Second Semester Examination
2023/2024 Academic Session

July / August 2024

EME 452 – Tribology
(Tribologi)

Duration: 3 hours
(Masa: 3 Jam)

Please check that this examination paper consists of SIX (6) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM (6) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer ALL **FIVE (5)** questions.

*[**Arahan**: Jawab **LIMA (5)** soalan]*

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1. (a) Factory A aims to promote a sustainable working environment while reducing operation cost by optimizing the tribology parameters. Discuss **THREE (3)** sustainability areas that can be achieved by practicing the knowledge in tribology.

(50 marks)

(b) Two rollers with a diameter of 15 mm and 20 mm are pressed with a normal load of 800 N, producing a line contact. Both rollers have the same length of 10 mm. The material properties and surface parameters of the rollers are given in Table 1.

Table 1: Material properties and surface parameters

Roller	Materials	Modulus Young, E (GPa)	Poisson's ratio, v	Hardness, H (GPa)	Roughness Standard deviation, ß (µm)	Asperity mean radius, R_m (µm)	Diameter (mm)
Roller 1	Aluminium	69	0.33	0.33	0.06	95	15
Roller 2	Brass	97	0.34	***X***	0.025	270	20

(i) Calculate the minimum value of brass roller hardness ***X*** at which the deformation of the asperities is predominantly elastic.

(20 marks)

(ii) Given that the yield stress P_y of the brass roller material is 95 MPa, discuss the contact behavior of the roller based on the calculated maximum Hertzian stress, P_o value.

(30 marks)

2. (a) Figure 2 (a) shows the variation of the film thickness and pressure acting on the contact of three roller bearings. The bearings have a dimensionless speed of U_1, U_2 and U_3. All bearings have a similar roller diameter of 10 mm, raceway diameter of 52 mm, and contact length of 10 mm. The bearings are used to support a load of 1500 N. Oil lubricant is used with a viscosity-pressure coefficient of 15 GPa^{-1}. Both components are made of steel with Young's modulus of 200 GPa with Poisson's ratio v = 0.3.

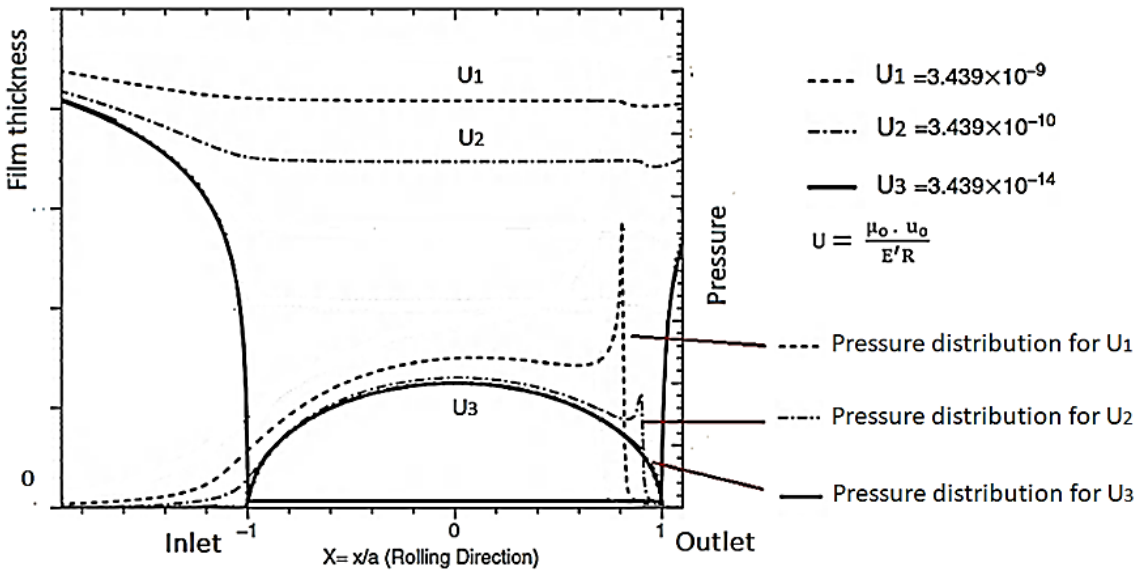

Figure 2 (a): Film thickness and pressure/stress distribution for different speed parameters, U.

(i) Calculate the minimum film thickness of roller bearings with a dimensionless speed U_2 = 3.439 x 10^{-10} and U_3 =3.439 x 10^{-14}.

(30 marks)

(ii) Based on your calculations, identify the suitable speed for the roller bearing to achieve operation in elastohydrodynamic lubrication. Justify your answer by discussing the film thickness and contact pressure distribution.

(20 marks)

(b) Figure 2 (b) shows the lubrication condition between two surfaces with asperities subjected to rolling contact.

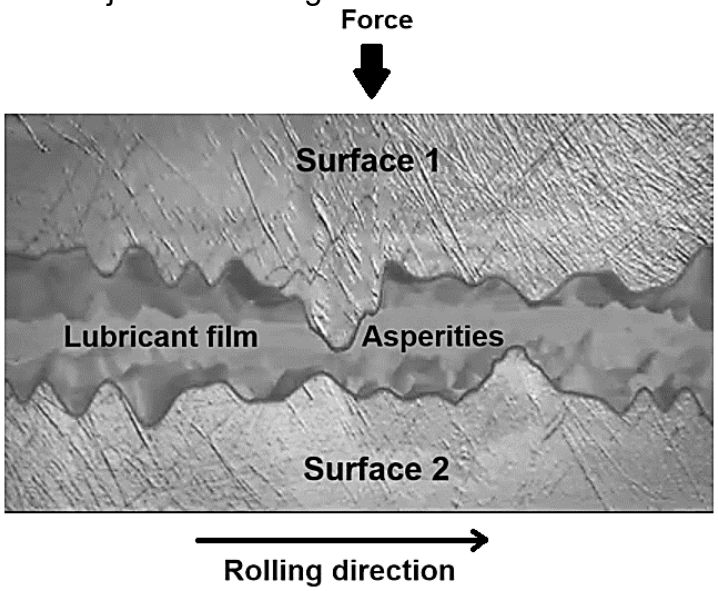

Figure 2 (b): Lubricant condition between surfaces in contact

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(i) Describe the lubrication regime in Figure 2 (b) and explain **TWO (2)** characteristics of this lubrication regime.

(10 marks)

(ii) Propose **TWO (2)** methods to improve the lubrication regime in Figure 2 (b).

(20 marks)

(iii) Suggest **ONE (1)** method that can be applied to ensure a sustainable and environmentally friendly lubrication.

(20 marks)

3. (a) To ensure a steady-state operating condition, the journal bearing is required to operate with a minimum film thickness, h_o of 18 μm. The operating temperature in journal bearing ranges between 70˚C to 90˚C. The journal bearing has 31.5 mm length and 31.5 mm diameter, with a radial clearance of 0.0254 mm. The bearing is lubricated with oil lubrication supplied at atmospheric pressure, subjected to a load of 95 N and a speed of 3000 rpm. Using the Raimondi and Boyd design chart:

(i) Calculate the absolute viscosity of the lubricant required to produce the desired minimum film thickness. If the journal bearing operator uses the SAE 60 grade oil, suggest a suitable operating temperature for the calculated oil viscosity.

(50 marks)

(ii) Calculate the fluid flow rate.

(10 marks)

(b) In hydrodynamic lubrication, the fluid flow rate is equal throughout the surface wedge from the inlet to the outlet of the contact. Discuss **TWO (2)** laws involved in the generation of hydrodynamic lubrication to ensure an equal fluid flow at the inlet and outlet of the surface.

(40 marks)

4. (a) Explain **THREE (3)** applications on the development of wear and defects that beneficial to machining process.

(30 marks)

(b) Give **THREE (3)** indicators showing that the surface roughness is important. List **THREE (3)** methods that are available commercially and explain **THREE (3)** ways to determine surface roughness topography experimentally.

(30 marks)

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(c) It is given that the mass density and specific heat of oil are 880 kg/m^3 and 1.88 J/g K, respectively. Using this information for a fixed-inclined-pad thrust bearing of length 200 mm and width 300 mm, with a minimum film thickness of 10 μm, operates at a sliding velocity of 1 m/s with a mineral oil of absolute kinematic viscosity of 0.03 Pa.s. Film thickness ratio is adjusted to produce the maximum load capacity, m=1.1889. With the help of formulas given from Equations (4.1 to 4.4) answer the question given below:

$$\boldsymbol{p_m = \frac{\eta_o u_o l}{h_o^2}\left[\frac{3m}{2(1+m)(2+m)}\right]} \qquad (4.1)$$

$$W_z = \frac{\eta_o u_o l^2 b}{h_o^2}\left[\frac{6\ln(1+m)}{m^2} - \frac{12}{m(2+m)}\right] \qquad (4.2)$$

$$Q_o = u_o b h_o \left[\frac{1+m}{2+m}\right] \qquad (4.3)$$

$$F_s = \frac{n_o u_o b l}{h_o}\left[\frac{4}{l}\ln(1+m) - \frac{6}{(2+m)}\right] \qquad (4.4)$$

(i) Calculate the maximum pressure, p_m (4.1) and the location of the maximum pressure, normal load capacity (4.2), film stiffness, volumetric flow rate (4.3), and the shear force experienced by the sliding surface (4.4).

(20 marks)

(ii) Determine the coefficient of friction(COF), the power loss (H_v), and the average temperature rise of the fluid. Comment on the results obtained for temperature rise during the motion.

(20 marks)

5. Factors that trigger the touching sensational feel are due to brain Somato sensory systems. This system depends on the pressure, surface of contact, sliding to feel the texture, friction generated through the contact counter surface, vibration in mechano-sensory cell, stretching of the skin due to expansion of our neuro-cell touch receptor and others.

(a) State **THREE (3)** essential testing characteristics and analyse suitable parameters used to study the tribology of contact lense rubbing on the cornea surface.

(30 marks)

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(b) Discuss how the cornea surface can be affected by the application of eyes moisturizer and during dry contact that lead to smearing of the cornea surface.

(30 marks)

(c) Discuss the issue of cornea damage due to excessive contact lenses applications and ways to prevent the pre-mature smearing processes due to frequent abrasion of the cornea.

(40 marks)

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