



MEC3406 – MATERIALS SELECTION FOR ENGINEERING DESIGN

Mid Semester Test Summary



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Types of materials

Metal/ Alloys

- Good conductor of electricity
- Not transparent to visible light
- Lustrous appearance
- Strong but deformable
 - o Ordered and disordered arrangement of atoms
 - o Packing of atoms in a given volume
- Extensively used in structural applications
- E.g. steel, aluminium, copper, silver, gold, iron, brass

Polymers

- Plastics, rubbers
- Organic compounds of C, H, O & other non-metallic elements
- Low densities & flexible

Ceramics

- Compounds of metallic and non-metallic elements
- Clay, cement, glass
- Non-conductor of electricity and heat
- Resistance to high temperatures and harsh environments
- Hard & brittle

Composites

- Engineering materials made from two or more constituent materials that remain separate and distinct on a microscope level
- Carbon fibre

Structures

Non-crystalline structures – amorphous structure

- Only localised ordered arrangement of atoms
- Only short range regular arrangement
- Pattern does not repeat itself in 3D

Crystalline structure

- Regular ordered arrangement of atoms
- Atoms situated in repeating or periodic array over large distances
 - o E.g. long range order
- Pattern repeats itself in 3D

Unit cells

- Basic unit of crystal structure
- Repeated in 3D
- Displays the symmetry of crystal structures

Atomic Packing fraction (APF);

$$APF = \frac{\text{volume of atoms in unit cell}}{\text{volume of unit cell}}$$

Co-ordination Number;

$CN = \text{number of nearest neighboring atoms}$

Metal	Type	Metal	Type
Al	FCC	Mo	BCC
Cr	BCC	Ni	FCC
Co	HPC	Pt	FCC
Cu	FCC	Ag	FCC
Au	FCC	Ti	HCP
Fe	BCC	Zn	HCP

Body Centred Cubic: (BCC)

- Cubic unit cell
 - o 1 atom at centre of cube
 - o 1 at each corner (+8)
- Centre atom touches each corner
 - o Co-ordination number
 - **$CN = 8$**
- Number of atoms in each unit cell
 - o $N_{BCC} = 1 + \frac{8}{8} = 2$
- **$APF = 0.68$**

Face Centred Cubic: (FCC)

- Cubic unit cell
 - o 1 atom at centre of each face (+6)
 - o 1 at each corner (+8)
- Face centre atom touches neighbouring corners
 - o Co-ordination number
 - **$CN = 12$**
- Number of atoms in each unit cell
 - o $N_{FCC} = \frac{6}{2} + \frac{8}{8} = 4$
- **$APF = 0.74$**
- Result is more ductile
 - o Close packed => Planes slip

Material selection overall approach

Goal; To create products that perform their function effectively, safely, at acceptable costs.

Product analysis;

- Enables us to understand the important material properties which must be considered for selecting the 'best' materials
 - o Processing, aesthetic, economic etc.
- Material properties limit performance
- Usually combination of properties are important
 - o Strength to weight ratio - $\frac{\sigma_f}{\rho}$
 - o Material Index - $P = f(F) X f(G) X f(M)$

Structural index

Material index

Basic material properties

Property	Measurement	Unit
General		
Weight	Density - ρ	kg/m^3
Expense	cost/kg	\$/kg
Mechanical		
Stiffness	Youngs Modulus – E	GPa
Strength	Elastic Limit – σ_y	MPa
Fracture strength	Tensile strength – σ_{ts}	MPa
Brittleness	Fracture toughness – K_{ic}	$Mpa m^{1/2}$
Thermal		
Expansion	Expansion Coefficient – α	
Conduction	Thermal Conductivity - λ	W/m .K
Electrical		
Conduction	Resistivity	R/m

Selection steps

1. Translate
 - o Customer speak to design
2. Screen
 - o Apply go/no-go criteria
3. Rank
 - o Based on material index
4. Support
 - o What else do you know about material
5. Function
 - o What is the purpose of the design?
6. Constraints
 - o What is fixed in design?
 - o What is desirable (not necessarily fixed)
7. Objective
 - o Identify the attribute to be maximised/minimised
8. Free Variables
 - o What parameters are able to be changed

Structure, defects, deformation, strengthening

Single Crystal

- Aggregate of atoms when
 - o Regular/ordered arrangement of atoms
 - o Orientation of atoms plans repeat
 - o All unit cells meet neighbouring cell without mismatch