Lecture No. (4)
Elastomer Materials
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Generally, the elastomer (rubber) material is an amorphous polymer, that stable in three dimensional structures (network) with large molecules chains motion depends on the material's glass transition temperature (Tg). All polymers above glass transition temperature (Tg), act as rubbers due to entanglements. However, when the entanglements break, the polymer will begin to flow. The glass transition temperatures of all rubber are quite low, usually below room temperature, therefore many polymers at room temperatures act as rubbers (elastomers) and being makes with many useful properties. The elastomers are used in many applications because of their unusual properties, which are unmatched by other types of materials.

The elastomer materials can be modified after curing by heat, irradiation, and vulcanization with chemical materials by chemical reaction. Elastomer have the property of viscoelasticity (having both viscosity and elasticity), also dissipates energy because of its viscoelastic nature. However, the vulcanization reduces the viscosity; increase the elasticity, also elastomer would be insoluble in boiling solvent and becomes more resilience.

The elastomer is often used interchangeably with the term rubber. The difference between an elastomer and a rubber is the term rubber, that previous use to refer the originally of natural rubber (NR), which naturally derived from organic materials that occurred naturally in nature, this term was first used by English. While, the elastomer used for materials which is derived from by-products of petroleum or natural gas, and produced synthetically by human, to give the synthetic rubber.

Behaviors of Elastomer Materials

An elastomer material is represented the one type of polymer materials which has very weak intermolecular forces with long molecules chains, and having high failure degree compared with other materials such as (steel and ceramic), and can be stretched to several times up to (10 times) of original
length and producing large deformations (strains), when subjected to external stress and complete returning to their original dimensions rapidly and forcibly when the stress is removed.

The elastomers (rubber) are differentiated from other polymers by the mechanical property, because any rubber material consist of relatively large and long molecules chains having a high degree of flexibility and mobility, which allow to high deformability of these materials, when subjected to external loads, this process as shown in Figure (1). These molecules chains are joined by chemical bonds into a network structure, also at some time a slightly cross linked structure, that are capable of recovering their original shape rapidly after being stretched, without any residual or non-recoverable strain, because of high chain mobility.

Hence, elastomers derived from two words (elastic polymer), elastic (describing the ability of a material to extension and return to its original shape when a load is removed) and mer (from polymer, in which poly means many and mer means parts).

Figure (1): (A) unstressed polymer, (B) same polymer under stress, when the stress is removed, it will return to their original configuration.
Under normal conditions the long molecules chains making up an elastomeric material as randomly distribution and irregularly coiled. But when application force on it, the molecules chains straighten out in the direction of force pulled. When removal of this external forces, the molecules chains spontaneously return to their normal configuration and original shape, also became random arrangement and irregularly coiled.

**Classification of Elastomers**

Depending on the polymer structure and degree of the chemical bonds in the polymers, elastomeric materials can have properties similar to thermosetting or thermoplastics, so elastomeric materials can be divided broadly into two types:

1- **Thermosetting Elastomers:** are those elastomer materials having a three dimensional (cross link) structure, and can be swelling but do not dissolve in solvents, which do not melt when heated, usually that require vulcanization, such as styrene butadiene rubber and butadiene rubber.

2- **Thermoplastics Elastomers:** are those elastomer materials having a liner structure, and can be dissolves in suitable solvents but do not swelling, which melt when heated, usually that not require vulcanization, such as polystyrene rubber, polyethylene rubber. The configuration of elastomers, thermosetting and thermoplastic types are shown in Figure (2).

![Figure (2): The Configuration of Three Types of Polymers.](image-url)
and natural rubber (NR). Whereas general elastomer are unsuitable in many applications and required higher performance the specialty elastomers are used, these materials are more costly and hence are produced in smaller volumes, such as silicon rubber (MQ), polyacrylic rubber (PAR). The thermosetting elastomers types are shown in Figure (3).

![Flow Chart of Thermosetting Elastomers Classification](image)

**Figure (3): Flow Chart of Thermosetting Elastomers Classification.**

Most elastomers are thermosets, these materials require curing. In the curing process, the long molecules chains held together by chemical bonds (covalent bonds), then material becomes stronger, and it cannot be remelted, remolded, recycled, and reprocessed. Some elastomers are thermoplastic, these materials not require curing and the molecules chains are joined by the physical bonds, this is weaker bonds such as (hydrogen bonds, vander walls bonds or dipole-dipole interactions) to aggregation of the molecules into hard domains. These materials melting to a liquid state when heated, and return to the solid state when cooled sufficiently, therefor, can be repeatedly remelted, remolded and recycled. The principal commercial elastomers are listed in the Table (1), which indicates some of their important properties and applications.
Table (1): Properties and Applications of Principal Commercially Elastomers.

<table>
<thead>
<tr>
<th>Polymer Type</th>
<th>Glass Transition Temperature (°C)</th>
<th>Melting Temperature (°C)</th>
<th>Oil Resistance</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>polyisoprene (natural rubber, isoprene rubber)</td>
<td>−70</td>
<td>25</td>
<td>P</td>
<td>tires, springs, shoes, adhesives</td>
</tr>
<tr>
<td>styrene-butadiene copolymer (styrene-butadiene rubber)</td>
<td>−60</td>
<td>—</td>
<td>P</td>
<td>tire treads, adhesives, belts</td>
</tr>
<tr>
<td>polybutadiene (butadiene rubber)</td>
<td>−100</td>
<td>5</td>
<td>P</td>
<td>tire treads, shoes, conveyor belts</td>
</tr>
<tr>
<td>acrylonitrile-butadiene copolymer (nitrile rubber)</td>
<td>−50 to −25</td>
<td>—</td>
<td>G</td>
<td>fuel hoses, gaskets, rollers</td>
</tr>
<tr>
<td>isobutylene-isoprene copolymer (butyl rubber)</td>
<td>−70</td>
<td>−5</td>
<td>P</td>
<td>tire liners, window strips</td>
</tr>
<tr>
<td>ethylene-propylene monomer (EPM), ethylene-propylene-diene monomer (EPDM)</td>
<td>−55</td>
<td>—</td>
<td>P</td>
<td>flexible seals, electrical insulation</td>
</tr>
<tr>
<td>polychloroprene (neoprene)</td>
<td>−50</td>
<td>25</td>
<td>G</td>
<td>hoses, belts, springs, gaskets</td>
</tr>
<tr>
<td>polysulfide (Thiokol)</td>
<td>−50</td>
<td>—</td>
<td>E</td>
<td>seals, gaskets, rocket propellants</td>
</tr>
<tr>
<td>polydimethyl siloxane (silicone)</td>
<td>−125</td>
<td>−50</td>
<td>F</td>
<td>seals, gaskets, surgical implants</td>
</tr>
<tr>
<td>fluoroelastomer</td>
<td>−10</td>
<td>—</td>
<td>E</td>
<td>O-rings, seals, gaskets</td>
</tr>
<tr>
<td>polyacrylate elastomer</td>
<td>−15 to −40</td>
<td>—</td>
<td>G</td>
<td>hoses, belts, seals, coated fabrics</td>
</tr>
<tr>
<td>polyethylene (chlorinated, chlorosulfonated)</td>
<td>−70</td>
<td>—</td>
<td>G</td>
<td>O-rings, seals, gaskets</td>
</tr>
<tr>
<td>styrene-butadiene-styrene (SBS) block copolymer</td>
<td>−60</td>
<td>—</td>
<td>P</td>
<td>automotive parts, shoes, adhesives</td>
</tr>
</tbody>
</table>
General Properties of Elastomers

1- Relatively soften.
2- High elasticity (flexibility).
3- High resiliency.
4- High durability.
5- Oil and fuel resistant.
6- Swell in the certain solvents.
7- Low permeability to gases, water and steam.
8- Good electrical and thermal insulation.
9- Weathering resistance.
10- Deteriorate by oxidation.
11- High abrasion resistance.
12- Low creep resistance under load.
13- Low modulus of elasticity.
14- High strength especially under conditions of shear and compression.

Special Properties of Elastomers

The most important properties of elastomer materials are elasticity and resiliency, which are explaining follow:

1- Elasticity

Elasticity is the property of elastomers that allows them to being compressed, stretched or bended, after force is applied and return to their original shape when the force is removed. The elasticity is derived from the ability of the long chains to reconfigure themselves to amorphous distribute as unapplied stress. The covalent bonds (cross-linkages) help and ensure the elastomer to return to its original configuration when the stress is removed, but without cross-link or with short cross-link, uneasily reconfigured chains.

Therefore, when the elastomer structure no contains cross-links, and a force application on it causes both elastic and plastic deformation; after the load is removed, the elastomer is permanently deformed, because of uneasily
reconfigured chains. But when cross-linking occurs in elastomer, the elastomers still undergo large elastic deformation; however, when the load is removed, the elastomer returns to its original shape, these behaviors as shown in Figure (4). As result of this materials have extreme flexibility, and extend from (5-10) times depending on the specific material.

![Figure (4): (a) Elastomer without Cross-Links, (b) Elastomer with Cross-Linking.](image)

2- Resiliency

Resiliency is the property of elastomers that refers to the speed of return (recovery) it's to the original shape after a deforming force (external force) is removed. The deforming force is applied as input energy to the elastomer, when the elastomer returns to its original shape, part of these input energy is not returned but is dissipated as heat energy within the elastomer. The ratio of the returned energy to the input energy is defined as the material’s resilience.