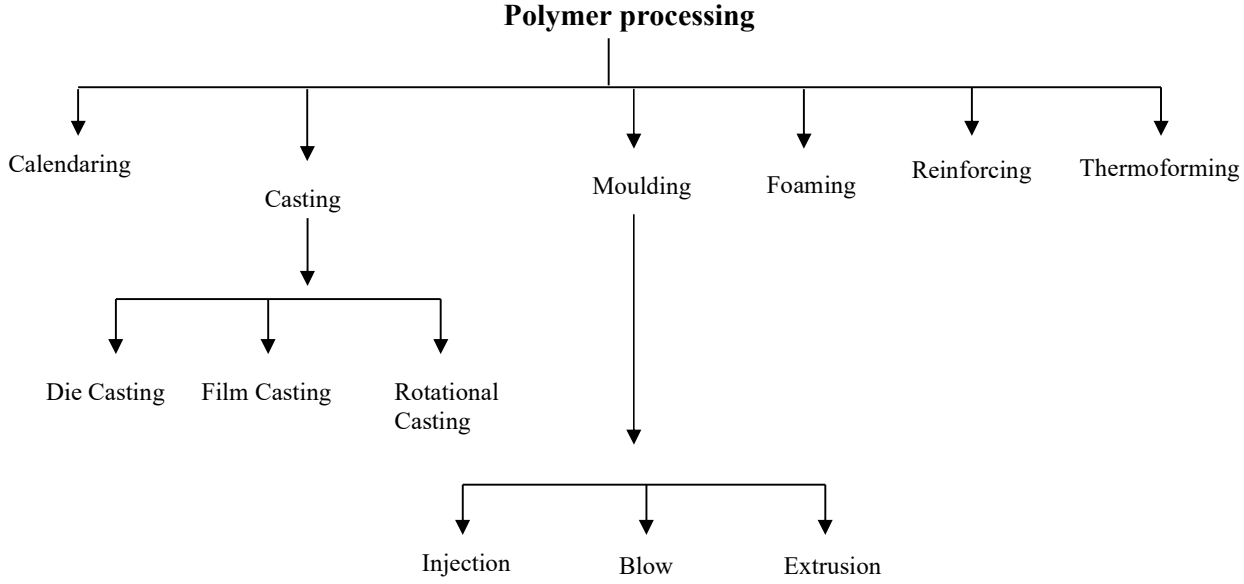
Polymer Processing

We know that polymeric materials are used in many forms such as, tubes, rods, films, sheets, foams, coatings, adhesives, moulded and fabricated articles etc. A majority of articles are either moulded or fabricated. Some others are made by casting liquid pre-polymers into a moulded and allow them to cure or crass linking. As per application of the polymeric materials, they are converted into required shape and size by applying different processes. Thus, the polymer processing is a technique to convert polymer into a broad spectrum of useful shapes and structures. In other words, it is an engineering especially used to convert polymeric materials into useful end products. Fibres are made by the process known as spinning.

The different techniques used in the polymer process are described below:



Calendaring

The calendaring process is employed to produce continuous films and sheets. The main part of a calendaring machine contains:

- A set of highly polished metal rollers rotating in opposite directions with provision for precise adjustment of the gap between them.
- Gide roller through which calendared sheet is passed to form the wind-up roll.

The calendaring machine is represented in the following figure:

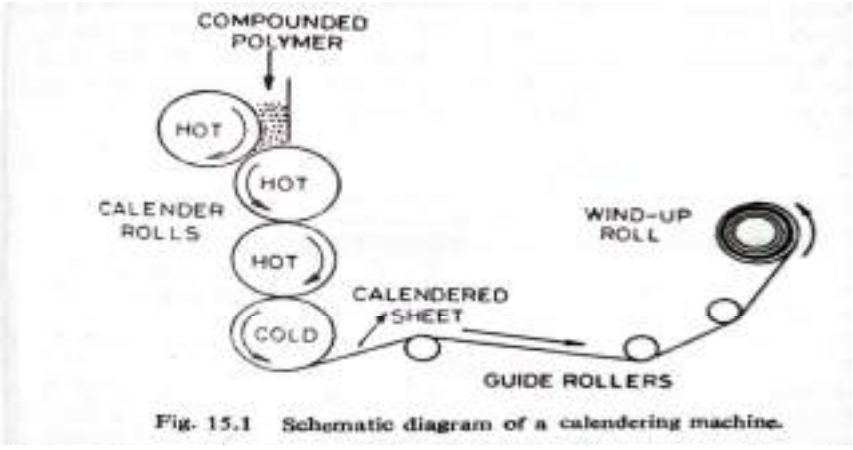


Fig. 15.1 Schematic diagram of a calendering machine.

The gap between the rollers determines the thickness of the sheet that calendared out. The compounded polymeric material is fed between the rollers which are maintained at an elevated temperature. The sheet emerging from rollers is cooled by passing through the cold rollers. The sheets are finally wound up in rolls.

If thin films are required instead of sheets, a series of rollers with a successive fine gap between them is employed. The embossed sheets of a suitable design are produced by using suitable engraved embossing roller in the calendaring machine. The decorative effects can be achieved by feeding the calendar with mixture of compounded materials of different colours. The marbleisation technique is usually employed in the production of vinyl floor tiles made by PVC. The polymers which are mainly calendared into sheet are; PVC, polyethylene, acrylonitrile-butadiene-styrene (ABS) and rubber

Casting

Casting is the process in which liquid polymeric material is poured into mould. The mould contains a hollow cavity of the desired shape and size. The moulded material is allowed to cool to make the solid. This solidified part is known as casting which is ejected out of the mould to complete the process. Mainly three types of casting techniques are known:

1. Die casting
2. Rotational casting
3. Film casting

1. Die casting: Die casting is usually low cost process in which liquid pre-polymer is converted into objects of desire shape and size. Sheets. Tubes, rods of limited length can be produced by this method.

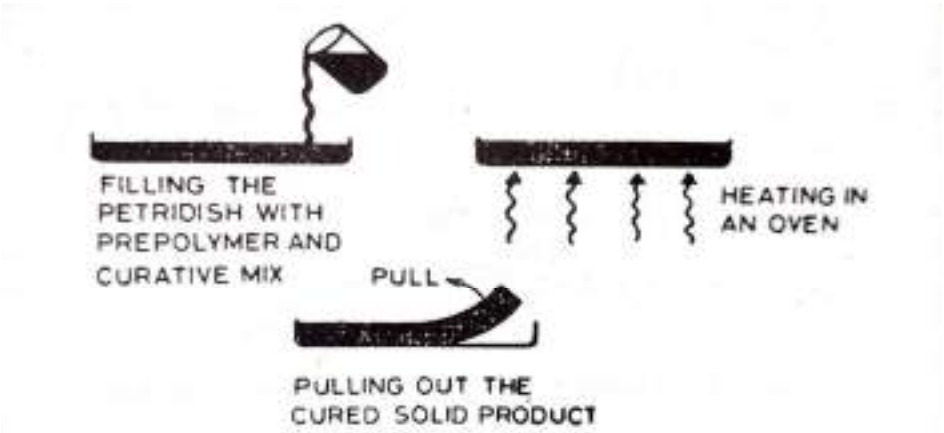


Fig. 15.2 Simple illustration demonstrating the casting process.

The pre-polymer compounded material with a creative and other ingredient are poured into a petridish. The petridish is then kept into oven at an elevated temperature to cure the polymeric material. On cooling at room temperature, the solid product from the petridish is pulled out. The solid thus, has the shape identical to the interior of the petridish. For the product in cylindrical shape, we use cylindrical die.

Polymerization is allowed to continue inside the die till the solid product is formed. Acrylics, epoxies, polyester and polyurethanes are suitable polymeric material for die

casting. Depending upon the convenience and availability, the die for casting are made of plaster of peris, lead or glass.

2. **Rotational casting:** Rotational casting is used to produce hallow articles such as ball, dolls and rain boots. The apparatus used in this process is shown below:

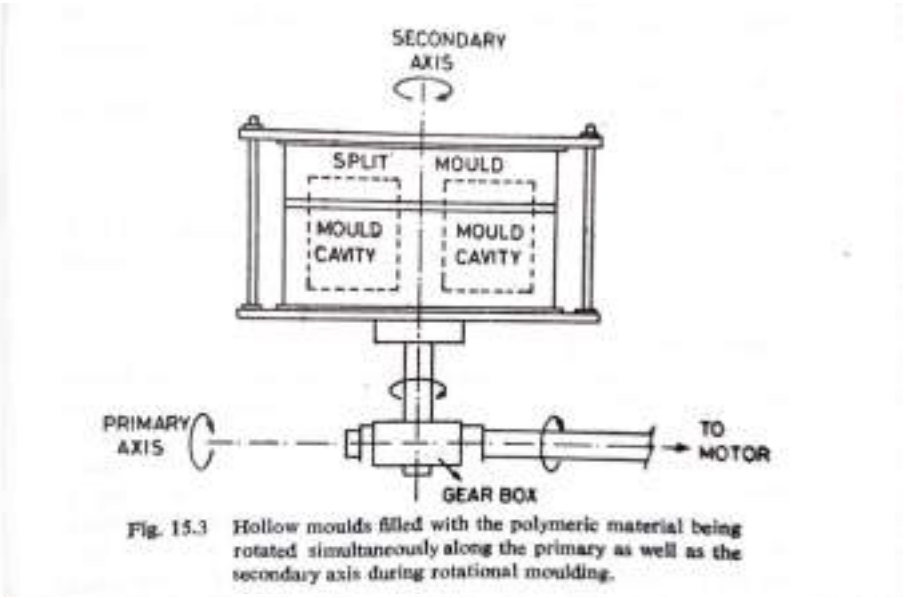


Fig. 15.3 Hollow moulds filled with the polymeric material being rotated simultaneously along the primary as well as the secondary axis during rotational moulding.

The compounded thermoplastic materials in the form of a fine powder is taken in the hallow mould. There is a provision to rotate the mould simultaneously along the primary and secondary axis. After casting the mould, it is heated and rotated. This process distributes the molten plastic uniformly along the entire surface of the inside cavity of the mould. After some times, the mould is chilled with cold water under rotation. Thus, the plastic material inside the cavity cools down and solidifies in the shape of that surface. The mould now opens and product is removed.

Instead of thermoplastic materials, a thermosetting type polymer and creative mixture can also be used and curing done under rotation at an elevated temperature.

3. Film casting:

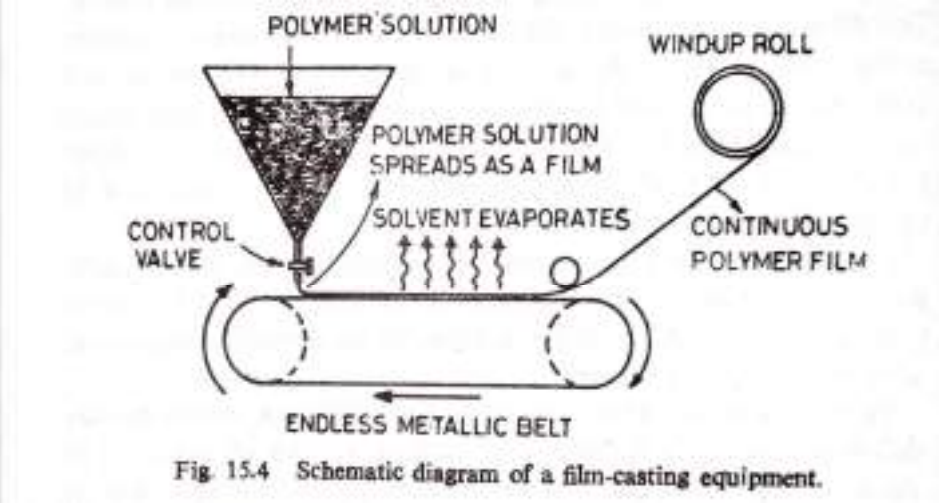


Fig. 15.4 Schematic diagram of a film-casting equipment.

With help of film casting, a polymer sheet is produced. In the process, the polymer solution in an appropriate concentration in a suitable solvent is allowed to fall at a certain rate on an endless metallic belt at a constant speed. Thus, the polymeric solution is spread over the metallic belt in the form of sheet. At the metallic belt, the solvent undergoes evaporation and polymer is converted into hard sheet.

Compression Moulding: The compression-moulding process is very widely used to produce articles from thermosetting materials. The mould is made of two halves-the upper

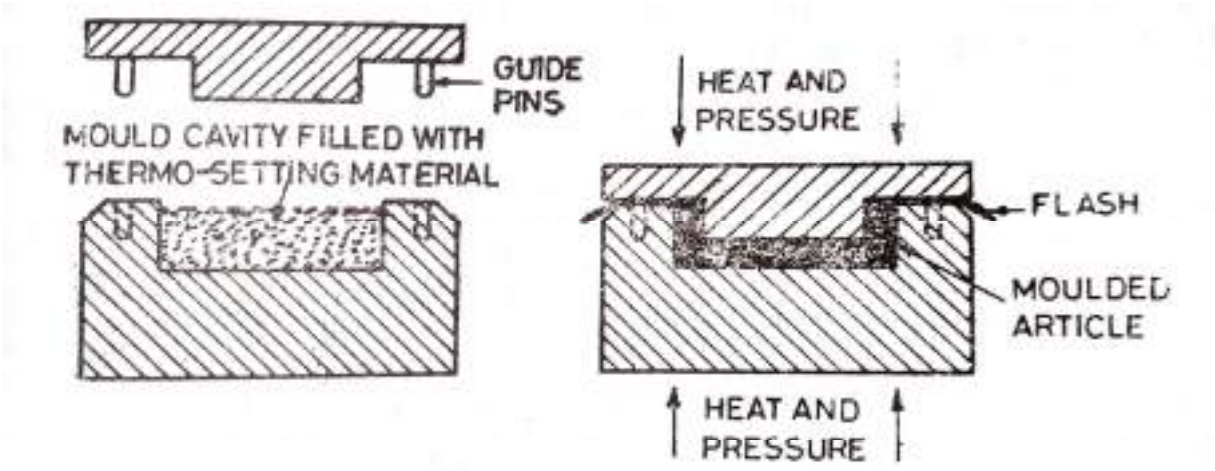


Fig. 15.5 Schematic diagram of a mould employed for compression moulding.

and the lower halves or the male and the female the half usually contains a cavity and the upper half has a projection which fits into the cavity when the mould is closed. The gap between the projected upper half and the cavity in the lower one gives the shape of the moulded article.

In compression moulding, the thermosetting material is subjected to heat and pressure in a single stroke. Moulding temperature and pressure can be as high as 200°C and 70 kg/cm^2, respectively. The actual temperature and pressure depends on the rheological, thermal and other properties of the plastic material to be moulded.

Injection Moulding: Injection moulding process is best suited for producing articles made of thermoplastic materials.

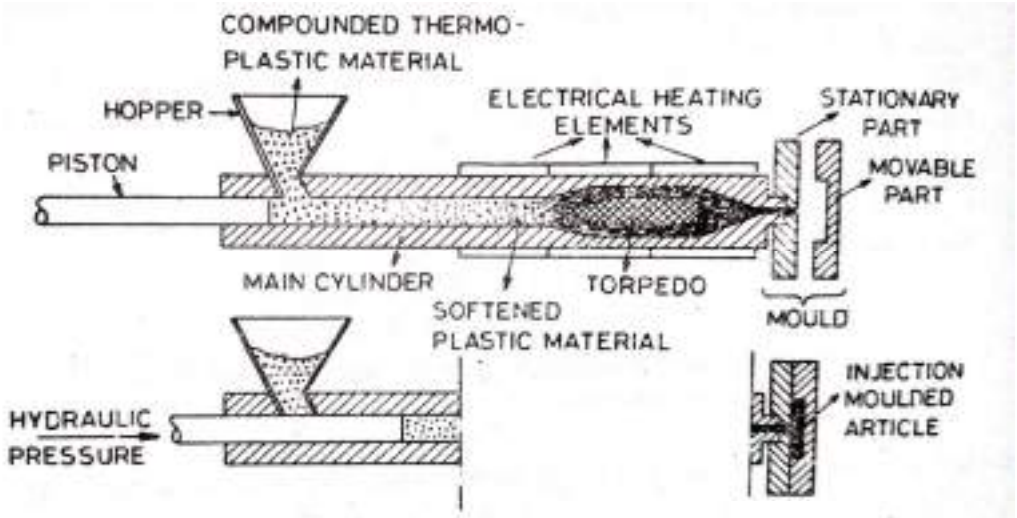


Fig. 15.6 Schematic diagram of an injection-moulding machine

In this moulding process, a definite quantity of molten thermoplastic material is injected under pressure into a relatively cold mould where it solidifies into the shape of mould. The process is feeding of compounded plastic materials in the form of granules, pellets or powder through hopper at a definite time intervals into net horizontal cylinder where it gets softened. Pressure is applied through a driven piston to push the molten material into the mould.

The hot zone of the cylinder called torpedo helps to spread the plastic material uniformly around the inside wall of the hot cylinder. The molten plastic material from the cylinder is injected through a nozzle into the mould cavity. The mould used has two parts; one is movable and other is fixed. The fixed part is located at the end of the cylinder and movable part is opened or locked on the fixed part. Now, the material is injected with help of a piston at the pressure about 1500 Kg/cm^2. After the mould is filled with the molten material under pressure, it is cooled by cold water circulation and then opened to take out the moulded articles.

Blow Moulding: Blow moulding is used to produce hallow plastic articles such as, containers, soft drinks bottles, water tank etc. Thermoplastic materials like polyethylene, polycarbonate, PVC, polystyrene, nylon, acrylics, acrylonitrile, and polypropylene can be moulded by this process.

Blow moulding basically belongs to the glass industry. A hot, softened thermoplastic tube, usually called **parison** is properly placed inside a two-piece hallow mould. The process is given in the figure below.When the two halves of the mould are closed, it pinches and closes one end of the parison and encloses a blowing pin at the other end. The parison is now blown by blowing compressed air through the blowing pin. The hot parison is inflated like a balloon and goes on expanding until it comes in intimate contact with the relatively cold interior surface of the hollow mould. The mould is allowed to cool and the rigid thermoplastic article formed is removed by opening the mould. The parison needed for blow moulding can be made either by injection or extrusion process and the technique can accordingly be called injection or extrusion blow moulding.

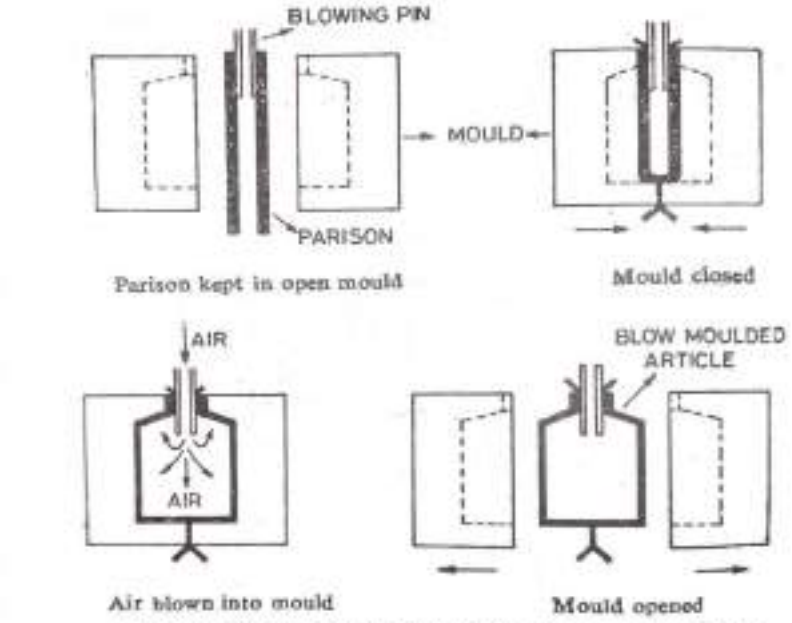


Fig. 15.8 Schematic diagram explaining the steps involved in blow-moulding process.

Extrusion Moulding:

It is one of the cheapest methods for producing many common plastic products of

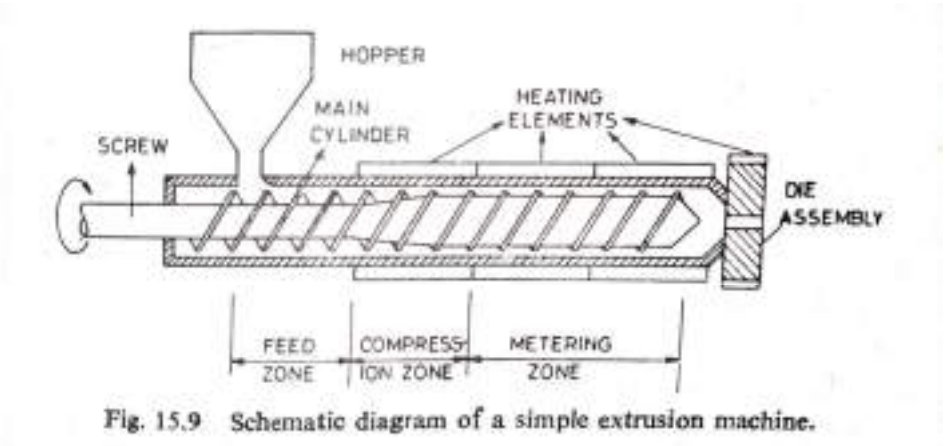


Fig. 15.9 Schematic diagram of a simple extrusion machine.

continuous lengths, such as films, filaments, tubes, sheets, pipes, rods, hoses and straps. A suitable die is used to obtain continuous extrusion. The molten plastic under suitable

conditions is forced through the die. A simple extrusion machine is illustrated in the figure above.

In the machine, the compounded plastic material is fed through the hopper as either powder or granules into a cylinder having provision for electrical heating for softening the material. The hot plastic is further pass through the cylinder by a helically flighted revolving screw. During its journey from the hopper to the die, the plastic material passes through distinct zones named feed zone, compression zone and metering zone.

Each zone contributes in its own way to the overall extrusion process. For example, the feed zone receives the charge from the popper and sends it over to the compression zone. No heating takes place in the feed zone. However, in the compression zone, the powdered charge melts due to heat conducted from the heating elements and is compressed by the working of the screw. The molten plastic material is then sent to the metering section, where it acquires a constant f low rate. The pressure built in this section enables the polymer melt to enter the die. For highly viscous material, one more zone is required that is called working zone. For cooling process, cold air blast and cold water spray are used. The product formed is cut to the desired length or wound on to rolls.

The extrusion process is also used for coating wires and cables with PVC ro rubber and for coating roll formed metal strips with suitable thermoplastics.

Thermoforming:

Thermoforming is a highly useful process for fabricating three dimensional articles from plastic sheets. Even some large products, such as submarine hulls are made of ABS sheets by thermoforming techniques.

In this technique, the thermoplastic sheet is heated to its softening temperature. The warm flexible sheet is then pressed into the female half of a matched metal die duly assisted by the male half. On cooling the shaped article becomes rigid and can be removed from the mould. In modified method, the hot plastic sheet is sucked into the cavity of the female mould under the influence of vacuum to give desired shape. This method is called vacuum forming.

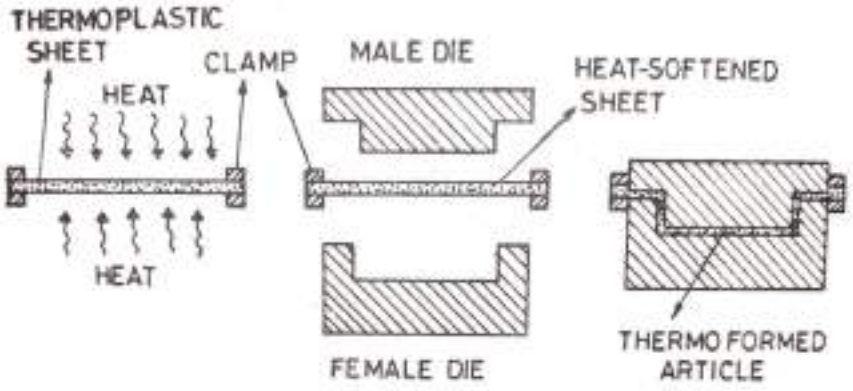


Fig. 15.10. Schematic diagram explaining thermoforming process.

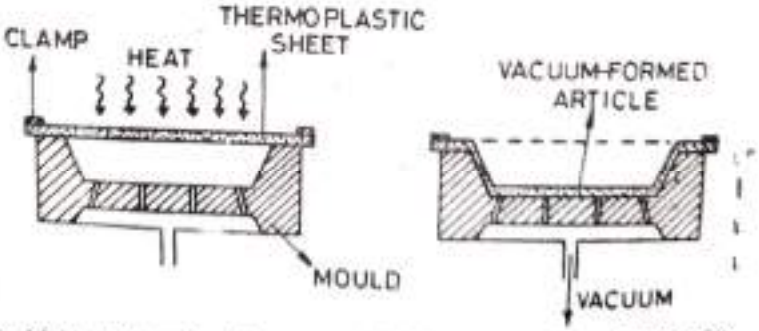


Fig. 15.11. Schematic diagram explaining vacuum-forming process.

Foaming:

It is a creative process for producing expanded or spongy materials. Special properties of these materials like cushioning ability, light weight and low thermal conductivity make them eminently suitable for several applications. The foamable polymers are polyurethanes, polyurethanes, polystyrene, polyethylene, polypropylene, silicones, epoxy and PVC. The foam structure consists either of discrete unit cells or of interconnecting cells.

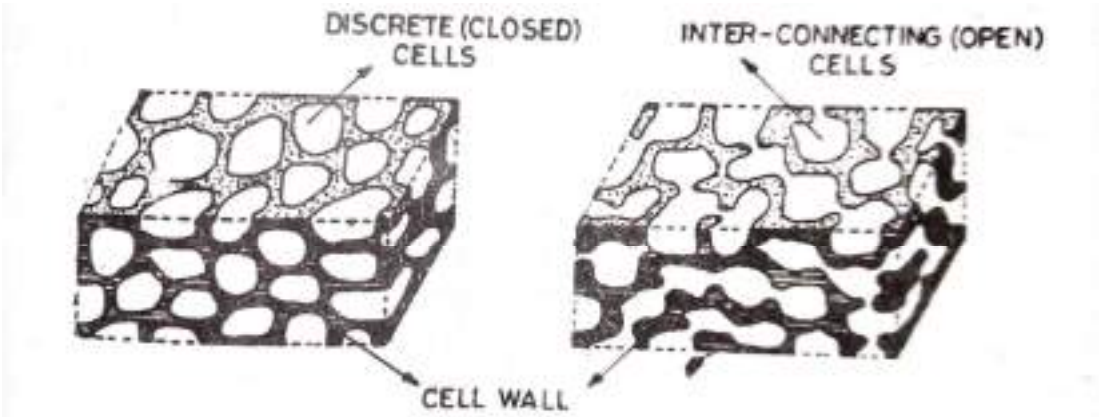


Fig. 15.12 Schematic representation of open type and closed type cell structures formed during foaming process

The discrete unit cells are closed cells and may enclose gases while the inter-connecting cells are of the open type. The open and close type structures are represented below:

There are different methods for producing foamed or cellular plastics. One method is to melt a compounded thermoplastic material and blow air or nitrogen in such a way that the whole matrix foams up. Addition of the surface active agents helps the foaming up process. When the required degree of foaming is achieved in the midst of blowing air or nitrogen, the matrix is cooled to the ambient temperature. In this process, the material is allowed to solidify in the foamed-up condition. Mainly, foaming is achieved by the addition of a foaming agent or blowing agent. Such agents are solvents with a low boiling point or certain chemical compounds. Solvents, such as n-pentane or n-hexane under normal cured temperature of polymeric materials, boil off and liberate large volumes of vapours.

The large volumes of vapours or gases liberated by blowing and foaming agents make the polymer matrix foam up. The polymer matrix in a foamed-up condition is cooled below the softening temperature or made to undergo the cure reaction so that the matrix as a whole in the foamed condition attains structural rigidity to maintain the foam structure. This is called the *stabilisation of foam*. If the polymer matrix is not cooled down to below its softening point or is not sufficiently cross-linked, the gases and vapours may escape out of the system and the foam may collapse. The foamed plastics can be made in flexible, rigid or semi –rigid forms.