LUKHDHIRJI ENGINEERING COLLEGE-MORBI

MANUFACTURING TECHNOLOGY (3151912)

2022_23

LAB MANUAL

STUDENT NAME : ______________________________

ENROLL NO. : ______________________________

BRANCH : ______________________________

BATCH : ______________________________

Vision: To deliver quality engineering education for Mechanical Engineers with Professional competency, Human values and Acceptability in the society.

Mission:

- To nurture engineers with basic and advance mechanical engineering concepts.
- To impart Techno-Managerial skill in students to meet global engineering challenges.
- To create ethical engineers who can contribute for sustainable development of society.

Vision of the Institute

- To provide quality engineering education and transforming students into professionally competent and socially responsible human beings.

Mission of the Institute

- To provide a platform for basic and advanced engineering knowledge to meet global challenges.
- To impart state-of-art know- how with managerial and technical skills.
- To create a sustainable society through ethical and accountable engineering practices.

MECHANICAL ENGINEERING DEPARTMENT

Vision of the Department

- To deliver quality engineering education for Mechanical Engineers with Professional competency, Human values and Acceptability in the society.

Mission of the Department

- To nurture engineers with basic and advance mechanical engineering concepts.
- To impart Techno-Managerial skill in students to meet global engineering challenges.
- To create ethical engineers who can contribute for sustainable development of society.

CERTIFICATE

This is to certify that Mr. / Ms. ________________________________ Enrollment no. _______________of 5th semester Bachelor of _______ __________Engineering has completed the term work satisfactorily in Manufacturing Technology (3151912) for the academic year __________as prescribed in the GTU curriculum.

Place:________ Date:________

Subject faculty **Head of Department**

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List of Experiments

Sr. No.	Title	COs	Start Date	End Date	Sign
1.	To study about different basic manufacturing processes.	CO1			
2.	To study about different types of pattern.	CO1			
3.	To calculate pattern allowance and hands on Exercise on Pattern Making.	CO1			
4.	To study about advance casting processes.	CO1			
5.	To study about Gas welding.	CO3			
6.	Demonstration of arc welding process.	CO3			
7.	To evaluate different welding parameters in resistance welding.	CO3			
8.	To study about metal forming processes.	CO2			
9.	To study about sheet metal forming Methods.	CO2			
10.	To study about plastic technology.	CO4			

Experiment No. 1

Aim: To study about basic manufacturing processes.

Objective: To aware about different basic manufacturing processes.

1 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

2 Classification of Manufacturing Process

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.

1. 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 under go further operations.

Some of the important primary shaping processes is:

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

2. 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 workpiece. 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
(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.

3. 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 metals forming processes are:

Hot working Processes

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

4. **Joining Processes**

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, semipermanent or permanent type of fastening to make a good joint is generally created by these processes. Temporary joining of component scan 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
(14) Nut and bolt joints.

5. 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.

6. 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
(9) Age hardening.

Exercise:

(1) Explain the importance of Manufacturing Processes in context of recent development.

(2) Give broad classification of various manufacturing processes. Also describe the factors affecting the selection of manufacturing process for a product.

Experiment No. 2

Aim: To study about different types of pattern.

Objective: To explain use of different types of pattern used in foundry practice.

1. Introduction

Pattern is the replica of the device which is the output of casting process. This when moulded in sand forms mould. After filling mould with the molten metal there is a formation of casting. Patterns play a very important role in casting as they decide the quality as well as perfection in a particular casting process. Gates and runners are the most important components in several types of pattern. Pattern is the basic requirement for creation of mould and it is always bigger than the size of casting. There should be a proper selection of pattern so it must be able to sustain rough handling. It forms mould cavity for casting processes. The patterns may be made of metals like aluminium, brass, plaster and wax.

There are some of the features of best pattern material used for designing:

• Water resistant.
• Cheap in cost and have very less weight.
• Long lasting and hard.
• Industry oriented patterns are mostly designed simple and they are repairable.

During patterning processes, to handle any structural problems different allowances are made. These allowances include shrinkage allowances, shake allowances, Draft allowances and finally distortion allowances.
Following are some of the key factors that decide the types of patterns of casting you must choose:

- Quantity of casting to be produced
- Size and shape of the casting
- Type of moulding method
- Design of casting.
- Features of the particular casting process,

2. Types of Patterns

The various types of patterns that we use in casting process are
1) Single piece pattern
2) Two piece pattern
3) Gated pattern
4) Multi piece pattern
5) Match plate pattern
6) Skeleton pattern
7) Sweep pattern
8) Lose piece pattern
9) Follow board pattern
10) Cope and drag pattern
11) Segmental pattern and
12) Shell pattern

1. Solid or Single Piece Pattern

Single piece pattern is the cheapest pattern among all other types of pattern. This pattern generally used in simple processes. It is applied in small scale production. It is often used for the generation of large castings such as stuffing box of steam engine and for creating simple shapes, flat surfaces like simple rectangular blocks. The important characteristic of this pattern is that there is no need of joint in the mould area. In this pattern one surface is considered as flat portion. This flat surface is used for parting plane. Sand tools are used to cut the sand which ultimately makes gating system. The moulding becomes a difficult task if there is absence of this flat surface. It is expected to lie in cope or drag.

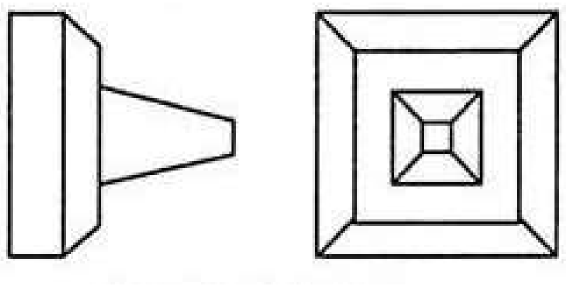


Fig. 1 Single piece pattern

2. Two- Piece Pattern

Two- piece pattern is also called as split piece pattern. It is the popularly used for intricate castings. The shape of casting decides the exact place of parting plane. This parting plane may be flat or irregular surface. In two- piece pattern half part is always moulded in drag and other half part is moulded in cope. The cope part of the pattern has dowel pins. These dowel pins are used to align the two halves of split piece pattern. Holes in the drag half of the two- piece pattern matches exactly with dowel pins. It is used in applications where it is very difficult to withdraw casting from the mould. Two- piece patterns are used where the depth of casting is very high.

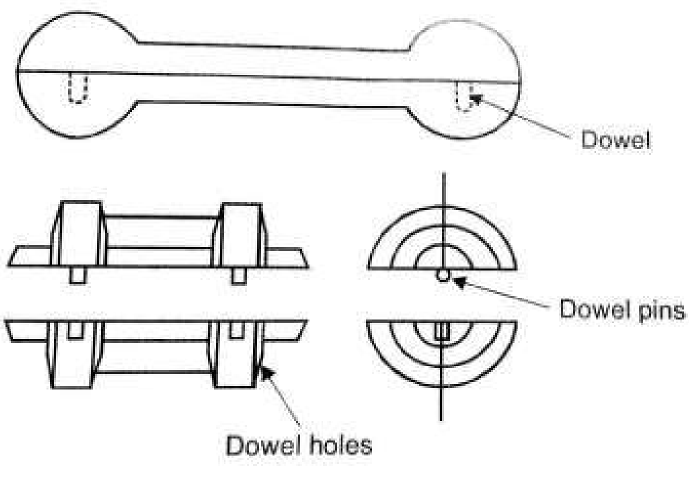


Fig. 2 Two piece pattern

3. Multi Piece Pattern

Sometimes castings have very difficult and complicated designs. In such difficult situations multi piece types of patterns are used. 3 or more patterns are included in multi piece pattern. For instance, if we consider three- piece pattern which comes under multi piece pattern. This three- piece pattern consists of top, bottom and middle parts. The bottom part is drag; top part is coping where the middle part is termed as check box.

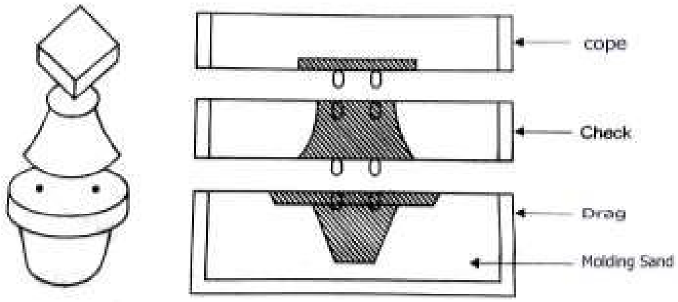


Fig. 3 Multi piece pattern

Applications:
It is used in various kinds of joints such as mitre joint, dowel joint.

4. Match Plate Pattern

Basically Match plate pattern is a split pattern. Cope and drag areas are on the opposite faces of metallic plate. This metallic plate is termed as Match Plate. This type of pattern requires very less hard work and gives very high output because the gates and runners are also on the match plate. This is used in various manufacturing industries. This is very expensive and gives accuracy as well as high yield. This pattern is widely used for casting metals like aluminium.

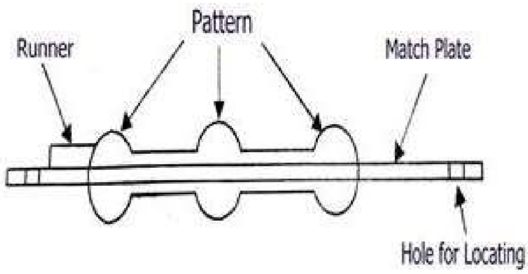


Fig. 4 Match plate pattern

Applications:
1) Used in piston rings of I.C. engines
2) Multi piece pattern has wide scope in rotor hub.

5. Gated Pattern

Gated types of patterns are used to make multiple components inside the single mould. Gated pattern is nothing but the pattern consisting one or more patterns. For joining different patterns gates are used. These are loose patterns where gates and runners have already attached. These patterns are very expensive. Due to their high cost they are used for creating small castings. These small castings further are used in moulding machines as well as in mass producing processes.

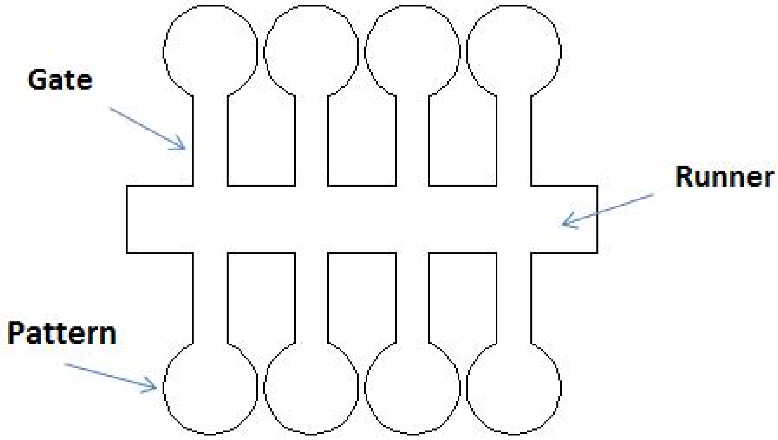


Fig. 5 Gated pattern

The important advantage of this pattern is –

1) Low moulding time
2) molten metal is uniformly distributed

6. **Skeleton Pattern**

Skeleton pattern is used for castings which have simple size and shape. These castings are usually large in size. The only disadvantages of skeleton types of patterns are – it is applicable for small number of components and it is not cheap. Economically, it is not the best pattern. Stickler is used to remove extra sand. These are nothing but frames of wood that highlight the area which is to be cast. These patterns also help moulder. They are widely used in process of pit or floor welding.

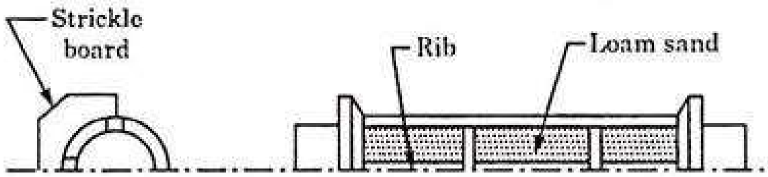


Fig. 6 Skeleton pattern

Applications:
1) Turbine manufacturing uses skeleton pattern
2) in daily applications such as water pipes are mostly designed with the help of skeleton pattern.

7. **Sweep Pattern**

In sweep pattern we make use of wooden board. This wooden board of proper size is to be rotated about one edge to shape the cavity as circular or rotational symmetry. Sweep pattern is often used when we have to create casting in very short interval of time. Moulds of extensive symmetrical casting can be made easily with the help of sweep pattern. Sweep pattern consists of three parts spindle, base and sweep which are wooden board. Spindle is directed in vertical direction and base is attached with sand.

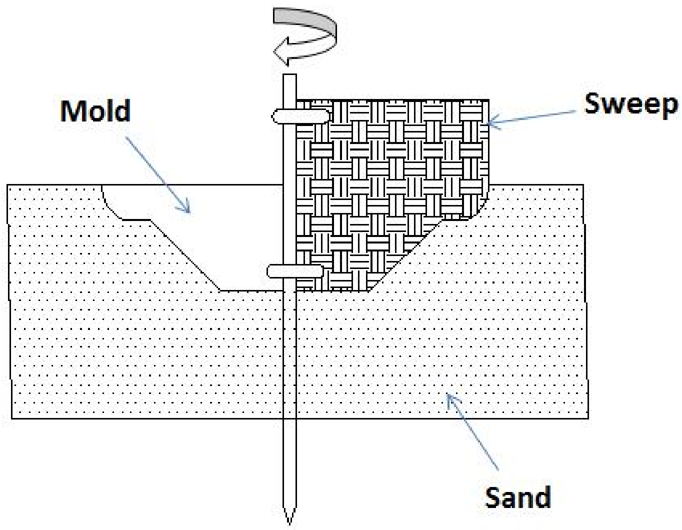


Fig. 7 Sweep pattern

Applications:
Circular discs, wheels, large kettles are produces by making use of sweep pattern.

8. Loose Piece Pattern

It is very difficult to remove one piece of solid pattern which is above or below the parting plane having projections from the mould. With the help of loose piece types of patterns projections can be made by loose pieces. It requires skilled labour work as well as it is very expensive. There is one disadvantage of this loose piece pattern is that their shifting can be done due to ramming process.

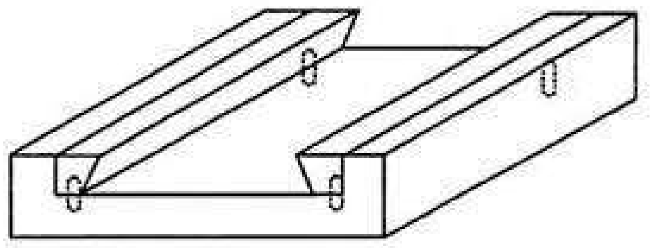


Fig. 8 Loose piece pattern

Applications:
1) In the production of axle pin.
2) Loose piece pattern is used in the rotor hub.

9. Cope and Drag Pattern

Cope and drag pattern is a split pattern. This pattern has cope and drag on separate plate. Cope and drag pattern has two parts which are separately moulded on moulding box. After moulding parts, these two separate parts are combined to form the entire cavity. Cope and drag pattern is almost like two-piece pattern.
This pattern types are used in the production of large castings where the moulds are very heavy and unhandy for a user.

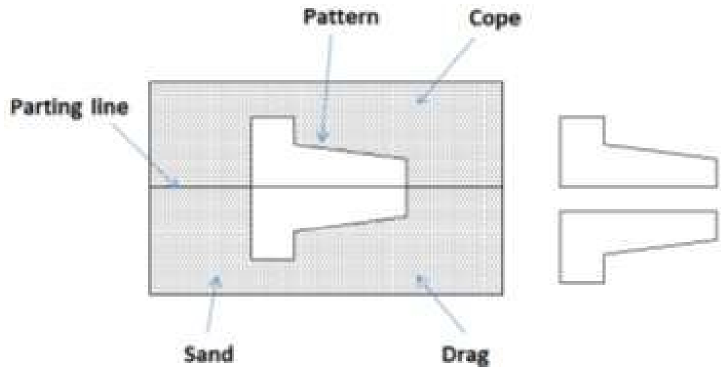


Fig. 9 Cope and drag pattern

Applications:
1) This pattern is used in building flange pipe.
2) Cope and drag pattern is used in water jacket which is an important component of JCB.

10. Follow Board Pattern

Follow board pattern consists of tool that is a simple wooden board which is used for several reasons. The wooden board is used as a base in follow board pattern for moulding process. This pattern is used in processes where casting structures are weak and they may break after the application of force.

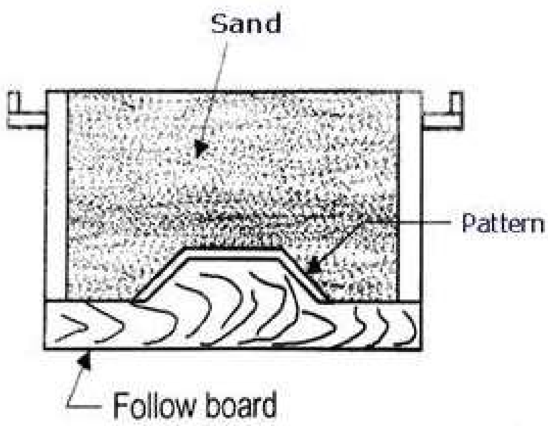


Fig. 10 Follow board pattern

Applications:
This pattern is used for casting master pattern for many purposes.

11. Segmental Pattern

It is just a similar to that of sweep pattern. The working structure of segmental pattern and sweep pattern is almost similar. For designing require shape or structure of mould they both employ a part of pattern. As the name suggest segmental pattern is in the form of segments and used for moulding circular or round structures. In sweep pattern there is complete rotation but in segmental pattern there is no complete rotation. For creating mould, we can rotate partly to get required output.

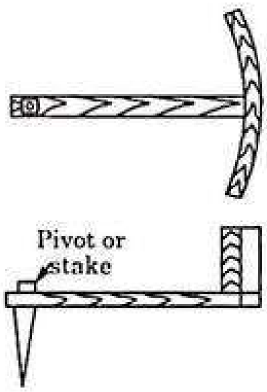


Fig. 11 Segmental Pattern

Applications:
Segmental pattern is used for constructing circular structures like wheels, rims, pulleys etc.

12. Shell Pattern

Shell pattern is specially used for obtaining hollow shaped structure. Along the centre the parting process is done. The resultant halves produced after parting are both doweled.

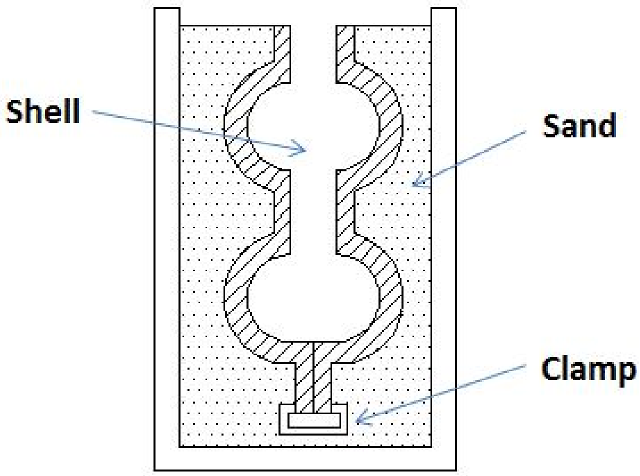


Fig. 12 Shell pattern

In casting, above mentioned patterns play crucial role. So we have to decide which pattern we should use according to requirements.

3. Pattern Colours

Actually, there is no universal standard for representation of various types of surfaces by different colours. This varies with different countries and sometimes with different manufacturers also.
Patterns are provided with certain colours and shade for following reasons:
I. To identify quickly the main pattern body and different pattern parts.
II. To indicate the type of the metal to be cast.
III. To identify loose pieces, core prints, etc.
IV. To visualize machined surfaces, etc.
An American colour scheme for pattern and core boxes is as follows:
1. Cast surfaces to be machined - **Red**.
2. Surfaces to be left un machined- **Black**.

3. Core print seats- Yellow.
4. Loose piece and settings- **Red strips on yellow base**.
5. Parting surfaces - **Clear or no colour**.
6. Supports or stop-offs - **Black strips on yellow base**.
7. Core prints for machined castings - **Yellow strips on black background**.

Exercise"

(1) Enlist the patterns material and explain any two with their advantages and limitation.

(2) What is pattern? Explain the following patterns with a schematic diagram.

(1) Gated Pattern (2) Follow board Pattern (3) Split Pattern

Experiment No. 3

Aim: To calculate pattern allowance and Hands on Exercise on Pattern Making.

Objective: (1) To calculate pattern allowance.
(2) To prepare the pattern for given component.

1. Introduction

The shapes of cast steel components reflect not only the functional requirements of the component, but also manufacturability requirements dictated by the casting process. Castings shapes must incorporate the proper use of draft allowances for successful mould making and machining allowances for surfaces requiring more precision and better surface finishes than can be achieved in the as-cast conditions. Draft and machine finish allowance guidelines and practices are presented to assist in the specification of draft and machining allowances for castings. Similarly, size or pattern allowances must be incorporated into the production of patterns and core boxes from which steel castings are made. These pattern allowances (sometimes call shrink rules) must also be correctly applied to ensure that final castings can meet customer dimensional tolerance requirements without extra pattern dimension adjustment cycles.

2. Pattern Allowances

A pattern is always made larger than the final casting, because it carries certain allowances due to metallurgical and mechanical reasons.
The following allowances are provided on the pattern:

(a) Shrinkage or contraction allowances.
(b) Machining allowances.
(c) Draft or taper allowances.
(d) Distortion allowances.
(e) Raping or shake allowances.

(a) Shrinkage or contraction allowances.

Almost all the metals used in the casting work shrink or contract during cooling from pouring temperature to room temperature.

This contraction takes place in three forms i.e.

- Liquid contraction
- Solidifying contraction
- Solid contraction

To compensate liquid and solidifying contraction, gates and risers are provided in the mould, whereas for solid contraction adequate allowances are provided on the pattern. The different metals shrink at different rates because shrinkage is the metal property, hence corresponding allowances are also different.

The shrinkage of metal depends on the following factors:

- The metal to be cast
- Pouring temperature of the molten metal

- Dimensions of the casting
- Method of moulding

Shrinkage allowance for different cast metals is given in the following Table 1:

Table 1: Shrinkage allowance for different metals

Sr.No.	Metal	Contraction (per cent)	Contraction (mm per metre)
1	Grey cast iron	0.7 to 1.05	7 to 10.5
2	White cast iron	2.1	21
3	Malleable iron	1.5	15
4	Steel	2.0	20
5	Brass	1.4	14
6	Aluminium	1.8	18
7	Aluminium alloys	1.3 to 1.6	13 to 16
8	Bronze	1.05 to 2.1	10.5 to 21
9	Magnesium	1.8	18
10	Zinc	2.5	24
11	Manganese steel	2.6	26.5

b. Machining allowance:

Machining allowance or finish allowance is the amount of dimension on a casting which is made oversized to provide stock for machining. A casting may require machining all over or on certain specified portions. Such portions or surfaces on the pattern are given adequate allowance in addition to the shrinkage allowance.

The amount of machining allowance depends upon following factors:

- Metal of casting
- Machining method used
- Casting method used
- Shape and size of the casting
- Amount of finish required on the machined portion

Ferrous metal needs more allowance than the non-ferrous metals and similarly, large castings need more allowance than small castings. Machining allowance varies from 1.5 mm to 16 mm, but 3 mm allowance is more common for small and medium castings.

Table 2 - Recommended values for machining allowances

Final size in mm	Machining allowance (reaming allowance) in mm
Less than 5	0.1 - 0.2
5 to 20	0.2 - 0.3
21 to 32	0.3
33 to 50	0.5
51 to 70	0.8
71 to 120	1.0 - 1.2
121 to 150	1.3 - 1.5

The required machining allowance, when considered along with the casting feature dimensional Tolerance should be interpreted as shown in Figure.

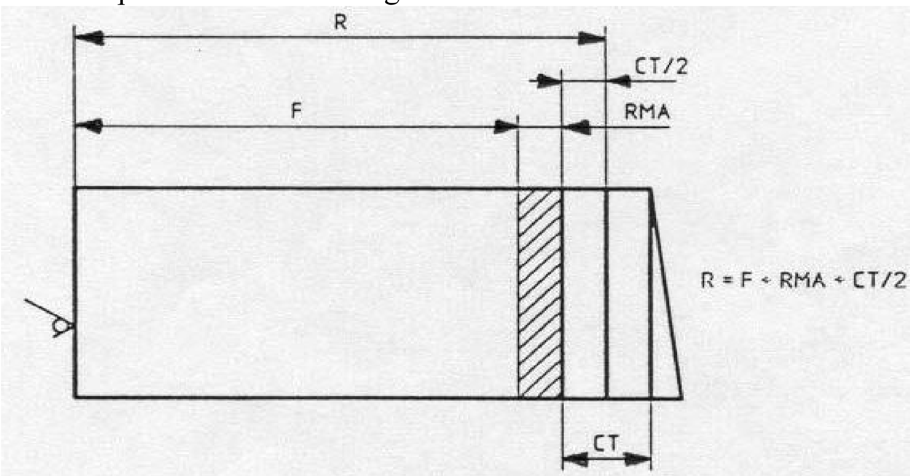
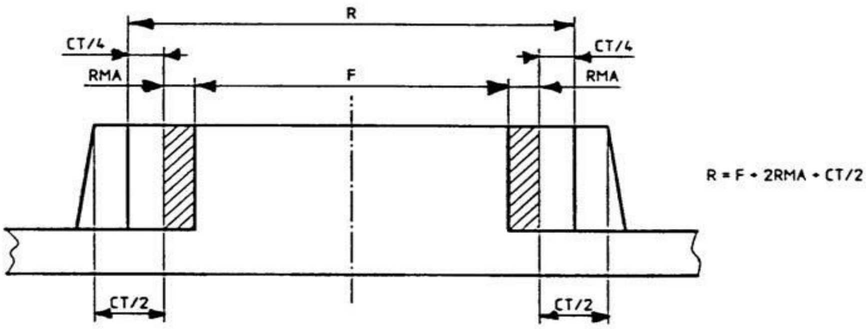


Fig. 1 Machining allowance on single side.



R = Raw casting basic dimension

F = Dimension after final machining

RMA = Required machining allowance

CT = Casting tolerance

Fig. 2 External Machining allowances.

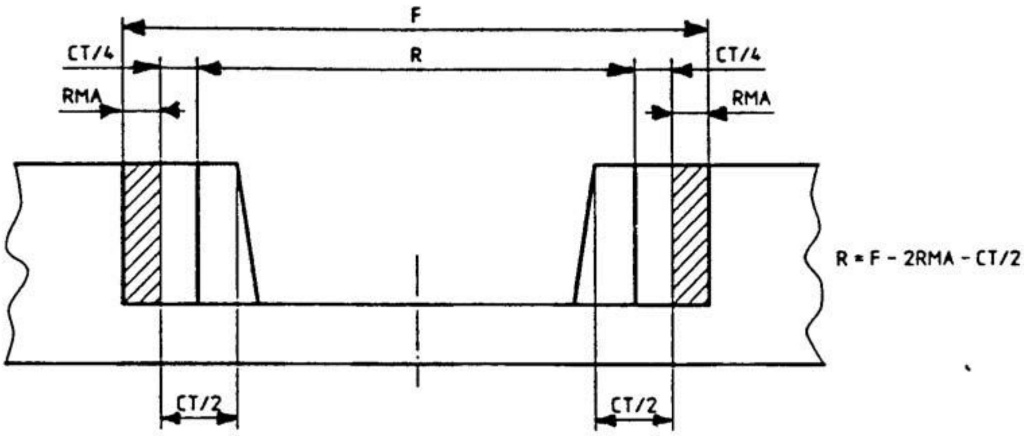


Fig. 3 Internal Machining allowances.

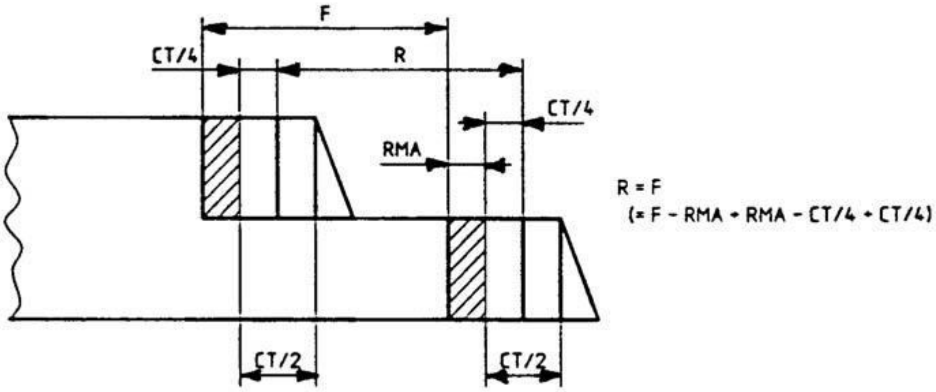


Fig. 4 Step Machining allowance

c. Draft allowance:

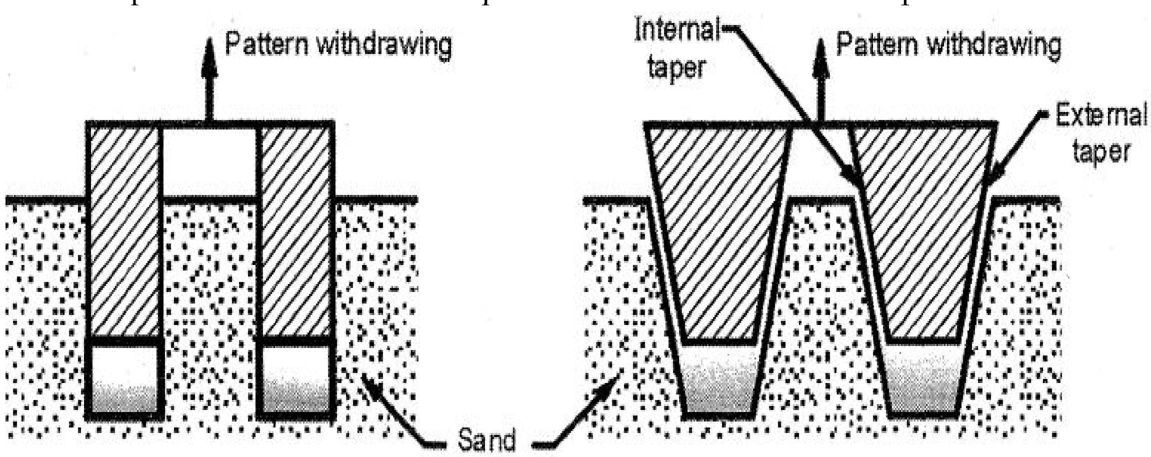
Draft allowance or taper allowance is given to all vertical faces of a pattern for their easy removal from sand without damaging the mould. This slight taper inward or outward on the vertical faces is known as draft. It can be expressed either in degrees or in mm/meter. Generally, it is more on internal surfaces as compared to external surfaces.

The amount of draft allowance depends on following factors:

- Shape and size (height) of the pattern
- Method of moulding
- Material of moulding

This allowance varies from 10 mm to 25 mm per meter on external surfaces and 40 mm to 65 mm per meter on internal surfaces. It can be seen that, it is easy to withdraw the pattern having taper allowance out of the mould without damaging the mould cavity.

Fig. 5 shows two patterns i.e. one without taper allowance and other with taper allowance.



(a) Pattern without allowance ***(b) Pattern with allowance***

Fig. 5: Taper or draft allowance

Table 3: Recommended value of Draft (Taper) Allowances

Moulding Process	Typical Draft (Taper) Angles	
	Most Features	Deep Pockets
Green Sand - Manual	1.5 °	2.0 °
Green Sand - Automated	1.0 °	1.5 °
No-bake & shell moulding	1.0 °	1.5°

Machine moulding will require a minimum amount of draft. Interior surfaces in green sand moulds usually require more draft than exterior surfaces. Draft can be eliminated in some cases through special moulding techniques, such as investment casting or through the use of cores. These situations and the specific amount of draft required should be discussed with personnel of the foundry that will produce the casting. A specific dimensional tolerance on a drafted surface is generally referenced from the drafted surface rather than from the surface dimension before draft is applied. That is, draft is added to casting surfaces first before dimensional tolerances or geometric tolerances applied, Figure 6 Draft allowances can be incorporated into dimensional tolerances or geometric tolerances only upon consultation with the foundry.

The dimensional changes needed to incorporate draft can be expressed as follows:

$DA = L \tan \theta$

Where:

DA = Draft allowance

L = Length

θ = Draft angle

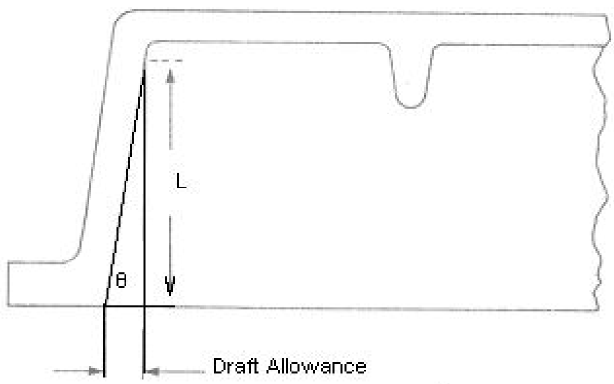


Fig. 6 Calculation of draft angle on pattern

d. Distortion allowance (Camber allowance):

When the mould is cooling process, the stress is developed in solid metal because of the uneven metal thickness or more cooling to allow in the casting. These stresses may be inducing distortion or bending in the casting. This can be avoided by initially distorting the pattern in opposite direction. The casting part thickness is uneven. Hence, the solidification process is not uniformly and thermal stress provided on the section. So those castings are distorted. To avoid that, the chamber provided in the opposite direction.

The casting will distort or warp if:

- It is of irregular shape.
- It is of or V-shape.
- The arms having unequal thickness.
- One portion of the casting cools at a faster rate than the other.

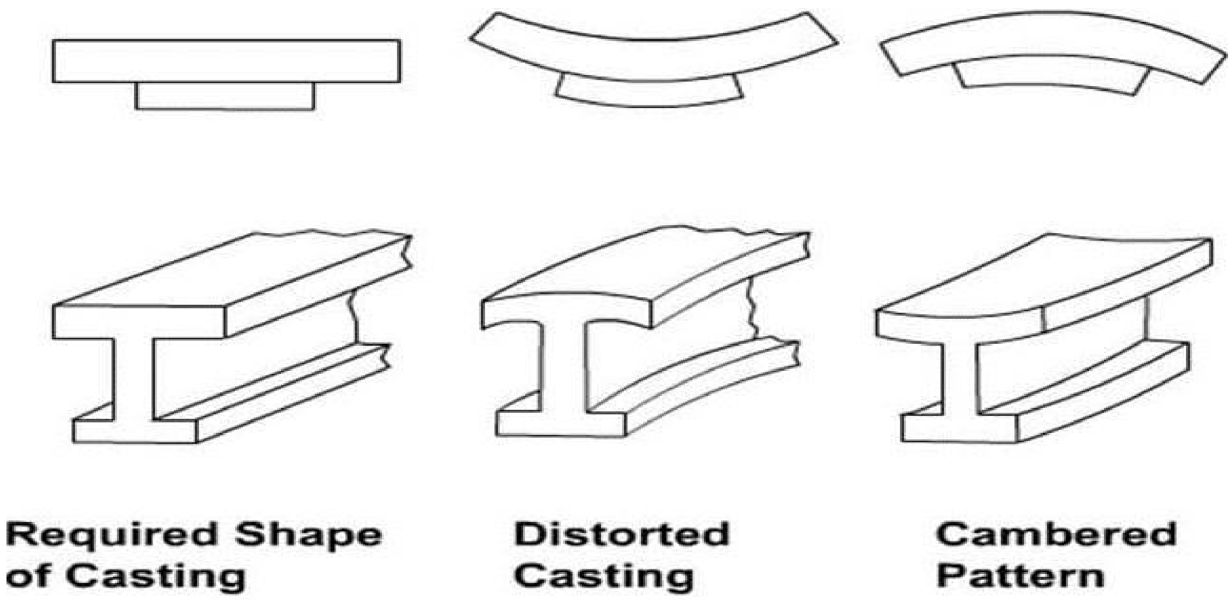


Fig. 7): Distortion or camber allowance

To eliminate this defect, an opposite distortion is provided on the pattern, so that the effect is balanced and correct shape of the casting is produced.

The amount of distortion allowance varies from 2 mm to 20 mm as per the size, shape and casting material.

e. Rapping or Shake allowance:

When a pattern is to be taken out from the mould, it is first rapped or shaken by striking it with a wooden piece from side to side. This is done so that the pattern surface becomes free from adjoining sand of the mould. Due to this, there is little increase in the size of the mould cavity. For this purpose, a negative allowance is provided on the pattern i.e. the dimensions are kept smaller. It is normally provided only to the large castings and negligible for small and medium sized castings.

Exercise/Practice

Experiment No. 4

Aim: To study about advance casting processes.

Objective: (1) To study about moulding process.
(2) To study the casting methods.

1. Introduction

Virtually nothing moves, turns, rolls, or flies without the benefit of cast metal products. The metal casting industry plays a key role in all the major sectors of our economy. There are castings in locomotives, cars trucks, aircraft, office buildings, factories, schools, and homes. Metal Casting is one of the oldest materials shaping methods known. Casting means pouring molten metal into a mold with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the mold either by breaking the mold or taking the mold apart. The solidified object is called the casting. By this process, intricate parts can be given strength and rigidity frequently not obtainable by any other manufacturing process. The mold, into which the metal is poured, is made of some heat resisting material. Sand is most often used as it resists the high temperature of the molten metal. Permanent molds of metal can also be used to cast products.

2. Classification of casting Processes

Casting processes can be classified into following categories:

1. Conventional Molding Processes
   a. Green Sand Molding
   b. Dry Sand Molding
   c. Flask less Molding
2. Chemical Sand Molding Processes
   a. Shell Molding
   b. Sodium Silicate Molding
   c. No-Bake Molding
3. Permanent Mold Processes
   a. Gravity Die casting
   b. Low and High Pressure Die Casting
4. Special Casting Processes
   a. Lost Wax
   b. Ceramics Shell Molding
   c. Evaporative Pattern Casting
   d. Vacuum Sealed Molding
   e. Centrifugal Casting

3. Green Sand Moulding

Green sand is the most diversified moulding method used in metal casting operations. The process utilizes a mould made of compressed or compacted moist sand. The term "green" denotes the presence of moisture in the moulding sand. The mould material consists of silica sand mixed with a suitable bonding agent (usually clay) and moisture.

Advantages

1. Most metals can be cast by this method.
2. Pattern costs and material costs are relatively low.
3. No Limitation with respect to size of casting and type of metal or alloy used.

Disadvantages

Surface Finish of the castings obtained by this process is not good and machining is often required to achieve the finished product.

Sand mould Making Procedure

- The first step in making mould is to place the pattern on the moulding board.
- The drag is placed on the board.
- Dry facing sand is sprinkled over the board and pattern to provide a non-sticky layer.
- Moulding sand is then riddled in to cover the pattern with the fingers; then the drag is completely filled.
- The sand is then firmly packed in the drag by means of hand rammers. The ramming must be proper i.e. it must neither be too hard or soft.
- After the ramming is over, the excess sand is levelled off with a straight bar known as a strike rod.
- With the help of vent rod, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification.
- The finished drag flask is now rolled over to the bottom board exposing the pattern.
- Cope half of the pattern is then placed over the drag pattern with the help of locating pins. The cope flask on the drag is located aligning again with the help of pins.
- The dry parting sand is sprinkled all over the drag and on the pattern.
- A sprue pin for making the sprue passage is located at a small distance from the pattern. Also, riser pin, if required, is placed at an appropriate place.
- The operation of filling, ramming and venting of the cope proceed in the same manner as performed in the drag.
- The sprue and riser pins are removed first and a pouring basin is scooped out at the top to pour the liquid metal.
- Then pattern from the cope and drag is removed and facing sand in the form of paste is applied all over the mould cavity and runners which would give the finished casting a good surface finish.
- The mould is now assembled.
- The mould now is ready for pouring.

4. **Dry Sand Moulding**

When it is desired that the gas forming materials are lowered in the mould, air-dried mould are sometimes preferred to green sand moulds.

Two types of drying of moulds are often required.
1. Skin drying and
2. Complete mould drying.
In skin drying a firm mould face is produced. Shakeout of the mould is almost as good as that obtained with green sand moulding. The most common method of drying the refractory mould coating uses hot air, gas or oil flame. Skin drying of the mould can be accomplished with the aid of torches, directed at the mould surface.

5. Shell Moulding Process

It is a process in which, the sand mixed with a thermosetting resin is allowed to come in contact with a heated pattern plate (200 oC), this causes a skin (Shell) of about 3.5 mm of sand/plastic mixture to adhere to the pattern... Then the shell is removed from the pattern. The cope and drag shells are kept in a flask with necessary backup material and the molten metal is poured into the mould. This process can produce complex parts with good surface finish 1.25 µm to 3.75 µm, and dimensional tolerance of 0.5 %. A good surface finish and good size tolerance reduce the need for machining. The process overall is quite cost effective due to reduced machining and clean-up costs. The materials that can be used with this process are cast irons, and aluminium and copper alloys.

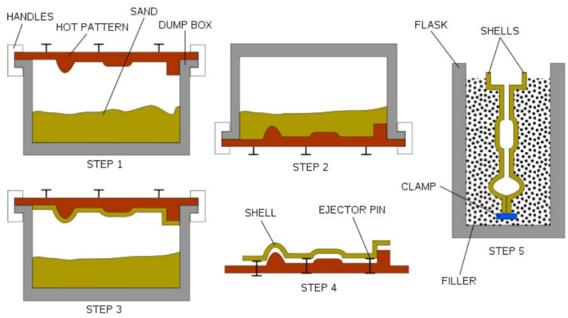


Fig. 1 Shell moulding process

6. Sodium Silicate Moulding Process

In this process, the refractory material is coated with a sodium silicate-based binder. For moulds, the sand mixture can be compacted manually, jolted or squeezed around the pattern in the flask. After compaction, CO 2 gas is passed through the core or mould. The CO 2 chemically reacts with the sodium silicate to cure, or harden, the binder. This cured binder then holds the refractory in place around the pattern. After curing, the pattern is withdrawn from the mould. The sodium silicate process is one of the most environmentally acceptable of the chemical processes available. The major disadvantage of the process is that the binder is very hygroscopic and readily absorbs water, which causes porosity in the castings... Also, because the binder creates such a hard, rigid mould wall, shakeout and collapsibility characteristics can slow down production.

7. Casting Processes

Following are the various casting processes which are commonly used:

a. Sand mould casting
b. Plaster mould casting
c. Metallic mould casting

I. Permanent mould casting
II. Slush casting
III. Pressure die casting d.
Centrifugal casting
e. Investment casting
f. Continuous casting
g. C02 - mould casting.
h. Ceramic mould casting

1. **Permanent Mould Casting**

The process is also called as gravity die-casting. The main difference between permanent mould casting and sand casting is that, in this the mould is permanent which is neither destroyed nor remade after each cast. For making permanent mould, high resistant fine grained alloy, iron and steel are commonly used. Pouring in permanent moulds is simply done due to gravity and hence called as gravity die-casting.

Stages in casting:

Fig. 2 shows a permanent mould which comprises of several blocks joined together. The mould is first preheated, by using some means, up to a temperature of 400°C. The mould is followed by the application of a refractory coating on the mould cavity surfaces, runner and riser, etc.

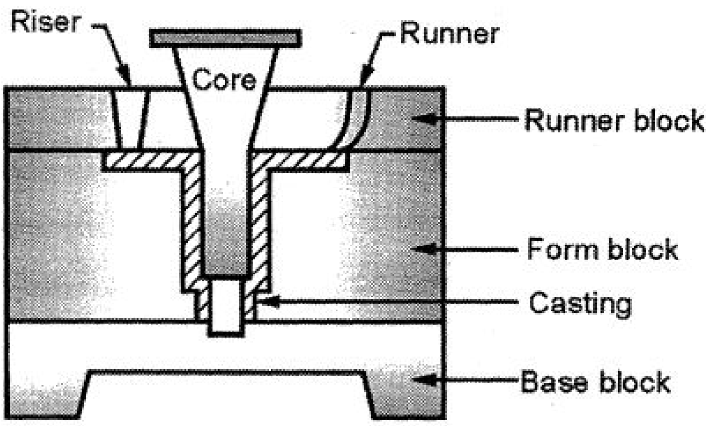


Fig 2: Section showing one half of a permanent mould

After attaining the mould temperature, the casting is poured. As the metal begins to solidify, cores are removed; otherwise it may shrink onto the surface of the metal. By blowing, the mould is then cleaned, coated with refractory coating, cores are assembled and closed again for pouring.

2. **Slush Casting**

It is basically a permanent mould casting process. It is used for producing hollow casting without using cores. It is mostly preferred for producing such articles, where accuracy is not required but the outer surface should have ornamental appearance. Molten metal is poured into the mould, which is turned over immediately, so that the metal remaining as liquid can run out. The thickness of solidified shell depends upon the chilling effect from the mould and the duration for which the metal is allowed to remain in the mould before turning over. The metals used for such articles are lead, zinc and various low melting alloys.

3. **Pressure Die-casting**

In pressure die-casting molten metal is poured by pressure into a metal mould known as die. Because the metal solidifies under pressure, the casting confirms to the die cavity in shape and surface finish. The pressure is generally obtained with the help of compressed air or hydraulically. The pressure varies from 70 to 5000 kg/cm2.

The main types of die-casting machines are:

a. Hot chamber die-casting

b. Cold chamber die-casting

The principle difference between the two methods is determined by the location of the melting pot. In the hot chamber method, a melting pot is included with the machine and the injection cylinder is immersed in the molten metal at all time. The injection cylinder is operated by either hydraulic or air pressure, which forces the metal into the dies to form a casting. Whereas, cold chamber machine consists of separate melting furnace and metal is introduced into injection cylinder by hand or mechanical means.

a. Hot chamber Die-casting:

In this method metal is forced into the mould and pressure is maintained during solidification either by a plunger or by compressed air.

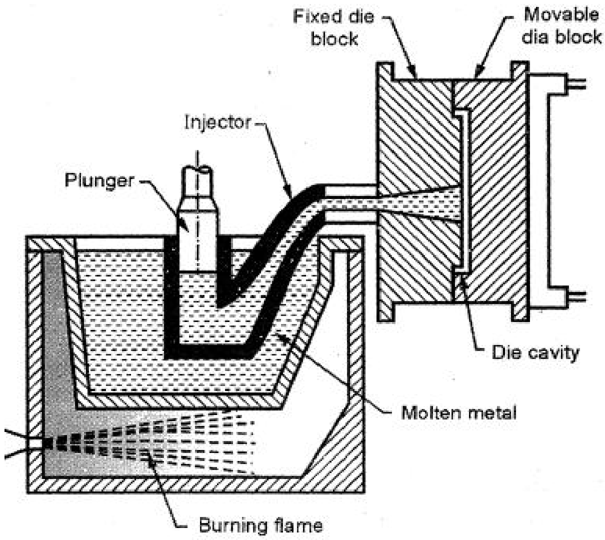


Fig. 3: Hot chamber die-casting machine

Fig. 3 shows the main parts of hot chamber machine. The plunger acts inside a cylinder formed at one end of the goose neck type casting submerged in the molten metal. Near the top of the cylinder, for entry of molten metal, a port is provided. When the bottom of the plunger is above the port, at that time the cylinder is connected to the melting pot through this port. This downward stroke of the plunger closes this port, cuts off the supply of metal and applies pressure on the metal present in the goose-neck to force it into the die cavity through the injecting nozzle. After sometime, the plunger is raised up, causing the remaining molten metal in the nozzle and channel to fall back into the casting. Before the end of upward stroke, the plunger uncovers the port, through which more amount of molten metal enters into the cylinder. Then the dies are opened and casting is ejected. These machines are generally used for producing castings of low melting point metals like zinc, tin and lead.

b. Cold chamber Die-casting:

Fig. 4 shows the working principle of cold chamber machine.

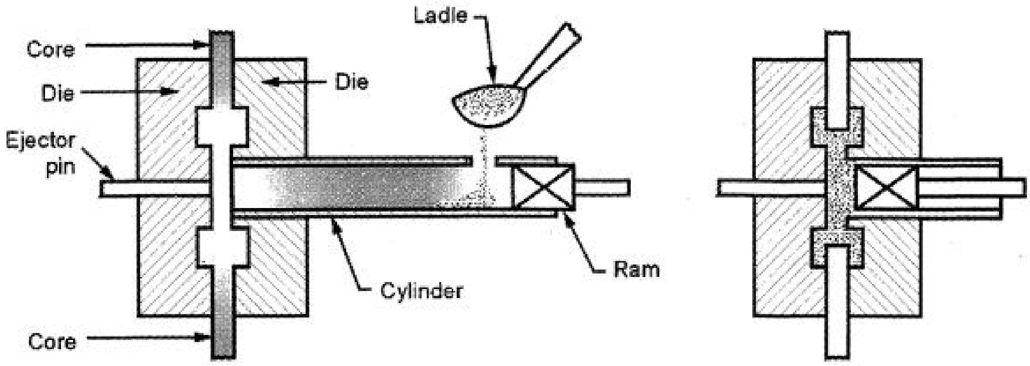


Fig. 4: Cold chamber die casting machine

The machine consists of separate furnace for melting the metal. The metal is melted separately in the furnace and transferred to cold chamber by using small hand ladle. After closing the die, the molten metal is poured into the horizontal chamber through the metal inlet. To force the metal into the die, the plunger is pushed forwards hydraulically. After solidification, the die is opened and the casting is ejected. Cold chamber machines are mainly used for making castings in aluminium, brass and magnesium. The life of these machines is more, because the melting unit is separated from the working parts. But, the life of die is less because the machine involves very high pressure i.e. about200 to 2000 kg/cm2

Advantages of pressure die casting:

- High production rates are possible.
- Economical for large production quantities.
- Close tolerances up to ± 0.076 mm on small parts is possible.
- Good surface finish can be obtained.
- Thin sections up to 0.5 mm can be cast. ·
- Limitations of pressure die casting:
- Only small parts can be made.
- Only non-ferrous alloys and metals can be commercially cast.
- Due to high cost of equipment and dies, the process is economical only for mass production.
- Due to entrapped air, the die castings are porous which reduces mechanical properties of the component.

Applications of pressure die casting:

- Household equipment like decorative parts, mechanical parts of mixers, fans, vacuum cleaners, washing machines, can openers; refrigerators, etc. can be made.
- Industrial equipment like motor housing, crane parts, motor, rotor fan, impeller wheel, etc. can be made.

- Automotive parts like windshield frames, window channels, bodies of fuel pump and carburettor, handles, rear view mirror parts, brake shoe (Al), etc. can be made.
- Toys like pistols, electric trains, model aircraft, automobiles, etc. can be made.
- Other parts like taps, valves, burners, fire alarm system, telephone sets, speakers,
- Staplers, typewriters, etc. can be mad

4. Centrifugal Casting

Centrifugal casting is also known as liquid forging. In this process mould is rotated at high speed and molten metal is poured into it. Due to the centrifugal force, the molten metal is directed outwards from the centre i.e. towards the inner surface of the mould with high pressure. Hence, a uniform thickness of metal is deposited all along the inner surface of the mould, where it solidifies and the impurities being lighter remains nearer to the rotation axis. This process produces casting with greater accuracy and better physical properties. This method is mainly suitable for producing casting of symmetrical shapes.

Centrifugal casting processes can be classified as:

a. True centrifugal casting
b. Semi -centrifugal casting
c. Centrifuging

a. True centrifugal casting:

An important feature of true centrifugal casting is that, the axis of rotation of the mould and that of the casting are the same. Also there is no need of central core for producing central hole. The axis of rotation· of the mould may be horizontal, vertical or inclined at any suitable angle.

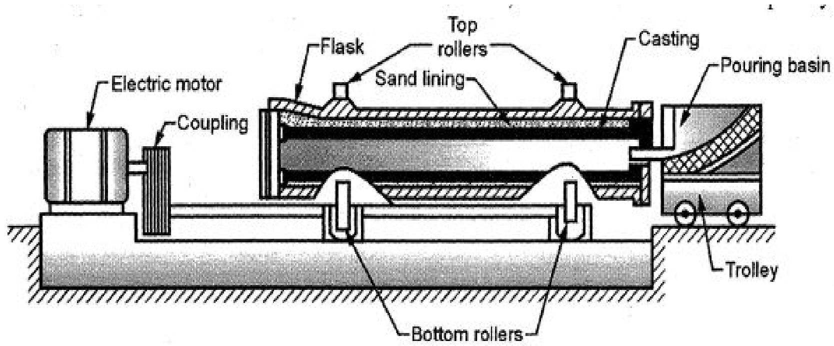


Fig. 5: Horizontal true centrifugal casting machine

During the operation, moulding flask is properly rammed with sand to confirm to the outer contour of the casting to be made. The flask is then dynamically balanced to reduce undesirable vibrations during the process. The finished flask is mounted between the rollers and the mould is rotated slowly as shown in Fig. 5. The molten metal is poured into the revolving mould. The centrifugal force throws the metal towards the outer walls. The amount of the metal poured determines the thickness of the casting. After pouring is completed; the mould is rotated at its original speed, till it solidifies to form the required casting. The outer surface of the mould is water cooled, therefore metal solidifies quickly. The casting machine is mounted on wheels with pouring ladle which has a long spout exceeding till the other end of the casting to be made. This method is used to cast hollow cylindrical objects such as hollow pipes, gun barrels, liner bushes, etc.

b. Semi centrifugal casting:

In semi-centrifugal casting method the mould is completely full of metal as it is spun about its vertical axis and risers and core may be employed. Rotational speed for these methods is not as great as for the true centrifugal process. The molten metal 1s poured through a central sprue as shown in Fig. 6.

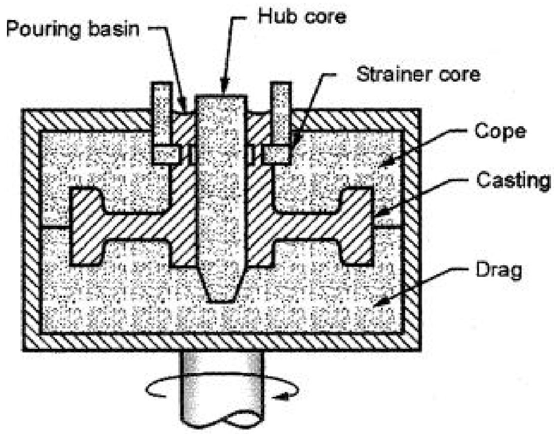


Fig. 6: Semi-centrifugal casting

As the speed of rotation is low, centrifugal force and pouring pressure produced are low. The impurities are not collected at the centre. The moulds used may be of green sand, dry sand, metal or any other suitable material. A central core is used to form the required inner surface of the casting. This method is used to produce larger sized symmetrical casting such as discs, pulleys, gears, sprocket wheels, etc.

c. Centrifuging:

In this method several casting cavities are located around the outer portion of a mould and the metal is fed to these cavities by radial gates from the centre. The centrifugal force produces sufficient pressure, to force the metal into the cavities. This method mainly differs from true centrifugal method in that, the axis of rotation and that of the mould do not coincide with each other as shown in Fig. 7. This method is also called as pressure casting. The internal cavities of these castings are irregular in shape and are formed by dry sand cores. This method is also used for unsymmetrical objects. It can produce casting of irregular shapes such as bearing caps or small brackets, etc.

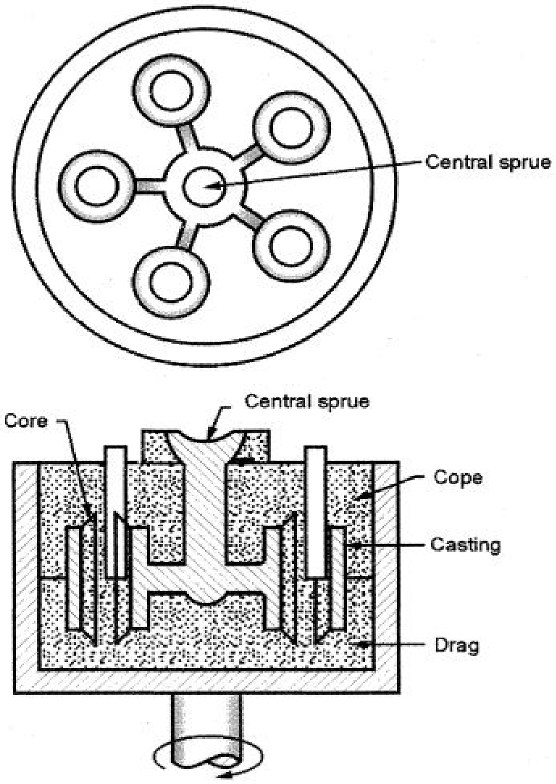


Fig. 7: Centrifuged casting

5. Investment Casting

Investment casting process is also known as lost-wax process. The term investment refers to a clock or special covering apparel. In investment casting, the clock is a refractory mould which surrounds the pre coated wax pattern. A wax pattern must be made for every casting and gating system also. A wax pattern is invested by liquid mould material which is latter allowed to be set and form a hard layer around the pattern. A mould cavity is then obtained by melting the wax pattern.

The steps in an investment casting process are as follows:

a. Die making:

A die for casting the wax pattern is made. These dies can be made by using a metallic master pattern and casting a low melting point alloy around it.

b. Wax patterns and gating systems:

Wax patterns and gating systems are produced from the metal dies by injection. Wax is injected into the die at a temperature of 70°C to 80°C and at a pressure of 8 to 150 kg/cm2.

c. Assembling the wax patterns:

The wax patterns so made are then attached to wax gates and Sprues already made with the help of heated tool known as hot wire welder. Assembling fixtures are used to minimize the operation time.

d. Pre coating:

The wax assembly is dipped into slurry of a refractory coating material. Typical slurry consists of 325 mesh silica flour suspended in ethyl silica solution of suitable viscosity to produce uniform coating.

e. Investing:

The coated wax assembly is then invested in the mould. This is done by inverting the wax assembly on a table, surrounding it with a paper lined steel flask and pouring the investment moulding mixture around the pattern. The whole system is then vibrated and then the material settles by gravity and the mould is then allowed to air-set.

f. Wax melting:

The wax is melted out of the hardened mould by heating it in an inverted position at about 200°C. Sometimes, the wax may be reused.

g. Pouring:

Prepared moulds are first preheated to a suitable temperature between 540°C to 1 040°C and the metal is gravity poured into the sprue. Air pressure may then be applied to the sprue with force to fill the mould cavity.

h. Cleaning and inspection:

After solidification, the casting is vibrated to separate itself from the investment material. The gates, risers, etc. are then chipped off. The castings are then subjected to sand blasting. Then they are inspected through the specified inspection method.

Fig. 8: Steps involved in making investment casting

Advantages:

- Better dimensional accuracy with close tolerances can be achieved.
- Complicated shapes and complex contours can be easily cut.
- Extremely thin sections up to 0.75 mm can be cast.
- Surface finish of the casting is very high.
- Castings are sound and free from defects.

Limitations:

- Size of the casting to be made is limited.
- Suitable only for small sized casting.
- Moulds used are single purpose only.
- Cost of investment material is high.
- It is a time consuming process.

Applications:

- Parts for aerospace industry, aircraft engines, frames, fuel systems, etc.
- Parts for food and beverage machinery, computers and data processing equipment, machine tools and accessories.

– Nozzles, buckets, blades, etc. for gas turbines.
– Costume jewellery can be made.

6. Continuous Casting

Continuous casting is accomplished by pouring molten metal into one end of a metal mould, which is open at both the ends, and by keeping it filled always. The metal at the lower end is cooled so that it solidifies and solid product thus formed is extracted in a continuous length from the lower end as shown in Fig. 9.

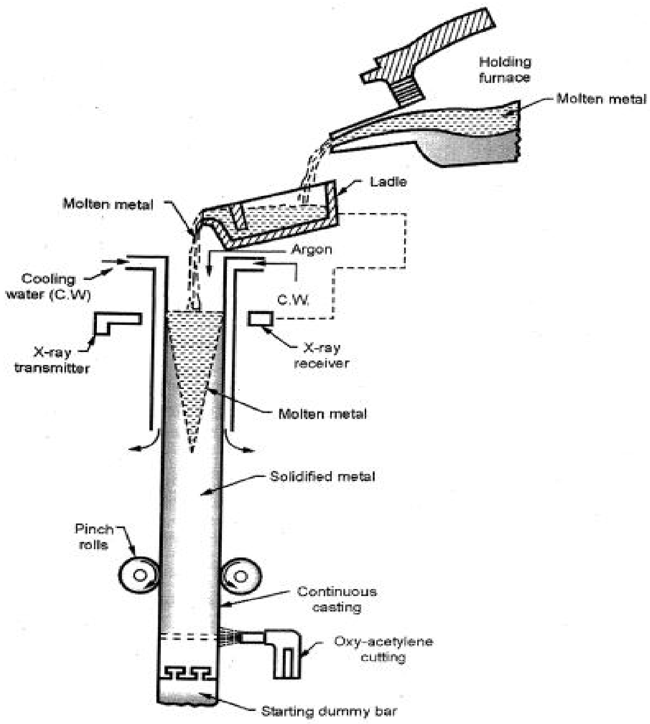


Fig. 9: Continuous casting process

In this, metal in the molten state is transferred from the holding furnace into a special ladle from where the same is poured onto the top of a bottomless graphite mould of the required shape. The molten metal should be slag free and should be poured with minimum turbulence to reduce mould friction. At the starting of the process, a dummy bar is placed in the mould upon which the first liquid metal falls. The liquid metal gets cooled and is pulled by the pinch rollers along with the dummy bar. Metal shrinks from the mould walls, which provides a very small gap between the metal and the mould, thereby reducing the friction between them and permits cast shape to move continuously through the mould. Pinch and guide rollers regulate the rate of setting of cast shape and keep proper alignment. As the casting passes out of the pinch rollers, it is cut to the required length by using some cutting method.

Advantages:

– The process is cheaper than rolling from ingots.
– There is no need of rough forming and breakdown rolling operation.
– Casting surfaces obtained are better than the static ingots.
– Grain size and structure of the casting can be regulated by controlling cooling rates.
– Casting is more dense and uniform than individual castings because each portion of the casting length gets same treatment in the same mould.

- Castings obtained by this process have improved quality.
- As the process is essentially automatic unit labour cost is low.

Applications:

- This process can produce any shape of uniform cross-section such as rectangular, square, hexagonal, gear toothed, etc. either solid or hollow.
- Production of blooms, billets, slabs and sheets.
- Materials like brass, zinc, copper and its alloys, aluminium and its alloys, alloy steel may be cast.

7. Ceramic Mould Casting

Ceramic mould is a variation of the investment mould. In this mould, slurry composed of refractory sand grains (Powder of zircon, alumina, and fused silica) and ceramic binder is poured into wax pattern. This results in a thin-wall shell of ceramic over the pattern surfaces. After this, pattern is baked in a less expensive fire clay and then it is removed from the mould and transferred to an oven for further heating mould. For producing castings, then the molten metal is poured into the mould cavity through the sprue. In this method, the preheated mould is used during pouring of molten metal which results in elimination of partial filling of moulding.

Advantages:

- Castings produced by this method do not require machining.
- Casting of intricate objects can be produced by this method.
- This method can cast high melting point alloys to accurate dimensions.
- Thin sections even for high melting point metals and alloys can be produced by this method.

Exercise:

(a) With suitable sketches, explain the various steps of investment casting Process.

(b) Explain the Dump box shell moulding process with sketch.

Experiment No. 5

Aim: To study about gas welding.

Objective: (1) To understand gas welding technics.
(2) To aware about safety precautions in welding.

1. Introduction

A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen) mixture is usually referred as 'gas welding'.

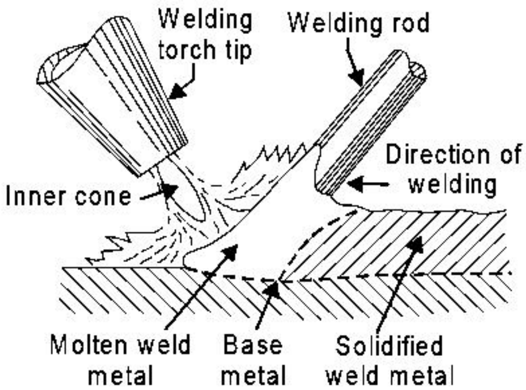


Figure 1 Gas welding

The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal. The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature. Oxy-acetylene flame is the most versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases.

2. Oxy-acetylene 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.

3. Types of flame

1. Neutral 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 colour. 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.

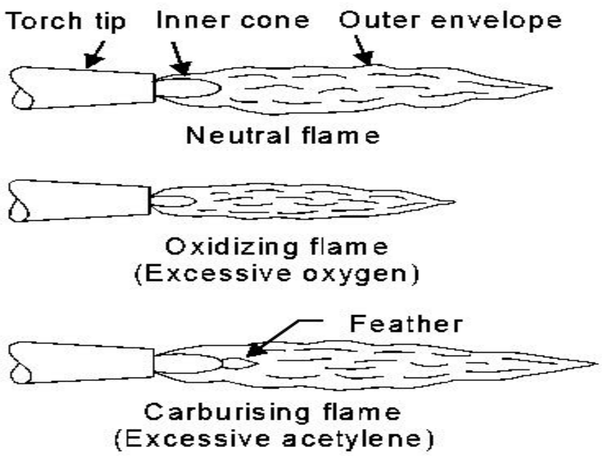


Fig. 2 Oxy-Acetylene gas flames.

2. **Carburizing 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 colour. 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 forwarding with low alloy steel rods and for welding those metals, (e.g., non- ferrous) that do noted to absorb carbon. This flame is very well used for welding high carbon steel.

3. **Oxidizing 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 colour 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 base metal oxide that protects the base metal.

4. **Position of welding**

1. **Horizontal welding**

In horizontal position, the plane of the work piece is vertical and the deposited weld head is horizontal. The metal deposition rate in horizontal welding is next to that achieved in flat or down hand welding position. This position of welding is most commonly used in welding vessels and reservoirs.

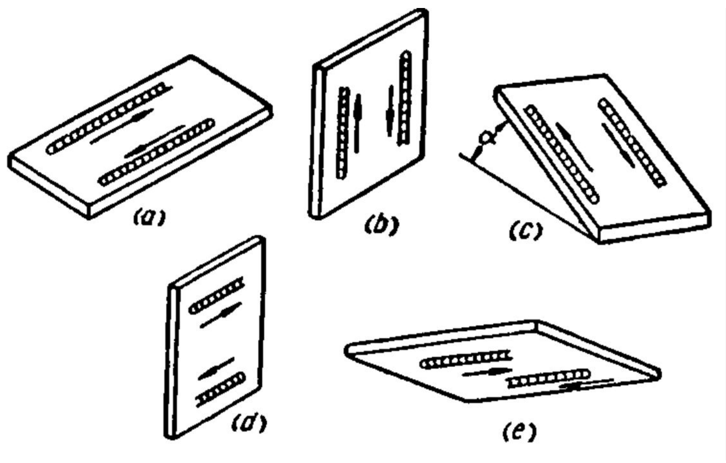


Fig.3 Position of welding

(a)Horizontal welding (b) Vertical welding (c) Inclined welding (d) horizontal welding in vertical direction (e) overhead welding

2. **Vertical welding**

In vertical position, the plane of the work piece is vertical and the weld is deposited upon a vertical surface. It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal. The welder must constantly control the metal so that it does not run or drop from the weld. Vertical welding may be of two types' viz., vertical-up and vertical-down. Vertical-up welding is preferred when strength is the major consideration. The vertical-down welding is used for a sealing operation and for welding sheet metal.

3. **Overhead welding**

The overhead position is probably even more difficult to weld than the vertical position. Here the pull of gravity against the molten metal is much greater. The force of the flame against the weld serves to counteract the pull of gravity. In overhead position, the plane of the work piece is horizontal. But the welding is carried out from the underside. The electrode is held with its welding end upward. It is a good practice to use very short arc and basic coated electrodes for overhead welding.

5. **Techniques of welding**

1. **Leftward (Forward) welding technique**

In this technique, the welder holds welding torch in his right hand and filler rod in left hand. The welding flame is directed from right to left as shown in figure. The welding torch should be given a small sideways movement and the filler rod should be moved steadily without sideways movement. The welding torch held at 60 to 70 to the weld plane and the filler rod at 30 to 40.

2. **Rightward (Backward) welding technique**

In this technique, the welder holds welding torch in his left hand and filler rod in right hand. The welding flame is directed from left right to as shown in figure. The welding torch has no lateral movement. The welding torch held at 40 to 50 to the weld plane and the filler rod at 30 to 40.

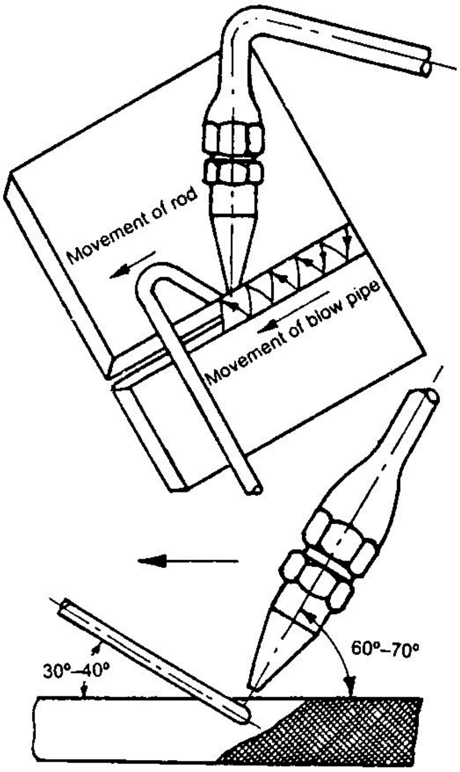


Fig. 4 Left ward welding

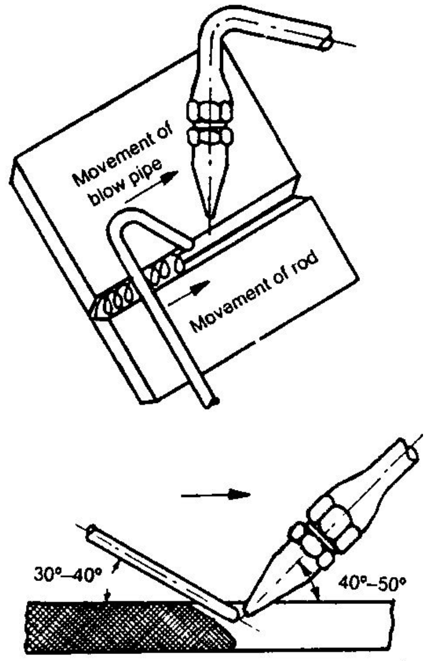


Fig. 5 Right ward welding

3. **Vertical welding**

The method is more advantageous for plate thickness of 6 mm and above. In this, the welder starts at the bottom of the welded joint and gives oscillating movement to the welding torch which points slightly upwards. It can be done by one or two operator. In case of single operator technique, the angle between the welding torch and plate increases as the plate thickness increases.

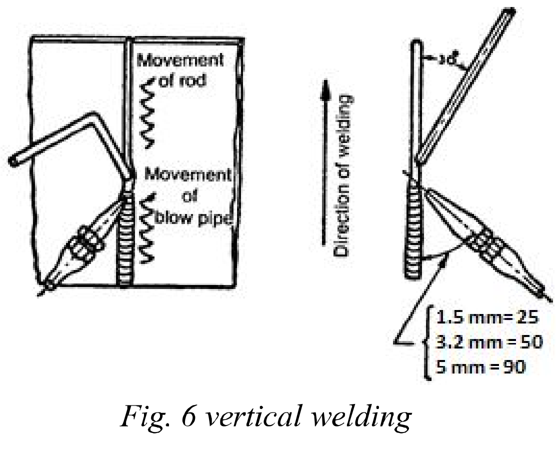


Fig. 6 vertical welding

6. **Welding Equipment**
1. **Cylinder**

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.

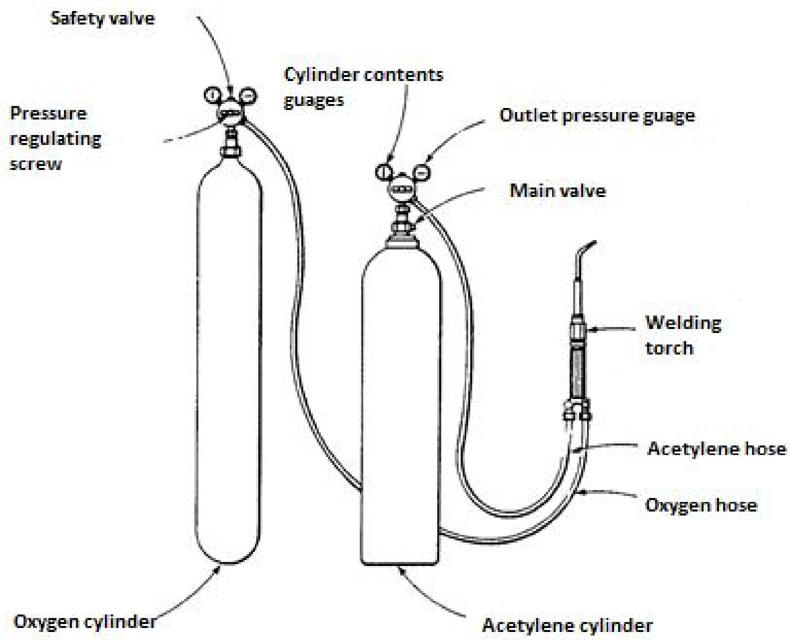


Fig.7 Oxy-Acetylene welding set

2. **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.

3. **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.

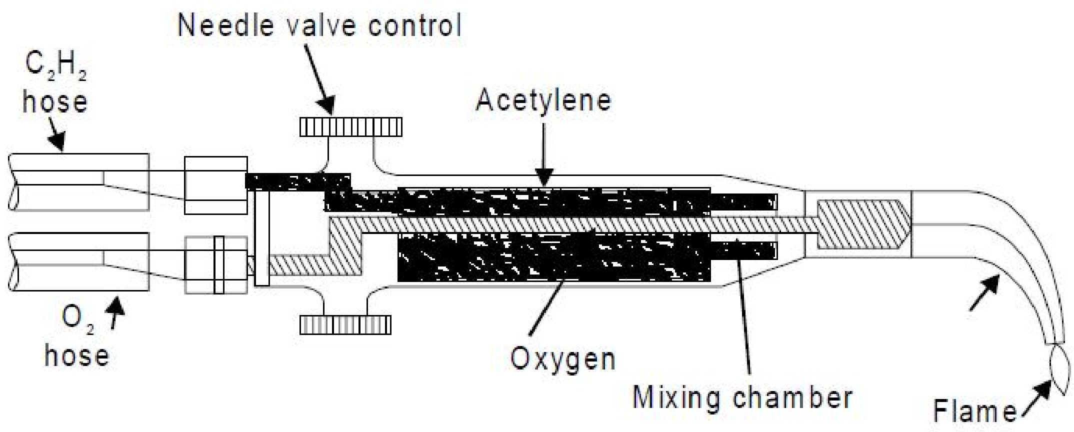


Fig. 8 welding torch

4. **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.

5. **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 colour for oxygen hose, red for acetylene, and black hose for other industrially available welding gases.

6. **Goggles**

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

7. **Gloves**

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

8. **Spark lighter**

It is used for frequent igniting the welding torch.

9. **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.

10. **Flux**

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.

Experiment No. 6

Aim: Demonstration of arc welding process.

Objective: (1) To understand arc welding technics.
(2) To do practice of different types of arc welding joints.

1. Introduction

The first arc welding method was developed in the 19th century, and it has become commercially significant within shipbuilding throughout the 2nd-World War. Nowadays it remains a significant process for the vehicles as well as steel structures fabrication. This is one of the famous welding methods which are used for joining metals in industries. In this type of welding, the joint can be formed by melting the metal with the help of electricity. So due to this reason, it is named as an electric arc. The main benefit of this welding is a high-temperature can be easily developed for welding.
A metal joining method in which the joining edges are heated and fused together with or without filler metal to form a permanent (homogeneous) bond is known as welding.
Or in other words, "Welding is a process of joining two or more pieces of the same or dissimilar materials to achieve complete coalescence. This is the only method of developing monolithic structures and it is often accomplished by the use of heat and/or pressure.

2. Arc welding

Electric arc is formed when both the terminals of an electric circuit are brought together and then separated by a small gap. When high current passes through an air gap from one conductor to another, it produces very intense and concentrated heat in the form of a spark. The temperature of this spark (or arc) is app. 3600°C, which can melt and fuse the metal very quickly to produce a homogeneous weld.

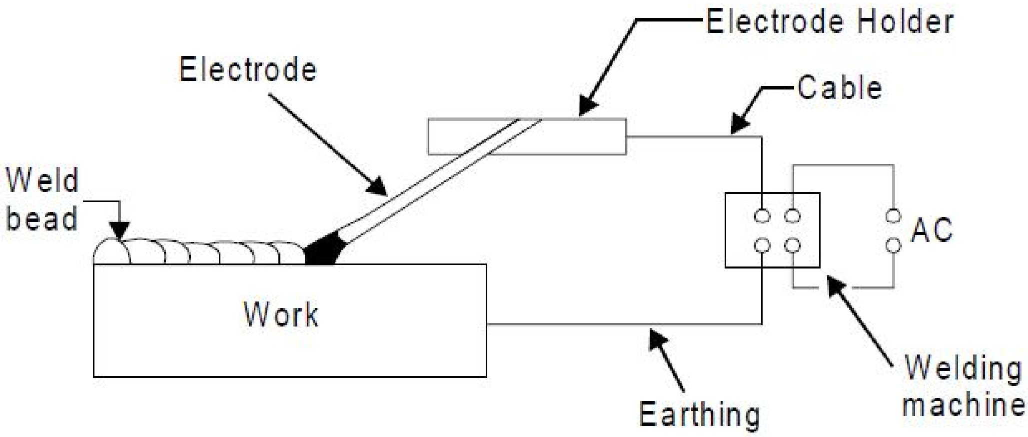


Figure 1 Arc Welding

3. Types of Arc Welding

The arc welding is classified into different types which include the following.

1. Carbon Arc Welding
2. Shielded Metal Arc Welding
3. Gas Tungsten Arc Welding
4. Gas Metal Arc Welding
5. Plasma Arc Welding
6. Atomic Hydrogen Welding

7. Electro slag welding

1. **Carbon arc welding**

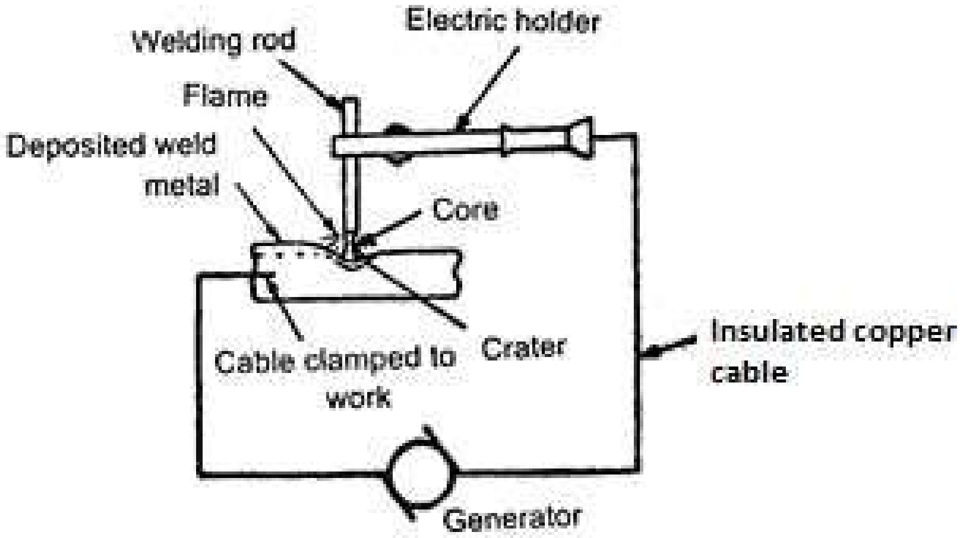


Figure 2 Carbon Arc Welding

In this process, a pure graphite or baked carbon rod is used as a non-consumable electrode to create an electric arc between it and the work piece. The electric arc produces heat and weld can be made with or without the addition of filler material.

Carbon arc welding may be classified as-

(1) Single electrode arc welding, and

(2) Twin carbon electrode arc welding

In single electrode arc welding, an electric arc is struck between a carbon electrode and the work piece. Welding may be carried out in air or in an inert atmosphere. Direct current straight polarity (DCSP) is preferred to restrict electrode disintegration and the amount of carbon going into the weld metal. This process is mainly used for providing heat source for brazing, braze welding, soldering and heat treating as well as for repairing iron and steel castings. It is also used for welding of galvanized steel and copper. In twin carbon arc welding the arc struck between two carbon electrodes produces heat and welds the joint. The arc produced between these two electrodes heats the metal to the melting temperature and welds the joint after solidification. The power source used is AC (Alternating Current) to keep the electrodes at the same temperature. Twin-electrode carbon arc welding can be used for welding in any position. This process is mainly used for joining copper alloys to each other or to ferrous metal. It can also be used for welding aluminium nickel, zinc and lead alloys.

2. **Shielded Metal Arc Welding**

Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder. It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the work piece.

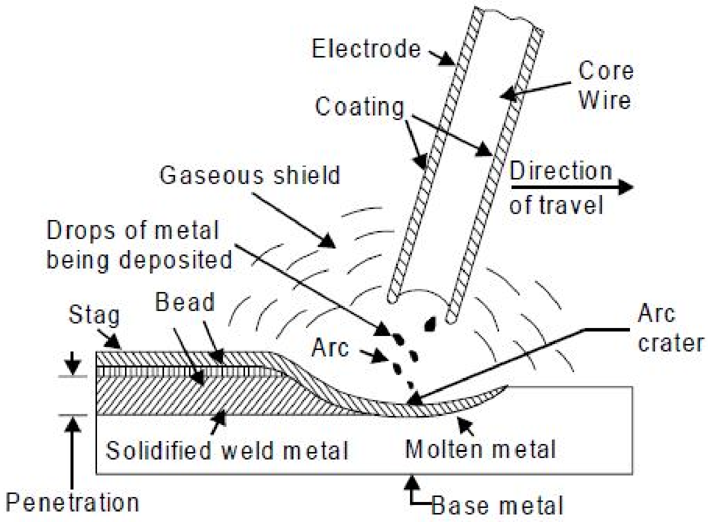


Figure 3 Shilded metal arc welding

The flux coating of electrode decomposes due to arc heat and serves many functions, like weld metal protection, arc stability etc. Inner core of the electrode supply the filler material for making a weld. The basic setup of MMAW is depicted in figure 3. If the parent metal is thick it may be necessary to make two or three passes for completing the weld.

 Advantages

- Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest weld quality.
- MMAW is the simplest of all the arc welding3. This welding process finds innumerable applications, because of the availability of wide variety of electrodes.
- Big range of metals and their alloys can be welded easily.
- The process can be very well employed for hard facing and metal resistance etc.
- Joints (e.g., between nozzles and shell in a pressure vessel) which because of their position are difficult to be welded by automatic welding machines can be easily accomplished by flux shielded metal arc welding.
- The MMAW welding equipment is portable and the cost is fairly low.

 Limitations

- Due to flux coated electrodes, the chances of slag entrapment and other related defects are more as compared to MIG and TIG welding.
- Due to fumes and particles of slag, the arc and metal transfer is not very clear and thus welding control in this process is a bit difficult as compared to MIG welding.
- Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.
- In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weld is to be progressed with the next electrode.
- Unless properly cared, a defect (like slag inclusion or insufficient penetration) may occur at the place where welding is restarted with the new electrode.

- The process uses stick electrodes and thus it is slower as compared to MIG welding.

Applications

- Today, almost all the commonly employed metals and their alloys can be welded by this process.
- Shielded metal arc welding is used both as a fabrication process and for maintenance and repair jobs.

3. Submerged Arc Welding

Schematic submerged arc welding process is shown in figure. In this welding process, a consumable bare electrode is used in combination with a flux feeder tube. The arc, end of the bare electrode and molten pool remain completely submerged under blanket of granular flux. The feed of electrode and tube is automatic and the welding is homogenous in structure. No pressure is applied for welding purposes. This process is used for welding low carbon steel, bronze, nickel and other non-ferrous materials.

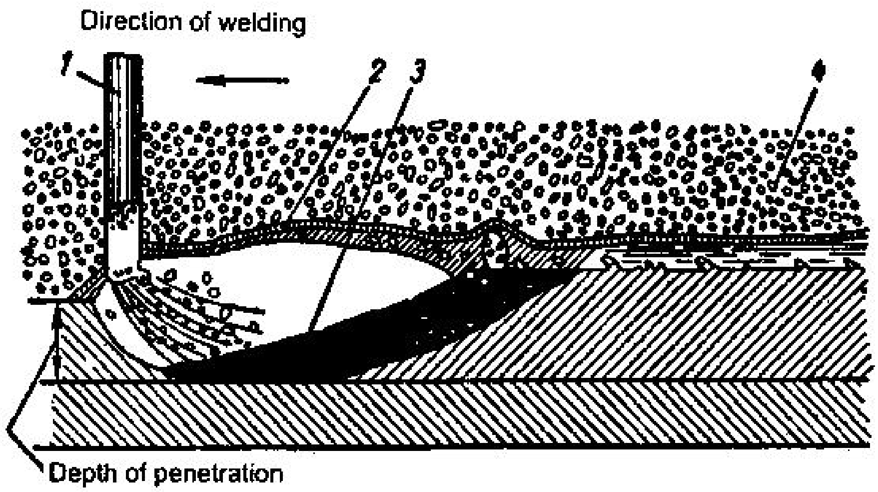


Figure 4 Submerged arc welding
1 Electrode 2 envelope of flux 3 molten metal 4 flux

4. Gas Tungsten Arc Welding

In this process a non-consumable tungsten electrode is used with an envelope of inert shielding gas around it. The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination. The shielding gases generally used are argon, helium or their mixtures. Typical tungsten inert gas welding setup is shown in figure. The electrode material may be tungsten, or tungsten alloy (thoriated tungsten or zirconiated tungsten). Alloy-tungsten electrodes possess higher current carrying capacity; produce a steadier arc as compared to pure tungsten electrodes and high resistance to contamination. Electric power source Both AC and DC power source can be used for TIG welding. DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas DC reverse polarity (DCRP) or AC is used for welding aluminium, magnesium or their alloys. DCRP removes oxide film on magnesium and aluminium Inert gases.

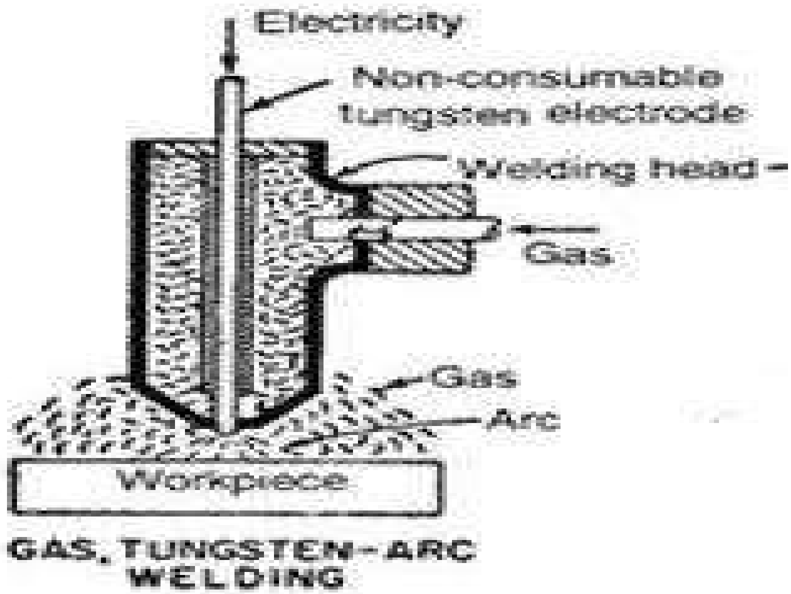


Figure 5 Tungsten inert gas arc welding

The following inert gases are generally used in TIG welding:

1. Argon
2. Helium
3. Argon-helium mixtures
4. Argon-hydrogen mixtures

5. Gas Metal Arc Welding

Metal inert gas arc welding (MIG) or more appropriately called as gas metal arc welding (GMAW) utilizes a consumable electrode and hence, the term metal appears in the title. There are other gas shielded arc welding processes utilizing the consumable electrodes, such as flux cored arc welding (FCAW) all of which can be termed under MIG. Though gas tungsten arc welding (GTAW) can be used to weld all types of metals, it is more suitable for thin sheets. When thicker sheets are to be welded, the filler metal requirement makes GTAW. In this situation, the GMAW comes handy. The typical setup for GMAW or MIG welding process is shown in Fig. 17.22. The consumable electrode is in the form of a wire reel which is fed at a constant rate, through the feed rollers. The welding torch is connected to the gas supply cylinder which provides the necessary inert gas. The electrode and the work-piece are connected to the welding power supply. The power supplies are always of the constant voltage type only. The current from the welding machine is changed by the rate of feeding of the electrode wire. Normally DC arc welding machines are used for GMAW with electrode positive (DCRP). The DCRP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer. With DCSP, the arc becomes highly unstable and also results in a large spatter. But special electrodes having calcium and titanium oxide mixtures as coatings are found to be good for welding steel with DCSP. In the GMAW process, the filler metal is transferred from the electrode to the joint. Depending on the current and voltage used for a given electrode, the metal transfer is done in different ways.

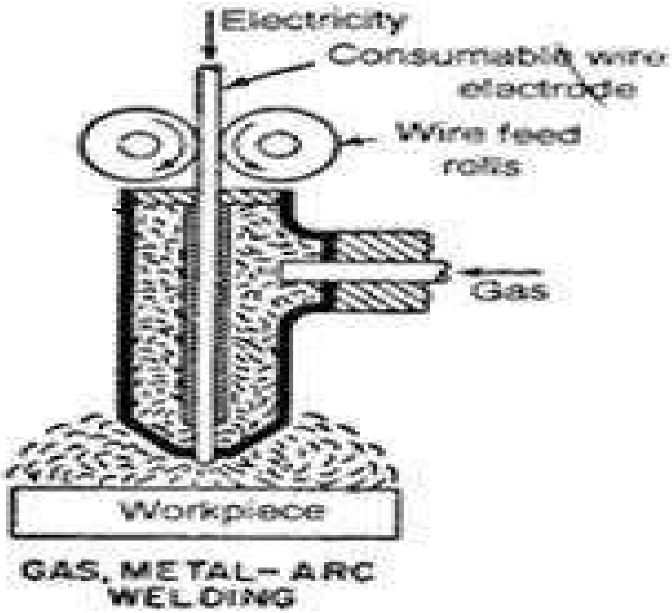


Figure 6 Metal inert gas arc welding

6. **Electro slag Welding**

Electro slag Welding is a welding process, in which the heat is generated by an electric current passing between the consumable electrode (filler metal) and the work piece through a molten slag covering the weld surface.

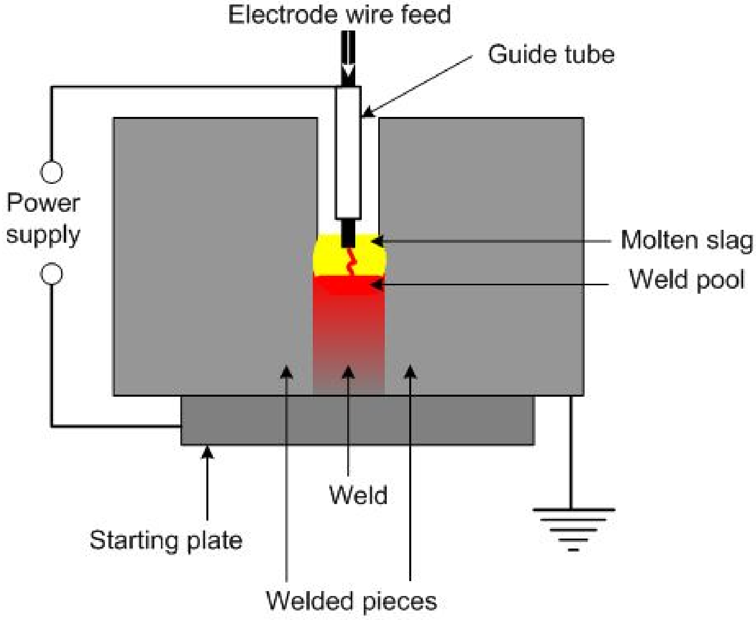


Figure 7 Electro slag welding

Prior to welding the gap between the two work pieces is filled with a welding flux. Electro slag welding is initiated by an arc between the electrode and the work piece (or starting plate). Heat, generated by the arc, melts the fluxing powder and forms molten slag. The slag, having low electric conductivity, is maintained in liquid state due to heat produced by the electric current. The slag reaches a temperature of about 3500°F (1930°C). This temperature is sufficient for melting the consumable electrode and work piece edges. Metal droplets fall to the weld pool and join the work pieces. Electro slag welding is used mainly for steels.

7. Electrodes for arc welding

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 work piece.

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

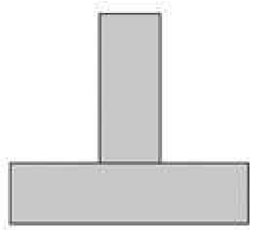
(*b*) Tungsten Electrodes

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 work piece. 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 non-consumable electrodes are usually copper coated carbon or graphite, pure tungsten.

8. Types Of Welding Joints:

Different jobs need different types of welds. Different types of welding joints are made to stand up to the needs and forces of each individual application. The experts at Cliff's Welding have been mastering the art of these welds for over 50 years. With professionals that have a wide variety of experience there really is not job too big or too small. Let's go over the 5 types of weld joints that we use to get the job done right.

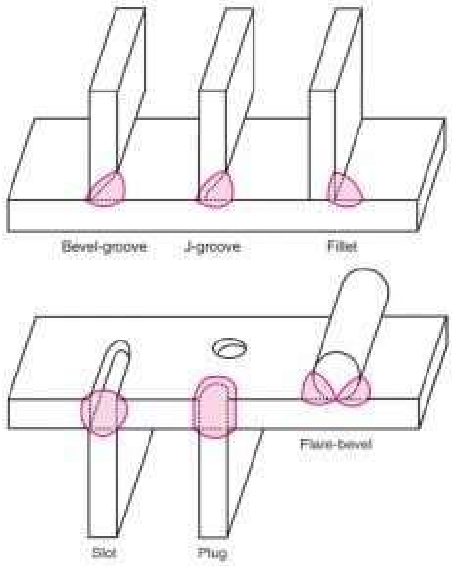
1. Tee Welding Joint



Tee Joint

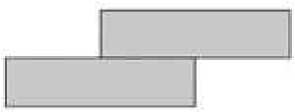
Tee welding joints are formed when two members intersect at a 90° angle which makes the edges come together in the centre of a plate or component. Tee Joints are considered a type of fillet weld, and can also be made when a pipe or tube is welded onto a base plate. Extra care is required to ensure effective penetration into the roof of the weld.

Welding Styles Used To Create T-Joints



- Plug weld
- Fillet weld
- Bevel-groove weld
- Slot weld
- Flare-bevel-groove weld
- J-groove weld
- Melt-through weld

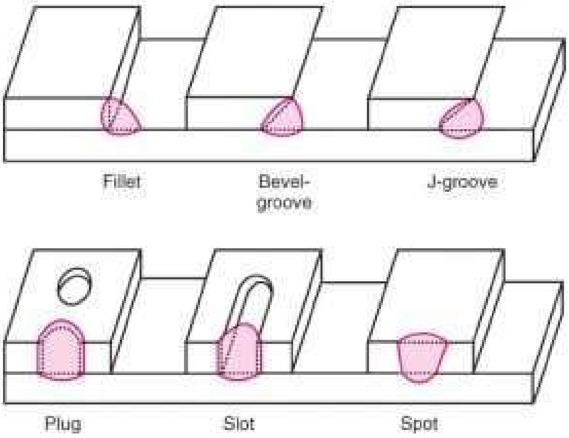
2. **Lap Welding Joint**



Lap Joint

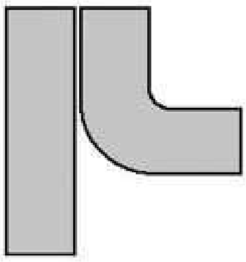
Lap welding joints are used most often to joint two pieces with differing thicknesses together. Also considered a fillet type, the weld can be made on one or both sides. A Lap Joint is formed when 2 pieces are placed in an over lapping pattern on top of each other.

Welding Styles Used To Create Lap Joints:



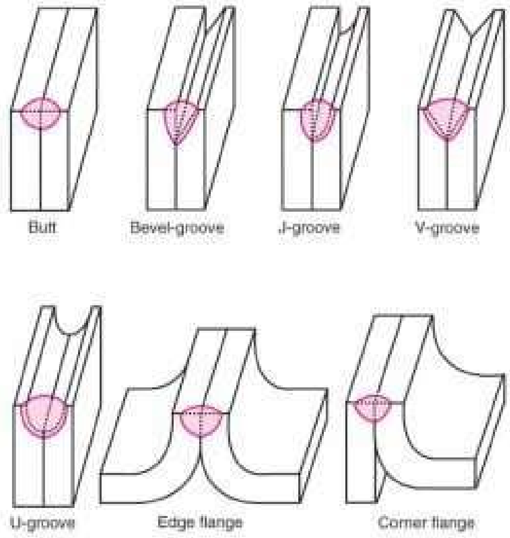
- Slot weld
- Plug weld
- Bevel-groove weld
- Spot weld
- Flare-bevel-groove weld
- J-groove weld

3. Edge Welding Joint



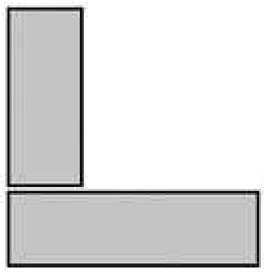
Edge Joint

Edge welding Joints are often applied to sheet metal parts that have flanging edges or are placed at a location where a weld must be made to attach to adjacent pieces. Being a groove type weld, Edge Joints, the pieces are set side by side and welded on the same edge. For heavier applications filler metal is added to melt or fuse the edge completely and to reinforce the plate.
Welding Styles Used To Create Edge Joints:



- Bevel-groove weld
- Square-groove weld or butt weld
- J-groove weld
- V-groove weld
- Edge-flange weld
- U-groove weld
- Corner-flange weld

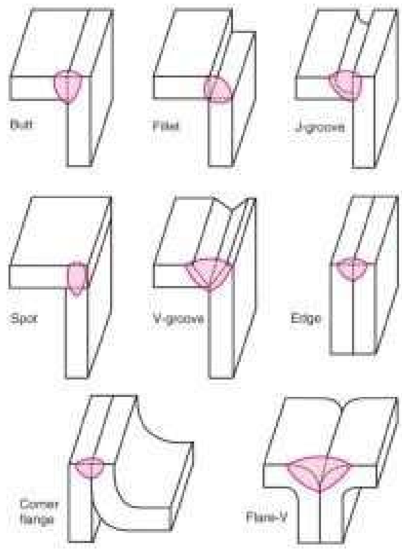
Corner Welding Joint



Corner Joint

being one of the most popular welds in the sheet metal industry the Corner welding joint is used on the outer edge of the piece. This weld is a type of joint that comes together at right angles between two metal parts to form an L. These are common in the construction of boxes, box frames and similar fabrications.

Welding Styles Used To Create Corner Joints:



- Spot weld
- Fillet weld
- V-groove weld
- Square-groove weld or butt weld
- U-groove weld
- Bevel-groove weld
- Flare-V-groove weld
- J-groove weld
- Corner-flange weld.
- Edge weld

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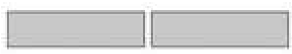
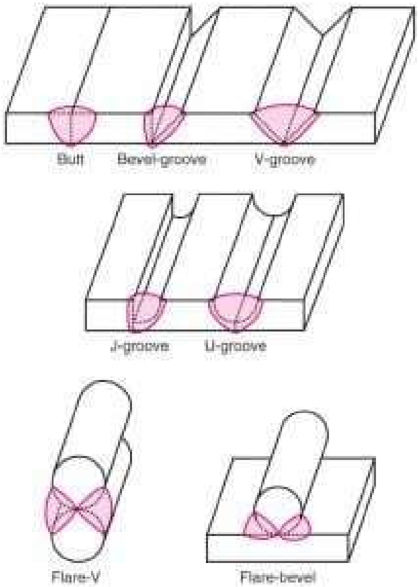
4. Butt Welding Joint



Butt Joint

Being the universally accepted method for attaching a pipe to itself it’s also used for valves, flanges, fittings, and other equipment. A butt welding joint is also known as a square grove weld. It’s the easiest and probably the most common weld there is. It consists of two flat pieces that are side by side parallel. It’s a very affordable option.

Welding Styles Used To Create Butt Joints:



- Bevel-groove butt weld
- Square-groove butt weld
- V-groove butt weld
- U-groove butt weld
- J-groove butt weld
- Flare-bevel-groove butt weld
- Flare-V-groove butt weld

5. **Fillet Welded Joints**

Fillet Welded Joints are just another terminology for corner, lap, and tee joints. Fillet Welded Joints are the most common type of welding joint and accounts for nearly 75% of joints made with arc welding. You do not need to prepare the edge and this type of joint make it easy to weld piping systems. Butt welds are more expensive than fillet welds. Fillet welds are mostly used in piping systems to join pipe to socket joints.

Exercise

(a) Practice different types of arc welding joints.

Experiment No. 7

Aim: To evaluate different welding parameters in resistance spot welding.

Objective: (1) To understand spot resistance welding technics.
(2) To evaluate spot welding parameters.

1. Introduction

Resistance spot welding is getting significant importance in car, bus and railway bodies etc. due to automatic and fast process. The major factors controlling this process are current, time, electrode force, contact resistance, property of electrode material, sheet materials, surface condition etc. the quality is best judged by nugget size and joint strength. This study presents a systematic approach to determine effect of process parameters (electrode force, weld time and current) on tensile shear strength of resistance weld joint of mild steel using Taguchi method. A general introduction for principle, working and parameters of spot welding is given below. Resistance Spot Welding (RSW) is among the oldest of the electric welding method that used in the industry and it is useful and accepted method in joining metal.

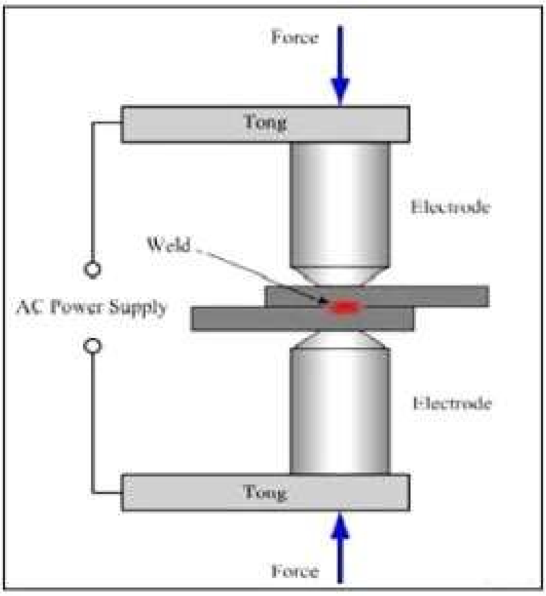


Figure 1: Resistance Spot Welding

Spot welding is widely used in welding carbon steel because they have higher electrical resistance and lower thermal conductivity than the electrode that made from copper. The Spot welding is commonly being used in automobile industry, where it is used to weld the sheet metal forming a car. Spot welders can also be completely automated, and many of the industrial robots found on assembly lines are spot welders. Spot welding also being used in the repair industries.

2. Principle of Operation for Resistance Spot Welding

Resistance Spot Welding (RSW) is included in the group of resistance welding processes that heat is used in joining the work parts of metal. Heat is generated from electrical resistance across the two work parts In Resistance Spot Welding two work part of metal are joined together by applying electric current and pressure in the zone to be weld and resistance welding is different From arc welding because it's not required filler metal or fluxes added to the weld area during the welding process.

Spot welding operates based on four factors that are:

1. Amount of current that passes through the work piece.
2. Pressure that the electrodes applied on the work piece.
3. The time the current flow through the work piece.
4. The area of the electrode tip contact with the work piece.

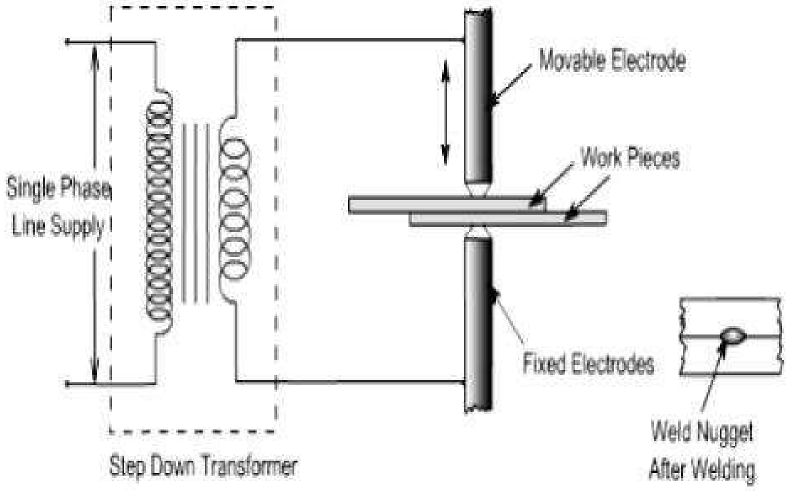


Figure 2: Resistance Welding Machine Circuits

During the welding process the amount of electric current is flow from the electrodes to the work pieces. The weld force is applied by leg pedal. Squeezing the electrode to the work pieces, the right amount of pressure that applied on the work pieces is very important in order to obtain the good quality of welds. During the welding process, the electric current is flow through electrode tips to the separate work pieces of metal to be joined. The resistance of the base metal to electrical current flow causes heat, the heat is limited to the area which the tip of the electrode and weld area contacts. While the welding force is maintained, the heat is generating. In the holding stage (where the pressure is still maintained), the current is switched off and the nugget is cooled under the pressure. The heat that generated in spot welding is basically depend on the electric current and the time being used and on the electrical resistance of material between electrodes.

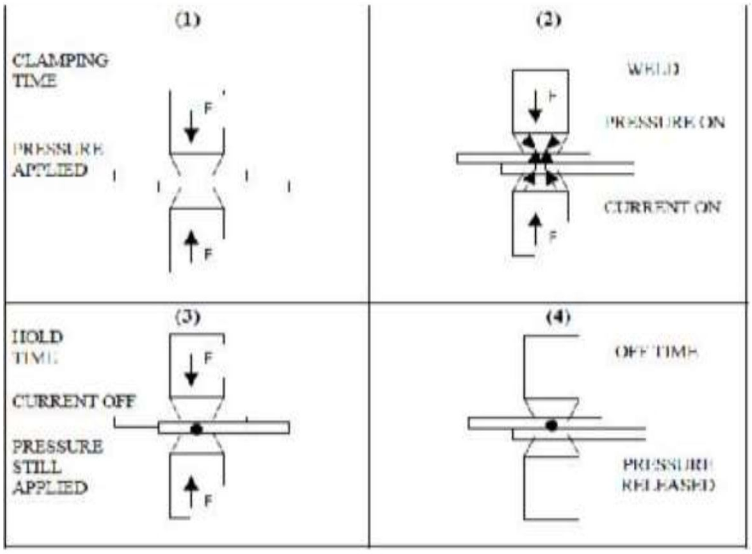


Figure 3: Time Sequence of the Resistance Spot Welding Cycle: (1) Clamping Time, (2) Weld Time, (3) Hold Time, (4) Off Time

The amount of heat generated is a function of current, time and resistance between the electrode the heat that generates in resistance spot welding according to Joule's law is expressed by the Equation.

$$H = I^2Rt$$

Where

H = Heat is generated in joules

I = Current (in amperes)

R = Resistance (in ohms)

t = Time to current flow (in seconds)

3. Resistance Spot Welding Parameters

The spot welding process parameters have their own importance. A small change of one parameter will affect all the other parameters. These parameters will determine the quality of the welds. The appropriate combination of the spot welding parameter will produce strong joining and good quality of welding. Spot welding parameters include.

1. Electrode force
2. Diameter of the electrode contact surface
3. Squeeze time
4. Weld time
5. Hold time
6. Weld current

1. Electrode Force

The purpose of the electrode force is to squeeze the parts to be weld and the primary purpose is to hold the parts to ensure the parts in intimate contact at the joining interface. When the electrode force is increased the heat energy will decrease, a high pressure that exerted on the weld joint will decrease the resistance at the point of contact between the electrode tips and the parts surface. This means that the higher electrode force requires a higher weld current. Weld spatter can be happen because the pressure on the tips is too light or when weld current becomes too high. Too heavy pressure will cause small spot weld. In other words when the pressure increases the electrical current and subsequent heat are transfer to a wider area, the penetration and area of the weld will reduce.

2. **Diameter of the Electrode Contact Surface**

One general criterion of resistance spot- welding is that the weld shall have a nugget diameter of $5 \times t^{1/2}$, "t" being the thickness of the steel sheet. Thus, a spot weld made in two sheets, each 1 mm in thickness, would generate a nugget 5 mm in diameter according to the $5 \times t^{1/2}$-rules. Diameter of the electrode contact surface should be slightly larger than the nugget diameter.

3. **Squeeze Time**

Squeeze Time is the time interval between the initial application of the electrode force on the work and the first application of current. Squeeze time is necessary to delay the weld current until the electrode force has attained the desired level.

4. **Weld Time**

Weld time is the time during which welding current is applied to the metal sheets. The weld time is measured and adjusted in cycles of line voltage as are all timing functions. One cycle is 1/50 of a second in a 50 Hz power system. As the weld time is, more or less, related to what is required for the weld spot, it is difficult to give an exact value of the optimum weld time.

5. **Hold time (Cooling-Time)**

Hold time is the time, after the welding, when the electrodes are still applied to the sheet to chill the weld. Considered from a welding technical point of view, the hold time is the most interesting welding parameter. Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be too long as this may cause the heat in the weld spot to spread to the electrode and heat it. The electrode will then get more exposed to wear. Further, if the hold time is too long and the carbon content of the material is high (more than 0.1%), there is a risk the weld will become brittle.

6. **Weld Current**

The amount of weld current is controlled by two things:

- The setting of the transformer tap switch determines the maximum amount of weld current available.
- The present of current control determines the present of the available current to be used for making the weld.

Normally low present current settings are not recommended because it may harm the quality of the weld. The weld current should be kept as low as possible. When determining the current to be used, the current is steadily increased until weld spatter occurs between the metal sheets. This indicates that the correct weld current has been reached. The temperature rises rapidly at the joined portion of the metal where the resistance is greatest if the current becomes too great internal spatter will result.

4. Types of Failure of the Welding Joint

There are two fracture modes of the spot welding joint have analysed, they are

- Interfacial mode (or nugget fracture): fracture of the weld nugget through the plane of the weld. The dominant failure mode for small diameter spot welds.
- Nugget pull-out mode (or sheet fracture): fracture of the sheet around the weld; the nugget remains intact. Dominant for large diameter spot welds.

Spot welds for automotive applications should have a sufficiently large diameter, so that nugget pull-out mode is the dominant failure mode. Interfacial mode is unacceptable due to its low load carrying and energy absorption capability.

5. Effect of Process Parameters on Strength

The spot welding process parameters play an important role for the strength of the welding joint. If one of the parameter changes, it may effect the strength of the joint so the combination of suitable parameters are very important to get a high strength welding joint. The process parameters affect as an increase in weld current, weld time and electrode force results in an increase in weld nugget diameter and width. An increase in weld current, weld time and electrode force results in an increase in electrode indentation. So the parameters used should provide the high strength.

6. Material selection

7. Methodology

8. Observation table

9. Conclusion

Experiment No. 8

Aim: To study about metal forming methods.

Objective: (1) To explain different types of metal forming methods.

1. Introduction

Mechanical working of a metal is a simply plastic deformation performed to change the dimensions, properties and surface conditions with the help of mechanical pressure. Depending upon the temperature and strain rate, mechanical working may be either hot working or cold working, such that recovery process takes place simultaneously with the deformation. The plastic deformation of metal takes place due to two factors i.e. deformation by slip and deformation by twin formation. During deformation the metal is said to flow, which is called as plastic flow of the metal and grain shapes are changed. If the deformation is carried out at higher temperatures, then the new grains start growing at the locations of internal stresses. When the temperature is sufficiently high, the grain growth is accelerated and continue still the metal comprises fully of new grains only. This process of formation of new grains is called as recrystallization and the corresponding temperature is the recrystallization temperature of the metal. Recrystallization temperature is the point which differentiates hot working and cold working. Mechanical working of metals above the recrystallization temperature, but below the melting or burning point is known as hot working whereas; below the recrystallization temperature, is known as cold working.

2. Plastic Deformation

Any external or internal forces cause stresses in the material resulting into deformation.

Deformation is of two basic types:

- Elastic Deformation: Stress is below the elastic limit,
- Plastic Deformation: Stress is above the elastic limit.

When the body regains its original shape on the removal of externally applied force the deformation is called as elastic deformation. Elastic deformation occurs up to the maximum value of stress up to which the deformations are elastic or temporary. Stress required during elastic deformation is lower than plastic deformation. The plastic deformation is an important property of metals and non-metals, due to which materials can be deformed permanently and shaped as per the requirement. Plastic deformation can be done through forming, rolling, drawing, forging, etc.

Plastic deformation may occur by:

- Slip or
- Twinning or
- both acting simultaneously

Plastic deformation is permanent and takes place when the applied stress level exceeds a certain limit known as yield stress.

3. Hot Working

Hot working is accomplished at a temperature above the recrystallization temperature but below the melting or the burning point of the metal, because above the melting or the burning point, the metal will burn and become unsuitable for use. Every metal has a characteristic hot working temperature range over which hot working may be performed. The upper limit of working temperature depends on composition of metal, prior deformation and impurities within the metal. The changes in structure from hot working improves mechanical properties such as ductility, toughness, resistance to shock and vibration, % elongation, % reduction in area, etc.

The principal hot working processes applied to various metals are as follows:

1. Hot rolling
2. Hot extrusion
3. Hot spinning
4. Roll piercing
5. Hot drawing
6. Hot forging

4. Cold Working

The working of metals at temperatures below their recrystallization temperature is called as cold working. Most of the cold working processes are performed at room temperature. Unlike hot working, it distorts the grain structure and does not provide an appreciable reduction in size. Cold working requires much higher pressure than hot working. If the material is more ductile, it can be more cold worked. Residual stresses are setup during the process; hence to neutralize these stresses a suitable heat treatment is required.

The principal methods of cold working are as follows:

1. Cold rolling
2. Cold drawing
3. Cold spinning
4. Stretch forming
5. Cold forging and swaging
6. Cold extrusion
7. Coining
8. Embossing
9. Cold bending
10. Roll forming
11. Shot peening
12. High Energy Rate Forming (HERF)

Cold Working results in Strain Hardening, distortion of grains and the crystallographic structure. Various mechanical properties are dependent on the crystallographic structure.

5. Metal Forming

Metal forming includes a large number of manufacturing processes in which plastic deformation property is used to change the shape and size of metal work pieces. During the process, for deformation purpose, a tool is used which is called as die. It applies stresses to the material to exceed the yield strength of the metal. Due to this the metal deforms into the shape of the die. Generally, the stresses applied to deform the metal plastically are compressive. But, in some forming processes metal stretches, bends or shear stresses are also applied to the metal. For better forming of metal, the desirable properties of metal are low yield strength and high ductility. These properties are highly affected by the temperature. When the temperature of the metal is increased, its ductility increases and yield strength decreases. The other factors which affect the performance of metal forming process are, strain rate, friction, lubrication, etc.

6. Rolling

The process of rolling consists of passing the hot ingot through the two rolls, rotating in opposite directions, at a uniform peripheral speed. To confirm the desired thickness of the rolled section, the space between the rolls is adjusted and is always less than the thickness of the ingot being fed. Hence, to reduce the cross-section and increase the length of passing ingot, the rolls are squeezed. When the metal passes through the rolls, there is change in its grain structure. Due to squeezing, the grains are elongated in the direction of rolling and the velocity of material at the exit is higher than that at the entry. After crossing the stress zone, the grains start refining.

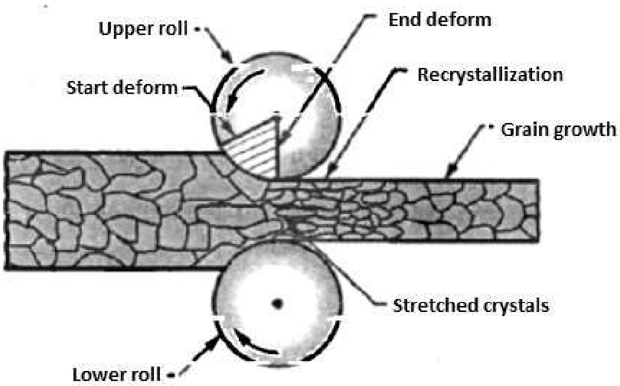


Fig. 1: Hot rolling recrystallization

7. Basic Definitions

The following are the basic terms used related to rolling process:

1. **Ingot:** Ingot is a larger casting section of suitable shape made for further processing.
2. **Bloom:** A bloom is a square or rectangular piece formed after reducing ingots. The size of blooms ranges between 1500 mm x 150 mm to 250 mm x250 mm. Rolling products from bloom: Structural shapes, Rails, etc.
3. **Billets:** Billets also formed after reducing ingot but have smaller cross sections. The size of billet ranges from 50 mm x 50 mm to 150 mm x 150 mm. Rolling product from billets: Rods, wires, etc.
4. **Slabs:** Slabs are metal pieces with rectangular cross section. It has thickness between 50 - 150 mm and width between 300 - 1500 mm. Rolling products from slabs: Sheets, plates, strips, etc.

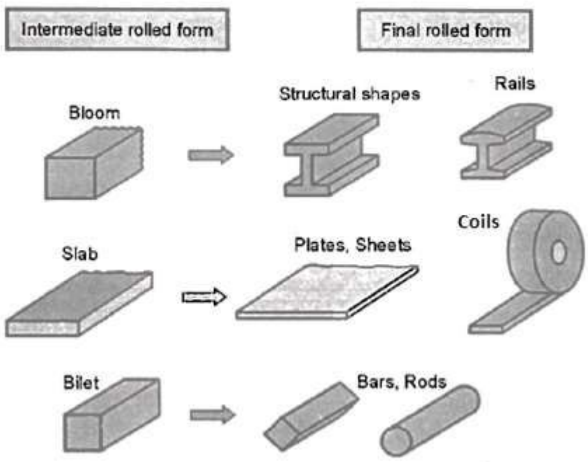


Fig. 2: Steel components made from rolling

8. Rolling of Various Sections

The main purpose of rolling is to convert larger sections such as ingots into smaller sections, which can be used directly in as rolled state or stock for working through other processes. As a result of rolling, there is an improvement in physical properties of cast ingot such as strength, toughness, ductility, shock resistance, etc. Various useful articles like structural sections, sheets, rails, plates and bars, etc. are produced through rolling.

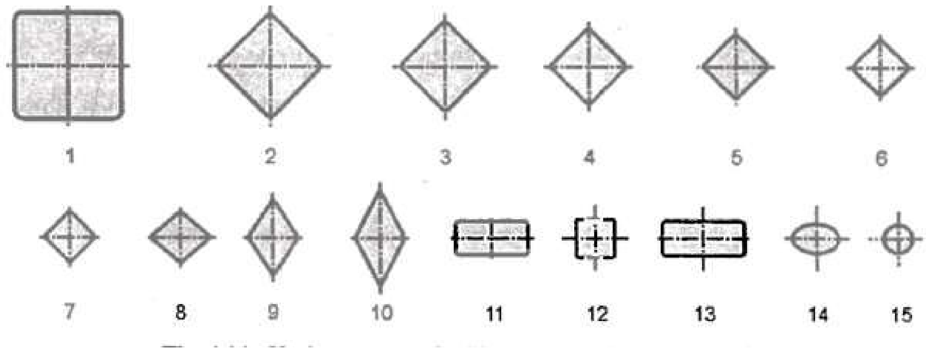


Fig. 3: Various stages of rolling and number of passes for Converting a steel billet into a round bar

The desired reduction in the cross-section of the billet and the required shape of the rolled section are not obtained in a single pass. Fig. 3 shows the sequence of rolling and the number of passes required to reduce the cross-section of a billet to a round steel bar. The process starts with the reduction of ingots which have been heated in a gas fired furnace up to a temperature of 1200 °C. The ingots are then taken to the rolling mill where they are rolled into immediate shapes as blooms, billets or slabs. A bloom has a square cross section with minimum size of 150 x 150 mm and a billet is smaller than bloom and it may have any square section from 38 mm up to the size of abloom. Slabs have a rectangular cross section with a minimum width of 250 mm and minimum thickness of 38 mm.

9. Types of Rolling Mills

According to the number and arrangement of the rolls, rolling mills are classified as follow:

1. Two-high rolling mill
2. Three-high rolling mill
3. Four-high rolling mill
4. Tandem rolling mill
5. Cluster rolling mill
6. Planetary rolling mill
7. Universal rolling mill

1. Two-high rolling mill:

It consists of two heavy horizontal rolls placed exactly one over the other. The space between the two rolls can be adjusted by raising or lowering the upper roll, whereas the position of the lower roll is fixed. Both the rolls rotate in opposite direction to each other as shown in Fig. 4 (a).

In this type, their direction of rotation is fixed and cannot be reversed. There is another type of two-high rolling mill which incorporates a drive mechanism that can reverse the rotation direction of the rolls. This type of rolling mill is called as two-high reversing mill.

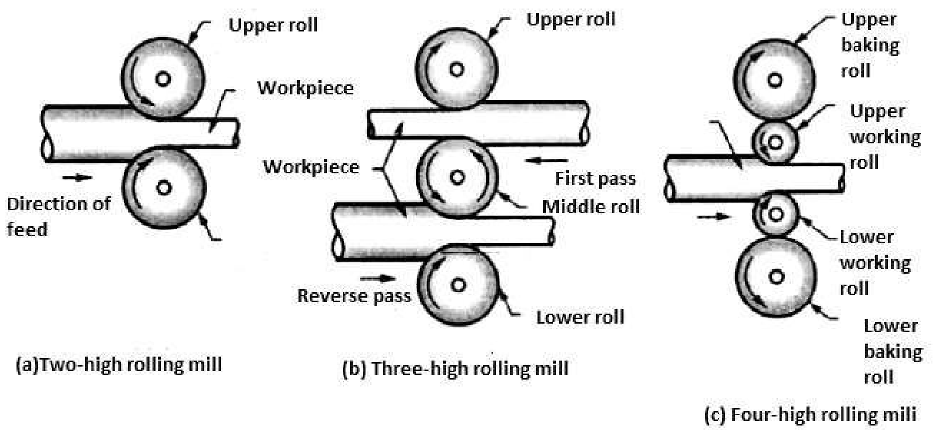


Fig. 4: Types of rolling mills

2. Three-high rolling mill:

It consists of three horizontal rolls positioned directly one over the other. The directions of rotation of the upper and lower rolls are same but the intermediate roll rotates in the opposite direction to each other as shown in Fig. 4 (b). All the three rolls revolve continuously in the same fixed direction and they are never reversed. The work piece is fed in one direction between the upper and middle rolls and in the reverse direction between the middle and lower rolls. This results in high production rate than the two-high rolling mill.

3. Four-high rolling mill:

It consists of four horizontal rolls i.e. two of smaller diameter and two of larger diameter arranged directly one over the other as shown in Fig. 4 (c). The larger diameter rolls are called back-up rolls and they are used to prevent the deflection of the smaller rolls, which otherwise would result in thickening of rolled plates or sheets at the centre. The smaller diameter rolls are called as working rolls, which concentrate the total rolling pressure over the metal. The common products of these mills are hot or cold rolled sheets and plates.

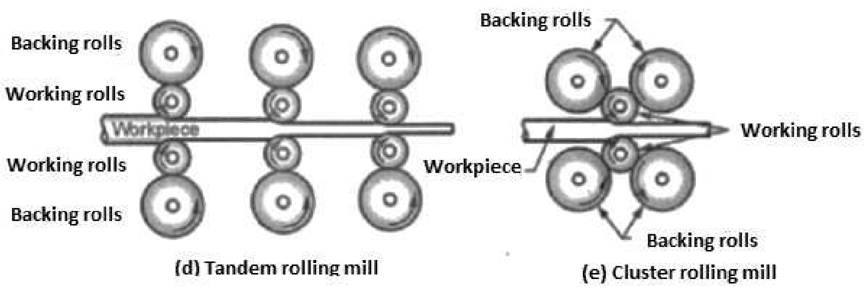


Fig. 5: Types of rolling mills

4. Tandem rolling mill:

It is a set of two or three stands of rolls set in parallel alignment. This facilitates a continuous pass through each one successively without change of direction of the metal or pause in the rolling process as shown fig.5 (d).

5. Cluster rolling mill:

It is a special type of four-high rolling mill. In this, each of the two working rolls is backed up by two or more of the larger backup rolls as shown in Fig. 5 (e). For rolling hard thin materials, it is necessary to employ work rolls of very small diameter but of considerable length. In such cases, adequate support of the working rolls can be obtained by using a backup rolls.

6. Planetary rolling mill:

For the rolling arrangements requiring large reduction, a number of free rotating wheels are used instead of a single small roll. Planetary mill consists of a pair of heavy backing rolls surrounded by a large number of planetary rolls as shown in Fig. 6 (f).

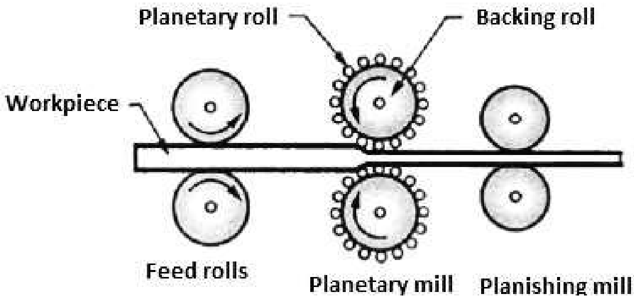


Fig. 6 (f): Planetary rolling mill

The main feature of this mill is that, it reduces a hot slab to a coiled strip in a single pass. Each pair of planetary rolls gives an almost constant reduction to the slab. The total reduction is the sum of a series of such small reductions following each other in rapid succession. The feed rolls are used to push the slab through a guide into planetary rolls. On the exit side planishing mill is installed to improve the surface finish.

7. **Universal rolling mill:**

In this type of rolling mill, the metal is reduced by both horizontal and vertical rolls as shown in Fig. 7 (g).

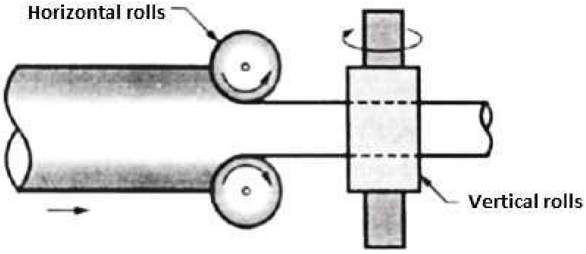


Fig. 7 (g): Universal rolling mill

The vertical rolls are mounted either on one side or on both sides of horizontal roll stand which makes the edges of bar even and smooth. The horizontal rolls may be either two-high, three-high or four-high arrangement.

8. **Roll Piercing or Seamless Tubing**

Roll piercing is a method of producing seamless tubes. Seamless tubing is a popular and economical raw stock for machining because it saves drilling and boring of parts. The piercing machine consists of two tapered rolls, called as piercing rolls. During the process, a round heated billet or steel is passed between these rolls over a mandrel. Both the rolls rotate in the same direction and the billet is provided with a small drilled hole at one end and uniformly heated to about 1100 °C. It is then pushed into the two piercing rolls which impart axial and rolling movement to the billet and force it over the mandrel. Hence, the combination of the revolving motion of billet and mandrel together with the axial advancement of the billet provides a helical tubing effect on the material. For production of 12 m length of up to 150 mm diameter rough tubing will take 10 to 30seconds, whereas for tubing of larger diameter (up to 350 mm) second piercing operation is required. As above produced rough tubing is further subjected to rolling, reeling and sizing, to bring it to the correct shape and size for providing a fine surface finish. Such tubes are produced in various metals and alloys such as steel alloys, aluminium, brass, copper, etc.

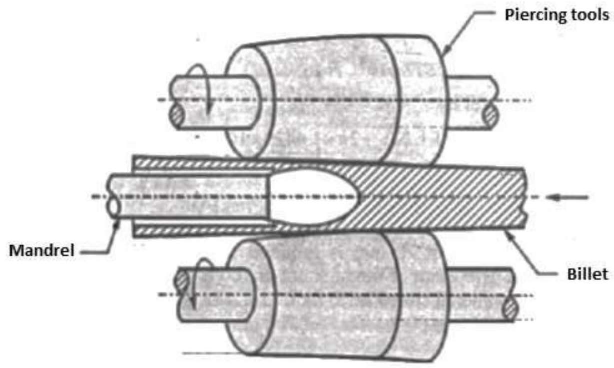


Fig. 8: Tube piercing

10. Forging

Forging is the process of shaping heated metal by the application of sudden blows (hammer forging) or steady pressure (press forging) and makes use of the characteristic of plasticity of the material. Forging is metal forming process which may be done by hand or by machine. In case of hand forging, hammering is done by hand; whereas forging by machine involves the use of dies and it is mostly used in mass production.

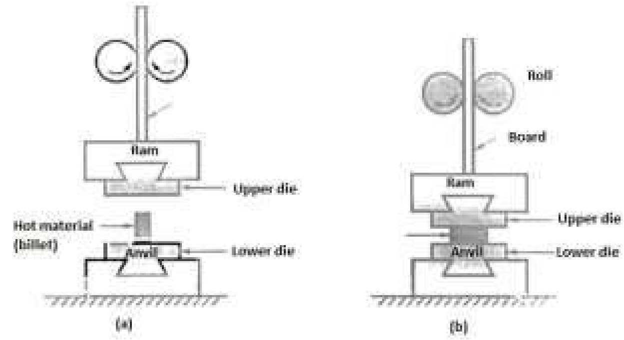


Fig. 9: Forging process

Whatever may be the method of applying pressure for shaping the metal, the primary requirement is to heat the metal to a definite temperature to bring it into the plastic state. This may done in an open hearth, called as Smith's forge for small jobs or in closed furnaces for large jobs. The shop in which the work is carried out is called as Smithy or Smith's shop. The metals which are used in forging process must possess the required ductility. We know that ductility refers to the capacity of a material to undergo deformation, under tension without failure. The commonly used forging materials are: Aluminium alloys, copper alloys, low carbon steels, alloy steels, nickel alloys, tungsten alloys, magnesium alloys, titanium alloys, beryllium, etc.

11. Types of Forging process

Forging process is classified as follows:

1. According to the working temperature

   a. Hot forging

Most of the forging operations are performed above the recrystallization temperature but below the melting point of the metals. During the process there is deformation of the metal which reduces the strength and increases the ductility of metal.

   b. Cold forging

For certain products like bolts, rivets, screws, pins, nails, etc. cold forging is also very common. It increases the strength which results from the strain hardening of the component.

2. According to the method of applying the blows

a. Impact forging

In this method of forging, a machine that applies impact load on the work piece is called as forging hammer.

b. Gradual pressure forging

In this method of forging, a machine that applies gradual pressure on the work piece called as forging press.

3. According to the degree to which the flow of work piece is constrained by the dies

a. Open-die forging

In this method of forging, the work piece is compressed between two flat dies which allows the metal to flow without constraint in a lateral direction relative to the die surfaces. Refer Fig.10 (a).

b. Closed-die or impression-die forging

In this method, the die surfaces contain an impression or shape which is applied to the work piece during the compression as shown in Fig.10 (b).

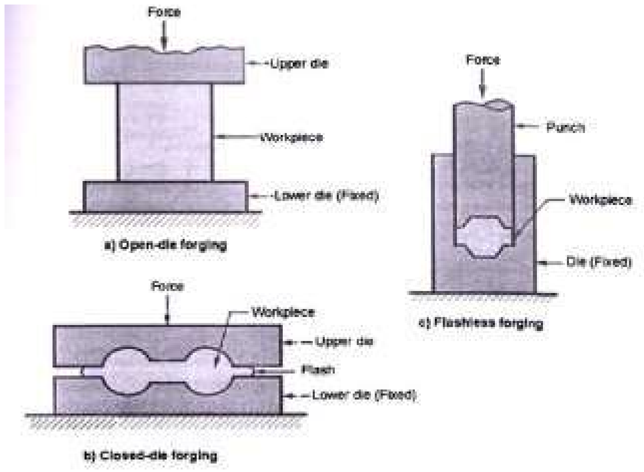


Fig. 10: Types of forging operations

c. Flash less forging

In this method, the work piece is completely constrained within the die and no flash is produced as shown in Fig. 10 (c). The volume of the initial work piece must be controlled closely so that it matches with the volume of the die cavity.

1. Open Die Forging

It is the simplest and important forging process. The shapes generated by this process are simple like shafts, disks, rings, etc. An example of open-die forging in the steel industry is the shaping of a large square cast ingot into a round cross-section. Open-die forging operations produce rough forms of work piece hence, subsequent operations are required to refine the parts to final shape. Open-die forging process can be depicted by a solid work piece placed between the two flat dies (lower die is fixed and upper die is moving) and reduced in height by compressing it. This process is called as upsetting or flat-die forging as shown in Fig. 11. Due to constancy of volume, any reduction in height of the work piece increases its diameter. In Fig. 11 (b) the work piece is deformed uniformly but practically the work piece develops a barrel shape which is called as pancaking or barrelling.

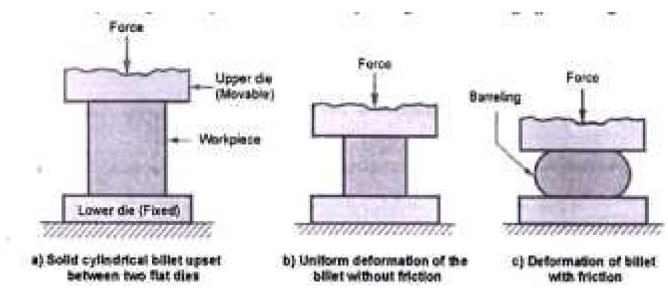


Fig. 11: Open-die forging

It is caused by the frictional forces at the die-work piece interfaces and it can minimised by using an effective lubricant. Some of the important operations performed in open-die forging process are as follows:

1. **Fullering**

It is performed to reduce the cross-section and redistribute the metal in a work piece in preparation for subsequent shape forging. It is performed with dies of convex surfaces as show in Fig. 12 (a).

2. **Edging**

Its working principle is similar to fullering operation, only the difference is that the dies have concave surfaces as show in Fig. 12 (b).

3. **Cogging**

It consists of a sequence of forging compressions along the length of work piece to reduce the cross-section and to increase the length as show in Fig. 12 (c). It is used to produce blooms, slabs, etc. from the cast ingots. The dies used in this operation are flat or have slightly contoured surfaces. This operation is also called as incremental forging.

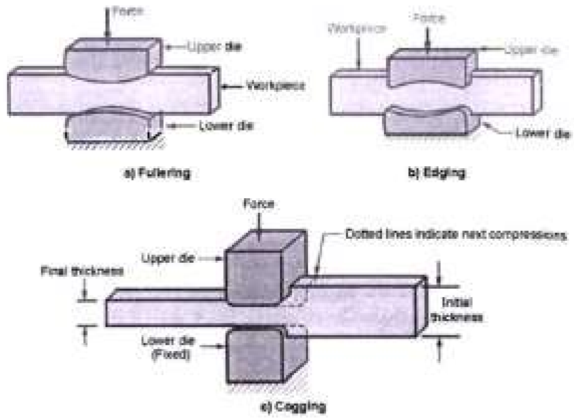


Fig. 12: Open-die forging operations

2. **Impression Die or Closed Die Forging**

Impression-die or closed-die forging is performed with dies which contain the inverse of the required shape of the component as shown in Fig. 13. Initially the cast ingot is placed between the two impressed dies. As the die closes to its final position, flash is formed by the metal. This flash flows beyond the die cavity and into the small gap between the die plates. The formed flash must be cut away from the final component in a subsequent trimming operation but it performs an important function that, it increases the resistance to the deformation of the metal. The initial steps in the process are used to redistribute the metal in the work part to achieve a uniform deformation and required metallurgical structure in the subsequent steps. The final steps bring the component to its final geometry. Also, when drop forging is used, number of blows of the hammer may be used for each step. As flash is formed during the process, this process is used to produce more complex components by using dies.

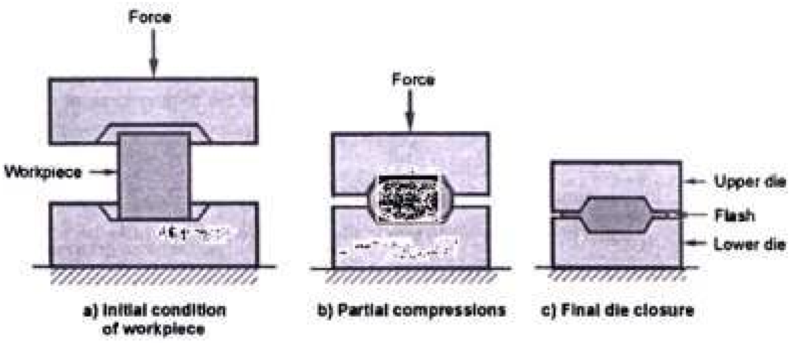


Fig. 13: Closed or impression dies forging

3. **Drop forging**

Drop forging is different from smith's forging as in drop forging closed impressions rather than open face of flat dies are used. This process utilizes closed impression die to obtain the required shape of the component. The dies are matched and separately attached to the movable ram and the fixed anvil. The forging is produced by impact or pressure, which compels hot and pliable metal to confirm to the shape of the dies. During the operation, there is a drastic flow of metal in the dies caused by repeated blows of hammers on the metal.

To ensure proper flow of the metal during the intermittent blows, the operation is divided into a number of steps. Each step changes the metal form gradually, controlling the flow of the metal until the final shape is obtained. The number of blows required varies according to the size and shape of the part, forging quality and required tolerances. The equipment used for applying the blows is called as drop hammer.

Three types of drop hammers are used in making drop forgings:

- Board or gravity hammer
- Air-lift hammer
- Power drop hammer or steam hammer

Fig. 14 shows the principle of a board or gravity hammer.

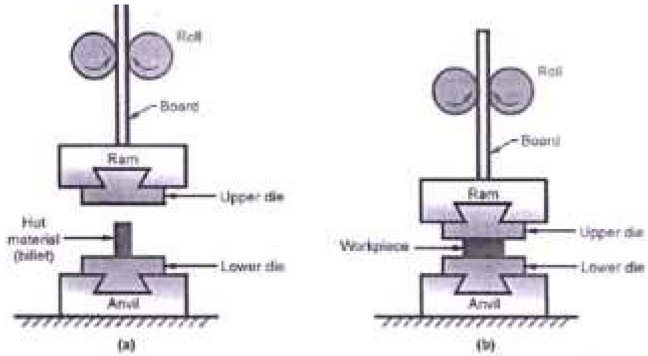


Fig. 14: Principle of a board or gravity hammer

The drop forging die consists of two halves i.e. lower half and upper half. The lower half of the die is fixed to the anvil of the machine while upper half is fixed to the ram. The heated stock or the work piece is kept in the lower die while the ram delivers four to five blows on the metal in quick succession, so that the metal spreads and fills the die cavity. The force of the blow can be varied by changing the distance of the fall. The anvil which must absorb the blow is generally 20 times heavier than the hammer. A board hammer which works rapidly, gives over 300 blows per minute. Board hammer can do a wide variety of work and they are less expensive as compare to the others. Components manufactured by drop forging are car axles, crankshafts, connecting rods, leaf springs, crane hooks, jet engine turbine dies and blades.

4. **Press Forging**

It is done in presses rather than by using hammers. The action is relatively slow squeezing instead of delivering heavy blows and penetrates deeply because it gives the metal time to flow. Press forgings are shaped at each impression with a single smooth stroke and they stick to the die impression more rigidly. Press forgings are generally more accurate dimensionally than drop forgings. Press for forgings may be of two type's i.e. hydraulic and mechanical press. The dies used carry relatively less draft and hence more complicated shapes can be forged. The life of the presses and dies is longer than that of the hammer and dies used on them. The process does not require highly skilled operator because the speed, pressure and travel of the die are automatically controlled. There are less vibrations and noise as compared to hammering. Presses of 500 to 600 tonnes capacities are generally used. Press forging is used for the manufacturing of large levers, flanges, toothed wheels, crankshafts, propellers, hollow bodies, railway wheel disks, tank bottoms, panels and other bodies of air-craft and rocket bodies.

5. **Machine or Upset Forging**

Machine forging is also called as hot heading. It consists of applying pressure longitudinally on a hot bar, which is gripped firmly between grooved dies, to upset a required portion of its length. All forgeable metals can be upset through this process. They may have any shape of cross-section, but round shape is most commonly used. The equipment used for this type of forging is known as forging machine or up setter. The machine provides forging pressure in a horizontal direction. The dies are so designed that, the complete operation is performed in several stages and the final shape is attained gradually. The operation is performed by using die and punch which is called as heading tool, as shown in Fig. 15. The die is either made hollow to receive the round bar through it or in two parts to open out and receive the bar. Between the heading tool and the die, a mechanical stop is placed which determine the correct projecting length of the bar. After the bar has been gripped firmly, with its correct length projecting outside, the stop is replaced and the heading tool is advanced into the die. Many such strokes are required to complete the upsetting. Forging of the ring and rod types with all kinds of heads and shoulders such as be bolts, nuts, washers, collars, pinion gear blanks, etc. can be easily produced by this process.

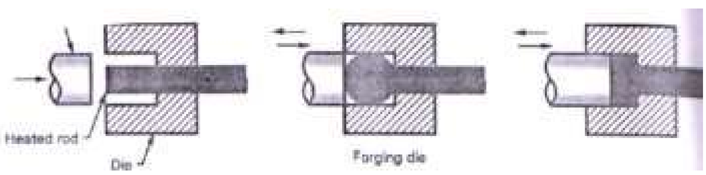


Fig. 15: Upset forging

6. **Roll Forging**

Roll forging process consists of placing raw stock between two roll dies which are of semi-cylindrical form and are grooved to impart a desired shape to the work piece being forged. Thee roll dies are carried on roll shafts and rotate continuously towards the operator.

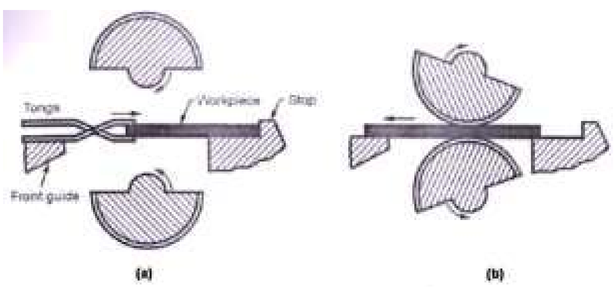


Fig. 16: Principle of operation of a roll forging machine

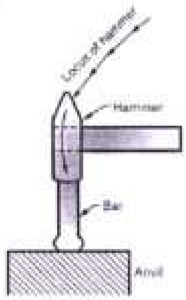
Fig. 16 (a) shows the rolls in an open condition, with the heated work piece in the tong and resting on the guide. In Fig. 16 (b) the rolls are brought together, with the stock gripped in the grooves of the rolls. The rolling action forces the stock towards the operator. When the dies are again in an open condition the stock is placed in appropriate grooves of the rolls and the operations are repeated until the required shape is not obtained. This process is also used to make large reductions in the cross-section and distribution of the metal of a billet, hence saving considerable work in the forging hammer or press. By using roll forging, parts such as knife blades, automobile drive shafts, axles, leaf springs and gear-shift levers are made.

12. Forging Operations

A number of operations are used to change the shape of the raw material to the finished form.
A typical smith forging operations are as follows:

1. **Upsetting:**

Upsetting is also called as jumping or heading. It is a process through which the cross-section of a metal piece is increased with a corresponding increase in its length. When a metal is sufficiently heated, it acquires the plastic stage, so that it becomes soft. If some pressure (blows) is applied to it, then the metal tends to swell or increase in its dimensions at right angles to the direction of application of force with corresponding reduction in its dimensions.



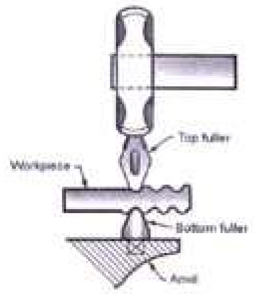


Fig. 17(a): Upsetting a bar *Fig. 17(b): Drawing out*

2. **Drawing out or drawing down:**

Drawing out is exactly a reverse process to that of upsetting. It is employed when a reduction in thickness, width of a bar is desired with a corresponding increase in its length. The desired effect is obtained by the use of either the peen of a cross peen hammer, a set of fullers or a pair of swages.

3. **Cutting:**

Cutting-off is a form of a chiselling whereby a long piece of stock is cut into several specified lengths, or a forging is cut-off from its stock. A notch is first made about one half the thickness or diameter of the stock. After that, the work piece must be turned through an angle of 180° and the chisel is placed exactly opposite the notch. The required length of metal can then be cut-off by giving the chisel a few blows with a sledge hammer.

4. **Bending:**

Bending is an important operation in smith forging and it is very frequently used. It may be classified as angular or curvilinear. Any required angle or curvature can be made through this operation. Bending operation is carried out on the edge of the anvil or on the perfectly square edge of a rectangular block. For making a right angle bend, particular portion of the stock is heated and jumped on the outer surface. When metal is bent, the layers of metal on the inside are compressed and those on the outside are stretched.

5. **Punching and Drifting:**

The term punching refers to the operation in which a punch is forced though a work piece to produce a hole. The work piece is first heated and then placed on the anvil face. The punch is then forced into it up to about half its thickness. The work piece is then turned upside down and placed over a tool called as bolster. The punch is again forced into the work piece and made to pass through by hammering. Punching without using a die is generally followed by drifting. In drifting, a tool known as drift is made to pass through the punched hole to produce a finished hole of the required size.

6. Setting down:

Setting down is the operation through which the rounding of a corner is removed, to make it square by using a set hammer. By putting the face of the hammer over the round portion, formed by bending or filleting of the corner and hammering it at the top a local reduction in thickness takes place resulting in sharp corner. Hence, finishing operation is performed through which the unevenness of a flat surface is removed by using a flatter or a set hammer.

7. Welding:

Welding or shutting is the principle operation performed by the smith. The metal which remains pasty over a wide range of temperature is most easily welded. For production of sound weld, the surfaces in contact must be perfectly clean, both mechanically and chemically, so that cohesion will take place when the metal is in aplastic state. A protection to the metal is a coating of flux which covers the surfaces of the metal and prevents oxidation. A forge weld is made by hammering together the ends of two bars which have been formed to the corrected shape and heated to a welding temperature in a forge fire. The method of preparing the metal pieces for welding is called as scarfing.

13. Extrusion

Extrusion is a compression process in which the work metal is forced to flow through a small opening which is called as die to produce a required cross-sectional shape. The extrusion process is similar to squeezing toothpaste or cream from a tube. Almost any solid or hollow cross-section may be produced by extrusion process. As the geometry of the die remains same during the operation, extruded parts have the same cross-section. During the process, a heated cylindrical billet is placed in the container and it is forced out through a steel die with the help of a ram or plunger. The products made by extrusion process are tubes, rods, railings for sliding doors, structural and architectural shapes, door and window frames, etc. Extrusion process is suitable for the non-ferrous alloys, steel alloys, non-ferrous metals, stainless steel, etc. Extrusion process is carried out on horizontal hydraulic press machines which are rated from 250 to 5500 tonnes in capacity.

Extrusion process is classified as follows:

1. According to physical configuration
   a. Direct (Forward) extrusion
   b. Indirect (Backward) extrusion
2. According to working temperature
   a. Hot extrusion
   b. Cold extrusion

1 Direct Extrusion

Direct or forward hot extrusion is most widely used and the maximum numbers of extruded parts are produced by this method. Fig. 17 shows the direct extrusion process in which the raw material is a billet. A billet is heated to its forging temperature and fed into the machine chamber.

Pressure is applied to the billet with the help of ram or plunger which forces the material through the die. The length of extruded part will depend on the billet size and cross-section of the die. The extruded part is then cut to the required length. As the ram approaches the die, a small portion of billet remains which cannot be forced through the die opening. This extra portion is known as butt who is separated from the product at the end. When the billet is forced to flow through the die opening, there is friction between the work piece and chamber walls. This friction is overcome by providing additional ram force. This is the major problem with this process. To overcome this problem oxide layer is provided on the billet or dummy block is used between the ram and billet. Direct extrusion process is also used to produce hollow or semi-hollow sections. To produce hollow sections, by direct extrusion process, a mandrel is used. When the billet is compressed, the material is forced to flow through the gap between the mandrel and die opening. This results in tubular cross-section.

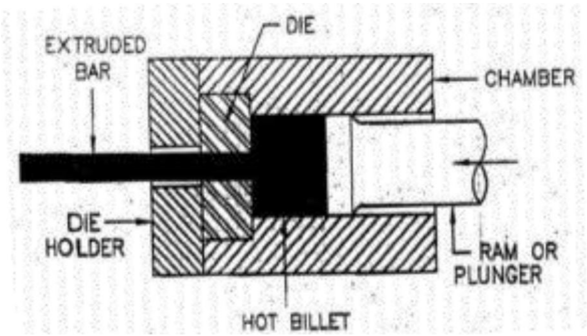


Fig. 17: Direct extrusion

2 Indirect Extrusion

Indirect extrusion is also called as backward extrusion. In this type, the ram or plunger used is hollow and as it presses the billet against the back wall of the closed chamber, the metal is extruded back into the plunger as shown in Fig. 18.

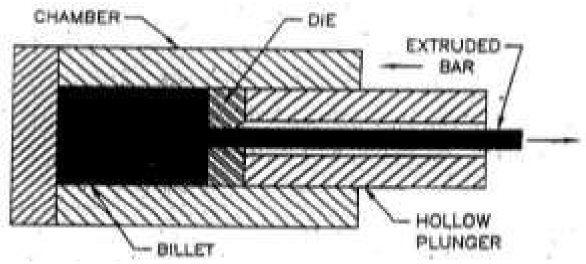


Fig. 18: Indirect or backward or reverse extrusion

It involves no friction between the metal billet and the chamber because the billet does not move inside the chamber. As compared to direct extrusion, less total force is required in this method. But the equipment used is mechanically complicated in order to support the passage of the extruded shape through the centre of the hollow ram. Indirect extrusion is also used to solid as well as hollow components. For producing solid parts ram is hollow whereas for producing hollow parts ram is solid.

3 Cold Extrusion (Impact Extrusion)

The most common cold extrusion process is impact extrusion. Various daily use products such as tubes for shaving creams, tooth paste and paints, condenser cans and such other thin walled products are impact extruded. The raw material is in slug form which have been turned from a bar or punched from a strip. By using punch and dies, the operation is performed. The slug is placed in the die and struck from top by the punch operating at high pressure and speed.

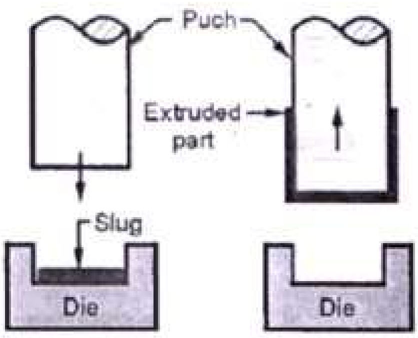


Fig. 19: Principle of impact extrusion

The metal flows up along the surface of the punch, forming a cup shaped component. When the punch moves up, to separate the component from the punch compressed air is used. At the same time, a fresh slug is fed into the die. The rate of production is fairly high i.e. 60 components per minute. This process is used only for soft and ductile materials such as lead, tin, aluminium, zinc and some of their alloys. The main advantages of this process are its speed, product uniformity and no wastage.

4 Hydrostatic Extrusion

In this type of extrusion process, the billet is surrounded by a working fluid which is pressurised by the ram to apply the extrusion force. In this process, hydraulic fluid remains between the billet and the chamber walls hence eliminating the contact between them. Also, it avoids the friction between the metal billet and the walls of the chamber. Fig. 20 shows the working principle of hydrostatic extrusion. Due to absence of wall friction, extrusion of very long billets or even wires and large reductions can be taken.

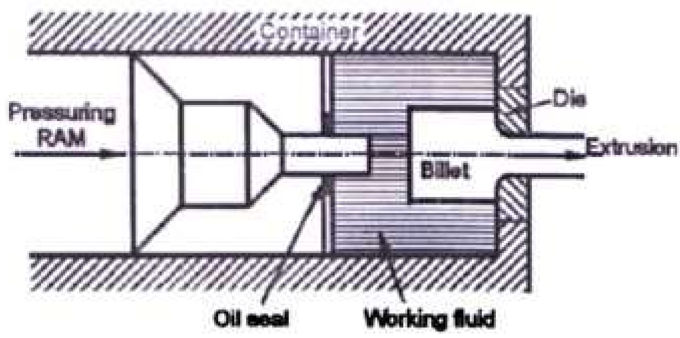


Fig. 20: Hydrostatic extrusion

During the process, the ram does not directly act on the billet, instead of that, it acts on the hydraulic fluid which forces the billet through the die and produces the extrusions. The materials which cannot be extruded successfully by conventional methods can be extruded by this process.

14. Wire Drawing

Drawing is an operation in which the cross-section of a bar, rod or wire is reduced by pulling it through a die opening. The general features of the drawing process are similar to extrusion. But the difference is that, in drawing the work piece is pulled through the die whereas in extrusion work piece is pushed through the die. During the process, tensile as well as compressive stresses are produced in the material. The main difference between the bar drawing and wire drawing is the stock size(work piece size). Bar drawing is used for large diameter (bar and rod) stock whereas wire drawing is used for small diameter stock.

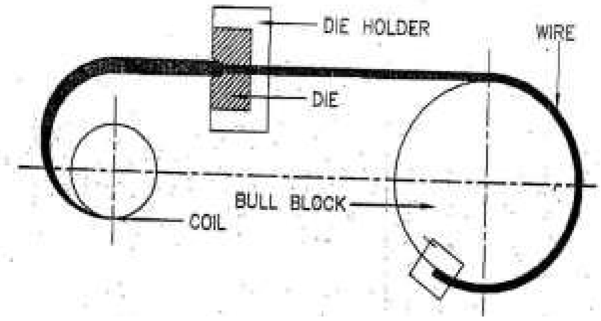


Fig. 21(a): Wire drawing

Wire sizes up to 0.03 mm can be drawn by wire drawing process. The process consists of pulling the hot drawn bar or rod through a die of which the bore size is similar to the finished product size. Depending upon the material to be drawn and the amount of reduction required, total drawing can be accomplished in a single die or in a series of successive dies. One end of the rod to be drawn into wire is made pointed, entered through the die and gripped at the other end by using tongs.

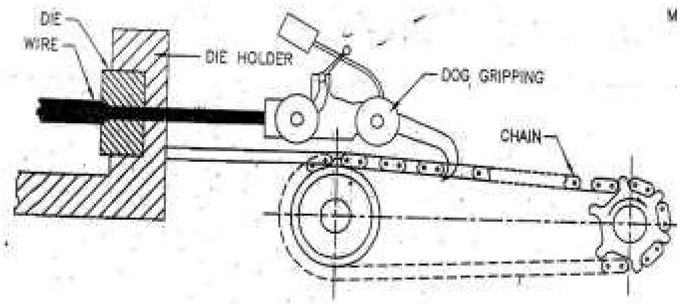


Fig. 21(b): Wire drawing

After pulling a certain length, this end is wound to a reel or draw pulley. When the pulley or reel is rotated, the rod is pulled through the die and its diameter reduces. The die is made of highly wear resistant material. Generally, tungsten carbide is used for die making. The die made of tungsten carbide is suitably supported in a die holder which is made of mild steel or brass.

15. Tube Drawing

As the initial tubing has been produced by other processes like extrusion, drawing can be used to reduce the diameter or wall thickness of seamless tubes and pipes. Tube drawing can be carried out either with mandrel or without mandrel the simplest method of producing tubes and pipes is shown in Fig. 22 (a) in which mandrel is not used. This method is also called as tube sinking. In tube sinking method there is no control over the inner diameter and wall thickness of tube.

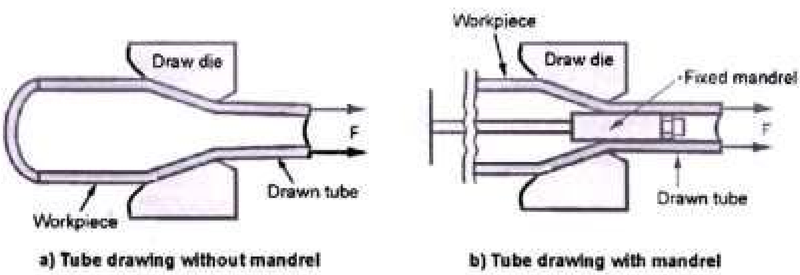


Fig. 22: Tube drawing

To overcome this drawback, mandrels are used in the process. Fig. 22 (b) shows tube drawing with mandrel. In this method, mandrel is fixed and attached to a long support bar to produce inside diameter and wall thickness during the process.

Exercise:

(a) Differentiate between Hot and Cold working processes.

(b) Discuss the defects, causes and remedies of forging defects.

Experiment No. 9

Aim: To study about sheet metal working processes.

Objective: (1) To explain different types of sheet metal processes.
(2) To explain different types of dies.

1. Introduction

Sheet metal work is very useful trade in engineering work and for our day-to-day needs. Many articles-(household and engineering) whose production by other methods will be uneconomical and complicated are made from metal sheets. It is necessary to understand the construction and working of hand tools, sheet metal working machines and basic principles of different operations, to attain proficiency in the trade. For successful working in the trade, we must have a good knowledge of projective geometry, development of surfaces and properties of different metals.

2. Sheet Metal Operations

Press operations may be grouped into two categories i.e. cutting operations and forming operations. In cutting operations, the sheet metal is stressed beyond its ultimate strength whereas; in forming operations the stresses are below the ultimate strength of the metal. In sheet metal cutting operations, the metal gets sheared hence these operations are also called as shearing operations. In these operations, the metal sheet is stressed beyond its ultimate strength.

Metal cutting operations include following operations:

1. Blanking

Blanking is the cutting operation of a flat metal sheet and the article punched out is known as blank. Blank is the required product of the operation and the metal left behind is considered as a waste as shown in Fig. 1 and Fig. 3 (a).

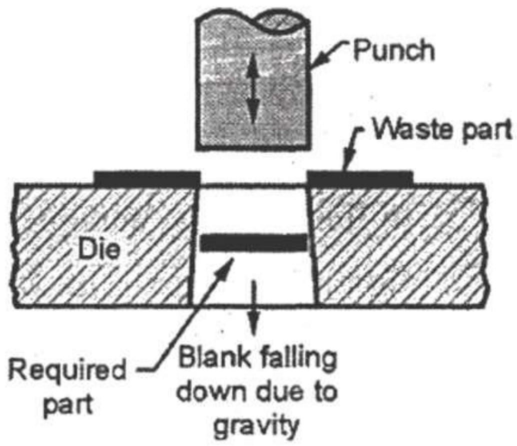


Fig. 1 blanking operation

2. Punching (Piercing)

It is the cutting operation with the help of which holes of various shapes are produced in the sheet metal. It is similar to blanking; only the main difference is that, the hole is the required product and the material punched out to form a hole is considered as a waste as shown in Fig. 2 and Fig. 3 (b).

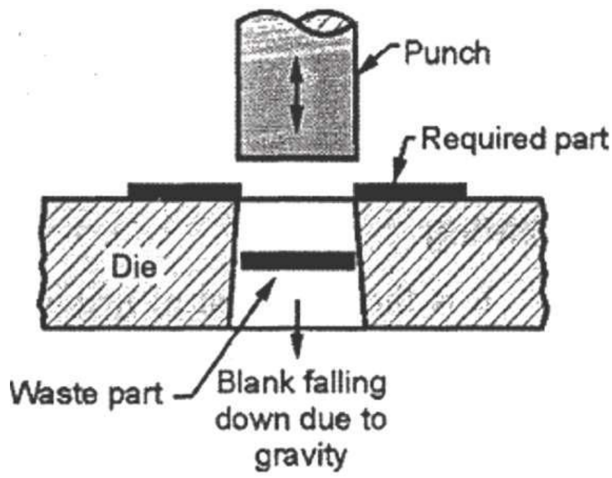
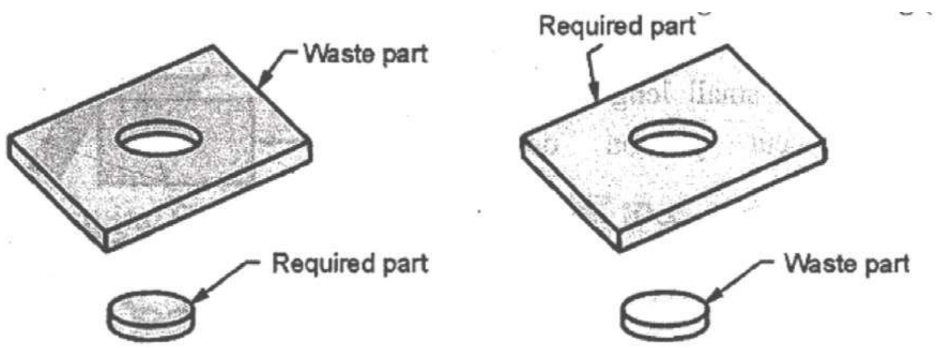


Fig. 2: Punching (Piercing)



(a) Blanking (b) Punching (Piercing)

Fig. 3: Blanking and punching (piercing)

3. **Notching**

It is similar to blanking operation, but in this full surface of punch does not cut the metal. In this operation, metal pieces are cut from the edges of a sheet.

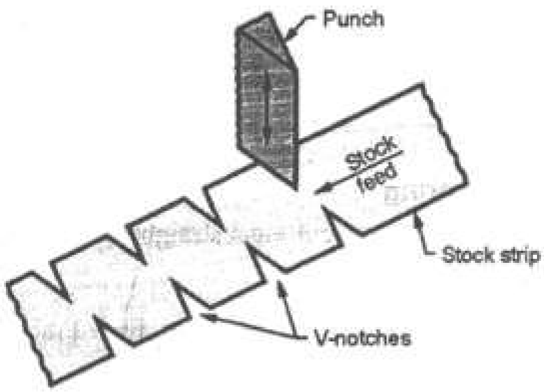


Fig. 4: Notching

4. **Perforating**

It is similar to piercing but the difference is that, to produce holes the punch is not of round shape. In this process, multiple holes which are very small and close together are cut in the sheet metal.

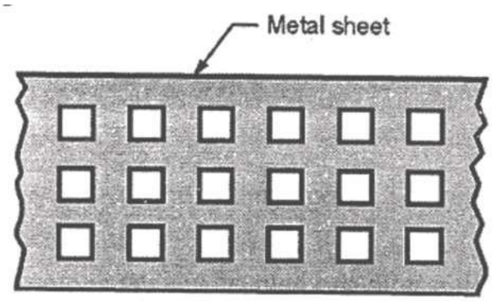


Fig. 5: Perforating

5. Slitting

It is the operation of making an unfinished cut through a limited length only as shown in Fig. 5.5.

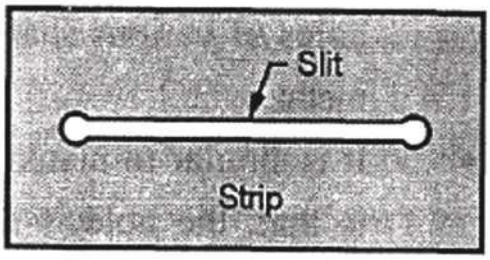


Fig. 6: Slitting

6. **Lancing**

In this operation, there is a cutting of sheet metal through a small length and bending this small cut portion downwards. As shown in Fig. 7.

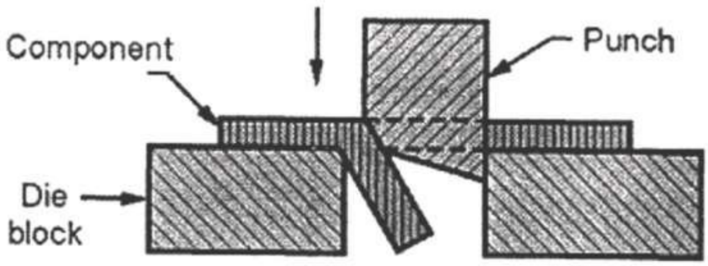


Fig. 7: Lancing

7. Shaving

This operation is used for cutting unwanted excess material from the periphery of a previously formed work piece as shown in Fig. 8. In this process very small amount of material is removed.

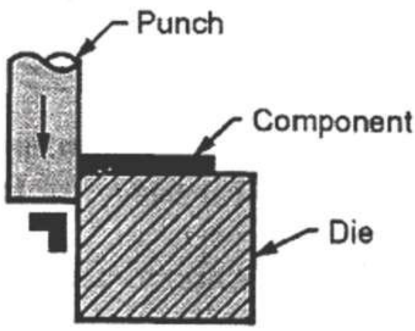


Fig. 8: Shaving

8. **Shearing**

It is a process of cutting a straight line across a strip; sheet or bar. Shearing process has three important stages:

i) Plastic deformation   ii) Fracture (Crack propagation)   iii) Shear

When the metal is placed between upper and lower blades of the shear and pressure is applied, plastic deformation of metal takes place. As the pressure is continued, the fracture or crack starts at the cutting edge of the blade. As the blade descends further, the small fractures meet and the metal is then sheared as shown in Fig. 9. Shearing is performed either by using hand or by using machines also.

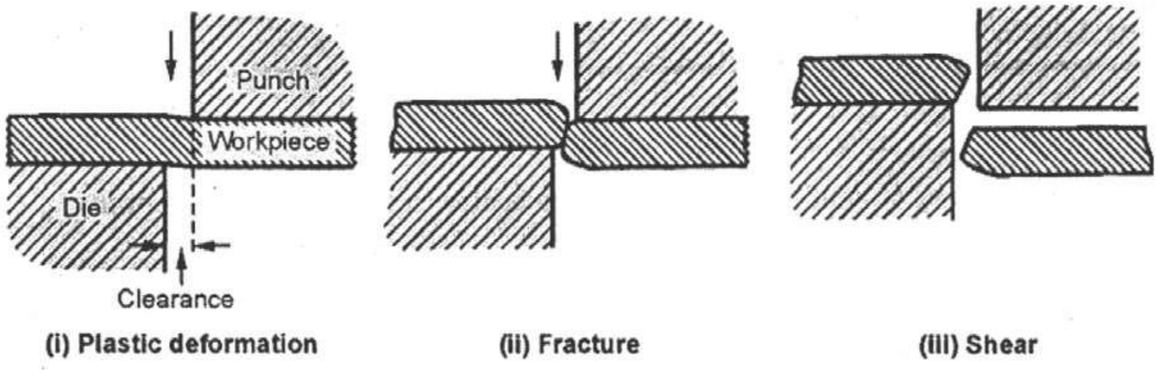


Fig. 9: Steps in shearing process

9. **Nibbling**

This operation is generally substituted for blanking. It is designed for cutting out flat parts from sheet metal. The flat parts range from simple to complex contours. It is used only for small quantities of components.

3. **Metal Forming Operations**

In metal forming operations, the sheet metal is stressed below the ultimate strength of the metal. In these operations, no material is removed hence there is no wastage. Metal forming operations include fol1owing operations.

1. **Bending**

It is a metal forming operation in which the straight metal sheet is transformed into a curve· form. In bending operations, the sheet metal is· subjected to both tensile and compressive stresses. During the operation, plastic deformation of material takes place beyond its elastic limit but below its ultimate strength.

The bending methods which are commonly used are as follows:

a. U-bending

Fig. 10 shows U-bending operation which is also called as channel bending. In this operation, the die cavity is in the form U, due to which component forms the Shape of U.

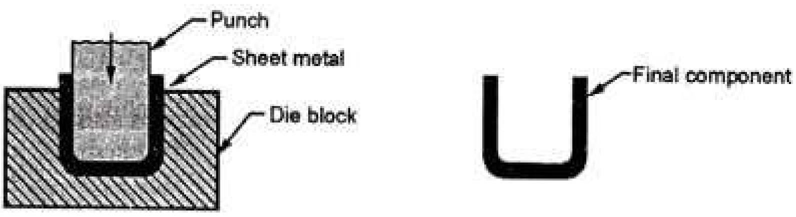


Fig. 10: U-bending

b. V-bending

Fig. 11 shows V-bending operation in which wedge shape punch is used. The angle of V may be acute, 90° or obtuse.

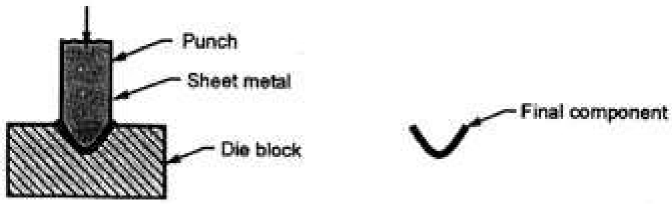
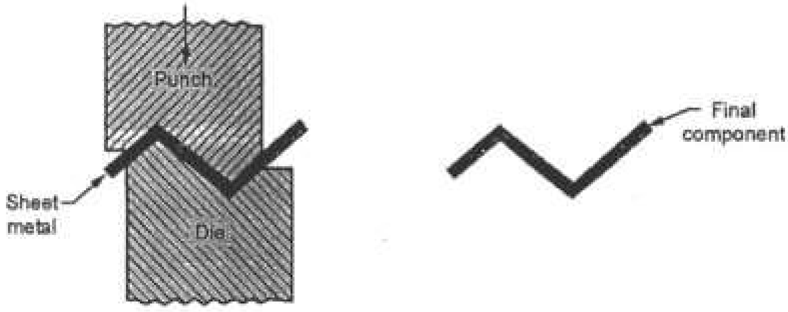


Fig. 11: V-bending

c. Angle bending

In this operation, there is a bending of a sheet metal at a sharp angle as shown in Fig. 12.



Fig; 12: Angle bending

d. Curling

In this operation, the edge of a sheet metal is curled around. The punch and die both are made to contain the cavity for cutting partially. After the operation, punch moves up and work piece is ejected out with the help of plunger as shown in Fig: 13.

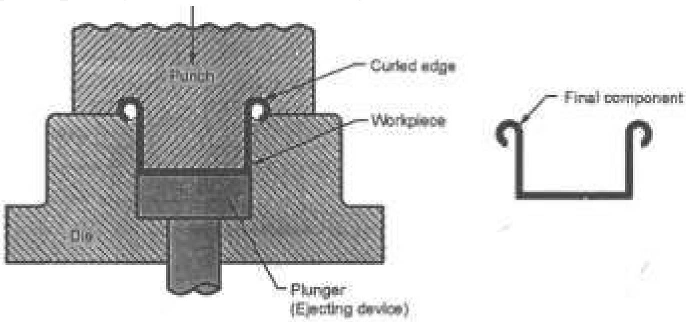


Fig. 13: Curling

This process is used in the manufacturing of drums, pots, vessels, pans, etc.

e. Roll bending

It is an operation in which generally large sheet metal parts are formed into curved sections with the help of rolls as shown in Fig. 14. When the sheet passes between the rolls, the rolls are brought towards each other to a configuration that achieves the required radius of curvature on the work piece. It is used for fabrication of large storage tanks, pressure vessels, used to bend metal plates, tubes, structural shapes etc.

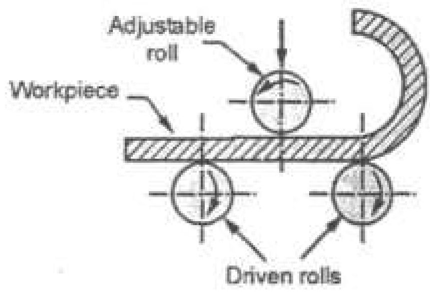


Fig. 14: Roll bending

f. Bending in a 4-slide machine

This type of machine is used for bending of relatively short pieces. These types of machines are available in different designs.

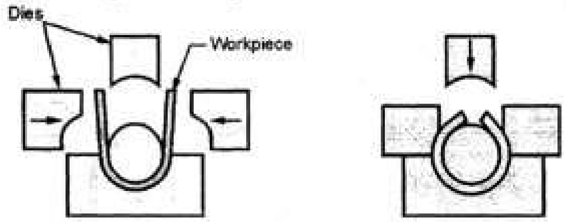


Fig. 15: Bending in a 4-slide machine

The lateral movements of the dies are controlled with the vertical die movement to form the part of desired shapes as shown in Fig. 15.

g. Edge bending

It involves cantilever loading of sheet metal. In this method a pressure pad is used to hold the base of the work piece against the die whereas the punch forces the work piece to yield and bend over the edge of the die.

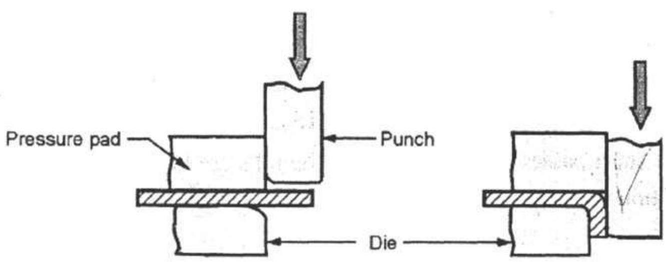


Fig. 16: Edge bending

The edge bending operation is limited to bend 90° or less. The dies used for edge bending is called as wiping dies. They can also be designed for bend angles greater than 90°. Due to pressure pad, wiping dies are more complicated and costly than the V-dies. These dies are used for high production work.

2. Drawing

In this operation, punch forces a sheet metal blank to flow plastically into the clearance between the punch and die. Finally, the blank takes a shape of cup as shown in Fig. 17.

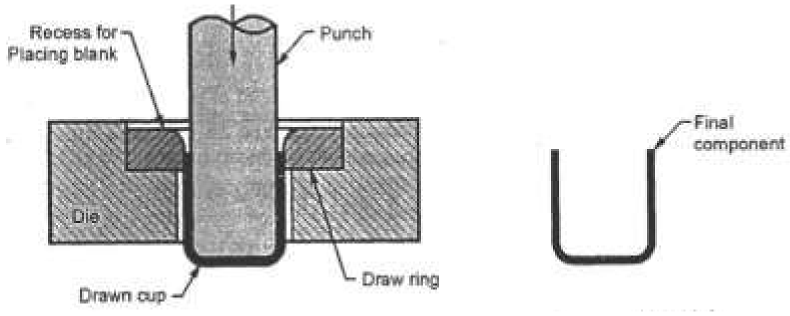


Fig. 17: Drawing

3. **Embossing**

With the help of this operation, specific shapes or figures are produced on the sheet metal. It is used for decorative purposes or giving details like names, trademarks specifications, etc. on the sheet metal as shown in Fig. 18.

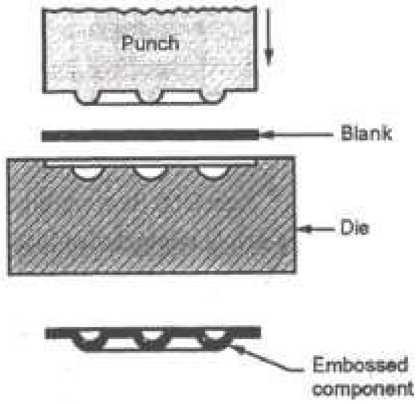


Fig. 18: Embossing

4. **Forming**

In forming operation, sheet metal is stressed beyond its yield point so. That it takes a permanent set and retains the new shape. In this process, the shape of punch and die surface is directly reproduced without any metal flow Shearing is performed either by using hand or by using machines also.

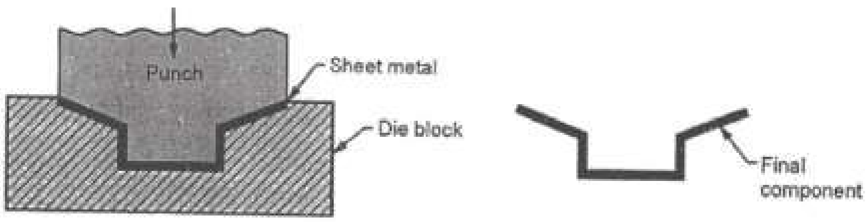


Fig. 19: Forming

This operation is used in the manufacturing of door panels, steel furniture, air-craft bodies, etc.

5. **Coining (Squeezing)**

In coining operation, the metal having good plasticity and of proper size is placed within the punch and die and a tremendous pressure is applied on the blank from both ends as shown in Fig. 20. Under severe compressive loads, the metal flows in the cold state and fills up the cavity of the punch and die. This operation is used .in the manufacturing of coins, medals, ornamental parts, etc.

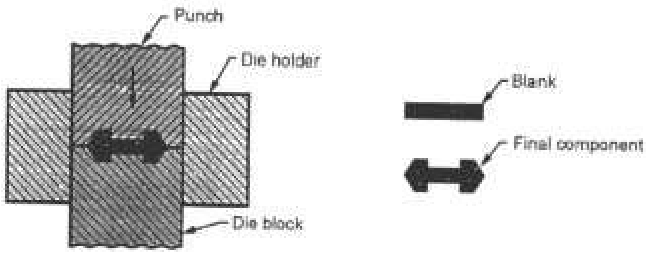


Fig. 20: Coining

6 Deep Drawing

It is a process of making the cup-shaped parts from a flat sheet-metal blank. To provide necessary plasticity for working, the blank is first heated an (then placed in position over the die or cavity as shown in Fig. 21.

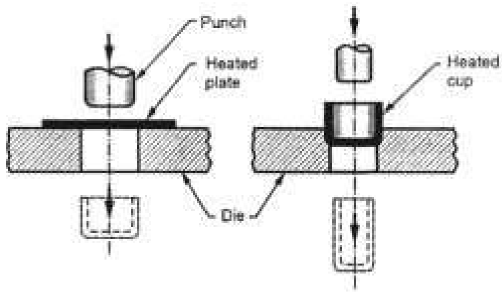


Fig. 21: Deep drawing

The punch descends and pushes the metal through the die to form a cup; hence this process is also called as cupping. To obtain cup shaped pieces of the desired size and wall thickness, the process may be continued through a series of successively smaller dies and punches.

4. Die Classification

a. Based on the types of press operations:

i. **Shearing operations:** Blanking, piercing, shearing, punching, perforating, notching, trimming, shaving, slitting, parting dies. All these are known as cutting dies.

ii. **Bending operations:** Angle bending, curling, forming, folding, plunging and reaming dies.

iii. **Drawing operations:** Flanging, embossing, bulging and cupping dies.

iv. **Squeezing operations:** Flattering, swaging, coining, sizing, pressing dies.

b. Based on the type of die construction:

- Simple die
- Compound die
- Combination die
- Progressive die
- Transfer die
- Multiple die, etc.

1. Simple dies:

Simple dies perform single operation for each stroke of the press slide. The operation can be any of the operation listed under cutting or forming operations.

2. Compound die:

In this type of dies, two or more operation can be performed at one station. Only cutting operations are carried out hence these dies are considered as cutting dies.

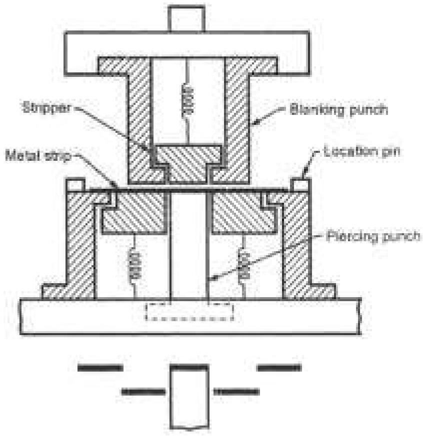


Fig. 22: Compound dies

Fig. 22 shows a simple compound die in which a washer is made by one stroke of the press. The washer is produced by simultaneous blanking and piercing operation. These dies are used because they are more accurate and economical in mass production as compared to simple dies.

3. **Combination dies:**

In this also, more than one operation can be performed at one station. It differs from compound die in such a way that, a cutting operation is combined with bending or drawing operation as shown in Fig. 23. The die ring, which is mounted on the die shoe, is counter bored at the bottom to allow the flange of a pad to travel up and down. This pad is held with the face of the die by a spring. A drawing punch of required shape is attached to the die shoe. The blanking punch is secured to the punch holder. A spring stripper strips the skeleton from the blanking punch. A knockout extending through the centre opening and through the punch ·stem ejects the port on the upstroke as it comes in contact with the knockout bar on the press. In operation, the blank holding ring descents as the part is blanked, then the drawing punch contacts and force the blank into the drawing die which is made in the blanking punch.

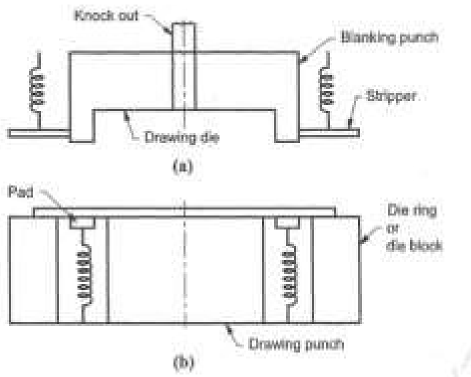


Fig. 23: Combination dies

4. **Progressive dies:**

A progressive die or follow on die has a series of stations. At each station, an operation is performed on a work piece during a press stroke. Between the strokes, the piece in the metal strip is transferred to the next station. A finished work piece is made at each stroke of the press. When the piercing punch cuts a hole in the strip, the blanking punch blanks out portion of the metal in which a hole has been produced at a previous station. Hence, after each stroke a finished washer is produced as shown in Fig. 24.

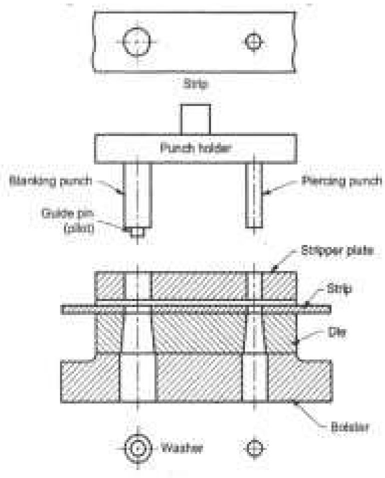


Fig. 24: Progressive die

5. **Transfer dies:**

It is similar to progressive dies, where the stock is fed progressively from one station to another. In transfer dies, already cut blanks are fed mechanically from station to station.

6. **Multiple dies:**

These dies are also called as Gang dies. It produces two or more work-pieces at each stroke of the press. Number of simple dies and punches are ganged together, to produce more parts at each stroke of the press.

Exercise:

(a) Explain the upsetting and drawing down operation with neat sketch.

(b) Explain following terms (1) Blanking (2) Piercing and (3) Coining.

Experiment No. 10

Aim: To study about plastic technology.

Objective: (1) To explain different types of plastic material.
(2) To explain different plastic processing processes.

1. Introduction

Describing the types of plastics is a bit like looking at a giant family tree; unless you know some of the people it does not make much sense. The resource: 'curing' explains the basic chemistry of plastics, and describes the difference between thermoplastic and thermoset plastics. They are like two branches of the family, and this section deals with the largest branch, thermoplastics.
One difficulty with describing plastics is that the same material with the addition of just a single additive like a blowing agent or plasticizer can make what appears to be a very different material. Take polyurethane for example. It can be used as a clear coating like varnish, expanded and rigid to form the core of a surfboard, and with a plasticizer it can become a soft car seat.

2. TYPES OF PLASTIC:

With plastics there are about 45 basic families, many with hundreds of offspring. We will look at five main branches, mainly because they are plastics which you will be familiar with. The five branches are; polyethylene, polypropylene, polystyrene, vinyl, and polyethylene terephthalate.

2.1 Polyethylene:

Most plastic household packaging is made from polyethylene. It is a versatile wax-like thermoplastic in almost a thousand different grades with varying melting temperatures, density and molecular weights. It has three main forms:

FORM	ACRONYM	CHARACTERISTICS	COMMON USES
Polypropylene	HDPE	Hard to semi-flexible, Waxy surface, opaque	Fertilizer bags, car petrol tanks, gas pipe, tanks and rope
Low Density	LDPE	Soft, flexible, waxy surface, translucent	Packaging film, bags, waterproof membranes, wire sheathing, pipes
Linear Low Density	LLDPE	Flexible, translucent, glossy, strong	Shopping bags, stretch wrap, greenhouse film

2.2 Polypropylene:

It was developed in Italy in 1954 from catalysts used to form HDPE. It is very versatile, and makes up about 12 per cent of the plastics used in Australia.

FORM	ACRONYM	CHARACTERISTICS	COMMON USES
High Density	PP	Hard, flexible, translucent, dry feel	Containers, appliances, toys, plumbing

2.3 Polystyrene:

This is one of the lower cost plastics to produce and is the easiest to shape. Packaging for a variety of products uses most of the plastic.

FORM	ACRONYM	CHARACTERISTICS	COMMON USES
Polystyrene	PP	Clear, glossy, rigid, brittle	Margarine containers
High Impact	HIPS	Opaque, tough, rigid	Refrigerator liners
Expanded	EPS	Foamed, lightweight, insulating	Stubby holders molded packaging
Styrene Acrylonitrile	SAN	Rigid, clear, tough	Mixing bowls, food containers
Acrylonitrile Butadiene Styrene	ABS	Rigid, tough, glossy opaque	Hard hats, computer cases, wheel covers

2.4 Vinyl:

Vinyl is among the most versatile of all thermoplastics, ranging from soft pliable films to rigid structural forms. They are cheap to make because about half the raw material comes from rock salt.

FORM	ACRONYM	CHARACTERISTICS	COMMON USES
Plasticized	PVC	Flexible, clear, elastic	Car linings, blood bags, floor covering
In-plasticized	PVC	Hard, rigid, clear	Pipe, cordial bottles, credit cards

2.5 Polyethylene terephthalate:

This is one of the more recent plastics, and it is being used for an increasing array of products. One reason for this is a ready supply of raw material (a petroleum by-product) and the only waste from the process is steam.

FORM	ACRONYM	CHARACTERISTICS	COMMON USES
Fiber	PET	Clear, tough, heat resistant	Fabrics and carpets
Sheet	PET	Clear, tough glossy, heat resistant	Soft drink bottles, audio video Tapes

3. PROCESSING OF PLASTICS:

One of the most important characteristics of plastics is the ease with which they can be formed into intricate shapes. Although the various machines which process plastics are very different, the process of softening, shaping and cooling the plastic material is common to each one.
The main methods of processing plastic are described here.

3.1 Blow moulding:

Blow molding is used for hollow containers like milk bottles. Plastic is melted into a hollow tube and placed between the halves of the mound. As the mound closes, compressed air forces the plastic against the walls of the mound.

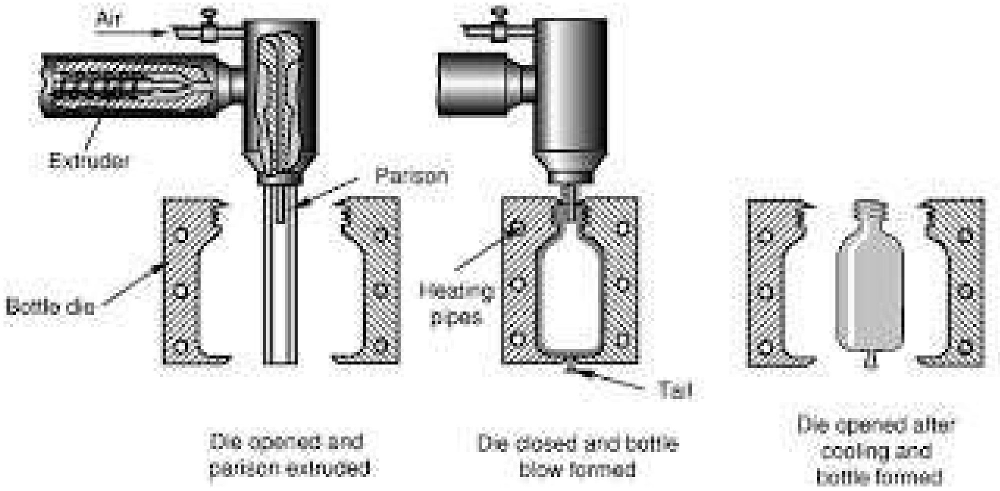


Figure 1: Blow Molding

Injection blow molding is used in the production of large quantities of hollow plastic objects. The process starts with the injection molding of a polymer onto a core pin which is then rotated to a blow molding station to be inflated and cooled. Typically used to make small medical and single serving bottles, injection blow molding is the least-used of all blow molding processes.

3.1.1 Extrusion Blow Moulding:

Extrusion blow molding can be used to process many different polymers including polyethylene, polyvinyl chloride, polypropylene and more. The process begins with the conventional downward extrusion of a tube. When the tube reaches the desired length the mound is closed catching and holding the neck end open and pinching the bottom end closed. Then a blow-pin is inserted into the neck end of the hot tube to form the threaded opening and inflate the tube inside the mold cavity. When the mound is completely cooled it is opened to eject the bottle and the excess plastic is trimmed from the neck and bottom areas.

3.1.2 Stretch Blow Moulding:

The main applications of stretch blow molding include jars, bottles, and similar containers because it produces items of excellent visual and dimensional quality compared to extrusion blow molding. The process first requires the plastic to be injection molded into a 'preform' with the finished necks (threads) of the bottles on one end.

The preform is then heated above its glass transition temperature and blown, using high pressure air, into bottles using metal blow molds. At the same time the preform is stretched with a core rod to fill inside of the mound. Strain hardening occurs as part of the stretching process of some polymers (such as Polyethylene Terepthalate) which allows the bottles to resist deforming under the pressures resulting from carbonated beverages (typically around 60 psi).

3.2 Injection moulding:

Injection molding is a common processing method for mass producing plastic parts. Plastic granules are heated in a chamber and an exact amount of molten plastic is forced into the mound which is made in two or more sections, held tightly together with a hollow the shape of the finished product inside. Plastic model kits have many parts molded at the one time, the molten plastic being forced from one part to the other through the tiny section which keeps the parts together.

Plastic has, quite literally, become the cornerstone of our society. We make so many things from plastic that it is hard to imagine what our lives would be like if it was never invented. With so many of our everyday products being made of plastic, it is easy to understand why plastic injection molding is such a huge industry.

Approximately 30% of all plastic products are produced using an injection molding process. Of this 30%, a large amount of these products are produced by using custom injection molding technology. Six steps are involved in the injection molding process, after the prototype has been made and approved.

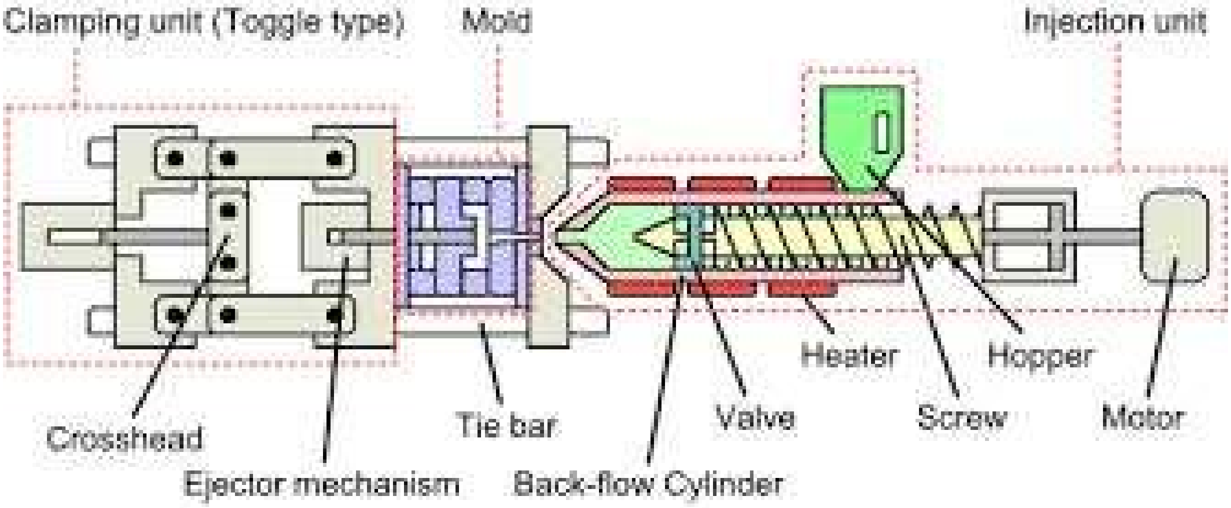


Figure 2: Injection moulding

The first step to the injection molding process is the clamping of the mold. This clamping unit is one of three standard parts of the injection machine. They are the mold, the clamping unit and the injection unit. The clamp is what actually holds the mold while the melted plastic is being injected, the mold is held under pressure while the injected plastic is cooling.

Next is the actual injection of the melted plastic. The plastic usually begins this process as pellets that are put into a large hopper. The pellets are then fed to a cylinder; here they are heated until they become molten plastic that is easily forced into the mold. The plastic stays in the mold, where it is being clamped under pressure until it cools.

The next couple of steps consist of the dwelling phase, which is basically making sure that all of the cavities of the mold are filled with the melted plastic. After the dwelling phase, the cooling process begins and continues until the plastic becomes solid inside the form. Finally, the mold is opened and the newly formed plastic part is ejected from its mold. The part is cleaned of any extra plastic from the mold.

As with any process, there are advantages and disadvantages associated with plastic injection molding. The advantages outweigh the disadvantages for most companies; they include being able to keep up high levels of production, being able to replicate a high tolerance level in the products being produced, and lower costs for labor as the bulk of the work is done by machine. Plastic injection molding also has the added benefit of lower scrap costs because the mold is so precisely made. However, the disadvantages can be a deal breaker for smaller companies that would like to utilize plastic injection molding as a way to produce parts. These disadvantages are, that they equipment needed is expensive, therefore, increasing operating costs.

3.3 Compression Moulding:

Specifically designed to facilitate the replacement of metal components with polymers (and other composites), the compression molding process is a method of molding in which a preheated polymer is placed into an open, heated mound cavity. The mound is closed with a top plug and pressure is applied to force the material to contact all areas of the mound. Throughout the process heat and pressure are maintained until the polymer has cured.

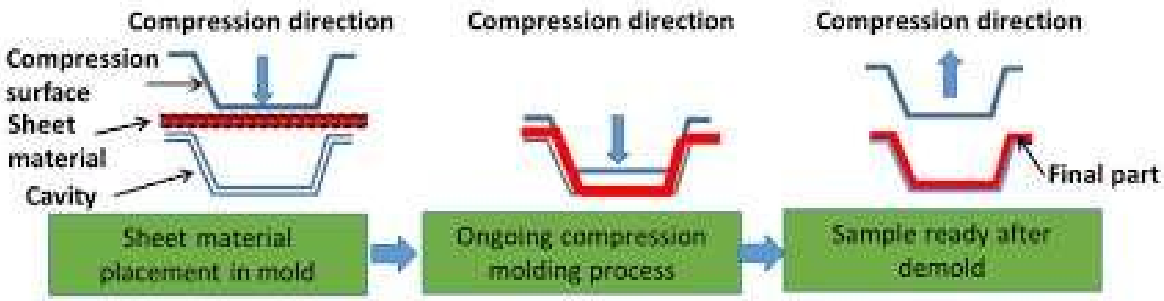


Figure 3: Compression Moulding

While the compression molding process can be employed with both thermosets and thermoplastics, today most applications use thermoset polymers. Advanced composite thermoplastics can also be compression molded with unidirectional tapes, woven fabrics, randomly orientated fiber mat or chopped strand.

Compression molding is a high-volume, high-pressure plastic molding method that is suitable for molding complex, high-strength objects. And with its short cycle time and high production rate, many organizations in the automotive industry have chosen compression molding to produce parts.

3.4 Blown film:

This is the process of molten plastic being blown like a huge balloon which is being drawn upwards at the same time into rollers which cool the film and press it flat. This is how thin plastic film like shrink wrap is made.

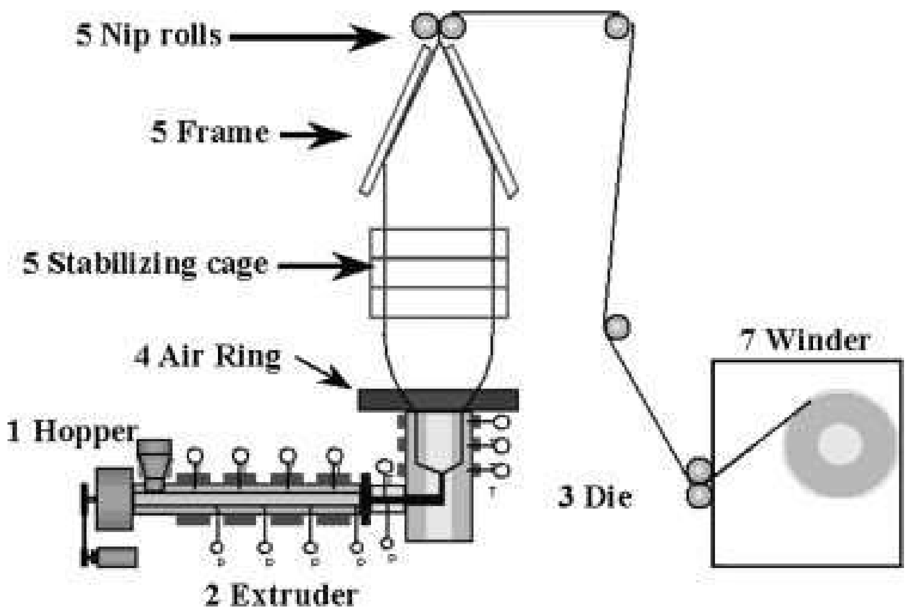


Figure 4: Blown film

3.5 Calendaring:

This is where molten plastic is poured and evenly squeezed between several sets of rollers until it cools.

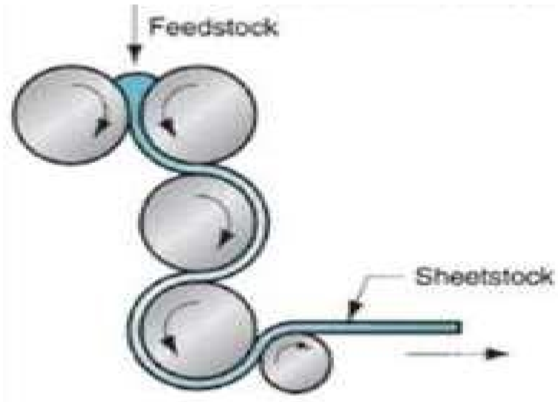


Figure 5 Calendaring Molding

3.6 Extrusion:

This is the process used for forming pipes and various sections like spouting and curtain track. Plastic granules are fed into a large revolving screw which forces the granules past a heating chamber where they melt. The molten plastic is forced through a hole, called a die, which is the shape of the finished section, and as the continuous section passes coolers it becomes rigid.

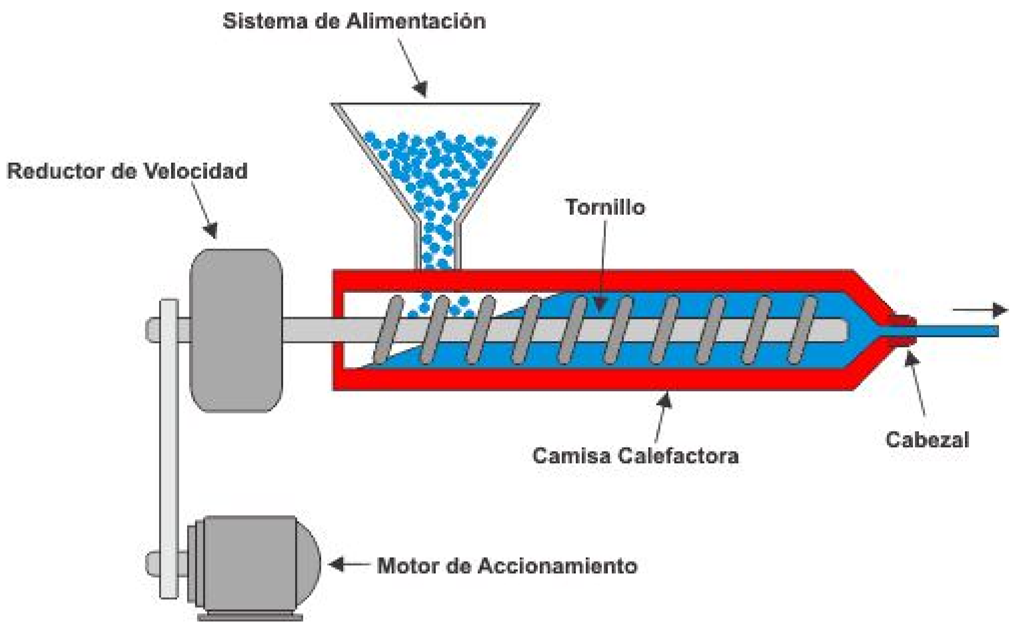


Figure 6: Extrusion

3.7 Rotational moulding:

This uses a hollow mound which is heated, and rotates through every axis. The plastic granules melt against the surface of the mound as it rotates, spreading an even thickness against the mound surface. The mound cools and when the parts are separated, the product such as a beach ball or rainwater tank is taken out. Easter eggs are made in rotational molds, and sometimes they are thicker on one end because the rotating mound stopped while some chocolate was still able to run to the lowest point.

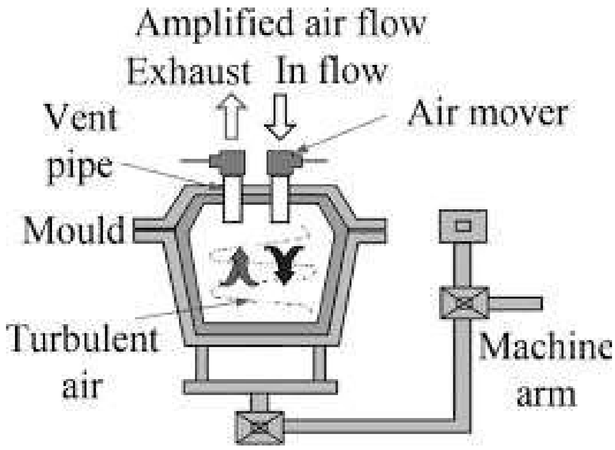


Figure 6: Rotational moulding