16.5 PLASTICS

Plastics are made from resin with or without fillers, plasticisers and pigments. These are organic materials of high molecular weight which can be moulded to any desired form when subjected to heat and pressure in the presence of a catalyst. Schonbein invented a plastic named cellulose in 1846. Later John Wesley Hyatt in 1890 developed cellulose, and Adolph spitter invented casein plastics. Bakelite was developed in 1909 by Dr. Bakeland. Since then a variety of plastics have been developed. These are natural (shellac and resin) or synthetic in origin.

Plastics are replacing glass, ceramics and other building materials due to the low temperature range in which they can be brought to the plastic state and the consequent ease of forming and fabrication and also for their low cost and easy availability. Plastics are classified as thermoplastic, and thermosetting.

The thermoplastic variety softens on heating and hardens on cooling, *i.e.*, their hardness is a temporary property subjected to change with rise or fall of temperature and can be brought again to plastic stage on heating. These are formed by addition polymerisation and have long chain molecular structure. They can be remoulded, for use, as many times as required. Examples are material resins— rosin, kopal, amber, shellac; cellulose derivatives— cellulose acetate, cellulose nitrate, nitrocellulose or celluloid, cellulose acetate-butyrate; polythenic or vinyl resin—polyethylene, polyvinyl chloride, polyvinyl acetate, vinyl chloride = vinyl acetate, poly vinylidene chloride, polystyrene, polymethyl methyacrylate or lucite or plexiglass and polytetrafluoroethylene; polyamides Nylon 6:6, Nylon 6 and Nylon 11. Some of the uses of the plastics are given in Table 16.1.

Table 16.1 Principal Uses of Plastics

S.No.	*Uses*	*Name of plastic*
1.	As a substitute of glass for doors and windows	Acrylic (Trade name Perspex), better than glass.
2.	Insulation of electric cables, light fittings, hand rails	Cellulose acetate
3.	Set squares, slide rules, fountain pens	Cellulose nitrate
4.	Electric insulation, kitchenware, toys, sheets for packing	Polyethylene
5.	Electric equipments, refrigerator parts, food containers, toys, as a rigid form for packing	Polystyrene
6.	Drainage pipes, floor finishes, emulsion paints	Polyvinyl chloride (PVC) Polyvinyl acetate (PVA)

Thermosetting plastic cannot be reused. They require great pressure and momentary heat during moulding and finally get hardened on cooling. The chemical reaction in this porcess cannot be reversed. Once solidified they cannot be softened. The thermosetting plastics acquire three-dimensional cross-linked structure with predominantly strong covalent bonds during polymerisation retaining strength even on heating; under prolonged heating they fail by charring. Compared to thermoplastics, they are hard, strong and more brittle. The important thermosetting resins are phenolic resins or phenoplasts (bakelite), amino resins, polyester resins, epoxy resins and silicon resins. The principal uses are in electrical equipments, plugs, sockets, switches, ash trays, knobs, handles, etc.

Properties

1. Can be moulded to any desired shape or size and have high tensile and compressive strengths.
2. Easy to work upon.
3. Light in weight and a few varieties are glossy like glass.
4. Not attacked by insects and fungi.
5. Available in desired colour and texture.
6. Require a little maintenance.
7. Good electrical insulators and have low thermal conductivity.
8. Shock absorbing material.
9. Can be sawn, drilled and punched and welded easily.
10. High strength to weight ratio.
11. High resistance to weathering conditions.
12. Corrosion resistance.
13. Decorative surface effect—painting or polishing of the surface is not required.
14. High refractive index.
15. Some varieties are as hard as steel.
16. Withstands moisture, oil and grease well.
17. Inflammable.
18. High coefficient of thermal expansion (about ten times of steel).
19. Deterioration under prolonged exposure to sun's ultra violet rays.
20. Low manufacturing cost, hence cheap.

16.6 CONSTITUENTS OF PLASTICS

The constituents of plastics are resin, plasticizer, filler, pigment and dye, lubricant and catalyst.

Resin acts as binder for holding different constituents together. Thermosetting resins are usually supplied as linear polymer of a comparatively low molecular weight being fusible and mouldable.

Plasticiser modifies plastic to impart desirable combination of strength, flexibility and toughness. Plasticizers, which are mostly liquids, are usually organic compounds or resins possessing very low vapour pressure. Their addition is particularly necessary when the softening temperature of a resin is too high. Plasticizer is supposed to neutralize a part of the intermolecular force of attraction between macromolecules of resins. Consequently the polymeric macromolecules of resin move with greater freedom, thereby increasing the plasticity and flexibility of the compounded material. However, tensile strength and chemical resistance is reduced. Some of the examples of plasticisers are vegetable oils (non-drying type), camphor, esters of stearic and oleic acids, tricresyl phosphate, tributyl phosphate, tetrabutyl phosphate and triphenyl phosphate.

Filler is added up to 50 per cent of the moulding mixture to increase the hardness, tensile strength, bond, opacity, finish and workability besides reducing the cost, shrinkage on setting, and brittleness of the final product. Some of the fillers are wood flour, asbestos fibres, mica, diatomaceous earth, saw dust, ground cork, paper pulp, corn husk, carbon black, cotton fibre, metallic oxides, metal powder (Al, Cu, Pb). Carborundum, quartz are found to be most suitable for extra hardness. Mica is used to improve electrical properties. Barium salts when added to plastics make them impervious to X-rays. Asbestos is used to make plastics heat resistant. Carbon and graphite impart chemical resistance and also serve as an internal lubricants.

Pigment is added to achieve desired colour of the plastic and should be resistant to the action of sunlight.

Lubricant is used to make the moulding of plastic easier to prevent sticking of materials to the mould for a flawless finish. The examples are stearates, oleates and soaps.

Catalyst is added only in the case of thermosetting plastics to accelerate the polymerisation of fusible resin during moulding operation into cross-linked infusible form.

Blowing Agent Sodium bicarbonate and ammonium carbonate are sometimes added to plastics to produce porous articles.

16.7 FABRICATION OF COMMERCIAL ARTICLES FROM PLASTICS

The method used for fabrication of commercial articles from plastics depends primarily on the type, resin used, shape, size and thickness of the articles. Following are the commonly used fabrication methods.

Moulding

Compression Moulding can be employed both for the thermoplastics and thermosetting plastics. The fluidised material is filled in the mould cavity by hydraulic pressure (Fig. 16.11). There is an arrangement to heat the plastic if desired. Temperature and pressure is applied till the chemical reaction is complete. Finally curing is done by heating (thermosetting plastics) or by cooling (thermoplastics). After curing is complete, mould is opened and moulded material is taken out.

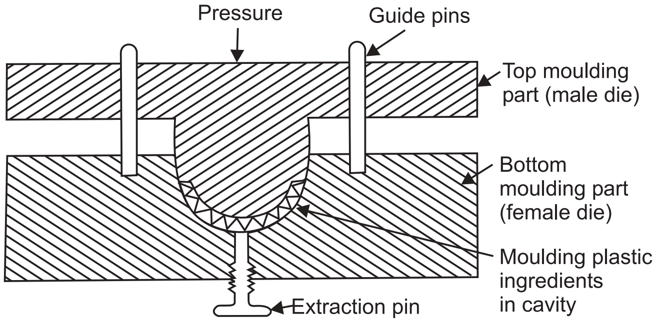

Fig. 16.11 Compression Moulding of Plastic

Injection Moulding is best suited for the moulding of thermoplastic materials. The plastic powder is fed into a cylinder from a hopper where it is heated. When the mould opens, a screw (Fig.16.12) or a plunger allows the material to go inside the cylinder from the hopper. The resin melts in the heating zone from where it is sent to the mould cavity through nozzle. The mould is kept cold to allow the hot plastic to cure and acquire the shape. Half of the mould is opened to cause enjection of the finished article.

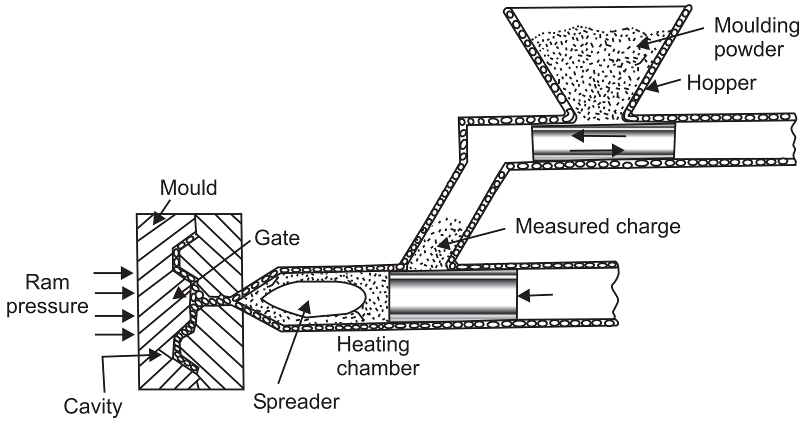

Fig. 16.12 Injection Moulding

Transfer Moulding uses the principle of injection moulding for thermosetting materials. Intricate machine parts are moulded by this method. The thermosetting material powder is heated to become just plastic and injected through an orifice, as shown in Fig. 16.13, into the mould by the plunger working at high pressure. The temperature of the material rises because of the friction at the orifice and the powder becomes almost liquid which flows into the mould and in turn is heated to curing temperature.

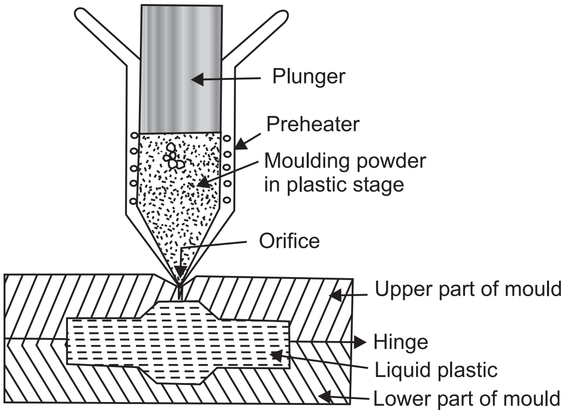

Fig. 16.13 Transfer Moulding of Plastic

Extrusion Moulding is used for continuous moulding of thermoplastic materials into articles of uniform cross-section such as tubes, rods, strips, electric cables, etc. The thermoplastic material is heated to plastic state and is pushed to a die by a screw conveyer (Fig. 16.14 and Fig. 16.15). As the extruder rotates it has a mixing, smearing, and frictional heating action which changes the dry granular charge into a soft plastic mass before it reaches the end of the screw. Here the plastic mass by air jets.

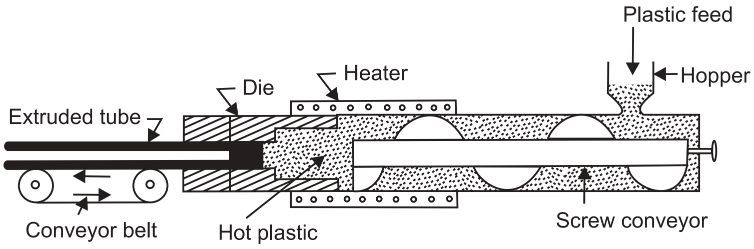

Fig. 16.14 Moulding of Tube by Horizontal Extrusion Moulding

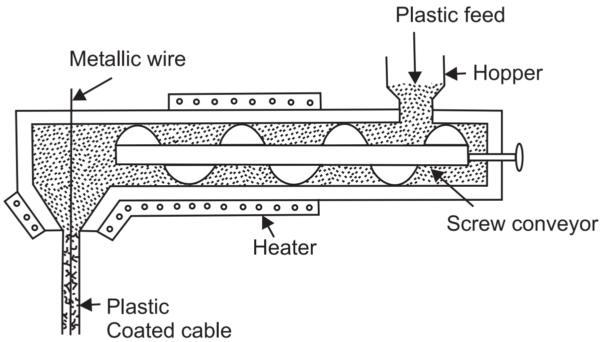

Fig. 16.15 Moulding of Cable by Vertical Extrusion Moulding

Blow Moulding Air pressure or vacuum are employed in this method of moulding to force the softened plastic powder into the mould.

Casting

The plastics are moulded without application of pressure. The resin is melted and poured into mould. The casting of plastics is similar to that of cast iron. Since the cast plastic is not so smooth just after casting, they are polished. This method is most suited to the plastics formed form cellulose acetate and cellulose nitrate.

Lamination

Thin sheets of cloth or paper asbestos are impregnated with thermosetting resin. These lamins are then pressed by a hydraulic press. Under temperature and pressure the lamins are bonded together to form one sheet. The laminated plastics exhibit improved mechanical and electrical properties. The thickness of laminated plastics ranges between 0.13 mm–15 mm. Vinyl resin is most suitable for lamination.

16.8 APPLICATIONS OF PLASTICS

Plastics have innumerable applications either to substitute or protect other building materials, or to improve the comfort conditions. However, because of relatively low stiffness they are not used as primary load bearing materials. Some of the uses of plastics are as follows.

Wall Facing Tiles Polystyrene tiles have excellent water proofing properties and are used for bathrooms, kitchens, lavatories, swimming pools and facing tiles.

Flooring Tiles Polyvinyl chloride synthetic resins used for floor tiles are nonabsorbent, resistant to abrasion, wear and tear.

Flooring Sheets Mastics, prepared from synthetic resins such as polyvinyl acetate with suitable plasticisers form decorative linoleum floor coverings.

Warer-proofing Membranes Polythene and polyvinyl resins with suitable fillers and plasticisers, oils and antipyrene compounds are used to make films which have high elastic strength, rupture value and acid resisting properties. These films are used for damp proofing courses, covering of concrete for curing, temporary protection from rain and wind.

Pipes and Sanitary Appliances Polythene, polypropylene and polyvinyl chloride are used for making pipes and sanitary wares and fittings.

16.9 PROPERTIES OF PLASTICS

The great diversity of plastic materials, modified by fillers, plasticisers, laminating sheets, etc. leads to a wide range of mechanical and physical properties.

Stress-Strain Relationships Typical tensile stress-strain curves for various types of plastics are shown in Fig. 16.16. Curve A of Fig.16.16 is typical of hard, strong, but unyielding plastics like moulded thermosetting materials and paper laminates. Curve B relates to materials like cellulose acetate, cellulose acetate butyrate, and some fabric materials. Curve C is typical of a large number of plastics. Curve D relates to some highly extensible plastics.

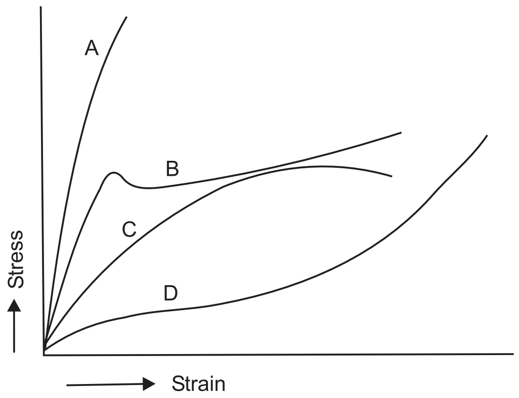

Fig. 16.16 Tensile Stress-Strain Curves for Various Types of Plastics

Rubbers behave similarly. The stress-strain curves for cellulose acetate sheet at various temperatures is shown in Fig. 16.17.

Creep, Relaxation, Memory

When a load is applied to a plastic specimen it quickly deforms and the load is sustained, the specimen continues to deform at a decreasing rate. If, after creep has occurred for a period of time, the load is released, a quick partial recovery takes place immediately, followed by slow recovery which may or may not completely restore the specimen to its original size and shape (Fig. 16.18 (a)).

If the deformation caused by a load is held constant, the load decreases. The phenomena is known as *relaxation* (Fig. 16.18(b)). *Memory* means that the behaviour of a plastic specimen under stress may be influenced by its previous stress history. As shown in Fig. 16.18(c), the specimen is subjected to a succession of loads of varying intensities, directions, and durations. There may not be time for normal creep recovery before a reversal of load occurs. The final deformation may, therefore, experience a reversal.

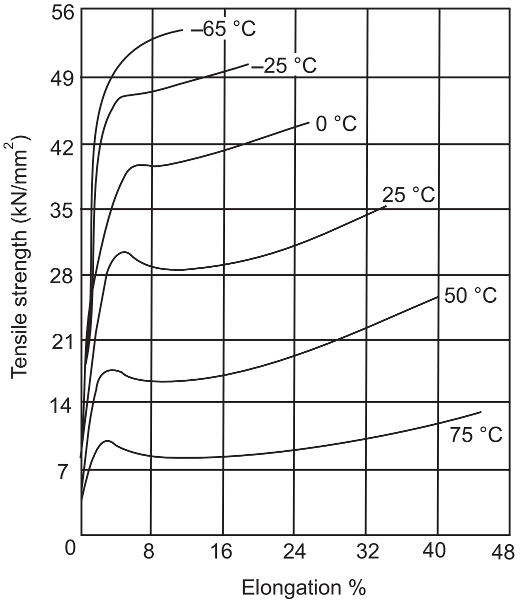

Fig. 16.17 Stress-Strain Curve for Cellulose Acetate Sheet at Various Temperatures

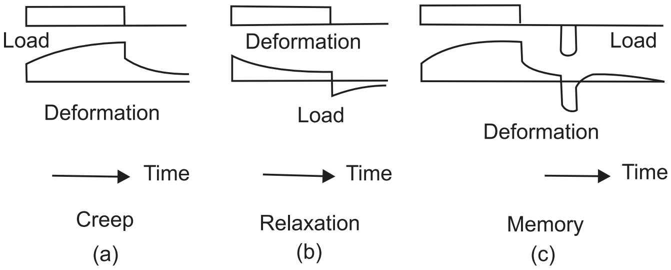

Fig. 16.18 Diagrammatic Representation of Creep, Relaxation, and Memory

16.10 EFFECT OF TEMPERATURE ON MECHANICAL PROPERTIES

Mechanical properties of all plastics are sensitive to changes in temperatures. Figure 16.19(a) and Fig. 16.19(b) show the respective effects of temperatures on thermoplastics and thermosetting plastics. The effect on ultimate elongation of thermoplastics is shown in Fig. 16.20.