MANUFACTURING PROCESSES

ANSWER KEY- JAN 2023

1. **What is the need for providing allowance for patterns?**

   The amount of increase in size is for compensating the reduction of dimensions due to shrinkage, machining, drafting, shaking and distortion effect.

2. **What is draft allowance?**

   The draft allowance or taper allowance is the taper provided on the vertical faces of the removable patterns so that the pattern can be withdrawn from the rammed sand without causing damage to the vertical sides and without the need for excessive rapping. Draft provides a light clearance for the vertical sides of the pattern as it is lifted up.

3. **State the limitation of welding process.**

   - It results in residual stresses and distortion of the workpieces.
   - Welded joint needs stress relieving and heat treatment.
   - It is a difficult task to dismantle the joined material through welding.
   - Requires skilled labor and electric supply.
   - Welding gives out harmful radiations (light), fumes and spatter.

4. **List the advantages of electron beam welding.**

   - As welding is done in vacuum, even highly reactive materials are welded easily
   - Welds are very clean
   - No thermal distortion to work piece.
   - Narrow welds with deep penetration can be obtained.
   - Temperature can be easily controlled
   - Very fast process.

5. **What is the effect on microstructure in metal forming process?**

   Metal microstructure changes in machining include recrystallization, grain growth, crystallization evolution, and phase transformation.

6. **Define extrusion.**

   Extrusion is the process by which a block of metal is reduced in cross section by forcing it to flow through a die orifice under high pressure.

7. **What is meant by grade arid structure of a grinding wheel?**

   The grade indicates the strength and hardness of the bond in the wheel. The structure denotes the spacing between the abrasive grains. The structure of grinding wheel depends on the hardness of the material being cut. Soft, ductile material and heavy cuts require an open structure whereas brittle material and finishing cut require a dense structure.

8. **What are the types of surfaces that can be produced using plain cylindrical grinders?**

   Two distinct types of grinding operation done on this type of grinder are (a) traverse grinding and (b) plunge grinding.

9. **State the classification of polymers**

   Polymers may be (a) natural polymers or (b) synthetic organic polymers.

   a) Natural polymers: These are prepared from natural organic materials, from animals and vegetable products.

   (b) Synthetic organic polymers: The polymers (or plastics) which do not occur in nature and are prepared artificially are called synthetic plastics (or synthetic polymers).

10. What is screw plastication?

The process of taking raw solid material into the liquid process for molding is known as plastification.

11. a) Classify the various production processes. Briefly explain the factors to be considered in selecting a process for production.

Manufacturing processes are broadly categorized as:

(a) Primary shaping processes
(b) Secondary shaping processes

Primary shaping processes

Primary shaping processes (also known as **basic manufacturing processes**) are probably the oldest manufacturing processes, practised by the craftsmen of older times. These are, however, still very popular and most used processes. Examples are: metal casting processes and hot forming processes or forging. *Primary shaping processes* are those processes which are used to produce or manufacture a product directly to its usable form (without any subsequent finishing or machining), and the products are made usually from those materials which are available in raw form, such as pig iron ingots or steel ingots. Primary shaping processes are, therefore, considered cheaper processes. Examples of products made by using primary shaping processes include cast products like cast-iron articles which can be sold directly in the market as cast and without any further processing on them (like machining, shaping or grinding). Other examples are hot-rolled metal products (called **wrought metals**) such as angles, channels, rods, bar stocks, I-sections, etc., which are also used in the market as direct outcome of hot-rolling processes of steel ingots.

Primary shaping processes are further divided as follows:

Primary shaping processes

Liquid state

(a) *Metal casting processes*

- Sand mold casting
- Permanent mold casting
- Shell mold casting
- Investment casting
- Die-casting
- Centrifugal casting
- Continuous casting

(b) *Molding processes*

- Compression molding
- Injection molding
- Transfer molding
- Extruding
- Laminating
- Powder metallurgy processes

Solid state

(*Primary hot forming processes*)

- Forging (hand or press)
- Rolling
- Upsetting
- Extruding
- Die-forging
- Extrusion molding
- Hot rolling and tube forming from solid bar

Secondary shaping processes

Secondary shaping processes (or secondary manufacturing processes) are those processes which are usually carried out on the outcome of primary shaping processes like castings or hot-rolled products, for example, cold working processes carried on the hot-rolled products for drawing them into finished bars for further machining (or wire drawing).

In many cases, products from the primary forming process (casting and hot-rolled products) are required to undergo further refinement in shape and size through various processes of metal removal (or metal cutting or metal machining) such as turning, milling, planing. Some other times, surface finish on the product is an essential requirement for many reasons (fatigue, etc.). Finishing processes such as buffing, lapping, etc. are done for providing surface finish on the product.

Secondary shaping processes are broadly categorized as follows:

Secondary shaping processes

Secondary shaping processes (Solid state)

- Cold-working
- Bending
- Shearing
- Blanking
- Punching
- Rolling
- Cold extrusion
- Impact extrusion
- Coining
- Embossing
- Thread rolling
- Drawing processes
- Stretch forming
- Spinning

Metal removal processes

- Cutting
- Drilling
- Shaping
- Planing
- Turning
- Milling
- Threading
- Grinding
- Unconventional methods of machining

Surface finishing processes

- Buffing
- Honing
- Tumbling
- Lapping
- Super finishing
- Belt grinding
- Sand blasting

11. b) List and explain different steps in casting process.

The procedure of moulding is explained using the split pattern shown in Fig. 11.8(b). The first step in making a mould is to place the pattern on a *moulding board*, which fits the flasks being used. The drag is placed on the moulding board and one half of the pattern is placed in the drag on the moulding board as illustrated in Fig. 11.8(a). Parting sand is sprinkled over the pattern and the moulding sand is then riddled in to cover the pattern. The sand is pressed around the pattern with fingers and then the drag is completely filled with sand. For small moulds, the sand is firmly packed in the drag by a hand rammer. Mechanical ramming is used for the large moulds and for the faster moulding. The amount of ramming required can be determined only by experience. If the mould is not sufficiently rammed, sand will not hold together when handled or when the molten metal strikes it. On the other hand, if it is rammed too hard, the permeability will reduce and it will not permit the steam and gases to escape when the molten metal enters the mould.

After the ramming has been completed, the excess sand is levelled off with a straight bar called a strike rod and trowels. To facilitate the escaping of gases when the metal is poured, small vent holes are made in the sand, within a fraction of an inch of the pattern, with the help of vent rod.

The lower half of the mould (the drag) is then turned over, upside down. Before turning, a little parting sand is sprinkled over the mould and another moulding board is placed at the top. This board should be moved back and forth several times to ensure an even bearing over the mould. After rolling over the drag, the moulding board is removed exposing the pattern. The surface of the sand is smoothened over with a trowel and covered with a fine coating of dry parting sand.

The cope is placed on the drag as shown in Fig. 11.8(b). The pins on either side hold it in proper position. The second half of the pattern is placed over the first half in proper location with the help of dowel pins. A sprue pin is placed about 20–30 mm away from the pattern at a suitable location. The operations of sand filling, ramming, and venting the cope proceed in the same manner as in the drag.

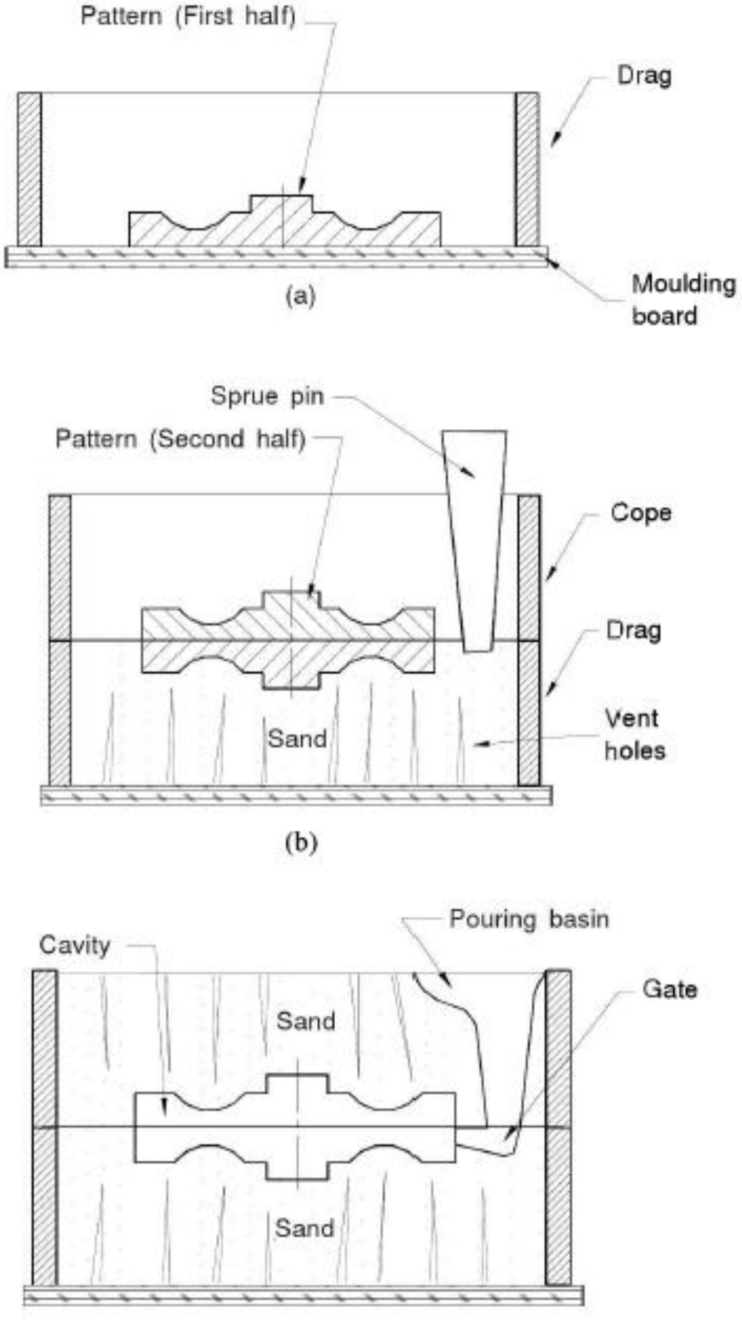


Figure 11.8 Procedure for making a mould.

The next step is to remove the pattern and the sprue pin. The sprue pin is first withdrawn and a funnel shaped opening is scooped out at the top so that there will be a large opening to pour the metal, see Fig. 11.8(c). The cope half of the flask is then carefully lifted off and placed on to one side. Before the pattern is withdrawn, the sand around the edge of the pattern is usually moistened with a *swab* so that the edges of the sand hold firmly together when the pattern is withdrawn. To loosen the pattern from the rammed sand, a draw spike is driven into it and rapped lightly in all directions. The pattern can then be easily withdrawn by lifting the draw spike. Both halves of the pattern from cope and drag are removed in this manner.

Next, a small passage known as the *gate* is cut between the cavity made by the pattern and sprue opening. This passage is shallowest at the mould cavity, so that after the metal has been poured; the metal in the gate may be broken off close to the casting. More about the gate and gating system will be discussed later in this chapter. The last step is to assemble the mould. The cope is carefully placed back in position above the drag and the mould is closed. The loose sand is blown off before closing the mould. The assembled mould is shown in Fig. 11.8(c).

To compensate for metal shrinkage during solidification, extra molten metal is stored in suitable location of the mould. A hollow is sometimes cut into the cope, which provides a supply of hot metal as the casting cools. This opening is called a *riser*.

12. a) Explain the terms pattern , core, mould and casting in casting process.

Pattern:

A pattern is defined as a model of a casting. Pattern is used to form the mould cavity in which molten metal is poured. A single pattern may be used to make many moulds, and hence, many castings, all of which will be identical. Pattern making involves study of materials used for making patterns, various types of patterns and pattern allowances.

<u>Types of patterns:</u>

- Solid pattern
- Split pattern
- Loose-piece pattern
- Gated pattern.
- Match plate pattern.

<u>Pattern allowances</u>

- Shrinkage allowance
- Machining allowance
- Draft or taper allowance
- Distortion allowance.
- Rapping or shake allowance

Core:

A core may be defined as a sand shape or form, that makes the contour of a casting for which no provision has been made in the pattern. Core of the desired shape is generally produced separate from the sand mould. It is baked to make it strong and facilitate handling during setting into the mould. Cores are placed in the moulds in specially created cavities called core prints. Cores may be made from sand, metal, plaster or ceramics.

Mould:

The cavity, made in a suitable refractory material that can withstand the high temperature of the molten metal, into which molten metal can be poured, is known as *mould.*

Casting:

Casting may be defined as a metal object obtained by pouring molten metal into a mould and allowing it to solidify.

12. b) list advantages and limitations of casting in casting process

Advantages

1. There is no restriction on the type of metal or alloy for the casting process. In other processes, like forging, only a ductile material can be shaped and a brittle metal like cast iron cannot be forged or hard materials cannot be machined.
2. There is no restriction on the size of the component for the casting. Products weighing from few grams to many tons can be produced by the casting process. There are severe problems in manufacturing larger parts by the forming or machining processes.
3. Casting process is economically suitable for both the small quantity job productions as well as for the mass production.

Disadvantages

1. Casting is a very high energy consuming process. For example, about 2000 kWh of power is required to produce a ton of finished steel castings.
2. Casting process is a highly labour-intensive compared to the other processes.
3. The quantum of raw materials required for producing castings is quite high, and needs large buildings, handling systems, large space, and inventory costs. For example, for producing one ton of steel castings about 2.2 tons of metal, 0.3 ton of parting sand, and 4 tons of moulding sand are needed apart from fuel and many other materials.
4. Time involved for manufacturing is more when compared to the machining processes.
5. The environmental pollution is high.

UNIT 2

13. a) Discuss the factors affecting weldability of metals.

Weldability denotes the relative ease of producing a weld free from defects such as cracks, porosity, non-metallic inclusion, etc. Weldability depends on one or more of the following factors:

(i) **Melting point:** When welding low-melting point alloys (e.g. aluminium alloys), care is to be taken to avoid melting too much base metal.

(ii) **Thermal conductivity:** Alloys with higher thermal conductivity are difficult to bring to fusion point and hence need more heat to be applied, for example, aluminium has much higher thermal conductivity as compared to steel and for a given size needs heat up to three times as much heat per unit volume as does steel.

(iii) **Thermal expansion:** Rapid cooling of alloys with high thermal coefficient of expansion results large residual stresses and excessive distortion.

(iv) **Surface condition:** Surface having coating of oil, dirt, oxides or paint hinders fusion and results in porosity.

(v) **Change in microstructure:** Not only are the steels above 0.4% carbon subjected to grain growth in the heat-affected zone (HAZ) but martensite is also formed whenever the temperature exceeds 723°C for a sufficient time.

13. b) Explain the parameters affecting the (HAZ)-Heat Affected Zone.

Heat-affected zone (HAZ)

Heat-affected zone (HAZ) is adjacent to weld zone. This zone comprises only the base metal that did not melt but was heated to very high temperature for a sufficient period to allow grain growth in the zone. The microstructure and mechanical properties of the base metal in HAZ have been affected and altered as a result of welding heat. The thermal cycle of HAZ is complex as it is subjected to sudden heating and rapid cooling. Because of this temperature variation and method of cooling the weld, HAZ consists of a variety of microstructures, for example, in plain carbon steels, the structures may vary from small region of martensite to coarse pearlite and hence make HAZ the weakest area in a weld.

The width of HAZ depends on the process of welding, for example, in arc welding, HAZ width is smaller (only a few mm from fusion boundary, the external boundary of melt zone), whereas in gas welding, HAZ is wider and so also in electroslag weld. This is because that in two later cases, base metal was heated more and for a longer period.

In a low carbon steel specimen, welded in one run by arc welding, there may be three distinct regions in HAZ: (i) grain growth region, (ii) grain refinement region and (iii) transition region (Figs. 7.80 and 7.81). The **grain growth region** is immediately next to fusion zone and in this, the metal has been heated to a temperature well above the upper critical temperature A_{C3} resulting into coarsening of grains or grain growth. Grain size and extent of grain growth depend on the cooling rate. Slower the cooling, more the grain growth. There will be a large region of pearlite and smaller grains of ferrite. In grain refined region, which is next to grain growth region while moving towards lower temperature zones, the base metal is heated to just above the upper critical (A_{C3}) temperature where grain refinement takes place and finest grain structure exists with finer areas of both ferrite (white) and pearlite (dark). In the transition region, a temperature range between (A_{C1}) and upper critical temperature (A_{C3}) exists when partial allotropic recrystallization takes place which makes pearlite grains still more finer. Beyond this zone (which is the last zone of HAZ) exists the unaffected base metal.

14. Explain the principle of resistance welding with neat sketch.

15.6 Resistance Welding

All of us know that when electric current flows through a wire, it generates heat due to the resistance offered by the metal of the wire to the flow of electrons. In *resistance welding*, the heat required for welding is produced by means of the electrical resistance between the two members to be joined. This process is also known as *electric welding*.

The heat generated in resistance welding is given by

$$H = I^2Rtk \tag{15.1}$$

where

H = heat generated, in joules (watt sec)
I = current in amperes
R = resistance in ohms
t = time of current flow in seconds
k = constant to account for losses due to radiation and conduction.

The value of k is normally less than one.

There are five basic methods of resistance welding, viz.

1. Spot welding
2. Seam welding
3. Projection welding
4. Flash welding
5. Upset welding.

In this text, we limit our discussion to the first two methods of resistance welding.

15.6.1 Spot welding

Spot welding is the simplest and most commonly used resistance welding process, mostly used to weld sheets. The process is shown in Fig. 15.11. In the resistance welding, the tips of the two solid cylindrical electrodes are placed on either side of the lap joint of two sheet-metals, and a high current is passed across the point of contact. The heat generated at the point of contact will melt the metals locally at the point of contact. After the current is switched off, the melt is allowed to solidify forming the joint, which creates a small circular weld. The strength of the joint obtained depends on roughness and cleanliness of surfaces to be welded. Hence, the surfaces to be welded must be cleaned thoroughly prior to welding.

15.6.2 Seam welding

In *seam welding,* the cylindrical electrodes of spot welding are replaced by electrode wheels. The process is shown in Fig. 15.12(a). The metals to be welded are drawn between the rollers. With a continuous a.c.

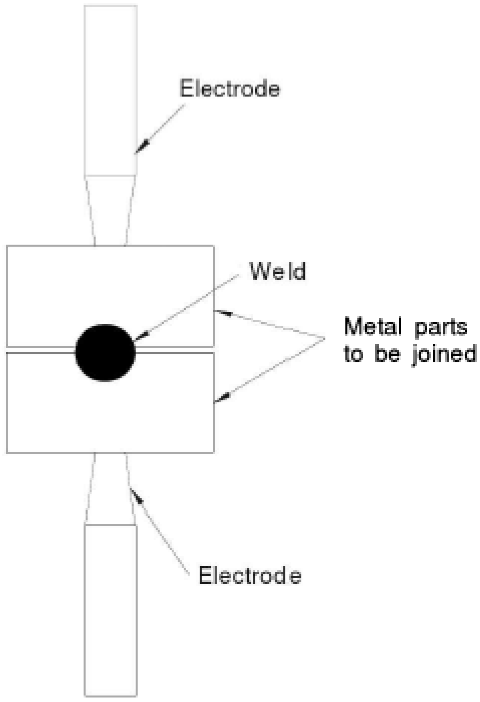


Figure 15.11 Spot welding process.

power supply, the electrically conducting electrode wheels produce continuous weld in two parts whenever the current reaches sufficiently high level in the a.c. cycle, resulting spot welds at regular intervals as illustrated in Fig. 15.12(b).

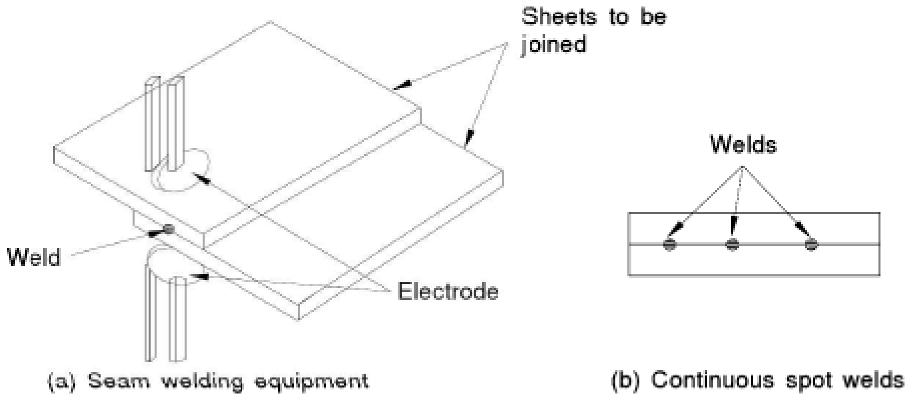


Figure 15.12 Seam welding process.

2.4.2 Butt welding

It is a type of resistance welding. There are two types of butt welding. They are upset butt welding and flash butt welding.

1) Upset butt welding

In this method, the metals to be welded are clamped in copper jaws so that there is a light contact at the ends of metals. When the current is passed through the jaws, high resistance is developed at the contact. This produces high heat and the ends of metal becomes plastic stage. When pressure is given by moving the jaws, the ends of metals are upset and strong weld is formed.

Application

Bar, rod, wire, tube and pipe can be welded by this method.

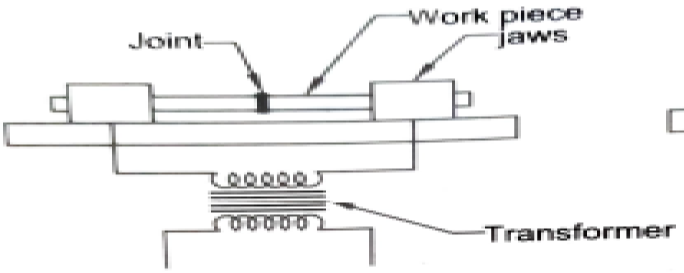


Fig.2.10 Upset butt welding

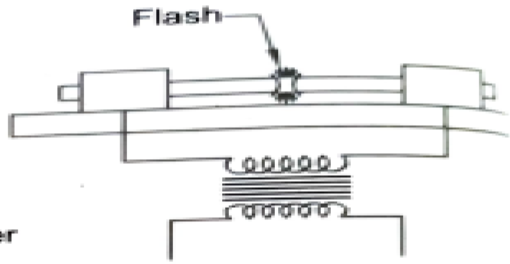


Fig.2.11 Flash butt welding

2) Flash butt welding

In this method, the metals to be wellded are clamped in jaws so that there is a small air gap between the ends of metals. When the current is passed through the jaws, a flash or arc is produced between the ends. The ends become plastic state due to the temperature of arc. When pressure is given by moving the jaws, the ends of metals are joined and strong weld is formed. There is no welding rod, gas or flux is needed for this welding.

Application

Flash butt welding is used for welding automobile body, axles and frames.

Advantages

1) It is a fast process.
2) The cost is less.
3) Different metals can be welded.

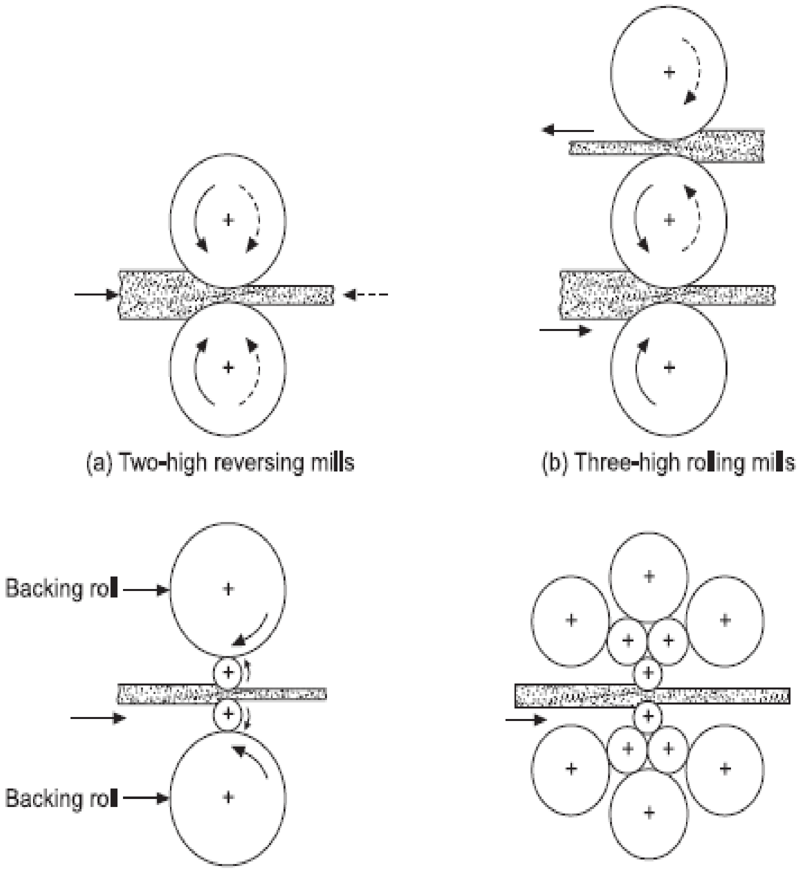
UNIT 3

15. a) what is roll separating force? Explain clearly its influence on metal working process.

The following types of hot rolling mills are in common use with industry.

(i) Two-high reversing mills
(ii) Three-high rolling mills
(iii) Four-high rolling mills
(iv) Cluster mills (sendzimir or *z*-mill)
(v) Continuous rolling mills (or tandem rolling mills)
(vi) Planetary rolling mills

1. **Two-high reversing mills:** Two-high rolling mills [Fig. 9.7(a)] also called *cogging mills*, are often used for hot rolling in initial breakdown passes (primary roughing) on cast ingots or continuous castings. These comprise two big rollers (diameter ranging from 0.6 metre to 1.4 metres) arranged one above the other and rotating in opposite directions. The direction of rotation of the rolls can be reversed. The position of lower roller may be fixed and the upper



(a) Two-high reversing mills (b) Three-high rolling mills

(c) Four-high rolling mills (d) Cluster mills

Fig. 9.7 Typical arrangement of rolls for various rolling mills.

roller can be raised up or lowered down to adjust the gap between the two rollers to accommodate the slabs of varying thickness during rolling. In operation, when the full length of metal has been passed through the rolls, they are stopped and reversed in direction and the operation of rolling is repeated. The metal ingot is rotated about its long axis by 90° at frequent intervals with the help of manipulators, to have uniform cross-section of rolled metal and also refinement of grains throughout the ingot by bringing all the four sides of the ingot in contact with rolls. Several repeated passes are needed to reduce the ingot into a bloom of smaller size as the mill provides a wide range of adjustments for the size of product and the rate of reduction. Various reductions in the cross-sectional area of the metal are obtained by using grooved rolls (both upper and lower) of different size grooves [Fig. 9.10(c)].

2. **Three-high rolling mills:** These consist of three rolls mounted one above the other as shown in Fig. 9.7(b). This arrangement eliminates the need for reversing the rolls as in case of two-high reversing mills. The top and bottom rolls revolve in the same direction whereas the intermediate roll revolves in opposite direction. Less power is needed in these mills but these are not as flexible in taking up large variety of jobs as the two-high reversing mills. In the three-high rolling mills, the direction of movement of the metal is reversed after each pass; the metal being rolled is first raised to the upper roll-gap, rolled and then lowered to the lower roll-gap and rolled (by moving the metal in opposite direction to the first rolling). All these operations are conducted using various types of elevators and manipulators. These mills are very common for rolling structural steels such as I-beam, channels and angles.

3. **Four-high rolling mills:** Four-high rolling mills use small diameter rolls [Fig. 9.7(c)] to lower the roller forces and power requirement with reduced 'spreading' [Fig. 9.3(a)]. The replacement of rollers (after being worn out) is less costly than replacing larger diameter rolls. Since small rolls deflect more under roll forces, these are supported by backing rolls. Four-high mills are commonly used for both hot and cold rolling of plates and sheets. Slabs from slabbing mills are usually sent to four-high mills for subsequent rolling them into sheets or plates.

4. **Cluster mills (sendzimir or z-mill):** A cluster mill consists of two working rolls of smaller diameter which are backed by four or more back-up rolls of larger diameter [Fig. 9.7(d)]. The sendzimir mill facility is extremely costly and is mostly used for cold rolling of thin sheets of high-strength metals. Common rolled widths are between 0.66 and 1.5 metres.

5. **Continuous rolling mills (or tandem rolling):** A continuous or tandem rolling mill consists of a number of stands of rolling mills arranged one after the other such that the metal strip can be passed continuously during rolling through all of the stands successively, to smaller gages with each pass. As the metal comes out of one set of rolls, it enters the second set of rolls, and then enters the third set of rolls, and so on and until finally it comes out with the reduced section of required shape and size of the final product. The speed of any successive set of rolls is greater than the preceding set of rolls to accommodate the increasing length of the workpiece. Each stand consists of a set of rolls (Fig. 9.8) with its own housing and controls. The control of gauge and of speed of strip is critical and this is managed using electronic and computerized systems with extensive hydraulic controls. A continuous mill is fast and requires minimum floor area and is a mass production mill giving high rate of production.

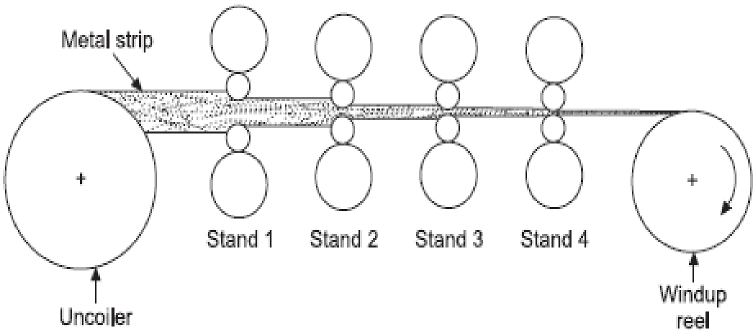


Fig. 9.8 Illustrating the schematic of strip rolling on a four-stand continuous rolling mill.

6. **Planetary rolling mills:** In these mills, small diameter rolls are used for rolling purpose. The rolling force is conveyed more effectively by small diameter rolls because of reduced area of contact of smaller rolls, which produce higher rolling pressures. The planetary rolling mills consist of two heavy and large backing rolls surrounded by small diameter planetary rolls mounted in a cage (Fig. 9.9). The strip to be rolled is fed forward for rolling with the help of serrated feed rolls. Since the upper and lower cages of the planetary rolls are geared together to bring corresponding small upper and lower rolls into contact with the metal strip being rolled in synchronism, each pair of roll thus bites into the red hot metal along the area of contact successively, extending the metal strip into length and reducing in thickness. The planetary rolling mills are capable of bringing thickness reduction to the tune of 25:1 as against 2:1 in conventional rolling mills.

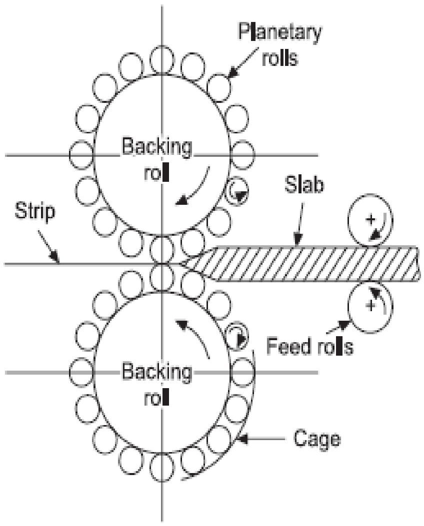


Fig. 9.9 Planetary rolling mill. Note that the small diameter rolls contained in a cage (shown partly) are used for rolling purpose. The chief feature of the planetary mill is that it reduces a hot slab directly to strip in one pass through the mill.

Besides the above types of rolling mills, sometimes rolling mills are called as per the product they make, for example, **blooming mills** which convert hot ingots into blooms; **billet mills** for making billets; **slabing mills**. Blooming mills and slabing mills are also called **primary mills** or **roughing mills** and those used for further rolling are called **secondary mills** or **finishing mills**.

15. b) In rolling a slab from 35 mm to 30mm, calculate the coefficient of friction and the length of arc of contact. Take the value of roll radius as 250mm.

Given data:

$t_o = 35mm$

$t_i = 30mm$

$R = 250mm$

To find

$\mu = ?$

$L_p = ?$

soln:

max. reduction $\Delta t = 35 - 30 = 5mm$

$$\cos\alpha = \left(1 - \frac{\Delta t}{2R}\right)$$

$$= \left(1 - \frac{5}{500}\right)$$

$$\cos\alpha = 0.99$$

Angle of bite $\alpha = 8.11°$.

W.K.T

$$\mu = \tan\alpha = \tan(8.11)$$

$$\boxed{\mu = 0.1425}$$

Length of Projection of arc of Contact $L_p = \sqrt{(R \cdot \Delta t)}$

$$= \sqrt{250 \times 5}$$

$$\boxed{L_p = 35.35mm}$$

16. Compare press forging and Hammer forging.

Comparison of drop forging and press forging

	Drop forging	Press forging
1)	The work piece gets the required shape by impact force.	The work piece gets the required shape by uniform pressure
2)	Power hammer is used.	Power press is used.
3)	Vibration and noise are more.	Vibration and noise are less.
4)	The density of work piece is not uniform.	The density of work piece is uniform.
5)	It is a slow process.	It is a fast process.
6)	Several die sets are required to produce a component with complicated shape.	One die set is sufficient to produce a component with complicated shape.

Unit 4

17. Explain in detail Hybrid Abrasive Machining process.

Abrasive machining or *grinding* is a chip-forming metal cutting operation. Most of us are familiar with the *grinding wheels*, used to sharpen knives and other tools, and sand paper which is used to smoothen surfaces and sharp corners. For grinding, generally, a rotating grinding wheel is used as a tool. The grinding wheel and sand paper consist of bonded abrasives. The abrasive grains have sharp edges that project out and cut the chips. In grinding, the high circumferential speed of the grinding wheel causes high friction and chips become red hot and fly as sparks. The grinding process is shown in Fig. 9.1.

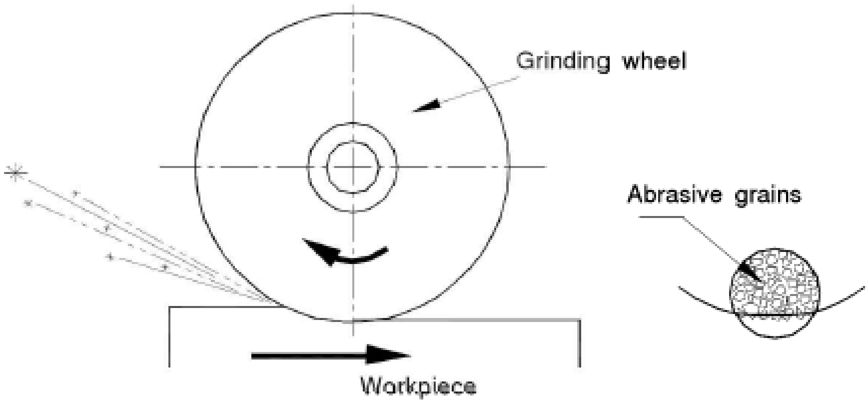


Figure 9.1 The grinding process and an enlarged view of a grinding wheel.

Machine tools used for grinding are called *grinding machines*. In grinding and other abrasive machining processes, a very large number of tiny cutting edges simultaneously cut the surface, each taking a very minute cut. This means that the depth of cut in grinding is very small and, hence, grinding can produce surface finish upto 2 microns and dimensional tolerances as small as 0.0025 mm. Grinding forces are much smaller than the cutting forces involved in the other metal cutting processes.

Grinding is used on the harder materials for machining them and/ or for obtaining better dimensional accuracy. In grinding, the grinding wheel is mounted on a grinding machine and made to rotate at a very high speed. The feed and depth of cut involved in the grinding process are very less. For example, a 300 mm diameter wheel can be rotated at about 2000 rpm with a depth of cut of the order 0.25 – 0.5 mm.

Grinding may be non-precision grinding for machining hard materials or precision grinding for getting close dimensional accuracy, and accordingly the grinding machines are classified as *non-precision* and *precision* grinding machines, respectively. Grinding machines are also *cylindrical* and *surface* grinding machine for grinding cylindrical surfaces and flat surfaces, respectively. Other grinding machines are classified according to their applications.

18. Express centreless grinding process with neat diagram.

Centreless grinding makes it possible to grind both external and internal cylindrical surfaces without the necessity of the workpiece being mounted between centres in a chuck. The principle of centreless external grinding is shown in Fig. 5.14. In centreless

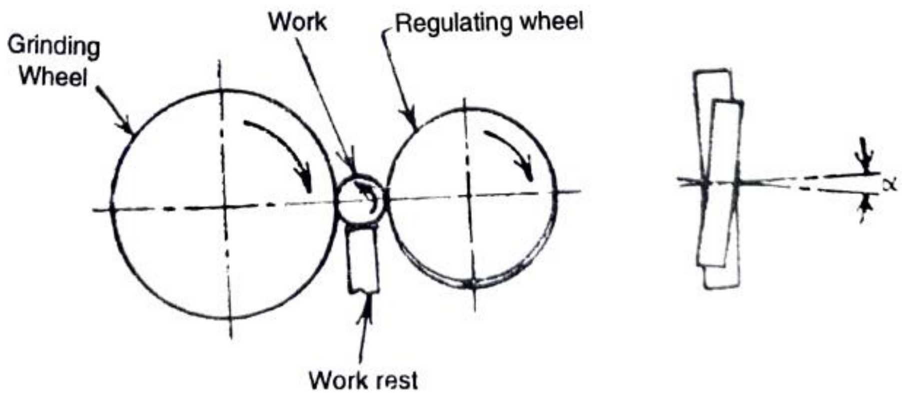


Fig. 5.14

grinding two wheels are used. The larger wheel called grinding wheel operates as regular grinding speeds and does the actual grinding. The small wheel called regulating wheel is mounted at an angle to the plane of grinding wheel. The work with its both ends freely supported on a vee formed by the work rest, rotates between

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the grinding and the regulating wheels. The grinding wheel is driven by an electric motor and rotates at a maximum surface speed of about 1850 metres per minutes. Normally, the regulating wheel speed range may lie within 33 to 130 metres per minute. The regulating wheel does not act as a cutting tool but it is mainly responsible for controlling the speed of rotation and longitudinal motion of the work. The wheels rotate clockwise and the work driven by the regulating wheel and having approximately the same peripheral speed rotates counter-clockwise. Axial traverse of the work is controlled by varying the inclination of the regulating wheel. The axial feed is approximately calculated by the formula :

$$f = \pi DN \sin \alpha.$$

where f = Feed in mm/minute.

D = Diameter of regulating wheel in mm.

N = R.P.M. of regulating wheel.

α = Angle of inclination of the regulating wheel.

Centreless grinding is carried out in three different ways :

(*i*) Through feed grinding.

(*ii*) Infeed grinding.

(*iii*) End feed grinding.

5.13.1. Through feed grinding

Through feed grinding is normally used for grinding plain cylindrical workpieces. In this process the work is automatically fed through continuously between the grinding wheel and the regulating wheel which have already been set with a particular gap. The grinding starts as soon as the work enters the grinding wheels and grinding of work is complete as soon as it comes out of the wheels. Since the work has to remain outside the wheels before and after grinding operation, suitable supports or guides are provided. (Fig. 5.15 *a*).

5.13.2. Infeed centreless grinding

In this process the work rest and the regulating wheel are retracted so that the work can be put in position and removed, when grinding is completed. When the work is in position the regulating wheel is fed inward until the desired diameter is obtained. The work does not move axially as in through feed but is kept supported against an end stop. This arrangement permits multiple diameters and curved parts to be ground (Fig. 5.15 *b*).

5.13.3. End feed centreless grinding

This process is used for grinding taper work. Both the wheels are tapered and thus produce tapered workpieces. In this process the work is feed from one side until it reaches the stop. Fig. 5.15 (*c*) shows the work being ground by the end feed method.

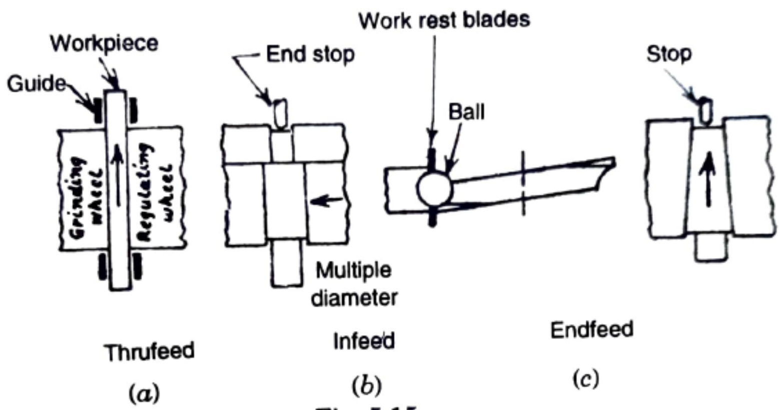


Fig. 5.15

5.13.4. Advantages

Various advantages of centreless grinding are as follows :

(*i*) Work chucking and its centring is not required. This saves setting time. Further errors associated with centering are absent and thus grinding allowance can be reduced.

(*ii*) The work-piece is supported rigidly during the operation and therefore no deflection takes place during grinding. This allows heavier cuts to be taken resulting in economical grinding.

(*iii*) It is very rapid process. Frequently it can be made automatic.

(*iv*) Very little skill is required for the operator.

Unit 5

19. a) What is glass transition temperature in polymers? Explain.

Glass Transition Temperature

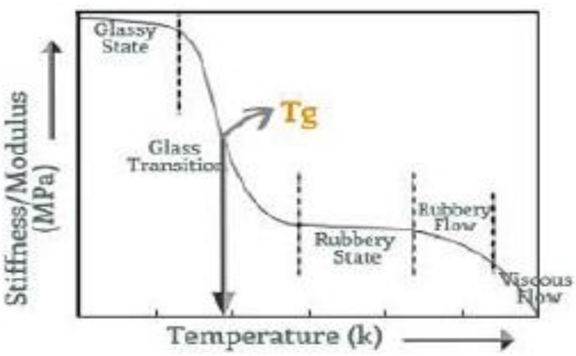
When an amorphous polymer is heated, the temperature at which the polymer structure turns "viscous liquid or rubbery" is called the Glass Transition Temperature, Tg. It is also defined as a temperature at which amorphous polymer takes on characteristic glassy-state properties like brittleness, stiffness and rigidity (upon cooling).

This temperature (measured in °C or °F) depends on the chemical structure of the polymer and can therefore be used to identify polymers.

Amorphous polymers only exhibit a Tg.
Crystalline polymers exhibit a Tm (melt temperature) and typically a Tg since there is usually an amorphous portion as well ("semi"-crystalline).
The value of Tg depends on the mobility of the polymer chain, and for most synthetic polymers lies between 170 K to 500 K.

The transition from the glass to the rubber-like state is an important feature of polymer behavior, marking a region of dramatic changes in the physical properties, such as hardness and elasticity.

At Tg, changes in hardness, volume, percent elongation to break and Young's modulus of solids are mainly seen. Some polymers are used below their Tg (in glassy state) like polystyrene, poly(methyl methacrylate) etc., which are hard and brittle. Their Tgs are higher than room temperature. Some polymers are used above their Tg (in rubbery state), for example, rubber elastomers like polyisoprene, polyisobutylene. They are soft and flexible in nature; their Tgs are less than room temperature.



b) Discuss the creep and stress relaxation phenomena in polymers.

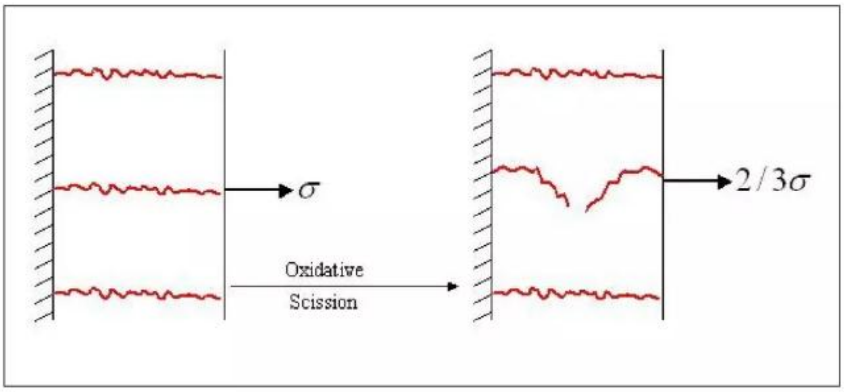
Stress relaxation is a viscoelastic viscoelastic property of an elastomeric material. In a stress relaxation experiment, the sample is rapidly stretched or compressed to a predefined strain and held constant. The stress is then recorded as a function of time. Creep experiments are carried out in a similar manner but instead of the application of a constant strain, a constant stress is applied and the deformations or the resultant strain is studied as a function of time. The stress relaxation modulus may be define as

$$E_{rel.}(t) = \sigma(t)/\varepsilon_0 \tag{1.9}$$

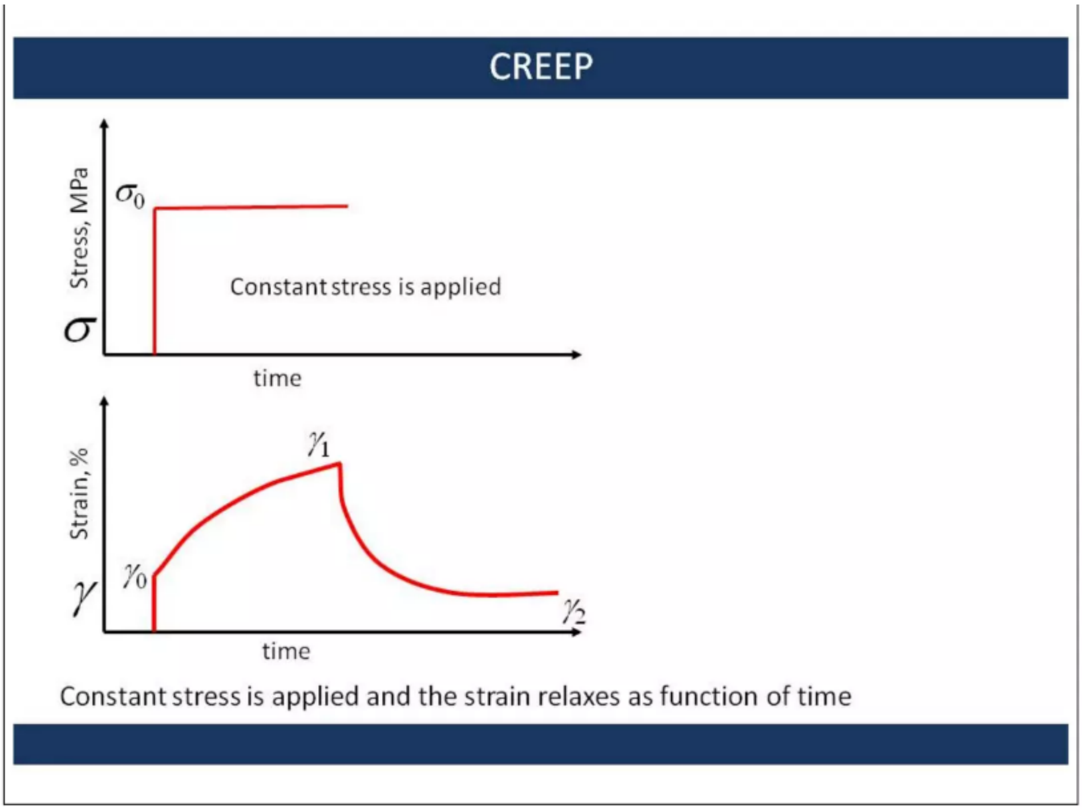
If there is no viscous flow in the material, the stress decays to a finite value for polymeric materials. For amorphous linear polymers at high temperatures, the stress may eventually decay to zero. For a linear viscoelastic solid, the instantaneous stress will be proportional to applied strain and will always decrease with time.

The molecular causes of stress relaxation and creep can be classified to be based on five different processes.

Chain Scission The decrease in the measured stress over time is shown in Figure(1.8) where 3 chains initially bear the load but subsequently one of the chains degrades and breaks.



Creep is an increase in plastic strain under constant stress. Creep is an increased tendency of a solid material to move slowly or deform continuously under the influence of mechanical stresses. In other words it tendes towards high strain and plastic deformation with no change in stress. Figure (1.10) shows a the stress and strain curves for a part undergoing creep. The material is stressed with an applied force. Creep tends to occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material. Over time, the force and stress do not change, although the shape of the part continuously deforms. When unloaded, there is additional permanent set. Old PVC pipes for electrical installations sag at the center when simply supported at the ends. This is an example of creep under the constant force of gravity. Creep in polymers at low strains (1 percent) is essentially recoverable after unloading.



20. Explain injection blow moulding process.

Blow molding is used extensively for making bottles and other light weight hollow products. The process combines the features of both injection molding and extrusion and accordingly is of two types, (i) Injection blow molding and (ii) Extrusion blow molding. The **injection blow molding** is used for making small bottles or containers. First, a parison or premolded tube is formed by injecting plasticized material through a hollow walled mandrel [Fig. 12.10(i)]. While the material is still in molten state and still attached with the inside of mandrel, it is transferred into a closed blowing mold [shown at (ii)] where air is blown through the mandrel to inflate the nearly molten parison into the form of a bottle [as shown at (iii)].

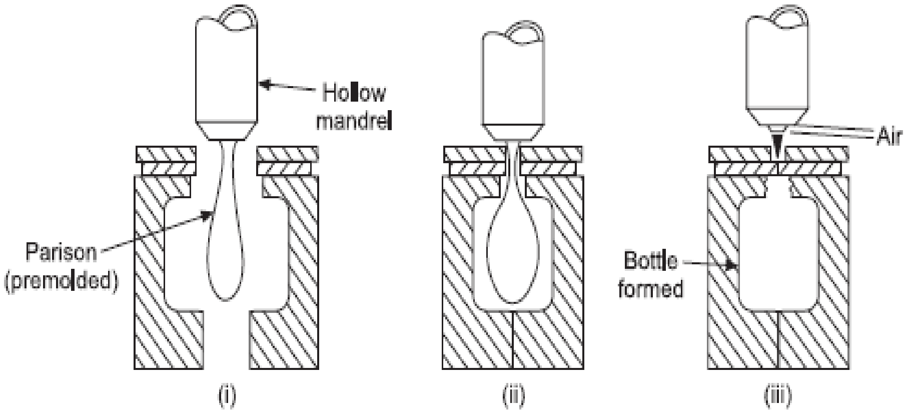


Fig. 12.10 Illustrating the principle of injection blow molding of tubes or small bottles (capacity 224 gm). The parison or tube is first formed by injecting molten plastic material through the hollow mandrel, shown at (i). While the material is still molten and still on the inside of mandrel, it is transferred into the closed blowing mold when air is used to inflate it, as shown at (ii) and (iii). It is possible to form accurate threads on the neck of the bottle thus blown.

In the **extrusion blow molding process**, a molten plastic pipe is first extruded inside a split mold (with mold open) and the mold is closed pinching the ends of the extruded pipe. This pipe is later blown or inflated by air pressure until the plastics contact the cold walls of the mold where it gets solidified into the form of a bottle or some other shape.