

MATE 221: Introduction to Mechanical Properties of Materials

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Homework 5

H5.Q1:

- (a) Define a slip system.
- (b) Do all metals have the same slip system? Why or why not?

H5.Q2:

- (a) Compare planar densities for the (100), (110), and (111) planes for fcc crystal structure.
- (b) Compare planar densities for the (100), (110), and (111) planes for bcc crystal structure..

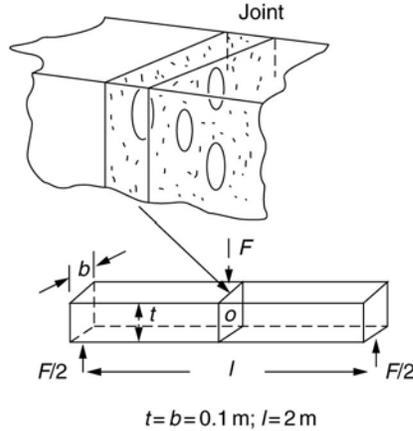
H5.Q3: One slip system for the bcc crystal structure is $\{110\}\langle 111\rangle$. Sketch a $\{110\}$ -type plane for the bcc structure, representing atom positions with circles. Now, using arrows, indicate two different $\langle 111\rangle$ slip directions within this plane.

H5.Q3 (CES Level 2):

- (a) Make a bar chart with $K_{Ic} = \sigma_f \sqrt{\pi a}$ for an internal crack of length $2a = 1$ mm plotted on the y-axis (use the 'Advanced' facility to form the function $\sigma_f = \frac{K_{Ic}}{\sqrt{3.142 \times 0.0005}}$). Which materials have the highest values?
- (b) Add an axis of density, ρ . Use the new chart to find the two materials with the highest values of σ_f / ρ .

H5.Q4 (Elements): Observe the general magnitudes of surface energies γ : they are about 1.5 J/m^2 . Thus, the minimum value for G_c should be about 2γ or 3 J/m^2 . Return to the CES Edu Level 3 database and find the material with the lowest value of G_c , which you can calculate as $(K_{Ic})^2/E$. Is it comparable with 2γ ? Limit the selection to metals and alloys, polymers, technical ceramics and glasses only, using a "Tree" stage (materials such as foam have artificially low values of G_c because they are mostly air).

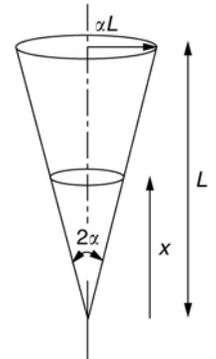
H5.Q5: Two wooden beams are butt-jointed using an epoxy adhesive as shown in the diagram. The adhesive was stirred before application, entraining air bubbles which, under pressure in forming the joint, deform to flat, cent-shaped discs of diameter $2a = 2 \text{ mm}$. If the beam has the dimensions shown, and epoxy has a fracture toughness of $0.5 \text{ MPa}\cdot\text{m}^{1/2}$, calculate the maximum load F that the beam can support. Assume $K = \sigma\sqrt{\pi a}$ for the disc-shaped bubbles.



H5.Q6: In order to test the strength of a ceramic, cylindrical specimens of length 25 mm and diameter 5 mm are put into axial tension. The tensile stress σ which causes 50% of the specimen to break is 120 MPa. Cylindrical ceramic components of length 50 mm and diameter 11 mm are required to withstand an axial tensile stress σ_1 with a survival probability of 99%. Given that $m = 5$,

use equation $P_s(V) = \exp\left\{-\frac{V}{V_0}\left(\frac{\sigma}{\sigma_0}\right)^m\right\}$ to determine σ_1 .

H5.Q7: The diagram is a schematic of a stalactite, a cone-shaped mineral deposit hanging downwards from the roof of a cave. Its failure due to self weight loading is to be modeled using Weibull statistics. The geometry of the stalactite is idealized as a cone of length L and semiangle α . The cone angle is assumed small so that the base radius equals αL . The stalactite density is ρ .



(a) Show that the variation of tensile stress σ with height x is given by

$$\sigma = \frac{1}{3} \rho g x . \text{ You may assume that the volume of a cone is given by}$$

$$V_c = \frac{\pi}{3} \times (\text{base radius})^2 \times \text{height} .$$

(b) Use the equation for Weibull statistics $\left(P_s(V) = \exp\left\{-\frac{1}{\sigma_0^m V_0} \int_V \sigma^m dV\right\} \right)$ with a varying stress to show that the probability of survival $P_s(L)$ for a stalactite of length L is given by

$$P_s(L) = \exp\left\{-\left(\frac{\rho g}{3\sigma_0}\right)^m \frac{\pi\alpha^2 L^{m+3}}{(m+3)V_0}\right\} .$$