Selecting the Most Suitable Material for Optimized Design Using the CES Edu Pack

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Key Words: Materials, Design, Selection.

Prerequisite Knowledge: A basic knowledge of materials properties and knowledge of the basic functionality of CES.

Objective(s): To select the correct material for a given series of given design requirements.

Equipment and Materials:

1) Cambridge Engineering Selector (CES) Edu Pack. Available from Granta Design Ltd[1].
2) Computer laboratory.

Introduction:

Prof. Mike Ashby and colleagues at both Granta Design and Cambridge University Engineering Department have developed an approach over the last 20 years the use in selecting materials for engineering designs. This involves the use of both materials property (or Ashby) charts and materials indicies. This approach to selection materials has now been integrated with a software teaching package called the Cambridge Engineering Selector (CES) EduPack. The philosophy behind it is that engineers make things out of materials; to do this well they need an understanding of the world of materials and the ability to select the material that best meets the design requirements. The selection of a material has four basic steps. They are 1) translating the design requirements as constraints and objectives, 2) screen the materials world to eliminate the materials that cannot do the job, 3) rank the materials that can do the job best and finally 4) explore the pedigree of the top rated materials. This method goes through these stages.

It should be pointed out at this stage, that the same process can be applied to selecting a Shaping, Joining for Surface Treatment process. The selection of a material can also be linked to the processes, which is important for a rigorous selection for design. The software can also be used in a number of other materials and process courses. This paper will explain the methodology of selecting the correct material that can then be applied to any design problem. Students can be introduced to CES and will be able to start making selections of materials within 20 minutes.

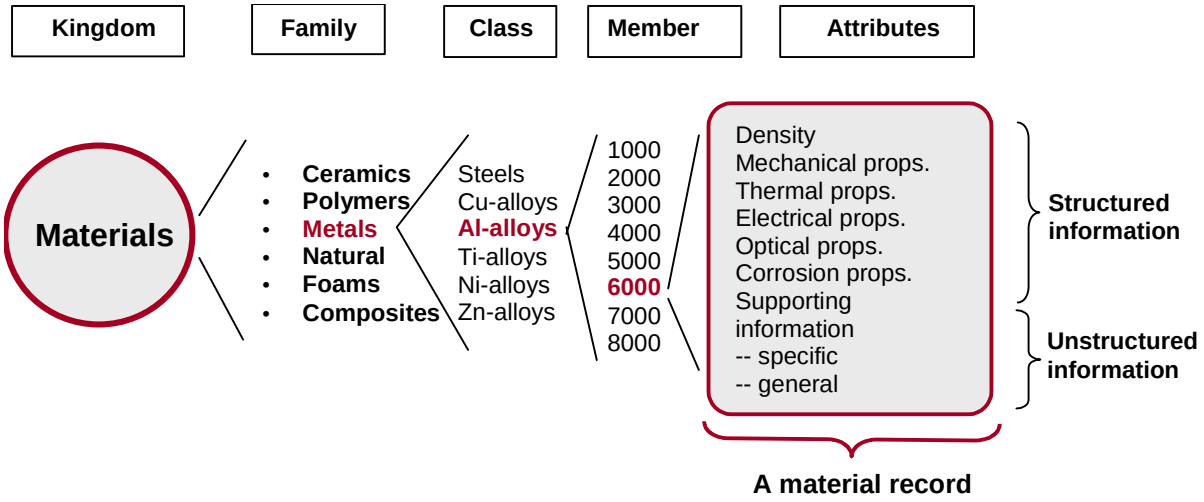

Figure 1: The World of Materials.

Procedure:

The starting point is the universe of materials, which contains families of Ceramics, Polymers, Metals, Natural Materials, Foams and Composites. Each family contains classes, sub-classes and members (fig.1). A member is characterised by a set of attributes such as mechanical and thermal properties and relevant supporting information, for example design guidelines which includes information on a materials strengths and weaknesses. From these attributes it is possible to plot a material property chart or an Ashby Plot. Student interest in the world of materials is stimulated by encouragement to use the plots generated in the CES EduPack software to explore the world of materials. For example, ceramics and metals have similar tensile strength, what properties make them so different? An easy introduction guide which helps students to have a working knowledge of CES is available[2] and contains around 15 step by step exercises to help get started. Once these exercises are complete a students should be able to apply their own design requirements into the software to choose the correct material.

The next stage is to set the design problem, whether you are simply looking for the correct material for a beam loaded in bending or for a more complicated design the procedure is the same. The selection exercise begins with an analysis of the design requirements. What is the function of the component? For example, a heat sink is designed to remove heat. These requirements are translated into constraints. For the heat sink the students would need to identify that the material must operate at a high enough temperature and that while the material needs to be a good thermal conductor, it must also be an electrical insulator. The students then need to consider other factors that may influence the design decision, you may want to minimise cost. Finally, the free variables are identified, in this case the choice of material and perhaps the shape. The CES selection software allows the student to eliminate materials that fail to meet the constraints. This can be achieved in a number of different ways. An example of which is to use the software to draw an Ashby plot, an example is given in figure 2. Even without prior knowledge of what would be an acceptable value of say thermal conductivity, students can identify the area of the plot where the materials have high values. The visual representation helps the students to identify the differences between the different classes of materials.

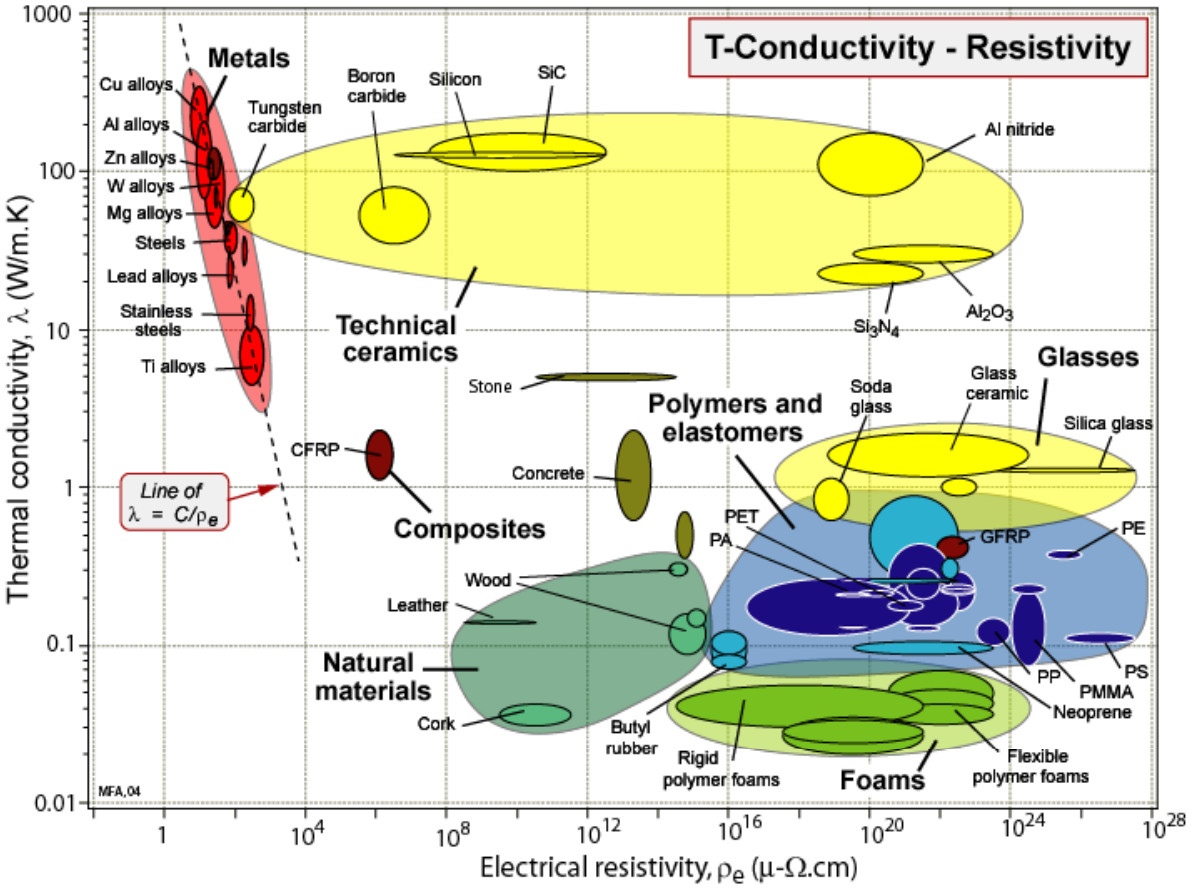

Figure 2: A Materials Property Chart of Thermal Conductivity plotted with Electrical Resistivity.

Constraints can then be added by choosing an area of the chart that contains materials with the properties that you are interested. The simplist way of doing this is a drawing a box around the area of interest (say high thermal conductivity). A more complex way would be to apply materials indicies. For a thourough explanation of these see reference 3. Constraints can also be added by using a Limit Stage where you can define set values of any of the attributes available in a materials property sheet.

Once the constraints have been added the students then need to rank the materials that remain by the ability to meet the objective that was defined in the design problem. This is usually to find the cheapest material but it may be the lightest or the best thermal conductor. If there are a small number of materials that meet the criteria and offer a solution, the students can then investigate the materials in more detail. If there are two objectives in conflict, trade-off methods allow a compromise to be found. Once the students have settled on one or two materials they can start to think about the manufacture of the design. Would the design be easy to make in this material? Would the process be economic? By applying the same method to selecting a process the students can use CES to complete the design process. More information regarding this method can be found in Materials Selection in Mechanical Design, MF Ashby[3].

Comments:

The needs of a course in design for Industrial Design Students will differ from those taking an Aeronautical Engineering Degree and within those courses the needs of a freshman student will be different to a senior student. The CES system is split into three levels of

database which makes the world of materials accessible to this wide range of students. Levels 1 and 2 are introductory and include 67 materials and 60 processes. The difference here is the number of attributes in the records. In level 3 there are over 3,000 materials and 200 processes. The level 3 database is the commercial level materials and process universe database that is used in industry across the world. There is also a range of teaching materials available to accompany the CES software system. These are available to license holders to download and include a series of lecture presentations, handouts and suggested projects that range from simple one week homework style projects to problems suitable for a senior design project. There are various packages available which make the EduPack suitable for use in many engineering disciplines including Mechanical, Materials, Aerospace, Polymer, Environmental and Chemical Engineering and Engineering Technology and Industrial Design.

References:

1) Cambridge Engineering Selector, available form Granta Design Ltd. Http://www.grantadesign.com

2) Getting Started Guide. http://www.grantadesign.com/userarea/tutorial.htm

3) Ashby, MF (1999) "Materials Selection in Mechanical Design", 2nd Edition, Butterworth Heinemann, Oxford, UK.

Bibliography:

Ashby, MF (1999) "Materials Selection in Mechanical Design", 2nd Edition, Butterworth Heinemann, Oxford, UK.