## 5.1 Introduction

In general, many organic materials are used in engineering industries. Plastics are belonged to the family of organic materials. The plastics are attained a firm place today. Main characteristics of plastics are no problem for designing it. Organic materials are those materials obtained directly from carbon and chemically combined with oxygen, hydrogen and other non-metallic compounds.

These organic materials are classified into two types. They are

1. Natural organic materials
2. Synthetic organic materials.

**1. Natural organic materials**

The wood, coal, petroleum and natural rubber are under the categories of natural organic.

**2. Synthetic organic materials**

The plastics, synthetic rubbers, ceramics glass are under the categories of synthetic organic. Technically, these organic materials are called polymers.

### 5.1.1 Polymers

The term polymer has it base in Greek terminology, where 'Poly' means 'Many' and 'Mars' means 'Parts'. The term polymer stands to represent a substance built up several repeating 'units'.

A single unit is called as 'monomer'. The monomers are small molecules. A polymer is made up of thousands of monomer joined together to form a large molecule. The characteristics of a polymer are that the molecule is either a long chain or a network of repeating units. Plastics are one kind of polymer. It is defined as an organic polymer. It can be moulded into any required shape with the help of pressure or heat or both heat and pressure. The liquid form of plastic is called as resin and it contains carbon as a central element. Oxygen, nitrogen and chlorine are linked to the carbon atoms to form the molecules. The main raw material for making plastics is resin. The different types of resin are acrylic resin, polyethylene resin and amino resin. These resins are produced by different types of polymerization process. Catalysts, binders, dyes and lubricants are added with the resin to form the plastics.

### 5.1.2 Polymerization Process

A polymer is made up of linking thousands of monomer and thus obtaining large molecule is called polymerization process. It is achieved by one of the two processing techniques. They are.

1. Addition polymerization
2. Condensation polymerization

**1. Addition polymerization**

In addition polymerization, similar monomers of large numbers are added chemically one by one. These monomers form a long chain molecule. The basic principle which is used in this bonding is Vander wall's force. The polyethylene is produced by addition polymerization.

In addition polymerization process, no catalyst is used. Polymerization takes place by applying energy in the form of pressure and heat. The addition of two or more different monomers is called co-polymerization process.

**2. Condensation polymerization**

In condensation polymerization, two or more unlike monomers are linked and there is a repetitive elimination of smaller molecules to form a by-product. During this process, by-product such as water or ammonic is formed. This by-product formation is known as condensation.

The condensation polymerization requires high pressure and it requires hours or days to complete the process.

**5.1.3 Materials Used for Processing of Plastics**

The properties of polymers are modified by the addition of agents such as 'additives' and 'fillers'.

**a) Additives**

**1. Plasticizers**

To improve the plastic behavior of the polymer, the plasticizers are added. The plasticizers are in the form of liquids with high boiling point. It acts as an internal lubricant for increasing the toughness and flexibility. The main role of a plasticizer is to separate the macromolecules, thus, decreasing the inter-molecular forces and facilitating the relative movement between molecules of the polymer. It means, making the deformation is easier.

***Examples***

Water, organic solvents, resins

**2. Catalyst**

Catalysts are usually added to promote faster and complete polymerization. The catalysts are also called 'accelerators' and hardeners.

**3. Dyes and pigments**

Dyes and pigments are added to impart a desired color to the material.

**4. Initiators**

The initiators are used to initiate the reaction. i.e. it allows to begin polymerization. They stabilize the end reaction of the molecular chains.

***Example:*** $H_2O_2$ is a common initiator

**5. Modifiers**

It is used to improve the mechanical properties of plastics such as strength, damping capacity, toughness, ductility, plasticity etc.

**6. Lubricants**

It is used to reduce friction during processing, to prevent parts from sticking to mould walls, to prevent polymer films from sticking to each other.

**Examples:** Oils, soaps and waxes.

**7. Flame retardants**

The flame retardants are added to the plastics to enhance the non-inflammability of the plastics.

***Examples:*** Compounds of chlorine, bromine and phosphorous

**8. Solvents**

It is useful for dissolving certain fillers or plasticizers and help to allow the processing in the fluid state.

***Example:*** Alcohol

**9. Elastomers**

It is added to the plastics to enhance their elastic properties.

**10. Stabilizers**

It is added to the plastics to retard the degradation of polymers.

**11. Fillers**

It is used to economize the quantity of polymer required and to very the properties to some extent. The fillers are used to improve the strength and stability of the plastics. The type of fillers used in plastics is mica, cloth fiber. The mica and asbestos are used to improve the heat resistance capacity of the plastics.

### 5.1.4 Properties of Plastics

The plastics possess various properties which help the end users to move for lightweight materials. The properties are listed below

(i) Elongation

(ii) Heat resistance

(iii) Insensitive to tension cracks

(iv) High rigidity

(v) Surface hardness

(vi) High viscosity

(vii) Maximum usage temperature

(viii) Short term maximum usage temperature

(ix) Density

(x) Ignition temperature

(xi) Humidity absorption

(xii) General chemical resistance

## 5.2 Types of plastics

All plastics are broadly classified into two main groups. They are

1. Thermosetting Plastics
2. Thermoplastics

### 5.2.1 Thermosetting Plastics

The plastics which are hardened by heat effecting a non-reversible chemical change are called thermo-setting.

Thermo setting plastics do not soften on reheating and cannot be reworked. Thermo setting molecules are formed by condensation polymerization.

The molecules of such type of plastics have three dimensional network and very strong binding force between molecules. The raw material for thermosetting plastics is in the form of liquid or solid. These types of plastics are polymerized when moulded or formed. It consumes more time for formation. The various types of thermosetting resin are discussed below.

**1. Phenol formal dehyde**

It is also named as bakelite. It is made by the reaction of phenol with formaldehyde. It is generally produced in dark colour and it has high strength, stability, and rigidity. It can be easily cast or laminated.

**Uses:** Plugs, knobs, pulleys, bottle caps, tooling and forming dies.

**2. Polyster resin**

It has low moisture, good electrical resistance and variety of colours. It is used in paper mat, TV parts and car bodies. The main drawback of the polyster is high cost.

**3. Melamines**

It has excellent electrical and heat resistance. It has good stability and low moisture absorption. The melamines are available under various names of melmac, catlin, melantine and plaskon. It is widely used for moulded parts.

**Uses:**

Telephone sets, circuit breakers, switch panels and lighting fixtures.

**4. Phenol furfural**

It has good flowability at low moulding temperatures and sets quickly at correct temperature. The phenol furfural has good resistance to moisture and electricity.

**Examples:**

Brake linings, electrical parts and instrument cabinets.

**Uses:**

It is used as a binder in resinoid abrasive wheels, laminating varnishes and adhesives.

**5. Epoxy resins:**

The most popular variety of epoxy resins is Araldite. It has good chemical and electrical resistances. It is mostly available in the form of liquid. They also have good resistance to wear and impact. But they are quite expensive.

**Uses:**

Tools and dies, jigs and fixtures, housings for electrical parts and enamels.

**6. Silicones:**

Silicones have high resistance to high temperature upto 260$^{o}$C and possess excellent dielectric strength at high temperatures. In liquid form, they are used as water repellants. They can be compressed and reinforced.

**Uses:**

- It is used in coatings, laminates, foam products and induction heating apparatus.
- In rubber form it is used in gaskets for providing high heat resistance.

**7. Urea formaldehyde (Amino resin)**

It is obtained by the condensation of urea and aqueous formaldehyde. It cannot be cast. But, it can withstand temperature up to 77$^{o}$C only. It is widely used as an adhesive and binding material

**Uses:**

It is used in toilet seats, table ware, buttons, clock cases, electric switches and plugs.

**8. Alkyds**

It is also known as oil-modified polyesters. Alkyds are used in synthetic enamels and lacquers. It is used in solid form where high electrical and heat resistances are required.

**Example:**

Automobile ignition parts

**9. Polyurethanes**

It is mainly used for cushions in transportation seats for insulation and electronic equipment as a packing material.

**5.2.2 Thermoplastics**

The thermoplastics have separate long and large size molecules arranges side by side. It does not have any cross linking in their molecular structure.

Some of the thermo plastic structure is amorphous in nature other than that all are crystalline structure in nature. It is formed by addition polymerization process. When thermo plastics are heated, it becomes very soft and rehardens on cooling. During heating, the linear bonding links between molecules breakup and molecules are separated. Relinking takes place on cooling and retains their hardness. It is easily remoulded or extruded to any shape. These plastics do not have a definite melting temperature. The various thermo plastics are discussed below. It is classified into:

1. Cellulose derivatives
2. Synthetic resins

**1. Cellulose Derivatives**

***i) Cellulose nitrate:***

It is obtained by treating the cellulose with a mixture of nitric and sulphuric acid. It has high toughness, good resistance to moisture and highly inflammable.

***Uses:***

Spectacle frames, toilet articles, pen bodies and table tennis balls

**(ii) Cellulose acetate:**

It is obtained by treating the cellulose with acetic acid. It can be injected and compressed in the mould for obtaining better stability and high mechanical strength. It is lighter than cellulose and tendency to absorb moisture.

***Uses:***

Photographic films, buttons, radio panels, toys and extruded sheets, tubes and rods

***iii) Ethyl cellulose:***

The ethyl cellulose is the lightest of all cellulose derivatives. It has good electrical properties, chemical resistance, surface hardness and strength.

***Uses:***

Jigs, fixtures, forming dies, hose nozzles and moulded articles.

***iv) Cellulose acetate-butyrate:***

It is obtained by treating cellulose with acetic and butoric acid. It has good stability against light and heat and moisture absorption tendency. It can also be injection moulded and extruded.

***Uses:***

Radio cabinets, pipes and tubing, steering wheels, insulating tapes, handles and coatings.

**v) Cellophane**

It is available in extruded form. It has attractive appearance and good resistance to moisture, fire and solvents.

***Uses:***

Curtains, drapers wrapping and packaging.

***vi) Cellulose propionate:***

It has low tendency for moisture absorption and can easily be moulded. The cellulose propionate can withstand temperature upto 93°C.

***Uses:***

Fountain – pens, telephones and flash light cases.

**2. Synthetic Resins**

***i) Polyethylenes:***

it has very high resistance to acids, alkalizes and solvents can be made flexible, tough and good insulators. It has low water absorption. The polyethylenes are softened at 93°C.

***Uses:***

Fabrics, trays, pipes and tubing chemical containers and corrosion resistant coatings.

**ii) Polystyrenes:**

It has dimensional stabilities and strain resistance. It is easily mouldable and has tendency to crack under load. The polystyrenes are easily jointed by cementing. It can be produced in any form and colours.

***Uses:***

Battery boxes, radio parts, tableware, toys and high frequency insulation parts.

***iii) Acrylic resins:***

It has high transparency tendency. It can be made in any colour with dielectric properties, resistance to moisture, good strength and excellent light transmitting power. It can also be cast injection moulded, extruded and stretch formed into sheets.

***Uses:***

Tubes, plates, coatings, and adhesives, laminates, display cases, lenses, valves and helmets.

***iv) Vinyles:***

Its trade name is PVC. Vinyl plastics are made in the form of flexible or rigid. It has good electrical and weather resistance. The vinyls are water resistant and produced in various colours.

***Uses:***

Tarpalin, water roofing, raincoats, tubes and insulation.

***v) Polytetra fluoroethylene:***

Its trade name is Teflon. It has maximum chemical resistance, can withstand temperatures upto 288°C, and cannot be dissolved in any solvent. It has high electrical

resistance, low friction and very low adhesion to other substances. It is available in forms such as rods, sheets and tubes.

***Uses:***

Gaskets, greaseless bearing, electrical insulators and chemical containers.

***vi) Polyamide:***

It is popularly known by its trade name Nylon. It has high strength, toughness and elasticity. It can be moulded and extruded into rods. The power metallurgy methods can also be used for this type of plastics. It is a good insulator and has good wear resistance.

***Uses:***

Yarn for cloth, bearings and coupling, gears, wire insulation and combs.

***vii) Methyl methacrylate:***

It trade name is Lucite and plexiglass. It can be formed easily at temperatures around 120°C. It is marked by its clear colour and high light transmission capability.

***Uses:***

Aircraft parts, transparent bowls, contact lenses and various surgical instruments.

### 5.2.3 Difference between Thermoplastics and Thermosetting Plastics

| S. No | Thermoplastics | Thermosetting plastics |
|---|---|---|
| 1. | It is softened by heating. | It cannot be softened by this process. |
| 2. | Structure is made of linear chair molecules. | Structure is made of cross linked molecules. |
| 3. | It is produced by addition polymerization process. | It is produced by condensation polymerization process. |
| 4. | It can be reproduced by heating and cooling. | It cannot be reproduced. |
| 5. | The temperature increases with increase in plasticity. | Plasticity is table at high tempeeratures. |
| 6. | It can be remoulded to any shape | It cannot be remoulded. |
| 7. | It is softer and less strong. | It is harder and strong. |
| 8. | Scrap can be reused. | Scrap cannot be reused. |