Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit 9: Material, Properties & Testing

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Suitability of Engineering Materials

Contents

INTRODUCTION

Determine the suitability of engineering materials for use in a specified role.

- *Materials used in Specific Roles:*
  - The relationship between product design and material selection.
  - Categorising materials by their physical, mechanical, electrical and thermal properties.
  - The effect heat treatment and mechanical processes have on material properties.
  - How environmental factors can affect material behaviour of metallic, ceramic, polymer and composite materials.
  - Consideration of the impact that forms of supply and cost have on material selection.

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.

1.1.1 Material Selection Charts

There are many different properties of any material that can be quantitatively measured and recorded, as well as being used to determine if a material should be selected for a specific use by comparing it to others. Properties of materials can be a constant that never changes or a variable depending on certain environmental input such as temperature. These standard properties of materials are all recorded and published by the relevant bodies and organisations.

The organisations which govern these records can depend on the type of material in question or the country in which they operate. Usually the manufacturer of the material will supply a data sheet which details the specific material properties, there are also large organisations such as British Standards and ISO which publish data standards on physical-chemical properties and mechanical behaviour of materials. There are many online sources of information which can be accessed easily and quickly however one must be wary of the authenticity and reliability of the information. It is therefore important to corroborate any information found online with at least one other source.
Some material properties are more commonly used than others to inform a designer/engineer of which group of materials may be suitable for a particular application. Usefully, common combinations of properties have been plotted and displayed in charts to provide an indication of these potentially useful materials. What is very useful for designers is that competing material choices can be quickly compared.

Some typical examples of these charts include: Young's Modulus vs Density, Strength vs Elongation and Electrical Resistivity vs Cost. There are many combinations of properties that can be used to identify which specific materials may be suitable. A generic material selection chart is shown below:

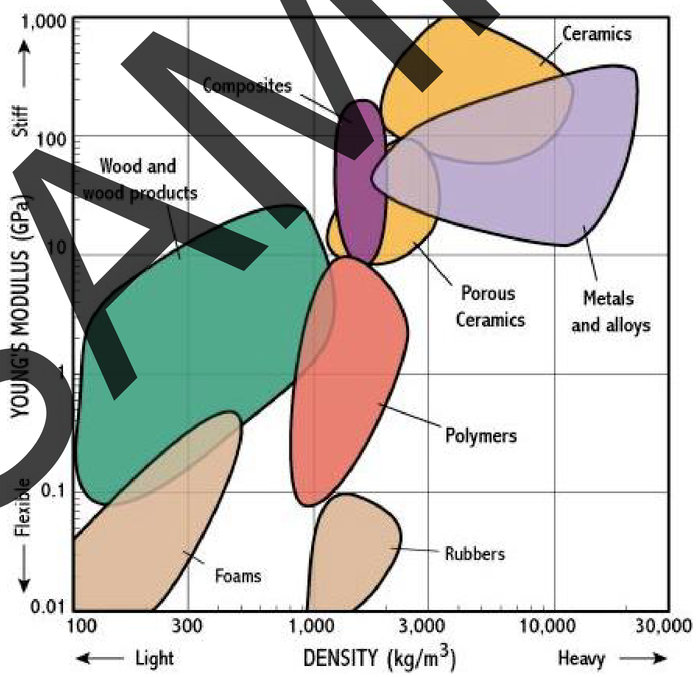

Figure 1.3: *Generic Material Selection Chart*

1.3 Heat Treatment & Mechanical Processes

1.3.1 Heat Treatment

All four categories of material can be heat-treated. This heat treatment usually comprises of heating or, in fact cooling, of the material to an extreme temperature in order to bring about a required result.

The results of this process in **metals** normally cause the them to become either harder or softer, some examples of metal heat treatments are annealing, tempering and quenching. Oftentimes, metal alloys are altered by heat treatment in order to change properties such as the elasticity, ductility, strength and hardness. At an atomic scale, the heat treatment process controls the rate of cooling which, in turn, controls the crystalline nature of the structure, in terms of composition and grain size.

Heat treatment process do not have to be limited only to one, for example there are some metal alloys which are subjected to multiple processes in order to achieve the properties required. Some examples of common heat treatment processes and the effects that they have on metals are described below:

Annealing involves the metal being heated to a specified temperature and then being cooled at a very specific and normally a rather slow rate. The intended result of this process is a refined structure on a microscopic scale, which entirely or, at least, partly separates the component parts of the metal. This means that the resultant metal material will most likely become softer so that its machinability is improved or other properties such as electrical conductivity are enhanced.

Tempering is a method of metal treatment, most commonly applied to steel in order to make it less brittle and the majority of applications call for tempering to be carried out. The metal is heated to a specific temperature below its ‘critical point’, (critical point is a term in thermodynamics signalling the point in a material where liquid and vapour coexist), the metal is then allowed to cool in still air. In order to achieve a hard but brittle result, the metal is tempered at a low temperature, whereas if a less brittle, softer result is desired, the tempering is carried out at a far higher temperature.

Quenching is a cooling process, which occurs very quickly. The results of quenching vary depending on the material being quenched. In general, a ferrous metal will become harder when quenched, whereas a non-ferrous metal will become softer. The general method is that the metal is heated above its upper critical temperature and then rapidly cooled in a fluid medium. Various different fluids can be used as the quenching medium, often forced air, water, oil and brine are used for this purpose.

Within **polymers**, annealing is another common process which reduces localised stresses and results in increased dimensional stability. The visual appearance of polymers can also be affected by the annealing process. A polymer is heated to around half of its melting temperature before being allowed to cool, this relaxes the material and results in reduced stresses when it is then moulded into its desired shape. An additional benefit to this process is that the polymer exhibits far better mechanical and thermal properties, meaning that it is less likely to crack when in service.

In general, heat treatment of polymers results in increased compressive strength and heat conductivity. These benefits are achieved at a microscopic level in a similar fashion to that of metals, the degree of crystallisation is controlled by the cooling rate.

1.4 Environmental Factors

Without sufficient protection against the environment a material is kept in, the material will eventually decay in some form or other. Ceramics are highly resistant to corrosion, much more so than most metals and alloys, however given enough time they will corrode. This may not be an issue as the length of time this takes will likely be a lot longer than the intended life cycle of the product itself anyway.

Generally, however the environment that a material exists in must be taken into account because it can have a profound effect on its properties and behaviour.

Metals usually corrode if they are left outdoors, exposed to the elements or in a wet environment, they will also begin to decay if exposed to an electrical current. Some metal alloys such as stainless steel, and natural metals like Aluminium, are non-corrosive and therefore can be considered as alternatives rather than other metals which would require some protection from corrosion. Clearly if corrosion were to occur, this would compromise the structural integrity of the material, quite significantly.

If a metal is kept in exposed sunlight for prolonged periods, this may well alter the properties of the material. Thermal expansion can occur in metals, polymers, composites and even in some ceramics on occasion. This phenomenon can cause a change in size, form and area, however exposure to high temperatures can also cause other unwanted or unexpected effects. Ferro-magnetic metals such as Iron, Nickel and Cobalt can actually lose magnetism when heated.

In general, ceramics and glass are fairly unreactive so the environment that they are kept in will have little to no effect on their behaviour and properties. Exceptions include intense heat and very highly acidic or alkaline conditions, ceramics and glass will become more ductile at very high temperatures. Some ceramics will also change in size and shape when stimulated by an electric field.

There is a small group of polymers, which are electrically active, that is to say they will undergo a change in shape and/or size when they are exposed to an electric field much like some ceramics. All metals will conduct electricity, and most will change shape when exposed to an electrical current to some degree.