made of metal, and is called a die. Fig. 4.10 shows a typical example of an aluminum alloy gravity die casting;

note that two castings are produced at each filling of the dies.

In Fig. 4. 10a we see a view of one die; note that the runner is in a central position, providing a large mass of metal to ensure filling the cavity at each side. Note also the riser at the top of each cavity.

In Fig. 4 10b we see the dies in the closed position, with liquid metal poured in the central runner. Pouring continues until the runner and both risers are full. Fig. 4. 10c shows the finished gravity die-casting as removed from the dies.

In Fig. 4.10d we see a pictorial view of the finished gravity die-casting, which is now ready for machining the base and drilling the holes.

This method produces castings that can be large (maximum mass about 60 kgs), and of much better quality than those produced by pressure die-casting.

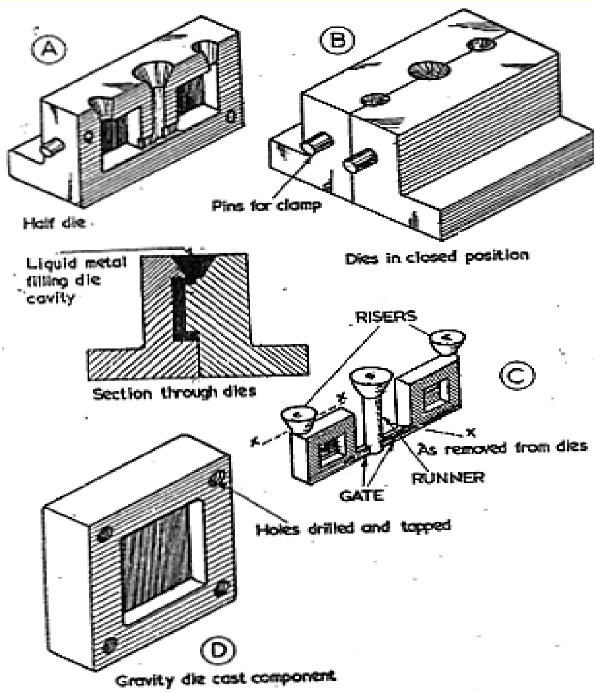


Fig. 4.10: A gravity die casting of an Aluminum alloys cast.

4.4.2 Pressure Die-Casting

As the name suggests, this casting process makes use of external pressure to force liquid metal into suitable metal dies, usually machined from alloy steel. The use of external pressure ensures not only that the dies are completely filled, but also that a very good impression is obtained, resulting in a well-defined casting and considerable accuracy.

There are two basic methods of forcing the metal into the die. They are called hot-chamber and cold-chamber processes.

Hot-Chamber Die-Casting This system is used for alloys of zinc, tin, lead and similar low melting-point alloys. Of these metals, zinc alloys are the most popular.

Fig. 4.11 illustrates a plunger-type machine. In the shown machine, the plunger and the injection cylinder are submerged in the molten metal. The molten metal pot is heated by a gas burner.

The movement of the plunger downwards will force the metal into the die. The most suitable casting pressure is about 10 MPa, with a casting temperature of about 400°C.

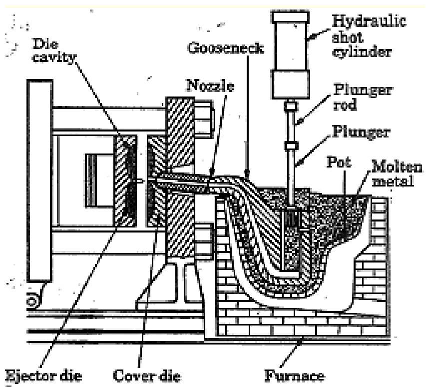


Fig. 4.11: Hot-chamber die casting.

As soon as the casting is solidified, the pressure is relieved, the dies are forced open, and the casting is ejected by means of ejector pins.

<u>Cold-Chamber Die-Casting</u> Fig. 4.12 illustrates a diagrammatic sketch of the cold-chamber machine. This system of pressure die-casting is the most suitable one for casting brass, magnesium and aluminum alloys. These alloys possess higher melting-points and require high casting pressures.

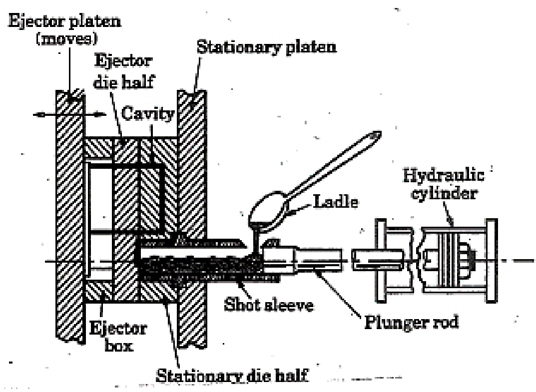


Fig. 4.12: Cold-chamber die casting.

The cold-chamber is a cylinder into which a plunger is fitted. The plunger is operated by a hydraulic press. The metal is melted in a separate pot made of graphite or other suitable refractory material.

Molten metal, sufficient for a single shot, is poured manually or mechanically into the cylinder, and is then forced into the die by means of the plunger.

Pressures between 20 and 180 MPa may be used. Castings can be produced by this system at a rate of about 100 pieces per hour, and they are of very high accuracy.

4.5 INVESTMENT CASTING

Also called the lost-wax process, and was originally used in ancient Egypt and China. The investment-casting process is expensive. This process is used to produce the accurate and most complex shapes, because the pattern is made of wax (sometimes of a plastics).

This casting method is not limited by the melting temperature of the metal to be cast; it employs an expandable pattern, around which the mould is built up (the pattern is said to be 'invested').

It was used in dental work, and in the manufacture of jewellery. It is now also being used for the production of gas-turbine parts and certain motor-car engine parts.

Fig. 4.13 illustrates the stages involved in the production of a casting by investment-casting, that according to the following steps:

Step 1 First of all, the master pattern for the casting is made (usually from steel or brass), and then the metal die is made.

Step 2 The pattern is made from a low melting-point material, usually wax, and is produced by injecting the material into the metal die, using a machine.

Step 3 The temperature of the mould is raised, causing the mould to become hard, and the pattern material (wax) to be melted, so that it runs from the mould.

Step 4 The pattern is cleaned up, and is attached to a wax runner (called a 'sprue').

Step 5 A refractory shell is gradually built up around the pattern and sprue, first using a liquid refractory, and then spraying on a fine-grain solid refractory.

Step 6 The investment is dried, and the process is repeated several times, so that a thick shell is produced around the pattern.

Step 7 The investment is then heated to about 350 C, to melt out the pattern material, and to harden the shell.

Step 8 The mould is finally fired by heating it to a higher temperature; this heating also prevents chilling during the casting operation that follows.

Step 9 The metal to be cast is melted in a small carbon-arc furnace, so that it can be inverted during the pouring operation.

Step 10 The hot mould is clamped to the mouth of the furnace, which is then inverted (step 6 in Fig. 4.13). Compressed air is used to ensure that the molten metal is packed into the mould.

Step 11 The mould is removed from the mouth of the furnace, and is set aside to cool. Finally, it is broken open, to remove the casting, which is then fettled.

4.6 CONTINUOUS CASTING

Cast bodies of circular, octagonal, or round-cornered square cross sections are called ingots when their diameter or side dimension is about 200 mm or greater, and are called billets when smaller. Bodies of rectangular cross section are generally called slabs.

Continuous casting processes are used for casting the vast majority of slabs and billets in aluminum and copper alloys and now also in steels.

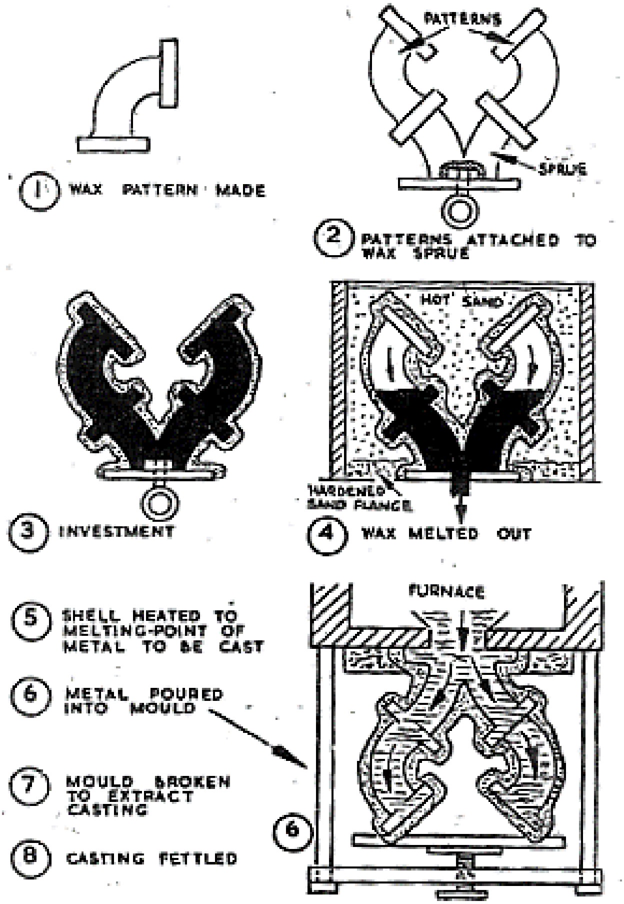


Fig. 4.13: The steps of investment casting.

Briefly, the process consists of continuously pouring molten metal into a mold, which has the facilities for rapidly chilling the metal to the point of solidification, and then withdrawing it from the mold.

Fig. 4. 14 shows one of the most popular continuous casting techniques which is known as Asarco Process. In this technique, the metal is fed by gravity into the mold from the furnace as it is continuously solidified and with-drawn by the rolls below. An important feature of this process is the water-cooled graphite-forming die. which is self-lubricating, is resistant of thermal shock, and is not attacked "by copper-base alloys. The upper end, in molten metal, acts as a riser and compensates for any shrinkage that might take place during solidification.

In starting the process, a rod of the same shape as that to be cast is placed between the drawing rolls and inserted into the die. This rod is tipped with a short length of the alloy to be cast. As the molten metal enters the die, it melts the end surface of the rod. forming a perfect joint. The casting cycle is then started by the drawing rolls, and the molten metal is continuously solidified as it is chilled and withdrawn from the die. When the casting leaves the furnace, it ultimately reaches the sawing floor where it is cut to desired length.

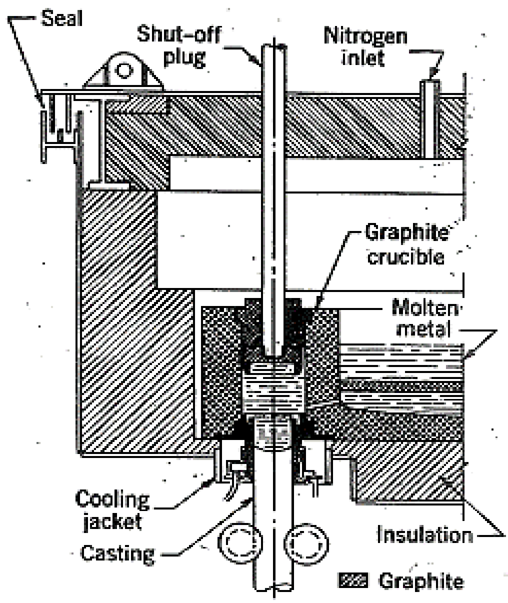


Fig. 4.14: Continuous casting.

4.7 CENTRIFUGAL CASTING

Centrifugal-casting is the process of rapidly rotating a mould while the molten metal solidifies; thus utilizing centrifugal force to position the metal in the mould. This method usually produces a symmetrical shapes, thin sections, dense metal structure and more homogeneous casting than is obtained when other methods are used.

Centrifugal casting machines are classified as either horizontal or vertical depending on the position of axis of rotation. Fig. 4.15 illustrates together, the two types of centrifugal casting; with some examples of the shapes which can be made in this method.

A thin-walled cylindrical casting is produced without using a core (long casting are produced by rotating about a horizontal axis, and pouring from the runner that start half way along the axis, and move outward, in opposite direction).

Horizontal machines, Fig. 4.15a, are usually used for casting pipes which may reaches 16m long and 125 mm wall thickness. In addition to pipes, typical parts made are bushings, engine-cylinder liners, and bearing rings. Speeds of rotation are from 200 to 1000 rpm.

Vertical-axis machines, Fig. 4.l5b may have one or several moulds arranged around the axis and pouring basins and cores may be employed.

In this technique, the center of the casting is usually solid but, since the pressure is less there, the structure is not so dense and impurities are often present. Therefore, this method is usually used for parts in which the center of the casting will be removed later by machining.

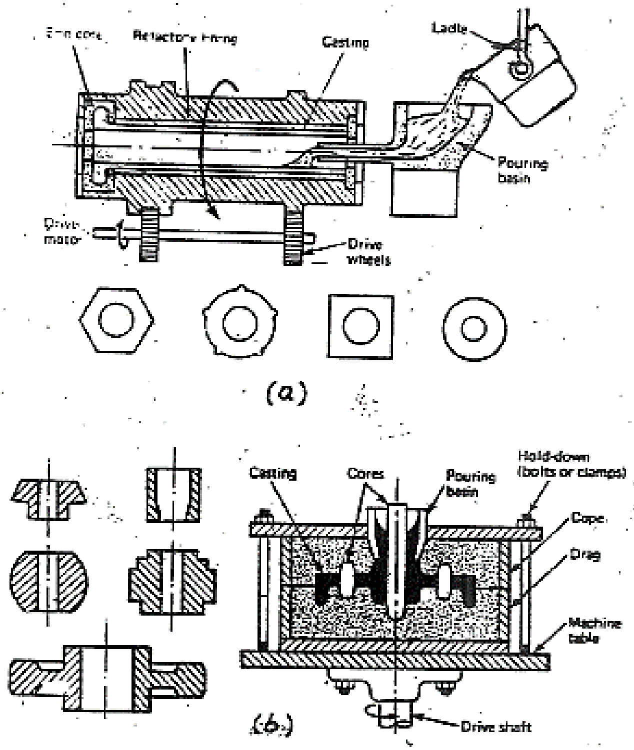


Fig. 4.15: Centrifugal casting.

4.8 COMPARISON OF SAND, DIE AND INVESTMENT-CASTING

When selecting the casting method to be used, the shape, accuracy, finish, material and economics must be taken into account.

Table 5.1. indicates a comparison between the three casting methods, sand, die, and investment-casting.

4.9 EQUIPMENT FOR MAKING CASTINGS

Some necessary equipment, tools and materials are used for making casting in the foundry. Some tools are used for preparing the sand-mould and removing the pattern from the mould. Fig. 4.16 shows some of these tools as follows:

1- Moulding Benches Are necessarily of sturdy construction to withstand the heavy work expected of them. Moulding sand is heavy; ramming the sand into the flasks requires considerable force, as the sand must be firm, and any vibrations resulting from lack of rigidity could result in a faulty mould. The bench has a recessed metal-lined working top and a bin to store the sand. Cupboards provide storage for other equipment.

2- Moulding Boxes or Flasks May be of cast-iron, aluminum or wood, their size depending upon the work to be cast. These are the boxes which hold the sand to make the mould, their inner surface being suitably grooved or ribbed to assist adhesion of the sand. The bottom box is the drag and the top one the cope. Locating pins in the cope fit into corresponding sockets in the drag. Both rest on a substantial 'bottom' board.

3- Foundry riddles Two are recommended; one with a fine mesh of 1.5 mm square holes to prepare face sand and one with a 6 mm mesh to clear the remaining sand of debris.

4- Rammers Should be of close-grained hardwood and are used to pack the moulding sand round the pattern and sprue pins. This must be done firmly. The wedge-shaped end is for use in corners and at the base of the sprues.

5- Sprue and Riser Pins Are also of close-grained hardwood, and are used to form the pouring hole and the riser in the cope. They are tapered to provide easy withdrawal.

6- Leveling-Off Bar This straight edge is used to scrape off surplus sand after ramming to give level surfaces on the cope and drag.

7- Moulding Trowels Are for making good any damage to the mould by removal of the pattern. A range of sizes and shapes is available.

8- Gate Knife The channels connecting the sprue to the mould cavity are cut with the gate knife.

9- Spoon Tools Are used to scoop out the pouring basin and the hollow at the base of the pouring hole.

10- Vent Rods Are made of spring-steel wire, as it is important they should remain straight and true.

By pushing the vent rod through the rammed sand in the cope to the pattern, small vent holes are made for the release of unwanted gases created as the metal is poured. It is particularly important to provide vent holes to any part of the mould where pockets of air may be trapped, as this would certainly result in a faulty casting.

11-Draw Pins Are used to remove the pattern from the mould. One, two or more are used, depending on its size. The pin is screwed into the pattern at a suitable point and 'rapped' gently to loosen the pattern in the sand so that it can then be withdrawn. Screwing the pin frequently into the pattern will cause damage, so if it is intended to have a long life, a rapping plate should be recessed into it. Plain holes allow a rapping bar to
be inserted, and a threaded hole is used for the , draw pin.

12-Parting Dust Is a fine powder of burnt clay or French chalk. Its purpose is to prevent the development of a bond between the sand in the cope and drag, or between the sand and the pattern. It is sprinkled over such surfaces from a cotton bag.

Table 4.1: Comparison of casting methods.

	Sand-Casting	Die-Casting	Investment-Casting
Shapes that can be cast	Limited by removal of pattern from mould (but pattern can be made in sections). Hollow shapes can be cast.	Limited by removal of casting from die. Hollow shapes can be cast by the 'gravity' method but not by the 'pressure' method (sand would collapse).	Not limited.
Accuracy	Rather poor due to sand. Parting error and rapping error (because of pattern removal) also present.	Good, but parting error (because of casting removal) also present	Good, no parting error because mould is one piece.
Finish	Poor- due to sand.	Very good.	Very good.
Choice of metal	Not limited by melting temperature.	Limited by melting temperature and by injector contamination	Not limited by melting temperature.
Economics	This is slow and therefore costly but is suitable for small quantities.	This is costly due to die costs and equipment cost, but economical for large quantities.	Very costly, but may be the cheapest, or only method of manufacture of awkward shape.

* **Note:** Only the three most common casting methods are considered herein.

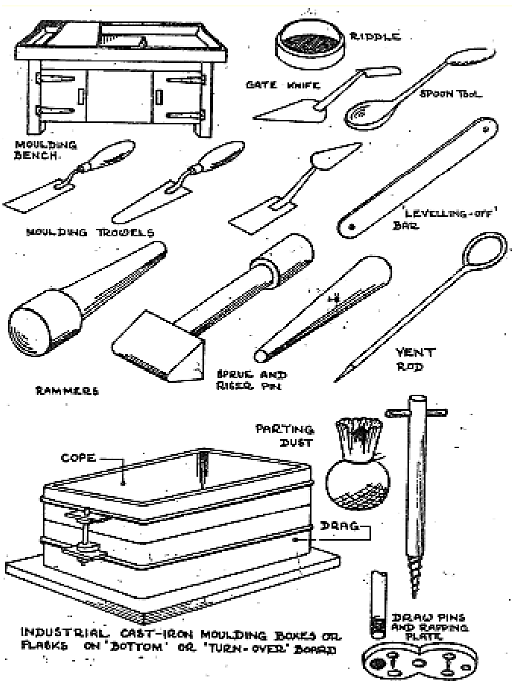


Fig. 4.15: The casting equipments.

CHAPTER 5
METAL FORMING

5.1 INTRODUCTION

Forming operations are those in which the shape of metallic part is changed by plastic deformation under the action of externally applied forces using various processes classified in the chart shown in Fig. 5.1. Different kinds of metal-formed products are shown in Fig. 5.2.

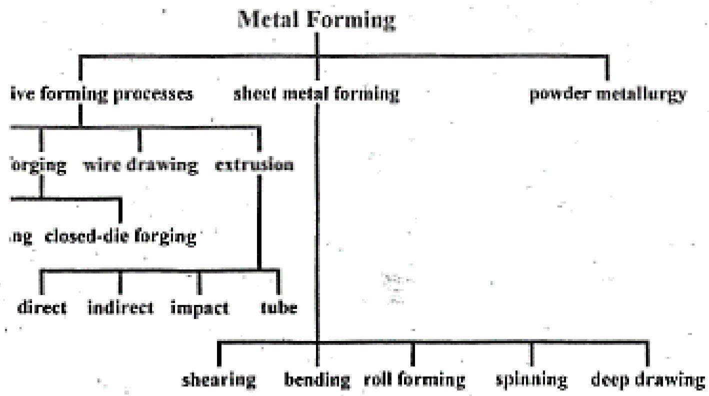


Fig. 5.1: Classification of metal forming.

There are two advantages for the metal forming process. The first advantage is the reduction in material cost due to minimize the losses in material. The second is that the mechanical properties of the metals and alloys that are formed are usually improved by mechanical working.

The metal forming is described as ***hot*** or ***cold*** working that depends upon whether the metal is worked above or below the recrystallization temperature. The recrystallization temperature for lead, tin and zinc is at or near room temperature and above 727°C for steels.

The working of metals above their recrystallization temperature is known as ***hot working***. Hot working increases the plasticity of the metals, and then reduces the required forming force.

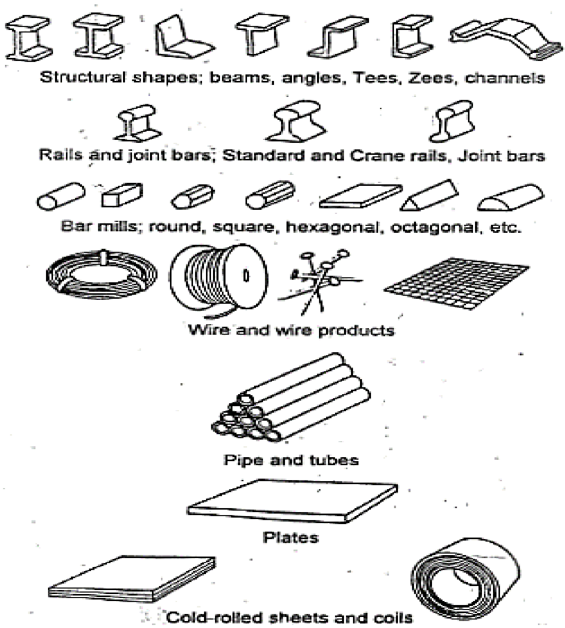


Fig. 5.2: Some metal forming products.

The working of metals below their recrystallization temperature is known as **cold working**. Most of the cold working processes are performed at room temperature. In cold working, the product gets a good surface finish, accurate dimensions, high hardness and high strength. On the other hand, cold working distorts the grain structure and does not provide an appreciable reduction in size. It also needs high forming forces and causes high rated wear in the forming dies.

Thus, if the aim of the forming process is to obtain a large change in the shape of apiece as quickly and cheaply as possible without precise surface finish and dimensions, hot working is most suitable. In some cases, the product is hot formed followed by cold forming is recommended to gain the advantages of both processes.

It is recommended that the heating of metals must be uniformly done. Heating to the proper forming temperature is done using fuel or electrical furnaces. They are provided in different sizes and usually equipped by environment control systems to suit the specific needs.

5.2. FORGING

The forging and smithing is a process of heating the metal to a plastic state and then shaping it either with a hand or mechanically operated hammers. The smithing is done by the blacksmith, so is called hand forging. It is an oldest form of the forging and is largely used where small parts are shaped by hearing them in an open fire or hearth. The forging is a process of heating the metal in a closed furnace and shaping it in dies under the pressure of heavy hammers. However, the term forging is usually referred to the production of heavy parts.

We may roughly divide forging into the processes of hand or free (open) forging, machine forging and drop forging, the two latter processes being of types adaptable for large quantity production of similar articles. In other words, the forging process can be earned out either open or with closed dies. High skill is required with open forging than with closed die forging. Faster output and smaller tolerances are obtained with closed die forging.

Free or open forging is; of course, much less costly than closed dies forging and more economical for a few parts. In free forging, two flat surfaces are used, but in practice the dies are sometimes V-shaped, half round or half oval. In free forging, the forming force is applied manually by the blacksmith and the shaping of metal is carried out under his hand control. The work accuracy depends upon the skill of the smith, thus gets the name smith forging. Free forging is suitable for small production of inaccurate dimensions.

There are many forging tools in the smithing and forging workshops; thus it is worth mentioning first the most important and widely used forging equipment.

5.2.1 Forging Equipment

1. Heating Furnaces The heating of metal is done in a smith's hearth. It is a very old method of heating but still it is used. A common form of hearth is shown in Fig. 5.3. It consists of a shallow dish or tray for holding combustible coke and made of heavy gauge mild steel or cast iron sheets. There is an inlet for blowing air into the fire either through the back or bottom. The air is applied under a slight pressure using a motorized fan blower through a tuyere. Because of the high temperature under which the tuyere operates, it is often water cooled by direct connection to the bosh. The heating furnace should have a chimney for carrying away smoke and gases. Usually a water tank (bosh) is also provided for quenching purposes.

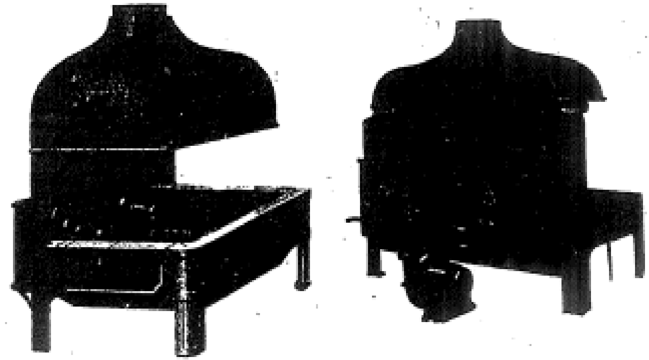


Fig. 5.3: The Blacksmith´s heart.

2.Anvil The anvil is the most important smith's tool. As shown in Fig. 5.4, it is used for supporting the work while it is struck with hammer, as well as providing means for other forging operations. It is made in several shapes but two most common forms are the English and French types. An English anvil has a single beak, as shown in Fig. 5.4, while the French anvil has a beak at each end. The body of the anvil is made of mild steel to which a piece of high carbon steel about 25 mm thick is welded on the top to give a hard top face. The beak is soft like the anvil body and its shape makes it useful for bending round metal section to different diameters. The ledge (table) between the beak and the anvil face is also soft and may be used for resting metal when cutting through with a chisel. The soft underneath metal does not damage the chisel edge.

In the top of the anvil are a square and a round hole. The square hole (known as hardie hole) is used for holding square shank shaping tools like bottom fullers, swages and hardie (bottom chisel) etc. The round hole is used for admitting the ends of the punches or drifts. This hole is also used for bending round bars of different curvatures.

The most common anvil has a weight of about 150-kg. The anvil is placed either on a wooden base or on cast iron stand such that the top face is about 700 mm from the floor.

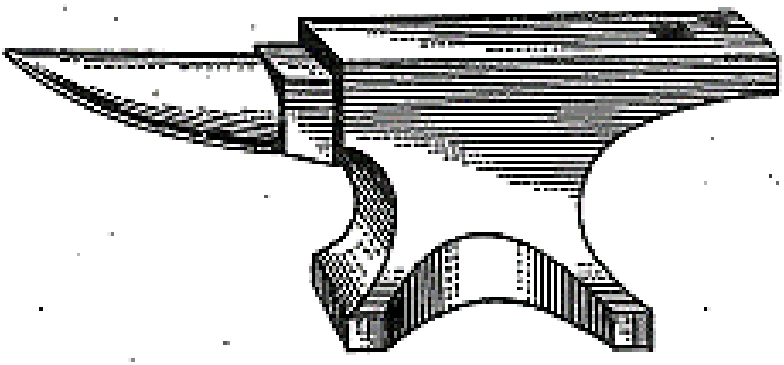


Fig. 5.4: An English anvil.

3. Tool bench as shown in Fig. 5.5, is used to keep the black-smith's tools in well-arranged way.

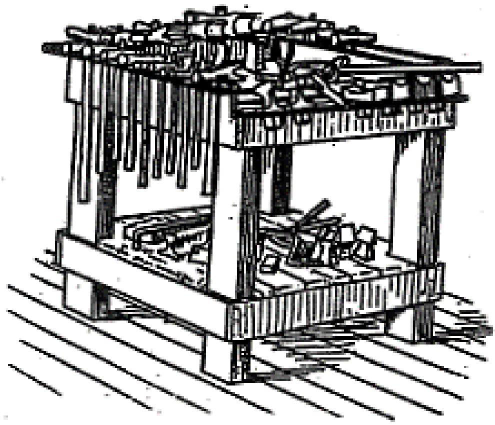


Fig. 5.5: The tool bench.

4. Hammers As shown in Fig. 5.6, the hammers commonly used in hand forging, are of the following two types:

i. Hand hammer used by the smith himself, and

ii. Sledge-hammer used by striker; the smith's helper.

The hand hammers are generally ball peen hammers as shown in Fig. 5.6a. They usually have a slightly convex striking face and should be from 1.0 to 1.5 kg in weight. The hammerheads should be of cast steel; the ends are hardened and tempered with the portion around the eye must be soft.

The sledge hammers are used by the smith's helper or striker. The weight of the sledge hammer varies from 4 to 6 kg for ordinary work and 8 to 10 kg for heavy work, the shaft being about one meter long. The shaft is mostly made of wood. The three types of sledge hammers are shown in Fig. 5.6b.

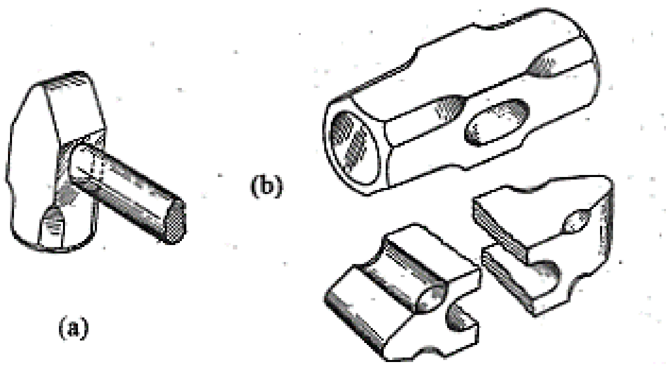


Fig. 5.6: The hummers kinds.

5- Tongs The blacksmith requires suitable tongs to handle the work while various forging operations. These are made of mild steel. The various types of tongs commonly used for holding work are shown in Fig. 5.7 as follows:

i. Closed mouth tong. A closed mouth tong, as shown in Fig. 5.7a, is used for holding thin sections.

ii. Open mouth tong. An open mouth tong, as seen in Fig. 5.7b, is suitable for holding heavier stocks.
iii. Round hollow tong. A round hollow tong, as shown in Fig. 5.7c, is used for holding round, hexagonal and octagonal sections.
iv. Square hollow tong. A square hollow tong, as shown in Fig. 5.7d, is used for holding square, hexagonal and octagonal work.
v. Pick-up tong. A pick-up tong, as shown in Fig. 5.7e, is used for picking up round bars, but not for holding work during forging.

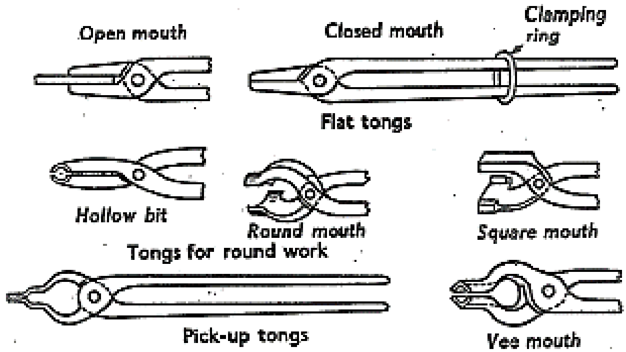


Fig. 5.7: Types of tongs.

6. Chisels The chisels are used for cutting metals and for necking prior to breaking. They may be hot, or cold, depending upon whether the metal is cut is cold or hot.

The cold chisel is made of tool steel having its edge hardened and tempered with an angle of about 60°. The hot chisel is made of low carbon steel with an edge angle of about 30°; hardening is not necessary, since in any case the hot metal would soften it. This type of chisel is fitted with wooden handle The edge of a chisel should not be quite straight but slightly rounded as shown in Fig. 5.8.

Chisels are generally used in pairs, a pair comprising a top tool and a bottom tool (often called the hardie). The hardie has a square shank and fits in the square hardie hole in the anvil face. The top chisel, which is held by the smith and hit by the striker, may be fitted with either a wooden handle or a metal wire handle as shown in Fig. 5.8.

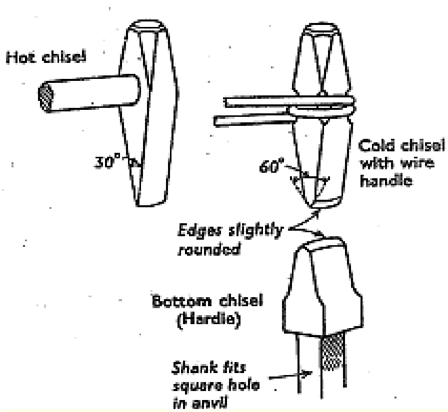


Fig. 5.8: The cold and hot chisel.

<u>7- Fullers</u> The fullers, as shown in Fig. 5.9, are used for necking down a piece of work, the reduction often serving as the starting-point for a reduction. It is mainly used to reduce the metal while making shoulders. The fullers are made of tool steel. As shown in Fig 5.9 a, they are made in top and bottom tools as in the case of chisels, the bottom tool fitting in the hardie hole of the anvil while the top held by the blacksmith and struck by the striker.

Fullers are made in various sizes according to the needs, the size denoting the width of the fuller edge. The use of fullers to neck before setting down is shown in Fig. 5.9b.

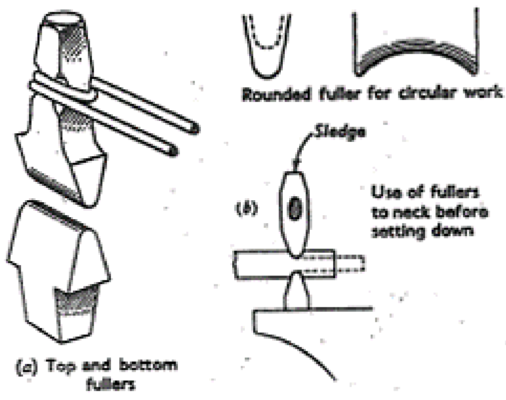


Fig. 5.9: Fullers.

8. Swages The swages are used in reducing and finishing the work to round or hexagonal form and are made with half grooves of dimensions to suit the work being reduced. The swages may be in separate top and bottom halves as shown in Fig. 5. 1 a, or the two halves may be connected by strip of spring steel, as shown in Fig. 5.1 b. The top and bottom swages are made of hardened steel and used as a pair to round off drawn-down sections.

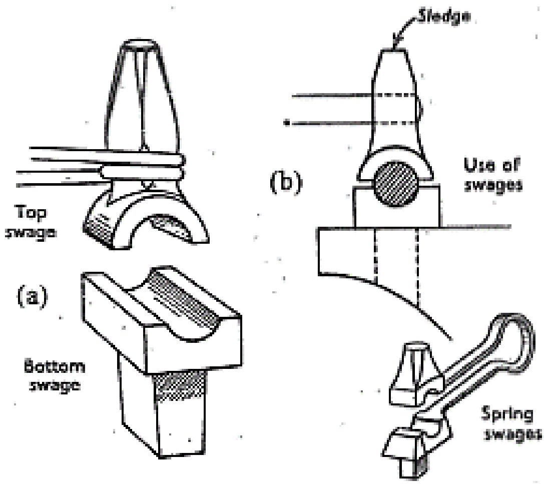


Fig. 5.10: Swages.

9. Swage block Various work shapes and sizes can be obtained by the help of the swage block shown in Fig. 5.11. The swage block, is generally made of cast iron and has round, square, rectangular and half round grooves. In addition to this, it is provided with holes, which are useful for holding bars while bending and knocking up heads. It is usually supported at a suitable height on a stand, which is adaptable to hold it flatwise, or on its edge.

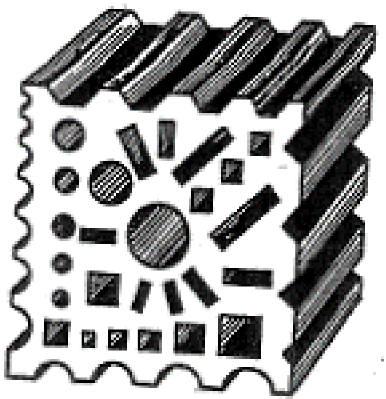


Fig. 5.11: Swage block.

10. Punches The punches, as shown in Fig. 5.12a, are used for making holes when the metal is at forging heat. They are made of hardened tool steel in various sizes and shapes such as square, round, and oval. The round hole in the anvil is provided for facilitating the punch to pass without getting damaged after punching. It is recommended that, the punching of a hole is carried out from both sides, as shown in Fig. 5.12b, to avoid driving the punch onto the hard anvil face.

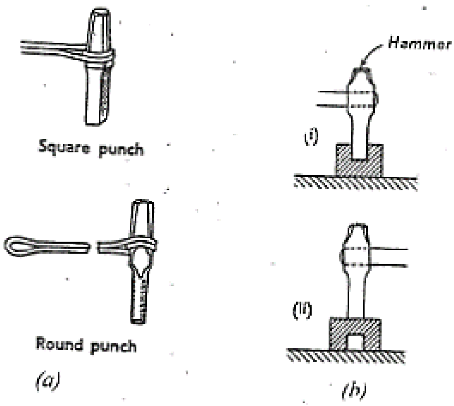


Fig. 5.12: Punches and their operations.

<u>11. Drifts</u> The drift, as shown in Fig. 5.13, is used to finish the size of the punched holes. They are made taper and bulging in the center. The drifts are made in various shapes and sizes like punches. They are also made of tool steel, hardened and tempered.

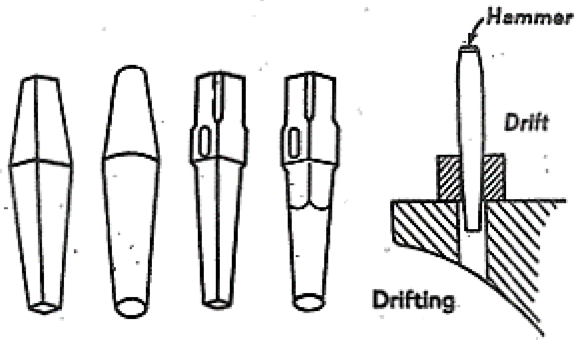


Fig. 5.13: Drifts and their uses.

12. Flatters As seen in Fig. 5.14, the flatter is used for finishing flat surfaces. It is made of tool steel with a perfectly flat face in size of about 75-mm square or round. It gives smoothness and accuracy to works, which have already been finished by swages and fullers. It is struck by a hammer on the head.

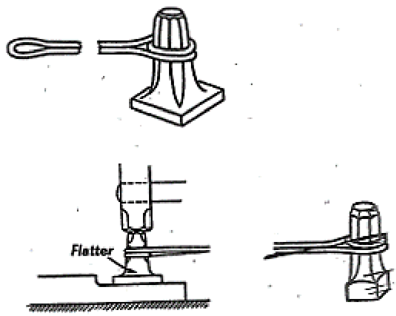


Fig. 5.14: Flatter and its use.

13. Set hammer The set-hammer, as shown in Fig. 5.15, is similar to flatter but is smaller. It is made of hardened forged steel. It is usually available in 40 mm square size. It is used to set down shoulders, finishing corners, or smooth out.

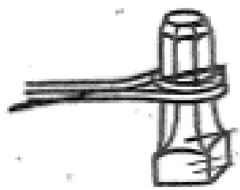


Fig. 5.15: Set hammer.

14. Floor mandrels They are heavy cones of wrought iron faced with hardened steel, and are used to true eyes, rings, and curves after forging on the anvil.

It will be realized that many forging operations are 'two-handed', and that the smith often requires the assistance of a striker to handle the sledgehammer.

5.2.2 Forging Operations

The number of operations is performed in a smithy shop for the formation of desired shape of object by forging. The commonly used operations are Upsetting, Drawing down, Setting down, Bending, and Hand welding. We shall now discuss these operations, in detail, in the following articles.

1. Upsetting

It is used when an increase in area or cross-section is required. It consists of increasing the cross-section of a bar at the expense of its length. In this process, first of all the heating is done and then the heavy blow is given by hand hammer. The swelling of work takes place at the heating portion. The position and nature of upsetting depends upon the heating and upon the type of blow delivered. In general, the increase in lateral swelling will be greatest at the parts where the metal is hottest. Fig. 5.16 shows the effect of heavy blow when the heating is done at one end, at both ends and at the center.

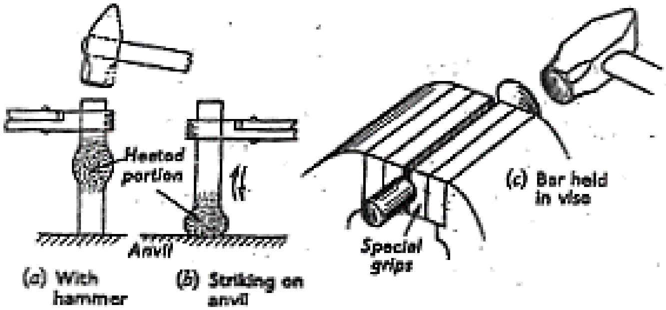


Fig. 5.16: Upsetting forging operations.

2. Drawing down

It is the process of reducing the cross-section or thickness or both of a bar at the expense of its length. The operation of drawing down is carried out in the following two steps:

i. First of all the hammering is done with a straight peen hammer by keeping the work at the edge or beak of the anvil. The bar is turned through 90o if the thickness in both directions is to be reduced. A pair of fullers, as shown in Fig. 5.17a, are also used for this process.

ii. Now the curved top of the work is levelled off with a set hammer as shown in Fig. 5.17b, and finally finished with a flatter as shown in Fig. 5.17c.

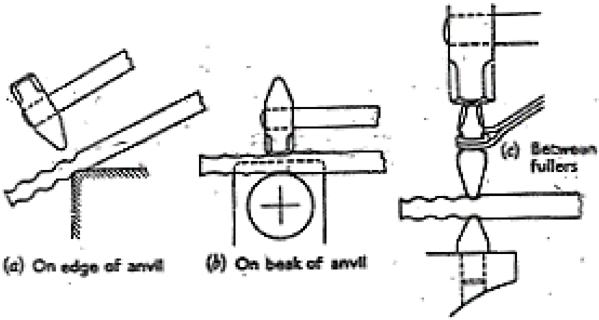


Fig. 5.17: Drawing down forging operations.

3. Setting down

It is a process of local thinning down effected by the set hammer or the flatter as shown in Fig. 5.18. This operation usually follows drawing down to give flat surfaces to the forged part.

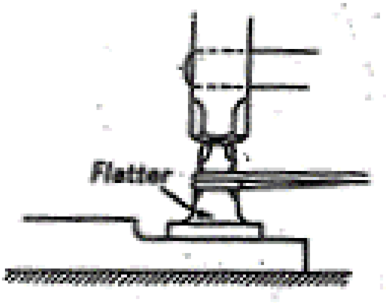


Fig. 5.18: Setting down operation.

4. Swaging

It is a process of forming round or hexagonal sections. Fig. 5.19. illustrates the use of both round and hexagonal swages. The hexagonal swage is often used in a preliminary operation to the production of a round surface using a round swage.

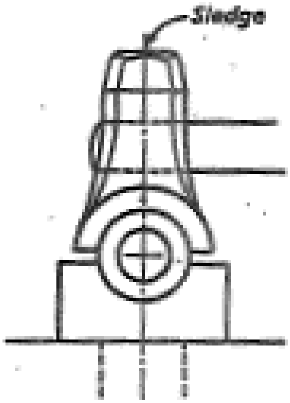


Fig. 5.19: Swaging operation.

5. Bending

It is an important operation in forging and is very frequently used. The bends may be either sharp cornered angle bends or they may be composed of more gradual curve. The angle bends may be made by hammering the metal over the edge of the anvil as shown in Fig. 5.20a, over a block of metal held in the hardie hole as shown in Fig. 5.20b, or over the vice jaw while the metal is being gripped as shown in Fig. 5.20c.

A little consideration will show that when the metal is bent the layers of metal on the inside are shortened and those on the outside are stretched, as shown in Fig. 5.20d. This causes a bulging of the sides at the inside and a radius on the outside of the bend. A sharp corner on the inside of a bend should be avoided, as it constitutes a weakness, which may lead to a fracture of the corner. In case double bends are to be made, a simple bending fixture should be used to save time and to enable more uniform results.

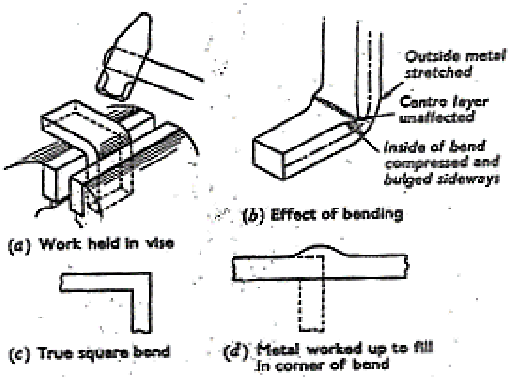


Fig. 5.20: Bending operations.

The gradual bends may be made by using the beak of the anvil as a former as shown in Fig. 5.21 a, or the metal may be bent round a bar of the correct radius held in a vice, as shown in Fig. 5.21 b. When a quantity of bending is to be done as shown in 5.21 c, some type of bending fixture should be used to save time and to produce better and uniform bends.

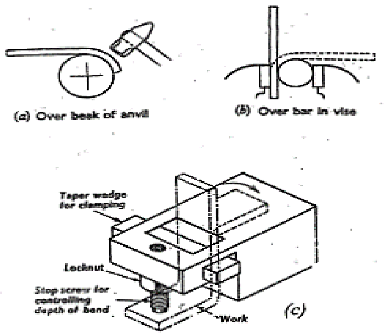


Fig. 5.21: Bending processes.

6. Punching and Drifting

As shown in Fig. 5.22, the hot metal is held over the punch hole on the face of the anvil and a smith's punch, of the center punch type, driven through, working from each side. The point must be quenched frequently to prevent softening, and the hole then enlarged and trued with appropriate drifts. Punching is stronger than drilling as no metal is removed, and the grain is not severed as shown in Fig. 5.22.

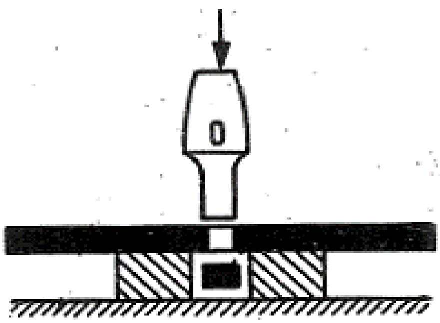


Fig. 5.22: Punching processes.

7. Splitting

The material can be split with a sharp hot or cold chisel as shown in Fig. 5.23

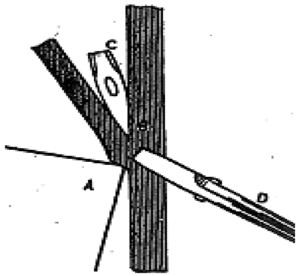


Fig. 5.23: Splitting process.

8. Twisting

Twisting As shown in Fig. 5.24, it is made mainly in square bar, but square and round sections are sometimes twisted together in composite bars for made right-and left-handed for use as matching pairs. The design of the work will determine the length and the turns required.

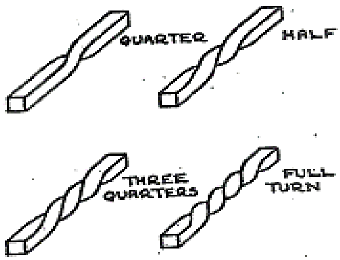


Fig. 5.24: Twisting process.

The metal must be heated beyond the length of the twist, then one end held in the leg vice and the other turned with a wrench or turnkey, keeping the bar as straight as possible at all times. Any truing up of the bar after twisting can be done with a copper or lead mallet on a lead block to avoid damage to the twist.

9. Hand or forge welding

It is the process of joining the two surfaces of metal under pressure after they are heated to the correct temperature. The correct temperature for wrought iron is about 1350°C whereas for mild steel the temperature is little lower than this. It may be noted that if the temperature is low, it will not cause the weld to take place. On the other hand, if the temperature is too high, it will ruin the metal by burning it. Fig. 5.25 shows some kinds of the forge-welded joints. However, the hand or forge welding technology will be discussed in details in the welding chapter.

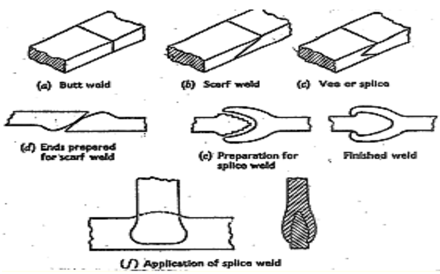


Fig. 5.25: Forge welding joints.

5.2.3 Applications of Forging

In the previous titles, we have discussed the forging operations in detail because most of the jobs are produced by a combination of these processes. It must always be borne in mind, however, that forging is a skilled trade and cannot be learned from books. We can only indicate the lines on which the work should be done and leave its execution to patient practice on the part of the student. We shall now discuss the steps involved in producing parts of everyday use in the following examples:

Example: 1

It is required to make the hexagonal bolt head shown in Fig. 6.26, from a round bar.

Procedure the tools required is anvil, hand hammer, tong, bush or size plate, flatter, swage, cupping tool, scale and caliper. The sequence of operations is as follows:

1. First of all, one end of the bar is heated up for a sufficient length to make the head.
2. The heated end is jumped up on the anvil, as shown in Fig. 5.26 a.
3. The head is flattened by hammering against the end of a bush through which the shank passes, as shown in Fig. 5.26 b.

4. The head is formed to hexagonal shape by keeping it on the bottom swage, as shown in Fig 5.26 c.
5. The chamfer is given on the head by means of cupping tool using the bush as support; Fig. 5.26 d.

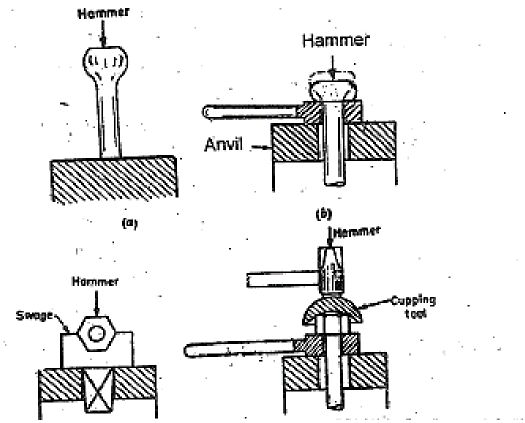


Fig. 5.26: Steps of a hexagonal-bolt head making.

Example: 2

To make flat drill from an octagonal bar of mild steel.

Procedure the tools required are anvil, hammer, tong, 'flatter, and scale. The sequence of operations as follows:

1. Firstly, one end of the bar is heated in a forge fire.

2. The heated end is flattened and the excess metal is cut off, as shown in Fig. 5.27a.
3. The cutting edge is hardened and tempered.
4. Now the cutting edge is ground to shape and the required angle, as shown in Fig. 5.27b.

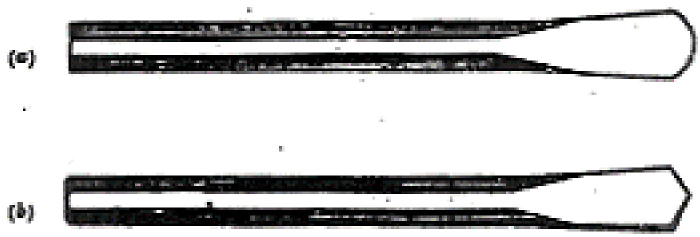


Fig. 5.27: A flat drill making.

Example: 3

It is required to make a small lever with boss; shown in Fig. 5.28, from a rectangular strip.
Procedure the tools required are anvil, hammer, tong, fuller, hot chisel, semi-circular swage, punch, square drift, and scale. The sequence of operations, as follows:

1. First of all, the bar is heated in a forge fire,
2. Fuller the flat sides,
3. Draw out lever leaving sufficient for final flatting,

4. Roughly flat faces of lever,
5. With hot chisel take off corners of boss; cut taper sides of lever and rough-shape end,
6. Swage semi-circular ends of boss and handle,
7. Punch hole in boss, and then drift it out square,
8. Smooth up all over.

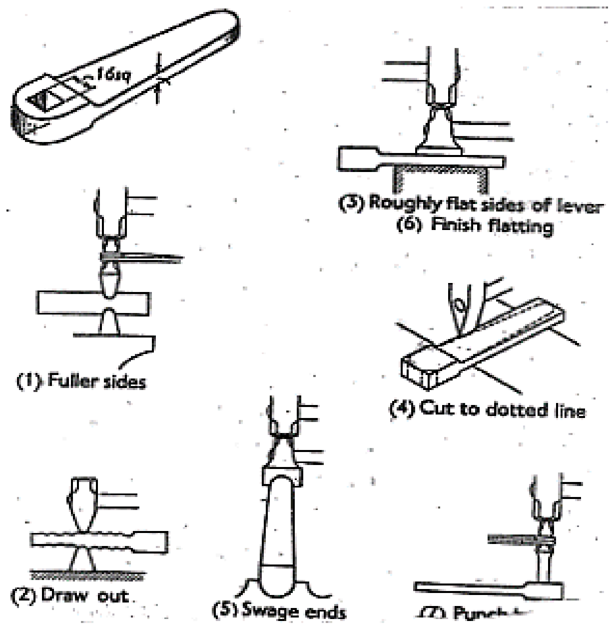


Fig. 5.28: Forging a lever with a square hole.

Example: 4

It is required to make small diestocks; shown in Fig. 5.28 a, from a rectangular strip.

Procedure use material with section large enough to make the boss. The tools required are anvil, hammer, tong, fuller, hot chisel, semi-circular swage, and scale. The sequence of operations is as follows:

1. First of all, the bar is heated in a forge fire,
2. Fuller on edges to just above thickness of handles,
3. Draw down handles approximately to square,
4. Trim boss roughly with hot chisel,
5. Flatten corners of handles, making them roughly octagonal in cross-section,
6. Swage boss and handles,
7. Flatten boss faces and smooth up.

After forging, the handles would be turned smooth in a lathe, and the boss bored to suit the die.

5.2.4 Drop Forging

The smith forging, as discussed previously, is a useful and indispensable process, but is not suitable for the production of large number of identical forging. When a large quantity of a certain component with sound and high-quality structure is required, a method known as drop forging or closed die forging is used. The dropforged parts are used in automobiles, airplanes, railroad equipment, engines, agricultural implements and house hold-appliances.

The drop forging is the process of hammering heated bars or billets of steel or other metals into closed impression dies. The closed impression dies compress the metal, causing it to flow and completely fill the die impression. A complete closed impression die consists of two alloy-steel blocks as shown in Fig.5.29. One of these blocks is called the top or upper die, which is fastened to the ram of a steam drop hammer, board drop hammer or other type of power hammer. A schematic sketch for a steam drop hammer is shown in Fig. 5.30. The other block is the bottom or lower die and it is fastened to the anvil. When these two die halves come together in alignment, a completely closed die cavity or die impression is formed. Since machined die impressions are employed, a much larger variety of shapes can be forged with greater accuracy and better detail than is possible with smith forging.

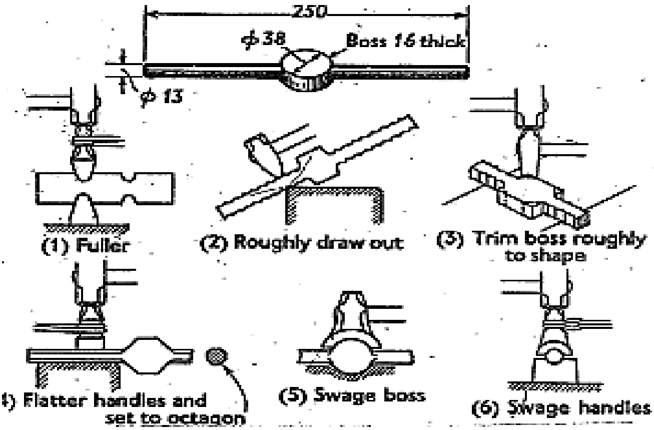


Fig. 5.28b Forging a small diestock.

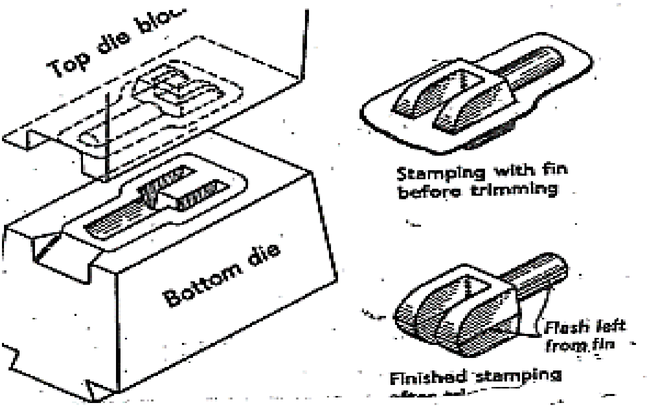


Fig. 5.29: A closed-die forging operation.

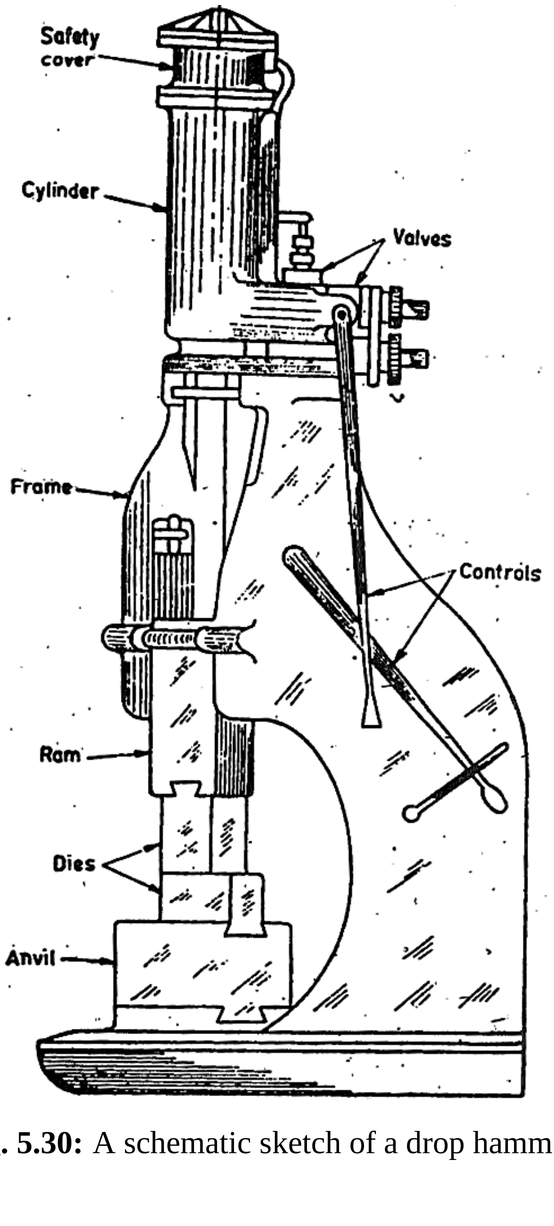


Fig. 5.30: A schematic sketch of a drop hammer.

5.3 ROLLING

The rolling process is the most rapid method of converting large sections into desired shapes. The forming of bars, plates, sheets, rails, angles, I-beams, and other structural sections are made by rolling. This rolling can be carried out either hot or cold. Hot rolling is very widely used because it is possible to achieve rapid and cheap change of shape. Cold rolling is carried out for special reasons such as the production of good surface finish or special mechanical properties.

The operation consists of passing the hot ingot through at least two rolls rotating in opposite directions at the same speed, as shown in Fig. 5.31. The rolls are generally cylindrical, producing a flat product such as sheets or strip as shown in Fig. 5.31.

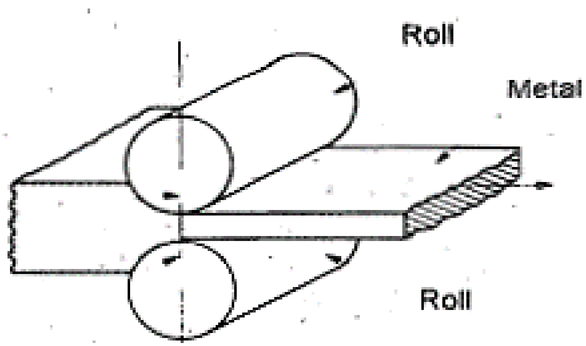


Fig. 5.31: The principle of rolling process.

They can also be grooved or textured on the surface in order to change profile as shown in Fig. 5.32. The space between the rolls is adjusted to conform to the desired thickness of the rolled section. The rolls, thus, squeeze the passing ingot to reduce its cross-section and increase its length.
The action of rolling is shown in Fig. 5.32a, and a mill consists of at least two rolls mounted on their necks in bearings and driven through the couplings as shown in Fig. 5.32b.

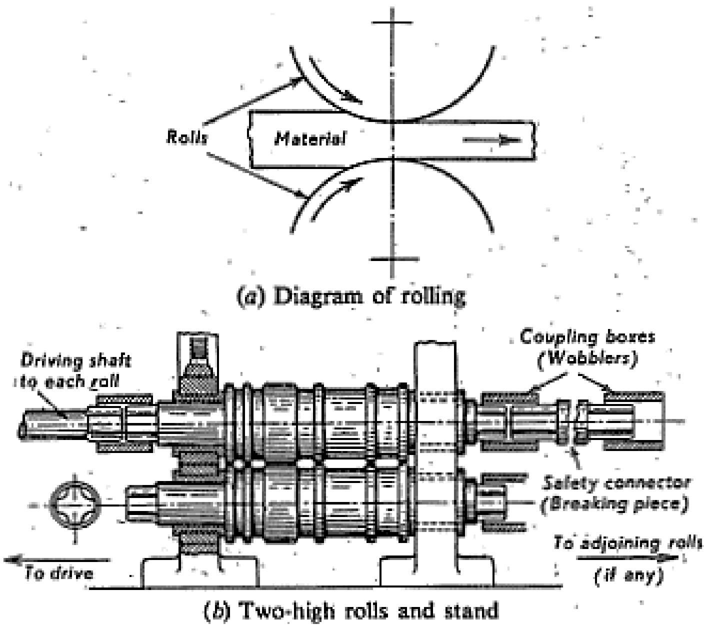


Fig. 5.32: The rolling process.

5.3.1 Types of Rolling Mills

The following types of rolling mills are commonly used for rolling:

1. ***Two-high rolling mill***. The two-high rolling mill, as shown in Fig. 5.31, consists of two heavy rolls placed exactly one over the other. One of the rolls is fixed while the other is adjustable. Sometimes both the rolls are adjustable. In its operation, the metal piece is passed between the two rolls rotating at the same speed but in opposite direction. After each pass, the direction is reversed. The metal is turned through 90° at frequent intervals, to keep the section uniform and to refine the metal throughout. It may be noted that about thirty passes are required to reduce a large ingot into a bloom.

2. ***Three-high rolling mill***. If three rolls are mounted so that rolling may be done between the top and the bottom roll, and the center one as seen in Fig. 5.33 a, it is called a 'three-high' mill. The upper and the bottom rolls rotate 4n the same direction whereas the middle roll rotates in the opposite direction. In this kind of mills, the roll gap cannot be adjusted. The three-high mill is less expensive to make and has a higher output than the two-high mill.

3. Four-high rolling mill. The four-high rolling mill consists of four rolls, two of which are working rolls and the other two are backing up rolls, as shown in Fig. 5.33 b. The backing up rolls has larger diameter and is used to prevent the deflection of small working rolls. These mills are used for rolling of slabs. It is really a combination of two-high mill with each roll backed up by another roll for strengthening purposes. Four-high mills are a special case of two-high mill.

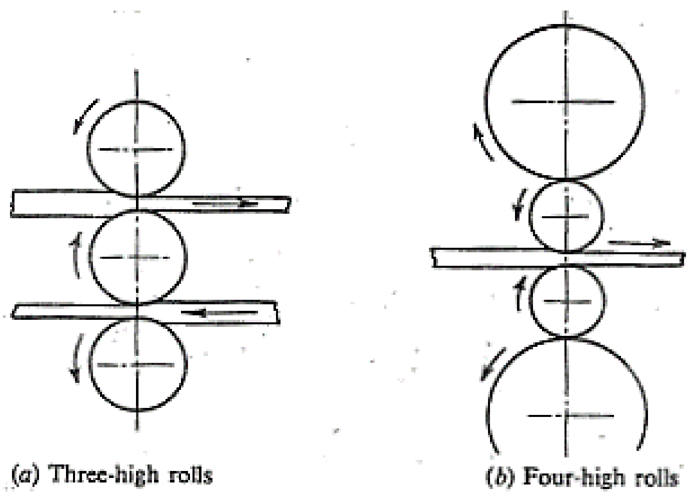


Fig. 5.33: The three and four-high rolling mill arrangement.

4. Cluster rolling mill. The cluster rolling mill consists of two working rolls and four or more backing up rolls. The number of back up rolls depends upon the amount of support required for the working rolls during the operation, as shown in Fig. 5.34. This type of mill is generally used for cold rolling.

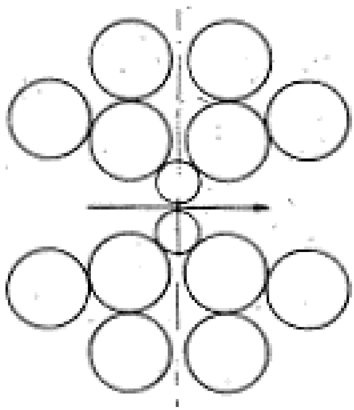


Fig. 5.34: The cluster rolling mill arrangement.

The size of a mill is expressed as the center distance of the rolls, blooming mills ranging from about 0.7 m to 1.2 m. The main rolls of a mill, which may vary from approximately 180 mm to 1.25-m diameter and from 300 mm to 5m in length, are generally driven by steam engine or by electric motor. Fig. 6.35a shows the successive stages in the reduction of a billet to a round bar, while Fig. 5.35b shows the rolls for a T-section.

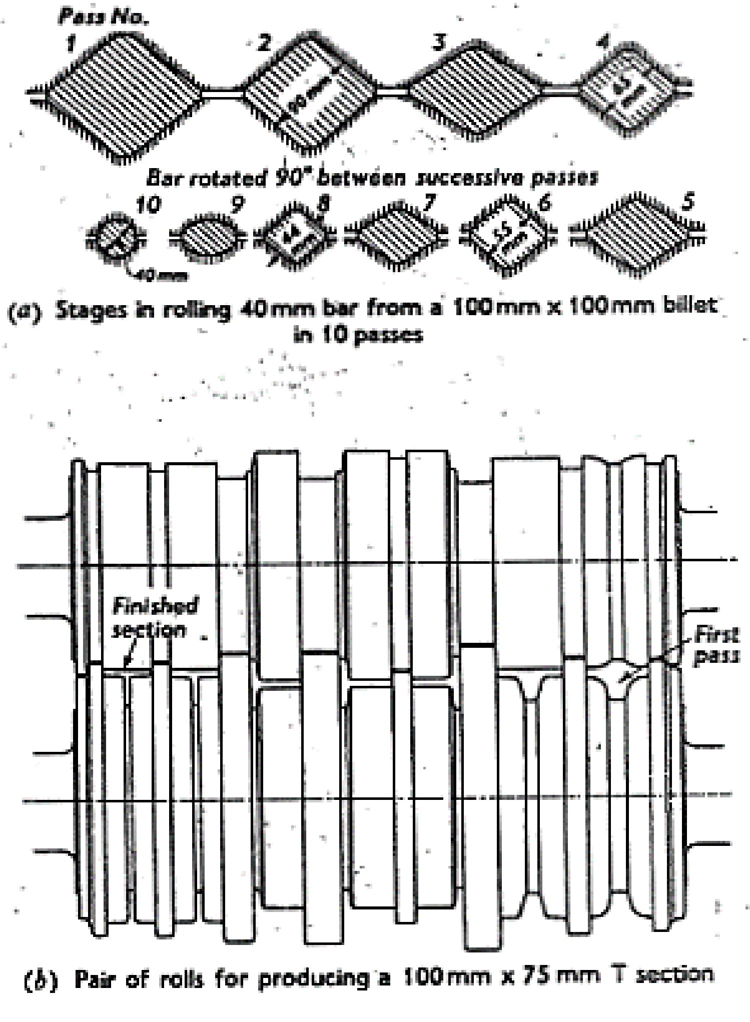


Fig. 5.35: **a)** Steps of a rolling process,
b) A pair of roll for producing a T-section.

5.4 EXTRUSION

Extrusion is the process by which metal are formed into specific shapes by forcing it out through specially formed dies. The principle of extrusion is similar to the act of squeezing toothpaste out from a tube. The extrusion process is carried out usually on a horizontal press that is hydraulically operated. Operating speeds, depending upon temperature and material; speeds up to 3 m/sec have been used in making steel tubes. Some metals such as lead, tin, and aluminum, may be extruded cold, whereas others require preheating before extrusion. For most alloys, the billet is heated to around 1300°C. The extruded material has a uniform cross- sectional shape and dimensions similar to the die orifice. Rods, tubes, structural shapes, brass cartridges, and lead-covered cables are typical products produced by extrusion.

Fig. 5.36 shows some typical extruded shapes. There are mainly three ways by which extrusion process can be done; **direct**, **indirect (inverted)** and **impact**.

Direct extrusion is schematically illustrated in Fig. 5.37. A cast billet of cylindrical shape is placed into a strong metal container and compressed by means of a dummy block and ram.

Indirect extrusion with this process, the die is held at the end of a hollow ram and is forced into the billet so that metal is extruded backwards through the die as seen in Fig. 5.38. Less force is required by this method since there is no frictional force between the billet and the container wall.

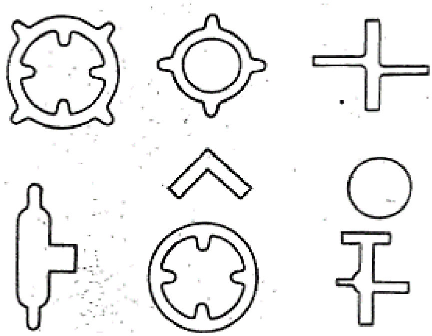


Fig. 5.36: Some of the extruded shapes.

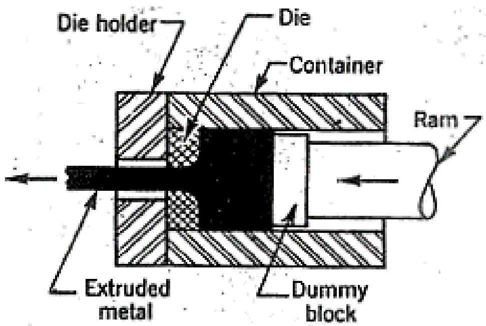


Fig. 5.37: Direct extrusion.

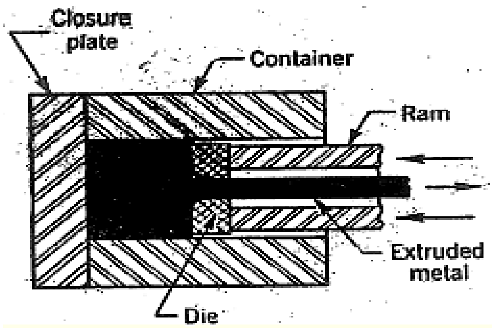


Fig. 5.38: Indirect extrusion.

The weakening of the ram when it is made hollow and the impossibility of providing adequate support for the extruded part constitute limitations of this process.

In impact extrusion, as shown in Fig. 5.39 a punch is directed to a blank with such a force that the metal from the blank be pushed up and around it. Impact extrusion is usually done on vertical presses. Most impact extrusion operations, are cold working. However, there are some metals and some products, particularly those in which thick walls are required, in which the blanks are heated to elevated temperatures.

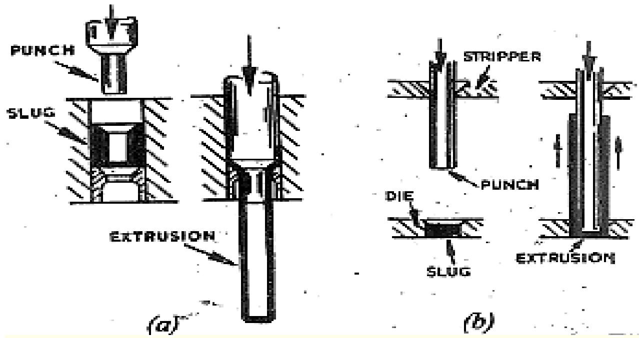


Fig. 5.39: Impact extrusion: **a)** Forwards b**)** Backwards

Tubes can also be extruded in the same way as in direct extrusion. In tube extrusion, a mandrel is used to shape the inside of the tube. It is a form of direct extrusion, but uses a mandrel to shape the inside of the tube. After the billet is placed inside the container, the die containing the mandrel is pushed through the ingot. The ram then advances and extrudes the metal through the die and around the mandrel. The usual method for extruding tubes is shown in Fig. 5.40.

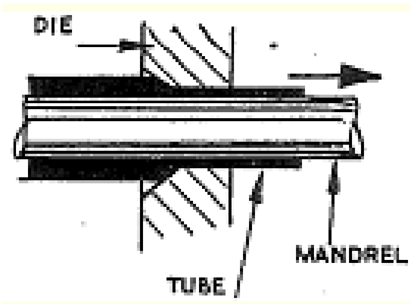


Fig. 5.40: The tube drawing.

5.5 WIRE AND ROD DRAWING

Rod or wire can be pulled through a die as shown in Fig. 5.41. In this process the diameter of a cylindrical piece of metal is reduced by pulling it through a tapered hole which is the internal profile of a drawing die. The metal feed is initially forced so that it protrudes through the die orifice and then be gripped and drawn.

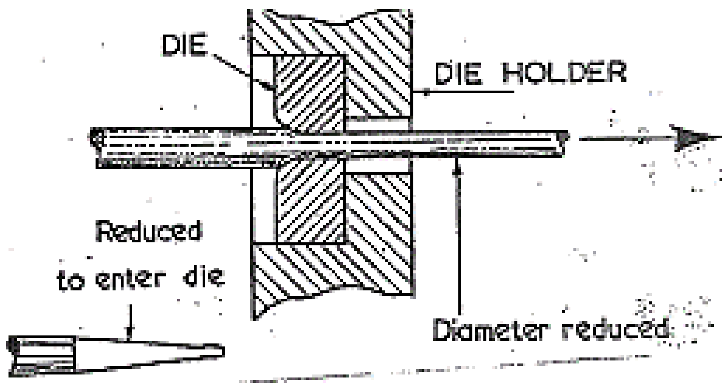


Fig. 5.41: Wire drawing.

Cold drawing of hot-rolled wire rods through one or more dies produces wires. A number of 4 to 12 dies arranged in series, are used as shown in Fig. 5.42. Drawing dies are usually made from tungsten carbide, although diamond dies can be used for drawing small diameters.

The wire rod, about 6-mm in diameter, is cleaned of scale before drawing. Pickling in acid solution does this. During the drawing operation, a lubricant must be used such as oil, animal fats, graphite, or soap. Lubrication reduces the required drawing force, enables a smooth surface to be obtained, and increase die life.

In these processes, using different shapes of die orifices, it is possible to get a variety of cross-section shapes.

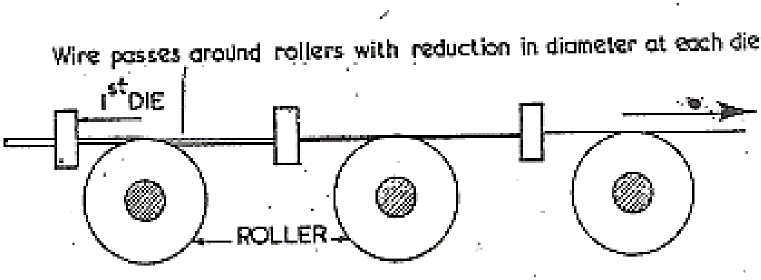


Fig. 5.42: Multi station arrangement for wire drawing.

CHAPTER 6
MACHINING

6.1 INTRODUCTION

In manufacturing products, it is important that the processes be efficient and capable of producing parts of acceptable quality. Both casting and metal forming require a suitable movement of the material particles either in the liquid or in the solid state. However, both the methods have limitations and, in a very large number of situations, neither is suitable. Casting imposes severe problems from the point of view of material properties and accuracy, whereas forming becomes impractical when the job is either very large; which requires very large forming force and consequently very large machines; or the material is not suitable for the forming operation. Apart from these, the geometric complexity of the final job may be such that these methods are of no use.

The foregoing problems can be overcome if the method used is such that the desired shape, size, and finish are obtained through the removal of excess material from the original workpiece of a suitable size and shape in the form of small chips. In most cases, a large-scale removal is not possible either for geometric reasons or for the size involved. This process is termed as machining, and is perhaps the most versatile manufacturing process. The body which removes the excess material through a direct mechanical contact is called the cutting tool and the machine which provides the necessary relative motions between the work and the tool is commonly known as the machine tool.

6.1.1 Relative Motions in Cutting Metals

Since the removal of material takes place only in the form of small chips, the machining of a finite area requires a continuous feeding of the uncut portion of a suitable rate. The relative motion between the tool and the workpiece responsible for the cutting action is known as the primary or cutting motion, and that responsible for gradually feeding the uncut portion is termed as the secondary or feed motion.

Depending on the nature of the two relative motions, various types of surfaces can be produced. To explain this in more detail, let us consider a point P shown in Fig. 6.1a, where the material is being cut at a particular instant. Now, if the cutting motion is rectilinear and the feed; which provided after the completion of each cutting stroke; is also rectilinear, the machined surface will be plain as shown in Fig. 6.1b. The line generated by the cutting motion is called the generatrix and the line from the feed motion is termed as the directrix (Fig. 6.1c). So, various geometries can be obtained depending on the shapes of the generatrix and the directrix and their relative directions.

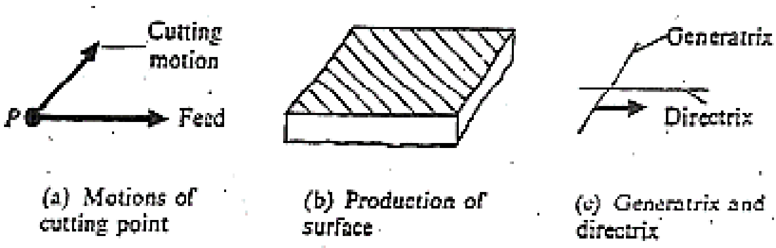


Fig. 6.1: Concepts of generatrix and directrix.

we shall now give a brief descriptions of the common machining processes:

(i)Turning This is a very basic operation and produces a cylindrical surface. Of course, a flat surface can also be obtained by face turning. The machine tool used for this type of an operation is known as a lathe. Fig. 6.2 shows a typical turning operation where a workpiece in the form of a cylindrical bar and is rotated about the axis of symmetry, the tool is provided with a feed motion parallel to the work axis. Thus, it is easy to see that with respect to the work the tool has a helical motion and always encounters an uncut layer of the workpiece. This operation results in a reduced work diameter and a new cylindrical surface. When the tool is fed in the radial direction along the face, a flat surface is produced and the length of the workpiece gets reduced.

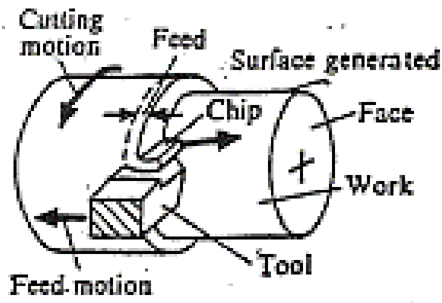


Fig. 6.2: Turning operation.

(ii)Shaping and planing In shaping and planing, the surface obtained is plain (As shown in Fig. 6.1b). In shaping, the cutting tool is given a reciprocating motion, and after every cutting stroke, the work is fed; as shown in Fig. 6.3; perpendicularly (during the return stroke, the workpiece is advanced by a small distance) in order to provide a layer of the uncut material to the tool. Since here the cutting is continuous, the machining is known as an intermittent cutting operation.

For a long job, it becomes inconvenient to provide long cutting strokes with the mechanism used in a shaping machine. In such a case , the work is provided with the cutting motion, whereas the feed is given to the tool; this is known as planing. The basic geometry of the machining operation is the same as that of shaping.

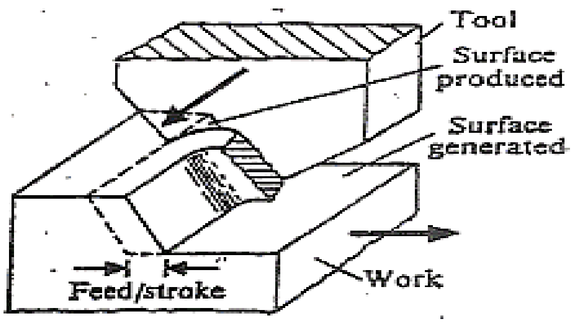


Fig. 6.3: Shaping operation.

(iii)Milling A versatile machining operation, it can produce various types of surfaces. A plain slab milling operation is shown in Fig. 6.4. The tool, normally known as a milling cutter, possesses a number of cutting edges. It is provided with a rotary motion and the workpiece is gradually fed. Small chips are removed by each cutting edge during revolution, and finally a flat surface is produced.

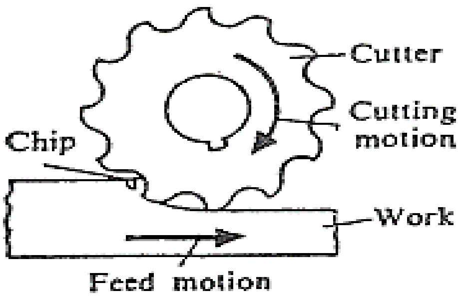


Fig. 6.4: Scheme of milling operation.

(iv)Grinding In grinding, the cutting tools are the sharp edges of the abrasive grains of the grinding wheel. These grains are very large in number and have a random orientation and distribution. However, if a particular grain is observed, its action would be as shown in Fig. 6.5. Of course, the size of chips removed by a grain is exceedingly small.

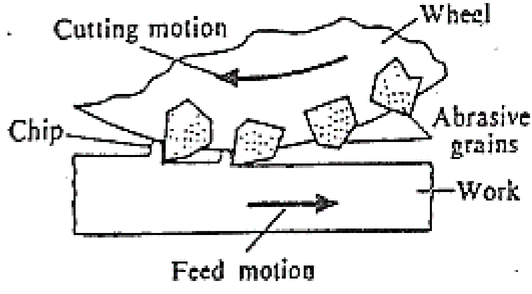


Fig. 6.5: Scheme of grinding operation.

(v) Drilling This is used for making a hole in a solid body. Fig.6.6 shows the operation schematically. The cutting motion is provided to the cutting edged (lips) by rotating the drill, and the feeding is done by giving a rectilinear motion to the drill in the axial direction. The final surface obtained is an internal cylindrical surface.

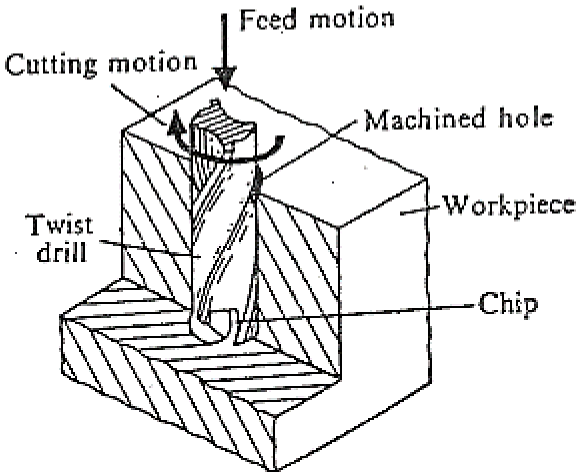


Fig. 6.6: Drilling operation.

6.2 TURNING

Turning is one of the most common operations. Surfaces of revolution are generally produced by this operation though the flat surfaces are produced by face turning. All turning operations are done on a machine called a lathe. The lathe is used for different turning operations as: (i)Turning of cylindrical and stepped cylindrical surfaces, (ii)turning of curved and tapered surfaces of revolution, (iii)face turning and parting, and (iv)turning of screw threads. When an internal surface is machined, the operation is commonly known as boring. The boring operations can also be performed for producing different types of internal surfaces of revolution. Fig. 6.7 shows some common turning and boring operations.

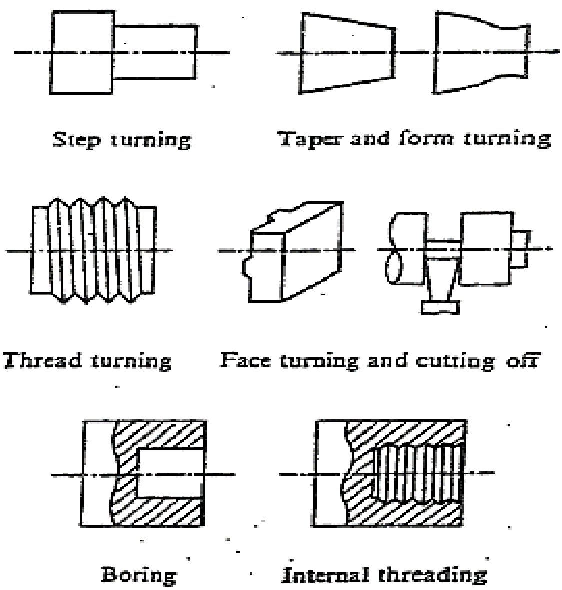


Fig. 6.7: Some common turning operations.

6. 2.1 Types of Lathes

The lathe is undoubtedly the most useful of all machines in the small and medium-size workshops where expense and other considerations limit the number of different types of machines. In the larger engineering shops the lathe is still regarded as essential for certain types of work, and for tool room and experimental production purposes. The lathes can be classified as follows:

1. General-purpose machines, center lathes, universal engine lathes, facing lathes, turret lathes and vertical lathes.
2. High-production machines, multiple-tool lathes, semiautomatic lathes, NC/CNC turning machines, etc.
3. Single-purpose and specialized lathes.

1. The Center Lathe

An example of one of the simplest types of lathes is the center lathe which is given schematically in Fig.6.8 The principal parts of the center lathe are: (i) the tailstock, (ii) the headstock, (iii) the carriage assembly, and (iv) the lathe bed. Fig. 6.9 shows the center lathe.

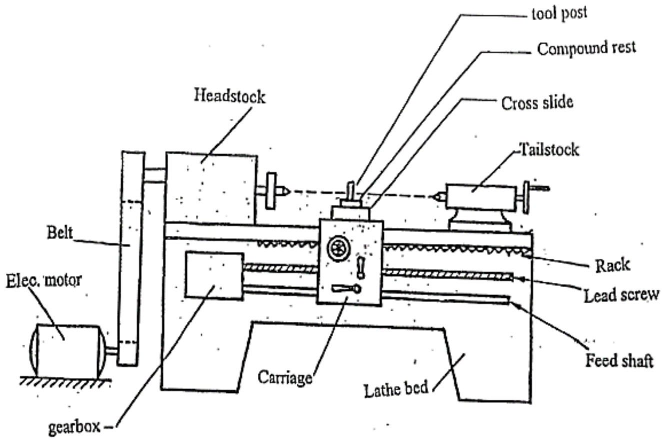


Fig. 6.8: Schematic diagram showing the main parts of the centre Lathe.

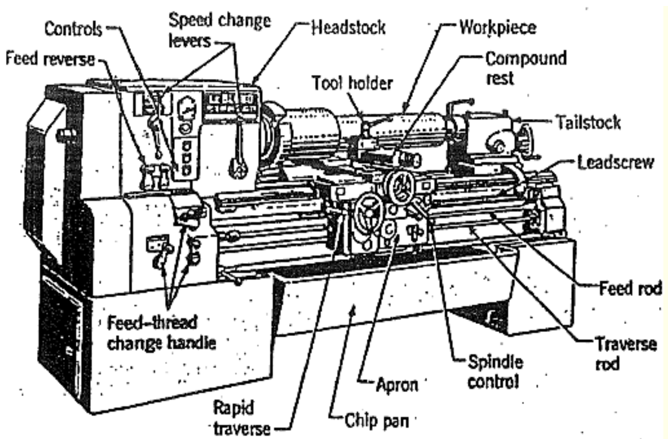
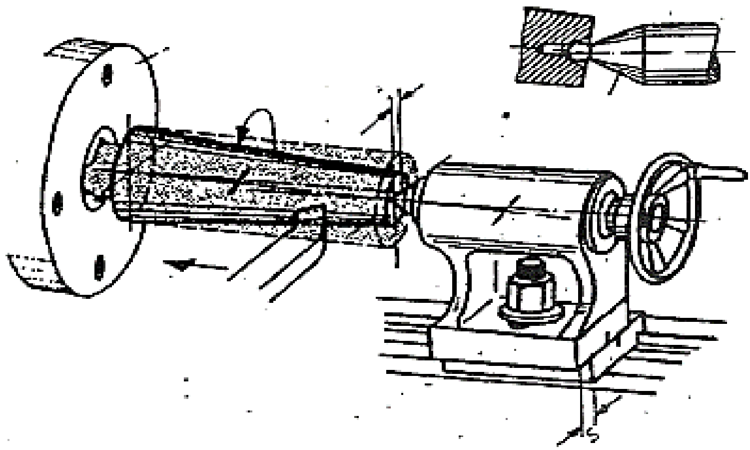


Fig. 6.9: The centre Lathe.

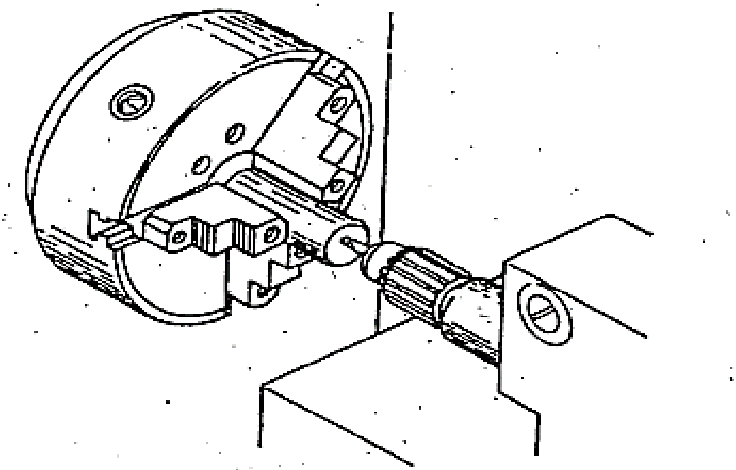
The tailstock can be moved along the bed of the lathe to accommodate different lengths of stock, it is commonly provided with a hardened ball bearing that is center mounted and that may be moved in and out by wheel adjustment, and with set-over screws at its base for adjusting the alignment of the centers and for taper turning. The tailstock is also used to mount a cutting too, such as a drill, as shown in Fig.6.10. The cutting motion is obtained by workpiece rotation, while the feed is done by the tailstock hand-feed.

The lead screw is a long, carefully threaded shaft coated slightly below and parallel to the headways extending from the headstock to the tailstock. It is geared to the headstock and its rotation may be reversed. It is fitted to the carriage assembly and may be engaged or released from the carriage during cutting operation. The lead screw is for cutting threads and should be disengaged when not in use to preserve its accuracy. Below the lead screw is feed shaft that transmits power from the gearbox to drive the carriage mechanism for cross and longitudinal power feed. Changing the speed of the lead screw or feed shaft is done at the gearbox located at the headstock end of the lathe.

The carriage assembly include the compound rest, tool post, and apron. Because it supports and guides the cutting tool, it must be rigid and constructed with accuracy.



a) Supporting a workpiece.



b) Make a drill.

Fig. 6.10: The tailstock and its usage.

The portion of the carriage that extends in front of the lathe is called an apron. It is a double-walled casting that contains the controls, gears, and other mechanisms for feeding the carriage and cross slide by hand or power. On the face of the apron are mounted the various wheels and levers.

The lathe bed is a cast-iron bed forms the base of the machine. The lathe size is expressed in terms of lathe bed, the diameter of the workpiece it will swing, and workpiece length as shown in Fig. 6.11 Some manufacturers use maximum work length between the lathe centers, whereas others express it in terms of bed length. The diameter that can be turned between centers is somewhat less than the swing because of the allowance that must be made for the carriage.

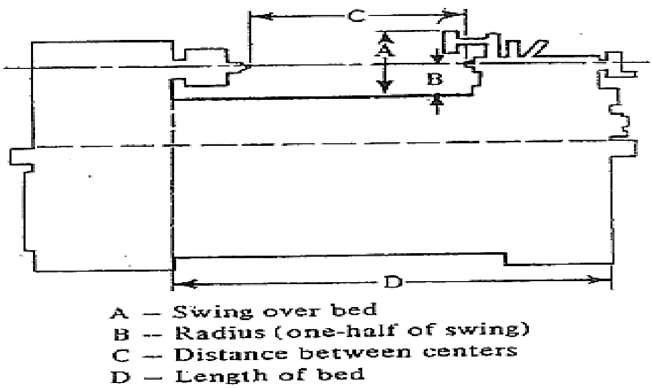


Fig. 6.11: Schematic diagram showing the specification of the centre leaf according to its size.

2. Turret Lathe

Turret lathes are a major departure from center lathes. These machines posses special features that adapt them to production. The skill of the labour has been built into these machines, making it possible for inexperienced operators to produce identical parts. As shown in Fig. 6.12 the main differences between the center and turret lathes is that the turret lathe is adapted to mass production work, whereas the center lathe is primarily used for miscellaneous jobbing or a single-operation work.

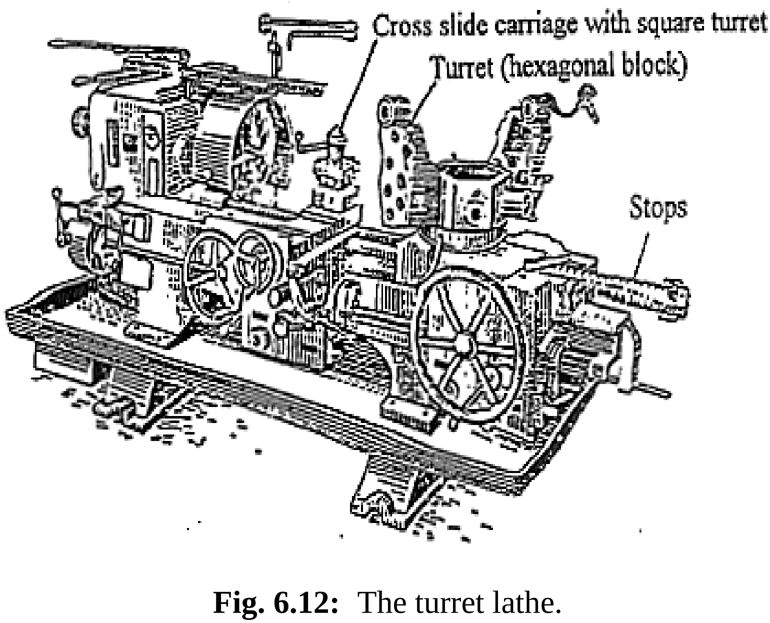


Fig. 6.12: The turret lathe.

The differences between the center and turret lathes are as follows:

1. The tailstock of the center lathe is replaced by a turret (a hexagonal block), each side of the turret may carry one or more tools. Fig. 6.13 shows the details of the turret.
2. Tools may be set up in the turret in the proper sequence for the operation.
3. Each station is provided with a feed stop or feed trip so that each cut of a tool is the same as its previous cuts.
4. Combined cuts can be made, Tools on the cross slide can be used at the same time that tools on the turret are cutting.
5. Multiple cuts can be taken from the same station at the same time, such as two or more turning or boring cuts.
6. The labour cost required in operating the turret lathe is less than that required in the center lathe. In turret lathe, the skill labour is required to set and adjust the tool properly, once they are correct less skill is required to operate them and many parts can be produced before adjustments are necessary.

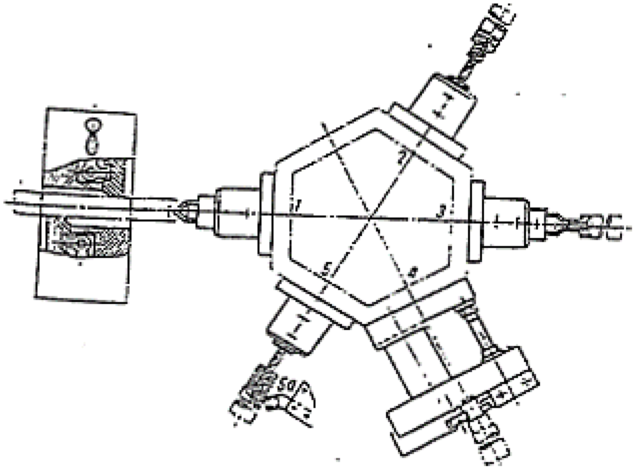


Fig. 6.13: The layout in the turret.

3. Facing Lathe

Facing lathes are designed for machining shorter workpieces of great diameters such as flywheel, pulleys, gears, etc. Workpiece is clamped on the faceplate with strap clamps; smaller workpiece-diameter may be held by jaws. Facing lathes are similar to center lathes but differ in their comparatively short length and the large diameter of the faceplate.

Most facing lathes do not have a tailstock, as shown in Fig. 6.14 When large heavy workpieces are clamped on the faceplates of such lathes, the weight of these overhanging workpieces loads the spindle and its bearings to a considerable extent. This circumstance have restricted the application of facing lathes. At the present time, facing lathes are seldom used; they have been replaced by vertical lathes.

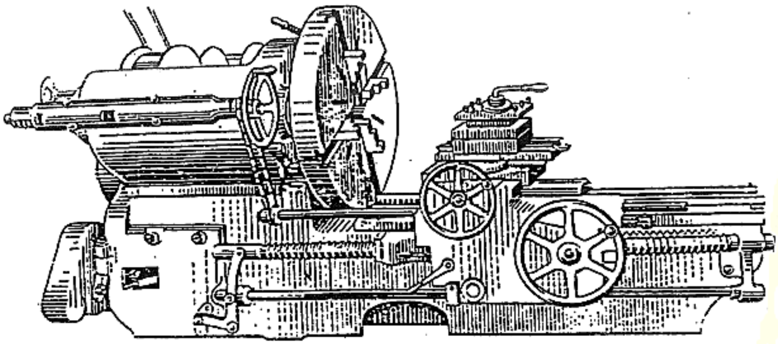


Fig. 6.14: The facing lathe.

6.2.2 Tools Used in Turning

In turning operations, the tools used are single-point tools that have only one cutting edge, but for special operations, multi-points' tool that has more than one cutting edge may be used.

Single-point tools may be classified according to their function, feed direction, and their manufacturing method, as follows:

i. **Classification of the tools according to its functions,** The turning tools, as shown in Fig. 6.15, may be classified according to the operation which is done, the cutting tools are named as follows:

1. Threading tool	5. Parting-off tool
2. Recessing tool	6. Facing roughing tool
3. Knurling tool	7. Corner forming tool
4. Inside roughing tool	8. Facing roughing tool

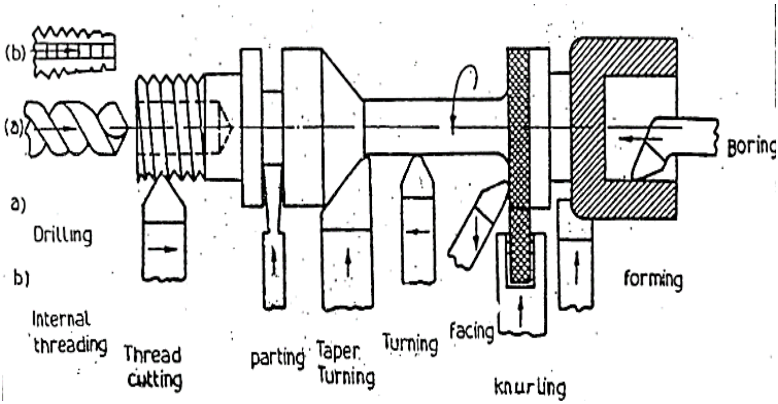


Fig. 6.15: The lathe operations.

ii. **Classification of the tools according to the feed direction**

There are right-cut and left-cut tools. A right-cut tool, as shown in Fig. 6.16a, is one in which the side-cutting edge is on the side of the thumb when the right hand is placed on the tool with the fingers pointing toward the nose of the tool, so that it is called right-hand tool. In a lathe, a right-cut cuts from right to left, i.e., from tailstock to headstock. A left-cut (left-hand) tool, as shown in Fig. 6.16b , is one in which cuts. from left to right, i. e., from headstock to tailstock.

a) Right-cut (Right-hand) tool.   b) Left-cut (Left-hand) tool.

Fig. 6.16: Classification of tools according to feed direction.

iii. **Classification of the tools according to the method of tool manufacturing**

There are forged and brazed-tipped tools. forged tools are manufacturing from carbon steel, or high speed steel (HSS) or from alloy steel by forging the end of a solid shank. The cutting edge is then grinding to give the required tool angles. Fig. 6.17a shows such a forged tool.

Brazed-tipped tools are composed of small tips brazed to the end of carbon steel shanks, as shown in Fig. The tool tip is made mainly from sintered carbide. A similar manufacturing method is done to reduce the cost of the HSS tools, where the tip of the tool is made from HSS and butt welded to a carbon steel shank as shown in Fig.6.17 c.

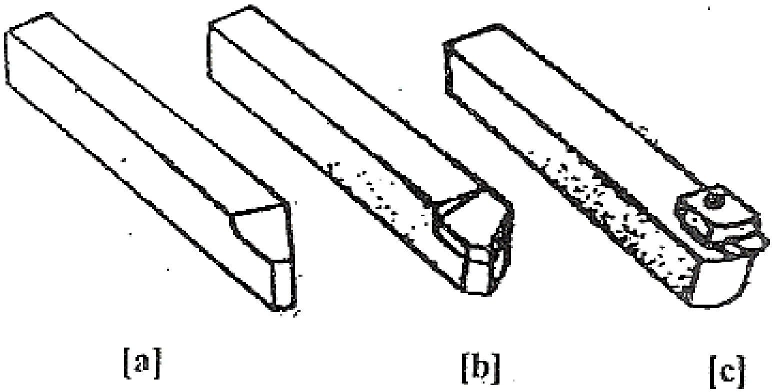


Fig. 6.17: Classification of tools according to manufacturing method;
(a) Forged tool,
(b) Brazed-tipped tool,
(c) HSS tip welded shank.

2.2.3 Workpiece Clamping

On all types of center lathes, as well is multiple-tool lathes, workpiece is held either between centers, in a chuck, or in special fixtures.

1 The Lathe Chucks

Lathe chucks are used for holding workpieces of short lengths and large diameters of regular or irregular shapes which cannot be conventionally mounted between centers. The lathe chucks are classified as:

i. Self-centering chucks.

   1) three-jaw universal and rapid-action chucks;
   2) collet chucks;
   3) two-jaw chucks.

ii. Independent-jaw chucks (four-jaw type).

   1) four-jaw independent chucks;
   2) four-jaw faceplates.

The most universal self-centering chuck is the three-jaw type. The three jaws move simultaneously in a radial direction as shown in Fig. 6.18a . In mass production, rapid-action chucks are more readily employed. The clamping action in such chucks is provided by pneumatic or electric power.

Another type of chuck is the collet chuck as shown in Fig. 6.18b. It is used for turret lathes and automatic bar machines, where precisely locating and concentricity of the machined surface are needed.

A four-jaw independent chuck is used in setting up heavy and irregular shaped workpieces. When large size workpiece is required to set in the four-jaw chuck, the jaws positions are reversed, as shown in Fig. 6.1.18C

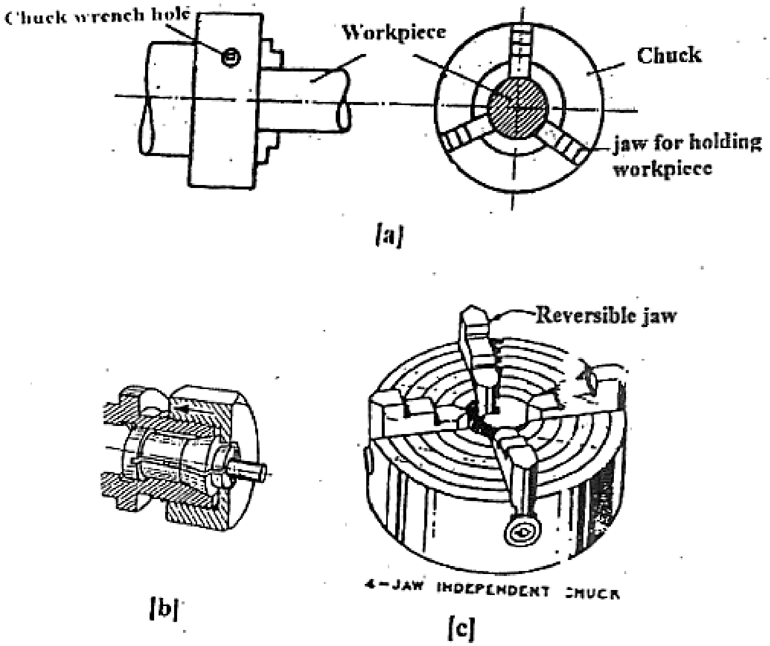


Fig. 6.18: Chucks types.
(a) Three-jaws self centering,
(b) Chuck collet,
(c) Four-jaws independent.

2.Clamping Between Centers

Workpieces of shaft type (long in length) are held between centers for machining. Both headstock and tailstock centers are fit into the center holes which are firstly bored in both ends of the workpiece as shown in Fig. 6.19. The Driving devices are used to transmit torque to the workpiece or to a mandrel on which the workpiece is mounted. In either case, the workpiece or the mandrel is mounted between centers.

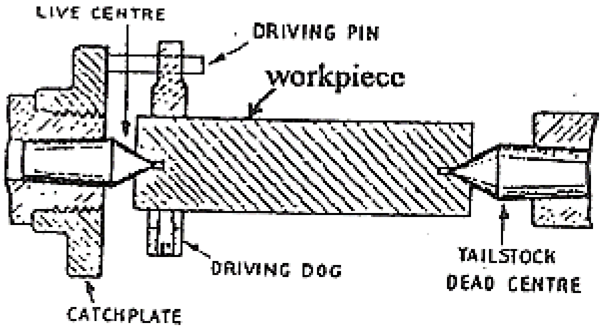


Fig. 6.19: Clamping between centers.

Solid mandrels are widely used for bored workpieces in center and multiple-tool lathes (as turret lathe). After holding the workpiece in mandrel, it is mounted between centers and both rotates as a single piece. Solid mandrels are used for thin-walled workpieces and in many cases, for finish turning operations. The solid mandrel is used when turning large numbers of identical workpieces having standard-holes size. Fig. 6.20a shows the solid mandrel.

Expansion mandrels have thin slotted sleeves which spring in the same way as collets and can therefore be expanded, as shown in Fig 6.20b. It is used when the difference in the workpiece diameters ranging from 0.5 mm to 2 mm. The accuracy with which a workpiece is centered on an expansion mandrel depends on the clearance between the mandrel before expanding and the bore of the workpiece. On the other hand, there is no clearance when workpiece is mounted on a solid mandrel (slightly tapered, 1: 2000).

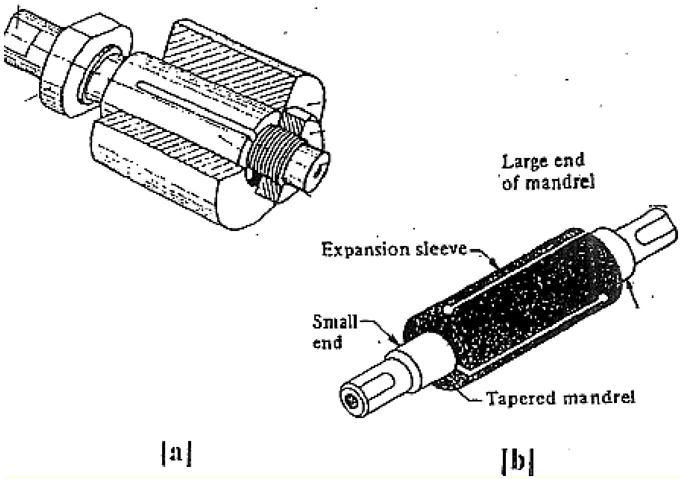


Fig. 6.20: Types of mandrels.
(a) Solid mandrel,
(b) Expansion mandrel.

3. Clamping in Faceplate

Workpieces of non-round or irregular shape; mainly castings and forging products; are clamping in faceplates by shifting independently the four jaws. Fig. 6.21 shows a workpiece clamped on a feceplate, where a balanced weight is used opposite to an angle plate which is used for workpiece clamping.

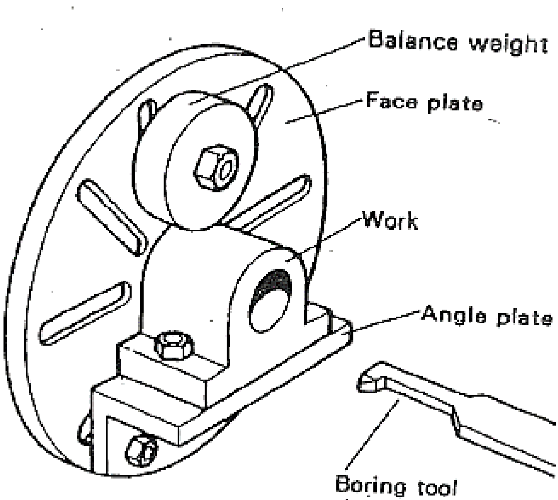


Fig. 6.21: Clamping on a faceplate.

6.2.4 Workpiece Supporting

There are two types of rests, steady rest and follow rest. They are designed to decrease the sag in the middle of long workpiece held between centers and for supporting one end of a shaft when the other held in the lathe-chuck.

The steady rest ; as shown in Fig. 6.22a ; is clamped in the required position in the bed and its jaws have either bronze inserted or rollers, which are anti-friction bearings. The follow rest is mounted on the carriage and travels with it along the lathe bed. Vibration-eliminating follow rests are being expediently used instead of the simpler designs follow rests. Fig. 6.22b shows the vibration-eliminating follow rests, which are used to eliminate vibrations beside its main job; which is preventing the sag in the workpiece.

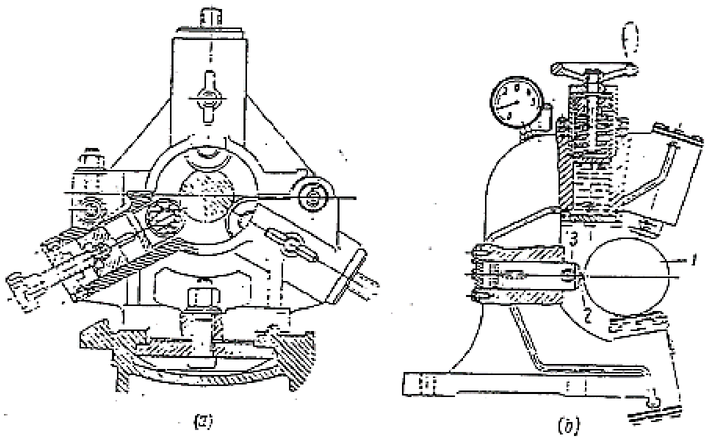


Fig. 6.22: Rests;
(a) Steady rest,
(b) Vibration-eliminating follow rest.

6.2.5 Machining Conditions in Turning

Before calculation of the time during which metal cutting is done, different machining conditions in a turning operation must be done. When turning a surface, there are three terms must be known carefully before beginning the operation; namely; the cutting speed v, the feed f, and the depth of cut a. Fig. 6.23 shows these conditions in a simple turning operation.

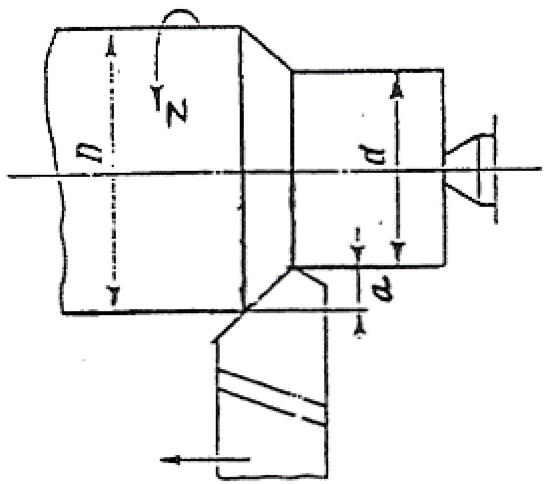


Fig. 6.23: Machining conditions in turning.

The cutting speed v, which is the linear velocity at which the cutting edge travel relative to the machined surface of the workpiece and is given as:

$$v = \frac{\pi DN}{1000} \quad \text{m/min…} \quad (6.1)$$

Where:

N is the rotational speed of the workpiece in rev/min.;

D is the diameter of workpiece in mm.

The feed f, is the motion of the tool relative to the workpiece and is given in mm/rev.

The depth of cut a, which is the depth of material removed from the surface of the workpiece by one pass of the tool. For longitudinal turning, the depth of cut is given by:

$$a = \frac{D-d}{2} \quad \text{mm} \quad \text{….}(6.2)$$

Where:

D is the diameter of the surface to be machined in mm:

d is the diameter of machined surface in mm.

In straight turning: the machining time is determined from the formula:

$$t = \frac{L}{f \times N} \text{ (i)} \quad \text{min.} \quad \text{--------} \ (6.3)$$

Where: L is the length of one pass, in mm, that the tool travels in the feed direction;

f	is the feed, in mm per revolution;
N	is the workpiece rotational speed, in rev per min.
i	is the number of passes.

And the number of passes $(i) = \frac{D-d}{2\,a}$ ---------(6.4)

The length of each pass L, as shown in Fig. 6.24; constitutes the sum of the workpiece length l1 plus the length l2 for feeding into the cut (approach of the tool), plus the length l3 which is the over-travel of the tool, i.e. $L = l_1 + l_2 + l_3$ ----------(6.5)

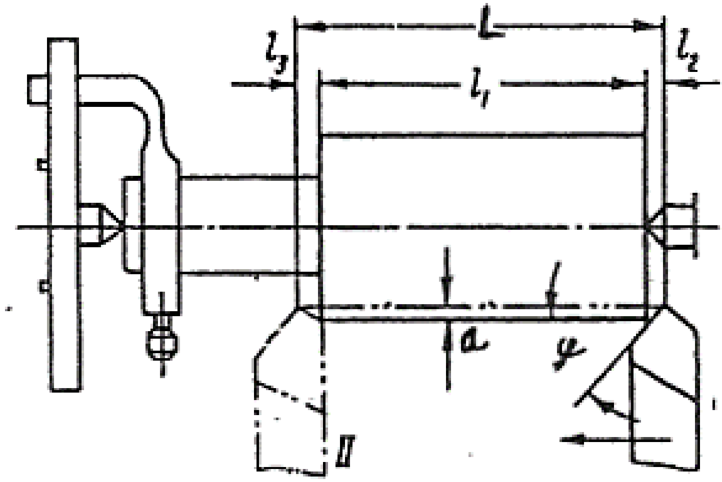


Fig. 6.24: Travel length in a straight turning.

Example 6.1

Calculate the machining time required to reduce a brass bar from 29 mm to 20 mm diameter, for a length of 80 mm. The cutting conditions are as follows: The feed is 0.4 mm/rev., the depth of cut is 1.5 mm, and the rotational speed is 1200 rpm.

Assume any missing data.

***Solution*:**

Assume the approach (l_2)and overtravel (l_3) of the tool are each 4 mm, then: $L = l_1 + l_2 + l_3 = 80 + 4 + 4 = 88$ mm

The number of passes $i = \frac{D-d}{2\,a} = \frac{29-20}{2\times1.5} = 3$ passes

The machining time $(t) = \frac{L}{f\times N} i = \frac{88}{0.4\times1200} 3 = 0.55$ min.

6.3 SHAPING AND PLANING

In machines of the type discussed in this chapter, either the tool moves in a straight line across the workpiece or the workpiece moves linearly by the tool. The essence of planing process is the same as turning. Workpieces are planed by single-point tools similar in shape to the lathe tools. A similarity also exists in chip formation in the two processes. At the same time, planing differs from turning in that planing is an intermittent process and chips are usually removed only during the straight forward movement of the tool or workpiece. Even though, the tool in the planing has an opportunity to cool in the return stroke when no cutting takes place, planing tools work are less favorable than in turning. Because a planing tool operates with impact, large cross-section tools are used in planing due to the initial shock carried by the tool.

6.3.1 Planing Metals

Workpieces are planed on shapers and planers. The basic nature of material removal process is the same in both cases. The major difference between the two is that, in shaping, the primary cutting motion is provided to the tool and the feed is given to the workpiece, as shown in Fig6.25a . In planing, it is just the opposite, where the tool is fed across the workpiece, as shown in Fig. 6.25b.

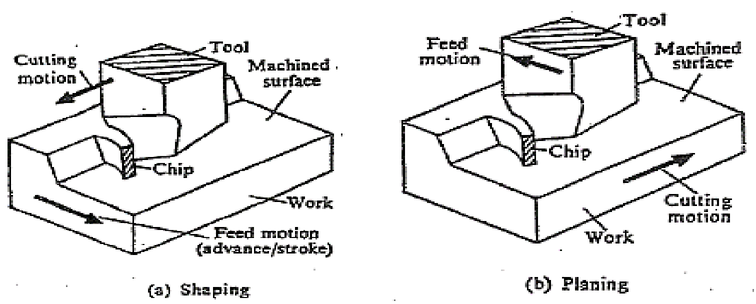


Fig. 6.25: Shaping and planning operations.

The cutting operation is intermittent in » nature and takes place during the forward stroke. During the return of the tool (or the workpiece, as the case may be), the feed motion is provided when there is no cutting action. Table 6.1 shows the differences between shaping and planing operations.

Table 6.1: The differences between shaping and planing operations.

	Shaping	**Planing**
Feed motion is carried by,	the workpiece	the tool.
Cutting motion is carried by,	the tool.	the workpiece

6.3.2 Types of Shapers

A shaper is a machine with a reciprocating tool of the lathe type that takes a straight-line cut. By successive movement of the work across the path of this tool, a plane surface is generated. Using special tools, attachments, and devices foe holding the workpiece, the shaper can cut external and internal keyways, spiral, grooves, gear racks, dovetails, and T-slots. Typical operations and tools required are illustrated in Fig. 6.26.

Shapers can be classified according to general design as follows:

i. Horizontal push cut,

1. Plain (production work)
2. Universal (toolroom work)

ii. Horizontal draw cut

iii. Vertical,

1. Slotter
2. Key sealer

iv. Special purpose as for cutting gears.

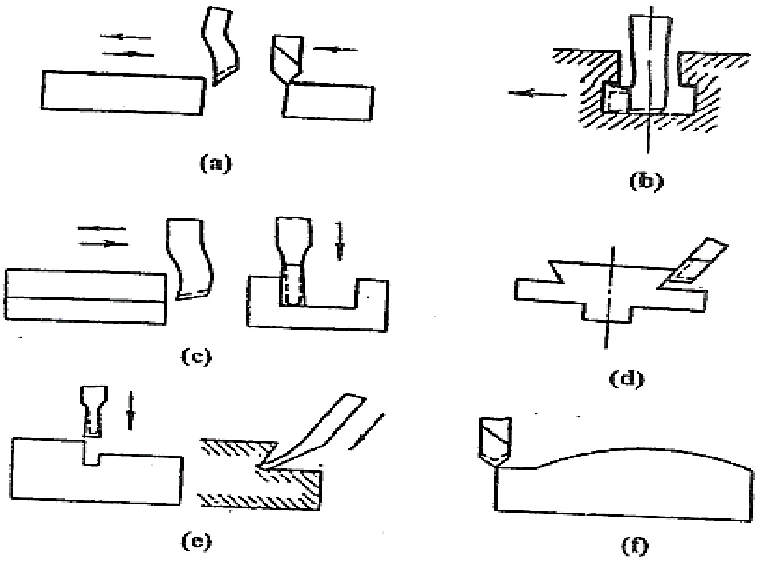


Fig. 6.26: Shaper and planer operations;
(a) Planing a flat surface with a straight tool,
(b) Planing a T-slot with a recessing tool,
(c) Planing a slot with slotting tool,
(d) Planing a dovetail with a dovetail side- cutting tool,
(e) Cutting grooves with grooving tool,
(f) Planing a formed surface.

1. The Horizontal Shapers

Horizontal simpers are commonly used for production and general-purpose work. Fig.6.27 shows a horizontal shaper, it is consists of a baseplate and frame that supporting a horizontal ram. The ram reciprocates in the ways of the column fastened to the baseplate. The tool head assembly is mounted on a circular seat at the front end of the ram. The crossrail carries the overhanging table which may be traversed horizontally (feed motion). The ram may either be driven by a hydraulic system or it may be mechanically driven by a crank and slotted arm mechanism. Fig. 6.28. shows schematic diagrams of both mechanisms.

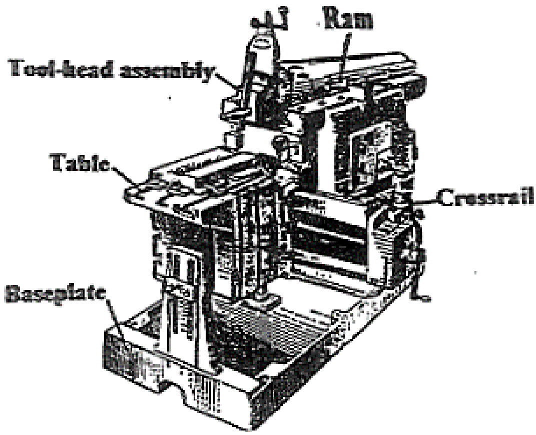


Fig. 6.27: The horizontal shaper.

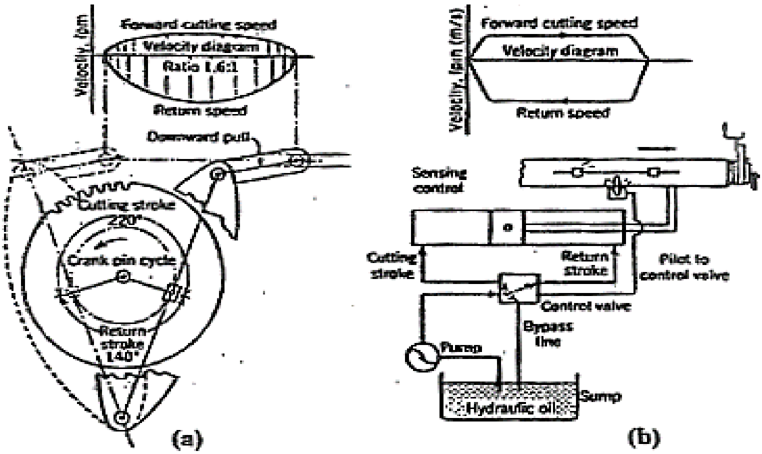


Fig. 6.28: Shaper drives;
(a) Mechanical system,
(b) Hydraulic system.

6.3.3 The Planers

A planer is a machine tool designed to remove metal by moving the workpiece in a straight line against a single-point tool. Planers are seldom used in production work, but they are still employed for special puiposes. Planers may be classified in a number of ways, but according to general construction there are four types:

1. Double housing
2. Open side
3. Pit type
4. Plate or edge.

Fig. 6.29 shows a double-housing planer, in Planer, the table may be driven by a rack-and-pinion arrangement as shown in Fig. 6.30 as well as by a hydraulic system. In hydraulic planers, higher table speeds and smoother reversal may be obtained than that with mechanical drives.

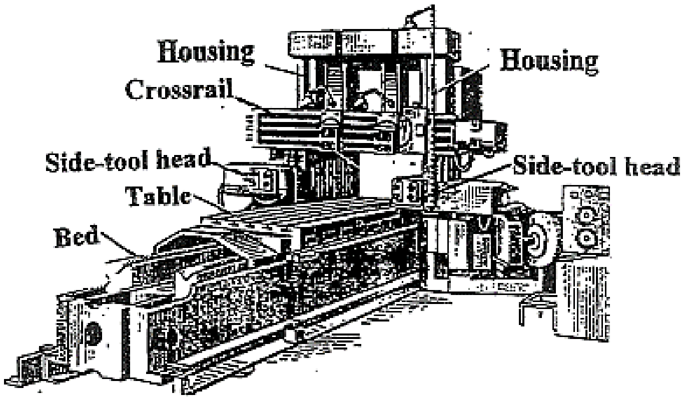


Fig. 6.29: The double housing planer.

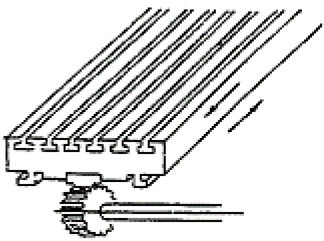


Fig. 6.30: Rake-and-pinion drive.

6.3.4 Planing tools

The cutting tools used in planing are single-point tools similar to that used in the lathes. The tool angles are the same as for lathe tools which work without cutting fluids. Since planing tools are subjected to impacts when starting each cutting stroke, their cross-section should be larger than for lathe tools.

Planing tools may be either of the gooseneck type or straight as shown in Fig.6.31. According to the type of work to be performed, straight planing, facing, slotting, and form tools are used.

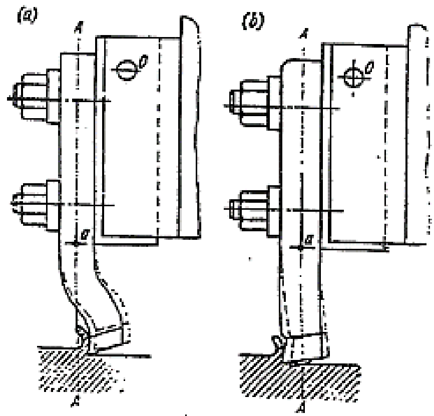


Fig. 6.31: Single-point planer tools;
(a) Gooseneck type,
(b) Straight type.

In most cases, these tools are of the gooseneck type. The advantage of the gooseneck tool is that, when the tool is on the return stroke, less friction is obtained between the flank of the tool and the machined surface. Fig. 6.32 shows the planing and slotting tools.

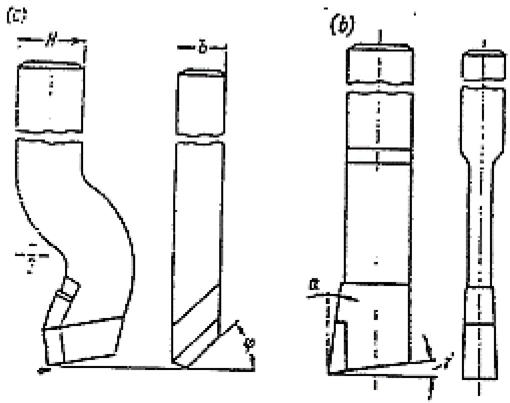


Fig. 6.32: Single-point tools;
(a) Planer tool,
(b) Slotter tool.

6.4 MILLING

Milling is perhaps the most versatile machining operation and most of the shapes can be generated by this operation. It is especially more indispensable for machining the parts without rotational symmetry. Unlike turning, shaping, and drilling tools, the milling cutter possesses a large number of cutting edge. In principle, the form of each of the teeth of a milling cutter is similar to that of a single-point tool.

A specific feature of the milling process, however, is that the cutter teeth contact the surface being milled intermittently. This condition enables the teeth to be cooled more effectively when they are not in actual cutting op nation and consequently reduces the effect of the heat generated in cutting on the cutting edges of the tool. On the other hand, due to this intermittent contact, the cutting process does not proceed as evenly and smoothly as in constant contact between the tool edge and the workpiece (as turning).

6.4.1 The Milling Process

The milling operations can be classified into two major groups, namely, (i) horizontal milling and (ii) vertical milling. In the horizontal milling operations, the cutter axis is horizontal. Horizontal milling, can, again, be divided into two groups depending on the relative directions of cutting and feed motion. When surfaces are milled by plain milling cutters. If the table with the workpiece is fed against the direction of cutter rotation as shown in Fig. 6.33a, the operation is called up milling (conventional milling). On the other hand, if the cutter is rotated in the same direction as the feed of the workpiece as in Fig. 6.34 b, this will be down milling (climb milling). In either method, the chips formed by each tooth will be wedge- or comma-shaped.

In up milling process, the chip thickness will gradually increase in the course of chip formation (see Fig.6.34a), while in the down milling, on the opposite, it will decrease (see Fig. 6.33b). Since in down milling there is a tendency of the workpiece being dragged into the cutter, up milling is safer and is commonly done. However, down milling results in a better surface finish, longer tool life, and also more metal can usually be removed per minute than in up milling. The advantages of up milling method are in the gradual and smooth load increase on the tooth in the cut and in the fact that the teeth start to cut into the metal under the surface scale. A disadvantages of up milling is the tendency of the cutter to lift the workpiece from table or fixture. It should be keep in mind that, the selection of up milling or down milling method will depend on the actual conditions for a definite job.

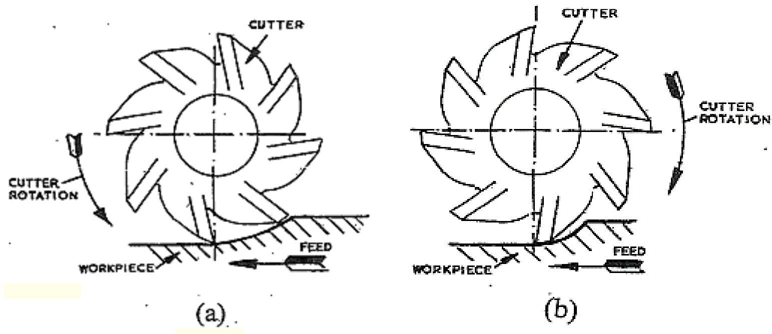


Fig. 6.33: Milling operations;
(a) Up milling,
(b) Down milling.

6.4.2 The Milling Machines

Milling machines are made of great variety of types and sizes. The drive may be either a cane pulley belt drive or an individual motor. The feed of the work may be manual, mechanical, electrical or hydraulic.

The principal types of milling machines can be classified according to the general design as follows:

i. General-purpose machines

1. Plain milling machines
2. Universal milling machines
3. Vertical milling machines

ii. Single purpose and specialized milling machines

1. The plain milling machines

Plain milling machines are of the types Knee-and- column machines. It is mainly consists of two parts, the knee and the column, as shown in Fig. 6.34. The knee can be raised or lowered on vertical ways on the face of the column. The saddle is mounted on the top of the knee and is traversed in a direction parallel with the axis of the spindle. The top of the saddle has ways on which the table is traversed in a direction perpendicular to the spindle axis. The machine is equipped with a speed gearbox and a feed gearbox.

The shaft on which the cutter is mounted is commonly known as the arbor. One end of the arbor is inserted in the machine spindle, the other end is supported by bracket on the overam. Shank-type cutters are inserted in the spindle; they are located by the taper hole and are held by a long-in bolt passing through the hollow spindle. The end of the bolt is screwed into a threaded hole in the cutter shank.

2. The Universal Milling Machine

Universal milling machine differ from plain milling machines in that, the table ways are contained in a swivel-base saddle plate that is mounted on a circular seat on top of the saddle. This arrangement permits the table to be swiveled in a horizontal plane to an angle up to 45° . In this manner the direction of table feed, in relation to the spindle axis, may be varied in a range from 45° to 90°. Such a setting is required to set up the machine for helical milling.

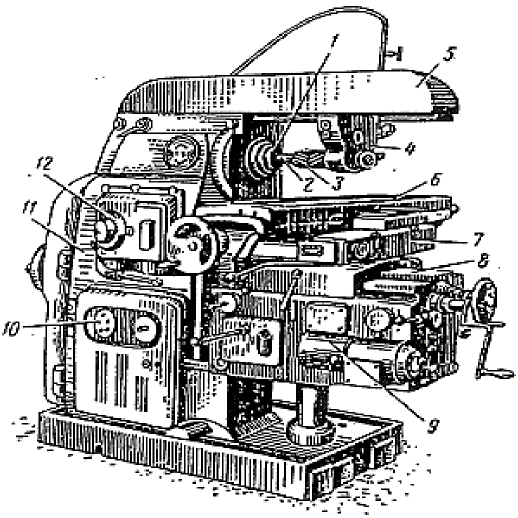


Fig. 6.34: The plain milling machine;

1. Spindle **2.** Arbor **3.** Cutters **4.** Bracket **5.** Overarm
6. Table **7.** Top of saddle **8.** Saddle **9.** Knee
10. Feed gearbox **11.** Column **12.** Speed gearbox

3. The Vertical Milling Machine

Vertical milling machines, as their name indicates, have a vertical spindle as shown in Fig. 6.35. As far as their other principle units are concerned, they differ very little from those of a plain milling machines. The spindle head may be swiveled, which permits setting the spindle in a vertical plane at any angle from vertical to horizontal. This machine has a short axis spindle travel to facilitate step milling. Some vertical milling machines are provided with a power-feed rotary milling attachment or rotating worktables. This enables it to machine circular grooves or continuous milling of small-production parts. In these types of milling machines, end mill cutters are used.

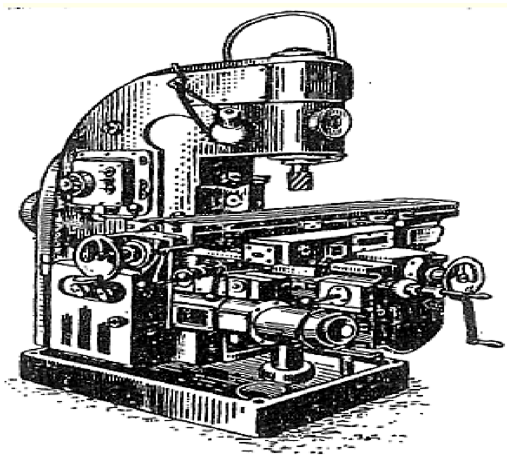


Fig. 6.35: The vertical milling machine.

4. The Planer-Type Milling Machine

This milling machine receives its name from its resemblance to a planer. It is a bed-type machine, where the workpiece is earned on a long table having only a longitudinal movement and is fed against the rotating cutter at the proper speed. The variable table feeding movement and the rotating cutter are the principle features that distinguish this machine from a planer. These machines are designed for milling large work requiring heavy stock removal and for accurate duplication of contours and profiles. A hydraulically operated machine of this type is shown in Fig. 6.36. Much work formerly done on a planer is now done on this machine.

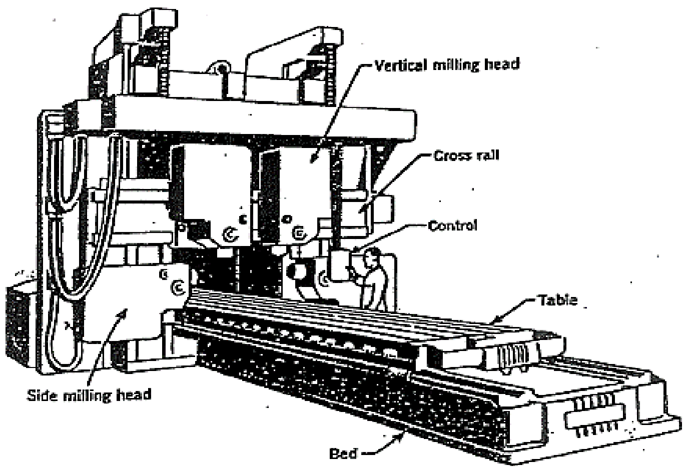


Fig. 6.36: The planer milling machine.

6.4.3 Dividing Heads

Dividing heads serve to change the angular position of a workpiece in relation to cutter. They are used to mill the gashes of cutting tools (as milling cutter, core drills, reamers, etc.) for cutting teeth on gears, etc. There are plain, universal, and optical dividing heads. The three systems of indexing by means of dividing head are direct, simple and differential indexing. Fig. 6.37 shows a general view of universal dividing head.

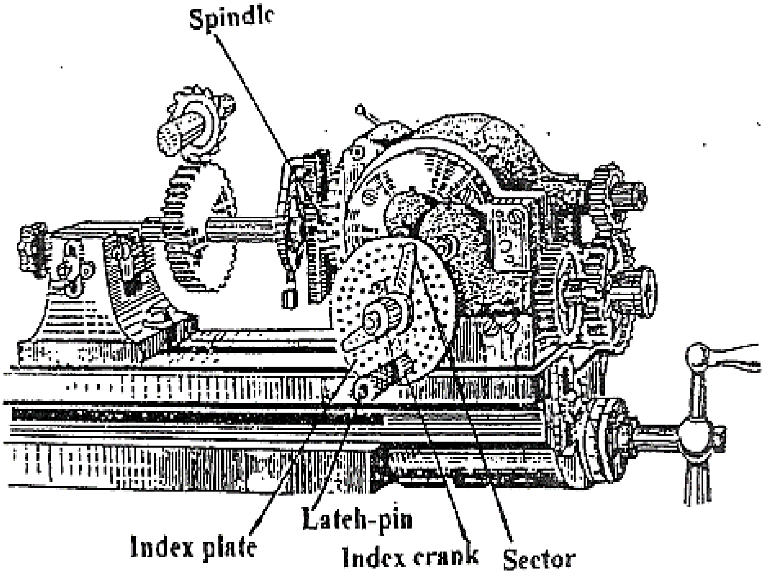


Fig. 6.37: Universal dividing head.

The purposes of universal dividing head are:

1. Turning the workpicce periodically through a given angle;
2. Importing a continuous rotary motion to the workpiece for milling helical grooves;
3. Setting the workpiece in a given inclined position in reference to the table.

The indexing head is equipped with three index plate, each having six circles of hole:

First index plate 15, 16, 17, 18,19 and 20 hole circles;

Second index plate 21, 23, 27, 29, 32 and 33 hole circles;

Third index plate 37, 39, 41, 43, 47 and 49 hole circles.

The holes are equally spaced in each circle. To index the work through (he required angle, the latch-pin (see Fig.6.37) is withdrawn from the index plate and the spindle is rotated through the required angle as determined by the sector. Then the latch-pin is relocated in the proper hole of the index plate.

In universal dividing head, the worm wheel usually has 40 teeth and meshes with a single-thread worm. The gearing ratio, therefore, will be, $i = \frac{1}{40}$

For simple indexing, the number of required turns of the index crank is determined by dividing the number of teeth in the worm wheel by the number of divisions required as:

$$x = \frac{z}{n} \quad \text{turns} \qquad \text{-----(6.6)}$$

Where: z is the number of teeth in the worm wheel (z = 40)

n is the required number of teeth of a gear blank to be cut.

Example 6.4

Calculate the number of turns of the index crank that will be required to index a gear blank on which 24 teeth are to be cut.

The given data is:

n = 24 teeth

Solution:

The number of turns *x* is calculated from equation 6.6 as:

$$x = \frac{z}{n} = \frac{40}{24} = 1\frac{2}{3} \quad \text{turns}$$

Therefore, in cutting this gear, we can use either of the three index plates. If the first index plate is used, the latch-pin should be set opposite either the 15-hole or 18-hole circle. We can either, rotate the index crank one full turn and 10 spaces m the 15-hole circle (the ratio $\frac{2}{3} = \frac{10}{15}$), or rotate the index crank one full turn and 12 spaces in the 18-hole circle (the ratio $\frac{2}{3} = \frac{12}{18}$)

6.4.4 The Milling Cutters

Milling cutters are classified on the basis of the form of then teeth into profile sharpened cutters and form relieved cutters. In the profile sharpened cutters, the cutting elements of the teeth are bounded by straight line, as shown in Fig 6.38a. Such cutters are sharpened by grinding on the periphery of the teeth. From relived cutters, as shown in Fig 6.38b , are sharpened by grinding the face of the teeth. The angles of milling cutter tooth are the same as for single-point tools. The chief angles are the rake angle (γ), the clearance or relief angle (α) and the lip angle (β), as shown in Fig.6.38. The larger the lip angle (β), the stronger the cutter tooth will be.

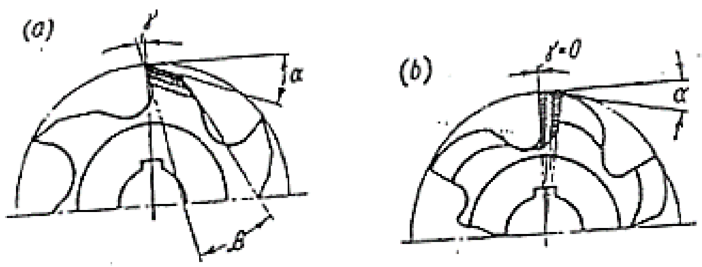


Fig. 6.38: The milling cutters;
(a) Profile sharpened,
(b) Form relieved.

As to their method of mounting, cutters are classified as shank-type, face-type, and arbor-type. Shank-type cutters have either a straight or taper shank to fit into the machine tool spindle. Face-type cutters are mounted directly on and driven from the machine spindle nose. Arbor-type cutter have a hole for mounting on an arbor and usually have a keyway to receive a driving key. Cutters of different types may be either solid or with inserted blades.

The chief types of the milling cutters are:

1. ***Plain milling cutters,***
2. ***Side milling cutters,***
3. ***Face milling cutters,***
4. ***Angle milling cutters,***
5. ***End mills,***
6. ***Form cutters.***

Plain milling cutters are designed mainly for milling flat surfaces. They may have either *straight* or *helical teeth*.

Face milling cutters are classified as *face mills, shell end mills* and *end mills*. Face mills and shell end mills have inserted blades.

Side milling cutters are classified as *half-side, side milling* and *slotting cutters* as shown in Fig. 6.39. side milling cutters are used mainly to produce slots.

In addition to side milling cutters, ***end mills*** are used to produce slots of all types and particularly keyways. Fig. 6.40 shows different shapes of end mills.

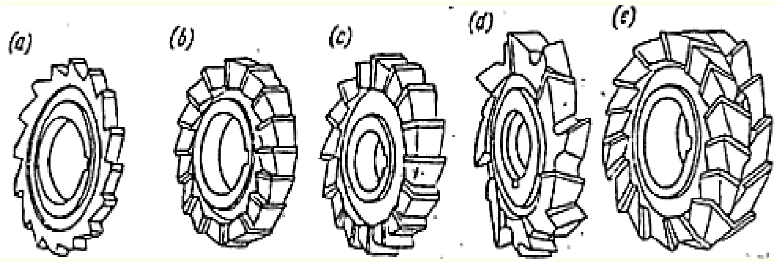


Fig. 6.39: Side milling cutters;
(a) Slotting cutter,
(b) Half-side cutter,
(c) Side milling cutter,
(d) Staggered-tooth side milling cutter
(e) Interlocking side milling cutter.

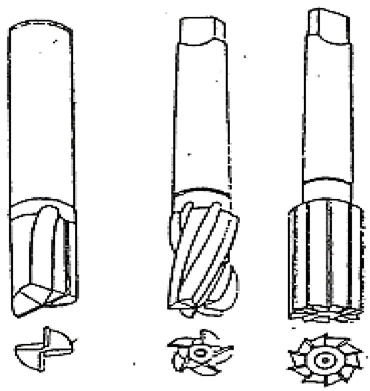


Fig. 6.40: End mills.

Angle and form milling cutters are designed for cutting the gashes or flutes of various types of cutting tools, as milling cutters, core drill and etc. these cutters may be ***single angle, double angle or form relieved***, as shown in Fig 6.41.

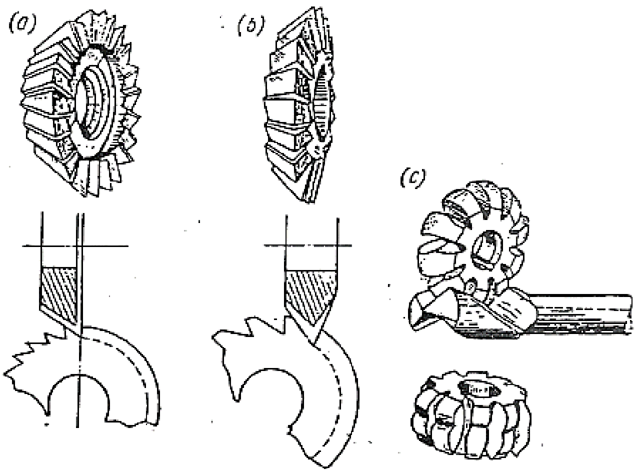


Fig. 6.41: Angles and form milling cutter;
(a) Single angle,
(b) Double angle,
(c) Form relieved.

6.4.5 The Operations Performed on Milling Machines

The milling operations can be classified into two major groups, (i) horizontal milling operations and (ii) vertical milling machines. In horizontal milling operations, the cutter axis is horizontal. Fig. 6.42 shows some common horizontal milling operations. On the other hand, when the cutter axis is vertical and generally perpendicular to the workpiece surface in vertical milling as shown in Fig. 6.43.

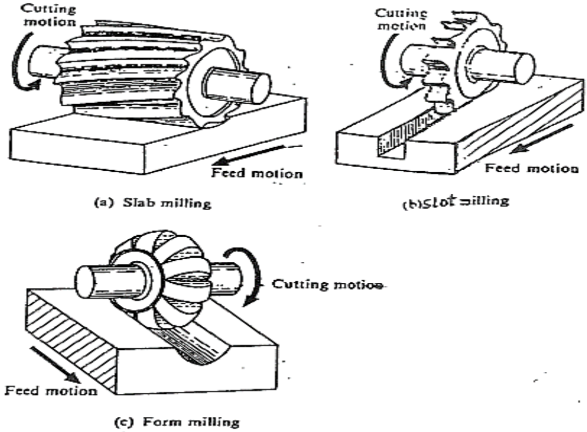


Fig. 6.42: The horizontal milling operations.

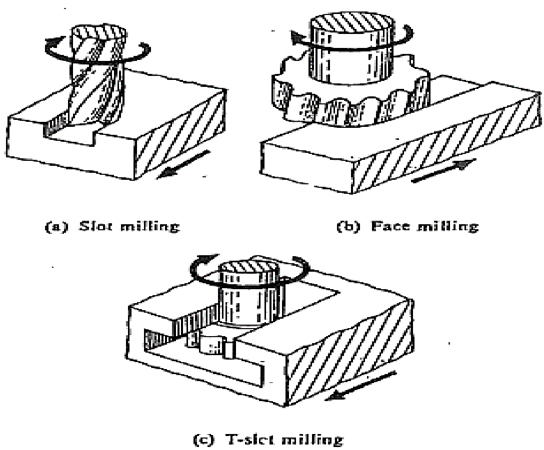


Fig. 6.43: The vertical milling operations.

CHAPTER 7
WELDING

7.1 BASIC CONCEPTS

Welding is the process of permanently joining two or more pieces of material, often metallic, together by the application of heat, pressure, or both.

7.1.1 The Advantages of Welding

Reviewing briefly some of the more common applications of welding, we find that in the heavy industries welding has almost entirely superseded riveting in the construction of buildings, bridges, ships, pressure vessels, tanks and many other types of steel work. Moreover, welding is not just another type of joint-its use generally improves the product. For example, a welded ship costs less to build and is up to 10% lighter than a riveted ship due to the elimination of rivet heads and plate overlaps, and to the use of light alloys; maintenance and during costs are also lower.

For many engineering productions, casting and forgings have been replaced by welded steel fabrications, which are lighter and stronger, less expensive, need less machining and can be produced with the usual facilities of a steel work fabrication shop.

An entirely different type of welding application is the deposition of wear-resisting metals, enabling parts that are subjected to severe wear in service to be made of comparatively inexpensive and easily fabricated metals, and yet have excellent wearing properties with wear resisting metal deposited on wearing surfaces and edges.

The repair and maintenance of metal parts and engineering equipment generally has been simplified by welding which enables broken and worn parts to be quickly repaired. Very often at a fabrication of the cost of a new replacement; foundries also make extensive use of welding for the reclamation of defective castings.

7.1.2 Fusion Welds

There are four basic types of fusion welds, as illustrated in **Fig. 7.1.**

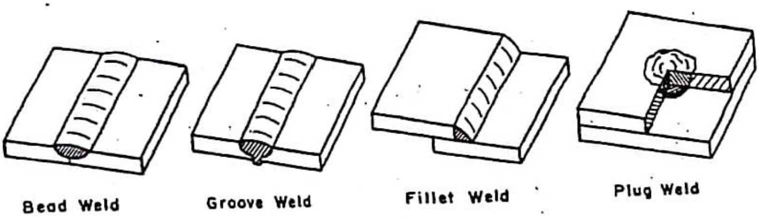


Fig. 7.1: Four basic types of fusion welds.

Bead welds require no edge preparation. However, because the weld is made on a flat surface and the penetration thus is limited, they are suitable only for joining thin sheets of metal, for building up surfaces, or for applying hard facing metals.

Groove welds are used where full – thickness strength is sought on thicker materials. These require some type of edge preparation to make a groove between the abutting edges. V, double V, U, and J configurations are most common, usually produced by oxyacetylene flame cutting. The type of groove configuration depends primarily on the thickness of the work, the welding process to be employed, and the position of the work, the primary consideration being to obtain a sound weld throughout the full thickness with a minimum deposit of weld metal. The weld may be made in either a single pass or by multiple-pass procedures, depending on the thickness of the material and the welding process used.

Fillet welds are used for tee, lap, and corner joints. The size of fillet welds is measured by the leg of the largest 45º right triangle that can be inscribed within the contour of the weld cross section. This is shown in **Fig. 7.2**, which also indicates the proper shape for fillet welds to avoid excess metal and to reduce stress concentration. Fillet welds require no special edge preparation. They may be continuous or made intermittently, spaces being left between short lengths of weld.

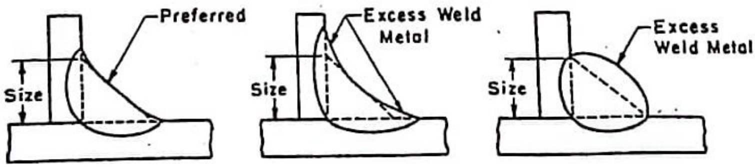


Fig. 7.2: Preferred shape of fillet welds and the method of measuring the size of a fillet weld .

Plug welds are used to attach one part on top of another, replacing rivets or bolts. A hole is made in the top plate, and welding is started at the bottom of this hole. They offer substantial saving in weight as compared with riveting or bolting.

Fig. 7.3 shows the five basic types of joint than can be made through the use of bead, groove and fillet weld.

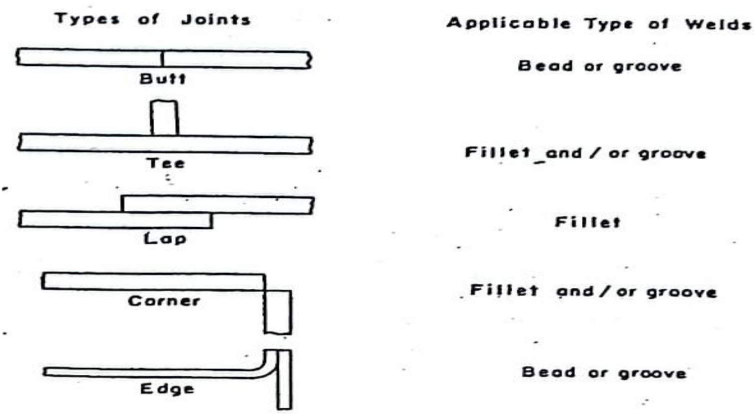


Fig. 7.3: Basic types of fusion-weld joints, and types of welds used in making them.

7.1.3 Edge Preparation before Welding

The edges of metal to be welded (base metal) are often prepared for welding by cutting, machining, or grinding. This preparation is done to insure that the base metal is welded through its entire thickness. Edge preparation is also done on thick metal to open up the joint area. This provides a space large enough to permit welding at the bottom of the joint.

1) Butt Joints:

The butt joint may be welded using one of the following types of grooves shown in **Fig. 7.4**: Square groove, Bevel groove, V groove, J groove, U groove, Flare-bevel-groove, Flare V groove, and Edge groove. The square groove is used when the base metal thickness up to 5 ÷ 8 mm. When the thickness does not exceed 5mm, it is often welded by placing edges close to each other with a gap of 1 to 2 mm. For thickness between 5 to 8 mm can be welded by increasing the gap to 2÷4 mm.

2) Corner Joints:

Corner joints maybe welded from the inside or outside of the corner. Occasionally the corner may be welded from both sides. **Fig. 7.5** shows the methods used to prepare an inside or outside corner joint for welding.

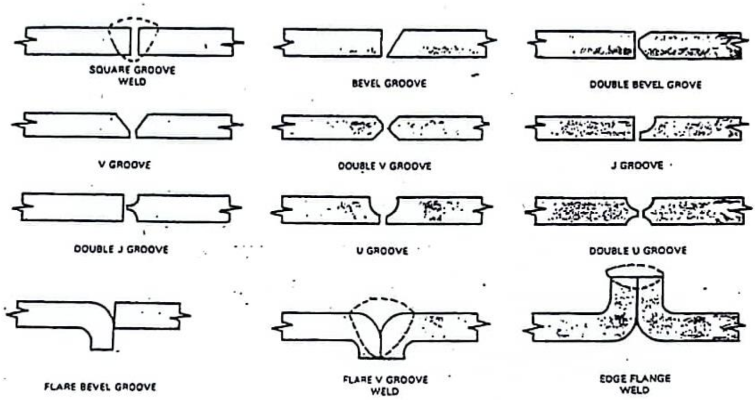


Fig. 7.4: Butt joint edge preparation methods.

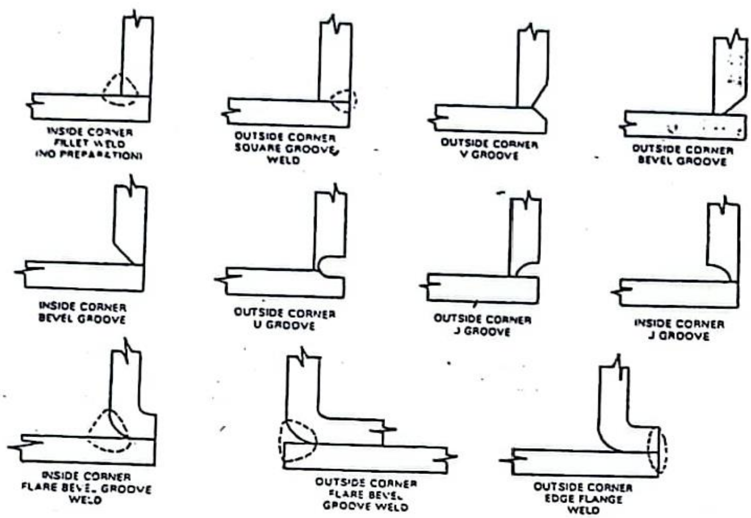


Fig. 7.5: Corner joint edge preparation methods.

3) T. Joints:

The T. joint obtains its name from the placement of the base metals to form a T shape. See **Fig. 7.6** for methods of preparing the metal edges for several types of T. joint welds.

4) Edge Joints:

Edge joints may be prepared in a number of ways also as seen in **Fig. 7.7.**

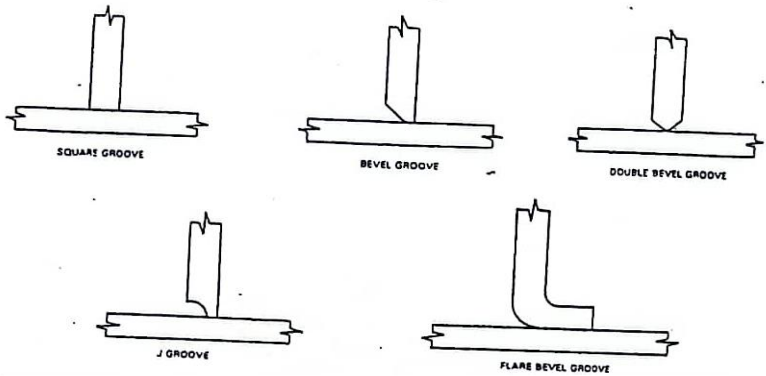


Fig. 7.6: T joint edge preparation methods.

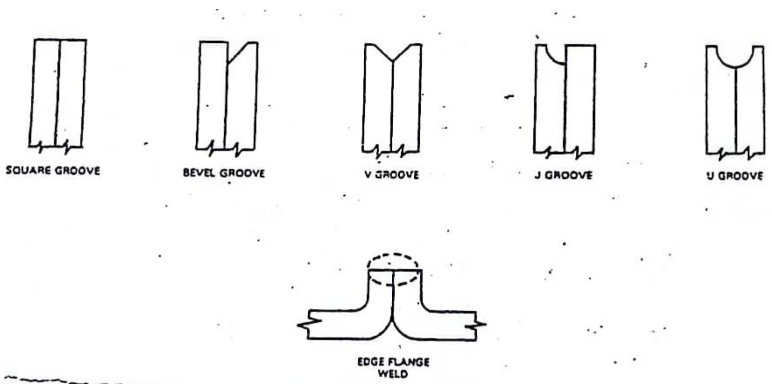


Fig. 7.7: Methods of preparing the edge joint for welding.

5) Lap Joints:

The metal which forms the lap joint is seldom altered in preparation for welding.

7.1.4 Welding Positions

Welders often must weld in a variety of positions. Welds may be made in the flat, horizontal, vertical, or overhead position **Fig.7.8**. On welding drawings, these positions are often abbreviated at the end of the welding symbol as F, H, V, and O. The American Welding Society refers to welding positions with a number and letter combination. Groove joints in the flat, horizontal, vertical, and overhead positions are referred to as 1G, 2G, 3G, and 4G, respectively. Fillet joints in the flat, horizontal, vertical, and overhead position are designated as 1F, 2F, 3F, and 4F respectively.

7.1.5 The Welded Joint Zones

A typical fusion weld joint is shown in **Fig. 7.8**, where three distinct zones can be identified :

(a) the base metal, that is, the metal to be welded;

(b) the heat-affected zone (HAZ); and

(c) the weld metal, that is, the region that has melted during welding.

The metallurgy and properties of the second and third zones depend strongly on the metals joined, the welding process, filter metals used, if any, and process variables. A joint produced without a filler metal is called autogenous, and the weld zone is composed of the molten and resolidified base metal. A joint made with a filler metal has a central zone called the weld metal and is composed of a mixture of the base and weld metals.

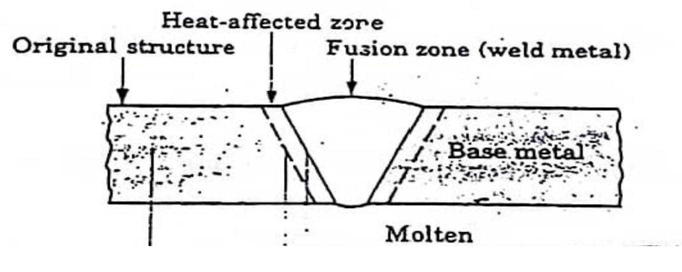


Fig. 7.8: The three zones of welded joints.

7.1.6 Weldability

We may define weldability of a metal as its capacity to be welded into a specific structure that has certain properties and characteristics and that will satisfactorily meet its service requirements.

Preheating the area to be welded can play an important rule in making good welds in some metals such as carbon steels with carbon content greater than 0.25% or cast iron.

The preheating temperature, T_p, can be calculated as follows:

$$\mathbf{T_p = 350\sqrt{[C] - 0.25}\ ^\circ C \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7\text{-}1)}$$

Where , [C] is the total carbon equivalent, and the value of 0.25 corresponds to the top limit of carbon for steels of ordinary weldability.

$$\mathbf{[C] = [C]_C\ (1 + 0.005\ t)\ \ldots\ldots\ldots\ldots\ldots\ldots\ (7\text{-}2)}$$

Where, $[C]_C$ is the chemical carbon equivalent, and “t” is the thickness of metal to be welded in millimeters.

$$\mathbf{[C]_C = C + Mn/9 + Cr/9 + Ni/18 + 7Mo/90\ .\ \ (7\text{-}3)}$$

7.2 Welding Processes

The major differences in the welding processes and used equipment, which have been developed, are related to:

a- The use and sources of heat for welding.
b- The use and sources of pressure required for welding.
c- The way of shielding the weld area from atmospheric contamination.
d- The welding situation for which the technique is suited.

The welding processes may be classified as solid state welding, resistance welding, oxyfuel welding, arc welding, and other joining processes such as brazing and soldering.

7.2.1 Solid State Welding

In solid state welding, joining is achieved by the application of heat, pressure or both. Unlike the resistance, gas, and arc welding processes, no liquid phase is present in the joint also, in solid state welding, the process is accomplished without fluxes or filler metals.

The different welding processes of solid state welding are: Forge welding, cold welding, friction welding, ultrasonic welding, and explosion welding.

Friction Welding:

In friction welding, the required heat for welding is generated through friction at the interface of the two members being joined. The machine used for this process looks somewhat like a large lathe. **Fig. 7.9** fitted with two chucks – one driven by a motor, the other fixed. The two parts to be joined are clamped in the chucks and one part is rotated. This rotated component must be round in cross – section, but he part held in the fixed chuck can be a matching section or flat.

When the rotating chuck reaches the welding speed, the parts are brought into contact under a light axial load. As the abutting faces rub together, friction between them generates heat and localized hot plastic zones are produced. With the end load maintained, heat continues to be generated until the whole interface has reached a uniform temperature. At the same time, the plastic metal starts to flow outwards towards the periphery, carrying with it any oxides present at the joint face. When sufficient heating has occurred, the relative rotation of the parts is stopped rapidly and the end load may be increased. The result is a forged pressure butt weld having an excess-metal flash which can be removed by machining. Weld times are short, being around 20 to 100 seconds.

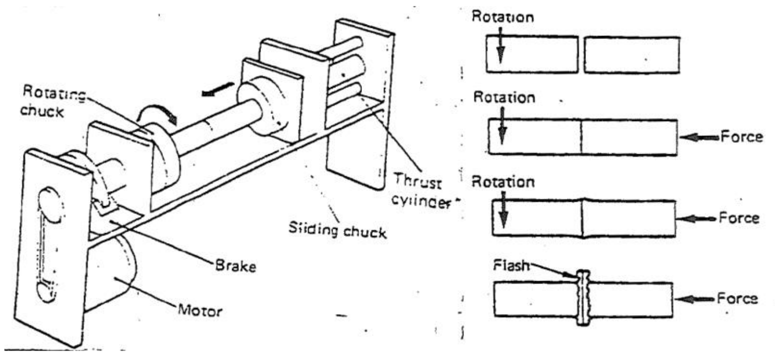


Fig. 7.9: Friction-welding sequence**.**

7.2.2 RESISTANCE WELDING

Resistance welding covers a number of processes in which the heat required for welding is produced by means of the electrical resistance between the two members to be joined. These processes are spot welding, seam welding, high-frequency resistance welding, flash welding, upset welding, stud welding, and percussion welding. These processes have major advantages, such as not requiring consumable electrodes, shielding gases, or flux.

Spot Welding:

In spot welding, the tips of two opposing solid cylindrical electrodes – made of copper base alloys and water cooled-contact the lap joint of two sheet metals, and resistance heating produces a spot weld **Fig. 7.10a.** in order to obtain a good bond in the weld nugget, pressure is also applied until the current is turned off.

Accurate control and timing of the electric current and pressure are essential in resistance welding. The strength of the bond depends on surface roughness and the cleanliness of the mating surfaces.

The weld nugget **Fig. 7.10b** is generally 6 – 10 mm is diameter. Current range from 3000A to 4000A, depending on the materials being welded and their thickness. The current (voltage 2 to 3V) flows for only a short time (typically 0.06 to 3 seconds) when the current is switched off (automatically) the weld solidifies under pressure. The required pressure is supplied through mechanical or pneumatic means.

Spot welding is widely used for fabricating sheet metal. Examples range from attaching handles to stainless – steel cookware, to rapid spot welding of automobile bodies with multiple electrodes. Modern equipment used for spot welding is computer controlled and the spot welding guns are manipulated by programmable robots.

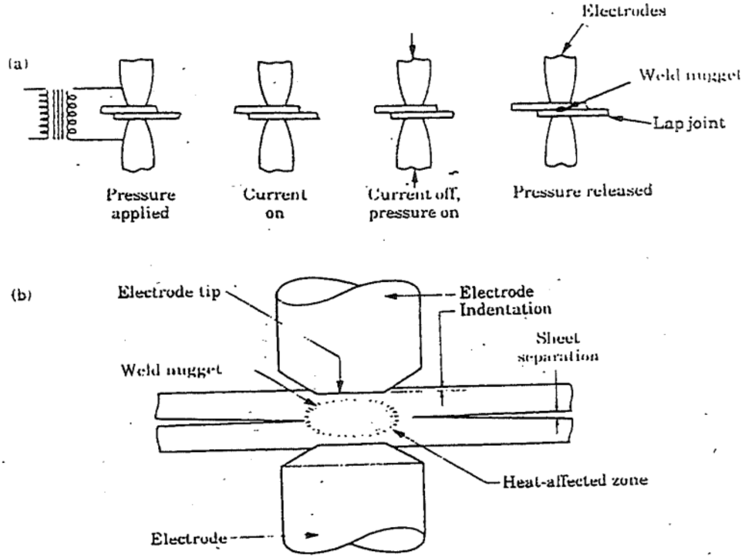


Fig. 7.10: a- Sequence in the resistance spot welding
b- Cross – section of a spot weld.

7.2.3 OXYFUEL GAS WELDING

Oxyfuel gas welding involves melting and fusion of the joint between two members. The thermal energy required for these welding operations is usually supplied by chemical means. Filler metals may or may not be used. Fusion welds made without the addition of filler metals are known as autogenous welds.

Oxyfuel gas welding is a general is a general term used to describe any welding process that uses a fuel gas combined with oxygen to produce a flame. This flame is used as the source of heat to melt the metals at the joint. The most common gas welding process uses acetylene fuel, and is known as oxyacetylene welding. Developed in the early 1900s, this process utilizes the heat generated by the combustion of acetylene gas (C_2H_2) in a mixture with oxygen in a torch.

The heat is generated in accordance with the following chemical reactions. The primary combustion process, which occurs in the inner cone of the flame (**Fig. 7.11)**, is:

$$\mathbf{C_2H_2 + O_2 \longrightarrow 2\,CO + H_2 + Heat}$$

This reaction dissociates the acetylene into carbon monoxide and hydrogen and produces about one – third of the total heat generated in the flame. The second reaction is:

$$\mathbf{4\,CO + 2H_2 + 3\,O_2 \longrightarrow 4\,CO_2 + 2H_2O + Heat,}$$

Which results in burning of the hydrogen and combustion of the carbon monoxide, producing about two – thirds of the total heat. The temperatures developed in the flame as a result of these reactions can reach 3300°C. the reaction of hydrogen with oxygen produces water vapour.

Types of Flames:

The proportions of acetylene and oxygen in the gas mixture are an important factor in oxyacetylene welding. At a ratio of 1 : 1, that is, when there is no excess oxygen, it is considered to be a neutral flame. With a greater oxygen supply, it becomes an oxidizing flame. This flame is harmful, especially for steels, because it oxidizes the steel. Only in copper and copper – base alloys is an oxidizing flame desirable because a thin protective layer of slag forms over the molten metal. If the supply of oxygen is lowered, it becomes a reducing or carborizing flame. The temperature of a reducing, or excess – acetylene, flame is lower. Hence it is suitable for applications requiring low heat, such as brazing, soldering, and flame hardening. Other fuel gases such as hydrogen, and methylacetylene propadiene can be used in oxyfuel gas welding. However, the temperatures developed are low, and hence they are used for welding metals with low melting points, such as lead, and parts that are thin and small.

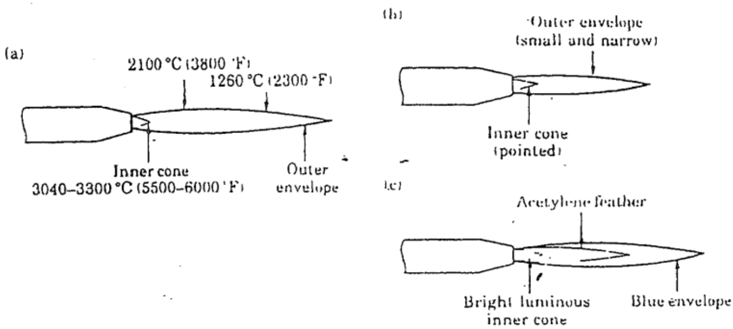


Fig. 7.11: Three types of oxyacetylene flames used in oxyacetylene welding and cutting perations:
a- neutral flames; b- oxidizing flame; and
c- carburizing, or reducing, flame.

Welding Equipment:

The equipment for oxyacetylene welding **Fig. 7.12** basically consists of a welding torch, which is available in various sizes and shapes, connected by hoses to high – pressure oxygen and acetylene cylinders. It is also equipped with pressure regulators which fitted with two pressure gauges: one showing the cylinder pressure and the other the outlet, or working, pressure.

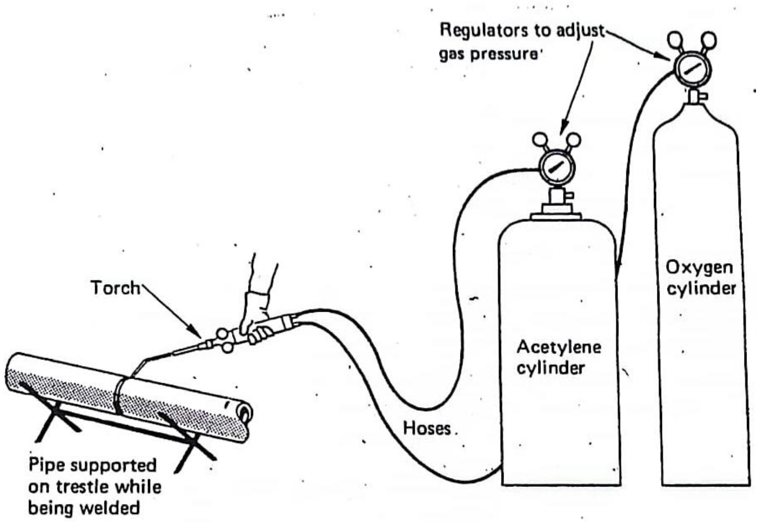


Fig. 7.12: Equipment for oxyacetylene welding.

The oxygen cylinder is a hollow seamless steel cylinder, but the acetylene one being also a steel cylinder has been filled with porous substance saturated with acetone which can absorb acetylene gas to stabilize it under pressure.

The gas regulators must be used to regulate the flow of gases to the welding torch. There are two types of regulators, single stage and two stage. The two-stage regulator provides more accurate gas regulation than the single stage.

To ensure that oxygen regulators or hoses cannot be inter – changed with that of acetylene, the inlet and outlet connections for acetylene have left – hand threads while that of oxygen have right – hand threads. Also for easy identification of hoses, red colour is used for acetylene hose and black colour for oxygen hose.

7.2.4 ARC WELDING

Arc welding is a joining technique that uses an electric arc to produce the heat necessary to cause the base metals to melt and fuse together. Filler metal in the form of an electrode (rod or wire), could be added to the joint, **Fig.7.13**.

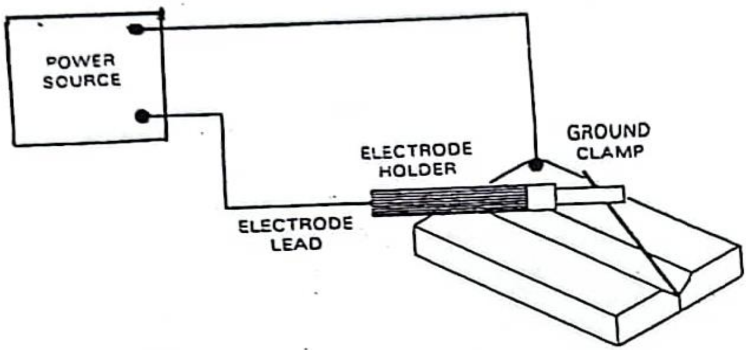


Fig.7.13: Basic arc welding circuit.

The used electrodes may be either consumable or non-consumable (carbon or tungsten). The arc is produced between the tip of the electrode and the workpiece to be welded. The arc produces temperatures in the range of 5000 to 3000 °C. the welding current provided by the power supply could be ac or dc. If dc current is used, the polarity may be straight (current flows through the electrode to the base metal to the electrode). The electric arc processes are used to weld a variety of geometries, such as those illustrated in **Fig.7.14**.

Arc welding includes various welding processes, which are shielded metal arc welding, submerged arc welding, gas metal arc welding, flux cored arc welding, and gas tungsten arc welding.

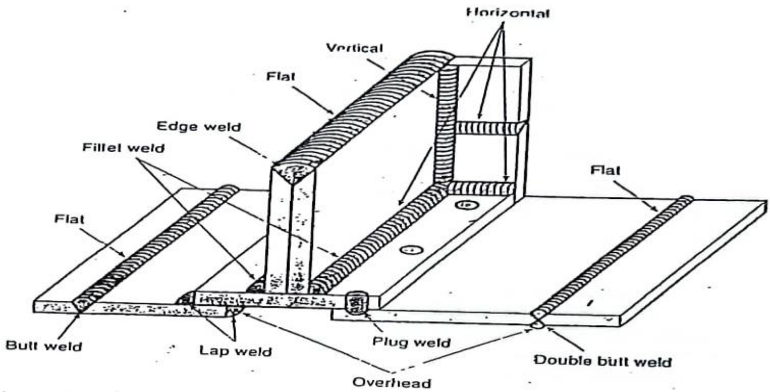


Fig.7.14: Typical geometries of welds produced by electric arc welding processes.

1) Shielded Metal Arc Welding:

Shielded metal-arc welding (SMAW) is one of the oldest, simplest, and most versatile joining processes. Currently, about 50 percent of all industrial welding is performed by this process. The electric arc is generated by touching the tip of a coated electrode against the workpiece and then withdrawing it quickly to a distance sufficient to maintain the arc **Fig.7.15**. The electrodes are in the shape of thin, long sticks, so this process is also known as stick welding.

The heat generated melts a portion of the tip of the electrode, its coating, and the base metal in the immediate area of the arc. A weld forms after the molten metal – a mixture of the base metal (workpiece), electrode metal, and substances from the coating on the electrode – solidifies in the weld area.

A bare section at the end of the electrode is clamped in an electrode holder. The holder is connected to one terminal of the power source, while the other terminal is connected to the workpiece being welded. The current usually ranges between 50 A and 300 A, with power requirements generally less than 10 kW. The current may be ac or dc, and the polarity of the electrode may be reverse polarity or straight polarity. The choice depends on the type of electrode, type of metals to be welded, arc atmosphere, and the depth of the heated zone. Too low a current causes incomplete fusion, and too high a current can damage the electrode coating and reduces its effectiveness.

The SMAW process has the advantage of being relatively simple and versatile, requiring a relatively small variety of electrodes. The equipment consists of a power supply, power cables, and electrode holder. This process is commonly used in general construction, shipbuilding, and pipelines, as well as for maintenance work, since the equipment is portable and can be easily maintained. It is especially useful for work in remote areas where portable fuel-powered generators can be used as the power supply. The SMAW process is best suited for workpiece thicknesses of 3-19 mm, although this range can be easily extended using special techniques and highly skilled operators.

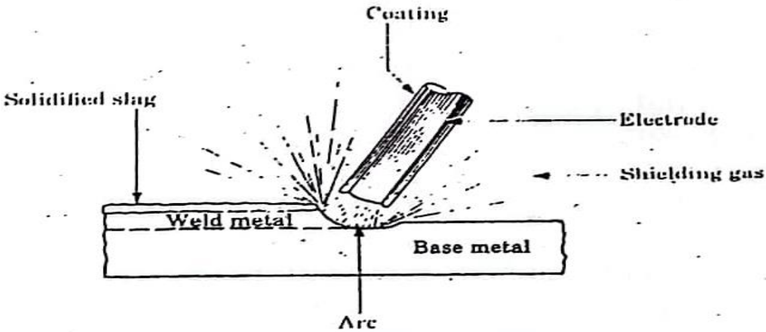


Fig.7.15: Schematic illustration of the shielded metal-arc welding process.

2) **Submerged Arc Welding:**

In submerged arc welding (SAW), the weld arc is shielded by granular flux, consisting of lime, silica, manganese oxide, calcium fluoride, and other elements.

The flux is fed into the weld zone by gravity flow through a nozzle **Fig.7.16**. The thick layer of flux completely covers the molten metal and prevents spatter and sparks-and without the intense radiation and fumes of the SMAW process. The flux also acts as a thermal insulator, allowing deep penetration of heat into the work piece. The welder must wear gloves, but other than tinted safety glasses, face shields generally are unnecessary.

The consumable electrode is a coil of bare round wire 1.5-10mm (1/16-3/8in.) in diameter, and is fed automatically through a tube (welding gun). Electric currents usually range between 600 A and 2000 A, from either ac or dc power sources, at up to 440 V. Because the flux is fed by gravity, the SAW process is somewhat limited to welds in a flat or horizontal position with back up piece. Circular welds can be made on pipes, provided that they are rotated during welding. The unfused flux can be recovered, treated, and reused. The quality of the weld is very high, with good toughness, ductility, and uniformity of properties. The SAW process provides very high welding productivity, depositing 4-10 times the amount of weld metal per hour as the SMAW process.

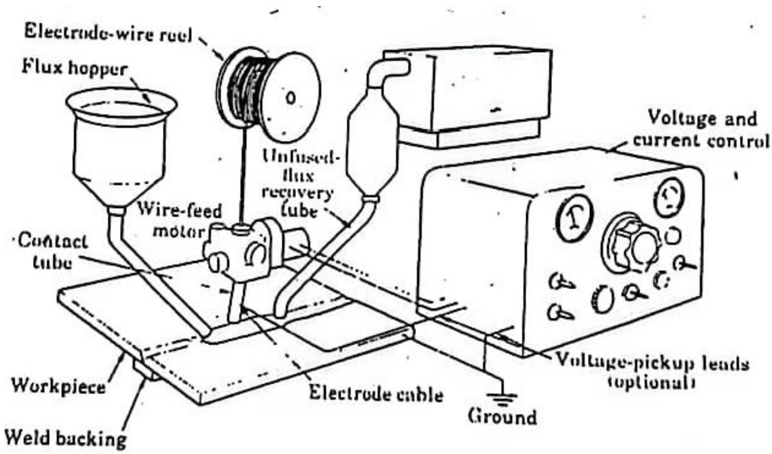


Fig.7.16: Schematic illustration of the submerged-arc welding process and equipment.

3) Gas Metal-Arc Welding:

In gas metal-arc welding (GMAW), the weld area is shielded by an external source of inert gas, such as argon, helium, carbon dioxide, or various other gas mixtures.

Fig.7.17, the consumable bare wire is fed automatically through a nozzle into the weld arc. In addition to the use of inert shielding gases, deoxidizers are usually present in the electrode metal itself, in order to prevent oxidation of the molten weld puddle. The welds made by this process are thus relatively free of slag, and hence multiple weld layers can be deposited at the joint without the necessity for intermediate cleaning of slag.

Metal can be transferred three ways in the GMAW process: spray, globular, and short circuiting. In spray transfer, small droplets of molten metal from the electrode are transferred to the weld area at rates of several hundred droplets per second. In globular transfer, carbon-dioxide rich gases are utilized, and globules propelled by the forces of the electric arc transfer the metal, resulting in considerable spatter. In short circuiting, the metal is transferred in individual droplets, at rates of more than 50 per second, as the electrode tip touches the molten weld arc and short circuits.

The GMAW process was developed in the 1950s and was formerly called metal inert-gas (MIG) welding. It is suitable for welding a variety of ferrous and nonferrous metals and is used extensively in the metal-fabrication industry. Because of the relatively simple nature of the process, training operators is easy. This process is rapid, versatile, and economical; welding productivity is double that of the SMAW process. The GMAW process can easily be automated and lends itself readily to flexible manufacturing systems and robotics. It has virtually replaced the SMAW process in present-day welding applications in manufacturing plants.

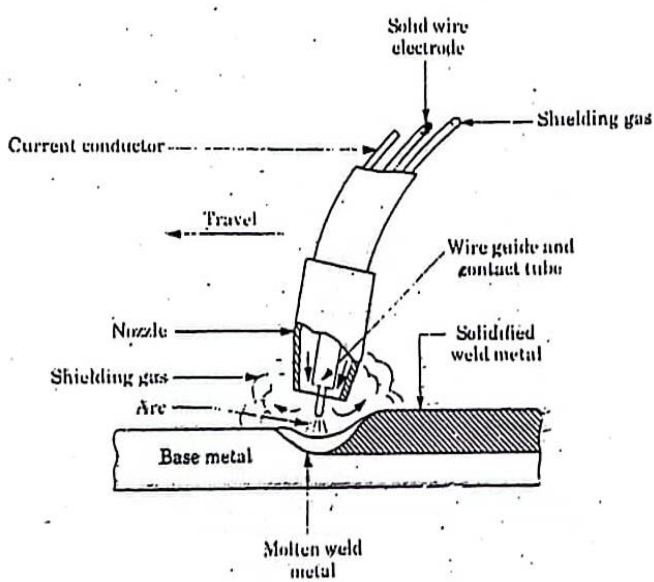


Fig. 7.17: Gas metal-arc welding process, formerly known as MIG (for metal inert gas).

4) Gas Tungsten-Arc Welding:

In gas tungsten-arc welding (GTAW), formerly known as TIG welding (for tungsten inert gas), the filler metal is supplied from a filler wire **Fig.7.18**. Because the tungsten electrode is not consumed in this operation, a constant and stable arc gap is maintained at a constant current level. Filler metals are similar to the metals to be welded, and flux is not used. The shielding gas is usually argon or helium, or a mixture of the two. Welding with GTAW may be done without filler metals, as in welding close – fit joints.

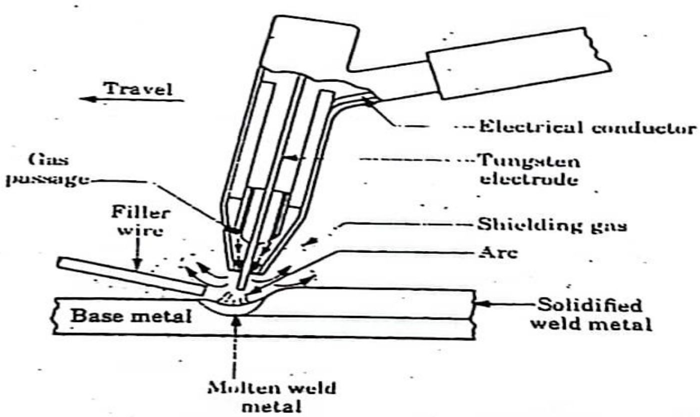


Fig.7.18: Gas tungsten-arc welding process, formerly known as TIG (for tungsten inert gas).

7.2.5 BRAZING

Brazing is a group of joining processes that use nonferrous alloys that have melting temperatures above 427°C. However, the filler metal's melting point is lower than the melting point of the metals being joined. It differs from welding in the following ways:

a- The composition of the brazing alloy is significantly different from the base metal.

b- The strength of the brazing alloy is substantially lower than the base metal.

c- The melting point of the brazing alloy is lower than that of the base metal, so the base metal is not melted.

d- Bonding requires capillary action.

Because of these differences, brazing has several distinct advantages:

a- Virtually all metals can be joined by some type of brazing metals. The process is ideally suited for dissimilar metals, such as joining nonferrous to ferrous, or metals with widely different melting points.

b- Since less heating is required than for welding, the process can be performed quickly and economically.

c- The lower temperatures reduce problems associated with heat-affected zones, warping, or distortion and thinner and more complex assemblies can be joined successfully.

d- Brazing is highly adaptable to automation and performs well when mass-producing delicate assemblies. A strong permanent joint is formed.

The major disadvantage of brazing is the fact that reheating can cause inadvertent melting of the braze metal, causing it to run, thus weakening or destroying the joint. Too often this occurs when people apply heat to brazed parts in attempting to repair or straighten such devices as bicycles or motorcycles. Such a consequence, of course, is not a defect of brazing, but it can lead to most unfortunate results. Consequently, if brazing is specified for use in products that later might be subjected to such abuse, adequate warning should be given to those who will use the product.

Brazing Metals:

The most commonly used brazing metals are copper and copper alloys, silver and silver alloys and aluminum alloys.

Copper is used only for brazing steel and other high-melting-point alloys, such as high-speed steel and tungsten carbide.

Fluxes:

Fluxes play a very important part in brazing by:

a- dissolving oxides that may be on the surface prior to heating.

b- preventing the formation of oxide during heating, and

c- lowering the surface tension of the molten brazing metal and thus promoting its flow into the joint.

One of the primary factors affecting the quality and uniformity of brazed joints is cleanliness. Although fluxes will dissolve modest amounts of oxides, they are not cleaners. Before a flux is applied, dirt, particularly oil, should be removed from the surfaces that are to be brazed. The less the flux has to do prior to heating, the more effective it will be during heating. Borax has been a commonly used brazing flux.

Heating Methods Used in Brazing:

A common source of heat for brazing is a gas-flame torch. In this torch-brazing procedure, oxyacetylene, oxyhydrogen, or other gas-flame sources can be used. Most repair brazing is done in this manner because of its flexibility and simplicity.

7.2.6 SOLDERING

Soldering is a method of joining metals with a nonferrous metal filler without having to heat them to a point where the base metals melt. Soldering is carried out at temperatures lower than 427°C. The process is sometimes called soft soldering.

The strength of solder is relatively low. It is used for low stress, low pressure applications.

Solder Metals:

Most solders are alloys of lead and tin with the addition of a very small amount of antimony – usually less than 0.5%. The three most commonly used alloys contain 60, 50, and 40% tin, and all melt below 241°C. Because tin is expensive, those having higher proportions of tin are used only where the high fluidity is required. For wiped joints and for filling dents and seams, as in automobile body work where no strength is required, solder containing only 20 or 30% tin is used.

Other soldering alloys have been developed for various purposes. Tin-antimony alloys are useful in electrical applications. Bismuth alloys have very low melting points. Aluminum is often soldered with tin-zinc, cadmium-zinc, or aluminum-zinc alloys. Lead-silver or cadmium-silver alloys can be used for high temperature service and indium-tin alloys are useful when joining metal to glass.

Soldering Fluxes:

As in brazing, soldering requires that the metal must be clean. Fluxes are usefor this purpose, but it is essential that all dirt, oil, and grease be removed before the flux is applied. Soldering fluxes are not intended to, and will not, remove any appreciable amount of contamination.

Soldering fluxes are classified as corrosive or noncorrosive. A common noncorrosive flux is rosin in alcohol. This is suitable for copper and brass and for tin-, cadmium-, or silver-plated surfaces, if the surfaces are clean. Aniline phosphate is a more active noncorrosive flux, but it has limited use because it gives off toxic gases. In addition to being suitable for copper and brass, it can be used on aluminum, zinc, steel, and nickel.

The two most commonly used corrosive-type fluxes are muriatic acid and a mixture of zinc and ammonium chlorides. Acid fluxes are very active but are highly corrosive. Chloride fluxes are effective on aluminum, copper, brass, bronze, steel, and nickel if no oil is on the surface.

Heating for Soldering:

Although any method of heating that is suitable for brazing can be used for soldering, furnace and salt-bath heating are seldom used. Dip soldering is used extensively for soldering wire ends, particularly in electronics work, for automobile radiators, and for tinning. Induction heating is used extensively where large numbers of identical parts are to be soldered. However, a large amount of soldering still is done with electric soldering irons or guns. The principal requisites of these are that they have sufficient heat capacity and that the surface that is held against the work be flat and well tinned so as to assure good heat transfer. For low melting point solders, infrared heat sources may be employed.

7.3 Defects and Testing of Welded Joints

7.3.1 Defects of Welded Joints

A welded joint may develop certain imperfection and discontinuities. As follows:

1) Porosity:

Porosity in welds is caused by trapped gases released during solidification of the weld area, by chemical reactions during welding, or by contaminants. Most welded joints contain some porosity, which is generally spherical in shape or in the form of elongated pockets. The distribution of porosity in the weld zone may be random, or it may be concentrated in a certain region. Porosity in welds can be reduced by the following methods:

a- Proper selection of electrodes and filler metals.

b- Improving welding techniques, such as preheating the weld area or increasing the rate of heat input.

c- Proper cleaning and preventing contaminants from entering the weld zone.

2) Slag inclusions:

Are compounds such as oxides, fluxes, and electrode-coating materials that are trapped in the weld zone. Welding conditions are important, and with proper techniques the molten slag will float to the surface of the molten weld metal and not be entrapped. Slag inclusions may be prevented by:

a- Cleaning the weld-bead surface before the next layer is deposited.

b- Changing the type of electrode.

3) Incomplete fusion (or lack of fusion):

Produces poor weld beads, such as those shown in **Fig. 7.19**. A better weld can be obtained by:

a- Raising the temperature of the base metal.

b- Cleaning the weld area prior to welding.

c- Changing the joint design and type of electrode.

4) In complete penetration:

Occurs when the depth of the welded joint is insufficient. Penetration can be improved by:

a- Increasing the heat input.

b- Lowering travel speed during welding.

c- Changing the joint design.

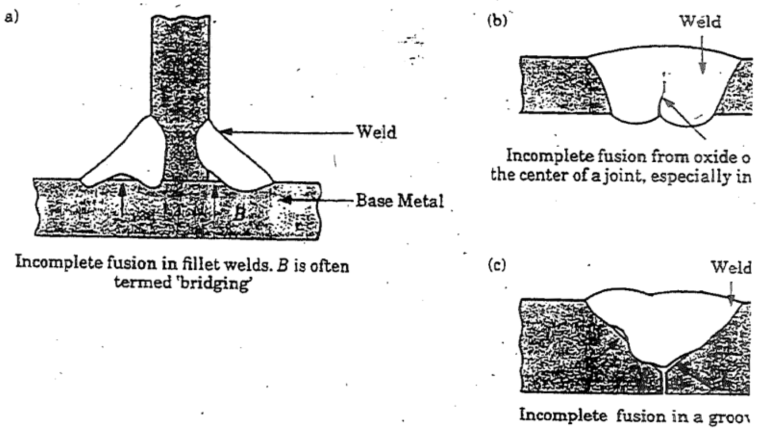


Fig. 7.19: Examples of various defects in fusion welds.

5) Weld profile defects:

Weld profile is important not only because of its effects on the strength and appearance of the weld, but also because it can indicate incomplete fusion or the presence of slag inclusions in multiple-layer welds **Fig. 7.20**. Under filling results when the joint is not filled with the proper amount of weld metal. Undercutting results from melting away the base metal and subsequently generating a groove in the shape of a sharp recess or notch. Unless it is not deep or sharp, an undercut can act as a stress raiser and reduce the fatigue strength of the joint – and may lead to premature failure. Overlap is a surface discontinuity. Weld profile defects generally caused by poor welding practice and selection of the wrong materials and heat input. A proper weld is shown in **Fig. 7.20c**.

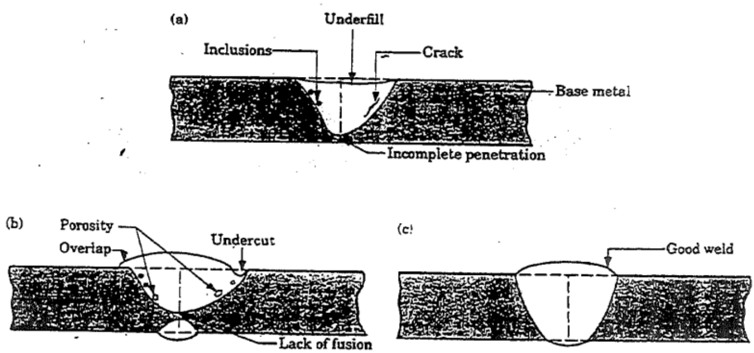


Fig. 7.20: Examples of various defects in fusion welds.

5) Cracks:

Cracks may occur in various locations and directions in the weld area. The types of cracks are typically longitudinal, transverse, crater, under bead, and toe cracks **Fig. 7.21**.

Cracks are classified as hot or cold cracks. Hot cracks occur while the joint is still at elevated temperatures. Cold cracks develop after the weld metal has solidified. Some crack – prevention measures are:

a- Preheat components being welded.
b- Avoid rapid cooling of the components after welding.
c- Change the weld design to minimize stresses from shrinkage during cooling.

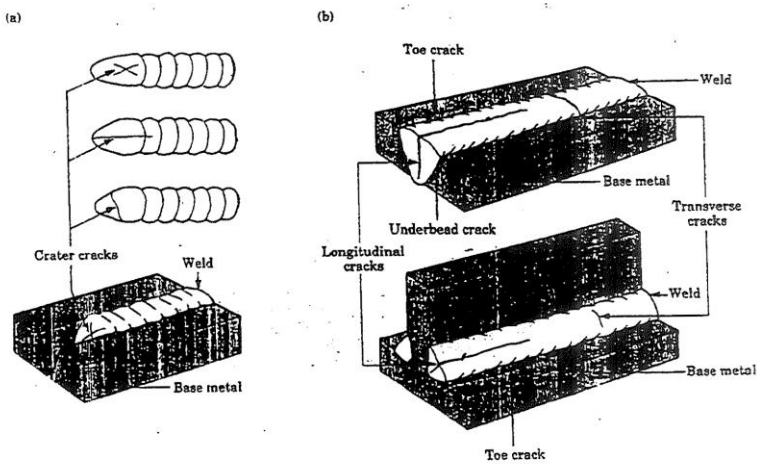


Fig. 7.21: Types of cracks in welded joints.

6) Surface damage and irregularities:

During welding, some of the metal may spatter and be deposited as small droplets on adjacent surfaces. In arc welding processes, the electrode may inadvertently touch the parts being welded at places not in the weld zone (arc strikes). Such surface defects may be objectionable for reasons of appearance or subsequent use of the welded part. Using proper welding techniques and procedures is important in avoiding surface damage.

7.3.2 TESTING OF WELDED JOINTS

As in all manufacturing processes, the quality of a welded joint is established by testing. Several standardized tests and test procedures have been established and are available from organizations such as ASTM. Welded joints may be tested either destructively or nondestructively. Each technique has certain capabilities, sensitivity, limitations, and need for special equipment and operator skill.

a) Destructive Techniques:

Destructive testing is used to determine the physical properties of a weld. To do so, destructive testing requires that a completed weld be damage in some way. Most such tests totally destroy the weld. The most common destructive tests include, tensile test, bend test, metallographic test.

1)Tensile test:

It is used to determine the tensile strength and ductility of a weld by applying a tensile load to a prepared sample until it breaks. The steps of the test are summarized as follows:

a- Make a butt weld on plate or pipe.

b- Remove a piece 2″ (50mm) wide. If plate or pipe is over 1″ (25mm) thick, the piece should be 1½″ (38mm)wide.

c- Prepare the piece as shown in **Fig. 7.22**.

d- Grind the face and root of the weld flush with the base metal. All grind marks must run lengthwise the metal samples. Also be sure to break all sharp edges along the reduced section area.

e- Measure the thickness and width if the specimen.

f- Mark two lines or points exactly 2’’ (50 mm) apart. The weld should be centered between the marks.

g- Put the piece to be tested into a tensile testing machine and apply force until the piece breaks and record the maximum force applied. If it breaks in the weld area, look for signs of porosity, slag inclusions or other defects.

h- Place the two pieces back together and measure the distance between the two points.

i- Calculate the tensile strength and ductility.

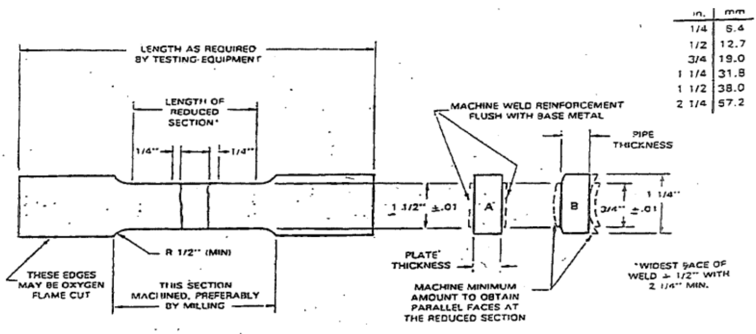


Fig. 7.22: Dimensions for tensile test specimens for plates under 1″ (25.4mm) and for pipe 6″ ÷ 8″ (152mm ÷ 203mm) in diameter.

2) Bend test:

Bend tests are used to evaluate the quality and ductility of a completed weld. The guided bend test is the most common type. The free bend test is also used. In both tests, a sample is bent into the "U" shape. In a guided bend test, the size or radius of the bend is controlled. Different sizes are used for different thicknesses and types of metal.

The aim of the bend test is to place one part of the welded joint into tension with the object of confirming that the metal has sufficient ductility to bend round a specified radius and assessing if any defects present will initiate cracks. Three forms of test are currently used **(Fig. 7.23):**

a- face bend, in which the top surface of the weld is in tension;

b- root or reverse bend, in which either the root of the weld or the reverse face of the weld is in tension;

c- side bend, in which a vertical slice is cut transverse to the weld so that the cross-section of the joint is in tension.

In each case the test strip, which is prepared to the dimensions specified in the standard, is placed across two rollers and a former is pressed against the opposite side to that which is being tested. The test piece is forced downwards between the rollers, so that the lower surface is in tension, until the sides are parallel. The surface is then examined for cracks and tears.

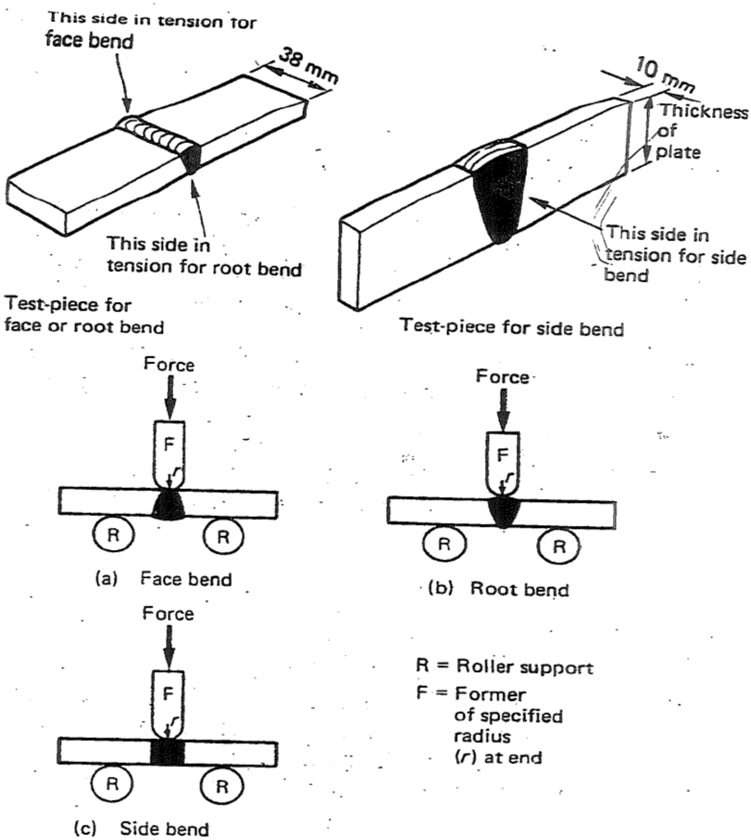


Fig. 7.23: Three types of bend test.

b) Nondestructive Techniques:

Welded structures often have to be tested non-destructively, particularly for critical applications where weld failure can be catastrophic, such as in pressure vessels, load-bearing structural members, and power plants. Nondestructive testing techniques usually consist of visual, dye-penetrant, magnetic-particle, radiography, and ultra-sonic methods.

1) Visual inspection:

Before either of nondestructive techniques is used, the experienced inspector will examine the joint visually. Often defects can be discovered by the naked eye and can be rectified or repaired at this stage.

In visual inspection, attention is paid to three aspects:

a- dimensions of the weld (especially in fillet welds, **Fig.s 7.24 and 7.25**),
b- penetration in joints welded from one side,
c- surface defects.

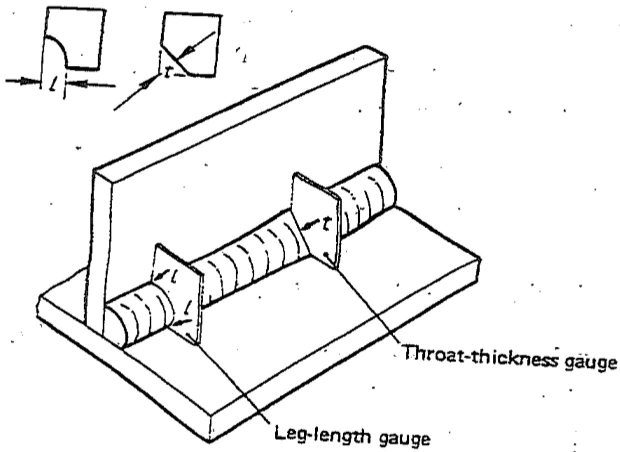


Fig. 7.24: Simple fillet – weld gauges.

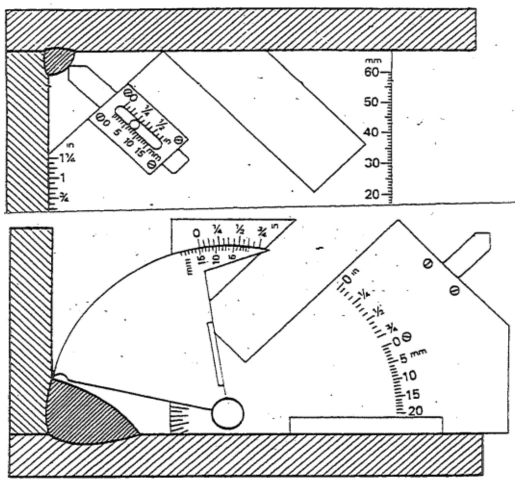


Fig. 7.25: Universal weld gauge: top throat measurement; bottom leg – length measurement.

In visual inspection magnifying lens and other visual aids may be used. Leakage in welded pressure vessels may be detected by pressurizing the part and submerging it in a water tank or by brushing soapy water on the welded joint. If exist leakage, bubbles will appear.

2) Dye-penetrant inspection:

If a liquid which has a low surface tension is poured on to the surface of the welded joint, it wets the metal and flows uniformly **Fig. 7.26**. In particular, it seeps into a crack or cavity. Wiping the surface of the parent metal and weld leaves the liquid in the crack. If an absorbent layer of chalk developer is deposited on the clean surface, the liquid is drawn out of the crack. By adding a red dye to the liquid, the location of the crack is indicated by a red stain on the chalk. Alternatively, the liquid may contain a dye which fluoresces when viewed under ultra – violet light.

3) Magnetic-particle inspection:

When inspecting ferromagnetic materials such as carbon steel, an alternative method of locating surface cracks is magnetic – particle inspection. In this technique, a magnetic field is created in the crack and is used to attract iron – oxide particles.

Consider a magnet in the shape of a bar **Fig. 7.27**. The lines of force within the magnet run from one end of the bar to the other, i.e. from the S to N poles. At the same time a magnetic field exists around the magnet. Iron powder sprinkled on to the bar collects around the poles, where the lines of force are close together. If another magnet is brought into proximity so that its N pole is opposite the S pole of the first magnet, the lines of force flow between the two magnets. When iron powder is sprinkled on to the new arrangement it collects in and around the gap between the N and S poles.

We can make a crack in a weld in steel behave in the same way as the gap between the magnets by inducing a magnetic field at right angles to it. The lines of force flow across the crack and leak out to the surface. Iron or iron – oxide particles deposited on the weld collect at the point where the magnetic field is leaking, thus indicating the presence of a crack.

Permanent or electromagnets can be used to create a magnetic field in the welded joint. More commonly, a current is passed through the area being examined **Fig. 7.28**.

4) Radiography:

Visual inspection, with or without the aid of dye – penetrant and magnetic particle techniques, can give positive information only about the defects which appear on the surface. Traditionally, radiography has been used to locate defects in the body of the weld, although in recent years ultrasonic has also become recognized as a complimentary method of non destructive testing.

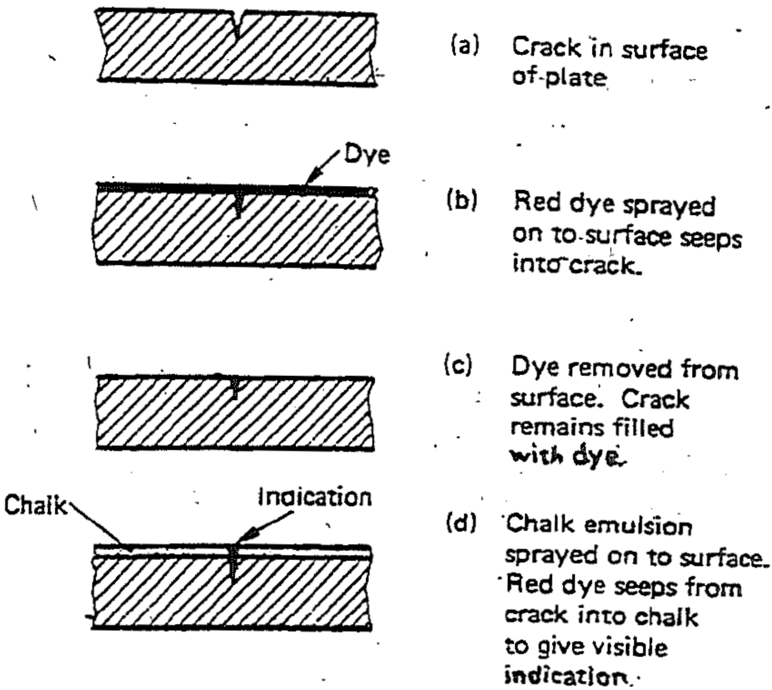


Fig. 7.26: Principles of dye – penetrant inspection.

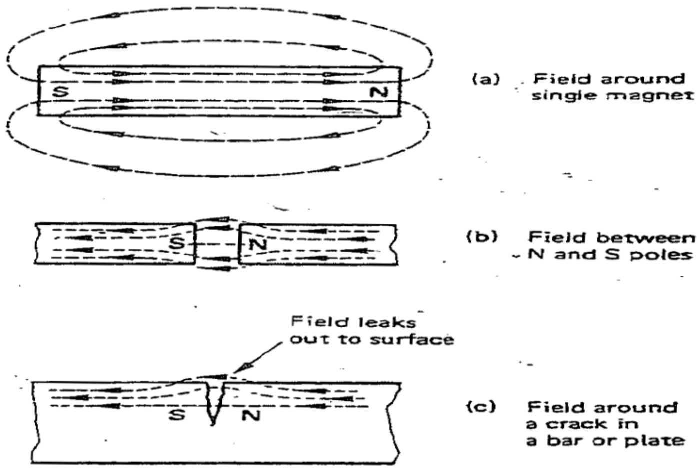


Fig. 7.27: Magnetic fields around bar magnets and a crack.

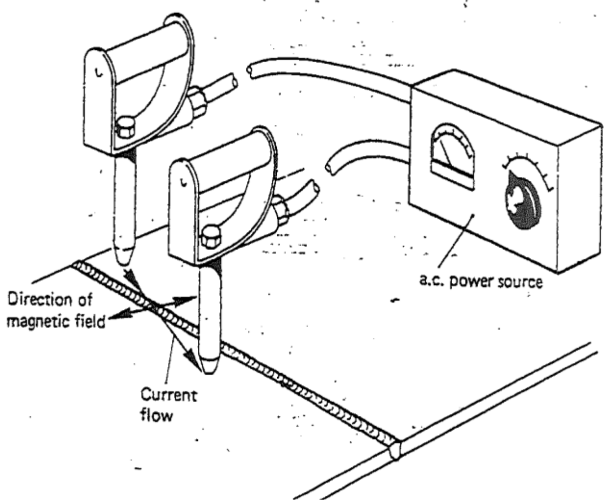


Fig. 7.28: Magnetic-particle inspection using alternating current.

The defection of defects in welds by radiography is based on the ability of X-rays or gamma rays to penetrate material which are opaque to ordinary white light.

During transmission through the material the X-rays are absorbed. If the material is homogeneous, the amount of absorption is uniform across the area exposed to the X-rays beam. On the other hand, if the material contains, say, a pore of gas, a smaller amount of the rays passing through this point is absorbed and there is a variation in the intensity of the emerbeam. This can be readily detected by placing a photographic film on the side of the material opposite to the source of the radiation **Fig. 7.29**. The film is exposed by the X-rays and its optical density depends on the intensity of the radiation. Thus the area under the gas pore receives more X-rays than the parent material on both side and the photographic emulsion is affected to a greater extent. On a negative film this shows up as a dark spot of the same shape as the pore **Fig. 7.30**.

The difference in intensities of the emergent rays depends on the relative absorption coefficients of the parent material and of the gas in the pore. Fortunately, defects in welded joints usually contain either gas, air, or slag, which have appreciably smaller absorption coefficients than the parent metal. Their presence is thus readily detected, since there is a marked variation in density in the film.

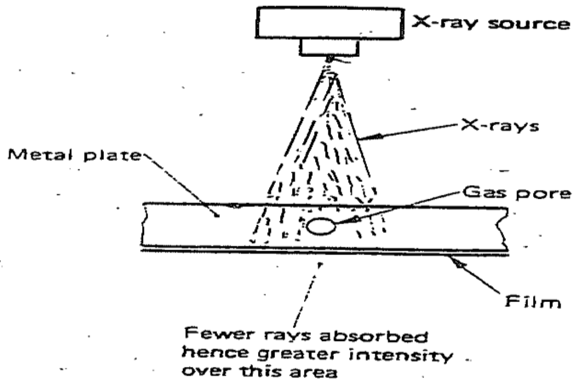


Fig. 7.29: Principles of radiography.

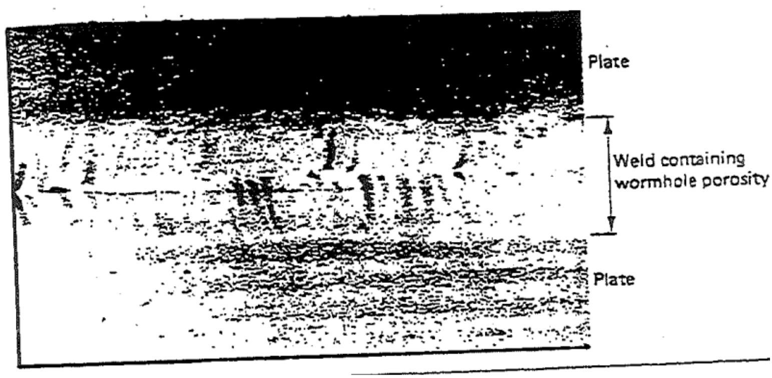


Fig. 7.30: Typical radiograph.

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APPENDIX

Higher Technological Institute (HTI)			
Department of Mechanical Engineering			
Academic Year:	2022/2023	Term:	First Term
Exam:	Final Exam	Time:	90 Min.
Subject:	Principles of Production Technology & Workshop	Code:	ENG 005
Examiners:	Examiners Committee	Group:	All groups

Answer the following questions:

Question (1): (9 Marks)

A- List some precautions that should be observed for the machinery workshop. **(2 Marks) LO1**

B- List the proper material and manufacturing method for:
Machine tool bed - Electric wire crank shaft – I-sections **(4 Marks) LO2**

C- Compare between: high-speed steel [HSS] and low carbon steel according to the chemical composition, properties and products for each metal. **(3 Marks) LO2**

Question (2): (9 Marks)

A- Show with sketches the files classification according to coarseness? **(2 Marks) LO3**

B- Name and sketch the proper chisel for chiseling Vee groove. **(2 Marks) LO3**

C- Define: Permeability – Plasticity – Flowability – Cohesion – Refractoriness. **(5 Marks) LO4**

Question (3): (8 Marks)

A- Describe using useful sketches:
Direct, Indirect and Impact Extrusion. Compare between them. **(3 Marks) LO4**

B- Sketch the following welding defects showing how to avoid them:
Cracks - porosity- Incomplete fusion. **(3 Marks) LO6**

C- Sketch the rolling mill used for rolling steel sheets. **(2 Marks) LO4**

Question (4): (14 Marks)

A- Find the number of indexing crank turns of cutting a gear of 28 teeth [indexing plate 37, 39, 41, 43, 47, 49] **(4 Marks) LO5**

B- Calculate the longitudinal turning time for a brass bar of 80 mm diameter and length is 250 mm. Diameter after turning is 73 mm. Cutting conditions are: Cutting speed 40 m/min., depth of cut/pass 0.9 mm, and feed rate 0.75 mm/rev. Take tool approach = tool overtravel = 5 mm. **(4 Marks) LO5**

C- Determine the preheating temperature for welding an alloy steel plate 18 mm thickness. Its chemical composition is: 0.25% C, 0.6% Mn, 0.5% Si, 4% Cr, 2% V. **(3 Marks) LO6**

D- Compare between up-milling and down-milling processes. **(3 Marks) LO4**

With my best wishes for success

Page **1** of **1**

Higher Technological Institute (HTI)			
Department of Mechanical Engineering			
Academic Year:	2022/2023	Term:	Second Term
Exam:	Final Exam	Time:	90 Min.
Subject:	Principles of Production Technology & Workshop	Code:	ENG 005
Examiners:	Examiners Committee	Group:	All groups

Answer the following questions:

Question (1): (9 Marks)

A- List some precautions that should be observed for the machinery workshop. **(2 Marks) LO1**

B- List the proper material and manufacturing method for:
Machine tool bed - Electric wire crank shaft – I-sections **(4 Marks) LO2**

C- Compare between: high-speed steel [HSS] and low carbon steel according to the chemical composition, properties and products for each metal. **(3 Marks) LO2**

Question (2): (9 Marks)

A- Show with sketches the files classification according to coarseness? **(2 Marks) LO3**

B- Name and sketch the proper chisel for chiseling Vee groove. **(2 Marks) LO3**

C- Define: Permeability – Plasticity – Flowability – Cohesion – Refractoriness. **(5 Marks) LO4**

Question (3): (8 Marks)

A- Describe using useful sketches:
Direct, Indirect and Impact Extrusion. Compare between them. **(3 Marks) LO4**

B- Sketch the following welding defects showing how to avoid them:
Cracks - porosity- Incomplete fusion. **(3 Marks) LO6**

C- Sketch the rolling mill used for rolling steel sheets. **(2 Marks) LO4**

Question (4): (14 Marks)

A- Find the number of indexing crank turns of cutting a gear of 28 teeth [indexing plate 37, 39, 41, 43, 47, 49] **(4 Marks) LO5**

B- Calculate the longitudinal turning time for a brass bar of 80 mm diameter and length is 250 mm. Diameter after turning is 73 mm. Cutting conditions are: Cutting speed 40 m/min., depth of cut/pass 0.9 mm, and feed rate 0.75 mm/rev. Take tool approach = tool overtravel = 5 mm. **(4 Marks) LO5**

C- Determine the preheating temperature for welding an alloy steel plate 18 mm thickness. Its chemical composition is: 0.25% C, 0.6% Mn, 0.5% Si, 4% Cr, 2% V. **(3 Marks) LO6**

D- Compare between up-milling and down-milling processes. **(3 Marks) LO4**

With my best wishes for success

3Higher Technological Institute (HTI)			
Department of Mechanical Engineering			
Academic Year:	2022/2023	Term:	Third Term
Exam:	Final Exam	Time:	90 Min.
Subject:	Principles of Production Technology & Workshop	Code:	ENG 005
Examiners:	Examiners Committee	Group:	All groups

Answer the following questions:

Question (1): (9 Marks)

A- Define: **Permeability** –**Flowability** – **Cohesion** – **Refractoriness**. (For sand) **(4 Marks) LO4**

B- Draw a schematic diagram showing the **classification of engineering materials**? **(2 Marks) LO2**

C- Explain with drawing the following: **(3 Marks) LO3**

Types of files according to their cross section

Type of chisel

Question (2): (12 Marks)

A- Compare with sketches between: **(4 Marks) LO5**

Open die forging and Closed die forging.

Wire drawing and Tube drawing

B- What are the advantages of **casting processes**? **(5 Marks) LO4**

(Outline the **steps of sand casting** with the sketch.)

C- Define the metal forming. **Outline** a classification of metal forming processes**.** **(3 Marks) LO5**

Question (3): (10 Marks)

A- What are the classifications of cast iron?
Mention some properties and products for each metal. **(3 Marks) LO2**

B- Write the constituent of a molding sand mixture. **(2 Marks) LO4**

C- Compare between **sand, die and investment casting according to:** **(5 Marks) LO4**

process	Mold type	Pattern type	Advantages	Disadvantages	Examples

Question (4): (9 Marks)

A- Describe using useful sketches: **(6 Marks) LO5**

Direct, Indirect and **Impact** Extrusion. **Compare between them**.

B- What are the types of rolling mills. **(3 Marks) LO5**

With my best wishes for success