OCD039

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG (HONS) MECHANICAL ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

ADVANCED MATERIALS & STRUCTURES

MODULE NO: AME6012

Date: Thursday 10th January 2019 **Time: 10:00 AM – 1:00 PM**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer any FOUR questions only.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Electronic calculators may be used provided that data and program storage memory is cleaned prior to the examination.

CANDIDATES REQUIRE: **Formula Sheet (attached)**

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Question 1

Consider the following stress tensor matrix below,

$$\underline{\sigma} = \begin{pmatrix} 30 & 0 & 10 \\ 0 & 0 & 20 \\ 10 & 20 & 0 \end{pmatrix}$$

i. Sketch the stresses acting on an infinitesimal cube in space with this stress system. (5 marks)

ii. Determine the principal stresses acting at this point given one of the principal stresses is 21 MPa in compression. (10 marks)

iii. Evaluate also the direction of the maximum stress and show this by a simple sketch related to the GCS (xyz) system. (5 marks)

iv. If the yield stress for the material is 320 MPa determine the factor of safety assuming the material follows the Von Misses criterion. (5 marks)

Total 25 marks

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Question 2

a) A simply supported beam of dimensions 10 mm wide by 2 m long is manufactured from glass- reinforced polymer with symmetrical cross-section construction is shown in Figure 1 below. If the beam needs to support 150N at its mid-point. Using UD-GRP with modulus of elasticity of E-Glass= 70 Gpa. The matrix is made from polyester with modulus of elasticity of resin = 3 Gpa. Volume fraction, V_f for UD-GRP = 60%. Volume fraction, V_f for WR-GRP = 40%

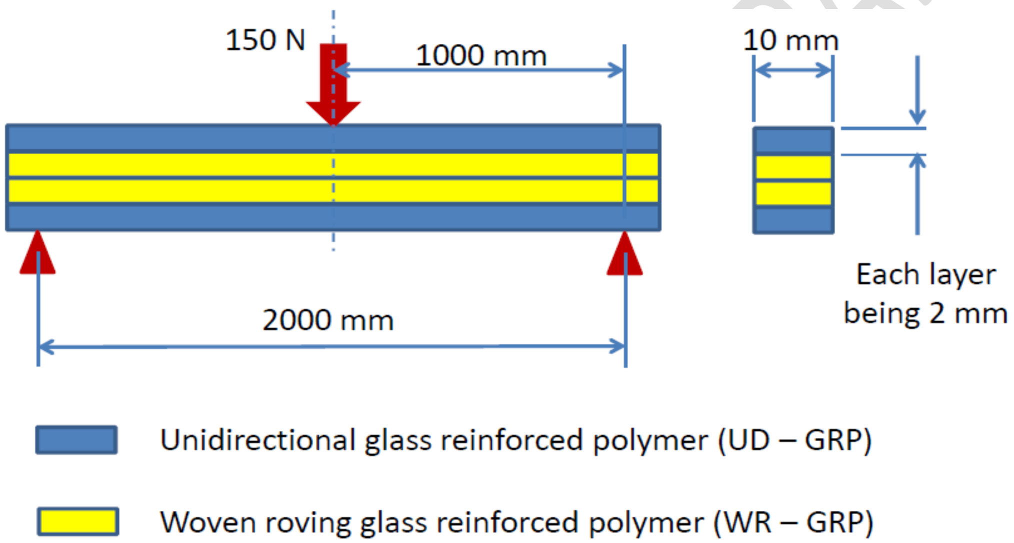

Figure 1: Simply supported composite beam.

Determine.

1) The stress in each layer of the composite beam (10 Marks)
2) The stress diagram showing salient points. (5 Marks)

Question 2 continued over the page

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Question 2 continued

b) Consider a sandwich panel with the beam dimensions outlined below in figure 2. Surface laminate is carbon fibre with a volume fraction of 65% and modulus of elasticity E = 400 GPa. With a design strain is 0.5%. For the cross section, breadth is b=100 mm, height of core, h=160 mm. Determine the thickness of the surface laminate. (All dimensions are in mm) (10 Marks)

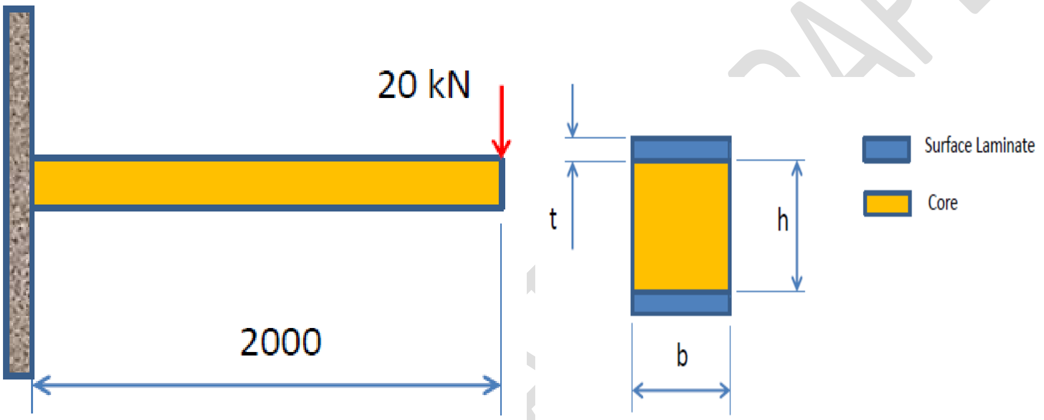

Figure 2: Composite sandwich panel with cross section.

Total 25 marks

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Question 3

a) The values of the endurance limits at various stress amplitude levels for low-alloy Constructional steel fatigue specimens are given in the Table 1 below:

Table 1: Stress & number of cycles

σ (MN/m^2)	N_f (Cycles)
550	1500
510	10050
480	20800
450	50 500
410	125000
380	275000

A similar specimen is subjected to the following programme of cycles at the stress amplitudes stated; N_f=3000 at σ =510 MN/m^2, N_f=12000 at σ =450 MN/m^2 and N_f =80000 at σ =380 MN/m^2, after which the sample remained unbroken. How many additional cycles would the specimen withstand at σ =480 MN/m^2 prior to failure? Assume zero mean stress conditions. (10 marks)

Question 3 continued over the page

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Question 3 continued

b) The fatigue behaviour of mild steel specimen under alternating stress conditions with zero mean stress is given by the expression:

$$\sigma_r^a.N_f=K$$

Where, σ_r, is the range of cyclic stress, N_f is the number of cycles to failure and K and 'a' are material constants of mild steel. It is known that $N_f = l0^6$ when a= 300 MN/m^2 and Nf = l0^8 when a, = 200 MN/m^2. Calculate the constants K and 'a' and hence the life of the specimen when subjected to a stress range of 100 MN/m^2.

(15 Marks)

Total 25 marks

Question 4

The portal frame shown in figure 3 below is applied with a horizontal force of 5KN and a vertical force of 10 KN, both the forces are situated at the center of the member. All the members are of equal length of 4m and a yield stress is 120 MPa,

a) Illustrate all the possible collapse mechanism for the portal frame considering the forces applied on the members. (5 Marks)

b) Evaluate the plastic modulus (Z_p) for the portal frame for all the possible cases. (15 Marks)

c) Determine the optimum beam dimensions for the likeliest failure mode for the hollow rectangular cross section; sketch the cross section showing all the dimensions. (5 Marks)

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Question 4 continued

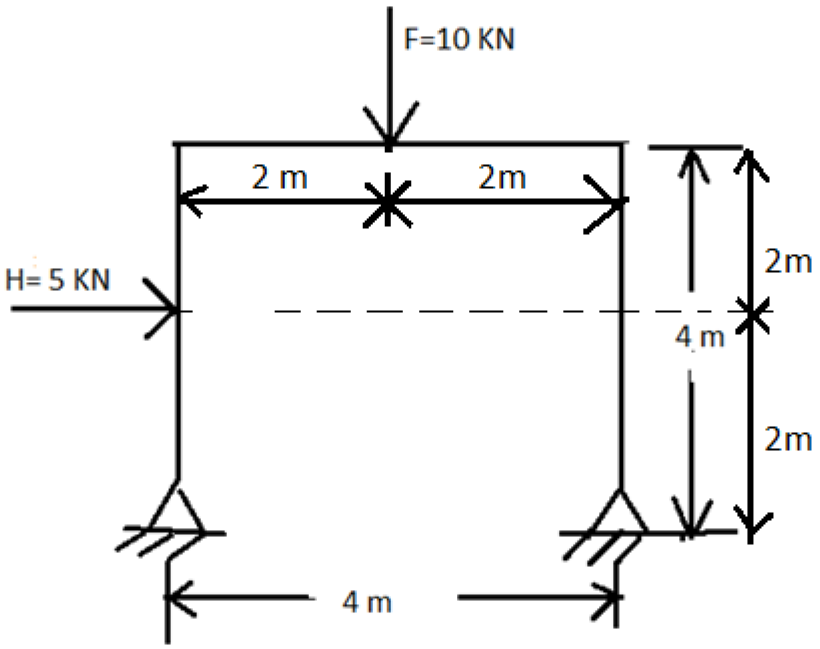

Figure 3, Portal frame with forces.

Total 25 marks

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Question 5

a) An aluminium aerofoil section of a racing car is shown in Figure. 4 with a span length of 1 m. Under the worst case scenario the section is subject to a torque of 770 Nm. Using the geometric information provided in table 2, calculate the maximum shear stress and state were this occurs. Assume modulus of rigidity, G for this material as 27 GPa. (13 marks)

b) Determine also for this condition the angle of twist over the 1m span. (3 marks)

c) If during a race the aluminium skin splits at position H determine the new maximum stress and angle of twist. (7 marks)

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Question 5 continued

d) Explain briefly why the value of the angle of twist is an overestimate compared to an actual section. (2 marks)

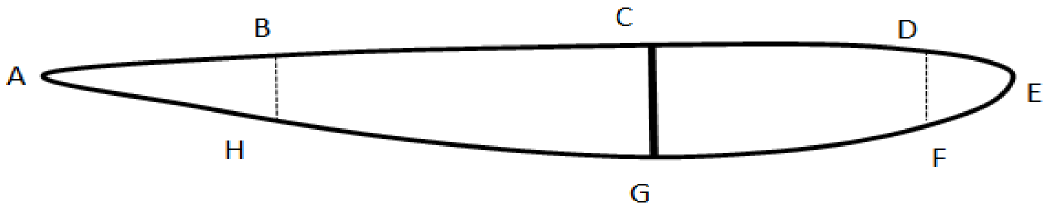

Figure 4, Aluminium Aerofoil Section

Table 2 Geometric Data of Aluminium Aerofoil Section

Position	Length (mm)	Thickness(mm)
AB	78	1.06
BC	86	1.06
CD	60	1.06
DE	38	1.06
EF	38	1.06
FG	64	1.06
GH	92	1.06
HA	80	1.06
CG	36	2.25

Area	Size (mm2)
ABH	960
BCGH	2700
CDFG	2300
DEF	160

Total 25 marks

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END OF QUESTIONS

Please turn the page for Formula Sheet

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Formula Sheet

Elasticity – finding the direction vectors

$$\begin{bmatrix} S_x \\ S_y \\ S_z \end{bmatrix} = \begin{pmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{pmatrix} \begin{pmatrix} l \\ m \\ n \end{pmatrix}$$

$$k = \frac{1}{\sqrt{a^2 + b^2 + c^2}}$$

Where a, b and c are the co-factors of the eigenvalue stress tensor.

$$l = ak \qquad l = \cos\alpha,$$
$$m = bk \qquad m = \cos\theta,$$
$$n = ck \qquad n = \cos\varphi.$$

Principal stresses and Mohr's Circle

Yield Criterion

$$\tau_{12} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\tau_{13} = \frac{\sigma_1 - \sigma_3}{2}$$

Von Mises

$$\tau_{23} = \frac{\sigma_2 - \sigma_3}{2}$$

$$\sigma_{von\ Mises} = \frac{1}{\sqrt{2}}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]^{1/2}$$

Tresca

$$\sigma_{tresca} = 2 \cdot \tau_{max}$$

$$\tau_{max} = \max\left(\frac{|\sigma_1 - \sigma_2|}{2}; \frac{|\sigma_1 - \sigma_3|}{2}; \frac{|\sigma_3 - \sigma_2|}{2}\right)$$

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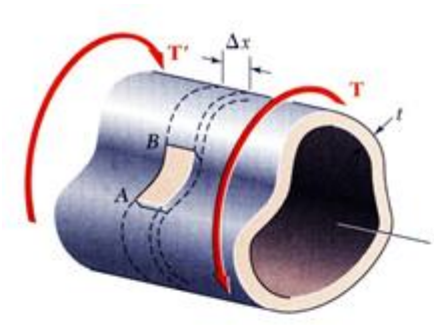
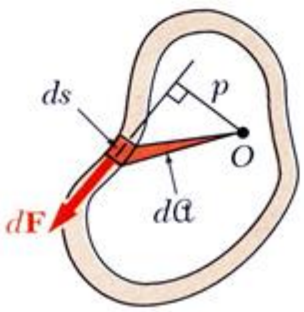
Torsion in close thin wall cross section (CTW)





- Shear stress varies inversely with thickness

$$\tau = \frac{T}{2tA}$$

- Shear flow q

$$q = \tau t$$

- Applied torque T

$$T = 2qA$$

- Angle of twist φ

$$\phi = \frac{TL}{4A^2G}\oint \frac{ds}{t}$$

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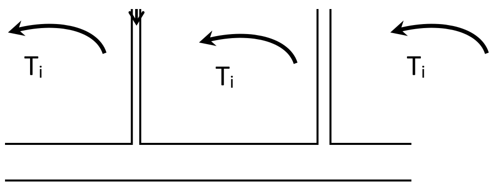
Torsion in multi-cells thin wall cross section

- Section considered as an assembly of N tubular sub-sections (compartments), each subjected to torque Ti as shown in the figure below:

$T =$



- Total torque

$$T = \sum_{i=1}^{n} T_i = 2\sum_{i}^{n} q_i A_i$$

- Common angle of twist for all compartments:

$$\theta = \frac{L}{4GA_i} \oint \frac{q_i - q'}{t(s)} ds$$

$$\varphi_1 = \frac{L}{2GA_1}\left(\frac{q_1 \ell_1}{t_1} + \frac{(q_1 - q_2)\ell_3}{t_3}\right)$$

$$\varphi_2 = \frac{L}{2GA_2}\left(\frac{q_2 \ell_2}{t_2} + \frac{(q_2 - q_1)\ell_3}{t_3}\right)$$

Where q is the shear flow of the main compartment, q' is the shear flow due to torque in adjacent compartments, A_i the area of cross-section i, t is the thickness of the cross-section and s is the circumference of the compartment.

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Torsion in open thin wall cross section (OTW)

$$If\ \frac{b}{t} \geq 10\ \ then\ \ \alpha = \beta = \frac{1}{3}$$

$$and\quad J_\alpha = J_\beta = J = \sum_{i=1}^{n} \frac{1}{3} b_i t_i^3$$

Shear stress

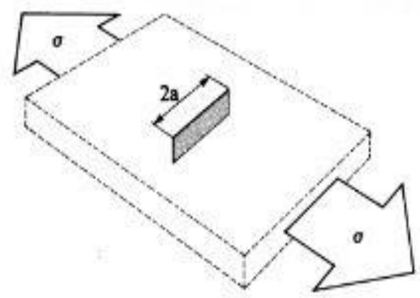
$$\tau_{\max} = \frac{T t_{\max}}{J}$$

Twist angle

$$\varphi = \frac{LT}{GJ}$$

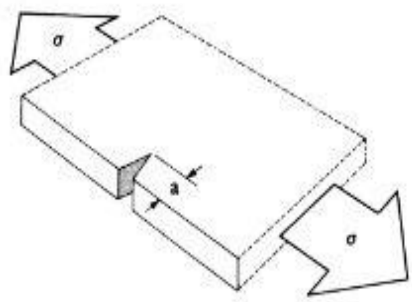
Fracture mechanics

Table: Y values for plates loaded in tension



(1) Through crack of length $2a$ in an *infinite* plate

$Y = 1$



(2) Edge crack of length a in an *infinite* plate

$Y = 1.12$

Because plane strain and plane stress have identical stress fields, this calibration is also for an edge scratch of depth a on a large body carrying tensile stress σ.

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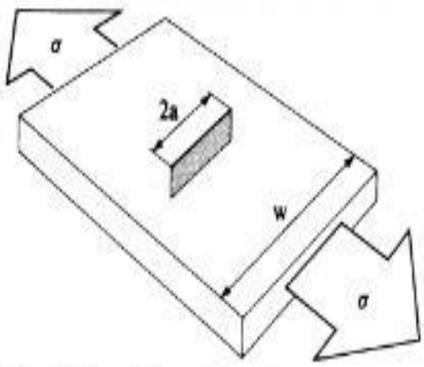
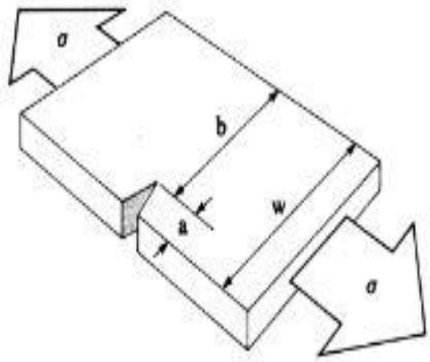


(3) Through crack of length $2a$ in a plate of width w.

$$Y = \left(\sec \frac{\pi a}{w}\right)^{1/2}, \quad \frac{2a}{w} \leq 0.7$$



(4) Edge crack of length a in a plate of width w.

$$Y = 0.265\left(\frac{b}{w}\right)^4 + \frac{0.875 + 0.265a/w}{(b/w)^{3/2}}$$

Life Calculations

$$K = Y\sigma\sqrt{\pi a}$$

$$\frac{da}{dN} = C(\Delta K)^m$$

$$N = \frac{1}{CY^m \sigma_a{}^m \pi^{\frac{m}{2}}} \left[\frac{a^{1-\frac{m}{2}}}{1-\frac{m}{2}} \right]_{a_0}^{a_1}$$

Composite materials

$$E_{composite} = E_{fibre}V_{fibre} + E_{matrix}(1 - V_{fibre})$$

<u>Miners Rule.</u>

Miners Rule $$\sum \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \ldots = 1$$

END OF QUESTIONS