Department of Mechanical Engineering

Michigan State University

Intermediate Solid Mechanics
Ph.D. Qualifying Examination

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You may use only one reference book.

All Questions are weighted equally

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1) A block of ductile AISI 1020 steel is confined on all four sides by a rigid die as shown in the figure. A uniform compressive stress $\sigma_z$ is applied to the surface of the steel block, and it may be assumed that there is no friction between the steel block and the die. Determine a) the value of $\sigma_z$ necessary to cause yielding using the maximum distortion energy criterion (octahedral shear stress criterion) and b) the normal strain $\varepsilon_z$ at yielding. The properties of AISI 1020 steel can be assumed to be the same in tension and compression and are given as follows: elastic modulus, $E = 203$ GPa, Poisson’s ratio $\nu = 0.29$, yield strength $\sigma_o = 260$ MPa, ultimate strength $\sigma_u = 441$ MPa.
2) A wood cantilever beam of rectangular cross section supports an inclined load $P$ at its free end. Data for the beam are as follow: $b = 75$ mm, $h = 150$ mm, $L = 1.4$ m, $P = 800$ N and $\theta = 30^\circ$. Determine a) the angle $\beta$, measured from the horizontal $z$ axis, giving the orientation of the neutral axis and b) the location and value of the maximum tensile stress due to load $P$. 

![Diagram of a cantilever beam with dimensions and load P at an angle theta]
3) The cantilevered bar in the figure is made from a ductile material and is statically loaded with $F_y=200$ lbf and $F_x=F_z=0$. Analyze the stress situation in rod AB by obtaining the following information:
(a) Determine the precise location of the critical stress element.
(b) Sketch the critical stress element and determine magnitudes and directions for all stresses acting on it.
(c) For the critical stress element, determine the principal stresses and the maximum shear stress.
4) A horizontal rigid bar $AB$ is pinned at end $A$ and supported by two wires ($CD$ and $EF$) at points $D$ and $F$. A vertical load $P$ acts at end $B$ of the bar. The bar has length $3b$ and wires $CD$ and $EF$ have lengths $L_1$ and $L_2$, respectively. Also, wire $CD$ has diameter $d_1$ and modulus of elasticity $E_1$; wire $EF$ has diameter $d_2$ and modulus of elasticity $E_2$.

(a) Obtain formulas for the allowable load $P$ if the allowable stresses in the wires $CD$ and $EF$, respectively, are $\sigma_1$ and $\sigma_2$. Disregard the weight of the bar itself.

(b) Calculate the allowable load $P$ for the following conditions:

\[
\begin{align*}
E_1 &= 72 \text{ GPa}, \quad d_1 = 4.0 \text{ mm}, \quad L_1 = 0.40 \text{ m}, \quad \sigma_1 = 200 \text{ MPa} \\
E_2 &= 45 \text{ GPa}, \quad d_2 = 3.0 \text{ mm}, \quad L_2 = 0.30 \text{ m}, \quad \sigma_2 = 175 \text{ MPa}
\end{align*}
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