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K. N. Toosi University of Technology

Faculty of Materials Science and Engineering

Selection of Engineering Materials

Third Session
(An Introduction to Materials Selection)

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An Introduction to Materials Selection

We should always try to choose the right material for an object according to its application. The reason for the existence of material engineering science is also the same matter. Engineering and materials science was created to achieve the following:

1- Knowing the specific application (what is the part? What does it do and how does it do it)

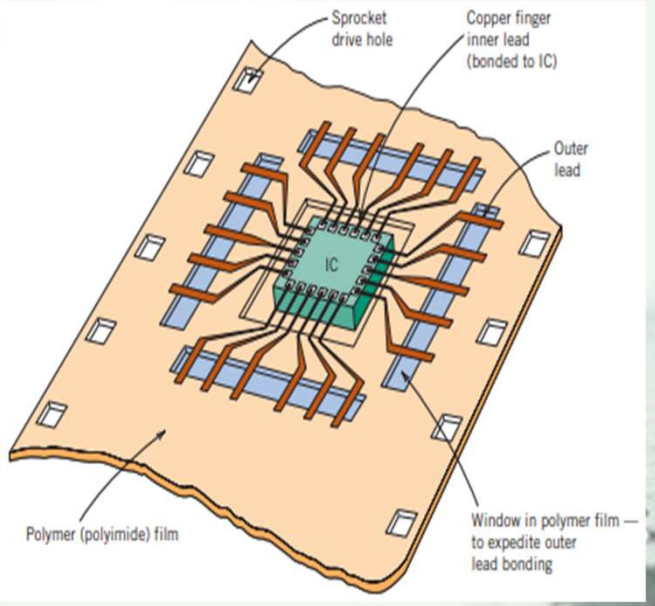
2- Determining the properties and specifications of the ideal material

3- The best choice among available materials in order to produce and manufacture the most economical and safest product

An Introduction to Materials Selection

Due to the wide application of materials in various uses and in order to respond to the above 3 cases, currently there are more than 40 thousand alloys and the same amount of non-metal engineering materials.

Artificial hip joint



IC chip

Propeller

An Introduction to Materials Selection

Classes of Property

Economic	Price and availability, Recyclability
General Physical	Density
Mechanical	Modulus, Yield and tensile strength, Hardness, Fracture toughness, Fatigue strength, Creep strength, Damping
Thermal	Thermal conductivity, Specific heat, Thermal expansion coefficient
Electrical and Magnetic	Resistivity, Dielectric constant, Magnetic permeability
Environmental Interaction	Oxidation, Corrosion, Wear
Production	Ease of manufacture, Joining, Finishing
Aesthetic	Color, Texture, Feel

An Introduction to Materials Selection

Example: A bottle for storing food and medicine must:

- Have proper strength.
- Have appropriate toughness.
- Preferably reusable.
- Be light.
- Comply with food and drug regulations.

To choose a bottle based on the above steps, you must first ask what the bottle is used for, then what properties are expected and finally what materials are suitable.

An Introduction to Materials Selection

There are three options for choosing a bottle: Metal, Glass and Plastic.

- Aluminum metal bottles have good impact resistance, light weight and fast cooling capability.
- Glass bottles have good corrosion resistance and no effect on the taste of food and can be reused.
- Plastic bottles have good corrosion resistance and lightness.

An Introduction to Materials Selection

For choosing milk bottles, weight and low price are important and reusability is not important, so plastic bottles and recently paper envelopes with plastic cover have been used. But in beverages, glass and aluminum bottles are more commonly used. Of course, it should be noted that recycling is also important.

An Introduction to Materials Selection

Comparing the Properties of Three Types of Bottles Made of Different Materials

Properties	Metal (Aluminium)	Glass	Plastic (Polyethylene)
Mechanical resistance	High	High	Medium
Toughness	High	Low	High
Hardness	Low	High	Low
Corrosion resistance	High	High	High
Thermal conductivity	High	Low	Low
Formability	High	Low	High
Recyclability	High	High	Low
Relative weight	Low	Medium	Low
Price	It depends on the economic conditions in the world and the country.		

An Introduction to Materials Selection

In general, to select materials for each application, it is necessary to first determine what properties are desired in this application, and in addition to that, economic issues should also be considered, and based on all aspects, the material with optimal conditions should be selected.

Materials Selection Process

- One of the most important requirements for designing and manufacturing products with a competitive price is the economic and appropriate selection of engineering designs, materials and manufacturing processes.
- With the vast number of materials and multiple available manufacturing processes, the selection process generally becomes a difficult one.

Materials Selection Process

- If the selection process is done without any particular order, there is a risk of not seeing attractive choices. But this risk can be reduced by using a legal selection method.

- There are several quantitative selection methods for analyzing the large amount of data related to the selection process that can be used to assess legitimacy.

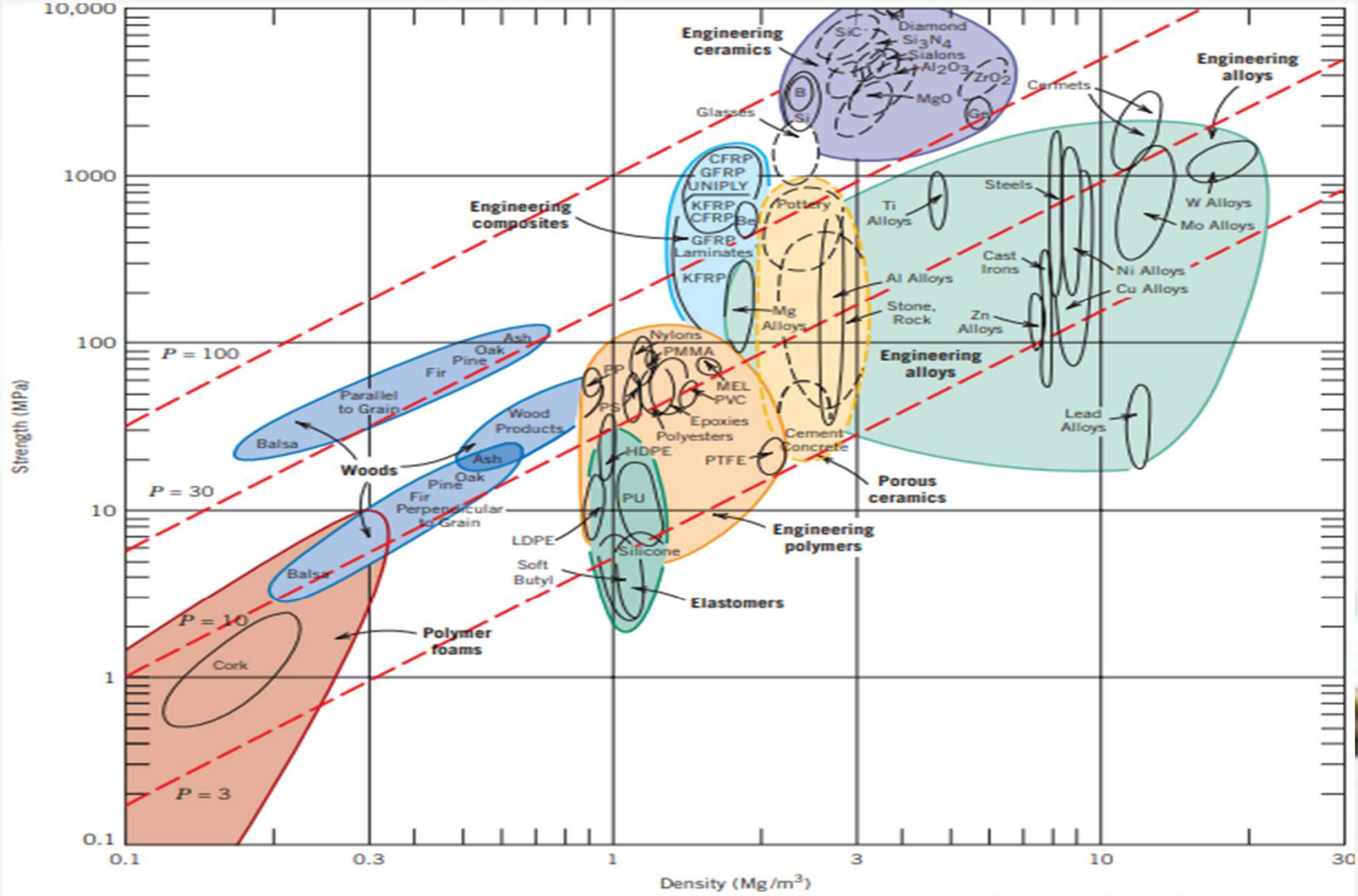
Materials Selection Process

- The industry generally does not use a long and detailed method for the selection process, and the selection is often based on previous experiences. Clearly, what has worked well before is a solution, but it may not be the optimal solution.

- It is not wise to completely ignore past experiences, but with the emergence of new materials and manufacturing processes, it is necessary to strive for possible improvements to produce more economical and competitive products.

Materials Selection Process

Ashby diagrams are one of the references for materials selection.



Materials Selection Process

Reasons for Revising the Type of Materials and Manufacturing Processes for an Existing Product

a) Taking advantage of the benefits of new materials or processes

b) Improving product performance, including more durability and higher reliability

c) Response to new legal requirements

d) Accepting the change of working conditions of the product

e) Reducing costs and increasing competitiveness

Materials Selection Process

In the initial stage of developing a new piece, the following three basic questions are asked:

1- What is this piece?

2- What does it do?

3- How does it do this?

To answer these questions, the functional requirements of the specified part and the general characteristics of the material and the general demands of the process must be determined. Based on this, certain categories of materials and processes are eliminated, and other remains as possible options for making the part.

Materials Selection Process

- After that, the relative properties of the part are determined and listed in order of importance.
- Reviewable items that have these characteristics are then sorted based on expected performance and cost. In this step, processing details are also checked.
- In this case, optimization methods can be used to select materials and optimal production method.

Materials Selection Process

In the manufacturing stage of the product, it may be necessary to make changes in the materials. For example, a problem in heat treatment, polishing, etc. will cause us to change the material. In this case, it may even be necessary to redesign due to the material change. The above steps can be summarized in the following 4 general steps:

1- Analysis of functional requirements

2- Creating different solutions for the problem

3- Evaluation of different solutions

4- Deciding on the optimal solution

Materials Selection Process

Analysis of Material Functional Requirements

The functional requirements of the material can be divided into the following five general groups:

a) Duty requirements

b) Processing requirements (processability)

c) Cost

d) Reliability

e) Resistance in working conditions

Materials Selection Process

A) Duty Requirements

Functional requirements are directly related to the desired characteristics of the part or product. For example, if the part is subjected to uniaxial tensile loading, the yield strength of the candidate material can be directly related to the force-bearing capacity of the product.

Materials Selection Process

A) Duty Requirements

Of course, some characteristics of the part or product may not have a simple relationship with the measured properties of the material, such as resistance to thermal shock, which must be related to the coefficient of thermal expansion, coefficient of elasticity, ductility and tensile strength.

Materials Selection Process

B) Processability Requirements

Processability requirements are a measure of the material's ability to accept deformation until reaching a final part.

Processability can be seen as casting, welding, machining, etc.

For a material to be deformed or hardened by heat treatment, ductility and hardenability are related properties, respectively.

It should also be noted that processing operations always affect the properties of the material.

Materials Selection Process

C) Cost

Cost is the determining factor in material evaluation. Because in many applications, there is a limit for the cost of the material, and if the cost exceeds that limit, it may be necessary to change the design so that a cheaper material can be used.

In the discussion of cost, the cost of raw materials and the process are both important, and in some cases, the total cost of work may be cheaper for a relatively expensive raw material compared to a cheaper material with a more expensive process.

Materials Selection Process

D) Reliability Requirements

Reliability requirements are the possibility of performing the intended task of the product during its lifetime without failure. It is difficult to measure the reliability of the material, because it depends not only on the inherent properties of the material, but also on the history of processing and manufacturing. But in any case, the reliability of new and unstandardized materials is less than known and standardized materials.

Materials Selection Process

D) Reliability Requirements

Failure analysis methods are used to predict possible solutions to prevent failure. By rooting out the causes of failure of a part during operation, it is usually possible to determine its relationship with defects in materials and processing, mistakes in design or unexpected conditions of use.

Materials Selection Process

E) Resistance in Work Conditions

The environment in which the product or part works plays a major role in explaining the functional characteristics of the material. For example, in a hot environment, to avoid creating thermal stresses, it may be necessary to have the same coefficient of thermal expansion of all materials, or in a humid environment, materials that are in electrical contact with each other must be carefully selected so that galvanic corrosion does not occur.

Materials Selection Process

In applications with relative motion between parts, the wear resistance of the materials involved must be considered. Overall, compatibility is a consideration in the selection process when there is more than one material in an application.

High Pressure Turbine Blade