Imperial College London

Year 1

AERO40005 - Materials 1

PROGRESS TEST n. 1 of 2

43%

Question 1

*IMPORTANT INFORMATION **(identical to what you will see in your real exam)**:*

- *Please submit a clear summary of all your answers to Question 1 as the first page of your exam script.*
- *For Parts (a) to (d) (multiple choice questions) you are required to submit your full written solution along with your chosen answer. Failure to do so, or submission of a wrong solution, will result in a mark of 0. The markers will check your procedure only for questions answered correctly.*
- *For part (e) (true or false questionnaire) you are not required to justify your answers. Note however that wrong answers will result in a negative mark, as detailed below.*

Part (a)

A component is made from an isotropic metal with mechanical properties $E = 100$ GPa; $\nu = 0.3$; $\sigma_Y = 300$ MPa. The stress state at a point in this component is given, in a certain Cartesian reference system, by

$$[\sigma] = \begin{pmatrix} 100 & 100 & 0 \\ 100 & 200 & 0 \\ 0 & 0 & 0 \end{pmatrix} \text{MPa.} = \begin{bmatrix} \sigma_{xx} & \tau_{xy} \\ \tau_{xy} & \sigma_{xy} \end{bmatrix}$$

The material obeys the Von Mises yield criterion.

i. Is the given state of stress sufficient to initiate plasticity at this point? Justify your answer.

$$\frac{100+200}{3} = 100\,(\text{MPa}) < \sigma_Y$$

A. Yes

B. No

$$\sigma_{eq} = \sqrt{\frac{1}{2}\left[(\sigma_{xx}-\sigma_{yy})^2 + (\sigma_{xx}-\sigma_{zz})^2 + (\sigma_{yy}-\sigma_{zz})^2 + 6(\tau_{xy}^2+\tau_{xz}^2+\tau_{yz}^2)\right]} = 244.9 < \sigma_Y$$

C. The information given is not sufficient to answer the question. 0 [9%]

ii. Calculate the volumetric strain in the component and state if this is

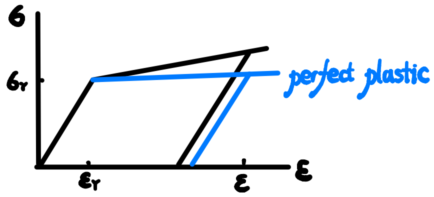
A. $\varepsilon_V = 0$

B. $\varepsilon_V = 1.2\ 10^{-3}$

$$\varepsilon_V = \frac{\sigma_H}{K} = \frac{\sigma_H}{\frac{E}{3(1-2\nu)}} = 1.2\times10^{-3}$$

C. $\varepsilon_V = 2.6\ 10^{-3}$

D. None of the above. 9 [9%]



Part (b)

A tensile specimen has gauge length $L_0 = 20$ mm. It is made from a perfectly plastic metal with nominal properties $E = 100$ GPa, $\sigma_Y = 300$ MPa. During a test the gauge portion is stretched by $\Delta L = 2$ mm and the specimen is subsequently unloaded. Necking does not occur.

i. Calculate the final gauge length of the specimen and state if this is

A. $L_f = 21.32\,\text{mm}$

B. $L_f = 21.94\,\text{mm}$

C. $L_f = 20.09\,\text{mm}$

D. None of the above.

$\varepsilon_Y = \frac{\sigma_Y}{E} = 3\times10^{-3}$

$\varepsilon = \frac{\Delta L}{L_0} = 0.1$ $\quad\therefore \Delta\varepsilon = 0.097$

$\cancel{\therefore \Delta\sigma = \Delta\varepsilon H}$

$L = L_0 + \Delta L = L_0 + L_0\Delta\varepsilon$
$= 21.94\text{mm}$

0 [18%]

ii. Calculate the hardness of the material after this test and state if this is

A. $100\,\text{MPa}$

B. $900\,\text{MPa}$

C. $> 900\,\text{MPa}$

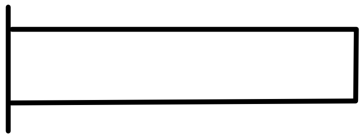
D. None of the above.

$H = 3\sigma_Y = 900\text{MPa}$

(Tabor's construction)

0 [8%]

Part (c)



A horizontal cantilever beam of length $L_0 = 3\ \mathrm{m}$ and square cross-section of area $t \times t$ needs to be designed. The beam, of density ρ, is required to carry only its own self-weight without yielding. The maximum stress for a cantilever subject to its own self-weight is given by

$$\sigma_{\max} = \frac{3\rho g L^2}{t},$$

where $g = 9.81\ \mathrm{m/s^2}$ is the acceleration due to gravity.

Calculate the merit index for a design of minimum cost and state if this is

A. $\sigma_Y{}^2 / (\rho^3 c)$

B. $\sigma_Y / (\rho c)$

C. $\sigma_Y{}^2 / (\rho c)$

D. None of the above.

cost = mc

$\sigma_{max} = \frac{3\rho g L^2}{t}$ $\therefore t = \frac{3\rho g L^2}{\sigma_Y}$

$m = \rho V = \rho t^2 L_0 = \rho \frac{9\rho^2 g^2 L^4}{\sigma_Y^2} L_0$

18 [18%]

$\therefore m \propto \frac{\rho^3}{\sigma_Y^2}$

$\therefore mc \propto \frac{\rho^3 c}{\sigma_Y^2}$

$\therefore M_I = \frac{\sigma_Y^2}{\rho^3 c}$

Part (d)

A resistance strain gauge of gauge factor $S = 2$ is inserted in a Wheatstone bridge in half-bridge configuration. If the strain gauge is subject to a strain of $\varepsilon = 10^{-3}$ and its original resistance is $R_0 = 120\,\Omega$, calculate the expected change in resistance ΔR and state if this is

$$\frac{\Delta R}{R} = S\varepsilon$$

A. $\Delta R = 2.304\ \Omega$

B. $\Delta R = 1.152\ \Omega$

C. $\Delta R = 0.002\,\Omega$

$$\therefore \Delta R = S\varepsilon R = 0.24\Omega$$

D. None of the above

0 [6%]

Part (e)

State if the following are true or false. You will receive 8 points for each correct answer, -8 points for each incorrect answer, 0 points for each unanswered question.

F i. The formula $\sigma_t = \sigma_n\left(1+\varepsilon_n\right)$ is only valid for metallic materials.

F ~~T~~ ii. The indentation of a solid by Rockwell, Brinnel or Vickers indenters gives rise to self-similar strain distributions.

T iii. A body is in equilibrium, subject to vanishing body forces $\left(\underline{b} = 0\right)$ and in a state of plane stress. If σ_{xx} does not depend on the x coordinate, then τ_{xy} does not depend on the y coordinate.

T iv. A body is subject to a state of equibiaxial plane stress, that is $\sigma_{xx} = \sigma_{yy} \neq 0$ while all other stress components are equal to zero. The state of stress in the $(x\text{-}y)$ plane is, in this case, independent of the choice of reference system.

16 [32%]