Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit 73: Materials Engineering with Polymers

Unit Workbook 2

in a series of 2 for this unit

Learning Outcome 3 & 4

Polymer Material Selection

Contents

INTRODUCTION

Distinguish between the main types of polymer materials to inform the selection of a polymer material for a given application.

- *Commodity & Engineering Thermoplastics:*
  - Commonly used
- *Thermosets:*
  - Epoxies
- *Rubber & Elastomers:*
  - Natural Rubber

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

These material section charts can also be made more specific to display specific materials rather than only material groups, as shown in the example below with certain polymers highlighted in a Toughness vs Strength chart:

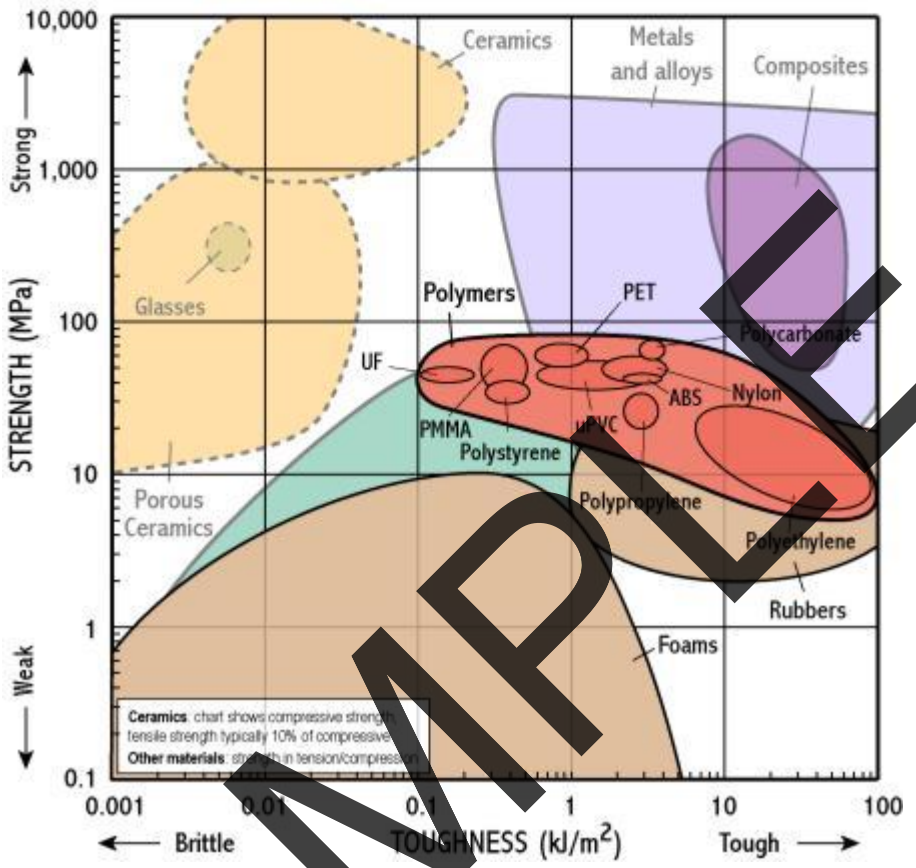

Figure 1.2: *Material Selection Chart (Polymers)*

In this chart it is clear to see that there are several materials which exhibit similar characteristics and their areas on the chart crossover. There are other factors that may also affect material selection and so therefore it is essential to consider all the relevant factors before coming to a final decision.

With an electrical wire, an insulator must be placed over the metal conductor in order to prevent current leakages. In this particular case, often PVC is used because it is naturally an electrical insulator, very tough, heat resistant and can be made with varying degrees of flexibility or hardness. In the manufacturing process the PVC is added over the metal inner through the process of extrusion at high temperature.

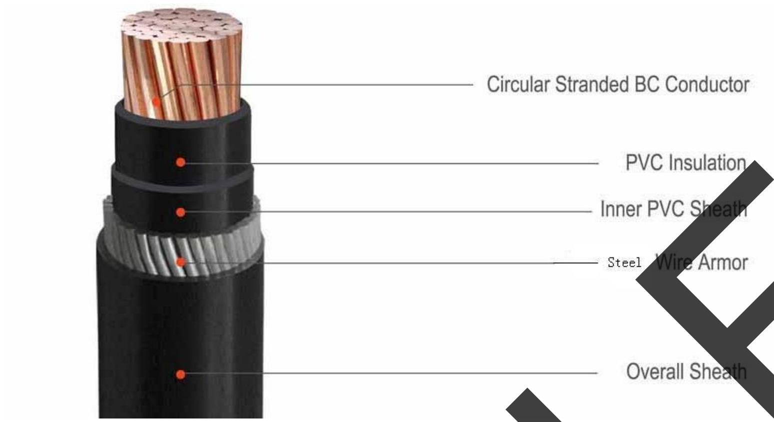

Figure 1.4: *Electrical Wire*

There are several different forms of rubber that are used in seals, gaskets and O rings. This material family is suitable for these sorts of applications because it is flexible, compressible, resistant to lubricants and oils, cost efficient to manufacture in high volume and resistant to friction and weathering. There are also several different options for manufacturing seals and O rings, they can be produced using extrusion, injection moulding, pressure moulding or transfer moulding.

Figure 1.5: *O Rings*

1.3 Identification Tests & Techniques

There are several techniques that can be used to identify a specific polymer material sample, ranging from quite simple tests that can be performed with some simple equipment to more complicated analysis techniques.

To identify a thermoplastic sample, one can simply heat it and if it starts to flow and when cooled becomes solid again this is a positive sign that it is indeed a thermoplastic. It is important to note that this process can be repeated many times, although there are a few exceptions to these rules it can be generally applied. Conversely, after processing into a finished state, thermoset plastics can only be broken down by melting after they have been chemically treated (by destroying the intermolecular crosslinks).

Generally, elastomers are easily distinguished by their physical appearance, which is usually very elastic or rubberlike. Elastomers will not melt until just below their decomposition temperature and when cooled again they will behave like a rubberlike elastomer.

With all plastics, their physical properties can be affected by additives which have a wide range off affects such as reinforcement, colour change and opacity change.

	Structure	Physical Appearance*	Density (g/cm^3)	Behavior on Heating	Behavior on Treating with Solvents
Thermoplastics	Linear or branched macromolecules	**Partially crystalline:** flexible to horn-like; hazy, milky to opaque; only thin films are transparent	0.9 – 1.4 (except PTFE: 2 – 2.3)	Material softens; fusible and becomes clear on melting; often fibers can be drawn from the melt;	May swell; usually difficult to dissolve in cold solvents, but usually readily dissolves on heating the solvent, e.g., polyethylene in xylene
		Amorphous: colorless; clear and transparent without additives; hard to rubbery (e.g., on adding plasticizers)	0.9 – 1.9	heat-sealable (exceptions exist)	Soluble (with few exceptions) in certain organic solvents, usually after initial swelling
Thermosets (after processing)	(Usually) tightly crosslinked macromolecules	Hard; usually contain fillers and are opaque. Without fillers they are transparent	1.2 – 1.4; filled: 1.4 – 2.0	Remain hard and almost dimensionally stable until chemical decomposition sets in	Insoluble, do not swell or only slightly
Elastomers**	(Usually) lightly crosslinked macromolecules	Rubber-elastic and stretchable	0.8 – 1.3	Do not flow until close to temperature where chemical decomposition occurs	Insoluble, but will often swell

Figure 1.3: *Comparison of Different Plastic Groups & Their Properties*

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add a drop of sulphuric acid to the sample or to dissolve in acetic anhydride. This will produce a reaction and a change in colour as depicted below:

	Dissolved in acetic anhydride	After addition of sulfuric acid
Colophonium	Nearly colorless	Bluish violet
Copal	Nearly insoluble, turbid	Yellowish brown
Shellac	Lemon yellow, clear	Faintly yellow brown

Figure 1.5: *Colour Reaction of Natural Resins*

The 'flame test' is also a relatively straightforward test to identify a phenolic resin which is flame-retardant and emits a distinct odour of formaldehyde. Conversely, amber resins easily ignite, even in contact with a hot piece of metal and give off the typical resin type odour.

With regards to the testing of rubbers, one simple test to perform to give an indication as to the material is to determine the melting point. Different synthetic rubbers have different melting points which are known values, so a sample can be tested to determine which recorded value it corresponds most closely to. With samples that have been exposed to the environment, there may be contaminants present within the sample that go on to affect the outcome of the melting point test and this should be considered. Leading to the conclusion that this test can only really ever be an estimation and should be combined with other identification tests to ascertain a more accurate result.

With any compound, one incredibly useful piece of equipment to test the identity is a Fourier Transform Infrared Spectrometer (FT/IR) which identifies a material's 'specific gravity'. Each material has a 'specific gravity' which is a value that has no dimensions and is essentially the ratio of the density to the density of water at a specific temperature. Some different material grades have very similar values of specific gravity and so therefore, further testing is required to identify specific grades.

The FT/IR fires infrared radiation at a sample and then measures the amount of this radiation that is absorbed and transmitted by the chemical bonds between the atoms. A 'fingerprint' of the molecule is generated which shows the amount of energy absorbed at a specific wavelength, different chemical bonds give off different sized wavelength peaks and the size of these peaks shows how much energy is being absorbed. The amount of energy absorbed helps to identify the molecular structure and therefore the material that the sample is made of.

1.5 Limitations of Polymers & Environmental Concerns

1.6.1 Polymer Failure

It is important to understand the limitations of polymer materials as well as how they can most effectively be utilised for suitable applications. As with all materials, polymers will eventually fail due to fatigue, wear and mis-use. However, unlike many traditional products such as metals and woods, polymers do not usually corrode as readily when exposed to air and water (there are several notable exceptions to this, however).

Other factors can lead to the failure of a polymer product, fractures frequently occur when the polymer product is exposed to extremes or even at relatively low stress levels. There are four main reasons for failure at low stress levels and they are: fatigue, cyclic stresses, creep rupture and long-term stresses.

On occasion, a polymer product may be subject to chemical attack or 'solvation' which results in a weakening of the structure, some acids, alkalis and salts can have this damaging effect on polymer materials. Solvation is the process whereby the polymer is penetrated by corrosive elements which, in turn, cause softening, swelling and ultimate failure. A polymer subject to a chemical attack will deteriorate regardless of whether the corrosive substance has penetrated it or not and may not even swell or soften but simply dissolve, become brittle or degrade.

1.6.2 Effects of Service Conditions to Failure

The life-expectancy of polymers is generally shorter than other traditionally used materials and they are often used or installed improperly which usually leads to earlier than anticipated failure. If a polymer used as a sealant, for example, is utilised above its softening point then the sealant material will distort and cause failure in situ.

Commonly, in real life applications, polymer materials are over-exposed to heat and sunlight which causes discolouration and potential structural weakening of the material. If the polymer is not resistant to UV and heat or has not been imbued with additives to make it so, then it will inevitably deteriorate.

1.6.3 Polymer Disposal, Recycling & the Environment

One of the greatest strengths of polymer materials is their un-reactiveness, however this is also one of their main weaknesses as it makes them difficult to dispose of. When a polymer product has reached the end of its useful life cycle there are normally several options for disposal: Landfill, Incineration, Recycling. Each of these options has issues and costs associated with them.

Landfill: This uses up large areas of valuable land which are then unsuitable for other constructive applications.

Incineration: Although polymers do release large amounts of heat when they are burned, which can be used to generate electricity, they also produce toxic gases and carbon dioxide which are harmful to humans, animals and the environment in general, adding to global warming.

Recycling: This method largely reduces the problems associated with disposal and means that, overall, it reduces the amount of crude oil that is used. However, this method can be difficult and expensive to implement as different polymers have got to be separated before they are recycled.