# Lecture No. (6)

# Thermoplastic Elastomers Materials

## Introduction of Thermoplastic Elastomers (TPE) Materials

It was not discovered until the 1950, when polyurethane polymers using in many applications and became available, thermoplastic elastomer became a commercial in 1959, since this time a find of new variations of this material, therefore, thermoplastic elastomer (TPE) is used about (680,000 tons/year) in 1990.

## Thermoplastic Elastomers Materials

The thermoplastic elastomers (TPE) materials, definition is a physical mixing of polymers, polymer blend or one type of block copolymers usually consist of plastic and rubber without crosslinking occur, which provide both thermoplastic and elastomeric properties, and above its melting temperature can be recycles and fabrication to desired shaped, as little as 20 seconds.

Not all amorphous polymers are elastomers, but some amorphous polymers are thermoplastics, because of an amorphous polymer is classify a thermoplastic or an elastomer depends on its glass transition temperature (Tg). Above this temperature, which a polymer becomes soft and pliable, and below which it becomes hard and glassy. If an amorphous polymer has (Tg) below room temperature, it will be an elastomer, because it is soft and rubbery at room temperature. But if an amorphous polymer has (Tg) above room temperature, it will be thermoplastic, because it is hard and glassy at room temperature. So the elastomers materials have low (Tg), while thermoplastics materials have high (Tg).

Thermoplastic elastomer (TPE) materials combine between the functional performance and properties of thermoset rubbers with the processability efficiency of thermoplastic polymers. TPE materials can be stretched to at least twice their original length at room temperature and return to the approximate original shape upon stress release.

The processability of most thermoplastics elastomers occur at melting temperature to easily manufacturing by injection molding and extrusion molding. Thermoplastic elastomers show advantages typical of both rubbery and thermoplastic materials.

## Molecular Nature of Thermoplastic Elastomers (TPE) Materials

The principal difference between thermosetting elastomers and thermoplastic elastomers the type of crosslinking bond in their structures. In fact, crosslinking is a critical structural factor which contributes to give high elastic properties.

All elastomer materials (thermosetting elastomers) have chemical bonds (crosslinks) that is usually strong and non-reversible such as (covalent bonds), between the polymer chains and joining all them into a single networked molecule. When the polymer chains are joined together like these bonds, that is lead to prevent flow under moderate stresses or when heating, therefore it is harder to pull them out of their original positions and back better when stretched. Also these polymers cannot be recycled, remelted or remolded easily because these type of bonds.

Some elastomer materials (thermoplastic elastomers) have physical bonds (physical entangled) is usually weak and reversible bonding, such as (hydrogen and fander walls bonds) between the polymer chains to bind them together. All these materials will disentangle and flow under moderate stress or when heating, therefore the physical entanglements will act as temporary interlinks. Because of the physical bonds is broken when heating and allow taking place a new shape then reform again when it is cools, these materials can be remelted, remolded and recycling easily of the scrap and rejecting parts and it called the thermoplastic elastomer.

It is difficult distinguish between two types of bonds in elastomer chains that are only physical bonds or chemical bonds. One method to distinguishing the bond type by the polymer dissolves in solvent or just swells without dissolving. Covalent bonding does not dissolve in any type of solvent, therefore this type of bonds is necessary using for solvent resistance and at high temperatures applications.

## Structural of Thermoplastic Elastomers (TPE) Material

All structure of thermoplastic elastomers (TPE) materials is composed of both crystalline and amorphous domains along the same polymer chain. The crystalline domains are referred to the hard phase, while the amorphous domains are referred to the soft phase. Both phases contribute to give mechanical and physical properties of thermoplastic elastomeric material. Thereby these phases act as a guide in selection or design of thermoplastic elastomers (TPE) compound, which include:

1- **Soft Phase:** providing the rubber properties which include (hardness, compression strength, flexibility and lower service temperature.
2- **Hard Phase:** providing the thermoplastic properties which include (tensile strength, tensile modulus, tear strength, heat resistance, chemical resistance, processing temperature, and adhesion resistance to ink or molding substrates.

**Thermoplastic Elastomers Compounding**

Elastomer compounding is the added and mixing selecting various materials such as (reinforcing agents, stabilizers, pigments, etc.) with rubber to produce a useful rubber properties and meets the final rubber product requirements.

**Applications of Thermoplastic Elastomers (TPE)**

These materials have large application, about (40%) of TPE products are used in the automotive applications (bumpers, tiers, gaskets and airbag doors) because of its greater resistance to deformation. TPE is also uses in electrical applications (electrical cable insulation, headphone cables, snowmobile), and in housing applications (window and switch contact points). Furthermore, TPE is using in medical applications (wrist straps and catheters).

**Properties of Thermoplastic Elastomers (TPE)**

1- High elasticity.
2- Colourability.
3- Low specific gravity.
4- Processable at elevated temperature.
5- High impact strength (shock absorption).
6- Absence of significant creep (slip resistance).
7- Easily recyclable, remolded, remelted, and reprocessed.
8- Excellent flexural and fatigue resistance.
9- Good tear and abrasion resistance.
10- Resistance to low and high temperatures from (-30 to 140 C).

11- Excellent chemicals resistance.

12- Excellent weathering resistance (ozone resistance).

**Benefits of Thermoplastic versus Thermosetting Elastomers**

1- Colourability

2- Lower costs.

3- Lower density.

4- Thinner wall sections.

5- Simplified processing.

6- No or little require compounding.

7- Easily recyclable, remolded, remelted and reprocessed.

**Considerations in Selecting of Thermoplastic Elastomers**

**A- Chemical or Fluid Exposure**

Various TPE types will exhibit the chemical and fluid resistances, giving each its high strengths or weaknesses when exposed to acids, bases, greases, organic solvents and other substances. Therefore, good selection of TPE material when it may be exposed during application to any type of fluids or chemicals materials.

**B- Service Temperature**

The continuous use temperature is referring to the highest temperature at which TPE material will retain its elastomeric characteristics while continuing to function, that is restricting to use many TPE materials in high temperature applications.

**Types of Thermoplastic Elastomers (TPE) Materials**

There are seven main TPE types available commercially, which include:

**1) Poly (Styrene-Butadiene-Styrene) (TPE-S)**.

The microstructure of these block copolymers have two phases (hard and soft), because of the incompatibility between the polystyrene and polybutadiene. The styrene end blocks provide the thermoplastic properties and the butadienes mid blocks provide the elastomeric properties. If low content of polystyrene the property of these material is elastomeric. Generally the SBS offer a much wider range of properties than cross-linked rubbers because the composition can be variation. The SBS block copolymer used in footwear, adhesives, seals, and where chemicals resistance required. The SBS when hydrogenated becomes SEBS, as the elimination of C=C bonds in the butadiene generated ethylene and butylene mid blocks, hence characterized by high heat resistance, chemical resistance and mechanical properties.

**2) Thermoplastic Polyolefin (TPE-O or TPO)**

These materials products by mechanical blends of polypropylene (PP) polymer and un-crosslinked ethylene propylene diene monomer (EPDM) rubber, in some cases a low degree of cross-linking required to limited elastomeric properties, and high hardness. These materials are used in many applications where are require high volume, low cost and high toughness over (PP) such as automotive bumpers, glass car and reactor, therefore this type now represented major type of elastomers.

**3) Thermoplastic Vulcanisates (TPE-V or TPV)**

These materials are compounds from blended of (PP) and crosslinked (EPDM), however they have been vulcanized during the processing step. They are using for automotive seals, pipe seals, and other applications where a heat resistance up to (120 ℃) and high compression resistance is required. The new TPE-V being, termed super TPV or elastomeric alloys which distinguish by high performance elastomers, high heat resistance and high chemical resistance.

**4) Thermoplastic Polyurethanes (TPE-U or TPU)**

These materials can be based on polyester urethane or polyether urethane types and they are used in many applications such as shoes, industrial belting, ski boots, wire and cable. Where, rubber products requires excellent tear strength, abrasion resistance, flexural resistance, fatigue resistance, hardness and melting point.

**5) Thermoplastic Polyesters (TPE-E)**

These types of TPE materials have crystalline domains, where one kind of block copolymer is crystallizes with other block copolymer is non-crystallizes in adjacent chains to give same effect of SBS rubber. These materials are used where required high chemical resistance and heat resistance up to (140 ℃). Also, exhibit good fatigue resistance, stiffness, abrasion resistance and tear strength. The applications of these materials in automotive, hose, snowmobile, bellows, wire and cable.

**6) Melt Processable Rubber (MPR)**

This material is designed for more applications that required high chemical resistance, particularly resistance to oil and grease and noise-dampening such as automotive components. The compression strength of this material is higher than the thermosetting elastomers, and possesses the properties similar to vulcanized rubber.

**7) Thermoplastic Polyether Polyamides (TPE-A)**

This type of TPE materials consist of bonding the polyether and polyamide to give good heat resistance, chemical resistance, and higher melting point. The melting point determines the processing temperatures that needed to shape it's, and determines the ultimate service temperatures. These materials are used in many applications such as electrical cable insulation and aerospace components.