Lect 1 & lect 2 selection of materials

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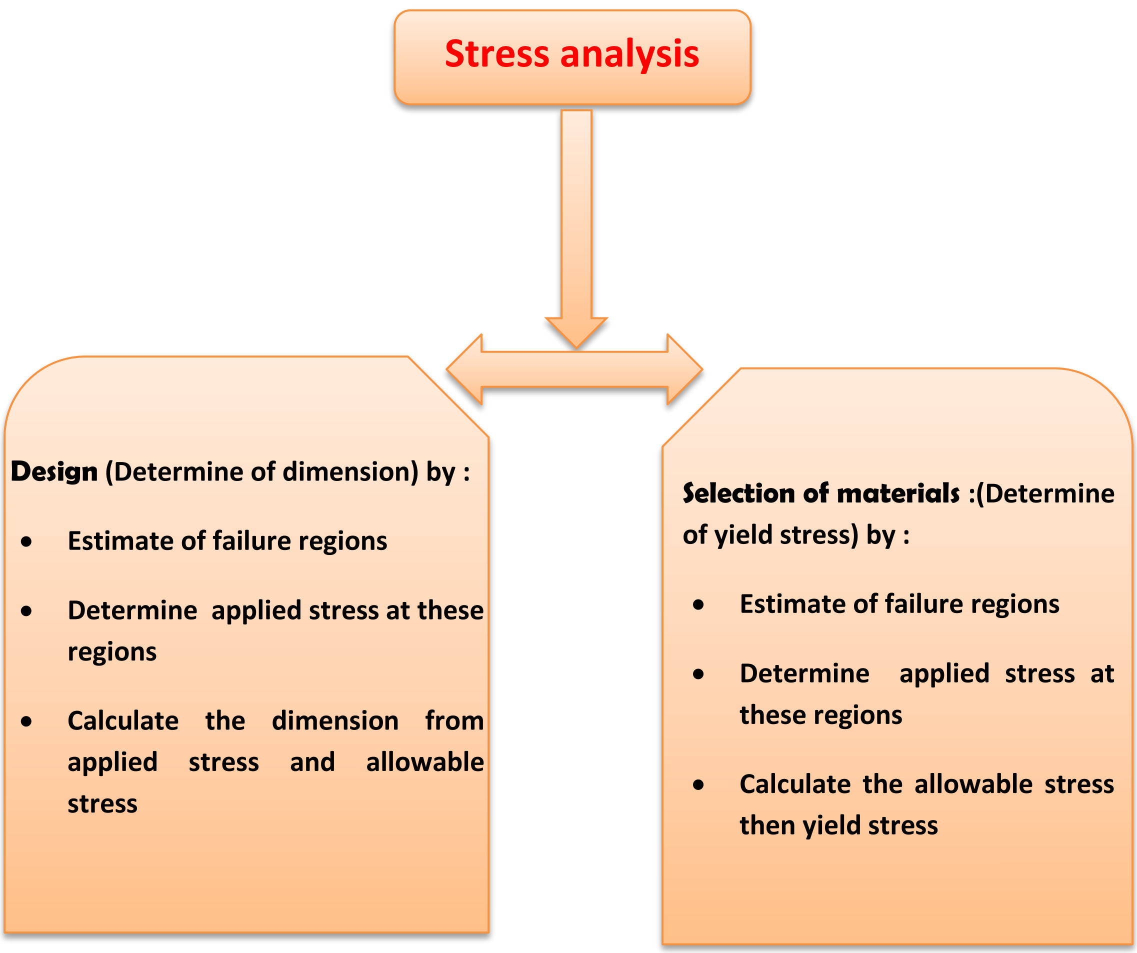
Introduction to Materials Selection:

The Material Selection Problem Design of an engineering component involves three interrelated problems: (i) selecting a material, (ii) specifying a shape, and (iii) choosing a manufacturing process.

Getting this selection right the first time by selecting the optimal combination your design has enormous benefits to any engineering-based business. It leads to lower product costs, faster time-to-market, a reduction in the number of in-service failures and, sometimes, significant advantages relative to your competition.



Factors affecting the selection of materials:

(1) - Mechanical and physical properties , service requirements and processing :

To select a suitable material for specific conditions, all mechanical and physical properties, *e.g.*,

- strength,
- hardness
- toughness,
- vibration
- heat resistance, creep and stress relaxation .
- Corrosion and wear resistance,
- fatigue
- electrical and thermal conductivity etc.
- Must consider how to make the part, for example: Casting ,Machining and Welding

(2)- Cost :

(A) Cost of the material:

In most of the cases, the cost of raw material accounts about 50 % of the finished cost. Obviously, the cost of the material is a major factor which influences the choice of the material or process. We must note that the use of cheaper material will not always reduce the final cost of the component or product. Use of cheaper material may be associated with higher processing cost due to large number of operations to be performed and also more scrap. We can easily see that this sometimes makes the overall cost more than that of expensive raw material in combination with low processing cost due to lesser number of operations and lesser scrap. The type of material affects the detailed aspect of design and hence the choice of material as well as the process is selected at the early design state *e.g*. whether the material is to be joined by spot welding, screws or rivets, must be decided at the design state.

(B) Cost of processing:

In most of the industries, the processing cost (labour cost) and other costs such as overhead costs account for about 50% of the production cost. Overhead cost in automatic industries is much more than the other costs. If one can somehow reduce all such costs, the total production cost will automatically reduce.

(3)- Component shape and dimension:

The shape and size of a component has great effect on the choice of the processing unit which ultimately effects the choice of the material. To make it more clear, we consider an example, let the best possible production method is selected, under given conditions, it is *die casting,* obviously, now the choice of the material becomes limited, i.e. one can only choose materials with lower melting points, e.g. *aluminum, zinc, magnesium* and *thermoplastics.*

There are some materials which can be finished to close tolerance while others cannot. Obviously, the required dimensional tolerance for finished components will, influence the choice of materials

(4)- Availability of the material:

We may find that sometimes the availability of the material becomes a governing factor. When the desired material supply is limited, then a costly material which is available in ample quantity may be chosen.

(5)- Application

(6) - ***Environment***

The effect that the service environment has on the part

The effect the part has on the environment

The effect that processing has on the environment

Generally, materials engineering may be classified into the following categories:

1) **Metals and alloys.**

2) **Ceramics.**

3) **Polymers.**

4) **Composites.**

5) **Advanced materials: such as semiconductors, biomaterials, smart materials, and Nano materials.**

A. Metals and alloys:

Metals are elements which have free valence electrons which are responsible for their good thermal and electrical conductivity. Metals readily loose their electrons to form positive ions. The metallic bond is held by electrostatic force between delocalized electrons and positive ions.

Note : Engineering metals are generally ***Alloys*.** There are metallic materials formed by mixing two or more elements, such as:

- **Mild steel Fe + C (C improves strength)**
- **Stainless steel Fe + C + Cr + Mn …etc. (Cr improves the corrosion resistance …etc.)**

Classification of metals and alloys:

- **Ferrous:**

Such as : ***Plain carbon steel, Alloy steel, Cast iron,***

- **Nonferrous:**

Such as *: Light Alloys* (Al, Mg, Ti, Zn), *Heavy Alloys* (Cu, Pb, Ni), *Refractory Metals* (Mo, Ta, W), *Precious metals* (Au, Ag)

B- Ceramics

• An organic components (oxides, nitrides, carbides, ..) with a combination of ionic and covalent binding , Complex crystal lattice or amorphous , (Generally) High E-modulus , Brittle especially under tensile loading and (relative) inert or very biodegradable .

C- Glasses

Close packed but disordered structure , Often network structures (silicates, phosphates, bio-active glass, ..)

D-Polymers

Chain structures with covalent bindings , Amorphous or semi-crystalline , Low E-modulus

E- Composites

Combination of two or more materials from the preceding families , Properties can be adapted by appropriate volume fractions and distribution of the different materials

Factors affecting the selection of materials:

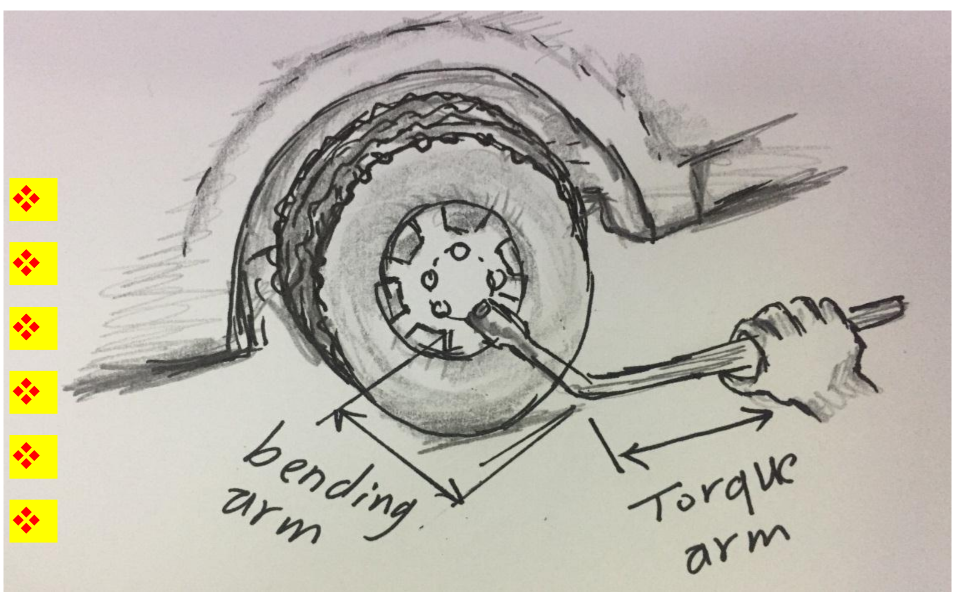
(1) - Mechanical and physical properties , service requirements and processing :

To select a suitable material for specific conditions, all mechanical and physical properties, *e.g.*,

Strength:

- Applied stress such as (axial , bending , torsion , combined stress) , this stress is not depend on materials , it is depend on shape and geometry
- Materials strength such as ultimate strength or yield stress , these type of strength is depend on materials properties only , it is not depend on the dimension or geometry , this strength can be obtain from tensile test (stress – strain curve)

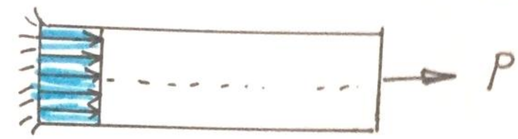
When the applied stress is higher than the yield stress of the material failure was occurs. σ applied (axial , bending , torsion or combined stress) $\geq \sigma$ yield



- axial stress

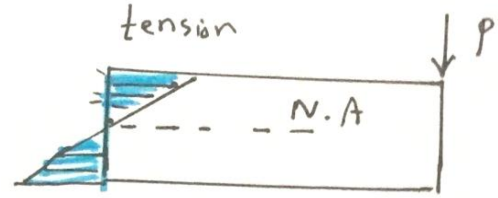
$$\sigma = \frac{P}{A}$$

uniform stress distribution



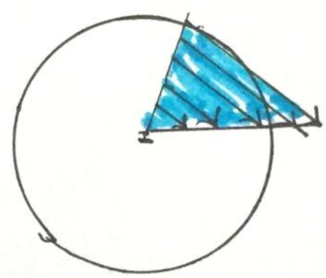
- bending stress

$$\sigma = \frac{MY}{I}$$

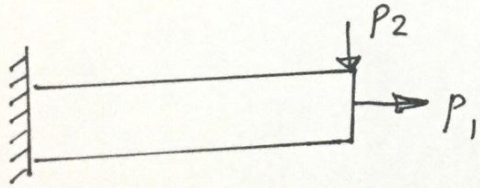


- Torsion

$$\tau = \frac{T.r}{J}$$

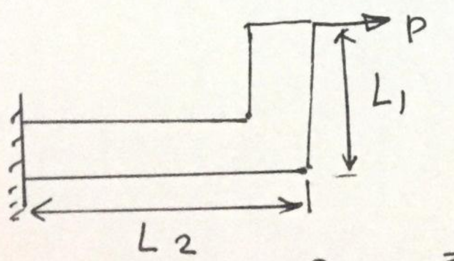


- Combined stress

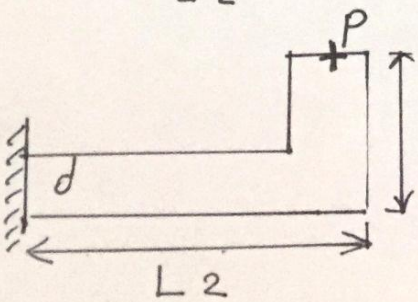


axial + bending

$$\sigma = \frac{P}{A} + \frac{MY}{I}$$



$$\sigma = \frac{P}{A} + \frac{P(L_1)Y}{I}$$



→ bending and Torsion

$$\sigma_b = \frac{(P \times L_2)Y}{I} \quad \text{and} \quad \tau = \frac{(P \times L_1)r}{J}$$

r → $\left(\frac{d}{2}\right)$

$$\sigma_{max} = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$$

❖ *(Torsion of Rectangular section) :*

. Rectangular sections

Detailed analysis of the torsion of non-circular sections which includes the warping of cross-sections is beyond the scope of this text. For *rectangular shafts*, however, with longer side d and shorter side b, it can be shown by experiment that the maximum shearing stress occurs at the centre of the longer side and is given by

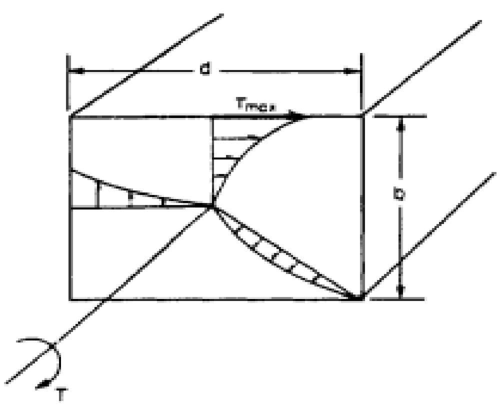
$$\tau_{max} = \frac{T}{k_1 d b^2}$$

where k_1 is a constant depending on the ratio d/b and given in Table below.

Table . Table of k_1 and k_2 values for rectangular sections in torsion'.

d/b	1.0	1.5	1.75	2.0	2.5	3.0	4.0	6.0	8.0	10.0	∞
k_1	0.208	0.231	0.239	0.246	0.258	0.267	0.282	0.299	0.307	0.313	0.333
k_2	0.141	0.196	0.214	0.229	0.249	0.263	0.281	0.299	0.307	0.313	0.333

The essential difference between the shear stress distributions in circular and rectangular members is illustrated in Fig. , where the shear stress distribution along the major and minor axes of a rectangular section together with that along a "radial" line to the corner of the section are indicated. The maximum shear stress is shown at the centre of the longer side, as noted above, and the stress at the corner is zero.



i.e. $$\tau_{max} = \frac{T}{\sum k_1 d b^2}$$

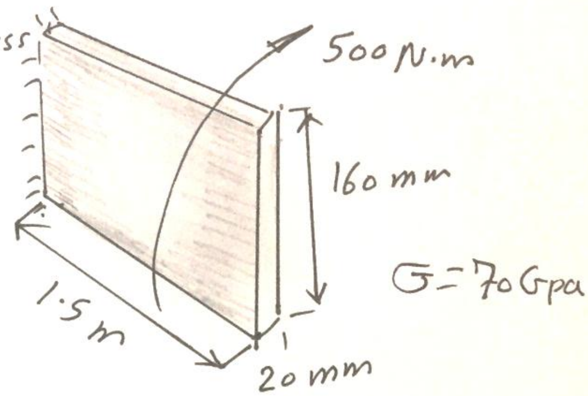
and $$\frac{\theta}{L} = \frac{T}{G \sum k_2 d b^3}$$

and for d/b ratios in excess of 10, $k_1 = k_2 = \frac{1}{3}$, so that

$$\tau_{max} = \frac{3T}{\sum d b^2}$$

$$\frac{\theta}{L} = \frac{3T}{G \sum d b^3}$$

Ex: Determine the max. stress and angle of twist.



sol:

$$\tau = \frac{T}{K_1 d b^2}$$

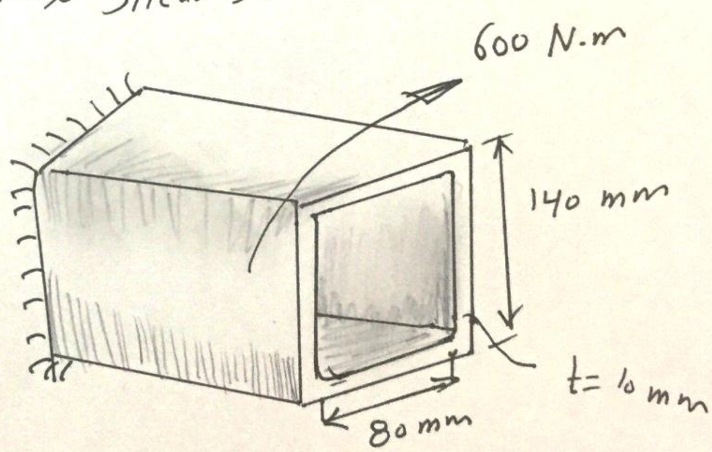
$$d/b = \frac{160}{20} = 8$$

From table $K_1 = 0.307$
$K_2 = 0.307$

$$\tau = \frac{500}{(0.307)(160 * (20)^2) \times 10^{-9}} = 25.4 \text{ Mpa}$$

$$\frac{\theta}{L} = \frac{T}{K_2 G d b^3}$$

Ex: Determin the max. shear stress



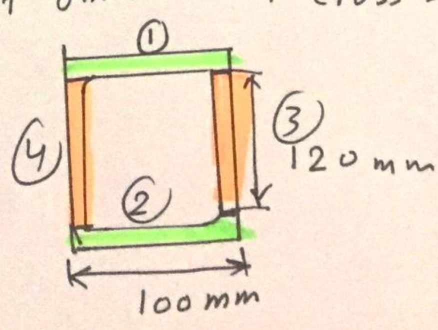
Sol:

There are four rect. therefore:

$$\tau = \frac{T}{\sum K_1 d b^2}$$

$$d/b = \frac{80}{10} = 8$$

We can rearrangement of dimension of cross section



$$d/b\,(1,2) = \frac{100}{10} = 10$$

$$d/b\,(3,4) = \frac{120}{10} = 12$$

$$K_1 = \frac{1}{3}$$

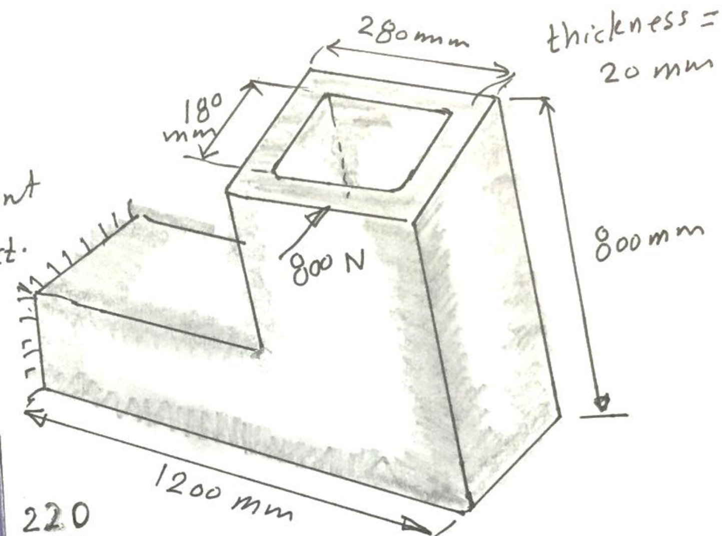
$$\tau = \frac{600}{\left(\frac{1}{3}\right)\left[2 * 100 \times 10^2 + 2 * 120 \times 10^2\right] * 10^{-9}} =$$

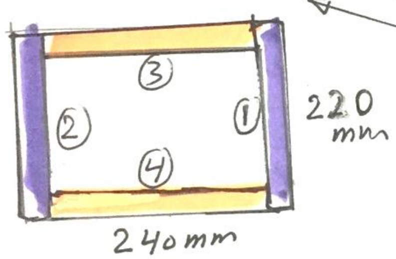
Ex: select of suitable material

Sol

$$\frac{d}{b} = 9$$

We rearrangement of dim. of cross sect.



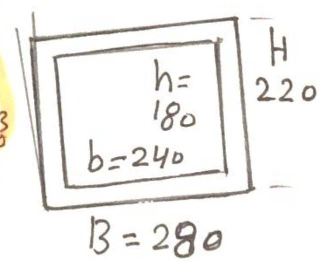


$$\frac{d}{b}(1,2) = \frac{220}{20} = 11$$

$$d/b\,(3,4) = \frac{240}{20} = 12 \Rightarrow k_1 = \frac{1}{3}$$

$$\tau = \frac{800 * (800)}{\frac{1}{3}\left(2 * 220 \times 20^2 + 2 * 240 \times 20^2\right) \times 10^{-9}}$$

$$\sigma_b = \frac{MY}{I} \rightarrow I = \frac{BH^3}{12} - \frac{bh^3}{12} = \frac{280 \times 220^3}{12} - \frac{240 \times 180^3}{12}$$



$$\sigma_b = \frac{800 * (1200 - 140)\left(\frac{220}{2}\right)}{I}$$

$$\sigma_{max} = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau^2}$$

select $\sigma_{max} \leq \sigma_y \rightarrow$ material From table.

Prob.
Select of suitable materials