THE ASSOCIATION OF PROFESSIONAL ENGINEERS

·MEC-B1 ADVANCED MACHINE DESIGN

NATIONAL COURSE EXAMINATION

May 2002 **TIME ALLOWED: 3:00 (three) Hours**

Please Note:

- *Answer QUESTION NUMBER-1, and only TWO questions from PART-II of examination.*
- *Make your answer neat, write your equations in symbol form first and intermediate and final results in boxes.*
- *Examination is open book (one book only). Students may use only one textbook of their choice plus their own notes.*
- *Any non-communicating calculator is permitted.*
- *State all assumptions clearly. If doubt exists as to the interpretation of any question, submit with the answer paper a clear statement of any assumptions or interpretation made.*
- *Assume any missing data and make sure to properly state it in your answer.*
- *Make sure your name and student number (if applicable) is written on the answer book and any other attachments.*
- *Total points of the examination are 100 marks.*

PART- I: ONLY QUESTION-1 – MUST BE SOLVED

QUESTION-1: DESIGN OF A LOG CRANE **(50 points)**

A log crane, schematically shown in Figure 1, is to be designed to handle a maximum load of 2000 kg. The crane must be able to transport the weight over a distance of 5 m (along the x-axis) and to a height of 3 meter in one plane without rotation at the swivel joint. The crane is pivoted to a motorized swivel joint that is capable of rotating a total of 180°. Tentative relative dimensions ratios of the crane arms are shown in the figure, where the length '*a*' is a design parameter. The two angles θ_1 and θ_2 should lie between 60° and 120°. To design the crane, it is required to perform the following steps:

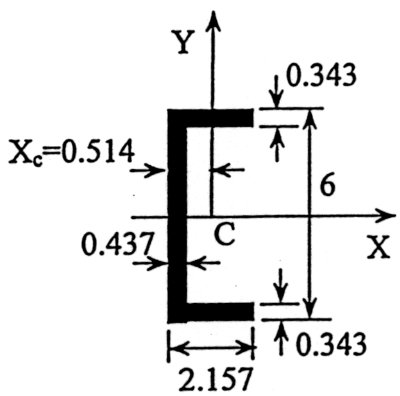
1. Draw the free body diagrams for the two crane arms AF and write down the equlibrium equations for the link (*Do not* solve the equations and neglect members weight).

2. *Briefly* explain how would you go about determining the design length parameter 'a' for the crane to achieve the distance and height design specification requirements. Do not perform any calculations. Make your explaination in a point form and make sure it is brief.

3. Assume the following data to design the arm AF:
   - Critical position of the arm occurs when the angle between the centerline AF and the x-axis is 45°.
   - The following forces are given at the critical position:
     At point D: F_{DX} = 40 KN, F_{DY} = 35 KN
     At point C: F_{CX} = 30 KN, F_{CY} = 30 KN
     At points F and A: $F_{AX} = F_{FX}$

   Draw the normal force, shear force and bending moment diagrams of the link and identify the critical section(s) of the link.

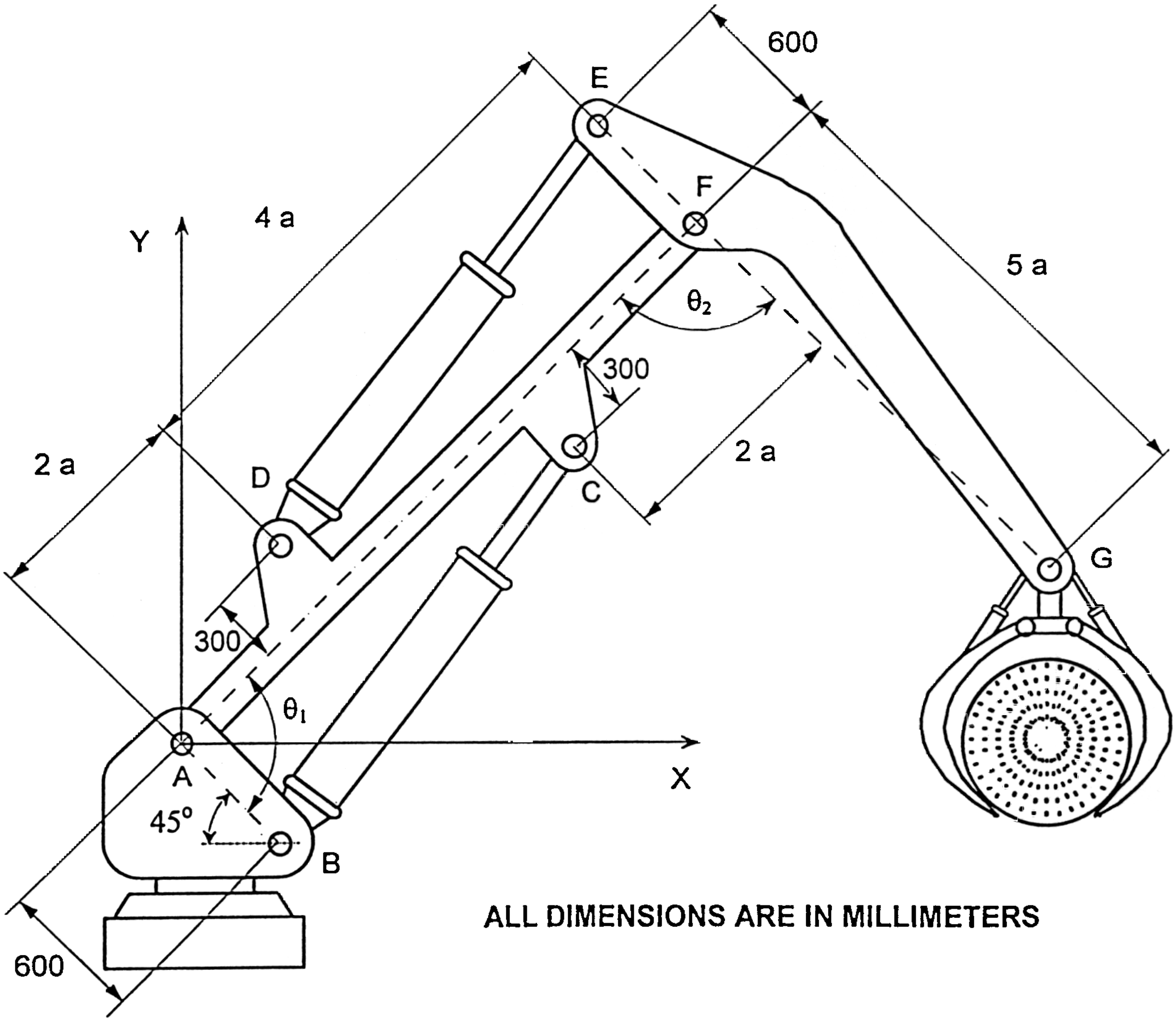
4. Assume that the the link AF will be made of a thin-walled C6X13 channel section with sectional properties (as shown in figure) and has the following material properties:
   Yield strength in tension: S_{yt} = 90 ksi (i.e., 90,000 psi),
   Ultimate strength in tension: S_{ut} = 120 ksi, Yield strength in shear: S_{ys} = 45 ksi
   Modulus of Elasticity: E = 30,000 ksi, Endurance limit: $S_e = 0.5\ S_{ut}$
   Endurance limit modifying factor = 0.8
   The critical section on the link is subjected to a vertical force in the negative Y-direction of magnitude P lbs, and to a bending moment about the X-axis of magnitude 50 P lb.in. The value of P changes from zero to P lbs. What is the maximum value of P that will ensure a minimum factor of safety of 2.5? Use Soderberg and Goodmnan lines for calculations.



Area: A=3.83 in^2
Moment of inertia:
I_{xx} = 17.4 in^4
I_{yy} = 1.05 in^4

5. Find the wall thickness of the hydraulic cylinder BC if the inside diameter is 200 mm. Assume the internal pressure to be 10 MPa. Choose appropriate material for the cylinder and find out the cylinder wall thickness. A factor of safety of 1.5 is required.

6. Provide a proper engineering drawing for the motorized swivel connection showing all necessary details. Assume any reasonable dimensions. You may use free hand or straight edge.



ALL DIMENSIONS ARE IN MILLIMETERS

PART- II: QUESTIONS 2, 3 AND 4 - ONLY SOLVE TWO QUESTION FROM THIS PART

QUESTION-2: DYNAMIC LOADS AND STRESS CALCULATIONS (25 points)

Figure (2) shows a power screw and slotted arm assembly. At the shown instant, the slotted arm is making an angle $\theta=30°$ with the horizontal, and the threaded collar **C** is moving downward with a velocity ***v*** and an acceleration ***a***. The mass of the arm is ***m*** and its mass moment of inertia about an axis passing through the center of gravity (point **G**) and perpendicular to the plane of the paper is ***J***. Assume no friction at the sliding joint.

It is required to:

(a) Draw the velocity and acceleration diagrams necessary to calculate the linear and angular accelerations of the slotted arm.

(b) Draw a free body diagram of the arm.

(c) If the arm cross-section has a thickness *t* and a height *H*, what are the internal forces and the stresses at a section at point G.

(No other calculation is required).

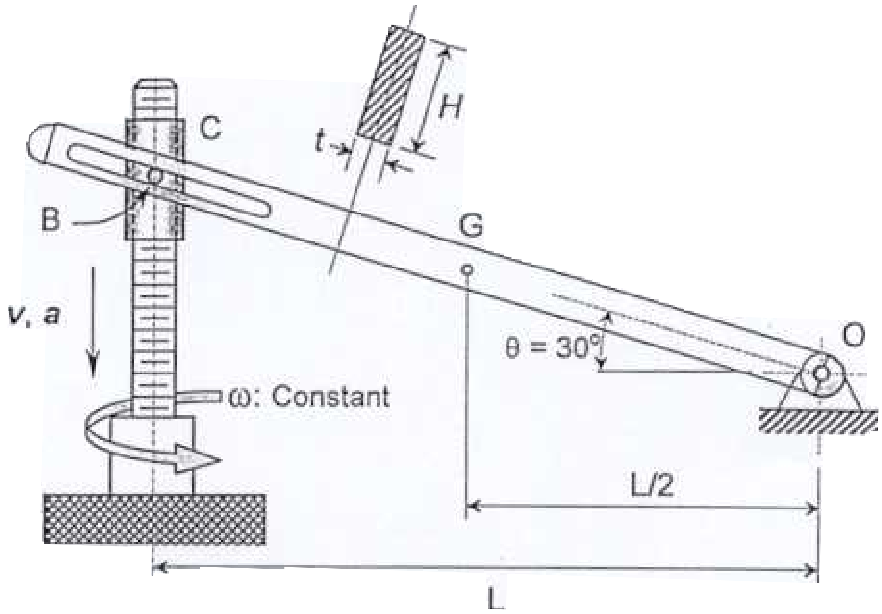


FIGURE (2)

QUESTION-3: JOURNAL BEARING DESIGN (25 points)

A journal bearing is to be designed for a gear reducer shaft that rotates at ***300 rpm*** (revolution per minute) and applies a radial load of ***1000 lb*** to the bearing. To minimize the use of radial space, an ***L/D*** ratio is chosen to be ***1.0***, where ***L*** is the bearing length and ***D*** is the bearing diameter. The clearance ratio ***c/R*** is chosen to be ***0.0015***, where ***R*** is the journal radius and ***c*** is the radial clearance. ***SAE 40*** oil is used for the bearing.

i) Determine an appropriate combination of ***L, D***, bearing material, and average oil temperature (assume that this can be controlled to a reasonable specified temperature by an external oil cooler).

ii) Plot ***f*** (coefficient of friction), h_o (minimum film thickness), ΔT (temperature rise), and ***Q*** (the oil flow rate) for a range of radial clearances. From the plot, suggest an appropriate range of production clearance and reason your choice.

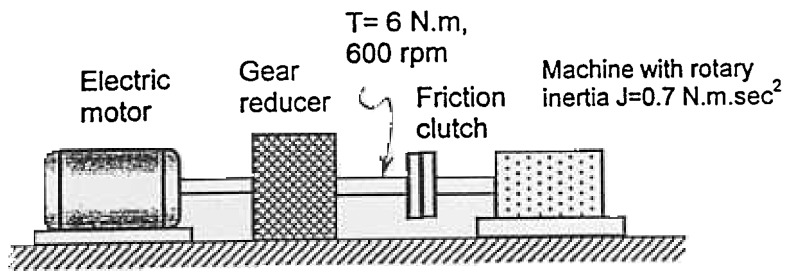


Figure (4a)

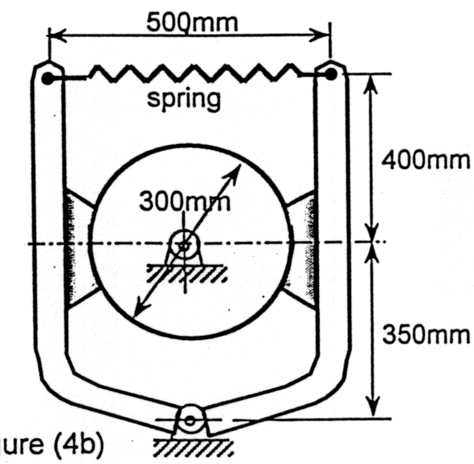


Figure (4b)

QUESTION-4: Brake and Cluthch Systems **(25 points)**

(a) An integral electric motor gear reducer is coupled by means of a friction clutch to a driven machine having an effective mass moment of inertia of 0.7 N.m.sec^2. The clutch is controlled so that during the engagement the output shaft of the gear reducer operates continuously at 600 rpm (revolutions per minute), delivering a torque of 6 N.m.What is the appropriate time required for the clutch to accelerate the driven machine from rest to 600 rpm? How much energy is delivered to the driven machine in increasing the speed to 600 rpm? How much heat energy is generated in the clutch during this engagement?

(b) Figure (4b) shows a spring-loaded brake. The brake is released by a hydraulic cylinder (not shown in figure). Assume a short shoe and a coefficient of friction of 0.3.
Draw a free body diagram for each of the brake shoe with the arm assembly, the spring and the drum. Show all forces in terms of the spring force F_s. What is the spring force required to produce a braking torque of 1200 N.m.?