AML 883 Properties and selection of engineering materials

Major Examination **2 hours** **5 May, 2005**

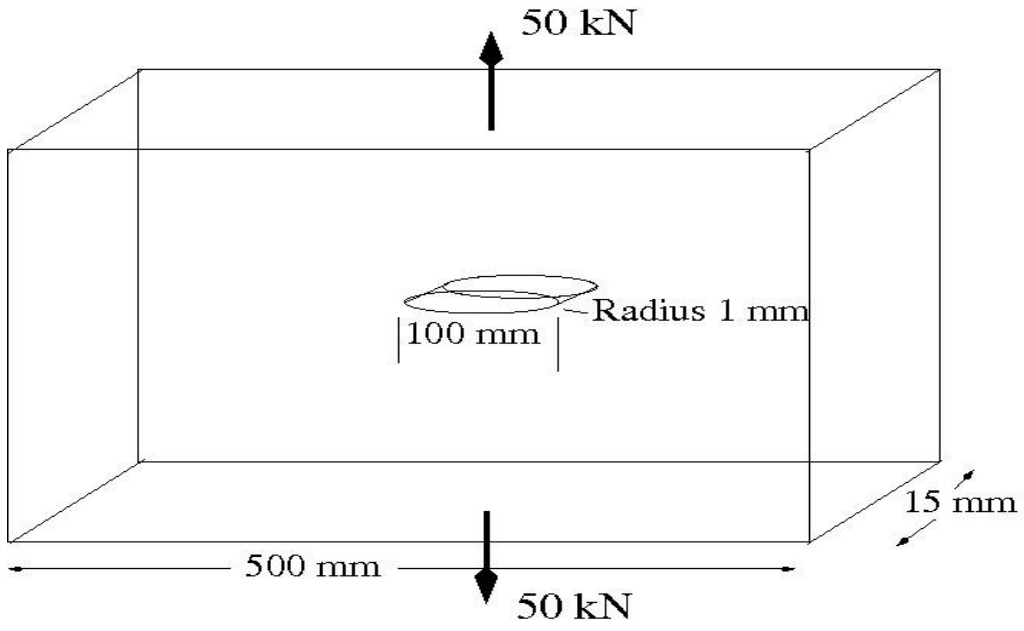
Instructions

- **Please answer all the questions**
- **Please answer all the questions in your own words**
- **For numerical examples, please give all the steps; wherever needed, draw neat diagrams and graphs with proper labelling; explain all symbols; give the answers in proper units**
- **This is an open book exam; use the book for data that might be needed (unless specified); write down the page number in brackets next to the data that you are taking from the book.**
- **The maximum points are 400**

Question 1

(a) The stiffness S of an atomic bond in a particular material is 50 N/m and its center-to-center atom spacing is 0.3 nm. What, approximately, is its elastic modulus? (15 points)

(b) A plate with rectangular section 500 mm by 15 mm carries a tensile load of 50 kN. It is made of a ductile metal with a yield strength of 50 MPa. The plate contains an elliptical hole of length 100 mm and a minimum radius of 1 mm, and is oriented with its length perpendicular to the applied stress as shown below. What are the nominal and maximum stresses in the plate? Will the plate start to yield? (30 points)



(c) Given the enthalpy of formation of vacancy in aluminium to be 68 kJ/mol, calculate the equilibrium concentration of vacancies at 0, 300 and 900 K. (30 points)

Question 2

(a) Consider two samples of well-annealed, pure iron; one of them, say, A, shows a yield strength of 272 MPa, while another, say B, shows a yield strength of 450 MPa (at room temperature). Which microstructural feature you think is responsible for this difference? (15 points)

(b) Consider two samples of a precipitation hardened aluminium alloy (with the same volume fraction of precipitates, nominal dislocation density, and composition); one of them, say A, shows a tensile strength of 500 MPa while another, say B, shows a tensile strength of 120 MPa. Which microstructural feature do you think is responsible for this difference? (15 points)

(c) The Young's modulus and yield strength (0.2 % proof) for beryllium are 318 GPa and 117 MPa respectively, while the corresponding values for a 6063 aluminium alloy are 60 GPa and 215 MPa, respectively. Schematically show the stress-strain cruves for these two materials on the same plot. (45 points)

Question 3

(a) Of the following four surface finishing processes, which one will be able to give both the best roughness and tolerance specifications? Precision machining, grinding, lapping and polishing. (15 points)

(b) Schematically show the microstructures of a metal casting (a) closer to the mould wall, and (b) at the centre of the cast. (35 points)

Question 4

(a) A 200-tonne 747 is brought to rest from 200 kmph. How much is the heat energy generated? (15 points)

(b) A 10 cm cube of copper (density 2710 kg/m^3 and yield strength 12 MPa) is placed on a very hard surface. Caluclate the actual area of contact. (15 points)

(c) For good oxidation resistance, the oxide layer should be adherent to the surface. The adherence of an oxide film is dependent on the ratio (known as Pilling-Bedworth ratio) of the volume of oxide formed to that of metal consumed during oxidation. What should this ratio be for a protective film to be formed on the surface? Why? (25 points)

(d) Pipework with a radius of 20 mm and a wall thickness of 4 mm made of 2 1/4 Cr Mo steel contains a hot fluid under pressure. The pressure is 10 MPa at a temperature of 600^{o}C. The creep constants for this steel are as follows: Reference strain rate $\dot{\epsilon}$ = 3.48 x 10^{10} /second. Reference stress σ_0 = 169 MPa. Rupture exponent, m = 7.5 and Activation energy Q_c is 280 kJ/mol. Calculate the creep rate of the pipe wall, assuming steady-state power-law creep. (45 points)

Question 5

(a) If the density of a new alloy is 7380 kg/m^3, give an estimate of its specific heat. (15 points)

(b) What is the energy that is responsible for making some materials ferromagnetic? Explain. (15 points)

(c) An X-ray system has a beryllium window to transmit the beam. The absorption coefficient of beryllium for the wavelength of X-rays of itnerest here is 3.02 x 10^2 m^{-1}. If the window is 2 mm thick, what fraction of the incident beam intensity will pass through the window? (15 points)

(d) Use the following data to make an electrical resistivity versus yield strength material property chart in the log-log graph sheet given to you. (55 points)

Material	Resistivity (10^{-8} ohm m)	Tensile strength (MPa)
Silver	1.5	125
Copper	1.7	210
Aluminium	2.8	60
Tungsten drawn wire	5.5	2800
Nichrome wire	108	1000
Kanthal wire	135	800

Question 6 (20 bonus points)

What do you think is the most important concept or fact that you learnt from this course?