

National Examinations - December 2002

98-Mec-A5, Design and Manufacture of Machine Elements

3 Hours Duration

Notes:

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. Any non-communicating calculator is permitted. Write the name and model designation of the calculator on the first inside sheet of the exam work book.
3. This is an open book examination.
4. There are 7 questions on the following 4 pages.
5. Any 5 (five) questions constitute a complete paper. Only the first five questions, as they appear in your answer book, will be marked.
6. All questions are of equal mark value (20%).

1. 20.0 HP (15.0 kW) is to be transmitted from a 2400 RPM shaft to one rotating at 1200 RPM by one pair of gears. 20° full depth spur teeth are to be used, with the smaller gear having 16 teeth.
 - a) Choose a diametral pitch (module) which appears to be appropriate for the load and speed given, and design a pair of gears for both tooth strength and fatigue (wear). Design in either metric or English units. You may use either hardened or unhardened steel. Assume negligible shock loading, and use AGMA standard design with 99% reliability, 10^7 cycles of loading and full face contact with less than accurate mounting. Assume a tooth width in the range $8/P_d$ to $12.5/P_d$. (8 times m to 12.5 times m , in mm). m = module, P_d = diametral pitch.
 - b) If your results from part (a) are not acceptable, clearly indicate a new diametral pitch (module) which would be used for a second design trial. Do not perform any further analysis.

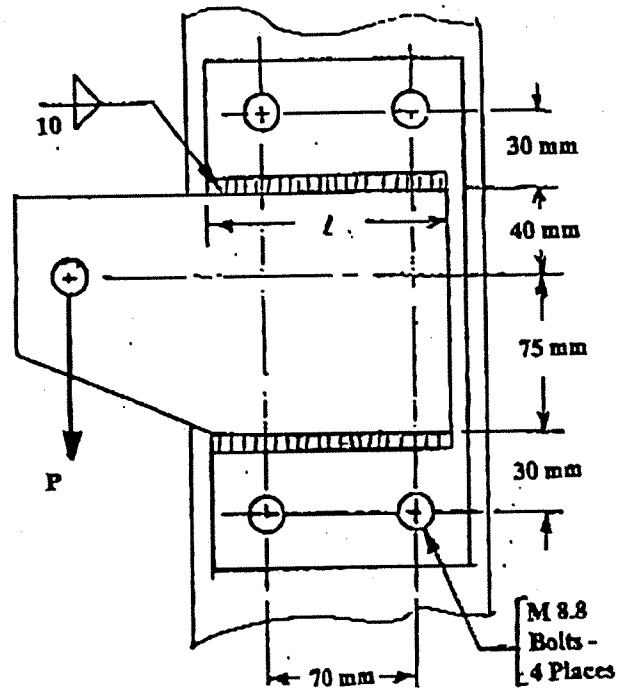
2. a) (6 marks)
 - i) Why are automotive designers investigating the use of ceramic coatings on engine pistons?
 - ii) What design and material limitations must they consider when choosing the type of ceramic material for this application?

- b) (8 marks) A built-up I-beam is to be designed for a high-technology application. Cost is relatively unimportant, but ultra-light weight and strength are vital. The beam is simply-supported, with gravitational loading - thus producing positive bending (a "smile").
 - i) Indicate the required mechanical strength property (samples: shear strength, tensile strength, etc.) for the:
 - top flange,
 - bottom flange
 - web.
 - ii) Suggest suitable composite materials for each of these 3 parts.
 - iii) What is the mechanical function of the bonding agent used to attach the web to each flange?

- c) (6 marks) State with clear reasons, whether you would specify random or oriented fibres when designing with composites (fibre-reinforced plastics) for the following:
 - i) a truck's hollow driveshaft (torsional loading)
 - ii) a boat hull
 - iii) the flanges in an I-shaped beam subjected to in-plane bending

3. A load $P = 120 \text{ kN}$ is supported by the bracket assembly shown. The vertical load P is located 85 mm outboard (left) of the leftmost pair of bolts.

- a) The bolts are loaded on their unthreaded sections, and have an allowable shear stress of 200 MPa. Find the smallest standard diameter bolts (same size for all 4).
- b) Discuss the similarities and differences in solution method, compared to part (a), in determining a suitable weld length, l , for the bracket. No calculations are required (or will be marked), but appropriate equations may be listed, if desired.

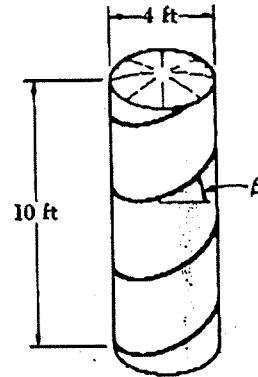


4. a) (7 marks)
 Two methods of casting aluminum are die casting and near-net-shape (lost foam) casting. Clearly describe the advantages and disadvantages of each, to be considered when choosing which one to use for a given application.

- b) (7 marks)
 Metal fibre composites are being studied for many applications. In this technique, high alloy fibres are cast into a matrix of base metal.
 - Specify the design considerations for a mass-produced automotive brake disc made of aluminum composite, indicating the orientation of the fibres in the disc.
 - Why not simply use a high strength aluminum alloy throughout?

c) (6 marks)
 A series of steel rollers is being designed; they will be used to produce a complex steel shape. High loads and wear problems are expected. In a few words, indicate the considerations for roll design (material, machining, surface (and core, if required) heat treatment, etc.)

5. This pressure vessel is to be designed from HR G 10200 (AISI 1020) mild steel, having a factor of safety of 4 based on yield. English units are given; metric equivalents are: 3.00 m long by 1.20 m diameter. The tank's maximum internal pressure is 1.40 MPa (200 p.s.i.).



- a) Find the minimum thickness of steel required for the cylindrical body of the vessel. Do not design the end caps.
- b) The vessel is to be constructed from rolls of steel, formed into a helix at an angle of $\beta = 30^\circ$ as shown.
 - i) What are the normal and shear stresses on this weld?
 - ii) E6010 electrode is used to make the full depth butt weld. What are the *extra* factors of safety, compared to permissible, for the tensile and the shear stresses in the weld?
- c) Pressure vessels must be designed to all applicable codes. Do these codes have higher built-in factors of safety for liquid- or for gas-containing pressure vessels? Why?

6. a) (7 marks)

In many applications, the designer has the choice of specifying cast iron, or cast steel for a part. Compare the two materials with respect to:

- i) manufacturing (cost, ease of manufacture, etc), and
- ii) design (various strength properties, ductility, etc.)

b) (7 marks)

Welding is the preferred attachment method for low alloy steel parts in many applications. However, welding may be difficult, or impossible, with heat-treated, and with high alloy steels. Discuss the problems (and solutions if any) of these two cases.

c) (6 marks)

The frames of several models of recently re-designed pickup trucks and truck-based SUV's have cross-members constructed from hydroformed tubes. (Note: the cross-members are located crosswise in the vehicle, and join the much longer front-to-back members).

- i) Discuss the advantages of using hydroforming for the designers .
- ii) Why would the manufacturing engineers specify that an axial compressive load be applied to the tubes during the hydroforming operation?

7. A compression coil spring is to be made from ASTM A-229 oil-tempered wire. The maximum steady load is 225 lb., and a spring constant of 150 lb/in is required. The free length is to be 10.0 inches and the solid height not greater than 7.50 inches.

Design the spring using squared and ground ends, with standard gauge wire (text, page 428 or other source of data).

Note: If you use a trial-and-error approach, perform one trial run, and clearly indicate the parameters to start the next run. Do not resolve.