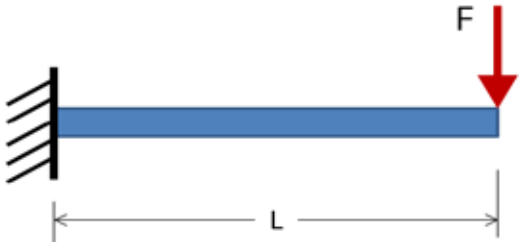
Name:

Student Id. #

Question 1: *{6 Marks}*

Consider an application of a simple cantilever beam of square cross-section with length 'L' and each side of cross-section 'b' with an objective of Stiff and Light. Develop an expression for mass of material required in terms of force (F), deflection (δ), length (L), density (ρ) and modulus of elasticity (E) of material. Group density and modulus of elasticity as one set in your solution. Also, find performance index for this application.

Deflection (δ) of this beam is given by the relation $\delta = {FL^3}/{3EI}$ where 'I' is the moment of inertia which in this case is $I = {b^4}/{12}$



Solution:

Function: Cantilever beam
Objective: Minimize mass (light) and Minimize deflection (stiff)
Constraints: Fixed length 'L'
Free variable: width of beam cross section 'b'
Mass $m = \rho.Vol = \rho b^2 L$

$$b = \sqrt{{m}/{\rho L}}$$

Deflection $\delta = {FL^3}/{3EI}$ and Since, $I = {b^4}/{12}$

$$\delta = \frac{12FL^3}{3Eb^4}$$

$$\delta = \frac{4FL^3}{Eb^4}$$

Substituting 'b' value in the above equation, we get

$$\delta = \frac{4FL^5\rho^2}{Em^2}$$

$$m = \frac{2\sqrt{F}.L^{5/2}.\rho}{\sqrt{E}.\sqrt{\delta}}$$

We are asked to group density and Elastic modulus as a set, in the question

$$m = \frac{2\sqrt{F}.L^{5/2}}{\sqrt{\delta}}.\frac{\rho}{\sqrt{E}}$$

Mass 'm' is the low if density ρ is low and elastic modulus E is high

Since F, L and δ are application based constants, Performance index 'P' is given by

$$P = \frac{\sqrt{E}}{\rho}$$

This equation gives us the maximum performance index value for the stiffest and lightest condition.

Question 2: *{4 Marks}*

a) Explain the general effect of the alloying elements in steel?

b) Which class of steel is used for tools such as drills? Explain the properties of this class of steel?

Solution:

(a)

- Increase in strength and hardness.
- Improved mechanical properties at high and low temperatures.
- Allows higher tempering temperatures while maintaining high strength and good ductility.
- Improved corrosion resistance and elevated temperature oxidation resistance.
- Improved special properties such as abrasion resistance and fatigue behavior.

(b)

High alloy steels or more specifically Tool steels are preferred for tools such as drills. Tool steels possess high hardness and high resistance to mechanical wear. Tool steels retain hardness at higher temperatures making them suitable for cutting. They also have higher resistance to corrosion.