UNIT 2 MANUFACTURING PROCESS

2. INTRODUCTION

Manufacturing is the backbone of any industrialized nation. Manufacturing and technical staff in industry must know the various manufacturing processes, materials being processed, tools and equipments for manufacturing different components or products with optimal process plan using proper precautions and specified safety rules to avoid accidents. Beside above, all kinds of the future engineers must know the basic requirements of workshop activities in term of man, machine, material, methods, money and other infrastructure facilities needed to be positioned properly for optimal shop layouts or plant layout and other support services effectively adjusted or located in the industry or plant within a well planned manufacturing organization.

The complete understanding of basic manufacturing processes and workshop technology is highly difficult for anyone to claim expertise over it. The study deals with several aspects of workshops practices also for imparting the basic working knowledge of the different engineering materials, tools, equipments, manufacturing processes, basic concepts of electro- mechanical controls of machine tools, production criteria's, characteristics and uses of various testing instruments and measuring or inspecting devices for checking components or products manufactured in various manufacturing shops in an industrial environment. It also describes and demonstrates the use of different hand tools (measuring, marking, holding and supporting tools, cutting etc.), equipments, machinery and various methods of manufacturing that facilitate shaping or forming the different existing raw materials into suitable usable forms.

It deals with the study of industrial environment which involves the practical knowledge in the area of ferrous and non ferrous materials, their properties and uses. It should provide the knowledge of basic workshop processes namely bench work and fitting, sheet metal, carpentry, pattern making, mould making, foundry, smithy, forging, metal working and heat treatment, welding, fastening, machine shop, surface finishing and coatings, assembling inspection and quality control. It emphasizes on basic knowledge regarding composition, properties and uses of different raw materials, various production processes, replacement of or improvement over a large number of old processes, new and compact designs, better accuracy in dimensions, quicker methods of production, better surface finishes, more alternatives to the existing materials and tooling systems, automatic and numerical control systems, higher mechanization and greater output.

2.2 MANUFACTURING ENGINEERING

Manufacturing is derived from the Latin word manufactus, means made by hand. In modern context it involves making products from raw material by using various processes, by making use of hand tools, machinery or even computers. It is therefore a study of the proesses required to make parts and to assemble them in machines.

Process Engineering, in its application to engineering industries, shows how the different problems related to development of various machines may be solved by a study of physical, chemical and other laws governing the manufacturing process. The study of manufacturing reveals those parameters which can be most efficiently being influenced to increase production and raise its accuracy. Advance manufacturing engineering involves the following concepts—

a. Process planning.
b. Process sheets.
c. Route sheets.
d. Tooling.
e. Cutting tools, machine tools (traditional, numerical control (NC), and computerized numerical control (CNC).
f. Jigs and Fixtures.
g. Dies and Moulds.
h. Manufacturing Information Generation.
i. CNC part programs.
j. Robot programmers.
k. Flexible Manufacturing Systems (FMS), Group Technology (GT) and Computer integrated manufacturing (CIM).

2.3 PRODUCTION PROCESS

It is the process followed in a plant for converting semi- finished products or raw materials into finished products or raw materials into finished products. The art of converting raw material into finished goods with application of different types of tools, equipments, machine tools, manufacturing set ups and manufacturing processes, is known as production. Generally there are three basic types of production system that are given as under.

1. Job production

2. Batch production

3. Mass production

Job production comprises of an operator or group of operators to work upon a single job and complete it before proceeding to the next similar or different job. The production requirement in the job production system is extremely low. It requires fixed type of layout for developing same products.

Manufacturing of products (less in number say 200 to 800) with variety of similar parts with very little variation in size and shape is called batch production. Whenever the production of batch is over, the same manufacturing facility is used for production of other batch product or items. The batch may be for once or of periodical type or of repeated kinds after some irregular interval. Such manufacturing concepts are leading to GT and FMS technology. Manufacturing of products in this case requires process or functional layout.

Whereas mass production involves production of large number of identical products (say more than 50000) that needs line layout type of plant layout which is highly rigid type and involves automation and huge amount of investment in special purpose machines to increase the production.

2.4 PROCESS PLANNING

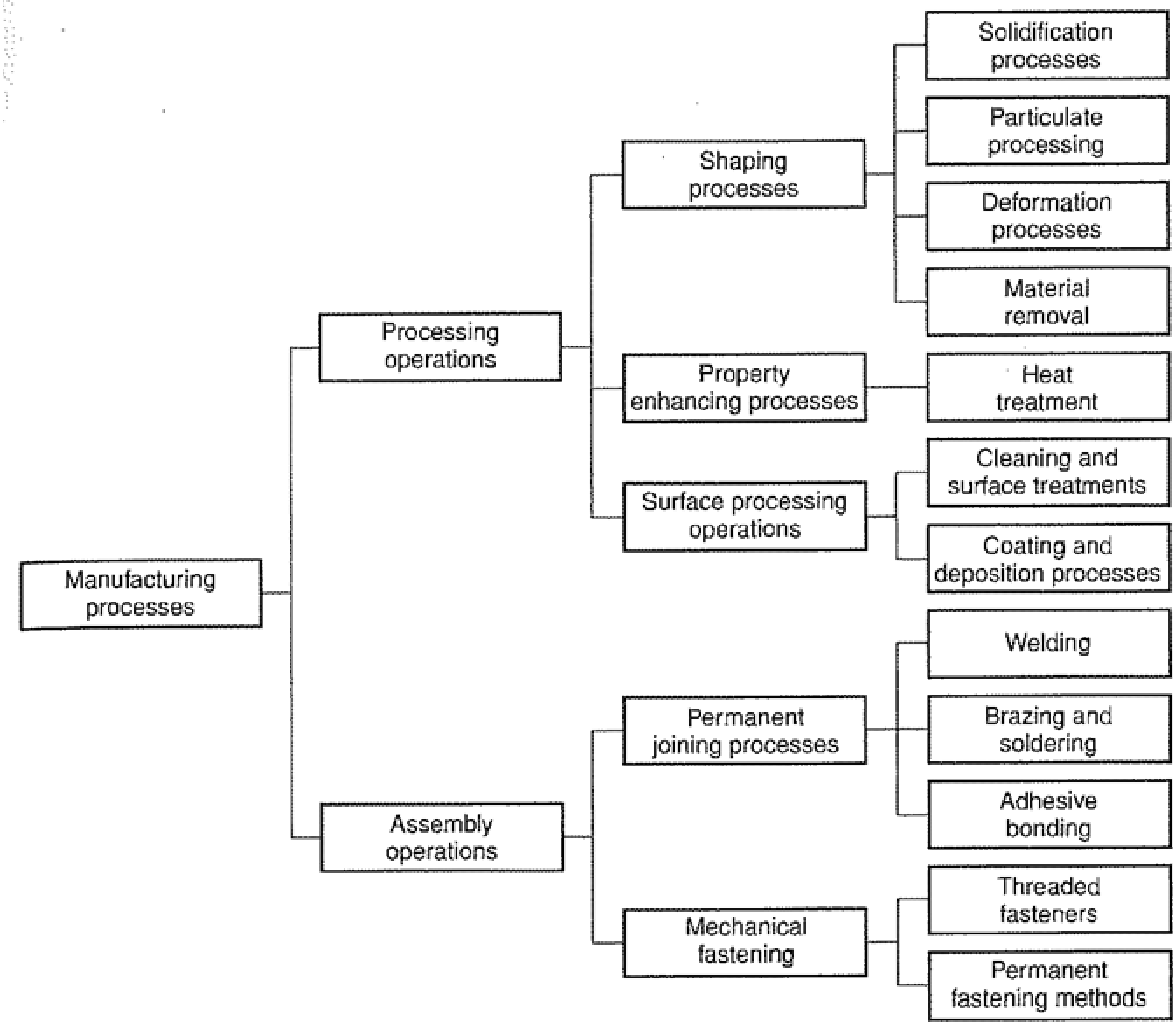
Process planning consists of selection of means of production (machine-tools, cutting tools, presses, jigs, fixtures, measuring tools etc.), establishing the efficient sequence of operation, determination of changes in form, dimension or finish of the machine tools in addition to the specification of the actions of the operator. It includes the calculation of the machining time, as well as the required skill of the operator.

It also establishes an efficient sequence of manufacturing steps for minimizing material handling which ensures that the work will be done at the minimum cost and at maximum productivity. The basic concepts of process planning are generally concerned with the machining only. Although these concepts may also be extended to other processes such as casting, forging, sheet metal forming, assembling and heat treatment as well.

2.5 MANUFACTURING PROCESS

Manufacturing process is that part of the production process which is directly concerned with the change of form or dimensions of the part being produced. It does not include the transportation, handling or storage of parts, as they are not directly concerned with the changes into the form or dimensions of the part produced.

2.5.1 CLASSIFICATION OF MANUFACTURING PROCESSES



For producing of products materials are needed. It is therefore important to know the characteristics of the available engineering materials. Raw materials used manufacturing of products, tools, machines and equipments in factories or industries are extracted from ores. The ores are suitably converted the metal into a molten form by reducing or refining processes in foundries. This molten metal is poured into moulds for providing commercial castings, called ingots. Such ingots are then processed in rolling mills to obtain market form of material supply in form of bloom, billets, slabs and rods.

These forms of material supply are further subjected to various manufacturing processes for getting usable metal products of different shapes and sizes in various manufacturing shops. All these processes used in manufacturing concern for changing the ingots into usable products may be classified into six major groups as primary shaping processes, secondary machining processes, metal forming processes, joining processes, surface finishing processes and processes effecting change in properties. These are discussed as under.

Primary Shaping Processes

Primary shaping processes are manufacturing of a product from an amorphous material. Some processes produces finish products or articles into its usual form whereas others do not, and require further working to finish component to the desired shape and size. Castings need re-melting of scrap and defective ingots in cupola or in some other melting furnace and then pouring of the molten metal into sand or metallic moulds to obtain the castings. Thus the intricate shapes can be manufactured. Typical examples of the products that are produced by casting process are machine beds, automobile engines, carburetors, flywheels etc. The parts produced through these processes may or may not require to undergo further operations. Some of the important primary shaping processes is:

(1) Casting, (2) Powder metallurgy, (3) Plastic technology, (4) Gas cutting, (5) Bending and (6) Forging.

Secondary or Machining Processes

As large number of components require further processing after the primary processes. These components are subjected to one or more number of machining operations in machine shops, to obtain the desired shape and dimensional accuracy on flat and cylindrical jobs. Thus, the jobs undergoing these operations are the roughly finished products received through primary shaping processes. The process of removing the undesired or unwanted material from the workpiece or job or component to produce a required shape using a cutting tool is known as machining. This can be done by a manual process or by using a machine called machine tool (traditional machines namely lathe, milling machine, drilling, shaper, planner, slotter).

In many cases these operations are performed on rods, bars and flat surfaces in machine shops. These secondary processes are mainly required for achieving dimensional accuracy and a very high degree of surface finish. The secondary processes require the use of one or more machine tools, various single or multi-point cutting tools (cutters), job holding devices, marking and measuring instruments, testing devices and gauges etc. for getting desired dimensional control and required degree of surface finish on the workpieces. The example of parts produced by machining processes includes hand tools machine tools instruments, automobile parts, nuts, bolts and gears etc. Lot of material is wasted as scrap in the secondary or machining process. Some of the common secondary or machining processes are—

(1) Turning, (2) Threading, (3) Knurling, (4) Milling, (5) Drilling, (6) Boring, (7) Planning, (8) Shaping, (9) Slotting, (10) Sawing, (11) Broaching, (12) Hobbing, (13) Grinding, (14) Gear cutting, (15) Thread cutting and (16) Unconventional machining processes namely machining with Numerical Control (NC) machines tools or Computer Numerical Control (CNC) machines tools using ECM, LBM, AJM, USM setups etc.

Metal Forming Processes

Forming processes encompasses a wide variety of techniques, which make use of suitable force, pressure or stresses, like compression, tension and shear or their combination to cause a permanent deformation of the raw material to impart required shape. These processes are also known as mechanical working processes and are mainly classified into two major categories i.e., hot working processes and cold working processes. In these processes, no material is removed; however it is deformed and displaced using suitable stresses like compression, tension, and shear or combined stresses to cause plastic deformation of the materials to produce required shapes. Such processes lead to production of directly usable articles which include kitchen utensils, rods, wires, rails, cold drink bottle caps, collapsible tubes etc. Some of the important metal forming processes are:

Hot working Processes

(1) Forging, (2) Rolling, (3) Hot spinning, (4) Extrusion, (5) Hot drawing and (6) Hot spinning.

Cold working processes

(1) Cold forging, (2) Cold rolling, (3) Cold heading, (4) Cold drawing, (5) Wire drawing, (6) Stretch forming, (7) Sheet metal working processes such as piercing, punching, lancing, notching, coining, squeezing, deep drawing, bending etc.

Joining Processes

Many products observed in day-to-day life, are commonly made by putting many parts together may be in subassembly. For example, the ball pen consists of a body, refill, barrel, cap, and refill operating mechanism. All these parts are put together to form the product as a pen. More than 800 parts are put together to make various subassemblies and final assembly of car or aero-plane. A complete machine tool may also require to assemble more than 100 parts in various sub assemble or final assembly.

The process of putting the parts together to form the product, which performs the desired function, is called assembly. An assemblage of parts may require some parts to be joined together using various joining processes. But assembly should not be confused with the joining process. Most of the products cannot be manufactured as single unit they are manufactured as different components using one or more of the above manufacturing processes, and these components are assembled to get the desired product. Joining processes are widely used in fabrication and assembly work.

In these process two or more pieces of metal parts are joined together to produce desired shape and size of the product. The joining processes are carried out by fusing, pressing, rubbing, riveting, screwing or any other means of assembling. These processes are used for assembling metal parts and in general fabrication work. Such requirements usually occur when several pieces are to be joined together to fabricate a desired structure of products. These processes are used developing steam or water-tight joints. Temporary, semi-permanent or permanent type of fastening to make a good joint is generally created by these processes. Temporary joining of components can be achieved by use of nuts, screws and bolts. Adhesives are also used to make temporary joints. Some of the important and common joining processes are:

(1) Welding (plastic or fusion), (2) Brazing, (3) Soldering, (4) Riveting, (5) Screwing, (6) Press fitting, (7) Sintering, (8) Adhesive bonding, (9) Shrink fitting, (10) Explosive welding, (11) Diffusion welding, (12) Keys and cotters joints, (13) Coupling and (14) Nut and bolt joints.

Surface Finishing Processes

Surface finishing processes are utilized for imparting intended surface finish on the surface of a job. By imparting a surface finishing process, dimension of part is not changed functionally; either a very negligible amount of material is removed from the certain material is added to the surface of the job. These processes should not be misunderstood as metal removing processes in any case as they are primarily intended to provide a good surface finish or a decorative or protective coating on to the metal surface. Surface cleaning process also called as a surface finishing process. Some of the commonly used surface finishing processes are:

(1) Honing, (2) Lapping, (3) Super finishing, (4) Belt grinding, (5) Polishing, (6) Tumbling, (7) Organic finishes, (8) Sanding, (9) deburring, (10) Electroplating, (11) Buffing, (12) Metal spraying, (13) Painting, (14) Inorganic coating, (15) Anodizing, (16) Sheradising, (17) Parkerizing, (18) Galvanizing, (19) Plastic coating, (20) Metallic coating, (21) Anodizing and (22) Sand blasting.

Processes Effecting Change in Properties

Processes effecting change in properties are generally employed to provide certain specific properties to the metal work pieces for making them suitable for particular operations or use. Some important material properties like hardening, softening and grain refinement are needed to jobs and hence are imparted by heat treatment. Heat treatments affect the physical properties and also make a marked change in the internal structure of the metal. Similarly the metal forming processes effect on the physical properties of work pieces Similarly shot peening process, imparts fatigue resistance to work pieces. A few such commonly used processes are given as under:

(1) Annealing, (2) Normalising, (3) Hardening, (4) Case hardening, (5) Flame hardening, (6) Tempering, (7) Shot peeing, (8) Grain refining and (9) Age hardening.

In addition, some allied manufacturing activities are also required to produce the finished product such as measurement and assembly.

PRODUCT SIMPLIFICATION AND STANDARDISATION

The technique of simplification and standardization of product is closely inter-related that leads to higher efficiency in production, better quality and reduced production cost. Simplification is a process of determining limited number of grades, types and sizes of a components or products or parts in order to achieve better quality control, minimize waste, simplify production and, thus, reduce cost of production.

By eliminating unnecessary varieties, sizes and designs, simplification leads to manufacture identical components or products for interchangeability and maintenance purposes of assembly of parts. Standardization is the important step towards interchangeable manufacture, increased output and higher economy.

The technique of standardization comprises of determining optimal manufacturing processes, identifying the best possible engineering material, and allied techniques for the manufacture of a product and adhering to them very strictly so long as the better standards for all these are not identified. Thus definite standards are set up for a specified product with respect to its quality, required equipment, machinery, labor, material, process of manufacture and the cost of production

INSPECTION AND QUALITY CONTROL

A product is manufactured to perform desired functions. It must have a specified dimension such as length, width, height, diameter and surface smoothness to perform or accomplish its intended function. It means that each product requires a defined size, shape and other characteristics as per the design specifications. For manufacturing the product to the specified size, the dimensions should be measured and checked during and after the manufacturing process. It involves measuring the size, smoothness and other features, in addition to their checking. These activities are called measurement and inspection respectively.

In the era of globalization, every industry must pay sufficient attention towards maintaining quality because it is another important requirement or function of a production unit. If a manufacturing concern wants to survive for longer time and to maintain its reputation among the users, it should under all condition apply enough efforts not only to keep up the standard of quality of its products once established but to improve upon the same from time to time.

For this, every manufacturing concern must maintain a full-fledged inspection and quality control department which inspects the product at different stages of its production. Vigilant inspection of raw materials and products depends upon the entire process of standardization. The production unit of manufacturing concern must produce identical products. However a minor variation may be allowed to a predetermined amount in their finished dimensions of the products. The two extremities of dimensions of the product are called limits. All the parts of which the finished dimensions lie within these limits are acceptable parts. This facilitates easy and quicker production, easy inspection, requires less skill on the part of worker and accommodates a slight inaccuracy in the machine as well, resulting in an overall reduction in the production cost of the part.

MECHANIZATION AND AUTOMATION

Mechanization means something is done or operated by machinery and not by hand. Mechanization of the manufacturing means is milestone oriented trend towards minimizing the human efforts to the extent of its possibility, by adopting mechanical and electrical means or methods for automating the different manufacturing processes. Such a trend may be in the area of automating and mechanizing the processes of material handling, loading and unloading of components, actual operations performed on the job or transportation, etc. But, no feedback is provided by the process, operation or machinery. Extension of mechanization of the production process is termed as automation and it is controlled by a closed loop system in which feedback is provided by the sensors. It controls the operations of different machines automatically. The automatic control may be applied for some operations or for all the operations of a machine or group of machines. Accordingly the machine will be known as semi-automatic or fully automatic. The term was identified shortly after the World War II at the Ford Motor Company to describe the automatic handling of materials and parts between the process operations. The word ‘automation’ is derived from the Greek word automatos meaning self-acting. Automation can also be defined as the process of following a predetermined sequence of operations with little or no human intervention, using specialized equipment and devices that perform and control the manufacturing process. Automation is a word that has many meanings in the industry today. Automatic machines of all kinds existed long before the term automation was conceived. But, it should be noted that all automatic machines do not come under the category of automation. Automation is a technology concerned with the application mechanical, electronic, and computer based systems to operate and control production.

Every machine should involve some automation, may be to a lesser degree or to a higher extent to which is mainly governed by economic considerations. Automation means a system in which many or all of the processes in the production, movement, and inspection of parts and material are performed under control by the self-operating devices called controllers. This implies that the essential elements of automation comprise of mechanization, sensing, feedback, and control devices. The reasons why one should go for automation are:

1. Increased productivity
2. Reduced cost of labor and dependence on labor shortages
3. Improved quality
4. Reduced in-process inventory
5. Reduced manufacturing time
6. Reduced dependence on operator skills
7. Increased safety or reduced risk of humans.

Automation can be classified into three categories, viz.

1. Fixed automation
2. Programmable automation
3. Flexible automation.

Fixed Automation

It is also known as hard automation which is utilized to produce a standardized product such as gears, nuts and bolts, etc. Even though the operating conditions can be changed, fixed automation is used for very large quantity production of one or few marginally different components. Highly specialized tools, devices, equipment, special purpose machine tools, are utilized to produce a product or a component of a product very efficiently and at high production rates with as low unit costs as possible relative to other alternative methods of manufacturing.

Programmable Automation

In programmable automation, one can change the design of the product or even change the product by changing the program. Such technique is highly useful for the low quantity production of large number of different components. The equipments used for the manufacturing are designed to be flexible or programmable. The production normally carried out in batches.

Flexible Automation

There is a third category possible between fixed automation and programmable automation that is called flexible automation using Computer Aided Design (CAD) and Computer Aided Manufacturing (CAD/CAM) activities. This is also called as flexible manufacturing system (FMS). It allows producing different products on the same equipment in any order or mix. One important example of programmable automation, in discrete manufacturing, is numerical control. Robot is another example of programmable automation. Robot being integral part of FMS and Computer Integrated Manufacturing (CIM) system can do a large number of manufacturing tasks for replacing the human labor.

COMPUTER AIDED MANUFACTURING (CAM)

The computer aided manufacturing implies manufacturing itself, aided or controlled by computers. In a wider sense, it denotes all the activities in the manufacturing environment like use of computers in inventory control, project management, material requirement planning, data acquisition, testing and quality control. Improved reliability in view of the better manufacturing methods and controls at the manufacturing stage, the products thus manufactured as well as of the manufacturing system would be highly reliable.

Since most of the components of a CAM system would include integrated diagnostics and monitoring facilities, they would require less maintenance compared to the conventional manufacturing methods. Because of the Computer Numerical Control (CNC) machines used in production and the part programs being made by the stored geometry from the design stage, the scrap level would be reduced to the minimum possible and almost no rework would be necessary. Since all the information and controlling functions are attempted with the help of the computer, a better management control on the manufacturing activity is possible

1. Greater design freedom

Any changes that are required in design can be incorporated at any design stage without worrying about any delays, since there would hardly be any in an integrated CAM environment.

2. Increased productivity

In view of the fact that the total manufacturing activity is completely organized through the computer, it would be possible to increase the productivity of the plant.

3. Greater operating flexibility

CAM enhances the flexibility in manufacturing methods and changing of product lines.

4. Shorter lead time

Lead times in manufacturing would be greatly reduced.

The integration of CAD and CAM systems is called Computer Integrated Manufacturing (CIM) system. The role of computer in manufacturing may be in two major groups namely computer monitoring and control of the manufacturing process and manufacturing support applications, which deal essentially with the preparations for act of manufacturing and post manufacture operations. Computers are used in controlling machine tools and other material handling equipments.

MANUFACTURING SYSTEM

Manufacturing basically implies making of goods or articles and providing services to meet the needs of mankind. It creates value by useful application of physical and mental-labor in the process. It is a chain of interrelated activities of production process and other support services activities of an manufacturing environment such as order processing, product design, design and manufacturing of tools, die, mould, jigs, fixtures and gauges, selection of material, planning, managing and maintaining control of the processes, production, and reliable quality of processed product in a systematic and sequential manner with proper coordination, cooperation and integration of the whole manufacturing system that will lead to economical production and effective marketing of proposed product in the minimum possible time. It is, therefore, evident that manufacturing today is not a one man activity as it was in the initial stages, wherein all the physical and mental inputs were applied by a single craftsman.

Manufacturing system requires a large number of activities, few independent and rests mostly interrelated. The manufacturing activities in a manufacturing system jointly contribute towards economic and qualitatively acceptable production of desired articles in minimum possible time. As per the need of the customer, the products are identified and their demands are determined roughly for market forecast by considering present and future competition. Products that may render the desired service over its expected life satisfactorily as per requirement of customers are identified in terms of their demand, conceived and developed for securing orders by the sales department. Once the product design activity is over and the design finalized from all angles, functional, aesthetic, material selection, safety, economy, etc., it is followed by preparation of production drawings of the product assembly and its components including a bill of materials. This is the stage where a make or buy decision has to be taken in order to decide as to which components are to be bought from outside and which are to be manufactured within the concern. It is followed by process planning i.e. selection of the best process and an its parameters, design of jigs, fixtures and dies, selection of tooling, programming of tool path as per need, for the components to be produced in-house. An important activity in process planning within the organization is also to involve latest research and development findings, through which the old processes are improved and new one’s are developed in order to ensure better quality and economic production. The interaction of different manufacturing activities in a manufacturing system can also be further enhanced by the use of computer and hence leading CIM. The real manufacturing or production activity is carried out on the shop. The layout of the shop floor has a significant influence on the tools required to be coordinated in order to an economical and high quality production of various components. It should be such that it ensures timely movement of raw materials, dies moulds, jigs and fixtures and finished components, adequate safety to men, material and machinery, enables timely inspection and quality control and minimizes handling time for material and parts, etc. During actual manufacturing a lot of different activities are called management function. Various engineers play an important role in the organizational function of a manufacturing concern. They are required to ensure proper movement of the material, tools and parts as per their specialized jobs in industry.

SHEET METAL WORK

Products made through the sheet metal processing include automobile bodies, utensils, almirah, cabinet's appliances, electronic components, electrical parts, aerospace parts, refrigeration and air conditioning parts etc. Sheet metal is generally considered to be a plate with thickness less than about 5 mm. Articles made by sheet metal work are less expensive and lighter in weight. Sheet metal forming work started long back 5000 BC. As compared to casting and forging, sheet-metal parts offer advantages of lightweight and versatile shapes. Because of the good strength and formability characteristics, low carbon steel is the most commonly utilized in sheet-metal processing work. The metal stampings have now replaced many components, which were earlier made by casting or machining. In few cases sheet metal products are used for replacing the use of castings or forgings. Sheet metal work has its own significance in the engineering work. Sheet metal processing has its own significance as a useful trade in engineering works to meet our day-to-day requirements. Many products, which fulfill the household needs, decoration work and various engineering articles, are produced from sheet meta1s. A good product properly developed may lead to saving of time and money.

In sheet-metal working, there is no need for further machining as required for casting and forging works. The time taken in sheet-metal working is approximately half of that required in the machining process. For carrying out sheet metal work, the knowledge of geometry, mensuration and properties of metal is most essential because nearly all patterns come from the development of the surfaces of a number of geometrical models such as cylinder, prism, cone, and pyramid. In sheet metal work, various operations such as shearing, blanking, piercing, trimming, shaving, notching, forming, bending, stamping, coining, embossing etc. are to be performed on sheet metal using hand tools and press machines to make a product of desired shape and size. Generally metals used in sheet metal work are black iron, galvanized iron, stainless steel, copper, brass, zinc, aluminium, tin plate and lead.

METALS USED IN SHEET METAL WORK

The following metals are generally used in sheet metal work:

Black Iron Sheet

It is probably the cheapest of all the metal used for sheet metal work. It is bluish black in appearance and is used generally in form of uncoated sheet. It can be easily rolled into the desired thickness. Since it is uncoated it corrodes rapidly. Hence to increase its life it can be painted or enameled. This metal is generally used in the making or roofs, food containers, stove pipes, furnace fittings, dairy equipments, tanks, cans and pans, etc.

Galvanized Iron (G.I.)

It is popularly known as G.I. sheets. It is soft steel coated with molten zinc. This coating resists rust formation on surface and improves appearance and water resistance. Articles such as pans, furnaces, buckets, cabinets etc. are made from GI sheets.

Stainless Steel

It is an alloy of steel with nickel, chromium and small percentages of other metals. It has good corrosion resistance. It is costlier but tougher than GI sheets. 1t is used in kitchenware, food processing equipments, food handling articles, tools and instruments for surgery work in hospitals and components of chemical plants etc.

Other metal sheets used for sheet metal work are made up of copper, aluminum, tin, and lead.

SHEET METAL TOOLS

The following tools are commonly used for sheet-metal work:

(*i*) Hand shears or snips

(*ii*) Hammers

(*iii*) Stakes and stake holder

(*iv*) Cutting tools

(*v*) Measuring tools

(*vi*) Miscellaneous hand tools such as chisels, groovers, seamers, rivet sets and hand punches. Some of the important sheet metal tools are described as under.

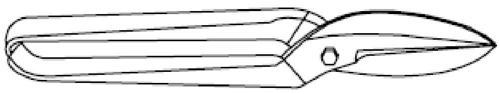
HAND SHEARS OR SNIPS

Fig 18.1 shows the types of hand shears or snips. They resemble with pair of scissors and are used like them to cut thin soft metal sheets of 20 gauge or thinner. They are required to size and shape the sheets. They can make straight or circular cuts. Different types of hand shears are:

(1) **Straight hand shear:** It is used for general purpose cutting, making straight cuts and trimming away extra metal.

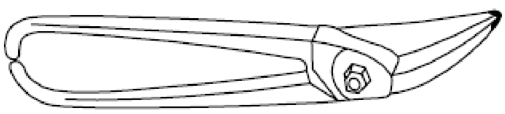
(2) **Universal shear:** Its blades are designed for universal cutting straight line or internal and external cutting of contours. It may be of right hand or left hand type, easily identifiable, as the top blade is either on the right of on the left.

(3) **Curved hand shear:** It is used for cutting circular or irregular curved shapes ranging from 20 to 35 cm



Straight hand shear

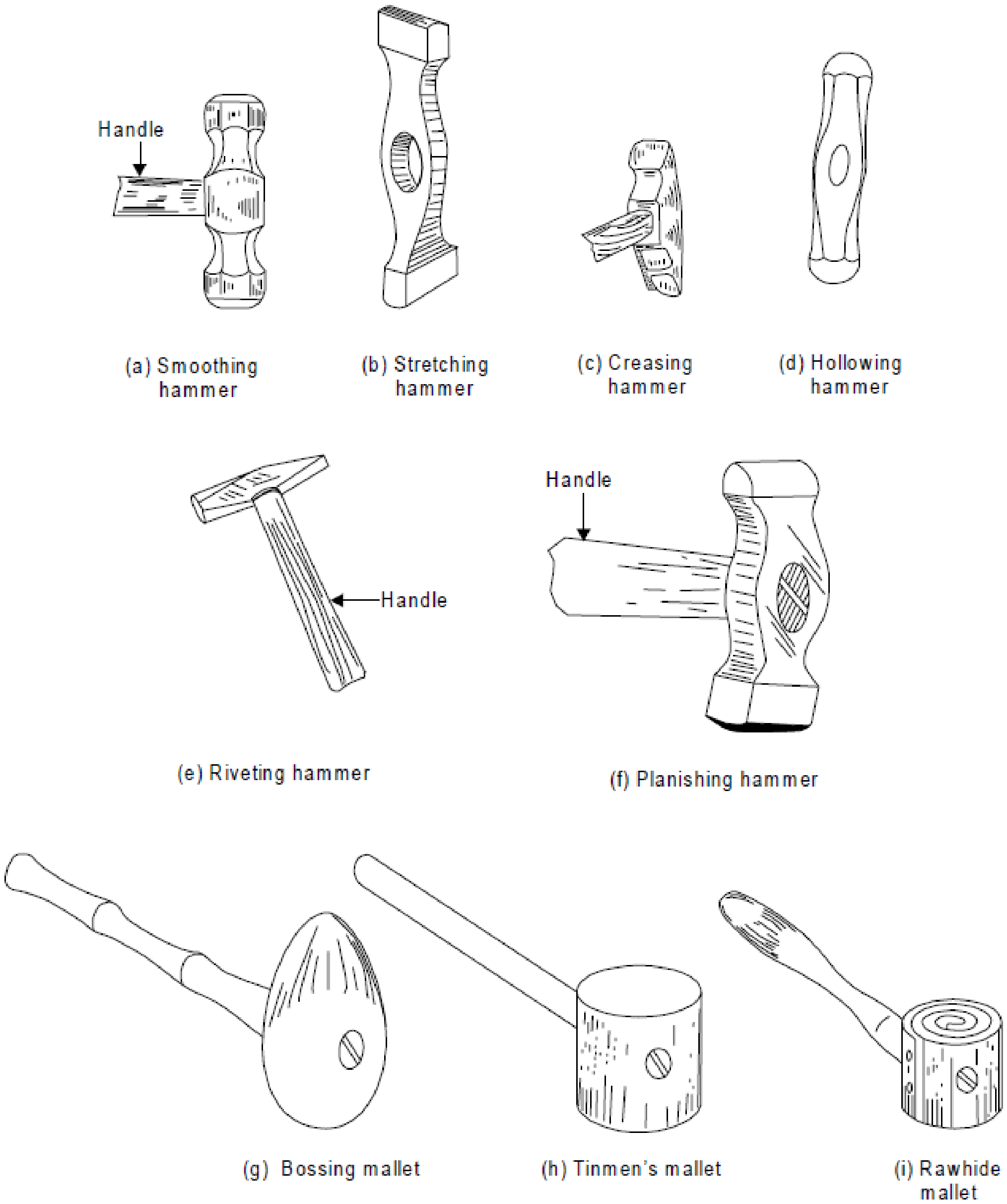
Universal shear



Curved hand shear

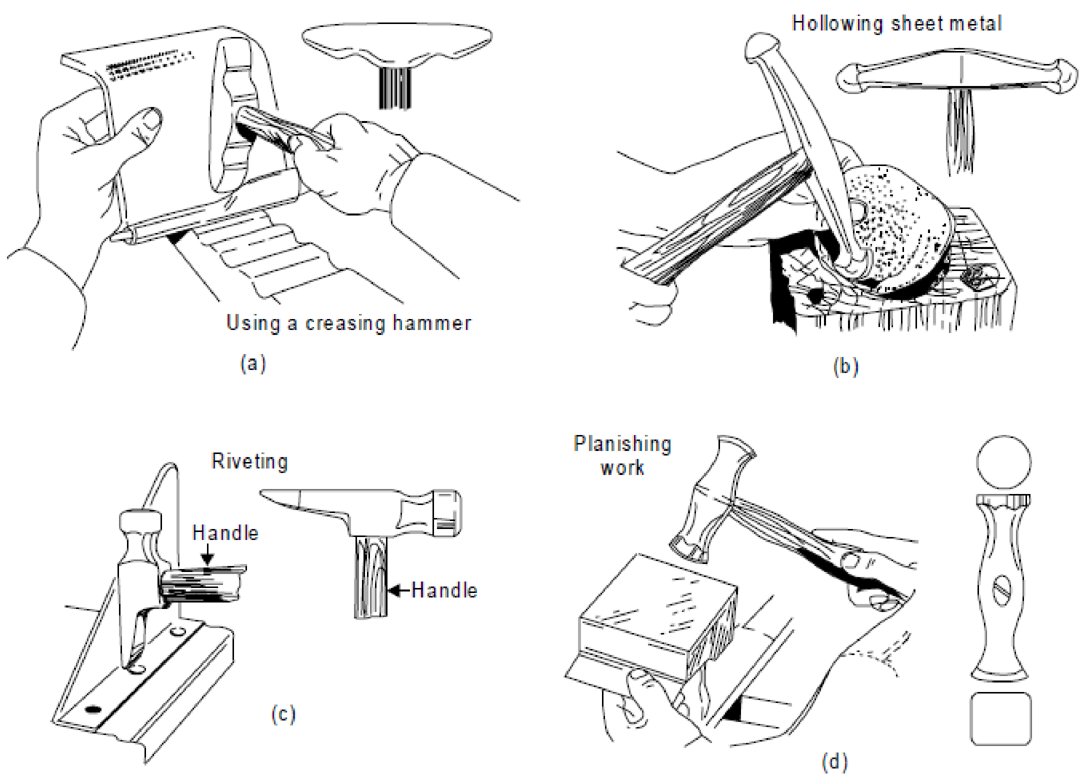
HAMMERS

Figure shows the various types of hammers used in sheet metal work for forming shapes. The uses of different kind of hammers are given as under:



a) **Smoothing hammer.** Smoothing hammer is used for leveling and smoothing a sheet metal joint.
b) **Stretching hammer.** Stretching hammer is used for stretching sheet.
c) **Creasing hammer.** Creasing hammer is used to close down joint edges of sheets metal part.
d) **Hollowing hammer.** Hollowing hammer is used for hollowing sheet metal part. It is used for generating sharp radii also.
e) **Riveting hammer.** Riveting hammer is used for forming riveted heads.
f) **Planishing hammer.** Planishing hammer is used for removing smallmarks or indentations from the sheet metal job surface and to true the shape of the work. It smoothens off the finished sheet metal work.
g) **Soft hammer or Mallets.** Mallets used during working with soft metal sheets. They may be of wood, rubber or raw hide. A mallet strikes a blow with theminimum damage to the surface. In sheet metal work, the commonly used mallets are bossing mallet, tinman's mallet (Fig. 18.3(h)) and rawhide mallet .

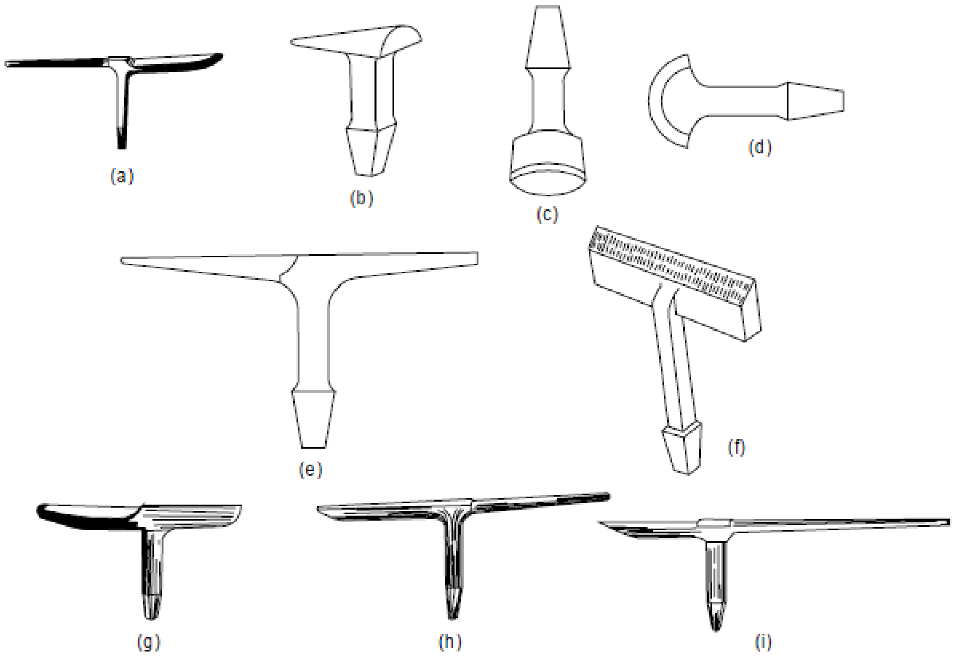
The uses of hammers for some sheet metal operations are depicted through following figures



Stakes

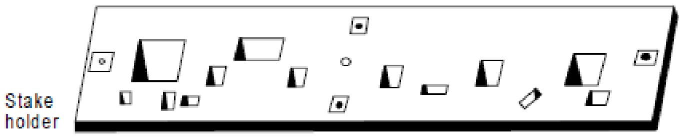
Stakes are used to form the metal sheets into various shapes. It is a sort of anvil, which supports the sheet for sheet metal work. It consists of a shank and a head or horn. The shank of stake is designed to fit into a tapered bench socket. The head or horn of stake is available in a number of varieties of sizes and shapes. Their working faces of stakes are machined or ground to needed shape. With the help of a hammer, operations such as bending, seaming or forming can be easily performed on these stakes. Some stakes are made of forged mild steel faced with cast steel. Whereas the better class stakes are made either of cast iron or cast steel. Fig 18.4 shows the various types of stakes, which are discussed below:

1. **Beak horn stake.** Beak horn is basically used for forming, riveting and seaming articles made of sheet metal part. It is not much suitable like blow horn stake. It has a thick tapered horn at one end and a rectangularly shaped horn at the other.
2. **Funnel stake.** Funnel stake is commonly used for planishing tapered work and hand forming of funnels and similar conical shapes of sheet metal.
3. **Half moon stake.** Half moon stake is basically used for throwing up edges of curved sheet metal work and for preliminary stages of wiring curved edges.
4. **Round bottom stake.** Round bottom stake is commonly used for squaring up edges and setting up the bottom of cylindrical jobs made up of sheets.
5. **Bick iron.** Bick iron stake is mainly used for forming taper handles, spouts and tubular work in general. The narrow flat anvil end of bick iron is very useful on rectangular work.
6. **Hatchet stake.** Hatchet stake is generally used for making sharp bends, bending edges and forming boxes and pans of sheet metal by hand. This stake has a sharp straight edge beveled along one side.
7. **Creasing with horn stake.** Creasing horn stake has a round horn used for forming conical shaped pieces in sheets. The other end has a tapering square horn with grooved slots for wiring and beading.
8. **Needle case stake.** Needle case stake is generally used for bending of sheets. It has a round slender horn for forming wire rings and tubes.
9. **Candle mold stake.** Candle mold stake has two horns for different tapers when forming, seaming and riveting long flaring articles made up of sheet metal.



Stake Holder

Figure shows the stake holder, which is a rectangular cast iron plate that has conveniently arranged tapered holes so that the various stakes may fit in and may be used in different positions for tackling the sheet metal job for a particular work.



Cutting Tools

Commonly used cutting tools involve types of files, chisels, scraper and hacksaws. Some of the commonly used cutting tools are discussed as under.

1. **Files.** These are flat, square, round, triangular, knife, pillar, needle and mill types.
2. **Chisels.** The flat chisel and round nose chisel are most widely used in sheet metal work.
3. **Scrapers.** These are flat, hook; triangular, half round types.
4. **Hacksaws.** Hacksaw used in sheet metal shop may be hand hacksaw or power hacksaw.

Measuring Tools

There are a fairly large number of measuring tools used in sheet metal shop, which are described in detail along with relevant figures in chapter 19 dealing with fitting work. The most commonly used measuring tools are given as under.

1. Folding rule
2. Circumference rule
3. Steel rule
4. Vernier caliper
5. Micrometer
6. Thickness gauge

SHEET METAL OPERATIONS

The major sheet metal operations carried out in sheet metal work are as follows:

1. Cleaning
2. Measuring

3. Marking
4. Laying out
5. Hand cutting
6. Hand shearing
7. Hand forming
8. Edge forming
9. Wiring
10. Joint making
11. Bending
12. Drawing
13. Soldering
14. Circle cutting
15. Machine shearing
16. Nibbling
17. Piercing
18. Blanking

Measuring and Marking

The standard sizes of metal sheets available in the market are quite large. But the required sheet size for making a component may be smaller and hence a standard size sheet may have to be therefore cut into several smaller pieces. Each piece must be sufficient for making one such component as per the needed size. Smaller sizes of sheet metal part are first decided and are then marked on the larger metal sheet to cut the latter into small pieces along the marked lines. A little allowance for cutting is always incorporated to the required overall sizes. The overall dimensions of the required smaller sizes are marked on the larger sheet with the help of marking tools such as a steel rule, a straight edge, a steel square and a scriber. The sheet surface may have to be coated with a coloring media so that the scribed lines arc clearly visible. If circular pieces are needed, a divider or trammel may be used to mark the circles.

Shearing. It takes place in form a cut when punch strikes and enters in the sheet placed on die. The quality of the cut surface is greatly influenced by the clearance between the two shearing edges of the punch and dies.

Cutting. It means severing a piece from a strip or sheet with a cut along a single line using suitable punch and die of press tool in press machine.

Parting. It signifies that scrap is removed between the two pieces to part them using suitable punch and die of press tool in press machine.

Blanking. It is a operation in which the punch removes a portion of material called blank from the strip of sheet metal of the necessary thickness and width using suitable punch and die of press tool in press machine.

Punching. It is the operation of producing circular holes on a sheet metal by a punch and die. The material punched out is removed as waste. Piercing, on the other hand, is the process of producing holes of any desired shape in the part or sheet using suitable punch and die of press tool in press machine.

Notching. It is a process to cut a specified shape of metal from the side or edge of the stock using suitable punch and die.

Slitting. When shearing is conducted along a line, the process is referred to as slitting. It cuts the metal sheet lengthwise using suitable punch and die of press tool in press machine.

Lancing. It makes a cut part way across a sheet and creates a bend along the cut using suitable punch and die.

Nibbling. It is an operation of cutting any shape from sheet metal without special tools. It is done on a nibbling machine.

Trimming. It is the operation of cutting away excess metal in a flange or flash from a sheet metal part using suitable punch and die of press tool in press machine.

Bending. Bending is the operation of deforming a sheet around a straight axis. The neutral plane lies on this straight axis. In bending all sheet material are stressed beyond the elastic limit in tension on the outside and in compression on the inside of the bend. There is only one line, the natural line that retains its original length. The neutral axis lies at a distance of 30 to 50% of thickness of the sheet from the inside of the bend. Stretching of the sheet metal on the outside makes the stock thinner. Bending is sometimes called as forming, which involves angle bending, roll bending, roll forming, seaming and spinning.

METAL JOINING PROCESS

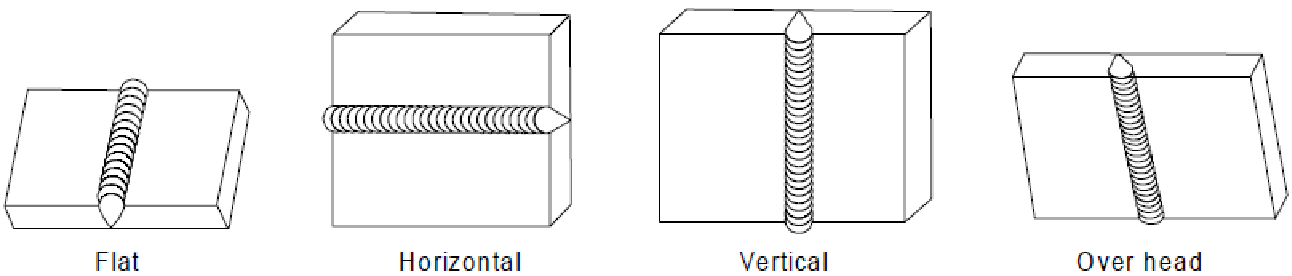
Welding is a process for joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be generated either from combustion of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

Welding provides a permanent joint but it normally affects the metallurgy of the components. It is therefore usually accompanied by post weld heat treatment for most of the critical components. The welding is widely used as a fabrication and repairing process in industries. Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc. Most of the metals and alloys can be welded by one type of welding process or the other. However, some are easier to weld than others. To compare this ease in welding term ‘weldability’ is often used.

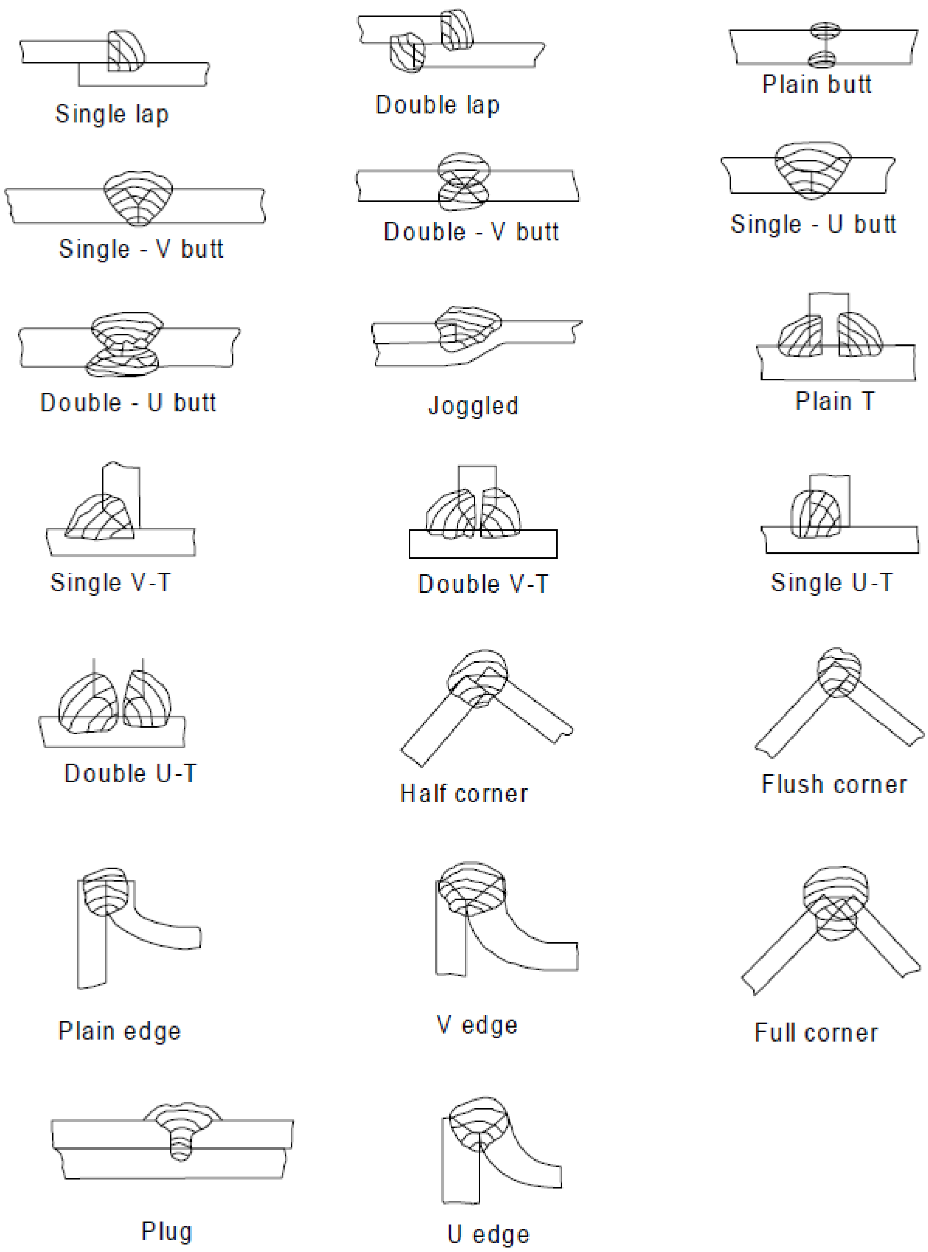
The weldability may be defined as property of a metal which indicates the ease with which it can be welded with other similar or dissimilar metals. Weldability of a material depends upon various factors like the metallurgical changes that occur due to welding, changes in hardness in and around the weld, gas evolution and absorption, extent of oxidation, and the effect on cracking tendency of the joint. Plain low carbon steel (C-0.12%) has the best weldability amongst metals. Generally it is seen that the materials with high castability usually have low weldability.

Welding Positions

As shown in Figure, there are four types of welding positions, which are given as:



Welding joints



ADVANTAGES AND DISADVANTAGES OF WELDING

Advantages

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

Disadvantages

1. It results in residual stresses and distortion of the workpieces.
2. Welded joint needs stress relieving and heat treatment.
3. Welding gives out harmful radiations (light), fumes and spatter.

4. Jigs, and fixtures may also be needed to hold and position the parts to be welded
5. Edges preparation of the welding jobs are required before welding
6. Skilled welder is required for production of good welding
7. Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

CLASSIFICATION OF WELDING AND ALLIED PROCESSES

There are different welding, brazing and soldering methods are being used in industries today. There are various ways of classifying the welding and allied processes. For example, they may be classified on the basis of source of heat, i.e., blacksmith fire, flame, arc, etc. and the type of interaction i.e., liquid / liquid (fusion welding) or solid/solid (solid state welding). Welding processes may also be classified in two categories namely plastic (forge) and fusion. However, the general classification of welding and allied processes is given as under

Welding Processes

1. Oxy-Fuel Gas Welding Processes

1. Air-acetylene welding
2. Oxy-acetylene welding
3. Oxy-hydrogen welding
4. Pressure gas welding

2. Arc Welding Processes

1. Carbon Arc Welding
2. Shielded Metal Arc Welding
3. Submerged Arc Welding
4. Gas Tungsten Arc Welding
5. Gas Metal Arc Welding
6. Plasma Arc Welding
7. Atomic Hydrogen Welding
8. Electro-slag Welding
9. Stud Arc Welding
10. Electro-gas Welding

3. Resistance Welding

1. Spot Welding
2. Seam Welding
3. Projection Welding
4. Resistance Butt Welding
5. Flash Butt Welding
6. Percussion Welding
7. High Frequency Resistance Welding
8. High Frequency Induction Welding

4. Solid-State Welding Processes

1. Forge Welding
2. Cold Pressure Welding
3. Friction Welding
4. Explosive Welding
5. Diffusion Welding
6. Cold Pressure Welding
7. Thermo-compression Welding

5. Thermit Welding Processes

1. Thermit Welding
2. Pressure Thermit Welding

6. Radiant Energy Welding Processes

1. Laser Welding
2. Electron Beam Welding

Allied Processes

1. Metal Joining or Metal Depositing Processes

1. Soldering
2. Brazing
3. Braze Welding
4. Adhesive Bonding
5. Metal Spraying
6. Surfacing

2. Thermal Cuting Processes

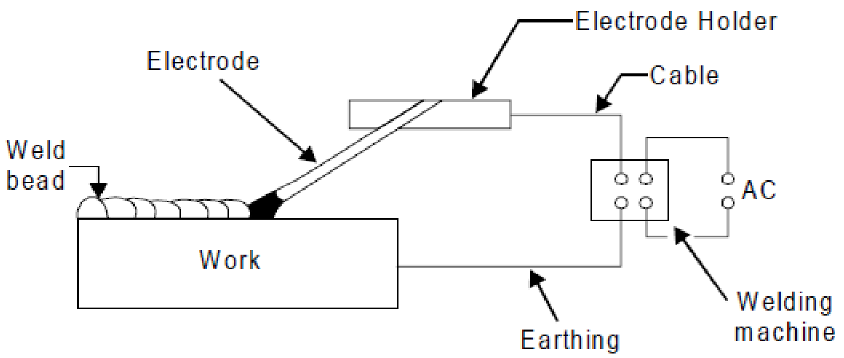
1. Gas Cutting
2. Arc Cutting

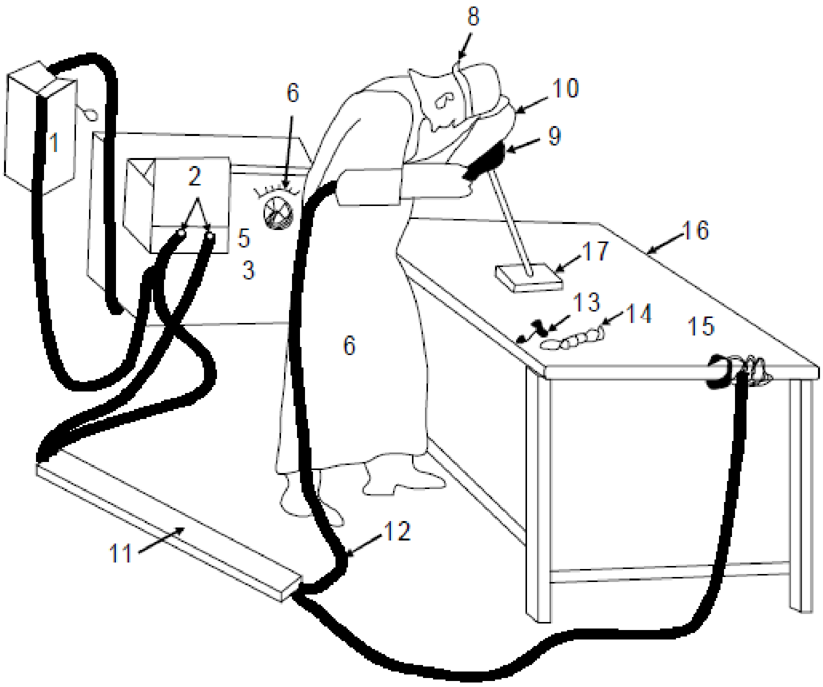
ARC WELDING PROCESSES

The process, in which an electric arc between an electrode and a workpiece or between two electrodes is utilized to weld base metals, is called an arc welding process. The basic principle of arc welding is shown in Fig 17.9(a). However the basic elements involved in arc welding process are shown in Figure Most of these processes use some shielding gas while others

employ coatings or fluxes to prevent the weld pool from the surrounding atmosphere. The various arc welding processes are:

1. Carbon Arc Welding
2. Shielded Metal Arc Welding
3. Flux Cored Arc Welding
4. Gas Tungsten Arc Welding
5. Gas Metal Arc Welding
6. Plasma Arc Welding
7. Atomic Hydrogen Welding
8. Electroslag Welding
9. Stud Arc Welding
10. Electrogas Welding





(1) Switch box.
(2) Secondary terminals.
(3) Welding machine.
(4) Current reading scale.
(5) Current regulating hand wheel.
(6) Leather apron.
(7) Asbestos hand gloves.
(8) Protective glasses strap.
(9) Electrode holder.
(10) Hand shield.
(11) Channel for cable protection.
(12) Welding cable.
(13) Chipping hammer.
(14) Wire brush.
(15) Earth clamp.
(16) Welding table (metallic).
(17) Job.

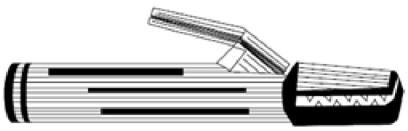
Arc Welding Equipment

Arc welding equipment, setup and related tools and accessories are shown in Fig. However some common tools of arc welding are shown separately through Fig. Few of the important components of arc welding setup are described as under.

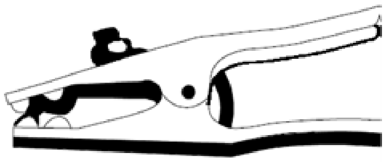
1. Arc welding power source

Both direct current (DC) and alternating current (AC) are used for electric arc welding, each having its particular applications. DC welding supply is usually obtained from generators driven by electric motor or if no electricity is available by internal combustion engines. For AC welding supply, transformers are predominantly used for almost all arc welding wheremains electricity supply is available. They have to step down the usual supply voltage (200- 400 volts) to the normal open circuit welding voltage (50-90 volts). The following factors influence the selection of a power source:

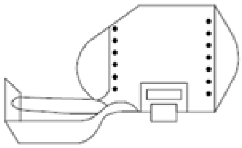
1. Type of electrodes to be used and metals to be welded
2. Available power source (AC or DC)
3. Required output
4. Duty cycle
5. Efficiency
6. Initial costs and running costs
7. Available floor space
8. Versatility of equipment



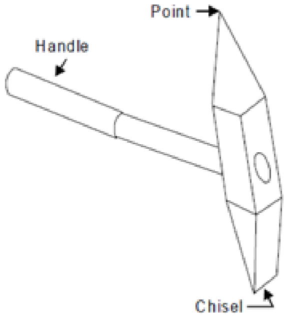
Electrode holder



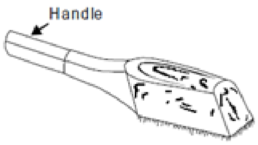
Earth clamp



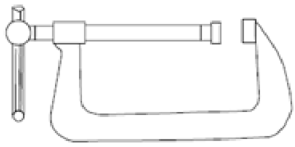
Hand screen



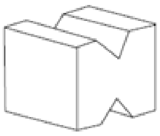
Chipping and hammer



Wire brush



C-clamp



V-block

Scriber

2. Welding cables

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

3. Electrode holder

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

4. Welding Electrodes

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

(1) Consumable Electrodes

a. Bare Electrodes
b. Coated Electrodes

(2) Non-consumable Electrodes

a. Carbon or Graphite Electrodes
b. Tungsten Electrodes

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

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

5. Hand Screen

Hand screen used for protection of eyes and supervision of weld bead.

6. Chipping hammer

Chipping Hammer is used to remove the slag by striking.

7. Wire brush

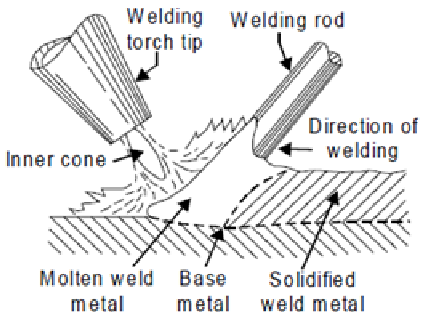
Wire brush is used to clean the surface to be weld.

8. Protective clothing

Operator wears the protective clothing such as apron to keep away the exposure of direct heat to the body.

GAS WELDING PROCESSES

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



Gas welding operation

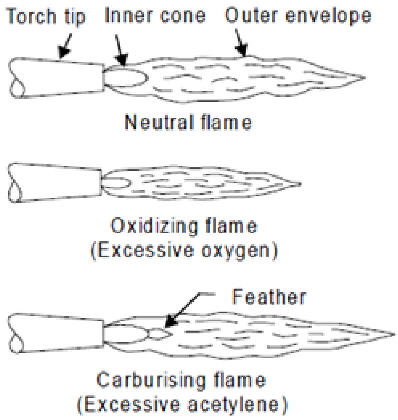
Oxy-Acetylent Welding

In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited. The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal. The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use. A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

Types of Welding Flames

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

1. Neutral welding flame (Acetylene and oxygen in equal proportions).
2. Carburizing welding flame or reducing (excess of acetylene).
3. Oxidizing welding flame (excess of oxygen).The gas welding flames are shown in Fig



Gas welding flames

Neutral Welding Flame

A neutral flame results when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. The temperature of the neutral flame is of the order of about 5900°F (3260°C). It has a clear, well defined inner cone, indicating that the combustion is complete. The inner cone is light blue in color. It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone. This envelope is Usually a much darker blue than the inner cone. A neutral flame is named so because it affects no chemical change on the molten metal and, therefore will not oxidize or carburize the metal. The neutral flame is commonly used for the welding of mild steel, stainless steel, cast Iron, copper, and aluminium.

Carburising or Reducing Welding Flame

The carburizing or reducing flame has excess of acetylene and can be recognized by acetylene feather, which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color. With iron and steel, carburizing flame produces very hard, brittle substance known as iron carbide. A reducing flame may be distinguished from carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame. A reducing flame has an approximate temperature of 3038°C.

A carburizing-flame is used in the welding of lead and for carburizing (surface hardening) purpose. A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition. It is used for welding with low alloy steel rods and for welding those metals, (e.g., non-ferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

Oxidising Welding flame

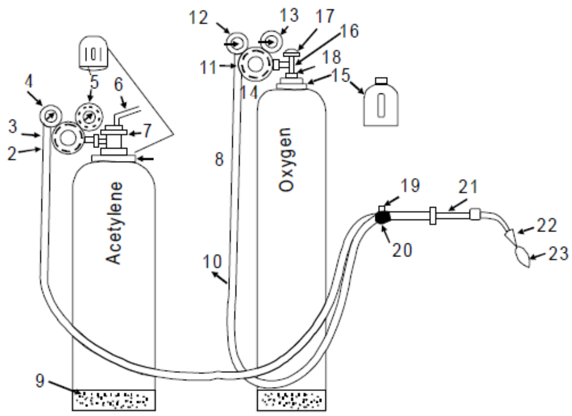
The oxidizing flame has an excess of oxygen over the acetylene. An oxidizing flame can be recognized by the small cone, which is shorter, much bluer in color and more pointed than that of the neutral flame. The outer flame envelope is much shorter and tends to fan out at the end. Such a flame makes a loud roaring sound. It is the hottest flame (temperature as high as 6300°F) produced by any oxy-fuel gas source. But the excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides. Moreover, an excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance. For these reasons, an oxidizing flame is of limited use in welding. It is not used in the welding of steel.

A slightly oxidizing flame is helpful when welding (*i*) Copper-base metals (*ii*) Zinc-base metals and (*iii*) A few types of ferrous metals such as manganese steel and cast iron. The oxidizing atmosphere in these cases, create a basemetal oxide that protects the base metal.

GAS WELDING EQUIPMENTS

Acetylene and oxygen gas is stored in compressed gas cylinders. These gas cylinders differ widely in capacity, design and colour code. However, in most of the countries, the standard size of these cylinders is 6 to 7 m3 and is painted black for oxygen and maroon for acetylene. An acetylene cylinder is filled with some absorptive material, which is saturated with a chemical solvent acetone.

Acetone has the ability to absorb a large volume of acetylene and release it as the pressure falls. If large quantities of acetylene gas are being consumed, it is much cheaper to generate the gas at the place of use with the help of acetylene gas generators. Acetylene gas is generated by carbide-to-water method. Oxygen gas cylinders are usually equipped with about 40 litres of oxygen at a pressure of about 154 Kgf/cm2 at 21°C. To provide against dangerously excessive pressure, such as could occur if the cylinders were exposed to fire, every valve has a safety device to release the oxygen before there is any danger of rupturing the cylinders. Fragile discs and fusible plugs are usually provided in the cylinders valves in case it is subjected to danger.



1. Acetylene hose
2. Adjusting screw
3. Acetylene regulator
4. Regulator outlet pressure gauge
5. Cylinder pressure gauge
6. Valve wrench
7. Acetylene cylinder valve
8. Cylinder cap
9. Fusible plugs
10. Oxygen hose
11. Oxygen regulator
12. Regulator outlet pressure gauge
13. Cylinder pressure gauge
14. Cylinder cap
15. Oxygen cylinder valve
16. Oxygen cylinder valve
17. Hand wheel
18. Bursting disc
19. Acetylene valve
20. Oxygen valve
21. Welding torch
22. Torch tip
23. Flame

Gas pressure regulators

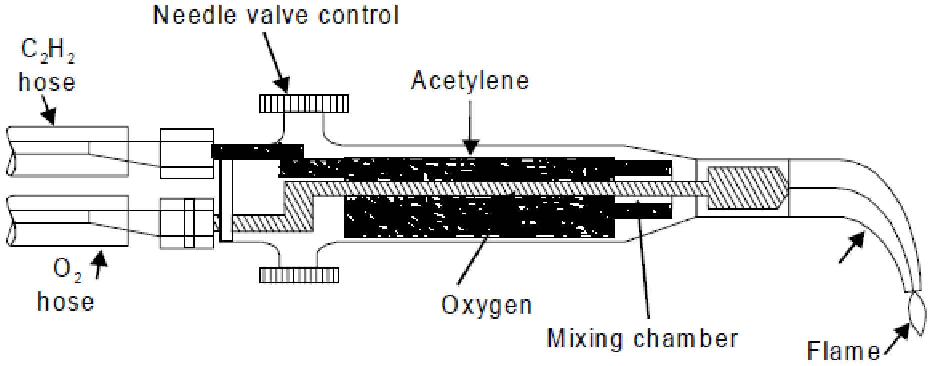
Gas pressure regulators are employed for regulating the supply of acetylene and oxygen gas from cylinders. A pressure regulator is connected between the cylinder and hose leading to welding torch. The cylinder and hose connections have left-handed threads on the acetylene regulator while these are right handed on the oxygen regulator. A pressure regulator is fitted with two pressure gauges, one for indication of the gas pressure in the cylinder and the other for indication of the reduced pressure at which the gas is going out.

Welding torch

Figure shows the construction of the welding torch. It is a tool for mixing oxygen and acetylene in correct proportion and burning the mixture at the end of a tip. Gas flow to the torch is controlled with the help of two needle valves in the handle of the torch. There are two basic types of gas welding torches:

(1) Positive pressure (also known as medium or equal pressure), and
(2) Low pressure or injector type

The positive pressure type welding torch is the more common of the two types of oxyacetylene torches.



Welding torch

Torch tips

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

Hose pipes

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

Goggles

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

Gloves

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

Spark-lighter

It is used for frequent igniting the welding torch.

Filler rods

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

Fluxes

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

Safety Recommendations for Gas Welding

1. Never hang a torch with its hose on regulators or cylinder valves.
2. During working, if the welding tip becomes overheated it may be cooled by plungingthe torch into water; close the acetylene valve but leave a little oxygen flowing.
3. Always use the correct pressure regulators for a gas. Acetylene pressure regulator should never be used with any other gas.
4. Do not move the cylinder by holding the pressure regulator and also handle pressure regulators carefully.
5. Use pressure regulator only at pressures for which it is intended.
6. Open cylinder valves slowly to avoid straining the mechanism of pressure regulator.
7. Never use oil, grease or lubricant of any kind on regulator connections

BRAZING

Like soldering, brazing is a process of joining metals without melting the base metal. Filler material used for brazing has liquidus temperature above 450°C and below the solidus temperature of the base metal. The filler metal is drawn into the joint by means of capillary action (entering of fluid into tightly fitted surfaces). Brazing is a much widely used joining process in various industries because of its many advantages. Due to the higher melting point of the filler material, the joint strength is more than in soldering.

Almost all metals can be joined by brazing except aluminum and magnesium which cannot easily be joined by brazing. Dissimilar metals, such as stainless steel to cast iron can be joined by brazing. Because of the lower temperatures used there is less distortion in brazed joints. Also, in many cases the original heat treatment of the plates being joined is not affected by the brazing heat. The joint can be quickly finished without much skill. Because of the simplicity of the process it is often an economical joining method with reasonable joint strength.

The brazed joints are reasonably stronger, depending on the strength of the filler metal used. But the brazed joint is generally not useful for high temperature service because of the low melting temperature of the filler metal. The color of the filler metal in the brazed joint also, may not match with that of the base metal. Because the filler metal reaches the joint by capillary action, it is essential that the joint is designed properly. The clearance between the two parts to be joined should be critically controlled. Another important factor to be considered is the temperature at which the filler metal is entering the joint.

During brazing, the base metal of the two pieces to be joined is not melted. An important requirement is that the filler metal must wet the base metal surfaces to which it is applied. The diffusion or alloying of the filler metal with the base metal place even though the base metal does not reach its solidus temperature. The surfaces to be joined must be chemically clean before brazing. However, fluxes are applied to remove oxides from the surfaces. Borax is the most widely used flux during the process of brazing. It will dissolve the oxides of most of the common metals.

Methods of Brazing

Torch Brazing

It is the most widely used brazing method. Heat is produced, generally, by burning a mixture of oxy-acetylene gas, as in the gas welding. A carbonizing flame is suitable for this purpose as it produces sufficiently high temperature needed for brazing.

Furnace Brazing

It is suitable for brazing large number of small or medium parts. Usually brazing filler metal in the granular or powder form or as strips is placed at the joint, and then the assembly is placed in the furnace and heated. Large number of small parts can be accommodated in a furnace and simultaneously brazed.

Braze Welding

In welding processes where the joint of the base metal is melted and a joint is prepared having higher joint strength, it is likely to cause metallurgical damage by way of phase transformations and oxide formation. In this process, the base metal is not melted, but the joint is obtained by means of a filler metal.

SOLDERING

Soldering is a method of joining similar or dissimilar metals by heating them to a suitable temperature and by means of a filler metal, called solder, having liquidus temperuatre not exceeding 450°C and below the solidus of the base material. Though soldering obtains a good joint between the two plates, the strength of the joint is limited by the strength of the filler metal used.

Solders are essentially alloys of lead and tin. To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmium and silver in various proportions. Soldering is normally used for obtaining a neat leak proof joint or a low resistance electrical joint. The soldered joints are not suitable for high temperature service because of the low melting temperatures of the filler metals used. The soldering joints also need to be cleaned meticulously to provide chemically clean surfaces to obtain a proper bond. Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering. To remove the oxides from the joint surfaces and to prevent the filler metal from oxidizing, fluxes are generally used in soldering.

Rosin and rosin plus alcohol based fluxes are least active type and are generally used for electrical soldering work. Because of the content of acids, these are corrosive at soldering temperature. They can be easily cleaned after the soldering. The organic fluxes such as zinc chloride and ammonium chloride are quick acting and produce efficient joints. But because of their corrosive nature the joint should be thoroughly cleaned of the entire flux residue from the joint. These are to be used for only non-electrical soldering work.

Fluxes are normally available in the form of powder, paste, liquid or in the form of core in the solder metal. It is necessary that the flux should remain in the liquid form at the soldering temperature and be reactive to be of proper use. The most commonly used soldering methods include soldering iron (flame or electrically heated), dip soldering, and wave soldering. A soldering iron is a copper rod with a thin tip which can be used for flattening the soldering material. The soldering iron can be heated by keeping in a furnace or by means of an internal electrical resistance whose power rating may range from 15 W for the electronic applications to 200 W for sheet metal joining.

This is the most convenient method of soldering but somewhat slower compared to the other methods.In dip soldering, a large amount of solder is melted in a tank which is closed. The parts that are to be soldered are first cleaned properly and dipped in a flux bath as per the requirement. These are then dipped into the molten solder pool and lifted with the soldering complete.

The wave soldering is a variant of this method wherein the part to be soldered (e.g.” an electronic printed circuit board, PCB) is not dipped into the solder tank, but a wave is generated in the tank so that the solder comes up and makes a necessary joint.

Basic Operations in Soldering

For making soldered joints, following operations are required to be performed sequentially.

1. Shaping and fitting of metal parts together

Filler metal on heating flows between the closely placed adjacent surfaces due to capillary action, thus, closer the parts the more is solder penetration. This means that the two parts should be shaped to fit closely so that the space between them is extremely small to be filled completely with solder by the capillary action. If a large gap is present, capillary action will not take place and the joint will not be strong.

2. Cleaning of surfaces

This is done to remove dirt, grease or any other foreign material from the surface pieces to be soldered, in order to get a sound joint. If surfaces are not clean, strong atomic bonds will not form.

3. Flux application

Soldering cannot be done without a flux. Even if a metal is clean, it rapidly acquires an oxide film of submicroscopic thickness due to heat and this film insulates the metal from the solder, preventing the surface to get wetted by solder. This film is broken and removed by the flux. The flux is applied when parts are ready for joining.

4. Application of heat and solder

The parts must be held in a vice or with special work holding devices so that they do not move while soldering. The parts being soldered must be heated to solder-melting and solder-alloying temperature before applying the solder for soldering to take place the assembly so that the heat is most effectively transmitted to the being soldered. As soon as the heat is applied, the flux quickly breaks down the oxide film (the insulating oxide layer barrier between the surface and solder). Now solder is applied which immediately melts and metal to metal contact is established through the medium of molten solder. Finally, the surplus solder is removed and the joint is allowed to cool. Blow torches dipping the parts in molten solder or other methods are also used for soldering.

Solders

Solders are alloys of lead and tin. Solder may also contain certain other elements like cadmium, and antimony in small quantities. The percentage composition of tin and lead determines the physical and mechanical properties of the solder and the joint made. Most solder is available in many forms-bar, stick, fill, wire, strip, and so on. It can be obtained in circular or semi-circular rings or any other desired shape. Sometimes the flux is included with the solder. For example, a cored solder wire is a tube of solder filled with flux.

Solder Fluxes

The flux does not constitute a part of the soldered joint. Zinc chloride, ammonium chloride, and hydrochloric acid are the examples of fluxes commonly used in soldering. The function of fluxes in soldering is to remove oxides and other surface compounds from the surfaces to be soldered by displacing or dissolving them. Soldering fluxes may be classified into four groups-

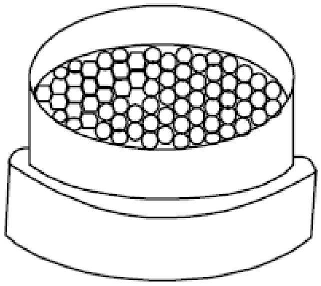
(1) Inorganic fluxes (most active)
(2) Organic fluxes (moderately active)
(3) Rosin fluxes (least active), and
(4) Special fluxes for specific applications

FOUNDARY

There are large number of tools and equipments used in foundry shop for carrying out different operations such as sand preparation, molding, melting, pouring and casting. They can be broadly classified as hand tools, sand conditioning tool, flasks, power operated equipments, metal melting equipments and fettling and finishing equipments. Different kinds of hand tools are used by molder in mold making operations. Sand conditioning tools are basically used for preparing the various types of molding sands and core sand. Flasks are commonly used for preparing sand moulds and keeping molten metal and also for handling the same from place to place. Power operated equipments are used for mechanizing processes in foundries. They include various types of molding machines, power riddles, sand mixers and conveyors, grinders etc. Metal melting equipment includes various types of melting furnaces such as cupola, pit furnace, crucible furnaces etc. Fettling and finishing equipments are also used in foundry work for cleaning and finishing the casting. General tools and equipment used in foundry are discussed as under.

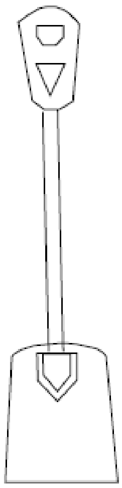
Hand Tools Used In Foundry Shop

The common hand tools used in foundry shop are fairly numerous. A brief description of the following foundry tools (used frequently by molder is given as under.



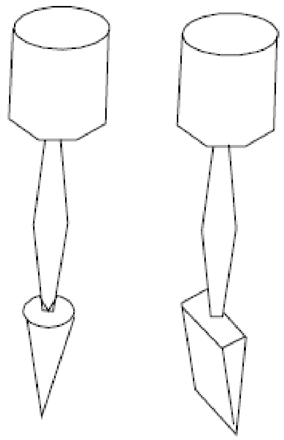
Hand riddle

Hand riddle is shown in Figure. It consists of a screen of standard circular wire mesh equipped with circular wooden frame. It is generally used for cleaning the sand for removing foreign material such as nails, shot metal, splinters of wood etc. from it. Even power operated riddles are available for riddling large volume of sand.



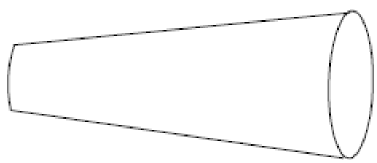
Shovel

Shovel is shown in Figure. It consists of an steel pan fitted with a long wooden handle. It is used in mixing, tempering and conditioning the foundry sand by hand. It is also used for moving and transforming the molding sand to the container and molding box or flask. It should always be kept clean.



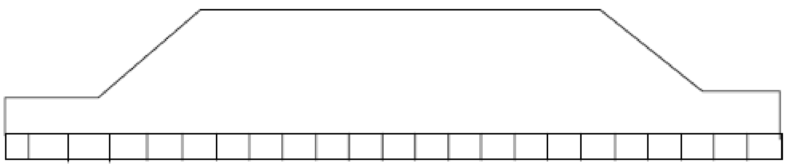
Sprue pin

Sprue pin is shown in Figure. It is a tapered rod of wood or iron which is placed or pushed in cope to join mold cavity while the molding sand in the cope is being rammed. Later its withdrawal from cope produce a vertical hole in molding sand, called sprue through which the molten metal is poured into the mould using gating system. It helps to make a passage for pouring molten metal in mold through gating system



Strike off bar

Strike off bar is a flat bar having straight edge and is made of wood or iron. It is used to strike off or remove the excess sand from the top of a molding box after completion of ramming thereby making its surface plane and smooth. Its one edge is made beveled and the other end is kept perfectly smooth and plane.

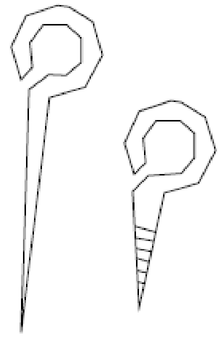


Mallet

Mallet is similar to a wooden hammer and is generally as used in carpentry or sheet metal shops. In molding shop, it is used for driving the draw spike into the pattern and then rapping it for separation from the mould surfaces so that pattern can be easily withdrawn leaving the mold cavity without damaging the mold surfaces.

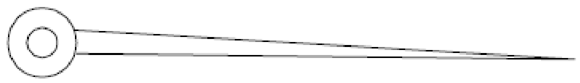
Draw spike

Draw spike is shown Figure. It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other. It may have screw threads on the end to engage metal pattern for it withdrawal from the mold. It is used for driven into pattern which is embedded in the molding sand and raps the pattern to get separated from the pattern and finally draws out it from the mold cavity



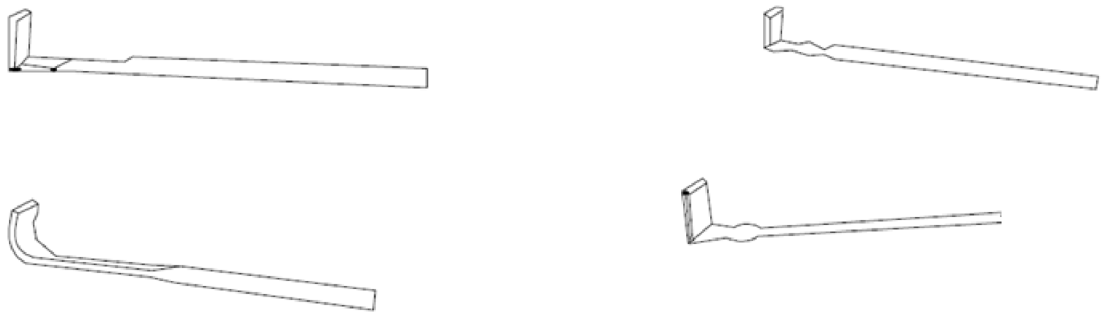
Vent rod

Vent rod is shown in Figure. It is a thin spiked steel rod or wire carrying a pointed edge at one end and a wooden handle or a bent loop at the other. After ramming and striking off the excess sand it is utilized to pierce series of small holes in the molding sand in the cope portion. The series of pierced small holes are called vents holes which allow the exit or escapeof steam and gases during pouring mold and solidifying of the molten metal for getting a sound casting.



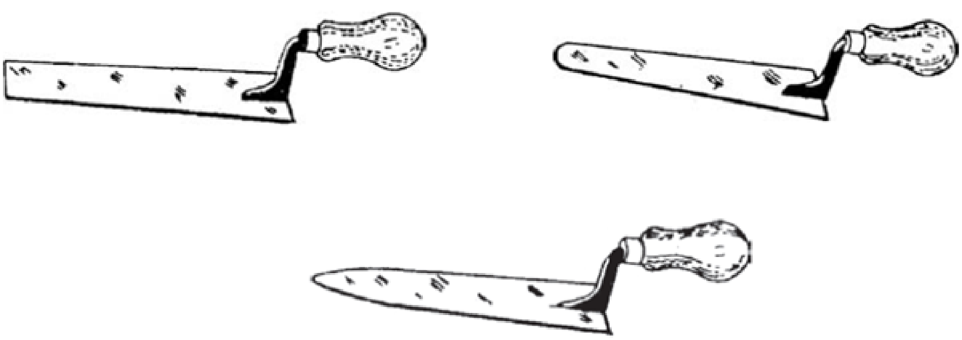
Lifters

Lifters are shown in Fig. 11.1(h, i, j and k). They are also known as cleaners or finishing tool which are made of thin sections of steel of various length and width with one end bentat right angle. They are used for cleaning, repairing and finishing the bottom and sides of deep and narrow openings in mold cavity after withdrawal of pattern. They are also used for removing loose sand from mold cavity.



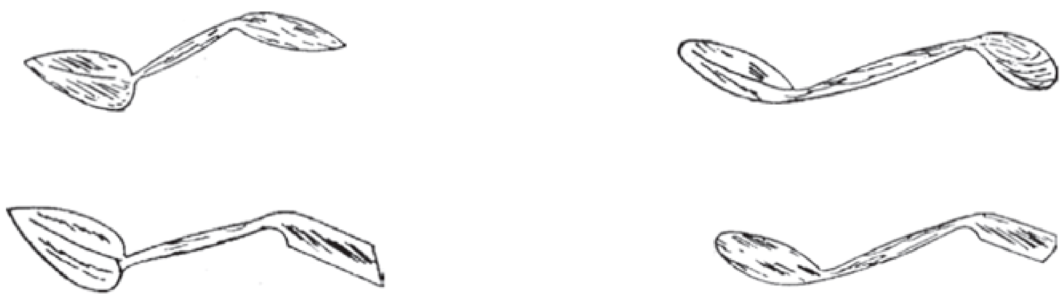
Trowels

Trowels are shown in Figures. They are utilized for finishing flat surfaces and joints and partings lines of the mold. They consist of metal blade made of iron and are equipped with a wooden handle. The common metal blade shapes of trowels may be pointed or contoured or rectangular oriented. The trowels are basically employed for smoothing or slicking the surfaces of molds. They may also be used to cut in-gates and repair the mold surfaces.



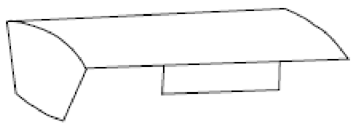
Slicks

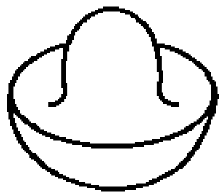
Slicks are shown in Figures. They are also recognized as small double ended mold finishing tool which are generally used for repairing and finishing the mold surfaces and their edges after withdrawal of the pattern. The commonly used slicks are of the types of heart and leaf, square and heart, spoon and bead and heart and spoon. The nomenclatures of the slicks are largely due to their shapes.



Smoothers

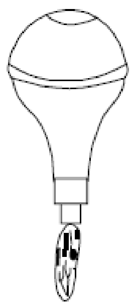
Smothers are shown in Figures. According to their use and shape they are given different names. They are also known as finishing tools which are commonly used for repairing and finishing flat and round surfaces, round or square corners and edges of molds.





Swab

Swab is shown in Figure. It is a small hemp fiber brush used for moistening the edges of sand mould, which are in contact with the pattern surface before withdrawing the pattern. It is used for sweeping away the molding sand from the mold surface and pattern. It is also used for coating the liquid blacking on the mold faces in dry sand molds.



Spirit level

Spirit level is used by molder to check whether the sand bed or molding box is horizontal or not.

Gate cutter

Gate cutter (Fig. 11.1(v)) is a small shaped piece of sheet metal commonly used to cut runners and feeding gates for connecting sprue hole with the mold cavity.

Gaggers

Gaggers are pieces of wires or rods bent at one or both ends which are used for reinforcing the downward projecting sand mass in the cope are known as gaggers. They support hanging bodies of sand. They possess a length varying from 2 to 50 cm. A gagger is always used in cope area and it may reach up to 6 mm away from the pattern. It should be coated with clay wash so that the sand adheres to it. Its surface should be rough in order to have a good grip with the molding sand. It is made up of steel reinforcing bar.

Spray-gun

Spray gun is mainly used to spray coating of facing materials etc. on a mold or core surface.

Nails and wire pieces

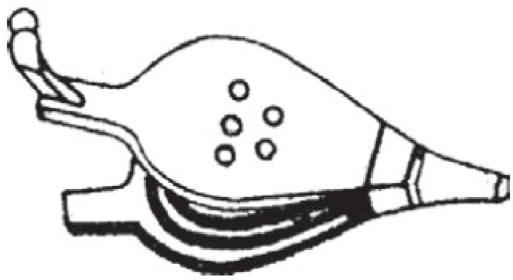
They are basically used to reinforce thin projections of sand in the mold or cores.

Wire pieces, spring and nails

They are commonly used to reinforce thin projections of sand in molds or cores. They are also used to fasten cores in molds and reinforce sand in front of an in-gate.

Bellows

Bellows gun is shown in Figure. It is hand operated leather made device equipped with compressed air jet to blow or pump air when operated. It is used to blow away the loose or unwanted sand from the surfaces of mold cavities.



Clamps, cotters and wedges

They are made of steel and are used for clamping the molding boxes firmly together during pouring.

MOLDING SAND

The general sources of receiving molding sands are the beds of sea, rivers, lakes, granulular elements of rocks, and deserts. The common sources of molding sands available in India are as follows:

1. Batala sand (Punjab)
2. Ganges sand (Uttar Pradesh)
3. Oyaria sand (Bihar)
4. Damodar and Barakar sands (Bengal- Bihar Border)
5. Londha sand (Bombay)
6. Gigatamannu sand (Andhra Pradesh) and
7. Avadi and Veeriyambakam sand (Madras)

Molding sands may be of two types namely natural or synthetic. Natural molding sands contain sufficient binder. Whereas synthetic molding sands are prepared artificially using basic sand molding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

KINDS OF MOULDING SAND

Molding sands can also be classified according to their use into number of varieties which are described below.

Green sand

Green sand is also known as tempered or natural sand which is a just prepared mixture of silica sand with 18 to 30 percent clay, having moisture content from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Green sand is damp, when squeezed in the hand and it retains the shape and the impression to give to it under pressure. Molds prepared by this sand are not requiring backing and hence are known as green sand molds. This sand is easily available and it possesses low cost. It is commonly employed for production of ferrous and non-ferrous castings.

Dry sand

Green sand that has been dried or baked in suitable oven after the making mold and cores, is called dry sand. It possesses more strength, rigidity and thermal stability. It is mainly suitable for larger castings. Mold prepared in this sand are known as dry sand molds.

Loam sand

Loam is mixture of sand and clay with water to a thin plastic paste. Loam sand possesses high clay as much as 30-50% and 18% water. Patterns are not used for loam molding and shape is given to mold by sweeps. This is particularly employed for loam molding used for large grey iron castings.

Facing sand

Facing sand is just prepared and forms the face of the mould. It is directly next to the surface of the pattern and it comes into contact molten metal when the mould is poured. Initial coating around the pattern and hence for mold surface is given by this sand. This sand is subjected severest conditions and must possess, therefore, high strength refractoriness. It is made of silica sand and clay, without the use of used sand. Different forms of carbon are used to prevent the metal burning into the sand. A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal. They are sometimes mixed with 6-15 times as much fine molding sand to make facings. The layer of facing sand in a mold usually ranges from 22-28 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.

Backing sand

Backing sand or floor sand is used to back up the facing sand and is used to fill the whole volume of the molding flask. Used molding sand is mainly employed for this purpose. The backing sand is sometimes called black sand because that old, repeatedly used molding sand is black in color due to addition of coal dust and burning on coming in contact with the molten metal.

System sand

In mechanized foundries where machine molding is employed. A so-called system sand is used to fill the whole molding flask. In mechanical sand preparation and handling units, no facing sand is used. The used sand is cleaned and re-activated by the addition of water and special additives. This is known as system sand. Since the whole mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.

Parting sand

Parting sand without binder and moisture is used to keep the green sand not to stick to the pattern and also to allow the sand on the parting surface the cope and drag to separate without clinging. This is clean clay-free silica sand which serves the same purpose as parting dust.

Core sand

Core sand is used for making cores and it is sometimes also known as oil sand. This is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin, light mineral oil and other bind materials. Pitch or flours and water may also be used in large cores for the sake of economy.

PROPERTIES OF MOULDING SAND

Refractoriness

Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of molding sands. Refractoriness can only be increased to a limited extent. Molding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained. The degree of refractoriness depends on the SiO2 i.e. quartz content, and the shape and grain size of the particle. The higher the SiO2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its melting point.

Permeability

It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mold can be further increased by venting using vent rods

Cohesiveness

It is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand. Thus, the binding capability of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core sand.

Green strength

The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould. For this, the sand grains must be adhesive, i.e. thev must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the molding box. Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also the erosion of mould wall surfaces does not occur during the flow of molten metal. The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

Dry strength

As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal. The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

Flowability or plasticity

It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections. In general, flowability increases with decrease in green strength, an, decrease in grain size. The flowability also varies with moisture and clay content.

Adhesiveness

It is property of molding sand to get stick or adhere with foreign material such sticking of molding sand with inner wall of molding box

Collapsibility

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered by the mold and thus results in tears and cracks in the casting. This property is highly desired in cores

Miscellaneous properties

In addition to above requirements, the molding sand should not stick to the casting and should not chemically react with the metal. Molding sand should be cheap and easily available. It should be reusable for economic reasons. Its coefficients of expansion should be sufficiently low.

PATTERNS

Patterns are replicas of the casting required. It is similar in shape and size to the final product, but not exactly. Usually, the mould is prepared in wet sand, to which some binder is added to hold sand particles together. The pattern is then withdrawn from inside the sand mould in such a manner that the impression cavity made in the mould is not damaged or broken in anyway. Finally molten metal is poured into this cavity and allowed to solidify and cool down to room temperature.

PATTERN MATERIALS

Wood

Wood is the most popular and commonly used material for pattern making. It is cheap, easily available in abundance, repairable and easily fabricated in various forms using resin and glues. It is very light and can produce highly smooth surface. Wood can preserve its surface by application of a shellac coating for longer life of the pattern. But, in spite of its above qualities, it is susceptible to shrinkage and warpage and its life is short because of the reasons that it is highly affected by moisture of the molding sand. After some use it warps and wears out quickly as it is having less resistance to sand abrasion. It can not withstand rough handily and is weak in comparison to metal. In the light of above qualities, wooden patterns are preferred only when the numbers of castings to be produced are less. The main varieties of woods used in pattern-making are shisham, kail, deodar, teak and mahogany.

Metal

Metallic patterns are preferred when the number of castings required is large enough to justify their use. These patterns are not much affected by moisture as wooden pattern. The wear and tear of this pattern is very less and hence posses longer life. Moreover, metal is easier to shape the pattern with good precision, surface finish and intricacy in shapes. It can withstand against corrosion and handling for longer period. It possesses excellent strength to weight ratio. The main disadvantages of metallic patterns are higher cost, higher weight and tendency of rusting. It is preferred for production of castings in large quantities with same pattern. The metals commonly used for pattern making are cast iron, brass and bronzes and aluminum alloys.

Cast Iron

It is cheaper, stronger, tough, and durable and can produce a smooth surface finish. It also possesses good resistance to sand abrasion. The drawbacks of cast iron patterns are that they are hard, heavy, brittle and get rusted easily in presence of moisture.

Brasses and Bronzes

These are heavier and expensive than cast iron and hence are preferred for manufacturing small castings. They possess good strength, machinability and resistance to corrosion and wear. They can produce a better surface finish. Brass and bronze pattern is finding application in making match plate pattern

Aluminum Alloys

Aluminum alloy patterns are more popular and best among all the metallic patterns because of their high light ness, good surface finish, low melting point and good strength. They also possesses good resistance to corrosion and abrasion by sand and there by enhancing longer life of pattern. These materials do not withstand against rough handling. These have poor repair ability and are preferred for making large castings.

Plastic

Plastics are getting more popularity now a days because the patterns made of these materials are lighter, stronger, moisture and wear resistant, non sticky to molding sand, durable and they are not affected by the moisture of the molding sand. Moreover they impart very smooth surface finish on the pattern surface. These materials are somewhat fragile, less resistant to sudden loading and their section may need metal reinforcement. The plastics used for this purpose are thermosetting resins. Phenolic resin plastics are commonly used. These are originally in liquid form and get solidified when heated to a specified temperature. To prepare a plastic pattern, a mould in two halves is prepared in plaster of paris with the help of a wooden pattern known as a master pattern. The phenolic resin is poured into the mould and the mould is subjected to heat. The resin solidifies giving the plastic pattern. Recently a new material has stepped into the field of plastic which is known as foam plastic. Foam plastic is now being produced in several forms and the most common is the expandable polystyrene plastic category. It is made from benzene and ethyl benzene.

Plaster

This material belongs to gypsum family which can be easily cast and worked with wooden tools and preferable for producing highly intricate casting. The main advantages of plaster are that it has high compressive strength and is of high expansion setting type which compensate for the shrinkage allowance of the casting metal. Plaster of paris pattern can be prepared either by directly pouring the slurry of plaster and water in moulds prepared earlier from a master pattern or by sweeping it into desired shape or form by the sweep and strickle method. It is also preferred for production of small size intricate castings and making core boxes.

Wax

Patterns made from wax are excellent for investment casting process. The materials used are blends of several types of waxes, and other additives which act as polymerizing agents, stabilizers, etc. The commonly used waxes are paraffin wax, shellac wax, bees-wax, cerasin wax, and micro-crystalline wax. The properties desired in a good wax pattern include low ash content up to 0.05 per cent, resistant to the primary coat material used for investment, high tensile strength and hardness, and substantial weld strength. The general practice of making wax pattern is to inject liquid or semi-liquid wax into a split die. Solid injection is also used to avoid shrinkage and for better strength. Waxes use helps in imparting a high degree of surface finish and dimensional accuracy castings. Wax patterns are prepared by pouring heated wax into split moulds or a pair of dies. The dies after having been cooled down are parted off. Now the wax pattern is taken out and used for molding. Such patterns need not to be drawn out solid from the mould. After the mould is ready, the wax is poured out by heating the mould and keeping it upside down. Such patterns are generally used in the process of investment casting where accuracy is linked with intricacy of the cast object.

TYPES OF PATTERN

The types of the pattern and the description of each are given as under.

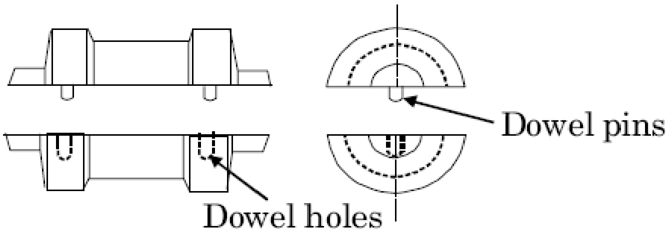
1. One piece or solid pattern
2. Two piece or split pattern
3. Cope and drag pattern
4. Three-piece or multi- piece pattern
5. Loose piece pattern
6. Match plate pattern
7. Follow board pattern
8. Gated pattern
9. Sweep pattern
10. Skeleton pattern
11. Segmental or part pattern

1. Single-piece or solid pattern

Solid pattern is made of single piece without joints, partings lines or loose pieces. It is the simplest form of the pattern.

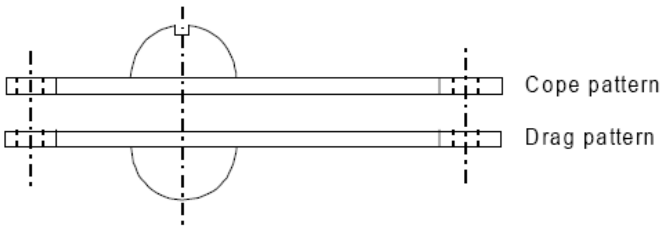
2. Two-piece or split pattern

When solid pattern is difficult for withdrawal from the mold cavity, then solid pattern is splited in two parts. Split pattern is made in two pieces which are joined at the parting line by means of dowel pins. The splitting at the parting line is done to facilitate the withdrawal of the pattern. A typical example is shown in Figure.



3. Cope and drag pattern

In this case, cope and drag part of the mould are prepared separately. This is done when the complete mould is too heavy to be handled by one operator. The pattern is made up of two halves, which are mounted on different plates. A typical example of match plate pattern is shown in Figure.

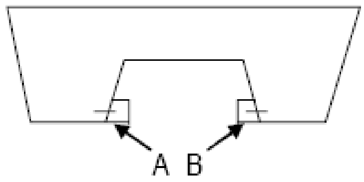


4. Three-piece or multi-piece pattern

Some patterns are of complicated kind in shape and hence cannot be made in one or two pieces because of difficulty in withdrawing the pattern. Therefore these patterns are made in either three pieces or in multi-pieces. Multi molding flasks are needed to make mold from these patterns.

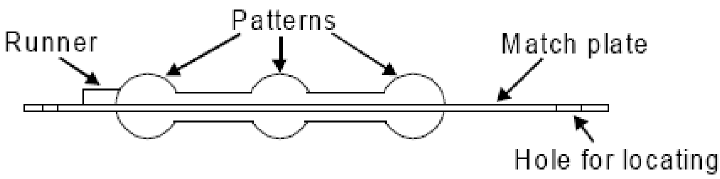
5. Loose-piece Pattern

Loose piece pattern is used when pattern is difficult for withdrawl from the mould. Loose pieces are provided on the pattern and they are the part of pattern. The main pattern is removed first leaving the loose piece portion of the pattern in the mould. Finally the loose piece is withdrawal separately leaving the intricate mould.



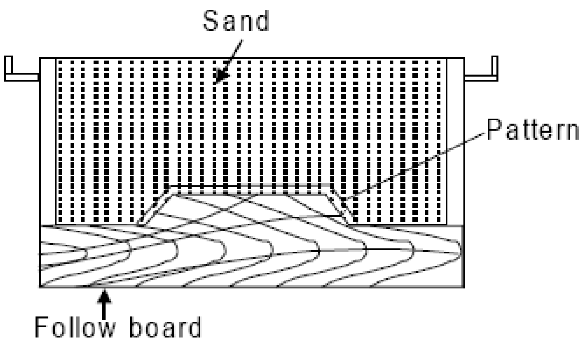
6. Match plate pattern

This pattern is made in two halves and is on mounted on the opposite sides of a wooden or metallic plate, known as match plate. The gates and runners are also attached to the plate. This pattern is used in machine molding. A typical example of match plate pattern is shown in Figure.



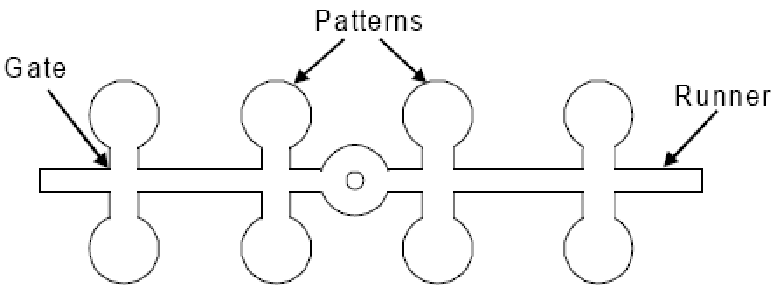
7. Follow board pattern

When the use of solid or split patterns becomes difficult, a contour corresponding to the exact shape of one half of the pattern is made in a wooden board, which is called a follow board and it acts as a molding board for the first molding operation as shown in Figure.



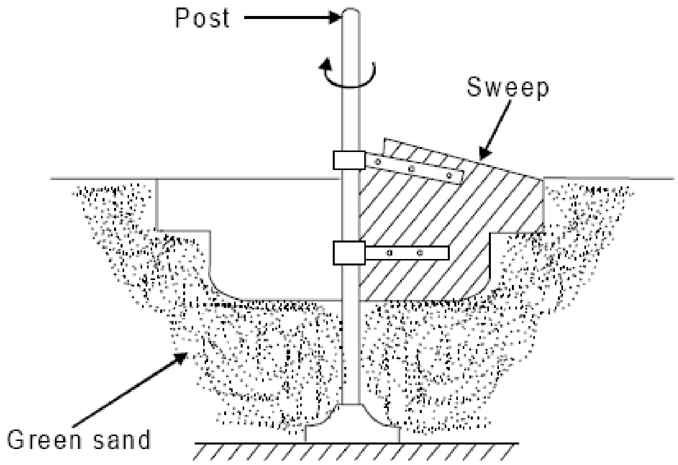
8. Gated pattern

In the mass production of casings, multi cavity moulds are used. Such moulds are formed by joining a number of patterns and gates and providing a common runner for the molten metal, as shown in Fig. 10.7. These patterns are made of metals, and metallic pieces to form gates and runners are attached to the pattern.



9. Sweep pattern

Sweep patterns are used for forming large circular moulds of symmetric kind by revolving a sweep attached to a spindle as shown in Fig. 10.8. Actually a sweep is a template of wood or metal and is attached to the spindle at one edge and the other edge has a contour depending upon the desired shape of the mould. The pivot end is attached to a stake of metal in the center of the mould.

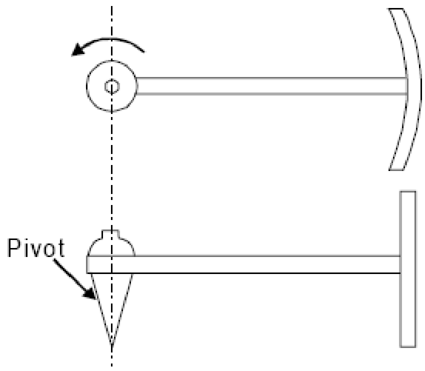


10. Skeleton pattern

When only a small number of large and heavy castings are to be made, it is not economical to make a solid pattern. In such cases, however, a skeleton pattern may be used. This is a ribbed construction of wood which forms an outline of the pattern to be made. This frame work is filled with loam sand and rammed. The surplus sand is removed by strickle board. For round shapes, the pattern is made in two halves which are joined with glue or by means of screws etc.

11. Segmental pattern

Patterns of this type are generally used for circular castings, for example wheel rim, gear blank etc. Such patterns are sections of a pattern so arranged as to form a complete mould by being moved to form each section of the mould. The movement of segmental pattern is guided by the use of a central pivot. A segment pattern for a wheel rim is shown in Figure.



PATTERN ALLOWANCES

Pattern may be made from wood or metal and its color may not be same as that of the casting. The material of the pattern is not necessarily same as that of the casting. Pattern carries an additional allowance to compensate for metal shrinkage. It carries additional allowance for machining. It carries the necessary draft to enable its easy removal from the sand mass. It carries distortions allowance also. Due to distortion allowance, the shape of casting is opposite to pattern. Pattern may carry additional projections, called core prints to produce seats or extra recess in mold for setting or adjustment or location for cores in mold cavity.

1. Shrinkage Allowance

In practice it is found that all common cast metals shrink a significant amount when they are cooled from the molten state. The total contraction in volume is divided into the following parts:

1. Liquid contraction, i.e. the contraction during the period in which the temperature of the liquid metal or alloy falls from the pouring temperature to the liquidus temperature.
2. Contraction on cooling from the liquidus to the solidus temperature, i.e. solidifying contraction.
3. Contraction that results there after until the temperature reaches the room temperature. This is known as solid contraction. The first two of the above are taken care of by proper gating and risering. Only the last one, i.e. the solid contraction is taken care by the pattern makers by giving a positive shrinkage allowance. This contraction allowance is different for different metals. The contraction allowances for different metals and alloys such as Cast Iron 10 mm/mt.. Brass 16 mm/mt., Aluminium Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. In fact, there is a special

2. Machining Allowance

It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting. If this allowance is not given, the casting will become undersize after machining. The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3 mm. to 18 mm.

3. Draft or Taper Allowance

Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier. The normal amount of taper on the external surfaces varies from 10 mm to 20 mm/mt. On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt. These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.

4. Rapping or Shake Allowance

Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases. Actually by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This movement may be insignificant in the case of small and medium size castings, but it is significant in the case of large castings. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 0.5-1.0 mm.

5. Distortion Allowance

This allowance is applied to the castings which have the tendency to distort during cooling due to thermal stresses developed. For example a casting in the form of U shape will contract at the closed end on cooling, while the open end will remain fixed in position. Therefore, to avoid the distortion, the legs of U pattern must converge slightly so that the sides will remain parallel after cooling.

6. Mold wall Movement Allowance

Mold wall movement in sand moulds occurs as a result of heat and static pressure on the surface layer of sand at the mold metal interface. In ferrous castings, it is also due to expansion due to graphitisation. This enlargement in the mold cavity depends upon the molddensity and mould composition. This effect becomes more pronounced with increase in moisture content and temperature.

MOULD PROCESS

Mould making is a very skilled operation. We shall describe, step by step, the procedure for making a mould for a split pattern.

Step 1: Place bottom half of the split pattern on a flat moulding board, with the parting surface face downwards. Sprinkle some parting sand on the pattern and the moulding board. Parting sand is silica sand without any clay or binding material. Then place a moulding box to enclose the pattern.

Step 2: Spread facing sand to cover all parts of the pattern up to a depth of 20–25 mm. Facing sand is freshly prepared moulding sand. Fill up the remaining space left in the moulding box with backing sand. Backing sand is prepared by reconditioning the previously used foundry sand which is always available on the foundry floor. Use of backing sand reduces the requirement of facing sand, which is quite costly.

Step 3: Next, the sand in the moulding box is rammed with a special tool. Ramming means pressing the sand down by giving it gentle blows. Sand should be packed in the moulding box tightly but not too tightly. If as a result of ramming, the level of sand goes down in the box, more sand should be filled in and rammed. Then with a trowel, level the sand lying on the top of the mould box. Next take a venting tool (it is a long thick needle), make venting holes in the sand taking care that they are not so deep as to touch the pattern. This moulding box will form the lower box, and is called "drag".

Step 4: Now turn over the moulding box gently and let it rest on some loose sand after levelling the foundry floor. Place the top half of split pattern in correct relative position on the flat surface of the bottom half of the pattern. Place another empty moulding box on the top of first moulding box (*i.e.*,drag) and clamp them temporarily. Sprinkle some parting sand upon the exposed surface of the top half of pattern and the surrounding sand. Cover the pattern in 20–25 mm deep facing sand. Place two taper pins at suitable places, where runner and riser are to be located. Full up the box with backing sand, pack in sand with ramming tool, level sand and make venting holes. Remove taper pins and make room on foundry floor, next to the drag box, for keeping the "cope" as the top box is called Unclamp the moulding boxes, lift 'cope' and place it down on its back. Now the flat parting surface of both parts of the split pattern can be seen one in each box.

Step 5: In order to lift the patterns from cope and the drag, locate the tepped holes on the flat surface and screw in a lifting rod in these holes. This provides a handle with which the patterns can be easily lifted up vertically. However first the patterns are loosened a bit by rapping these handles gently before lifting them. This minimises the damage to sand moulds.

Step 6: After removing wooden pattern halves, the mould cavities may be repaired in case any corners etc., have been damaged. This is a delicate operation. Also, if any sand has fallen into the mould cavity, it is carefully lifted or blown away by a stream of air.

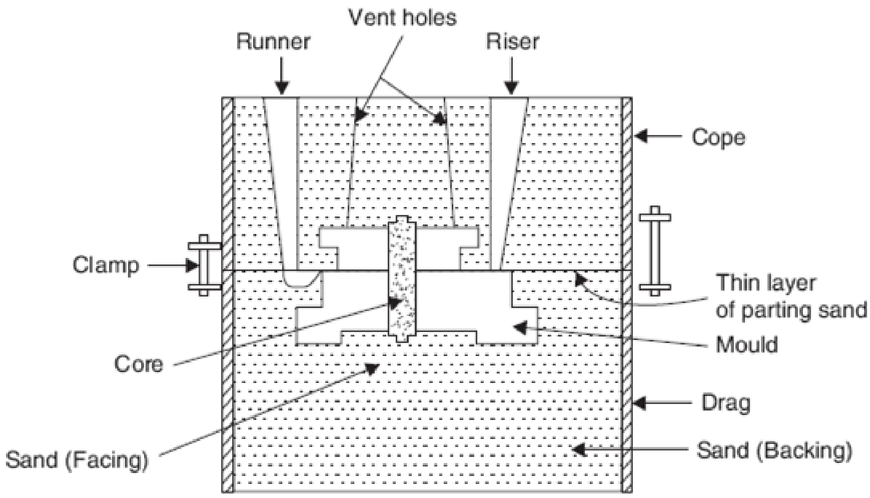
Step 7: In case, any cores are used to make holes in the casting, this is time for placing the cores in the mould cavity. Of course, the cores are supported properly by means of core prints or other devices like chaplets etc. Lack of adequate support for cores may result in their displacement from correct position when the liquid metal is poured in.

Step 8: Before closing of the mould boxes, graphite powder is sprinkled on the mould surface in both boxes. In the drag box, a gate is cut below the location of the runner (in the cope box). The molten metal poured in the runner will flow through the gate into the mould cavity. In case, the moulds have been dried, instead of graphite powder, a mould wash containing suspension of graphite in water is lightly spread over the mould surface. After all these operations are complete, the cope box is again placed on the drag and clamped securely. Now the mould is ready for pouring molten metal. Molten metal is poured until it shows up in the riser. It ensures that mould cavities are full of metal and that it will not run short. A complete mould ready for pouring is shown in Fig. 6.4. Sand moulds are of three kinds:

(*a*) **Green sand mould:** In such moulds, pouring of molten metal is done, when the sand is still moist.

(*b*) **Skin dry moulds:** Such moulds are superficially dried by moving a flame over mould cavity so that mould dries only up to a depth of few mm.

(*c*) **Dry moulds:** After preparing such moulds, they are dried by keeping the mould for 24–36 hours in an owen whose temperature is maintained at 130–150°C. Dry sand moulds are stronger and cannot give rise to any moisture related defects in the casting. Mould wash improves the surface finish of castings.



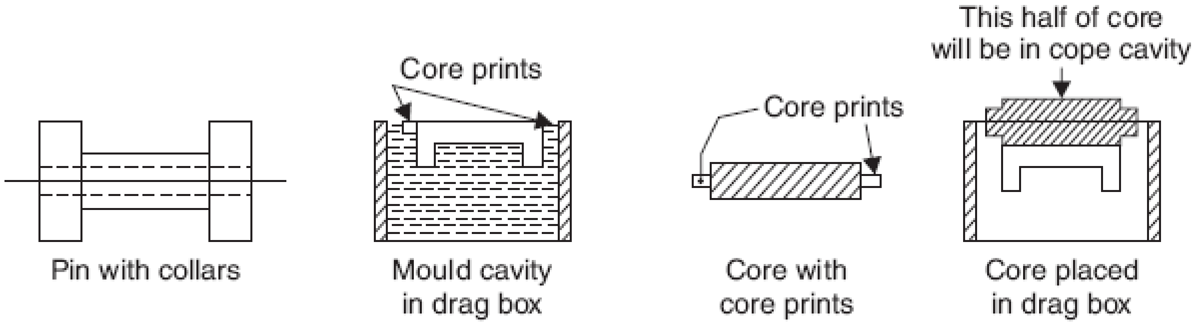
A mould ready for pouring

CORES

Whenever a hole, recess, undercut or internal cavity is required in a casting, a core, which is usually made up of a refractory material like sand is inserted at the required location in the mould cavity before finally closing the mould. A core, being surrounded on all sides by molten metal, should be able to withstand high temperature. It should also be adequately supported otherwise due to buoyancy of molten metal, it will get displaced. When the molten metal around the core solidifies and shrinks, the core should give way, otherwise the casting may crack (hot tear). Cores, as explained previously, should be made of oil sand and dried in owens before use. Cores are made with the help of core boxes. Core boxes are made of wood and have a cavity cut in them, which is the shape and size of the core. The sand in mixed and filled in the core boxes. It is then rammed. A core box is made in two halves, each half contains half impression of core. Sometimes a core may need reinforcements to hold it together. The reinforcements are in the shape of wire or nails, which can be extracted from the hole in the casting along with core sand.

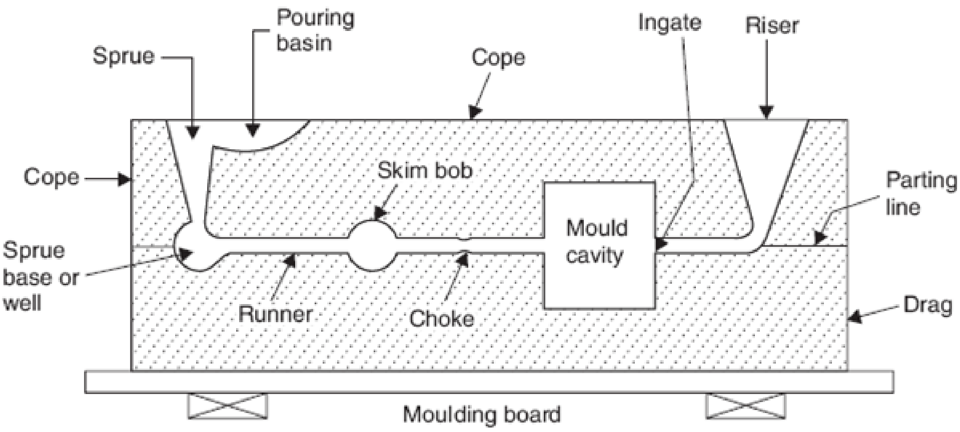
CORE PRINTS

A core must be supported in the mould cavity. Wherever possible, this is done by providing core prints. Core prints are extensions of the core which rest in similar extensions of the mould cavity so that core remains supported in the mould cavity without the core falling to the bottom of the cavity. For example, if the pin with collars shown in Figure had a central hole, the hole could be produced by inserting a core in mould cavity as shown in Figure. Another device to support cores is “chaplets”. These are clips made of thin sheets of the same metal as the casting. These clips are used to support the weight of cores. When the molten metal is poured, chaplets melt and merge into the molten metal.



GATES, RUNNERS AND RISERS

The passage provided in the mould through which molten metal will flow into the mould cavity is known as the gating system. It is provided by scooping out sand in the drag box to cut necessary channels. The top of the runner hole in the cope is widened into a pouring basin. The molten metal then flows down through the runner into a well from where it enters the gating system and into the mould cavity. At a suitable location in the mould cavity the riser hole is connected. Without a gate, the metal would have fallen straight into the mould cavity damaging it. Besides, the gating system is so designed as to trap impurities from entering into mould cavity. The function of the riser is twofold. Firstly, it provides a visible indicator that the mould cavity is full. Secondly and more importantly, the molten metal in the riser provides a reservoir to feed the shrinkage caused as the casting progressively solidifies and cools. It is desirable that the metal in the riser remains molten as long as possible. This is done by providing a ‘‘hot-top”. Sometimes, the riser does not open out to the top surface of the cope box, it is then called a blind riser. In that case, its sole function is to feed the shinkage associated with solidification of molten metal. The various terms associated with gating system will be clear by studying the gating system shown in Figure.

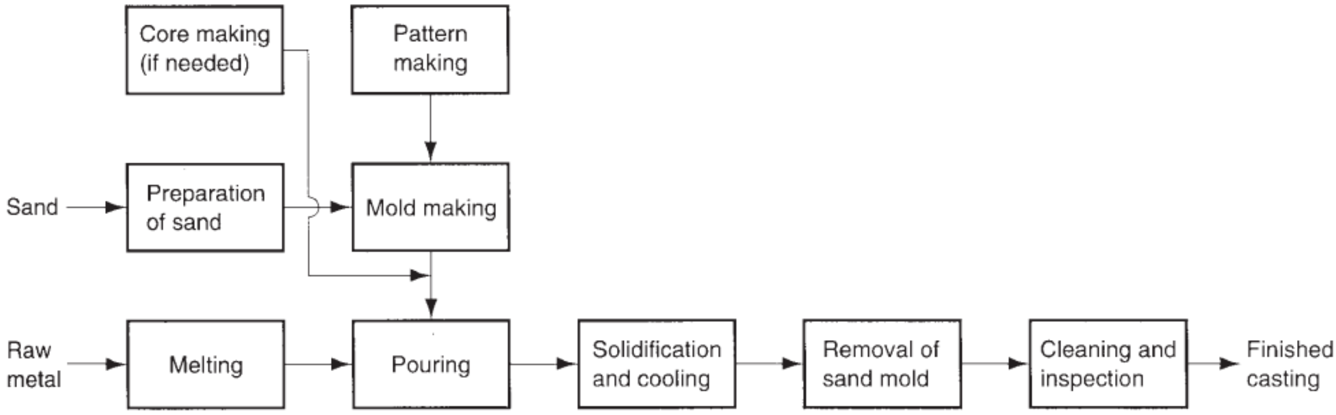


Gating system

Manufacture of a machine part by heating a metal or alloy above its melting point and pouring the liquid metal/alloy in a cavity approximately of same shape and size as the machine part is called casting process. After the liquid metal cools and solidifies, it acquires the shape and size of the cavity and resembles the finished product required. The department of the workshop, where castings are made is called foundry. The manufacture of a casting requires:

(a) Preparation of a pattern,
(b) Preparation of a mould with the help of the pattern,
(c) Melting of metal or alloy in a furnace,
(d) Pouring of molten metal into mould cavity,
(e) Breaking the mould to retrieve the casting,
(f) Cleaning the casting and cutting off risers, runners etc., (this operation is called ‘fettling’), and
(g) Inspection of casting.

Castings are made in a large number of metals and alloys, both ferrrous and non-ferrous. Grey cast iron components are very common; steel castings are stronger and are used for components subject to higher stresses. Bronze and brass castings are used on ships and in marine environment, where ferrous items will be subjected to heavy corrosion. Aluminium and aluminium-magnesium castings are used in automobiles. Stainless steel castings are used for making cutlery items. Casting is an economical way of producing components of required shape either in small lots or in larger lots. However, castings are less strong as compared to wrought components produced by processes such as forging etc. However castings offer the possibility of having slightly improved properties in certain part of the casting by techniques such as use of chill etc. In casting process, very little metal is wasted.



DIE CASTING

A sand mould is usable for production of only one casting. It cannot be used twice. Die is essentially a metal mould and can be used again and again. A die is usally made in two portions. One portion is fixed and the other is movable. Together, they contain the mould cavity in all its details. After clamping or locking the two halves of the dies together molten metal is introduced into the dies. If the molten metal is fed by gravity into the dies, the process is known as gravity die casting process. On the otherhand, if the metal is forced into the dies under pressure (*e.g.*, a piston in a cylinder pushes the material through cylinder nozzle), the process is called “pressure die casting”.

The material of which the dies are made, should have a melting point much higher than the melting point of casting material. A great number of die castings are made of alloys of zinc, tin and lead, and of alloys of aluminium, magnesium and copper. Hence dies are made out of medium carbon low alloy steels. The dies are usually water or air blast cooled. Since most materials contract on cooling, extraction of castings from dies becomes important otherwise they will get entangled in the die as they cool. Therefore, in the design of dies, some arrangement for extraction of casting is incorporated.

STEPS IN DIE CASTING

1. Close and lock the two halves of a die after coating the mould cavity surfaces with a mould wash, if specified:
2. Inject the molten metal under pressure into the die.
3. Maintain the pressure until metal solidifies.
4. Open die halves.
5. Eject the casting along with runner, riser etc.
6. The above cycle is repeated.

Two pressure die casting methods are used:

Hot chamber process: This uses pressures up to 35 MPa and is used for zinc, tin, lead, and their alloys. In this process the chamber, in which molten metal is stored before being pressure injected into the die, is kept heated.

Cold chamber process: In this process, pressures as high as 150 MPa are used. The storing chamber is not heated. This process is used mainly for metals and alloys having relatively higher melting point *e.g.,* aluminium, magnesium and their alloys.

Advantages and disadvantages of die casting:

1. It is used for mass production of castings of small and medium size. *e.g.,* pistons of motorcycle and scooter engines, valve bodies, carburettor housings etc.
2. The initial cost of manufacturing a die is very high. It is a disadvantage.
3. This process produces high quality, defect free castings.
4. The castings produced by this process are of good surface finish and have good dimensional control and may not require much machining. All castings produced are identical.
5. Large size castings cannot be produced by this process. It is a disadvantage.
6. Castings with very complex shapes or with many cores are difficult to produce by die casting.
7. In case of mass production, castings can be produced cheaply.
8. The process does not require use of sand and requires much less space as compared to a conventional foundry using sand moulds.

CASTING DEFECTS

Some of the common defects in the castings are described below:

1. **Blow-holes:** They appear as small holes in the casting. They may be open to surface or they may be below the surface of the casting. They are caused due to entrapped bubbles of gases. They may be caused by excessively hard ramming, improper venting, excessive moisture or lack of permeability in the sand.
2. **Shrinkage cavity:** Sometimes due to faulty design of casting consisting of very thick and thin sections, a shrinkage cavity may be caused at the junction of such sections. Shrinkage cavity is totally internal. It is caused due to shrinkage of molten metal. Remedy is to use either a chill or relocation of risers.
3. **Misrun:** This denotes incomplete filling of mould cavity. It may be caused by bleeding of molten metal at the parting of cope and drag, inadequate metal supply or improper design of gating.
4. **Cold shut:** A cold shut is formed within a casting, when molten metal from two different streams meets without complete fusion. Low pouring temperature may be the primary cause of this defect.
5. **Mismatch:** This defect takes place when the mould impression in the cope and drag do not sit exactly on one another but are shifted a little bit. This happens due to mismatch of the split pattern (dowel pin may have become loose) or due to defective clamping of cope and drag boxes.
6. **Drop:** This happens when a portion of the mould sand falls into the molten metal. Loose sand inadequately rammed or lack of binder may cause this defect.
7. **Scab:** This defect occurs when a portion of the face of a mould lifts or breaks down and the recess is filled up by molten metal.
8. **Hot tear:** These cracks are caused in thin long sections of the casting, if the part of the casting cannot shrink freely on cooling due to intervening sand being too tightly packed, offers resistance to such shrinking. The tear or crack usually takes place when the part is red hot and has not developed full strength, hence the defect is called “hot tear”. Reason may be excessively tight ramming of sand.

9. Other defects include scars, blisters, sponginess (due to a mass of pin holes at one location) and slag inclusions etc.

BASIC METAL FORMING PROCESS

Metal forming processes, also known as mechanical working processes, are primary shaping processes in which a mass of metal or alloy is subjected to mechanical forces. Under the action of such forces, the shape and size of metal piece undergo a change. By mechanical working processes, the given shape and size of a machine part can be achieved with great economy in material and time.

Metal forming is possible in case of such metals or alloys which are sufficiently malleable and ductile. Mechanical working requires that the material may undergo "plastic deformation" during its processing. Frequently, work piece material is not sufficiently malleable or ductile at ordinary room temperature, but may become so when heated. Thus we have both hot and cold metal forming operations.

Many metal forming processes are suitable for processing large quantities (*i.e.,* bulk) of material, and their suitability depends not only upon the shape and size control of the product but also upon the surface finish produced. There are many different metal forming processes and some processes yield a better geometry (*i.e.*, shape and size) and surface-finish than some others. But, they are not comparable to what can be achieved by machining processes. Also cold working metal forming processes result in better shape, size and surface finish as compared to hot working processes.

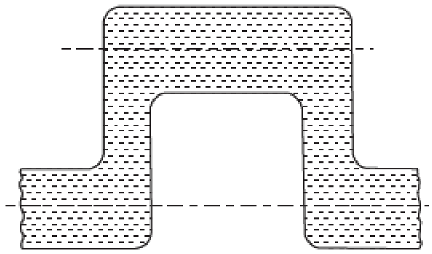
Hot working results in oxidation and decarburisation of the surface, formation of scales and lack of size control due to contraction of the work piece while it cools to room temperature.

ADVANTAGES OF MECHANICAL WORKING PROCESSES

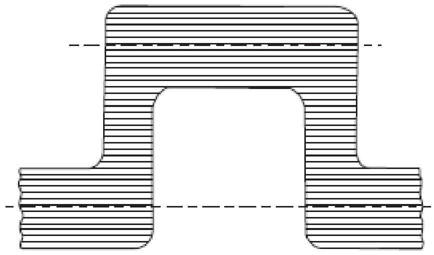
Apart from higher productivity, mechanical working processes have certain other advantages over other manufacturing processes. These are enumerated below:

1. Mechanical working improves the mechanical properties of material like ultimate tensile strength, wear resistance, hardness and yield point while it lowers ductility. This phenomenon is called "strain hardening".

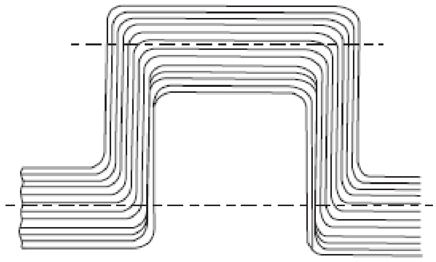
2. It results in grain flow lines being developed in the part being mechanically worked. The grainflow improves the strength against fracture when the part is in actual use. This is best explained by taking illustration of a crankshaft. If the crankshaft is manufactured by machining from a bar of largecross-section, the grain flow lines get cut at bends whereas in a crankshaft which is shaped by forging (which is a mechanical working process), the grain flow lines follow the full contour of the crankshaft making it stronger. This is illustrated in Figure.



(a) Casting (No grain flow)



(b) Machining (Parallel)



(c) Forging
(Grain flow follows contour)

DIFFERENCE BETWEEN HOT AND COLD WORKING

Cold working (or cold forming, as it is sometimes called) may be defined as plastic deformation of metals and alloys at a temperature below the recrystallisation temperature for that metal or alloy. When this happens, then the strain hardening which occurs as a result of mechanical working, does not getrelieved. Infact as the metal or alloys gets progressively strain hardened, more and more force is required to cause further plastic deformation. After sometime, if the effect of strain hardening is not removed, the forces applied to cause plastic deformation may infact cause cracking and failure of material.

Hot working may be explained as plastic deformation of metals and alloys at such a temperature at which recovery and recrystallisation take place simultaneously with the strain hardening. Such a temperature is above recrystallisation temperature. Properly done hot working will leave the metal or alloy in a fine grained recrystallised structure. A word about recrystallisation temperature will not be out of place here. Recrystallisation temperature is not a fixed temperature but is actually a temperature range. Its value depends upon several factors. Some of the important factors are:

(*i*) **Nature of metal or alloy:** It is usually lower for pure metals and higher for alloys. For pure metals, recrystallisation temperature is roughly one third of its melting point and for alloys about half of the melting temperature.

(*ii*) **Amount of cold work already done:** The recrystallisation temperature is lowered as the amount of strain-hardening done on the work piece increases.

(*iii*) **Strain-rate:** Higher the rate of strain hardening, lower is the recrystallisation temperature. For mild steel, recrystallisation temperature range may be taken as 550–650°C. Recrystallisation temperature of low melting point metals like lead, zinc and tin, may be taken as room temperature. The effects of strain hardening can be removed by annealing above the recrystallisation temperature.

ADVANTAGES AND DISADVANTAGES OF COLD AND HOT WORKING PROCESSES

(*i*) Since cold working is practically done at room temperature, no oxidation or tarnishing of surface takes place. No scale formation is there, hence there is no material loss. In hot working opposite is true. Besides, hot working of steel also results in partial decarburisation of the work piece surface as carbon gets oxidised as CO2.

(*ii*) Cold working results in better dimensional accuracy and a bright surface. Cold rolled steel bars are therefore called bright bars, while those produced by hot rolling process are called black bars (they appear greyish black due to oxidation of surface).

(*iii*) In cold working heavy work hardening occurs which improves the strength and hardness of bars, but it also means that high forces are required for deformation increasing energy consumption. In hot working this is not so.

(*iv*) Due to limited ductility at room temperature, production of complex shapes is not possible by cold working processes.

(*v*) Severe internal stresses are induced in the metal during cold working. If these stresses are

not relieved, the component manufactured may fail prematurely in service. In hot working, there are no residual internal stresses and the mechanically worked structure is better than that produced by cold working.

(*vi*) The strength of materials reduces at high temperature. Its malleability and ductility improve at high temperatures. Hence low capacity equipment is required for hot working processes. The forces on the working tools also reduce in case of hot working processes.

(*vii*) Sometimes, blow holes and internal porosities are removed by welding action at high temperatures during hot working.

(*viii*) Non-metallic inclusions within the work piece are broken up. Metallic and non-metallic segregations are also reduced or eliminated in hot working as diffusion is promoted at high temperatures making the composition across the entire cross-section more uniform.

Typical Hot Working Temperatures

Steels 650–1050°C

Copper and alloys 600–950°C

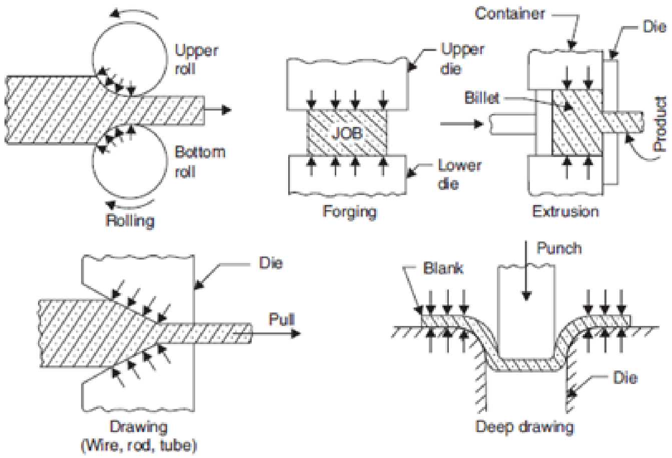
Aluminium and alloys 350–485°C

CLASSIFICATION OF METAL FORMING PROCESSES ACCORDING TO TYPEOF STRESS EMPLOYED

Primary metal working processes are those in which the bulk material in the form of ingots, blooms and billets is broken down to required shapes and sizes by processes such as forging, rolling, extrusion etc. These processes can be categorised on the basis of the kind of stress employed in the material, that is:

- *(ii)* Mainly compression type, (Examples: forging, rolling, extrusion etc.).
- *(iii)* Mainly tension type (Example: drawing).
- *(iv)* Combined compression and tension type, (Examples : deep drawing, embossing etc.).

Many of these processes are shown schematically in Figure.



Typical metal working processes

FORGING

In forging, metal and alloys are deformed to the specified shapes by application of repeated blows from a hammer. It is usually done hot; although sometimes cold forging is also done. The raw material is usually a piece of a round or square cross-section slightly larger in volume than the volume of the finished component. Depending on the end use of the component, the forged part may be used as such or (more frequently) it has to be machined to correct size to close tolerances. The initial volume of material taken must, therefore, allow for loss due to scaling and the machining allowance.

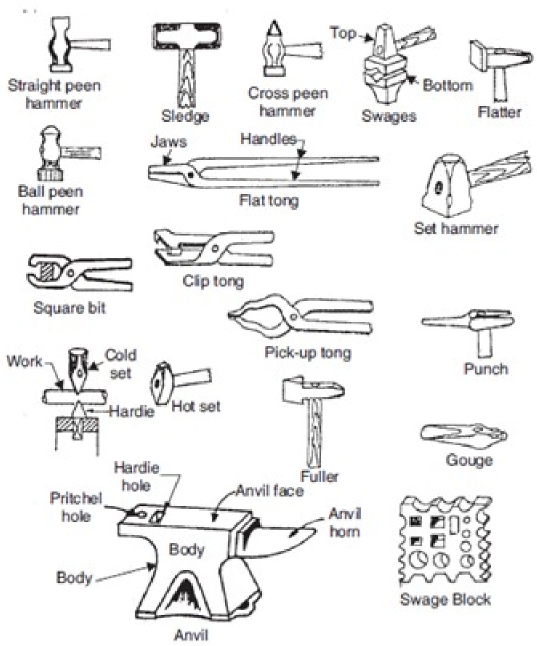
CLASSIFICATION OF FORGING

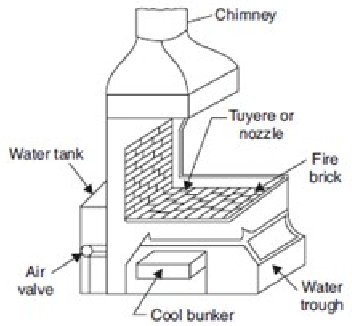
Forging is done by hand or with the help of power hammers. Sometimes hydraulic presses are also used for forging.

(*a*) **Hand Forging:** Under the action of the compressive forces due to hammer blows, the material spreads laterally *i.e.*, in a direction at right angles to the direction of hammer blows. Obviously brittle material like cast iron cannot be forged as it will develop cracks under the blows from hammer. An ordinary blacksmith uses an open-hearth using coke (or sometimes steam coal) as fuel for heating the metal and when it has become red-hot, blacksmith’s assistant (called striker on hammerman) uses a hand held hammer to deliver blows on the metal piece while the blacksmith holds it on an anvil and manipulates the metal piece with a pair of tongs. This type of forging is called “hand forging” and is suitable only for small forgings and small quantity production. A blacksmith’s hearth, ancillary equipment and tools used by the blacksmith are shown in Figure. Basic forging operations employed in giving required shape to the work piece are described below:

(*i*) **Upsetting:** It is the process of increasing the cross-section at expense of the length of the work piece.

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





Smith's forge

Tools used in smithy and smith's forge

(*iii*) **Cutting:** This operation is done by means of hot chisels and consists of removing extra, metal from the job before finishing it.

(*iv*) **Bending:** Bending of bars, flats and other such material is often done by a blacksmith. For making a bend, first the portion at the bend location is heated and jumped (upset) on the outward surface. This provides extra material so that after bending, the cross-section at the bend does not reduce due to elongation.

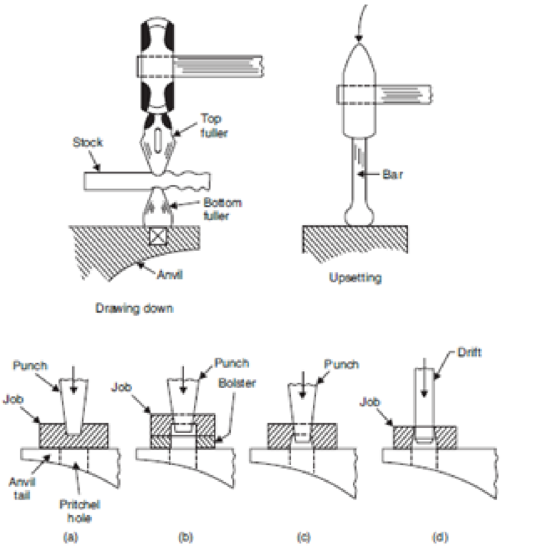
(*v*) **Punching and drifting:** Punching means an operation in which a punch is forced through the work piece to produce a rough hole.The job is heated, kept on the anvil and a punch of suitable size is forced to about half the depth of the job by hammering. The job is then turned upside down and punch is forced in from the otherside, this time through and through. Punching is usually followed by drifting *i.e*, forcing a drift in the punched hole through and through. This produces at better hole as regards its size and finish.

(*vi*) **Setting down and finishing:** Setting down is the operation by which the rounding of a corner is removed to make it a square. It is done with the help of a set hammer. Finishing is the operation where the uneven surface of the forging is smoothened out with the use of a flatter or set hammer and round stems are finished to size with the use of swages after the job has been roughly brought to desired shape and size.

(*vii*) **Forge welding:** Sometimes, it may become necessary to join two pieces of metal. Forge welding of steel is quite common and consists of heating the two ends to be joined to white heat (1050°C – 1150°C). Then the two ends of steel are brought together having previously been given a slight convex shape to the surfaces under joining. The surfaces are cleaned of scale. They are then hammered together using borax as flux. The hammering is started from centre of the convex surface and it progresses to the ends. This results in the slag being squeezed out of the joint.

Hammering is continued till a sound joint is produced. Several types of joints can be made *viz.*, butt joint, scarf joint or splice joint. Various forging operations described above and forge welding joints are shown in Figures.

(*b*) **Forging with Power Hammers:** The use of hand forging is restricted to small forgings only. When a large forging is required, comparatively light blows from a hand hammer or a sledge hammer wielded by the striker will not be sufficient to cause significant plastic flow of the material. It is therefore necessary to use more powerful hammers. Various kinds of power hammers powered by electricity, steam and compressed air (*i.e.*, pneumatic) have been used for forging. A brief description of these hammers is now given.



(*a*) Job placed on anvil and punched half-way on one side (*b*) Job turned upside down, being punched through using a bolster (*c*) Job turned upside down, being punched through using Pritchel hole (*d*) Operation of drifting

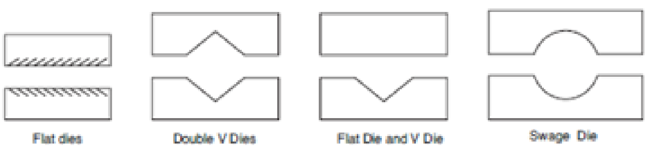
Some common hand forging operations

DIE FORGING WITH POWER HAMMERS

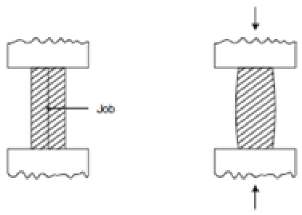
The tools used for power hammers are similar in shape to the tools used in hand forging but are larger and more robust. As far as possible, effort is made to finish the shape required in one heat only. Usually the bottom surface of the tup and the top of the anvil is flat as in the case of hand forging, but to increase production and cutdown cost, dies are often used. The top die, is fastened securely to the tup and the bottom die is fitted securely on the anvil. One half of the impression of the finished job is sunk in the top die, while in the bottom die, the other half of impression is sunk. The correct volume of raw material is heated in the furnace and a rough shape is first given to it. Thereafter it is placed on the bottom die and blows are given with the tup and top die. The material spreads to fill all the vacant space in the impressions sunk in the dies. Such a method of forging is called die forging. Three types of die forging methods are prevalent. These are (*i*) Open die forging (*ii*) Impression die forging and (*iii*) Closed die forging.

OPEN DIE FORGING

In this type of forging, the metal is never completely enclosed or confined on all sides. Most open dies forgings are produced on flat, V or swaging dies. Swaging dies are usually round but may also be of other shapes *e.g.*, double V.



Open dies



Upsetting with open dies

The common "upsetting" operation done on a hammer can also be considered as an example of open die forging with two flat dies as shown in Figure.

Advantages claimed for open die forging are (*i*) Simple to understand and operate (*ii*) Inexpensive tooling and equipment as no die-sinking is involved and (*iii*) Wide range of work piece sizes can be accommodated. The main disadvantage is low volume of production and difficulty in close size control.

CLOSED DIE FORGING

Closed die forging is very similar to impression die forging, but in true closed die forging, the amount of material initially taken is very carefully controlled, so that no flash is formed. Otherwise, the process is similar to impression die forging. It is a technique which is suitable for mass production.

DROP STAMPING OR DROP FORGING HAMMERS

Very often, for closed die or impression die forging, a modified version of power hammer is used. It is called a drop stamping or drop forging hammer and gives better results. In this case, the tup is not an integral part of the piston and the piston rod assembly, but is separate. The tup, to which the upper half of die is fixed is lifted by means of flexible ropes or a flexible canvas belting. It is then dropped on to the anvil to which the lower half of die is attached. Its downward movement is a gravity controlled free fall guided by the vertical guides provided in the frame of the hammer. The flexible ropes ensure, that after striking the anvil, the tup is free to rebound. Usually one fall of the tup may complete the forging. The metal piece is given a rough shape before being drop stamped.

PRESSES

Use of mechanical and hydraulic presses for forging and extrusion has been mentioned earlier. Knuckle type mechanical presses are used widely for sheet metal work. These presses are usually of vertical configuration. These presses are provided with a heavy flywheel driven by an electric motor. A ram moves up and down the guide ways provided in the frame of the press, when the ram is connected to the flywheel through a connecting rod and a crank mechanism. The clutch for transferring the motion from the flywheel to the ram is operated by a foot operated treadle. The arrangement is somewhat similar to the mechanism of a reciprocating engine. Such presses are very useful for providing short powerful strokes.

These presses are available in two configurations:

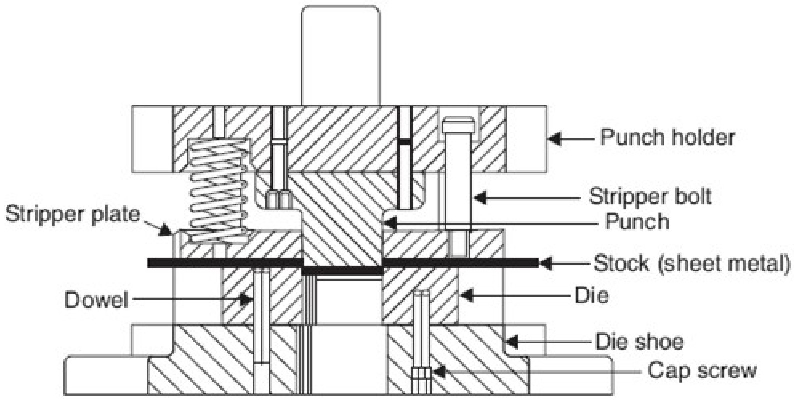
(i) Open frame type, and
(ii) Closed frame type.

Open frame type presses are less robust as compared to closed frame type, but provide greater access for loading material as they are open in front as well as sides. Due to their appearance, they are also referred to as C-frame or gap presses as well. Closed frame type presses are used for heavier work. The capacity of the press is indicated by the force (or tonnage), the press is capable of exerting.

TOOLS

A set of dies is the required tooling for working with the presses. A die set consists essentially of three parts: (*i*) a punch (male tool), (*ii*) a die (a female tool) and (*iii*) stripper plate. The punch is fixed or bolted to the ram and the die is fixed on the machine bed in such a manner that the two are in perfect alignment. When the punch alongwith the ram of the press moves downwards, the punch passes centrally through the die. A die and punch assembly for making holes in metal-sheets is shown in Figure.

When the punch descends, it shears the metal-sheet. The hole punched through has the same profile as the punch. If the remaining portion of the sheet metal is the useful part, the punched out portion is thrown away as scrap. In this case, the operation is called “punching”. However, if the punch out portion is the useful part, the operation is termed “blanking” and the punched out piece is referred to as blank. The size of blank is determined by the size of hole in the die.



Standard die set with a punch and die mounted in place

The function of the stripper plate is to keep the sheet held down during the subsequent upward movement of the punch; otherwise, the sheet may get entangled with the punch during the upward movement of the ram and the punch. For efficient operation and clean cut surfaces, some clearance is provided between the punch and the die. It is a function of thickness of sheet under shear and is 3–5% of thickness. Actually, after the bottom surface of the punch comes into contact with the sheet, it travels or penetrates through the sheet upto about 40% of the sheet thickness inducing higher and higher compressive stress in the sheet metal. Ultimately, the resultant shear stress at the perimeter of the blank exceeds the maximum shear strength of the material and the blanks gets sheared off through the remaining 60% of the sheet thickness. The depth of penetration-zone and shear zone are demarcated and easily seen, if the periphery of the blank is examined visually

OTHER OPERATIONS PERFORMED WITH PRESSES

Apart from punching and blanking, several other useful operations are performed with the help of mechanical presses:

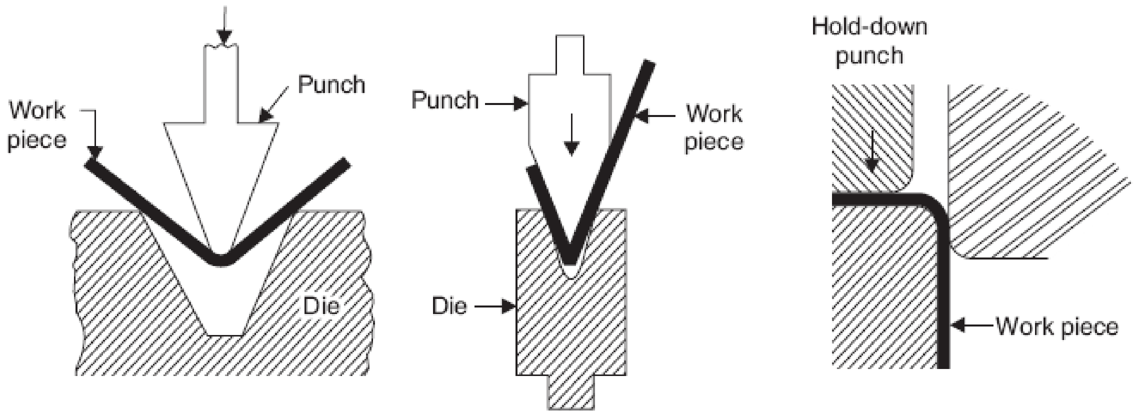
Some of these are listed below:

- *(i)* Bending,
- *(ii)* Deep drawing,
- *(iii)* Coining, and
- *(iv)* Embossing.

These operations are described briefly.

BENDING

Bending means deforming a flat sheet along a straight line to form the required angle. Various sections like angles, channels etc., are formed by bending, which may then be used for fabrication of steel structures.Three common methods of bending are illustrated in Figure.



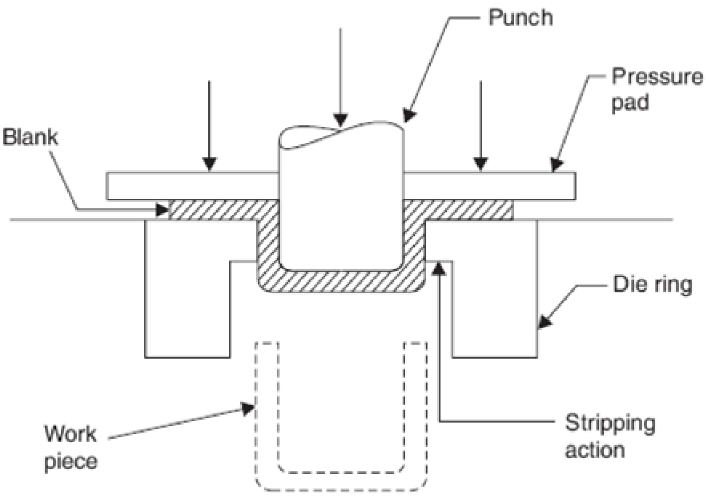
(a) Air bending (b) Die bending (c) Wiper bending

The operation of bending is done with the help of a V-shaped punch, a die and press specially designed for such work. The stroke of such presses can be controlled at operator's will and such presses are called press brakes. In V-bending, a V-shaped punch forces the metal sheet or a flat strip into a wedge-shaped die. The bend angle will depend upon the distance to which the punch depresses. Bends of 90° or obtuse as well at acute angle, may be produced. Wiper bending is used only for 90° bends. Here the sheet is held firmly down on the die, while the extended portion of sheet is bent by the punch.

Spring back: At the end of the bending operation, after the punch exerting the bending force is retrieved, due to elasticity, there is a tendency for the bend angle to open out. This is called "spring back". The effect of spring back may be offset by slight overbending in the first place. Other methods toprevent spring back are bottoming and ironing. For low carbon steels spring back is 1– 2°, while for medium carbon steel it is 3–4°.

DEEP DRAWING

In deep drawing process, we start with a flat metal plate or sheet and convert it into cupshape by pressing the sheet in the centre with a circular punch fitting into a cup shaped die. In household kitchen, we use many vessels like deep saucepans (or BHAGONA), which are made by deep drawing process. If the depth of cup is more than half its diameter, the process is termed as deep drawing and with a lesser depth to diameter ratio, it is called shallow drawing. Parts of various geometries and shape are made bydrawing process.



Deep drawing operation

During the drawing process, the sheet metal part is subjected to a complicated pattern of stress.The portion of the blank between the die wall and punch surface is subjected to pure tension, whereas the portion lower down near the bottom is subject both to tension and bending.

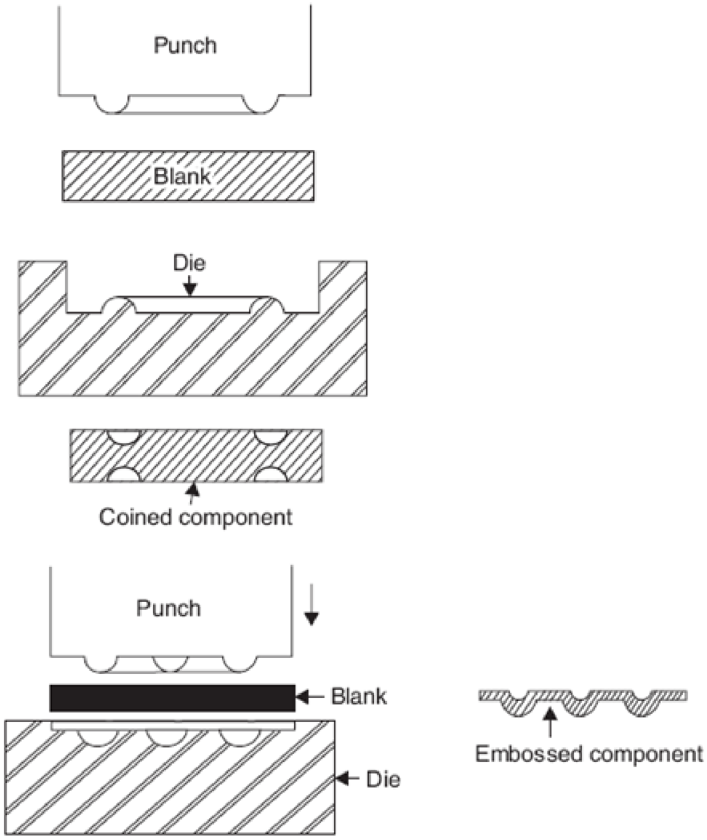
The portion of metal blank, which forms the flange at the top of the cup is subjected to circumferential compressive stress and buckling and becomes thicker as a result thereof. The flange has therefore to be held down by a pressure pad, otherwise, its surface will become buckled and uneven like an orange peel. Deep drawing is a difficult operation and the material used should be specially malleable and ductile, otherwise it will crack under the induced stresses.

The wall thickness of a deep drawn component does not remain uniform. The vertical walls become thinner due to tensile stresses. But the thinnest portion is around the bottom corner of the cup all around. This thinning of sheet at these locations is called “necking”. After deep drawing, the component may be subjected to certain finishing operations like “irowing”, the object of which is to obtain more uniform wall thickness.

COINING AND EMBOSSING

Both coining and embossing operations are done ‘cold’ and mechanical presses with punch and die are used for these operations. In embossing, impressions are made on sheet metal in such a manner that the thickness of the sheet remains uniform all over even after embossing has been done. It means that if one side of the sheet is raised to form a design, there is a corresponding depression on the other side of the sheet. Basically it is a pressing operation where not much force is needed.

The sheet is spread on the bottom die and the stroke of the punch is so adjusted that, when it moves down to its lowest position, it leaves a uniform clearance between the impressions carved in the punch and the die which is equal to the thickness of the sheet being embossed. The design is transferred on to the sheet by bending the sheet up or down without altering its thickness anywhere. Many decoration pieces with religious motifs are made in this way.



Coining and embossing operations

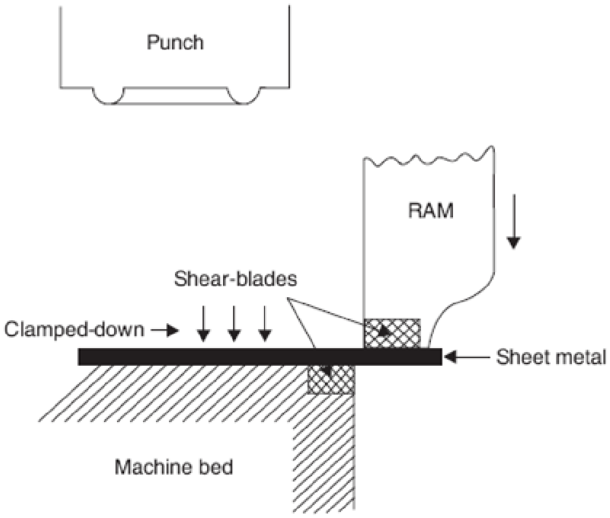
COINING

In coining process, a blank of metal which is softened by annealing process is placed between two dies containing an impression. The blank is restricted on its circumference in such a manner, that upon the two dies closing upon the blank, the material cannot flow laterally *i.e.,* sideways. The material is onlyfree to flow upwards (as a result of which it fills up the depressions in the upper die) and downwards (when it fills up depressions in the bottom die). The result of the coining operation is that the design engraved on the top and bottom dies gets imprinted on the corresponding faces of the blank in relief (*i.e.,* raised material) without the size of the blank-circumference changing. Coins used as money in daily usage are manufactured in this manner. Here forces required are much higher, enough to cause plastic-flow of material. The embossing and coining processes are illustrated in Figure.

GUILLOTINE SHEAR

Readers may have noticed, that for all press work, the raw material is in the form of sheets or plates. Commercially, sheets and plates are available in sizes 2500 × 1000 mm or 2500 × 1250 mm. They have to be cut in smaller rectangular or square pieces, as per sizes required before other operations like, bending, punching etc. are performed. For cutting sheets into smaller pieces with straight cuts, guillotine shears, (which are also mechanical presses) are used.

Guillotine shears are provided with two straight blades of adequate length made of die steel. The blades are hardened and finished by grinding to give smooth and sharp edges. One blade is fixed to the ram (which is much longer in case of guillotine shear), while the other one is fixed to the edge of machine bed in the manner shown in Figure.



Guillotine shear

The sheet is placed on machine bed with one end projecting. It is held down by clamp. When the ram moves down, the blades shear the sheet along the blade length. Steel plates up to 10 mm thick can be sheared in this way on 250 tonne presses. No sheet-metal shop is complete without a guillotine shear.

FORGING DEFECTS

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

1. Laps and Cracks at corners or surfaces lap is caused due to following over of a layer of material over another surface. These defects are caused by improper forging and faulty die design.
2. Incomplete forging—either due to less material or inadequate or improper flow of material.
3. Mismatched forging due to improperly aligned die halves.
4. Scale pits—due to squeezing of scales into the metal surface during hammering action.
5. Burnt or overheated metal—due to improper heating.
6. Internal cracks in the forging which are caused by use of heavy hammer blows and improperly heated and soaked material.
7. Fibre flow lines disruption due to very rapid plastic flow of metal.