GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1996

MECHANICS OF MATERIALS
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

-- **Please sign your name on the back of this page** --

Please **print** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

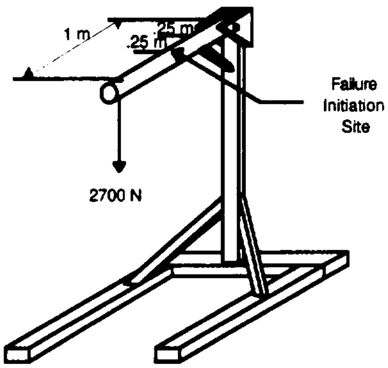
prob. I:

The sketch shows a hoist that failed at mid-span of the top member. Inspection revealed that the failure initiated from a 5 mm long through flaw that grew due to combined corrosion and fatigue. Please model this member as simply supported (neglect the horizontal force component). Determine whether the failure was by fracture or yield.

The manufacturer specified a maximum safe load of 2700 N. The operator was lifting a 2700 N engine. The weight of the engine that dropped was verified as 2700 N. How do you suppose the failure occurred?

Properties of the member:
Round aluminum tube, 7075 T651. 60mm diameter, 1mm wall thickness.
Yield strength = 505 MPa
Fracture toughness = 29 MPa$\sqrt{\text{m}}$

Recall: $I = \frac{\pi}{8} d^3 t$



Prob. II :

Hook's Law is given as

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\nu}{E}(\sigma_y + \sigma_z)$$

$$\varepsilon_y = \frac{\sigma_y}{E} - \frac{\nu}{E}(\sigma_x + \sigma_z)$$

$$\varepsilon_z = \frac{\sigma_z}{E} - \frac{\nu}{E}(\sigma_y + \sigma_x)$$

$$\gamma_{xy} = \frac{\tau_{xy}}{G}$$

$$\gamma_{xz} = \frac{\tau_{xz}}{G}$$

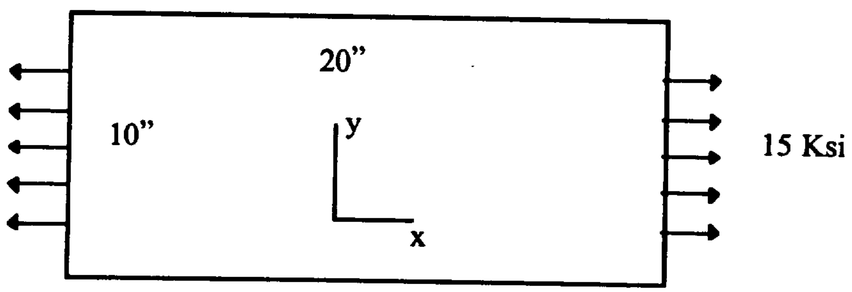
$$\gamma_{yz} = \frac{\tau_{yz}}{G}$$

a) In deriving Hook's Law, four primary assumptions are made. What are they and what do they imply about the material behavior?

b) Determine from first principles, the relationship between E and G.

c) How would you modify these equations to account for uniform heating or cooling?

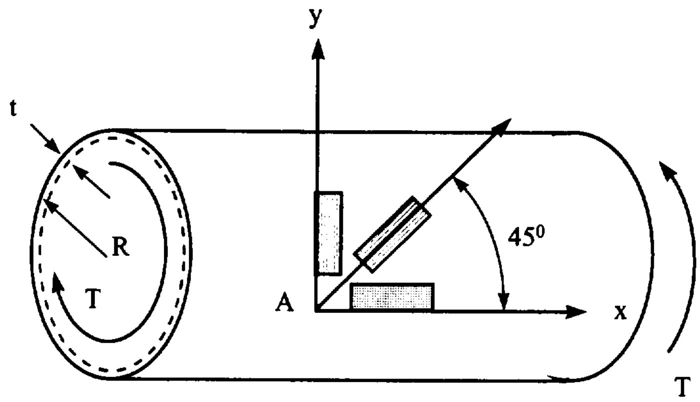
d) The 10 x 20 inch steel plate of thickness 0.25 inch shown below is subjected to a uniform stress $\sigma_x = 15$ Ksi. What stress σ_y is needed to keep the thickness constant? Take $E = 30 \times 10^6$ psi and $\nu = 0.3$.



Prob. III:

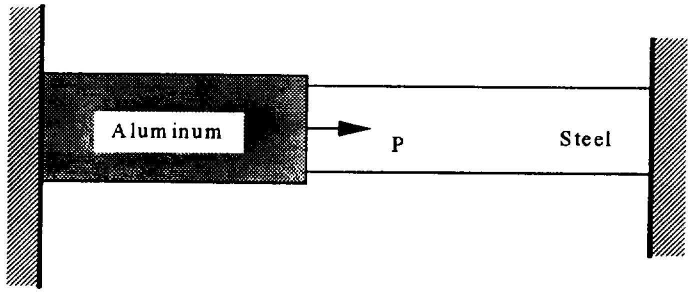
A thin-walled vessel is subjected to internal pressure p and longitudinal torque T. The vessel has a wall thickness of t and an average radius R. Three strain gauges are mounted on its surface as shown. The corresponding strain components are found to be ε_{xx}, ε_{yy} and ε_{45}, respectively. Assume that the elastic constants of the material, E and ν, are known. Find

(1) the strain tensor at point A;
(2) using the Mohr's circle, find the principal normal and principal shear strains at this point;
(3) the torque T.



Prob. IV :

Figure below shows an aluminum and a steel bar joined together and constrained between two rigid non-moving surfaces. The aluminum bar has a cross-section area of A_{Al}, length of L_{Al}, and a modulus of elasticity of E_{Al}, while the steel bar has a cross-section area of A_{St}, length of L_{St} and a modulus elasticity of E_{St}.

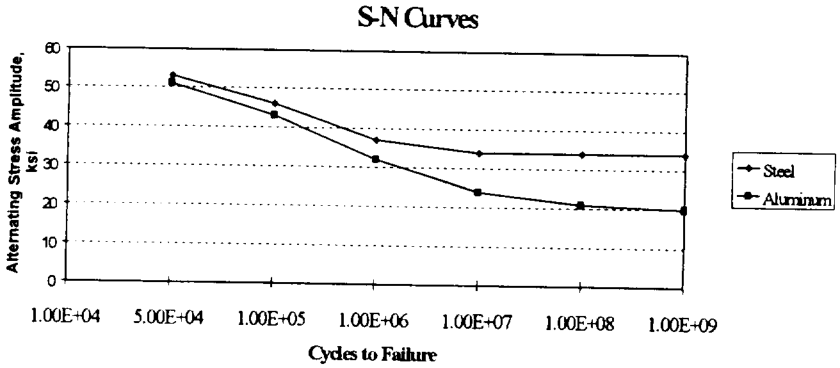


A sinusoidally varying axial force $P = P_0 \sin \omega t$ is applied through a collar with a crank arm attached at the aluminum-steel joint.

1) Determine the stresses in the aluminum and steel bars in terms of the variables specified above.

Prob. IV (cont.)

2) Assume that A_{Al} is 0.6 in^2, L_{Al} is 4.0 in, and E_{Al} is 10.3×10^6 psi; and A_{St} is 0.5 in^2, L_{St} is 8.0 in and E_{St} is 30.0×10^6 psi; P_0 is 30,000 lbf and ω 10 rad/sec. Ignoring all other modes of failure, determine the approximate number of cycles to fatigue failure for aluminum and steel bars using the S-N Curves given below.



3) Now assume that the axial force is changed to 5000 + 30000 sin 10t. Without actually working out the numbers, explain in words how you would determine the fatigue life under such loading conditions.

prob. V.

The uniformly-loaded simply supported composite beam is made of 3 layers of steel. The yield strength of top and bottom layers is σ_o, while the middle layer has been treated to raise its yield strength to $1.5\,\sigma_o$. Calculate the maximum elastic moment M_e (at the initiation of yielding) and the maximum plastic moment M_p (when the whole cross-section yielded) which can be applied to the beam. Assume that steel is elastic-perfectly plastic.