

## 05 Properties of materials: 3. Polymers

### ***Polymers***

Of the three basic types of materials, polymers are the newest and at the same time the oldest known to man. Polymers form the living organisms and vital processes of all life on Earth.

With the exception of natural rubber, nearly all of the polymeric materials used in engineering today are synthetic. The materials themselves are made by chemical processing, and most of the products are made by solidification processes.

A polymer is a compound consisting of long-chain molecules, each molecule made up of repeating units connected together. There may be thousands, even millions of units in a single polymer molecule.

The word is derived from the Greek words *poly*, meaning many, and *meros* (reduced to *mer*), meaning part. Most polymers are based on carbon and are therefore considered organic chemicals.

Polymers can be separated into plastics and rubbers. As engineering materials, they are relatively new compared to metals and ceramics, dating only from around the mid-1800s

For our purposes in covering polymers as a technical subject, it is appropriate to divide them into the following three categories, where:

(1) and (2) are plastics and,  
(3) is the rubber category

(1) Thermoplastic polymers.

(2) Thermosetting polymers.

(3) Elastomers.

### ***(1) Thermoplastic polymers.***

also called thermoplastics (TP), are solid materials at room temperature, but they become viscous liquids when heated to temperatures of only a few hundred degrees.

This characteristic allows them to be easily and economically shaped into products.

They can be subjected to this heating and cooling cycle repeatedly without significant degradation of the polymer.

### ***(2) Thermosetting polymers.***

or thermosets (TS), cannot tolerate repeated heating cycles as thermoplastics can.

When initially heated, they soften and flow for molding, but the elevated temperatures also produce a chemical reaction that hardens the material into an infusible solid.

If reheated, thermosetting polymers degrade and char rather than soften.

### ***(3) Elastomers.***

are the rubbers. Elastomers (E) are polymers that exhibit extreme elastic extensibility when subjected to relatively low mechanical stress.

Some elastomers can be stretched by a factor of 10 and yet completely recover to their original shape.

Although their properties are quite different from thermosets, they have a similar molecular structure that is different from the thermoplastics.

Thermoplastics are commercially the most important of the three types, constituting around 70% of the tonnage of all synthetic polymers produced.

Thermosets and elastomers share the remaining 30% about evenly, with a slight edge for the former.

On a volumetric basis, current annual usage of polymers exceeds that of metals. There are several reasons for the commercial and technological importance of polymers:

- (1) Plastics can be formed by molding into intricate part geometries, usually with no further processing required. They are very compatible with net shape processing.
- (2) Plastics possess an attractive list of properties for many engineering applications where strength is not a factor:
  - (a) low density relative to metals and ceramics.
  - (b) good strength-to-weight ratios for certain (but not all) polymers.
  - (c) high corrosion resistance.
  - (d) low electrical and thermal conductivity.
- (3) On a volumetric basis, polymers are cost-competitive with metals.
- (4) On a volumetric basis, polymers generally require less energy to produce than metals. This is generally true because the temperatures for working these materials are much lower than for metals.
- (5) Certain plastics are translucent and/or transparent, which makes them competitive with glass in some applications.
- (6) Polymers are widely used in composite materials.

*On the negative side, polymers in general have the following limitations:*

- (1) strength is low relative to metals and ceramics;
- (2) modulus of elasticity or stiffness is also low—in the case of elastomers, of course, this may be a desirable characteristic

(3) service temperatures are limited to only a few hundred degrees because of the softening of thermoplastic polymers or degradation of thermosetting polymers and elastomers

(4) some polymers degrade when subjected to sunlight and other forms of radiation

(5) plastics exhibit viscoelastic properties, which can be a distinct limitation in load bearing applications.