National Examinations - May 2009

07-Mec-A4, Design and Manufacture of Machine Elements

3 Hours Duration

Notes: See Especially Number 6 Below:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a closed book examination. Candidates may use one of the two approved calculators, the Casio or Sharp models, and two textbooks of the candidate's choosing.

3. *No notes* are allowed, either loose or inscribed into either of the textbooks.

4. There are 7 questions on the following 3 pages, divided into Part A and Part B.

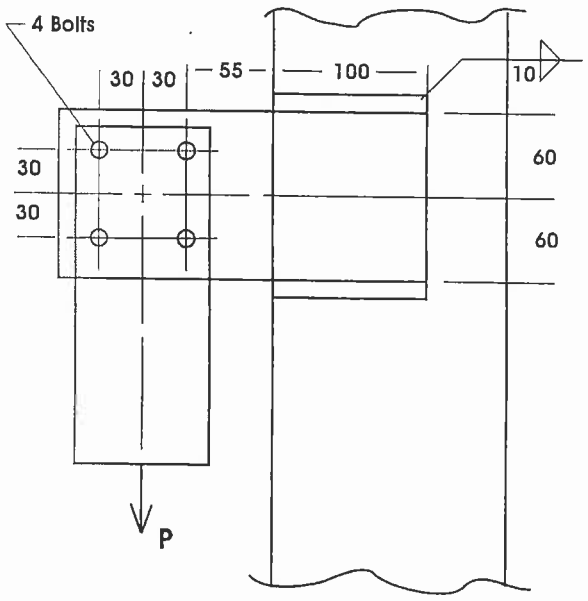
5. All questions are of equal mark value (20%). 5 (five) questions constitute a complete paper. Only the first five questions, as they appear in your answer book, will be marked, subject to # 6 below. Clearly cross off any question you do not want marked.

6. *Candidates can only answer **one or two** problems from **Part B**. Only the first two (2) problems from Part B which appear in your answer book will be marked.*

7. You may keep this examination paper.

PART A: Choose any three (3) or four (4) problems from part A.

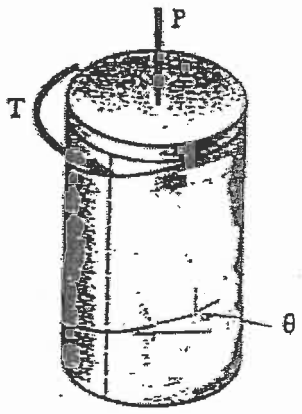
1. A cable support is constructed by welding the cable to a vertical plate. This plate is bolted to horizontal plate using four class 8.8 bolts of equal diameter. The horizontal plate is welded to a support column by two10 mm fillet welds made with E6010 electrodes. There is no twisting in the assembly.
All dimensions are in mm.



   a) Find the maximum static force P that will not overload the welds, using the AISC Code for permissible stress.

   b) Find the minimum standard bolt diameter assuming that the bolts are loaded on their major diameters (no threads at the interface). Use a factor of safety of 3.

2. A spacecraft contains a 750 mm (30.0 in) inside diameter, 5.00 mm (0.20 in) wall thickness pressure vessel operating at an internal gauge pressure of 2.75 MPa (400 p.s.i.). During take off, a maximum torque T = 160,000 Nm (120,000 lb-ft) can act on the vessel in the direction shown. Work in either S.I. or English units.



   a) For P = 0, find the angular direction θ of the maximum principal stress on the surface of the vessel.

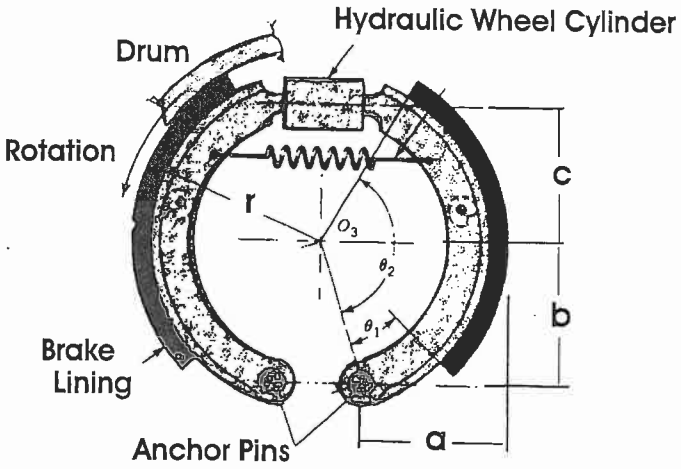
   b) For P = 0, find the maximum principal stress and the maximum shear stress on the surface of the vessel.

   c) For P = 0, repeat (b), but for through wall stresses.

   d) Discuss the effect on your answers from part (b) if an additional force P is found to act on the vessel.

3. Select a suitable steel for a solid circular rotating shaft having a 40.0 mm (1.50 inch) diameter. Shaft loading is such that the maximum bending moment of 350 Nm (250 lb-ft) and maximum torque of 900 Nm (625 lb-ft) occur at the same location. The factor of safety is 1.5. Use a reliability of 95 %, or infinite life. Loading is low shock, and is gently applied (can be considered static). You may work in either S.I. or English units.

4. This drawing shows an internal shoe brake for the rear axle of a low cost car or truck. Shoe brakes are called 'self-energizing' when friction *assists* the hydraulic wheel cylinder to create braking torque, and 'deenergizing' when it *reduces* the braking torque for the same cylinder force. Assume that the net brake friction acts horizontally through the brake centreline, and that the parameters a, b, c and r apply to both shoes.
Note: Use simple brake analysis. Some texts will show brake action is a function of the shoe contact angle; ignore this theory.



a) (7 marks) Using a fully labelled free body diagram for each shoe, clearly explain which shoe (left or right) is self-energizing, and which is deenergizing, for this direction of rotation.

b) (6 marks) Derive an expression for braking torque, T, as a function of F, the hydraulic force from either end of the wheel cylinder, parameters a, b, c and r, and , μ the coefficient of friction between the shoe and drum for: - self-energizing action,
- deenergizing action.

c) (4 marks) For the parameters F = 2000 N, $\mu = 0.55$, a = 100 mm, b = 50 mm, c = 100 mm and r = 125 mm find the braking torque from a self-energized shoe. How do you interpret this result?

d) (3 marks) Sketch how you would redesign this brake so that both shoes are self-energizing for this direction of drum rotation.

PART B: Choose any one (1) or two (2) problem(s) from Part B.

5. a) (6 marks) Indicate with clearly-stated reasons which *aluminum alloy(s) and temper(s)* you would choose for:
   i) a welded energy-absorbing bumper system for a lightweight recreational vehicle,
   ii) an automotive wheel which requires significant machining,
   iii) a pressurized liquid-carrying trailer in the shape of a cylindrical vessel,
   iv) the outer shell or "skin" of an unpainted house trailer.

   b) (8 marks) Indicate with clear reasons, which steel or other metallic material (completely identified) you would specify for:
   i) a casting which requires considerable machining, moderate strength and cost,
   ii) a *lightweight* casting to which 3 studs of similar material must be welded; some machining required,
   iii) a casting subject to large impact loads, with some machining required,
   iv) a casting requiring high compressive strength, low cost and some machining.

   c) (6 marks) Automotive crankshafts can be cast or forged. What physical properties would a *design* engineer consider in choosing each one? (Production considerations are not to be listed).

6. In Part A, six load situations are given. For each one
   - specify the *cross-section* (with your reasons) most appropriate to resist the loading, and
   - pick three (3) materials suitable for each applications from Part B. *Indicate clearly which physical property or properties you considered in making each selection* (i.e.: ultimate shear strength, tensile yield strength, modulus of elasticity, etc.).

   These steady loads are applied at room temperature. NO calculations are necessary, nor formulas required, but may be employed by the candidate, if desired.

   Part A: Load Cases:
   i) a member subjected to an axial tensile load, minimum deflection and area required,
   ii) a "short" member subjected to an axial compressive load,
   iii) a "long" column (in the Euler range) subjected to an axial compressive load,
   iv) a shaft loaded in pure torsion,
   v) a beam with transverse loads located in *one* plane,
   vi) hanging cables for a very deep pit.

   Part (B): Materials (*Use each material no more than three (3) times*):
   - mild steel
   - gray cast iron, ASTM grade 40
   - brass, annealed yellow
   - titanium alloy
   - nylon thermoplastic
   - high strength steel (4xxx alloy)
   - aluminum alloy (7xxx)
   - epoxy matrix carbon fibre
   - magnesium alloy
   - epoxy thermoset plastic
   - other non-ferrous materials of your choice.

7. Note: *Answer part questions totalling 20 marks, in any combination desired. Clearly indicate which part question you are answering.*

a) (2 marks for each part)
Clearly indicate one preferred method of metal removal in your choice of the following situations, involving steel members:
i) the teeth on an internal gear (teeth cut on the inside surface of the blank, before hardening),
ii) the final finish for a needle roller bearing surface on a 1050 (G10500) CD shaft,
iii) the through keyway on the inside surface of a gear hub,
iv) reducing the thickness of a 90 mm by 200 mm flat mild steel plate from 12 mm to 11.25 + 0.10 mm thickness.
v) a low carbon solid circular section transmission shaft, with many steps of varying depth, *and* suggest a steel for use in this application,
vi) the final tooth shape for a hardened steel gear, if a "precision finish" is specified,
vii) the complex "teardrop" shape for a through port in the end plate of a hydraulic pump,

b) (8 marks total)
i) A gear is subjected to heavy impact loads. Clearly stating your reasons, would you design the gear with high strength, high alloy steel with no hardening, or having a medium grade steel with hardened tooth surfaces.
ii) In a hardened gear, what reasoning would you use in specifying either induction or carburizing?
iii) Under what conditions would you specify a finish grinding operation on hardened gear teeth?

c) (6 marks for each part)
New techniques are being developed for the building of steel car bodies.
i) Many body panels can be formed by using "tailored blanks". In this process, dissimilar sheets of steel are laser-welded together. Use the outer panel of a car door as one application, and consider strength, formability and environmental problems. Indicate clearly how you would design a lightweight tailored-blank door panel.
ii) The complex fore-and-aft rails above the doors can be formed in one piece by the hydro-forming process. Discuss the advantages of using this process in this application. What method(s) would have been used to form this part prior to hydroforming?