GX 915

Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

Semester II Examinations, 2002/2003

Front Page Template

Exam Code(s)	4BM121
Exam(s)	4th Mechanical Engineering
Module Code(s)	ME402
Module(s)	Advanced Mechanical Analysis and Design
Paper No.	1
Repeat Paper	Special Paper
External Examiner(s)	Prof. P.J. Mallon
Internal Examiner(s)	Prof. J.F. McNamara
	Dr. P.E. McHugh

Instructions:

Answer 5 questions.
All questions will be marked equally.
Tables 8.1, 9.4, 11.1 and 11.2, and Figure 11.6 from Burr & Cheatham are attached.

Duration	3hrs
No. of Answer books	

Requirements:

Handout		
MCQ		
Statistical Tables		
Graph Paper		
Log Graph Paper		
Other Material	X	Mathematics Tables

No. of Pages	7
Department(s)	Mechanical Engineering

1(a) Derive the relationship between the point-wise definition of axial strain ε and the displacement field u, as a function of axial position x, for an axially loaded bar. From this write down the relationships between the three components of normal strain and the three components of displacement for a body loaded in three dimensions (assuming a Cartesian x, y, z coordinate system).

(4)

(b) Establish the compliance equations (strains as functions of stresses) for an isotropic linear elastic material in three dimensions (assuming a Cartesian x, y, z coordinate system). Write the final result in matrix form. Clearly state the assumptions of plane stress, plane strain and generalised plane strain. Simplify the compliance equations for the cases of plane stress and plane strain.

(10)

(c) Clearly state the assumptions of axial-symmetric deformations. Assuming a cylindrical polar coordinate system (r, θ, z), derive expressions for the radial strain ε_r and the tangential strain, ε_t, in terms of the displacement field. Comment on the form of the result.

(6)

2. A pipe enlargement joint, as shown in Figure 2, was designed and put into service carrying a gas flow under high pressure. The joint consisted of two constant-radius knuckle regions, the first between A and B, and the second between B and C. The increase in radius achieved by the joint was $R_2 = 1.5\,R_1$. Unfortunately, the joint fractured in the knuckle region between A and B.

i) Determine the stresses σ_m and σ_t in the structure immediately above and below each of the points A, B and C, in terms of pR_1/t (12 stresses in total) and list them in a table. (18)

ii) Use the result of (i) to help explain the failure of the joint. (2)

You are given the following expressions:

$$\sigma_m = \frac{pR_t}{2t} \qquad \sigma_t = \sigma_m\left(2 - \frac{R_t}{R_m}\right)$$

Hint: At point B, R_t = BD = $1.69\,R_1$.

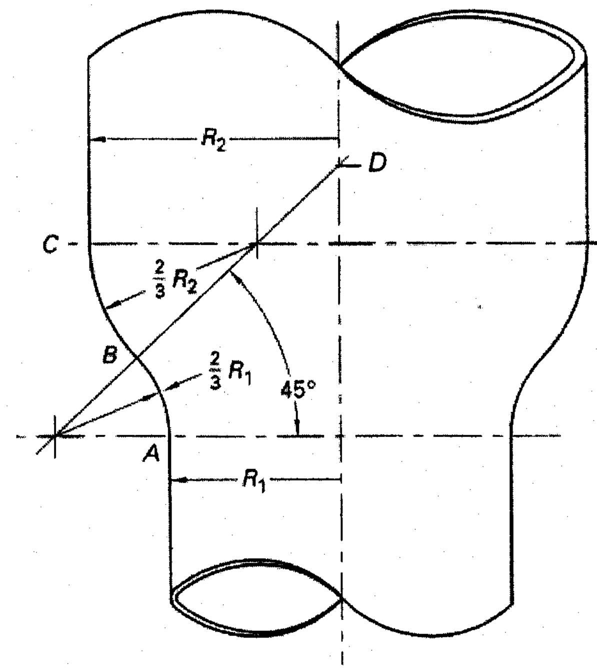

Figure 2.

3. A circular saw blade, shown in Figure 3, consists of a thin steel disc 600 mm in diameter on which are mounted 96 equally spaced tool-steel inserts, each weighing 0.75 N. It is placed over an 80 mm diameter spindle that rotates at 3000 rpm. The centre of mass of each insert is at the periphery of the disc. What disc thickness is required if the yield strength of the material is 250 MPa and the factor of safety is 2.5? Assume the density of steel is 7.778×10^3 kg/m^3 and that the Poisson's ratio is 0.3. Note also that weight is given by mass multiplied by g (acceleration due to gravity, 9.81 m/s^2).

(20)

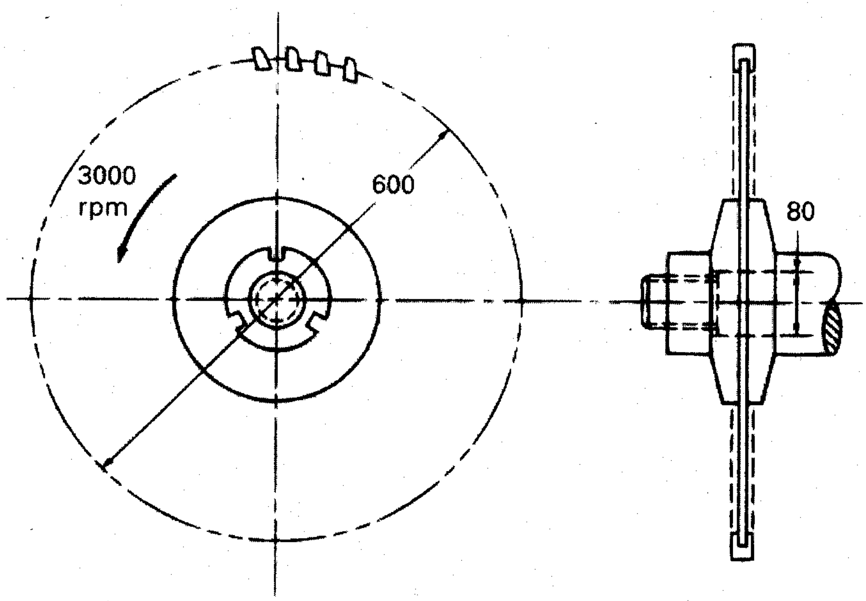

Figure 3.

4. A fatigue testing machine is to be designed based on the principle of electromagnetism, where a test sample is subjected to cyclic displacement when connected to a magnet that moves in the presence of an alternating electromagnetic field. The magnet is connected to a base plate by two L-shaped springs, as shown in Figure 4, of vertical height l and horizontal length c. To design the machine, the relationship between the electromagnetic force P and the resulting vertical displacement of the magnet is required, as are the reactions at the support joints. The joints at points 0 and 2 can be considered to be built-in, and also to not allow horizontal motion. The magnet can be considered rigid and its motion will generate horizontal and vertical reaction forces and reaction moments at points 0 and 2.

i) Derive expressions for the horizontal and vertical reaction forces and the reaction moments at the support points 0 and 2. (12)

ii) Derive an expression for the vertical displacement of the magnet and simplify it as much as you can. (8)

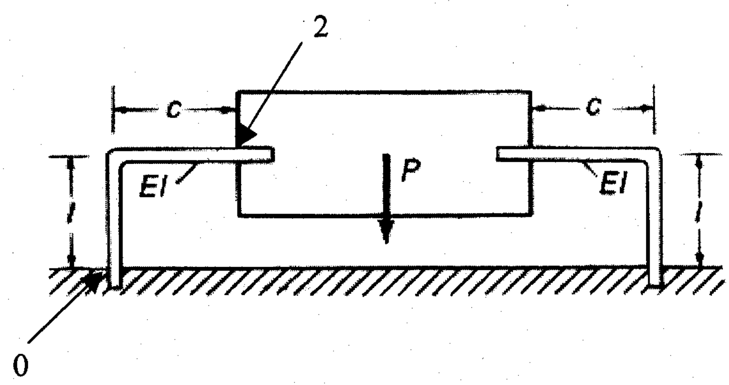

Figure 4.

5. A large gear is fabricated by welding together three parts, a steel ring for a rim, a hollow cylindrical hub and a plate or web between them, as shown in Figure 5a. To form the gear, teeth are cut into the rim. When transmitting torque, the maximum tooth load is estimated at 5000 N. The weld joining the web to the hub is to be composed of four equal lengths of fillet weld, as shown in Figure 5a, with cross sectional dimension b = 1 cm, as shown in Figure 5b. The rim diameter (gear tooth pitch diameter) is 1.2 m and the outer hub diameter is 15 cm.

i) Determine the web-hub fillet weld lengths, based on a maximum allowable shear stress of 40 MPa. (10)

ii) Consider a shaft in the hub that is subjected to a transverse load causing a bending action at the hub. When the gear is not transmitting torque, estimate the maximum bending moment that can be applied to the hub before the weld will fail. You may assume a maximum allowable normal stress of 80 MPa. In making your estimate, you may ignore the curvature of the circumference of the hub and idealise the weld lengths, determined in (i) above, as being straight. (10)

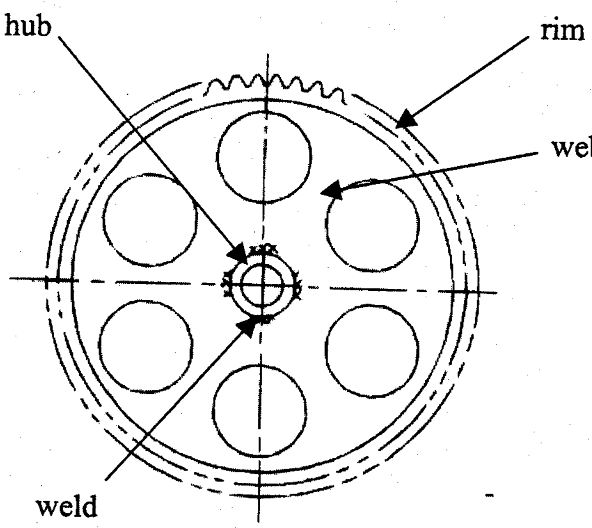

Figure 5a

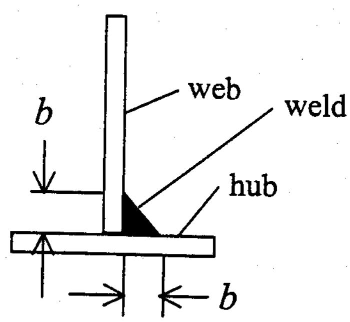

Figure 5b

6. A split piston ring of uniform rectangular section composed of cast iron is to be designed for a contact pressure between the piston wall and the ring equal to 22 kPa. The width of the ring, b, is specified as 12 mm and the mean ring radius, R, is 120 mm. The yield strength and Young's modulus of the cast iron are given as 300 MPa and 200 MPa, respectively, and a factor of safety of 3 is specified for the yield stress.

Determine the required thickness (dimension in the radial direction, h) of the ring and the initial gap, Δ, such that an allowable stress, based on the yield stress and a factor of safety of 3, is not exceeded. Derive all formulae used. (20)

7. A Geneva wheel, as shown in Figure 7, is a mechanism for converting continuous rotation into intermittent rotation, consisting of a driving arm upon which a pin is mounted, and a wheel with slots within which the pin moves radially. The wheel in Figure 7 has straight-sided radial slots and the pin is a cylindrical roller. The wheel is to be made from nickel cast iron (E = 138 GPa, ν = 0.25) and the pin from steel (E = 207 GPa, ν = 0.3). The pin is to have the same length as its diameter. The mechanism must transmit a torque of 75 Nm.

i) Determine the maximum contact force that the pin experiences. (4)

ii) Determine the minimum pin dimensions based on a maximum allowable contact pressure of 545 MPa. (16)

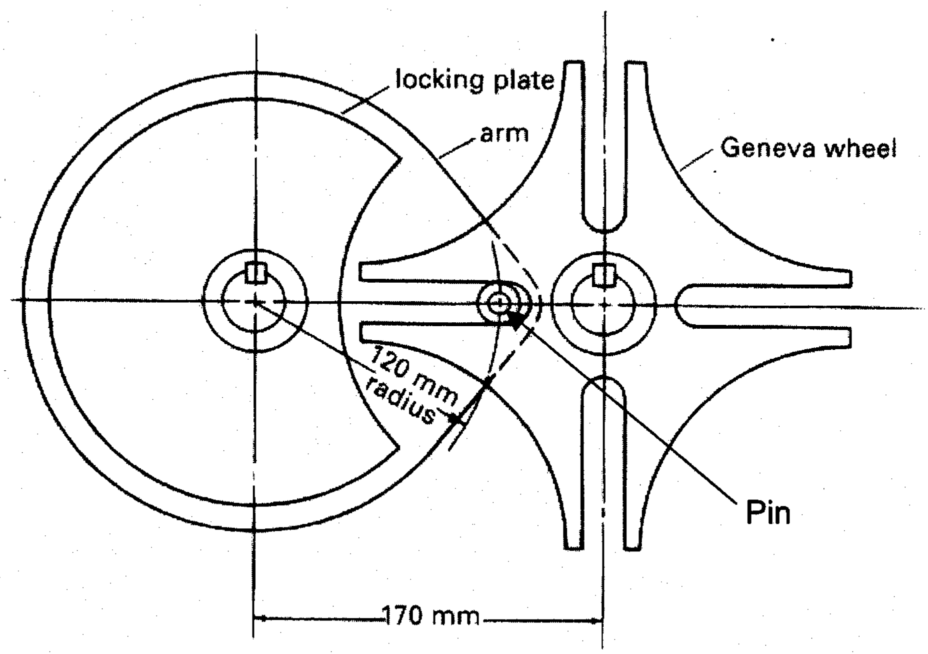

Figure 7.