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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX4306 Design of Machine Elements**
Academic Year	: 2020/21
Date	: February 13, 2020
Time	: 0930 -1330hrs
Duration	**: 4 hours**

General Instructions: *READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THE QUESTION PAPER*

1. **Attach the question paper the answer script. Do not remove any part of the question paper out of the examination hall.**
2. This question paper has two parts, **PART A** and **PART B**. Answer the question (Question 1) in PART A which is **compulsory**, and any three out of five questions from **PART B.**
3. Answers to the question in PART A carries **50** marks, whereas in PART B, each **17** marks.
4. **Attempt all parts in Question 1** in that given order. Spend approximately 2 hours and 45 minutes to answer the question in PART A and rest for Questions in PART B.
5. Wherever appropriate, use the given catalogue, information, and data sheets, provided to you in the examination hall. At the end of the examination return all such material to theexaminer/ supervisor of the examination hall. You will be provided with, *1.* Instruction booklet of spur and helical gear design, *2.* Motor catalog, *3.* Bearing selection manual, *4.* Handbook of metric keys and keyways and *5.* Handbook of V-belt drives as per your request.
6. **Any missing data can be sensibly and reasonably assumed**, but such assumptions are not acceptable unless they are justified and clearly stated.
7. Wherever relevant use neatly drawn sketches to explain your answers.
8. Any result from calculations should have units, unless they are dimensionless.
9. All answers to the given questions should be underlined for the purpose of easy identification.
10. Write the question numbers to which you have answered, on the cover page.

The roller force F (N): $F = L\,W\,Q\,\sigma$

Contact length between the roll and work L (m): $L = \sqrt{R(h_o - h_f)}$

Power requires to rolling operation P (W): $P = F\,L\,\omega$

Where,
- W – Width of the work (m)
- Q - Pressure multiplying factor
- σ – Mean stress (Nm^{-2}) of rolling stock (rolling material)
- h_o, h_f – Initial and final thickness
- R – Radius of Roller (m)
- ω – Angular speed of the rolls (rad/sec)

2. In addition to the data given on separate sheets, you may assume the following.

   Mean's stress of rolling stock $= 100 \times 10^6\ Nm^{-2}$
   Radius of the rollers = 50 *mm*
   Width of the work = 50 *mm*
   Pressure multiplication factor = 1.2
   Initial thickness = 30 *mm*
   Thickness after rolling = 24 *mm*
   Rotating speed of rolls = 50 *rpm.*
   Young's modulus $E = 200 \times 10^3\ Nmm^{-2}$

3. Power losses.

   Mesh points – 0.04
   Couplings – 0.03
   Gearings – 0.02
   Belt drive – 0.04

4. Axis of all the shafts in the gear wheels and pulleys lie on a same vertical plane.

5. All the spur wheels have a module of 4 mm and a pressure angle of 20o.

6. V-belt drive has a speed ratio of 2 - 4 and centre distance between pulleys is approximately less than 1 m. This system is required to operate for 8 hours continuously a day.

7. For power transmission shafts shock and fatigue factors for bending and torsion are 2 and 1.5 respectively.

8. Shafting material has allowable bending and shear stresses 60 MN/m2 and 50 MN/m2 respectively.

9. Consider safety factors appropriately.

Answer the following questions.

i. Estimate the motor power required to operate the rolling mill at its full capacity.

ii. Select a suitable motor to drive the mill.

iii. Illustrate the components of the machine from the motor to the mill and indicate how the speed is reduced at each stage.

iv. Design a suitable V-belt drive system incorporating standard pulleys.

v. Neatly sketch the gear arrangement of the reduction gearbox.

vi. Design the gear and pinion (1st gear mesh) of the reduction gearbox which the pinion is attached to the input shaft (connects to the driven pulley of the belt drive). All the gears are spur gears.

vii. Determine the minimum diameter of the input shaft to the reduction gear box (which the driven pulley is attached).

viii. Select an appropriate pair of rolling element bearings to support the input shaft of the reduction gear box (*you may just select the bearing from the catalogue and do not perform any calculations*).

ix. Neatly sketch the gear arrangement of the 2nd gear box (pinions) and state what type of gear are suitable for this application with justification.

x. Suggest the most suitable types of couplings to type 1, type 2 and type 3.

*END OF QUESTION 1 AND **PART A***

PART B

Question 02

a. i. Distinguish between **ductile** and **brittle** materials, and list 3 examples for each type.

ii. Define **proof stress** of a material.

iii. What are **engineering** and **true** stress-strain curves. Illustrate using stress-strain diagram.

b. Distinguish between **fatigue** and **creep** failures. Illustrate how fatigue and creep test results are presented.

c. Define **hardness**. Explain the importance of appropriately hardening the surface of engineering components, and also explain how to improve the hardness of a surface of a metallic slab.

d. What is **residual stress** and explain how to remove the undue residual stresses from an engineering component.

Question 03

Write short notes on the following.
Note: you may use neat sketches wherever necessary.

a. Selecting appropriate bearing for a load carrying shaft (*your answer shall address at least six factors needed to be considered in selection*).

b. Second moment of area (I) and polar moment of area (J) and their relationship (*your answer shall state the equation/s to calculate these two parameters*).

c. *It is said that more power could be transmitted by a V-belt drive than to a Flat belt drive.* Do you agree? Justify your answer.

d. Stress concentration and stress concentration factor. Discuss how to compensate undue stress concentrations when designing machine components.

Question 04

A shaft transmits 20 kW at 200 rpm. The shaft carries a central load of 900 N perpendicular to its axis and is simply supported between two bearings at ends, 2.5 *meters* apart. The shaft is made from mild steel which has allowable shear stress of 42 MPa. Both maximum tensile and compressive stresses are not exceed 56 MPa.

i. Determine the diameter of the shaft.

ii. Determine the required diameter of the shaft if the load is gradually applied. For rotating shafts with gradually applied loads the shock and fatigue factors, $K_m = 1.5$ and $K_t = 1$.

You may use the following equations (in usual notations), if necessary,

$$T_e = \sqrt{(K_m \cdot M)^2 + (K_t \cdot T)^2}$$

$$M_e = \frac{1}{2}\left[K_m \cdot M + \sqrt{(K_m \cdot M)^2 + (K_t \cdot T)^2}\right]$$

Question 05

a. For a square thread show that in the presence of a thrust collar, the torque (T) required to lift an axial load (W) is given by,

$$T = W\left[\frac{d}{2}\tan(\alpha + \phi) + \mu R\right]$$

Where,
W - axial load on screw
d - mean diameter of the thread
ϕ - angle of friction
α - helix angle
μ - friction coefficient of nut on thrust collar
R - mean radius of the thrust collar

b. A double start square threaded screw is used to support a vertical load of 8 kN. The mean diameter of the thread is 100 mm and pitch is 20 mm. The axial thrust on the screw is taken by a collar bearing of 250 mm outside and 100 mm inside diameter. Find the force required at the end of a lever which is 400 mm long to lift and lower the load.
The coefficient of friction for the vertical screw and the nut is 0.5 and that for the collar bearing is 0.2.

Question 06

a. Figure.$Q6$ shows a cone clutch.

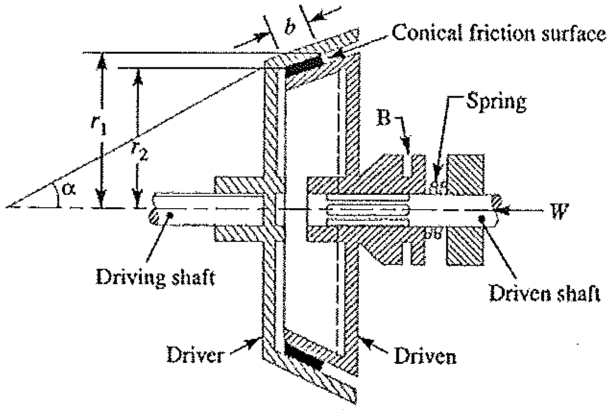

Figure.$Q6$

Considering the uniform pressure condition (new clutch), derive that the torque ***T*** which can be transferred by the clutch as,

$$T = \mu W_n R$$

Where,

W_n – W cosec α
W - load acting on the clutch
μ - coefficient of friction between the contact surfaces
r_1 - outer radius of friction surface
r_2 - inner radius of friction surface
R - mean radius, $R = \frac{2}{3}\left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2}\right]$
α - Semi angle of the cone
b - width of the friction surfaces

b. Find the outer radius and inner radius of a cone clutch which is used to transmit 30 kW at 750 rpm.
Following data are provided.

Normal pressure between the contact surfaces (P_n) = 0.075 to 0.1 N/mm^2

Load factor = 1.75

$\mu = 0.2$

Mean diameter of cone = 6 to 10 times of the diameter of the shaft

Mean diameter to face width ratio = 6

$\alpha = 12\frac{1}{2}$ degrees

Torque developed by the clutch, $T = 2\,\pi\,\mu\,P_n\,R^2 b$