

Chapter 4

Plastic Processing and Techniques

4.1 Plastic Processing

Plastics are seldom used in the virgin condition for product manufacture. They are always mixed with different ingredients called processing aids, fillers, and modifiers which improve their properties, processibility and quality.

Environment produces main irreversible changes in the chemical structure and physical properties of the polymers. This leads to change in colour and appearance, degradation of mechanical properties and reduction of useful life. This process is called weathering.

Humidity, radiations, heat, oxygen, ozone and other weather factor are responsible for weathering and ageing in polymer products. Different types of polymer stabilizers are used to prevent photo degradation and oxidation.

4.2 Processing Aids

Important additives used in plastic compounding are:

1. Plasticizers
2. Lubricants
3. Antioxidants
4. UV stabilizers
5. Thermal stabilisers
6. Antistats
7. Coupling agents
8. Colourants
9. Impact modifiers
10. Reinforcements
11. Fillers. etc.

These additives are generally known as processing aids.

4.2.1 Plasticizers

According to IUPAC, a plasticizer is a substance or material incorporated generally in plastics or elastomers to increase its workability, flexibility or distensibility. The plasticizer modifies the rheological properties of high polymeric material by lowering the melt viscosity, T_g (glass transition temperature) or the elastic modulus of the plastic. It is a stable chemical material of low vapour pressure miscible with the polymeric material.

e.g. Dimethyl Phthalate, Diethyl phthalate, Triacetin, Tributyl citrate, Triphenyl phosphate, Dioctyl phthalate, etc.

4.2.2 Classification

There are three classification of plasticizers based on physical properties, and performance characteristics.

Primary Plasticizers and Secondary Plasticizers.

Primary plasticizers are active solvents for resins. i.e there are forces of attraction between plasticizer molecule and resin. By active solvents, we mean a substance what will maintain the dispersion or solution of the resin. This will generally depend on chemical classes and thickness of the specimen. Thus it is difficult to give an exact definition of primary plasticizer.

Secondary plasticizers are non solvents and must always be blended with active plasticisers to give satisfactory performance. Thus butyl, acetyl, resinoleates is a primary plasticizer for nitrocellulose but is only a secondary plasticizer for vinyl chloride.

Simple and Resinous plasticizers

Simple plasticizer are low molecular weight liquids of a low viscosity which can be easily poured. A few simple plasticizer are also crystalline solids like camphor, phenyl phthalates. Resinous plasticizer represent a commercially important class of compound but have small plasticizer market. These are formed by the repetitive reaction of monomeric units like vinyl or epoxy. Some of these plasticizers are fluid. Thus fluid low molecular weight polymers or poly condensate are termed as resinous plasticizer.

Inert and convertible plasticizer

Inert plasticizer do not undergo any change after their incorporation in the plastic composition. A convertible plasticizer reacts to increase the molecular weight during processing. At present, no convertible plasticizers are commercially available.

Action of Plasticiser

A plasticizer is is employed to modify the rheological properties of highly polymeric material. It is a stable chemical material which through its vapour pressure and miscibility with polymeric materials permanently improves the plasticity of the compound. The mixing of a plasticizer with a polymer is like the mixing of two liquids. First of all the plasticizer wets the surface of the polymer and then enters the microscopic cracks. The whole process depends on the actual miscibility of the plasticizer and the polymer. The miscible type of plasticizer forms a plastic- plasticizer-plastic contact.

In simpler terms plasticizer molecules lead to a type of lubrication of the chains comprising polymer structure. Thus plasticizers act as a lubricant between the polymer molecules rendering the flow process easier, decrease the elasticity of the product, increase the extensibility, improve the resistance to impact and reduce the flow temperature.

Mechanism of Plasticizer Action

There are four theories that have been given to account for the effects of plasticizers.

1. Lubricity Theory :- The resistance of a resin to deform is due to inter molecular friction. The plasticizer acts as a lubricant to facilitate the movement of macromolecules over each other and provides internal lubricity. Thus, these lubricants both internal and external, do not allow the resin to melt.
2. Gel Theory :- Plasticizers of different classes are attached to the resin macromolecules by forces of different magnitude but none of them are bound permanently. There is continuous exchange of plasticizer molecules. One plasticizer molecule becomes attached to a given active group only to be replaced by another. This results in a dynamic equilibrium, when a certain fraction of the force centres of the polymer chain are marked by the plasticizer under a given condition of temperature, pressure, concentration etc.Hence there is the formation of an internal 3-D, honeycomb structure or gel.
3. Mechanistic Theory :- Mechanistic theory assumes that solution brings about aggregation of molecules, while dissolution brings about disaggregation of molecules. This constant aggrega-

tion and disaggregation of resin molecules is brought about by the plasticizer. According to mechanistic theory, plasticizer action involves four steps:

- (a) There is rapid intake of plasticizer molecules as they enter the porous areas of the resin and adhere there.
- (b) When absorption takes place, with decrease of in the total volume of resin plasticizer although there is swelling of resin particles.,
- (c) Then diffusion of plasticizer takes place so that polymer molecules disentangle and separate,
- (d) Since plasticizer forms clusters of molecules between bundles of polymer molecules, with supply of energy to the system, the polymer molecules are no longer held tightly but are free to move behaving like rubber.

Thus with the plasticizer molecules penetrating the bundles of resin molecules plasticization becomes complete.

4. Free Volume Theory :- The theory assumes that there is free space between molecules and this free volume increase with increase in temperature and increased molecular motion. The addition of a flexible side chain by end group plasticization increases the free volume. With the addition of small plasticizer molecules the free volume can be increased, freedom of movement is increased and the polymer chain moves more readily at a given temperature.

Properties of Plasticizers

1. Low vapour pressure.
2. Chemical stability.
3. Miscibility with polymers.
4. Insolubility in water or hydrocarbons.
5. Non-toxicity.
6. Non - inflammability.
7. absence of colour.
8. Chemical inertness.
9. Good electrical insulating value.
10. Resistance towards hydrolysis.
11. Thermal stability.
12. Low cost.
13. Commercially easily available.

4.2.3 Fillers

Fillers are most widely used additives in polymer composition. They are used in all plastics, natural and synthetic rubber and in coatings. A filler is an inert material added to a polymer composition to improve its properties and /or to reduce its cost. On being mixed with the resin, it forms a heterogeneous miniature which can be moulded under the influence of heat or pressure or both.

4.2.4 Types of Fillers

There are three different types of fillers.

1. Reinforcing fillers.
2. Active fillers.
3. Inactive fillers.

Reinforcing Fillers

When a polymer is reinforced with high strength fibres, it is known as Fiber Reinforced Plastic (FRP). They have high elastic modulus, high strength to weight ratio, excellent corrosion resistance, and are easy to fabricate.

The main reinforcing fibres are glass, graphite, alumina, carbon, boron and baryta.

Advantages

1. In case glass are used as fillers, gives a product of high elastic modulus and small elongation.
2. Highly oriented organic steel-like fibres give very high strength product.

Disadvantage

There is a problem with shrinkage. During fabrication they undergo decrease in volume and it brings about distortion in the shape of the article and causes internal stresses.

Active Fillers

Fillers that increase the mechanical strength are called active fillers and those that do not are called inactive fillers. The active fillers act more strongly on the synthetic elastomers and rubbers increasing the strength by 10 to 20 times. Below T_g addition of active filler increases the value of forced elasticity, but decreases the brittleness. e.g. carbon black, silica gel, graphite, clay, etc.

Inactive Fillers

These fillers are used to bring down the cost of material as well as improve the finish of the moulded product. They contain wood and other similar materials in different shapes and sizes. They also bring about considerable decrease in volume. Therefore the filler to matrix ratio is very important which can be adjusted by trial and error method.

Inactive fillers may be organic or inorganic, Organic fillers may be further subdivided into natural and synthetic products. e.g. cellulose materials like wood flour, cotton, jute, nylon rayon, silicates, carbonates, inorganic fibres etc.

Classification Based on Type

1. Particulate fillers :- Particulate fillers are divided into two types, inert fillers and reinforcing fillers. The term inert filler is something of a misnomer as many properties may be affected by incorporation of such a filler. For normal uses, such fillers should be quite insoluble in any liquids that the polymer compound is liable to come into contact. Each type of filler may differ in the following ways:
 - (a) Average particle size and size distribution.
 - (b) Particle shape and porosity.
 - (c) Chemical nature of the surface.
 - (d) Impurities such as grit and metal ions.

The common observation is that the finer the particle sizes the higher the values of the tensile strength, modulus and hardness. Coarser particles will tend to give less strong compounds than the virgin material (i.e. material without the filler), but if the particle size is fine there is an enhancement of the mechanical properties and the phenomenon is called as reinforcement.

Impurities in the fillers can have serious effects on the polymer compound. Coarse particles lead to points of weakness in soft polymers and will therefore fail under stresses below that which might be expected. In general, the phenomenon of reinforcement appears to depend on three factors:

- (a) An extensity factor – the total amount of surface area of filler per unit volume in contact with the polymer.
- (b) An intensity factor – the specific activity of the filler – polymer interface causing chemical and/or physical bonding.

(c) Geometrical factors such as structure and porosity of the particles.

2. Rubbery fillers :- Rubbery fillers are often incorporated into rigid thermoplastics to improve their toughness. The increase in toughness of the material leads to significant increase in the fracture resistance of the material.
3. Fibrous fillers :- Fibrous fillers have been long used in plastic materials. Fibrous fillers are often embedded in the laminar form. The fibers have higher modulus than the resins in which they are embedded so that when the composite of resin plus the fiber is strained in the plane of the fibrous layer the bulk of the stress is taken up by the fiber. As a result of this, both the strength and the modulus are enhanced when compared to the unfilled resin

4.2.5 Extenders

Formerly, fillers were used predominantly to cheapen end products, in which case they are called extender fillers or extenders.

The extender fillers primarily occupy space and are mainly used to lower the formulation cost. The role of extender is:

1. Be spherical to permit retention of anisotropic properties.
2. Have an appropriate particle size distribution for particle packing.
3. Cause no chemical reactivity with the polymer or the additives
4. Have low specific gravity.
5. Have desirable refractive index and colour.
6. Be low in cost.

e.g. Calcium carbonate, wood flour, clay, cotton seed hulls, wall nut shell powder, etc.

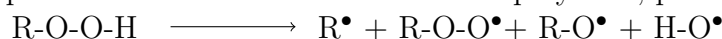
4.2.6 Antioxidants

Antioxidants are added to plastics to protect the polymer from oxidative degradation by atmospheric oxygen. They minimize degradation during processing, storage, and use. There are active materials which get oxidised themselves and protect the polymer from oxidation. Different types of degradative reactions occur in polymer systems. Chemical bonds are broken to form free radicals by heat light and stressors. Atmospheric oxygen easily react at the free radical sites to form peroxides and hydro peroxides. These compounds ultimately decompose by chain cleavage to form hydroxyl and carboxy derivatives. Some antioxidants may combine with oxidising polymer to form stable products, Others may act as free radical scavengers and terminate the propagation of radicals. Aromatic amine, substituted phenols and amino phenols are uses as antioxidants.

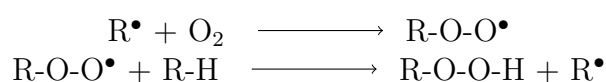
Mechanism of Action

Initiation

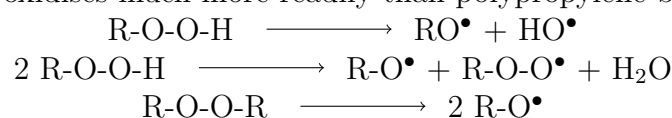
Hydro peroxide present in almost all the commercial polymers, produces free radicals



Propagation



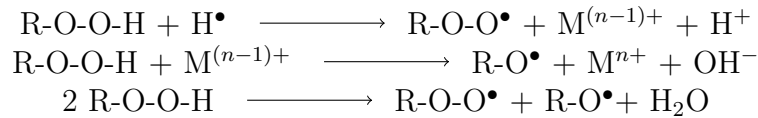
Polybutadiene oxidises much more readily than polypropylene by auto catalysis



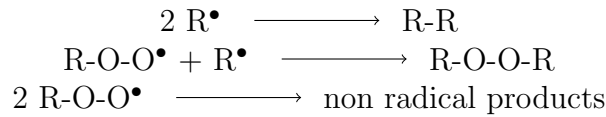
The rate is very slow to start with but increase with time.

Metal catalysed oxidation

Traces of transition metal ions accelerate the rate of oxidation.

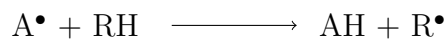


Termination



The antioxidants are hydrogen donating like hindered phenols and secondary aromatic amines.

For high activity of the antioxidant, the phenolic hydroxy groups should be hindered by bulky alkyl groups so that the phenoxy radical is made more incapable to remove a hydrogen atom from the substrate to produce an alkyl radical.



Therefore the oxidation is hampered. Similar is the case with aromatic amines, hindered amines, peroxide decomposers, divalent sulphur compounds, trivalent phosphorous compounds, etc. All these compounds interact with reactive polymer radicals formed by oxygen attack etc. to convert them to stable products. Also the radicals formed from the antioxidant being stabilised by resonance cannot attack a new polymeric chain.

4.2.7 Accelerators

An accelerator is a material that, when mixed with a catalyst or a resin, speeds the chemical reaction between the catalyst and the resin. Therefore, accelerators are not usually employed alone, but they are used within a cure package.

Accelerators are additives that, as the name implies, accelerate or speed up the chemical reaction or the curing of the polymers into the final plastic. Accelerators are also sometimes called promoters. In rubbers, accelerators are used to increase the crosslinking reaction with sulfur in the vulcanization of rubber. e.g. N-(1,1-dimethylethyl)-2-benzothiazolesulfenamide, 2-Mercaptobenzothiazole, Ethylene thiourea, etc.

4.2.8 Colourants

Colourants or pigments are added to plastics to make the product attractive by imparting suitable colour. There are two types of pigments.

1. Reinforcing pigments :- Inert substances which improve the adhesion, impermeability, and physical characteristics of the coating belongs to this category. e.g. talc, asbestos, asbestine, silica flour, clay and mica etc.
2. Inhibitive pigments :- They are used in coatings for atmospheric conditions rather than for immersion, e.g. zinc chromate, barium chromate, lead chromate, red lead, and zinc powder.

Many colourants used in plastics are of organic nature. They can be divided into two categories, namely dye stuff and pigments.

Dye stuffs are soluble in the application medium and are physically absorbed or chemically bound to the substrate. e.g. Toluidine red, phthylcyamine etc. Organic pigments are insoluble in the substrate to be coloured. e.g. Quinacridone, diazo benzimidazole etc.

The most important properties of pigments are :

1. Colour.
2. Bulking value.
3. Hiding Power.

4. Particle size distribution.

Commonly used colourants are:

Colour	Pigments
White	White lead, Titanium dioxide, Zinc dust, Aluminium flakes, stainless steel flakes
Blue	Prussian blue, ultramarine blue, Copper phthalocyanine, cobalt blue
Green	Chromium oxide, paris green(copper acetoarsenite)
Yellow	Chrome yellow, Zinc chrome, Cadmium yellow, Molybdenum orange
Red	Read Lead, Venetian red, Chrome red
Brown	Vandyke brown Prince's metallic brown
Black	Lamp black, carbon black, Ivory black

4.2.9 Lubricants

Lubricants are added to improve flow of the polymeric material during processing by reducing melt viscosity. They help to reduce internal and external friction. Esters, waxes, soaps, long chain alcohols and fatty acids are used as lubricants.

4.2.10 Ultraviolet Stabilisers

Many polymer show sever outdoor failure due to photo oxidation reactions. UV radiations have enough energy to break chemical bonds and oxidise or cross link the polymeric chains to yield low strength brittle materials. This also caused colour changes and reduction of mechanical properties in polymer products. Polymers with tertiary hydrogen are easily degraded by UV light. Thus poly propylene easily undergoes photo degradation and hence always used with a stabiliser.

Ultraviolet stabilisers alone or in combination with UV absorbers inhibit photo degradation process by trapping the free tadical. e.g 2-hydroxy benzophenone, hydroxy benzotriazoles etc.

4.2.11 Antistats

A plastic material on keeping develops static charge on the surface. This charge not only attracts the dust but creates serious problems such as hindrance in production, spark leading to explosion and damage to integrated circuits in electronic controls. Antistats are materials that help to reduce surface charges, Quarternary ammonium salts are used as antistats.

4.2.12 Coupling Agents

Coupling agents are used to improve adhesion between different polymers or polymer and fillers. They are considered as molecular bridges between two substrates. They modify the interface region and improve adhesion, wetting and rheological properties. Organosilanes, titanate, and zirconates are used as coupling agents.

4.2.13 Antimicrobials

They are preservatives incorporated in a polymer to protect it from attack of micro organism which will lead to foul odours, embrittlement and product failure. Phenols and chlorinated phenols are used for this purpose.

4.2.14 Impact Modifiers

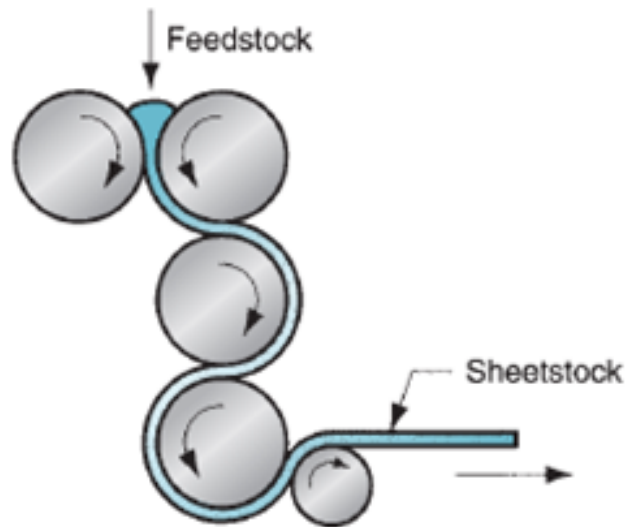
Many plastics are brittle under use at elevated temperatures. Impact modifiers are used to increase the impact resistance of plastics, Many rubbers are used a impact modifies. Styrene is a brittle polymer. Small quantities of poly butadiene is used to improve its impact strength which give high impact polystyrene.

4.3 Calendering

The calendering process is employed to produce continuous films and sheets.

The main part of a calendering machine is a set of highly polished metal rollers rotating in opposite directions with provision for precise adjustment of the gap between them. The gap between the rollers determines the thickness of the sheet calendered out.

Compounded polymeric material is fed between the rollers which are maintained at an elevated temperature and the sheet emerging form the rollers is cooled by passing through cold rollers. The sheers are finally wound up in rolls.



If thin films are required instead of sheets, a series of rollers with a successive diminishing gap between them is employed.

Polyvinyl chloride, polyethylene, acrylonitrile-butadiene-styrene copolymer and rubbers are among the main polymers which are usually calendered into sheets.

By incorporating a suitably engraved embossing roller in the calendering machine, embossed sheets of suitable design could be produced. and also special decorative effects could be achieved.

4.4 Extrusion Moulding

Extrusion is a process in which polymeric materials are mixed, pressurized and pumped through a die to get continuous shapes.

Extrusion is used to process plastics, rubbers and even viscous liquids

Extrusion is considered to be the heart of polymer processing.

Large volumes of thermoplastics and rubbers are processed using extruder.

4.4.1 Extruder - Types

There are two types of Extruders

1. Ram Extruders.

2. Screw Extruders

Ram Extruders

In Ram extruders pressure is applied using a ram

Screw extruders

In screw extruders a screw is used to generate pressure. Screw extruders are simpler and more popular.

Types of Screw extruders

There are different types of screw extruders.

1. Single screw extruders

2. Twin screw extruders

3. Multiple screw extruders

Single Screw Extruders

A single screw extruder consists of a screw that rotates in a metallic barrel, a feed hopper, a head and a die.

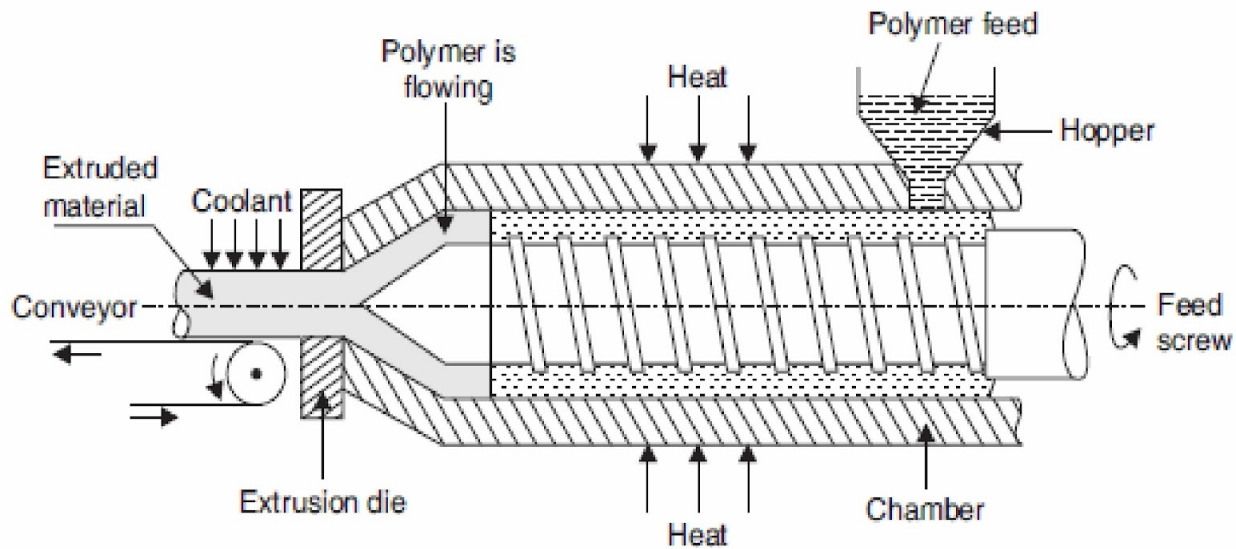


Fig. 4.2 Extrusion of plastics

The main part of the extruder is the screw. The screw is divided into three zones, each with a specific function. They are

1. Solid conveying zone.
2. Melting and compacting zone.
3. Metering zone.

The feed zone is attached with the hopper for the introduction of the polymer.

The three zones are provided with separate heating devices so that each each can be maintained at different temperature.

4.4.2 Process

The polymer is introduced at the solid conveying zone. As the screw rotates it is conveyed to the compression zone. In this zone the loosely packed polymer is compacted, melted and formed into a continuous stream.

Then the belt moves to the metering section where required pressure is developed to permit a uniform flow rate. The metering section ends at the head. The purpose of the head is to equalise the pressure from the screw and to transport the polymer to the die.

The die is mounted on the head. The material should move smoothly and uniformly to the die at equal pressure and speed. The die gives the material the desired shape. Adequate temperature control of the extruder, barrel, screw, head and die is necessary to produce quality goods.

The feed in the form of pellets, powder or stripes is introduced through the hopper onto the flights of the screw. During rotation, the polymer is melted and transported towards the metering zone. From the metering zone it is pushed through the die under required pressure and gets the shape.

The extruders for rubbers are classified into hot feed extruders and cold feed extruders.

Hot feed extruders are fed with preheated strips of rubbers while cold feed extruders take the feed strips at room temperatures.

Cold feed extruders are more economic compared to hot feed extruders.

When the fluid polymer is forced through the die or capillary, the diameter of the extrude is generally larger than the diameter of the die.

The tendency of the polymers to enlarge when emerging out from an extruder die is called die swell. It is expressed as the ratio of cross sectional area of the extrudate to the die.

Die swell depends upon extrusion rate, temperature, die length to diameter type of polymer, filler and its amount.

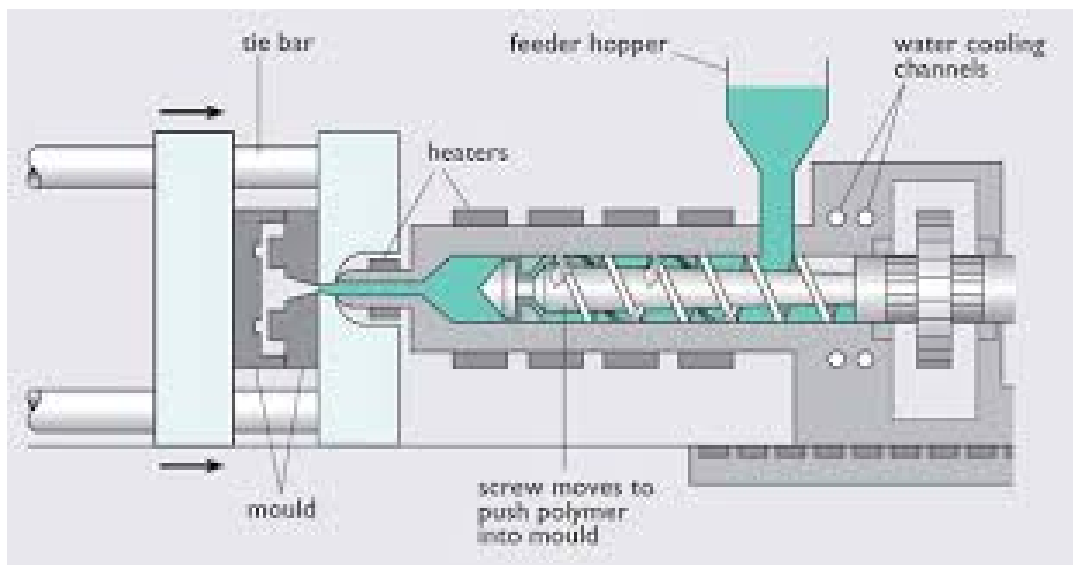
Uses

Extrusion is largely used for production of

1. Pipes, tubes and rods.
2. Polythene bags, furniture canes
3. Filaments
4. Electrical cables, wires hoses
5. Belting, tyre plies, tread stripes

4.5 Injection Moulding

Injection moulding is almost similar to Extrusion



It is the most widely used cyclic process for product manufacture. This technique is widely used with thermoplastics. The process involves forcing or injecting the polymer into a closed mould where it takes the shape of the cavity.

4.5.1 Working

The screw injection moulding machine consists of a reciprocating screw enclosed with a barrel. The screw and the barrel can be heated electrically. It has three sections, feed zone, compression zone, and metering zone. The polymer in the form of pellets and powder is introduced through the hopper into the barrel. As the screw rotates the polymer is plasticized, melted, mixed thoroughly and pushed forward to accumulate at the tip of the screw where the nozzle is placed. The melt is then injected through the nozzle into the mould cavity.

The mould is made of two or more pieces depending on the structure of the product. It includes a stationary part and a non stationary part. When properly closed the mould enclose a the shape of the product, which is known as the mould cavity. When more than one product is made in the same mould it is called a multi cavity mould. The mould has the provisions for cooling and the ejection of the product.

The first step is closing the mould to get the mould cavity. Immediately the screw rotates to melt and collect molten resin which is the conveyed to the space at the end of the screw where it accumulates as a pool. Then the entire screw moves forward and injects the exact amount of melt in to the mould cavity. During injection the melt flows through the sprue, runner, and gate before entering the mould cavity.

4.5.2 Process

The gate is the end of runner and entry path to the mould. The runner is used to carry the melt uniformly to the mould cavity. The Screw is driven using hydraulic pressure. As the melt touches the cold walls of the mould, it start solidification. Once the solidification is complete, the mould plates open and the product is ejected. This makes one cycle. The cycle is continued to produce many product units. Depending upon the size and shape of the product cycle time varies..

Advantages

1. Screw injection moulding offer uniform melting. mixing and dispersion of additives.
2. High production rate resulting in less manufacturing cost.
3. Multi cavity moulds are used to increase number of articles per cycle.

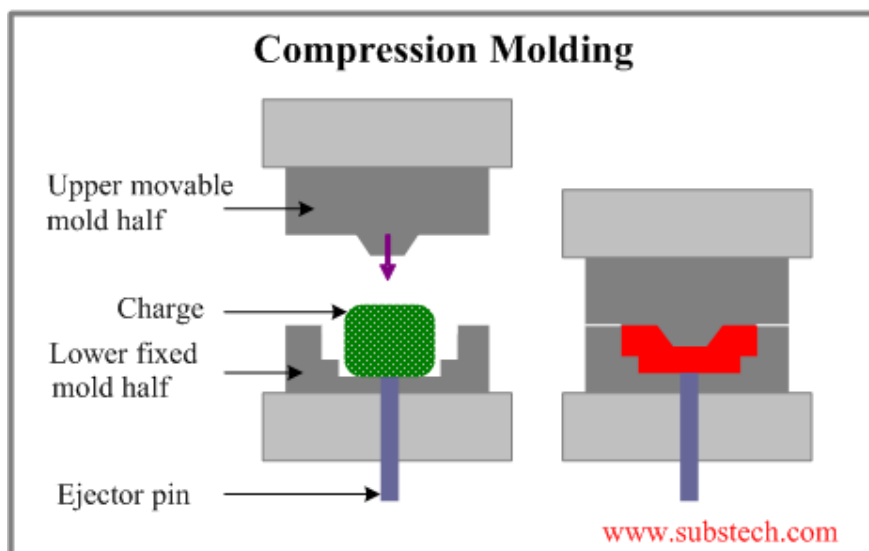
Applications

Injection moulding is used to produce the following items.

1. Buckets, mugs, tumblers
2. shopping bags, decorative items, ice buckets, radio cabinets.
3. furniture, automotive parts

4.6 Compression moulding

Compression moulding is a very widely used techniques used to produce articles from thermosetting materials. The mould is made of two halves- the upper and lower halves or male and the female. the lower 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.

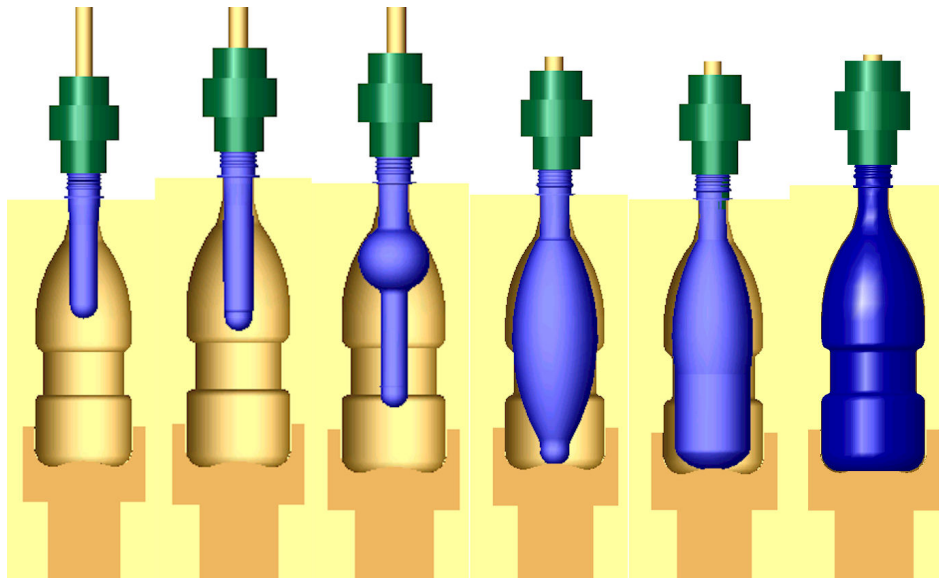
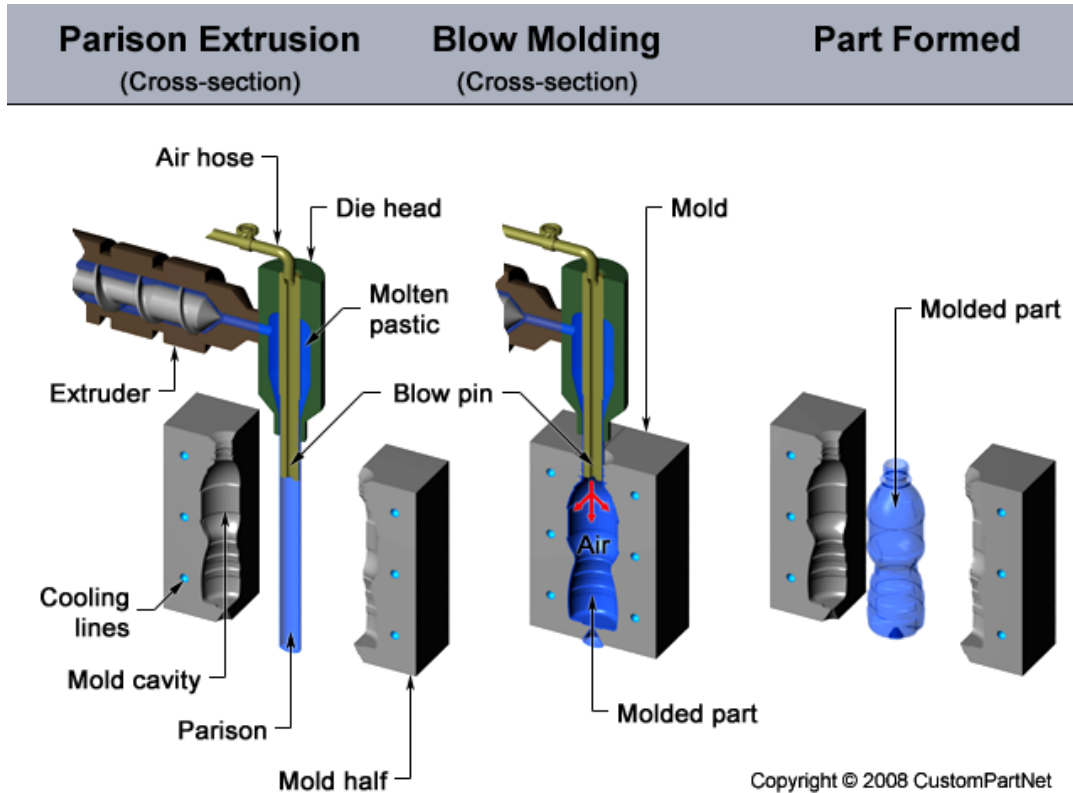


In compression moulding, the thermosetting material is subjected to heat and pressure in a single stroke. This is accomplished by using a hydraulic press with heated plattens. Moulding temperature and pressure can be high as 200°C and 70 kg.cm^{-2} , respectively. The actual temperature and pressure depends on the rheological, thermal and other properties of the plastic material to be moulded. The compounded material is places in the cavity of the mould so as to fully fill the cavity. As the mould closes down under pressure, the material is squeezed or compressed between the two halves and compacted to shape inside the cavity. The excess material flows out of the mould as a thin film. This film, expelled out of the mould is known as 'flash'. Under the influence of heat the compacted mass gets cured and hardened to shape. Th mould can be opened while it is still hot to release the moulded product.

4.7 Blow moulding

Blow moulding is a plastic forming process used for the manufacture of hollow articles like bottles containers and like products.

The first step in blow moulding is the preparation of a preform called parison. The parison is made either by extrusion or by injection moulding. The parison is then placed in a mould and blown to conform to the shape of the mould. Blowing is done using compressed air or steam.



4.7.1 Types of blow moulding

Based on the techniques used for the preparation of parison, blow moulding is categorized into different types.

1. Extrusion blow moulding.
2. Injection blow moulding.
3. Stretch blow moulding.

4.7.2 Extrusion blow moulding

Extrusion blow moulding uses an extruder die to prepare the parison. The parison thus formed is transferred into a blowing mould where it is blown to get the shape.

This method is more popular and extensively used for small and medium sized products.

4.7.3 Injection Blow Moulding

In injection moulding parison is formed by injecting a definite mass of the melt into a closed mould. Then it is transferred to the blowing mould.

4.7.4 Stretch Blow Moulding

In stretch blow moulding the plastics given a biaxial stretching which introduces a high amount of molecular orientation as a result the product gets higher strength and physical properties.

The stretching process also offers considerable cost saving and improvement in mechanical and optical properties.

This method is largely used for the manufacture of transparent bottles. PET bottles for carbonated drinks are manufactured by this method.

Applications of Blow Moulding

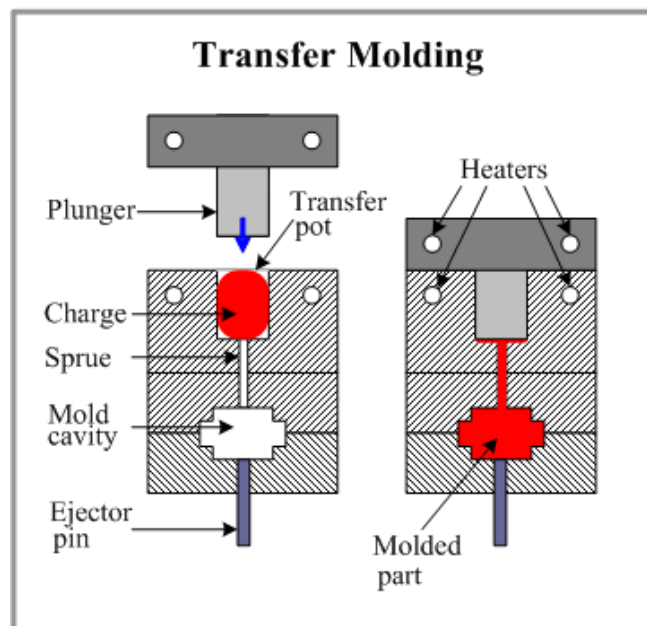
Different types of thermoplastics like PE, PP, PVC, PET, and PS are used for blow moulding

Blow moulding is used for the production of bottles, barrels, toys, gas tanks, cases, drums, flower pots and flexible bottles.

4.8 Transfer Moulding

It is a type of compression moulding. In this process the polymer charge is first heated in a separate chamber called pot or transfer chamber on the top of the mould.

The pot is fitted with Ram or Piston, which will help to transfer the charge to the hot mould. In the mould cavity actual curing and setting of the shape takes place.



4.8.1 Advantages

1. The process is mainly used for thermosetting resins and rubber compounds.
2. The main advantage of this process is that it takes shorter curing time as the mould is fed with hot charge.
3. Since the actual amount of charge is introduced, the process produces minimum flash.

4.8.2 Disadvantage

This process has the disadvantage that transfer moulding establishment cost is higher than compression moulding.

Applications

Products such as switches, plugs, holders, sockets, components of domestic appliances, telephone sets, dinner wares, rubber components, tires, gaskets etc. are produced using this technique.

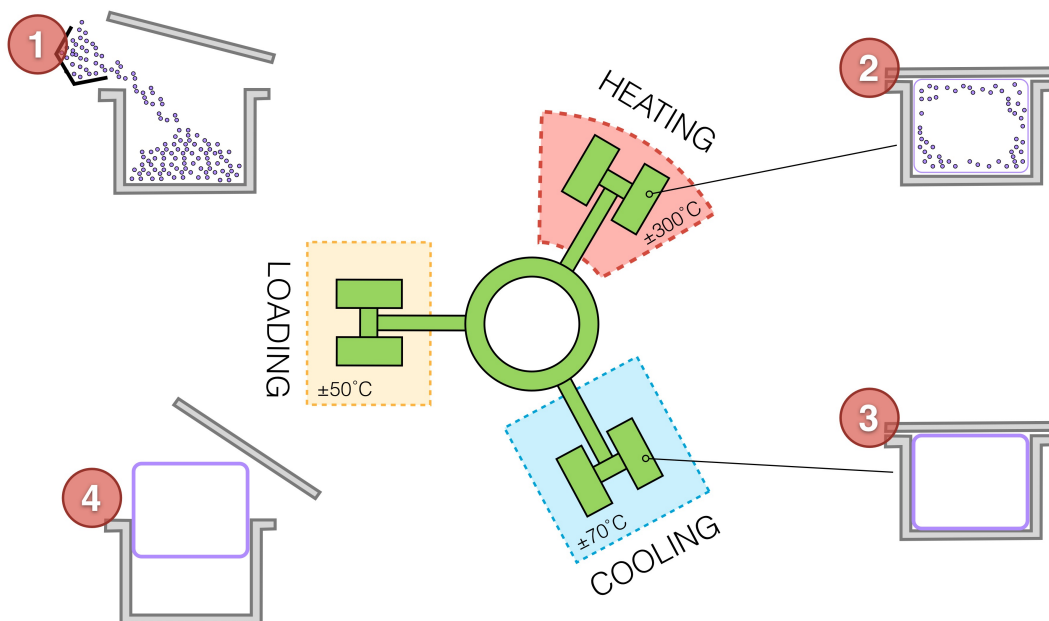
4.9 Rotational moulding

Rotational moulding is used for the production of hollow configurations especially large products by blow moulding. It is mainly used with thermoplastics.

The moulding machine consists of a frame with three arms that can be rotated in two planes at right angles to each other. On the frame one or more moulds can be mounted. Major steps are involved in the rotational moulding are

1. Loading.
2. Heating.
3. Cooling and unloading.

4.9.1 Working



Loading

This involves the loading of correct amount of polymer into the cold mould. This is done in the loading compartment.

Heating

This mould is then moved into an oven where it is heated so that fusion of the polymer takes place. At the same time it is rotated biaxially so that a uniform layer of plastic is deposited on the inner surface of the mould. Heating period is the longest part in the mould cycle.

Cooling and Unloading

When the fusion becomes complete the mould is transferred into a cooling station. The rotation is continued until cooling sets the shape of the product. Cooling is done using cold air or by spraying cold water. After cooling the mould moves into the unloading compartment to take out the product.

4.9.2 Advantages and Applications

Advantages:-

1. Lower cost of equipment and mould.
2. The process requires no pressure.

Disadvantage

The main disadvantage is that it has large cycle time.

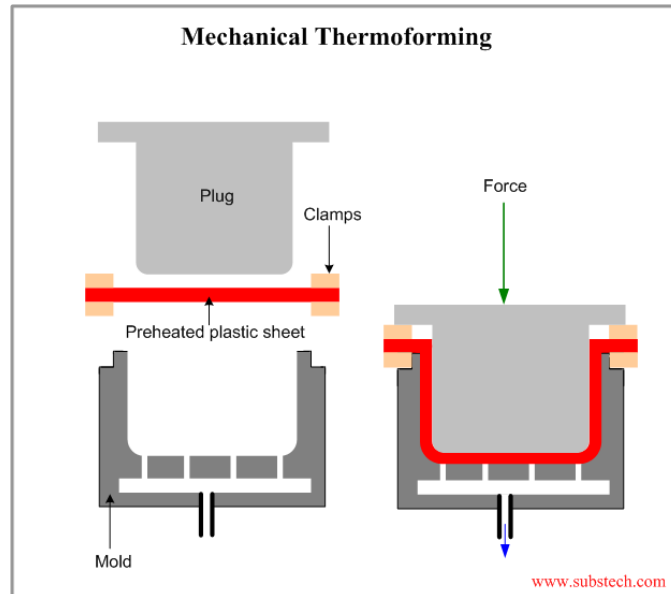
Applications

Rotational moulding is used to make large water storage tanks, drums, floats, containers, furnitures, and sandwiched structures.

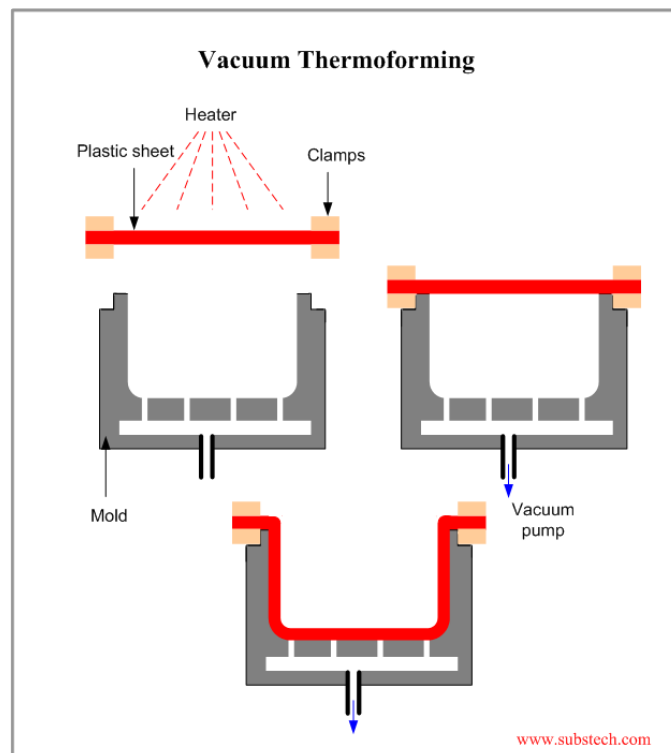
4.10 Thermoforming

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.

The technique can be outlined as follows. 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 male half. Now the sheet assumes the required shape of the mould. On cooling, the shaped article becomes rigid and can be removed from the mould.



In a modified method, the hot plastic sheet is sucked into the cavity of the female mould under the influence of vacuum to give the desired shape. This method is called vacuum forming



4.11 Laminating Process

Laminated structures are formed from layers of materials bonded together into a unit body. The strongest products of the plastic and elastomer industries are laminates and it is mainly through

them that high polymers have invaded the field of structural applications formerly reserved almost solely for metals. They are produced for the manufacture of electrical and decorative laminates, various mechanically moulded parts, filter papers, and battery separators.

Mostly thermosetting resins are employed as binders, though sometimes thermoplastic resins are also employed. They have a higher impact structural strength.

Resins

Resins are used as a solution in a volatile solvent or water. sometimes a resin emulsion is also used. In case a laminate is required, to be die punched or oil modified varnish is used.

filler

Fillers are used in the form of a sheet, be it a paper or other cellulosic material. Various textile sheets are also useful.

4.11.1 Preparation of the Laminate

When the lamination is available as a practically endless pliable sheet. e.g. paper or fabric, readily capable of absorbing a liquid, production is carried out as follows; An A-stage resin or unvulcanised rubber is dissolved in a solvent or emulsified to form a dispersion of suitable viscosity. The filler is unwound from a roll and passes continuously through a trough where it is impregnated with the polymer dispersion. It then passes through squeeze rolls or doctor blades, whose clearance is adjusted according to the amount of binder to be left in the product. Sometimes the dispersion is applied to only one side of the sheet.

The impregnated sheet is may be passed through a heated drying tunnel to remove solvents and, in the case of thermosetting resins, to advance the polymerisation to a non-tacky B-state. In this stage, the handling of the stack in the laminate is to be made. The correct numbers of the sheet stacked one upon the other are simultaneously subject to heat (150°C to 175°C) and pressure $84 \times 10^8 \text{Pa}$ - $135 \times 10^8 \text{Pa}$ between polished plates. The binder curing or setting to C-stage.

Laminated tubes and rods

To make tubes or hoses, the stock is wound upon heated mandrels while under tension or pressure until the desired thickness has been built up. A so-called 'rolled tube' is next baked in an oven at atmospheric pressure until the binder has cured. To make a moulded tube, on the other hand, the assembly is cured in a mould under combined heat and pressure. Moulded tubes are denser and stronger but shows seams at the parting lines of the mould.

Solid laminated rolls are often made by winding the impregnated filler on a very thin mandrel, which is withdrawn before moulding.

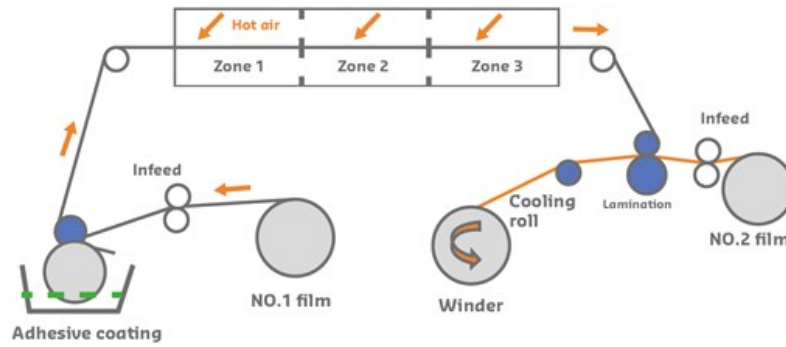
The entire channel is filled up when the pressure is applied. Rods may also be turned out of a flat laminated stock. If the stock is rigid and machinable.

Cotton Fabric Reinforced Laminates

Cotton fabric gives laminated products with higher mechanical strength. They are resistant to heat, wear, lubricants, solvents, acids, weak alkalis and have very low water absorption. The resins are dissolved in methanol, ethanol, acetone, or toluene. The cloth is impregnated with 50% resin and solvents are removed as far as possible. The dry impregnated cloth is cut to size and pressed at a pressure of 10 N.mm^{-2} at 160°C to 165°C . A curing time of 4 m.MM^{-1} is required and it requires 8 to 10 hours for cooling thick laminates. These are used for cogwheels. Laminates are also prepared from synthetic, inorganic and other fabrics.

4.11.2 Techniques

Dry lay ups involve the impregnation of the cloth or filament bundle with either a 100% solid or a solvent-containing resin system in advance of the production operation. If a 100% solid system is employed, the liquid resin is mixed with the curing agent and applied to the glass, then it is heated to B-stage to produce a solid resin at room temperature which is capable of flow on the application of heat. The mixture is applied to the glass by squeeze rolls or coating bars in such a manner to control the resin build up, and also solvents are driven off to leave a dry but only partially polymerised coating.



When dry lay-ups are employed pressure is normally required to assure adequate flow and fill. Building panels with optimum thermal insulating properties are prepared from glass reinforced phenolic resin. The laminates have satisfactory fire and freeze resistance.

Articles of irregular shape are often formed by cutting binder impregnated sheets to pattern, then stalking and moulding. Gears, bearings are often made in this way.

High Pressure and Low Pressure Laminates

The pressure applied during moulding affects both the manufacturing cost and the properties of the finished products. The thermosetting binders used in the production of the early plastic laminates were such that relatively high moulding pressures. High temperatures ranging from 300°F were likewise necessary. Hot processed laminates of this kind are still manufactured in great quantity and have the best properties for many applications.

Low pressure moulding is moulding performed at pressures ranging from a simple contact pressure of 1 psi or less to a maximum of about 300 psi and using the thermosetting binders in the liquid syrup or emulsion form.

4.12 Film Manufacturing

Plastic film is a thin continuous polymeric material. Thicker materials are called sheets. Different methods are used for film manufacturing. Out of this two important process's are

1. Film casting and
2. Film blowing.

4.12.1 Film Casting

Casting technique is used to produce polymeric films. In this technique the solution in an appropriate concentration of the polymer in a suitable solvent is allowed to fall at a pre calculated rate on an endless metallic belt of high finish moving at a constant speed. A continuous sheet of the polymer solution is thus formed on the surface of the metallic belt. When the solvent is subsequently evaporated under controlled conditions, a thin film of the polymer is formed on the surface of the belt. The film could be removed simply by stripping. Most of the commercially available varieties of cellophane sheets and photographic films are prepared by this technique.



4.12.2 Film blowing

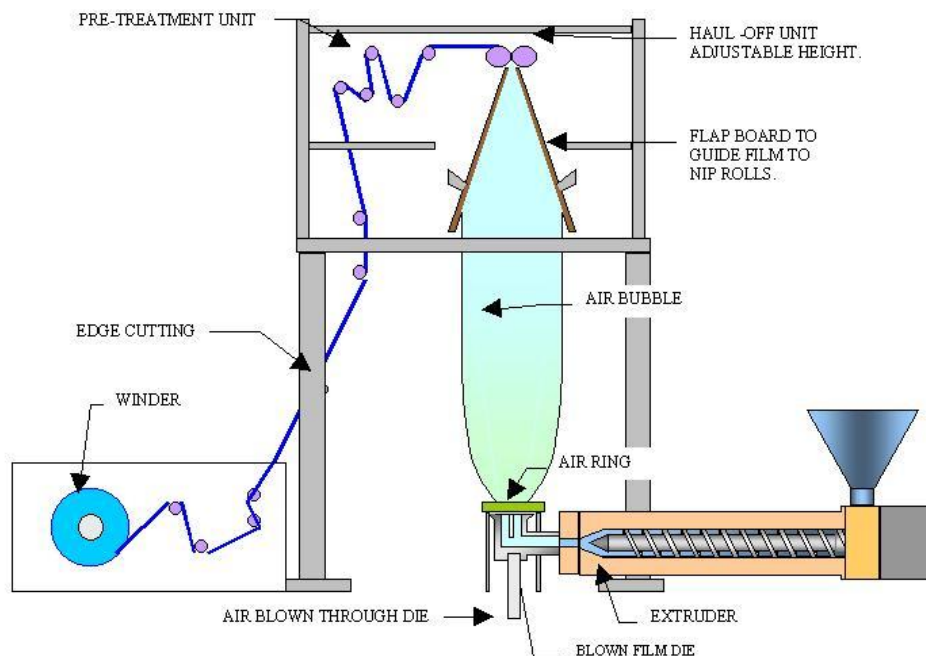
Film blowing involves extruding a tube of molten polymer through an annular die and inflating to several times its initial diameter to form a thin film bubble.

Working

The bubble is pulled upwards from the die and cooled. After cooling the bubble is collapsed using a set of nip rollers. The collapsed film is pulled out using Idler rolls and wound up into rolls.

Blowing and pulling gives the polymer an orientation and hence blown films develop better mechanical properties.

TUBULAR BLOWN FILM PLANT



Applications

The process is mainly used with PE and PP. Plastic films are largely used in packaging. Blown films are used in food packaging, carry bags, collection bags, shopping bags, clothing bags, and industrial liners.