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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

TERBUKA

COURSE NAME	:	TRIBOLOGY
COURSE CODE	:	BDC 40503
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2016/ JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FIVE (5)** OUT OF 6 QUESTIONS **ONLY**

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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Q1 (a) Describe the meaning of the following terminologies:

(i) Tribology

(ii) Saybolt Universal Seconds

(iii) Viscosity Index

(iv) Average roughness

(v) Fretting wear

(5 marks)

(b) Describe the mechanisms that control the coefficient of friction value, subsequently evaluate the role of lubricants and surface modification in tribological applications.

(5 marks)

(c) The Stribeck curve shows how the boundary, mixed, and hydrodynamic lubrication are divided. Describe the curve with graphics illustration.

(5 marks)

(d) List 5 assumptions made in the derivation of Reynolds equation.

(5 marks)

Q2 Roller with 2 mm radius and 5 mm length is coated with Diamond Like Coating (DLC) and rolls without sliding with a speed of 60 rpm on a DLC coated flat surface. Water with viscosity of 0.00025 Pas is used as intervening fluid. Load of 2 mN is applied. The composite roughness of the surface is 100 nm. Modulus of elasticity for DLC is 800 GPa with Poisson's ratio of 0.2 and take its shear strength to be 100 MPa. The water meniscus force, F_m for DLC is $5x10^{-4}$ mN. If the average asperity tip radius is 1 μm, and assume 1,000 such asperity-pairs in the contact area.

(a) Calculate the regime film thickness of lubricant and discuss its lubrication regime.

(14 marks)

(b) Determine the adhesive coefficient of friction.

(6 marks)

Q3 A semi-automated assembly machine, assembles and welds automotive components for a single shift of 7.5 hours, 5 days a week, planned throughput is 250 units/hour; actual output = 3875 units/week.

The following losses are encountered during assembly:

- Incorrect assembly causes the machine to stop and needs re-set on average 5 times/hr. where 1 unit and 2 minutes are lost. (This leads to performance loss due to minor stoppage and also quality loss.
- Worn out electrodes are to be replaced once per week, it takes 1 hour when 30 units are scrapped.
- Burst out cooling hose causes a machine breakdown once in a month and replacement takes 5 hours.
- Misaligned fixture causes a loss of 220 units/ week.
- For different size parts, fixtures to be removed and replaced and electrode position to be adjusted 3 times/week which takes 2.25 hours where 24 units are scrapped each time.
- Actuating cylinder sometimes sticks for 30 minutes/day causing production delay which takes double cycle time.
- Application of rust protective spray by operator stopping the machine at the start and end of the day takes 5 minutes each time.
- Limit switches corrode once in every 6 weeks stopping the machine and replacement takes 6 hours.

(a) Calculate the availability of this process.

(5 marks)

(b) Calculate the performance rate.

(5 marks)

(c) Calculate the quality rate.

(5 marks)

(d) Find the overall equipment effectiveness.

(5 marks)

Q4 An instantaneous contact of a pair of spur gear teeth is represented by a rigid roller of 5 mm radius and length 10 mm against a semi-infinite elastic half space of equivalent elastic modulus E^*. The sliding speed of the gear teeth is 1 m/s and the lubricant entrainment speed is 0.5 m/s. This gear is running under load of 600 N. The lubricant viscosity at atmospheric pressure is 0.07 Pas and the pressure viscosity coefficient is 10^{-8} Pa^{-1}. Both gears are made of heat treated steel of Young's modulus of elasticity 210 GPa, and Poisson's ratio 0.3 (assume elastic line contact with maximum Hertzian pressure distribution and isothermal conditions).

(a) Calculate the lubricant film thickness under this situation.

(6 marks)

(b) Find the footprint area of contact of these two gears,

(4 marks)

(c) Determine the lubricant viscosity by using "Roeland's" equation.

(6 marks)

(d) Find the coefficient of friction.

(4 marks)

Q5 A turbine engine is running at 12000 rpm, under load of 50 kN. The dimension of the journal bearing is 20 cm in diameter, and 10 cm in length. The oil temperature is 30 °C with density of 860 kg/m³. The coefficient of specific heat of lubricant is 1880 J/kg°C and the constant of heat removal k_l is 0.75, with reciprocal Sommerfeld number is 0.7855. The film thickness is estimated not more than 40 microns. The flow rate constant is 0.751 and friction constant is 17.1. The eccentricity ratio is 0.35.

(a) Illustrate by aid of sketch the journal bearing geometry and define its clearance and eccentricity ratio.

(7 marks)

(b) Calculate the radial clearance of the journal.

(3 marks)

(c) Find the increase of the lubricant temperature.

(5 marks)

(d) Determine the lubricant viscosity under this situation.

(5 marks)

Q6 A circular hydrostatic central orifice step bearing supports the end of a 0.02 m diameter shaft under purely axial load. The outside diameter of the bearing is 0.2 m and its recess diameter is 0.01 m. From a constant pump supply pressure of 10 MN/m^2, an oil of viscosity 25 cP is fed, via a capillary tube, to a pressure in the recess of 5 MN/m^2; the bearing film thickness is to be 10^{-4} m. (assume $L/d = 100$ is sufficient to maintain purely viscous flow).

(a) Determine the load capacity of the bearing.

(4 marks)

(b) Calculate the flow of lubricant.

(4 marks)

(c) Determine the stiffness of the bearing.

(6 marks)

(d) Determine the lifting power of the bearing.

(2 marks)

(e) Design suitable capillary tube dimension if viscous flow is to be maintained within it.

(4 marks)

- END OF QUESTIONS -

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USEFUL FORMULAS

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$$U = 2\pi RN$$

$$h_o = \frac{4\ L\ U\ \eta_o\ R}{W}$$

$$\lambda = \frac{h}{\sigma}$$

$$F_n = F_m + W$$

$$F_a = A\tau_s$$

$$A = 3.2\frac{F_n}{E^*}\sqrt{\frac{r}{\sigma_p}}$$

$$\mu = \frac{F_a}{F_n}$$

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$$\frac{1}{E^*} = \frac{1-{\nu_1}^2}{E_1} + \frac{1-{\nu_2}^2}{E_2}$$

$$\frac{h_o}{R} = 2.076\left(\frac{\alpha\eta_0 V}{R}\right)^{\frac{8}{11}}\left(\frac{E^*R}{P'}\right)^{\frac{1}{11}}$$

$$a = \left(\frac{4WR}{\pi LE^*}\right)^{\frac{1}{2}}$$

$$Z = \frac{\alpha}{(5.1\times10^{-9})[ln(\eta_o) + 9.67]}$$

$$p_o = \left(\frac{WE^*}{\pi LR}\right)^{\frac{1}{2}}$$

$$\eta = \eta_o\left(\frac{63\times10^{-6}}{\eta_o}\right)^{1-\left\{1+\frac{p}{196}\right\}^z}$$

$$\tau = \left(\frac{\eta U}{h_o}\right)$$

$$F_a = A\tau_s$$

$$\mu = \frac{F}{W}$$

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$$c = \frac{h_o}{(1-\varepsilon)}, c = \frac{h_1}{(1+\varepsilon)}$$

$$K_1 = \frac{k_1}{\rho \, c_p}$$

$$\Delta\theta_s = \frac{2\,\mu^*\,K_1\,W}{Q^*R\,L}$$

$$\eta = \frac{1}{S}\left(\frac{W}{\pi NDL}\right)\left(\frac{c}{R}\right)^2$$

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$$A = \pi R^2$$

$$\bar{A} = \frac{1}{2}\left(\frac{1 - 1/\bar{R}^2}{\ln(\bar{R})}\right)$$

$$\bar{R} = R/R_o$$

$$\bar{B} = \frac{\pi}{6\ln(\frac{R}{R_o})}$$

$$W = Ap_r\bar{A}$$

$$Q = \frac{p_r h^3}{\eta}\bar{B}$$

$$W = \frac{Ap_s\bar{A}}{h^3K_c\bar{B} + 1}$$

$$\lambda_c = \frac{3W}{h}\left(\frac{1}{1 + (1/\bar{B}K_c h^3}\right)$$

$$P = Qp_r$$

$$K_c = \frac{128L_c}{\pi d^4}$$

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Availability (A) = {(loading time) – (down time) } / loading time

Performance rate (P)= { Quantity produced } / { Time run x Capacity / Given time }

Quality (Q)= { Amount produced – defects – reprocess } / Amount produced

Overall equipment effectiveness (OEE) = (A)(P)(Q)

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