



# **EXAMINATIONS 2014 / 2015**

## **AHOLIADAU 2014 / 2015**

## **Semester 1**

**FACULTY OF: Applied Design & Engineering**

**NAME OF COURSE/PROGRAMME:** BEng Manufacturing Systems Engineering  
BEng Mechanical & Manufacturing Engineering

**YEAR OR LEVEL:** Year 3 (PART TIME)

**NAME OF MODULE/UNIT/EXAM PAPER:** Advanced Stress Analysis

**MODULE NO:**

**DATE OF EXAMINATION:** 23/01/15

**EXAMINATION TIMES:**

**START TIME:** 1:30 pm

**FINISH TIME:** 3:30 pm

**TIME ALLOWED:** 2 hours

### **INSTRUCTIONS TO CANDIDATES:**

Answer 3 from 4 questions.

1.

- i. A steel rod has a square cross section 10mm x 10mm and a length of 2m. Calculate the strain energy when a stress of 400MPa is produced by stretching it. (E=200GPa) [3 Marks]

- ii. The rod then has a metal collar fitted at the lower end, and a mass, m, is dropped onto the collar. Show, by considering the energy transferred from the falling weight to the rod, that the height, h, is related to the stress,  $\sigma$ , by the following relationship;

$$h = \frac{\sigma^2 V}{2Emg}$$

Where V is the volume of the bar, and L is the length. Assume that the extension of the bar is NOT significant in the energy transfer. [3 Marks]

- iii. If the stress must not exceed 70MPa, from what height could 100kg fall onto the collar, without exceeding this? [4 Marks]

b.

Two shafts are of the same material, length and weight. Shaft A is solid with a diameter of 100mm. Shaft B is hollow with an external diameter of  $D_B$  and an internal diameter of  $d_B$  ;

- i. By considering the volumes of the shafts prove;

$$D_B^2 - d_B^2 = 0.01\text{m}^2 \quad [2 \text{ Marks}]$$

- ii. Assuming the maximum shear stress in both shafts, use the simple theory of elastic torsion to show;

$$\frac{T_A}{T_B} = \frac{D_B J_A}{D_A J_B}$$

Where T is the torque carried, J is the polar second moment of area, and subscripts A and B represent shafts A and B respectively. [2 Marks]

- iii. Given that the hollow shaft is to store 25% more energy than the solid shaft when transmitting torque show;

$$\frac{J_A}{1.25J_B} = \frac{T_A^2}{T_B^2} \quad [2 \text{ Marks}]$$

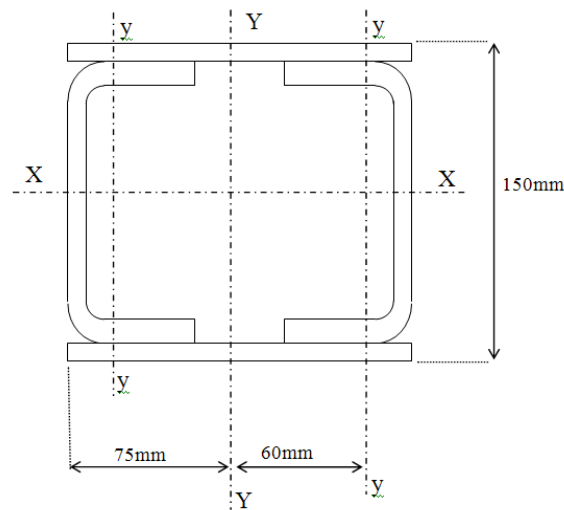
- iv. Hence find the internal and external diameters of shaft B [4 Marks]

2.

- a) Given the fact that Aluminium is approximately one third the density of steel but also one third the stiffness, briefly discuss why, in terms of vehicle stiffness, structural panels made from Aluminium can be beneficial over steel panels.

[2 Marks]

- b) The engine longitudinal of an integral vehicle chassis is fabricated from steel and is 1m long. The fabrication is symmetrical about the YY axis and is constructed from two flat 2mm plates and two 'C section' folded steel sheets as shown below. Given that the Young's Modulus,  $E$ , is 200GPa the compressive yield stress,  $\sigma_c$ , is 320MPa and a constant  $a$  of 1/7500, assuming the longitudinal is fixed at one end and free at the other, determine the following;



Properties of ONE  
folded sheet steel  
section;

$$I_{xx} = 1.5 \times 10^6 \text{ mm}^4$$

$$I_{yy} = 5.5 \times 10^5 \text{ mm}^4$$

$$A = 384 \text{ mm}^2$$

- i. Which axis will the longitudinal buckle about?  
[5 Marks]
- ii. What is the radius of gyration about this axis?  
[1 Mark]
- iii. What is the slenderness ratio of this longitudinal?  
[1 Mark]
- iv. According to Euler theory, what load will this longitudinal buckle at?  
[3 Marks]
- v. According to Rankine-Gordon theory, what load will this longitudinal buckle at?  
[3 Marks]
- vi. Comment on the results of (iv) and (v), and with the use of a diagram explain the difference between experimental results and buckling loads according to Euler theory.

[5 Marks]

3

- a) Figures Q3.1, Q3.2, Q3.3 below each show a different mode of failure. Identify each failure mode and briefly explain the mechanism of failure.

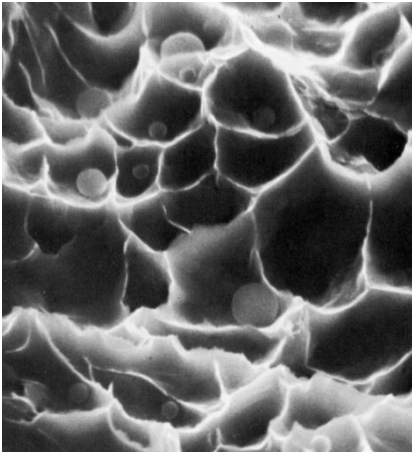


Figure Q3.1

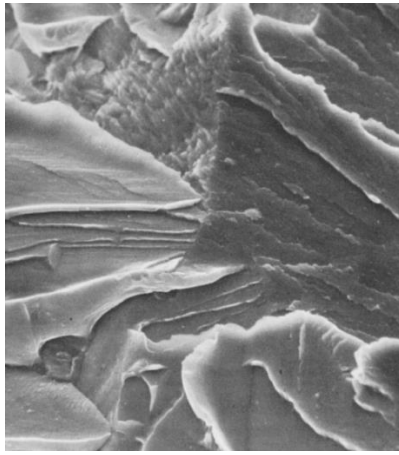


Figure Q3.2

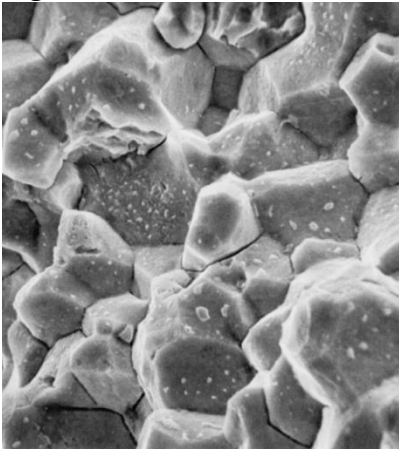


Figure Q3.3

(6 marks)

- b) Explain what is meant by the term *ductile-brittle transition*.

(2 marks)

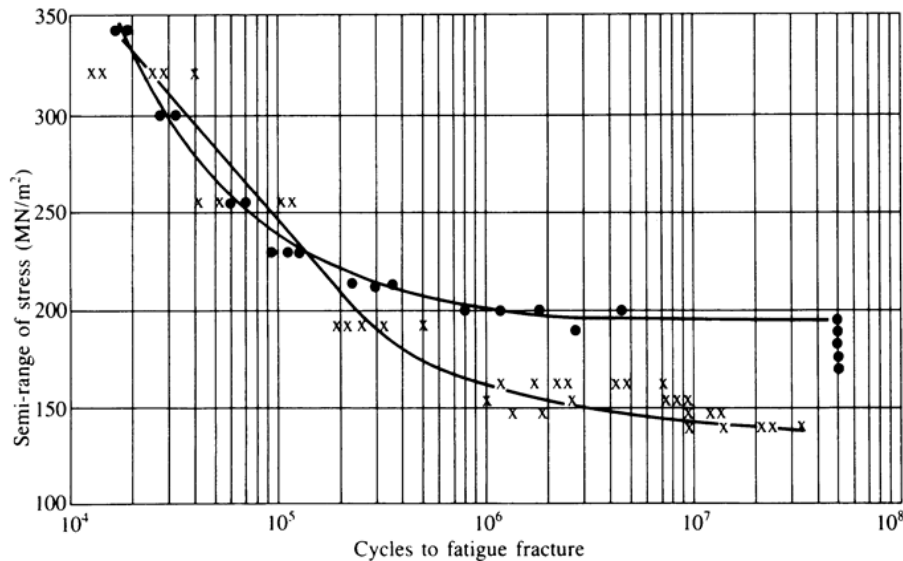
- c) Critically explain the role of each of the following factors in the ductile-brittle of steels:

- i. Temperature;
- ii. The presence and geometry of a notch;
- iii. Specimen thickness;
- iv. Strain rate;
- v. Composition;
- vi. Grain size

(12 marks)

4

- a) A mild steel shaft has a pulley mounted on each end and is supported symmetrically in between in two housings. When rotated under load the shaft will be subjected a cyclical bending moment of  $\pm 1.2$  kNm. Using a safety factor of 2 determine a suitable diameter for the shaft for infinite fatigue life.



(4 marks)

- b) The fatigue endurance from the S-N curve for a certain steel are given in the table below. If a component manufactured from this steel is subjected to 400 000 cycles at 300MPa, 200 000 cycles at 350 MPa and 125,000 cycles at 400 MPa how many cycles can the material be expected to withstand at 450 MPa before fatigue failure occurs, assuming that the Palmgren-Miner relationship applies

| Stress (MPa) | Fatigue endurance (cycles) |
|--------------|----------------------------|
| 300          | 2 500 000                  |
| 350          | 1 000 000                  |
| 400          | 500 000                    |
| 450          | 300 000                    |

(6 marks)

- c) The analysis of the cyclic stresses on part of the furnace loading car for a blast furnace shows that during each loading operation it is subjected to the stress history given in the table below. If the S-N curve for the component material is given by  $S = 600N^{-0.07}$ , where S is in MPa, estimate how many loading operations this component can withstand before fatigue failure occurs.

|                                |
|--------------------------------|
| 100,000 cycles at $\pm 60$ MPa |
| 20,000 at $\pm 100$ MPa        |
| 1,000 cycles at $\pm 125$ MPa  |
| 500 cycles at $\pm 150$ MPa    |
| 100 cycles at $\pm 180$ MPa    |
| 20 cycles at $\pm 200$ MPa     |

(10 marks)

## FORMULA SHEET

$$U = \frac{P^2 L}{2AE} \quad \text{Strain energy in tension}$$

$$U = \frac{Q^2 L}{2AG} \quad \text{Strain energy in shear}$$

$$U = \frac{M^2 L}{2EI} \quad \text{Strain energy in bending}$$

$$U = \frac{T^2 L}{2GJ} \quad \text{Strain energy in torsion}$$

$$I_{NA} = \frac{BD^3}{12} \quad \text{Second moment of area of a rectangle}$$

$$I = \frac{\pi D^4}{64} \quad \text{Second moment of area of a circle}$$

$$I_{NA} = I_G + Ah^2 \quad \text{Parallel axis theorem}$$

$$\text{P.E.} = mgh \quad \text{Potential energy}$$

$$\text{K.E.} = \frac{1}{2} mv^2 \quad \text{Kinetic energy}$$

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R} \quad \text{The simple theory of elastic bending}$$

$$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L} \quad \text{The simple theory of elastic torsion}$$

$$J = \frac{2\pi R^4}{4} = \frac{\pi D^4}{32} \quad \text{Polar second moment of area for a solid circular shaft}$$

$$\text{slenderness ratio} = \frac{L}{k}$$

$$k = \sqrt{\frac{I}{A}} \quad \text{Radius of gyration}$$

$$P_e = \frac{\pi^2 EI}{L^2} \quad \text{Buckling: pinned-pinned}$$

$$P_e = \frac{\pi^2 EI}{4L^2} \quad \text{Buckling: fixed-free}$$

$$P_e = \frac{4\pi^2 EI}{L^2} \quad \text{Buckling: fixed-fixed}$$

$$P_e = \frac{2\pi^2 EI}{L^2} \quad \text{Buckling: fixed-pinned}$$

$$P_R = \frac{\sigma_y A}{1 + a(L/k)^2} \quad \text{Rankine Load}$$