EDEXCEL NATIONAL CERTIFICATE

UNIT 10: PROPERTIES AND APPLICATIONS OF ENGINEERING MATERIALS

NQF LEVEL 3

OUTCOME 3 - TUTORIAL 1
SELECTION OF MATERIALS

3 Know how to use information sources to select materials for engineering uses

Information sources: relevant standard specifications e.g. British Standards (BS), European Standards (EN), International Standards (ISO); material manufacturers' and stockholders' information e.g. data sheets, catalogues, websites, CD ROMs

Design criteria: properties e.g. mechanical, physical, thermal, electrical and magnetic; surface finish; durability e.g. corrosion resistance, solvent resistance, impact resistance, wear resistance

Cost criteria: initial cost e.g. raw material, processing, environmental impact, energy requirements; processing e.g. forming, machining, casting, joining (thermal, adhesive, mechanical); quantity; mode of delivery e.g. bulk, just-in-time (JIT); recycling

Availability criteria: standard forms e.g. sheet and plate, bar-stock, pipe and tube, sectional, extrusions, ingots, castings, forgings, pressings, granular, powder, liquid

CONTENTS

1. INFORMATION SOURCES

When searching for a material, the following information should be useful but in reality finding published data on material properties is quite difficult. You need access to the internet and to be able to register with various organisations. Good library resources with access to international standards are very useful. In the work environment, an engineer should have a good selection of manufacturers catalogues both in paper form and electronic form. These can usually be downloaded from the internet.

STANDARDS

A **standard** is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something. They are created by bringing together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process or service. All parties benefit from standardization through increased product safety and quality as well as lower transaction costs and prices.

EUROPEAN STANDARDS

European Standard (EN) automatically becomes a national standard in the 31 member countries. A standard (French: Norme, German: Norm) is a technical publication that is used as a rule, guideline or definition. **A European Standard (EN)** is a document that has been adopted by one of the three recognized European Standardization Organizations: CEN, CENELEC or ETSI. An EN is available, in principle, in the three official languages of CEN (English, French and German). A standard represents a model specification or a technical solution against which a market can trade. It codifies best practice and is usually state of the art. In essence, standards relate to products, services or systems. Today standards are no longer created solely for technical reasons but have also become platforms to enable greater social inclusiveness and engagement with technology, as well as convergence and interoperability within a growing market across industries.

Visit their web site http://www.cen.eu/cen/pages/default.aspx

INTERNATIONAL STANDARDS ORGANISATION (ISO)

ISO (International Organization for Standardization) is the world's **largest developer** and publisher of **International Standards**.
ISO is a **network** of the national standards institutes of **162 countries**, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.
ISO is a **non-governmental organization** that forms a bridge between the public and private sectors. On the one hand, many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. On the other hand, other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations.
Therefore, ISO enables a **consensus** to be reached on solutions that meet both the requirements of business and **the broader needs of society**
Visit their web site http://www.iso.org/iso/home.htm

Most British Standards now conform to ISO and when viewing BS the equivalent ISO is given.

A useful list of international standards and properties of materials may be found at
http://www.westyorkssteel.com/Steel_Specifications/natstds.htm

BRITISH STANDARDS SPECIFICATIONS (BS)

This is a very wide range of standards. In relation to materials it specifies sizes and properties to which manufacturers should conform. For example BS4 gives the dimensions of standard rolled steel universal beams. These standards are available for purchase.
http://www.bsonline.bsi-global.com/server/index.jsp

MANUFACTURERS AND STOCKISTS and DATA BASES

Properties of materials as well as sizes are also supplied by manufacturers and stockist. Finding actual properties on the web is difficult.

Often the best way into web sites is through directories and for mechanical engineering many links will be found at http://www.roymech.co.uk

This website lists the standard sizes of Steel beams and columns.
http://www.processsteels.co.uk/images/sections-big.jpg

This website gives access to the properties of their range of copper, nickel and beryllium alloys.
http://www.brushwellman.com/#

This website gives access to aluminium alloy properties.
http://aluminium.matter.org.uk/aluselect/default.asp

This website gives properties of plastics and in addition you will find much information about polymers.
http://www.bpf.co.uk/

Many organisations have produced material data bases which are available on CD rom or over the net. One of the most useful is
www.matweb.com

The following link has limited material search including a useful one on compatibility.
http://www.upchurch.com/TechInfo/chemComp.asp

The following link gives a good data base for noble metals.
http://www.platinummetalsreview.com/jmpgm/index.jsp

Some useful general material properties can be found at this link.
http://www.efunda.com/materials/materials_home/materials.cfm

This web site has some useful information on Aluminium
http://www.world-aluminium.org

This web site had many downloads on properties of metals and other information on the areas covered in these tutorials.
http://www.aalco.co.uk

These web sites let you check the compatibility of some materials with chemicals.
http://www.coleparmer.com/techinfo/chemcomp.asp
http://www.flotronicpumps.co.uk/templates/page_01.php?cfp=page:0004S

2. INTRODUCTION TO MATERIAL SELECTION

The choice of material to be used for a given component/structure/product depends on many things. The most important thing is to know and understand the properties of materials so that you can search for a suitable one. Here is a list of material properties that you might be required to enter in a search. It is not complete and the explanations of some of them are spread throughout these tutorials.

MECHANICAL PROPERTIES
Modulus
- Elastic (E)
- Shear(G)
- Bulk (K)

Poisson's ratio
Ductility - % elongation and area reduction
Strength
- Tensile
- Compressive strength
- Shear strength

Hardness
- Brinell
- Rockwell
- Vickers

Malleability
Impact strength:-
- Brittleness - Izod, Charpy
- Toughness - Izod, Charpy
- Notch sensitivity - Izod, Charpy

Fatigue properties
Creep properties
Density
Porosity
Coefficient of friction.

THERMAL PROPERTIES
Melting point
Solidus
Latent heat of fusion
Thermal conductivity
Thermal expansion
Temperature coefficient of resistance
Brittle transition temperature
Glass Temperature
Maximum service temperature
Melt flow
Processing Temperature
Vicat softening Temperature

MAGNETIC PROPERTIES
Permeability

DURABILITY/DEGRADATION
Deterioration at high temperatures
Corrosion Resistance
Resistance to oxidation
Resistance to Suphidation
Stability of properties when in service
Resistance to abrasion and erosion
Resistance to various chemical attacks
Compatibility with solvents.

SUITABILITY FOR MANUFACTURE
Machineability
Weldability
Arc Resistance
Ability to be hot and cold rolled
Ability to be drawn
Ability to be forging
Ability to be Extruded
Ability to be Cast
Mould Shrinkage
Surface finish and appearance

ELECTRICAL PROPERTIES
Resistivity
Permittivity
- Dielectric Constant
- Dielectric Strength

OPTICAL
Emissivity
Reflection Coefficient
Refractive Index

OTHER
Water Absorption
Oxygen Index
Solubility

Values can be entered into various search engines connected to data bases to find materials with the property values required. In arriving at these values you will go through other processes and the following is about these processes. Something not mentioned in the syllabus that has become a major consideration is the recycling of the materials at the end of the life span and perhaps recyclability will one day be a property.

3 DESIGN CONSIDERATIONS

The design engineer has a very large say in the choice of materials. Some of the things they should consider in the design process are given here.

STRENGTH

The component/structure/product must not fail under the action of expected stresses and forces during its intended life span. Strength can mean many things, tensile, compression, shear or torsional. The strength can be weakened due to service factors such as stress corrosion and fatigue so there are many things to consider.

ELASTICITY

The elasticity of a component depends on its modulus and explanations of Elastic, Shear and Bulk modulus along with the relationship with Poisson's ratio will be found in other modules that you should be studying.

DEGRADATION

The material must not become degraded due to service or environmental factors. This will reduce its intended life span. There are many things that cause a material to degrade such as corrosion, wear, chemical attack and radiation.

WEAR

Wear is a form of degradation due to surfaces rubbing together. The designer needs to understand Tribology (friction and wear of rubbing surfaces). He must select materials with suitable compatibility and wear resistance.

IMPACT RESISTANCE

This can be a form of degradation but also affects the strength. It occurs when the surface becomes damaged due to being struck. This could lead to fatigue failure or to sudden cracking in brittle materials. It also affects the visual appearance and may be important in house hold goods such as work tops and cooker surfaces.

SURFACE FINNISH

The final treatment of manufactured parts is called the finishing process and materials must be suitable for the process. This is conducted in order to do the following.

- ***Protect the part from corrosion and other chemical attacks.***
- ***To produce enhanced physical surface properties.***
- ***To produce an attractive appearance.***

Here is a list of finishing processes that might be used.

- ***Galvanising***
- ***Sherardising***
- ***Calorising***
- ***Chromising***
- ***Chromating***
- ***Phosphating***
- ***Metal Spraying***
- ***Cladding***
- ***Anodising***
- ***Electroplating***
- ***Plastic Coating***
- ***Paint Coating***

Some of the processes enhance the physical properties of the surface material. For example shot blasting and some machining processes place the surface into compression and so prevent the propagation of cracks. Shot blasting also relieves surface stresses. Polishing removes fine surface cracks and improves the fatigue life of the component. Coating the surface may produce better lubrication (e.g. coating in a soft metal such as indium). Other coatings (such as chrome plating) produce a hard surface. Surface hardening will make the surface resist wear and scratches.

4 CHOICE OF MANUFACTURING PROCESS

The cost of producing the component is always a big factor and the designer must consider how the component/structure/product is manufactured. To a large extent, the manufacturing process is governed by the material. The shape, size and quantities of the component are a major factor governing the manufacturing process. The mechanical properties of the finished component are affected by the manufacturing method. For example forging a crankshaft is better than turning one because it produces a grain flow that makes it stronger and more resistant to fatigue failure. Grinding and polishing also produces better fatigue strength.
Here is a list of manufacturing processes. Its is not a complete list

MATERIAL REMOVAL	**WITHOUT REMOVING MATERIAL**
Turning (lathes)	Casting.
Milling.	Moulding.
Drilling.	Forging.
Shaping.	Drawing.
Broaching.	Bending.
Blanking.	Pressing.
Grinding.	Electrical erosion.
	Chemical erosion.

The tolerance on the finished size also governs the method. Casting and moulding does not produce a high tolerance and generally material removal is the best way to produce an accurate size or fit. (e.g. grinding the outer and inner ring of a bearing race). If a mass produced component with a high tolerance is to be made, special machine tools such as broaches might be best.

WELDABILITY

Clearly any structured designed for welding must be suitable for that process and the weldability of the material is an important consideration. Arc resistance may also be a consideration.

5 COST

The cost of the product depends on the design and manufacture (processing) as covered in the preceding work. In addition costs depend on the following.

RAW MATERIAL

When more than one material meets the required specifications, the cheapest material would be logically chosen and these depend largely on the price of the raw material. For example when copper is expensive, there is a tendency to make electrical conductors from aluminium even though the cable diameter has to be increased to meet the resistance criteria.

Materials chosen for large scale manufacture may well be different to those chosen for small scale quantities. For small quantities, the material cost is not so important.

STORAGE

The material to be used and the end product may have to be stored and transported so the material must not degrade whilst in storage. Steel stock, for example should not be stored in the open where rain will accelerate rust. If a supplier can reliably supply stock quickly, then you need not bear the cost of storage.

AVAILABILITY

Again if more than one material meets the required specification, the final choice of material may depend on the availability and the one most readily available would be chosen.

QUANTITY

The price of materials may well depend on contractual arrangements with discount for quantities and regularity of orders. The choice of material, all other being equal, is not so important for small quantities.

6 FORMS OF SUPPLY

The choice of material may depend on the form of supply. The manufacturing process governs this to a large extent. For example a cylindrical component might be made from stock tube or made from flat sheet. The latter is cheaper but extra costs are involved in forming it.

Here are some of the many forms of material

Plate Coil Bar Tube

The material may be supplied in a form close to required finished product so cost can be saved in the manufacture. Standard extrusions and standard sections may be cheaper to buy and modify than fabricating or machining the shape from cheaper forms such as bar stock. Here are some examples of extrusions.

Other forms of material might include, ingots, castings and mouldings, forgings and pressings, granules and powders, chemical liquids

The raw material for many products may be in the form of liquid, pellets, grains and powder.

SELF ASSESSMENT EXERCISE

1. Go to http://www.coleparmer.com/techinfo/chemcomp.asp and determine if ABS plastic is dissolved by petroleum.

2. Go to http://www.flotronicpumps.co.uk/templates/page_01.php?cfp=page:0004S and determine if petroleum is compatible with natural rubber.

3. Go to the website http://www.matweb.com and if necessary register and log. Once you have practised using the web site, use the advanced search to find a material with the following 3 properties.

   Ultimate Tensile Strength between 55 and 65 MPa
   Hardness between 70 and 80 on the Rockwell E scale.
   Charpy notched impact energy between 0.2 and 0.25.

4. Go to the website http://www.matweb.com and find the specification for Aluminium 1050-H14. Obtain the hardness and ultimate tensile strength.

5. A structure is being designed and it is being considered whether to make it out of 4 m lengths of aluminium tube with a wall 6.36 mm thick or a stainless steel tube (304 satin polished) with a wall 1.5 mm thick. Go to the web site http://www.metals4u.co.uk and find the price of each and conclude which is the cheapest.