The University of Nottingham

DEPARTMENT OF MECHANICAL, MATERIALS, AND MANUFACTURING ENGINEERING

A LEVEL 2 MODULE, AUTUMN SEMESTER 2011-2012

MECHANICS OF SOLIDS 2

Time allowed ONE Hour and THIRTY Minutes

Candidates may complete the front cover of their answer book and sign their desk card but must NOT write anything else until the start of the examination period is announced

Answer THREE questions

Only silent, self contained calculators with a Single-Line Display or Dual-Line Display are permitted in the examination.

Dictionaries are not allowed with one exception. Those whose first language is not English may use a standard translation dictionary to translate between that language and English provided that neither language is the subject of this examination. Subject specific translation dictionaries are not permitted.

No electronic devices capable of storing and retrieving text, including electronic dictionaries, may be used.

DO NOT turn examination paper over until instructed to do so

ADDITIONAL MATERIAL: Graph Paper

INFORMATION FOR INVIGILATORS:

1. A steel drive shaft, shown in Fig. Q1, is subjected to a torque of 1 kNm and has a self weight which acts as a uniformly distributed load along the full length of its span of 2 m. The shaft is supported at either end by short bearings which can be modelled as simple supports.

   Given that the shaft has a hollow circular cross-section with outer diameter, 75 mm, and inner diameter, 60 mm, determine the principal stresses and the maximum shear stress at position A on the lower surface at mid span.

   [ρ_{steel} = 7800 kg/m^2] [33]

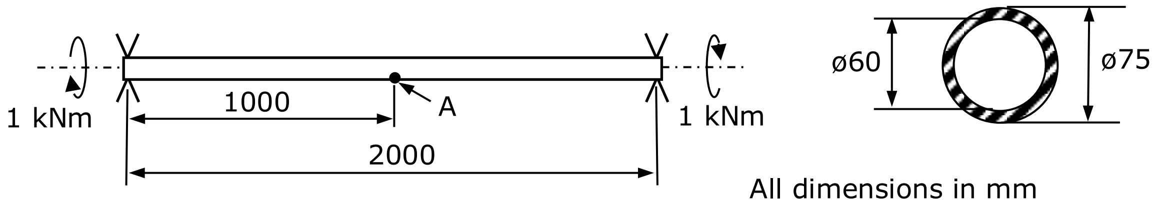

Fig. Q1

2. The inverted T-section, symmetrical about the vertical centre line, with dimensions shown in Fig. Q2, is subjected to a vertical shear load, S = 45 kN, acting down the vertical centre line of the section. The neutral axis (N.A.) for the section is at a position 77 mm below the top surface.

   Determine:

   (a) The 2nd moment of area of the section about its neutral axis. [10]

   (b) the magnitudes of the vertical shear stress on the centre line at the join between the flange and the web and at the neutral axis [18]

   (c) Using the values determined in (b), sketch the variation of vertical shear stress down the vertical centre line. [5]

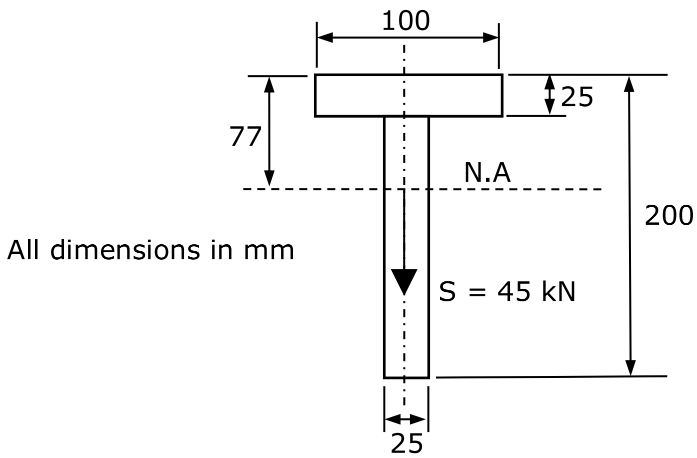

Fig. Q2

3. (a) Describe the 3 key stages in the process of fatigue crack growth. [10]

(b) Compare and contrast the S-N approach and the stress intensity factor approach to fatigue life calculation [10]

(c) A large steel plate has a centre crack for which

$$K_{max} = 1.12\sigma\sqrt{\pi a}$$

The steel has a fracture toughness of 200MN/$m^{3/2}$ and σ_y = 210 MN/m^2. If the operating stress is 150 MN/m^2, determine the critical initial crack size assuming linear elastic material. [13]

4. (a) The beam, ABC, shown in Fig. Q4, is mounted on a wall, at end A, by a pin joint and is supported by a vertical cable at position B, half way along its span. A load, P = 5 kN, is applied at the free end C. Use Macaulay's method to determine:

i) the deflection at the free end C. [12]

ii) the slope at the free end C. [12]

[EI = 10^4 Nm^2]

(b) The cable is replaced by a spring with spring constant k = 20x10^6 N/m. What is the deflection at the free end C under these conditions? [9]

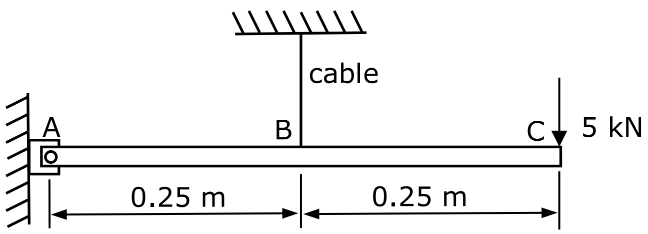

Fig. Q4

5. A closed end thin-walled pressure vessel, made from steel, has a mean diameter 80 mm, and wall thickness 1 mm. It is subjected to an external torsional load of 1 kNm acting about its axial axis.

(a) Using the Tresca yield criterion, determine the maximum allowable pressure of the cylinder. [16]

(b) Using the von Mises yield criterion, determine the maximum allowable pressure of the cylinder. [17]

[The modulus of elasticity of steel is 200 GPa and the yield strength is 250 MPa]

Tresca criterion: $\left|\max\left(\sigma_1 - \sigma_2, \sigma_2 - \sigma_3, \sigma_3 - \sigma_1\right)\right| \geq \sigma_y$

von Mises criterion: $\frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2} \geq \sigma_y$

where σ_1, σ_2, σ_3 are the principal stresses.