Second Semester Examination
2021/2022 Academic Session

July/August 2022

EME 452 – Tribology
(Tribologi)

Duration : 2 hours
(Masa : 2 jam)

Please check that this examination paper consists of FIVE (5) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA (5) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions : Answer **FOUR (4)** questions.

*[**Arahan**: Jawab **EMPAT (4)** soalan.]*

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1. A cylindrical roller bearing with a roller diameter of 15 mm and length of 15 mm and raceway diameter of 52 mm is used in machinery with a running speed of 3000 rpm. The bearing is used to support a load of 1 kN. The lubricating oil viscosity is 0.01 Pa.s at atmospheric pressure and the viscosity-pressure coefficient is 15 GPa^{-1}. Both components are made of steel with Young's modulus of 200 GPa with Poisson's ratio v = 0.3.

   (a) Using the Pan and Hamrock equation (1989), calculate the minimum film thickness based on the elastohydrodynamic lubrication.

   (60 marks)

   (b) Given the RMS roughness for roller and raceway surfaces is 0.025 μm and 0.03 μm respectively. Determine the lubrication film parameter, λ. With the help of sketch, describe **TWO (2)** characteristics of the lubrication regime related to the obtained λ value.

   (25 marks)

   (c) Based on the lubrication regime obtained in (b), decide if further surface machining should be carried out for the surfaces to be fully separated by the film thickness. Justify your answer.

   (15 marks)

2. (a) A journal bearing with 70 mm length and 140 mm diameter with a radial clearance of 0.05 mm is used to support a load of 120 kN when the shaft is rotating at 1500 rpm. The bearing is lubricated with oil lubrication, supplied at atmospheric pressure and the average operating temperature is maintained at 70 degrees Celsius. The lubricant is required to produce a minimum film thickness, h_o of 16 μm in order to ensure a steady-state operating condition. By using the Raimondi and Boyd design chart, find the absolute viscosity of the lubricant that is required to produce the desired minimum film thickness and suggest the grade of oil that is suitable for this case.

   (50 marks)

   (b) With the help of a sketch, explain **TWO (2)** laws that are applicable to ensure an equal fluid flow at the inlet and outlet of the surface separation for the case of hydrodynamic lubrication.

   (50 marks)

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3. (a) Compare between bio-tribology, natural tribology and man-made tribology by giving **TWO (2)** examples of each phenomenon.

(20 marks)

(b) Sketch the four quadrants that shows the appropriate mapping of the coefficient of friction (COF) versus wear rate (Wr) for giving **ONE (1)** example for each application in the quadrant. Discuss on the optimized values of friction and wear rate in the daily applications mentioned beforehand.

(40 marks)

(c) With the help of the sketch on Stribeck curve, discussed the four phases of lambda (λ) that define the lubricants phases that applicable to the practices nowadays. List out the **FOUR (4)** type of lubrications in every day applications.

(40 marks)

4. The wear in rubber and plastics occurred in a manner that it follows Hooks law and characterized by their elastomeric characteristics. Under normal mechanical and practical procedures, the wear-rate normally changes through three different stages: primary stage or early run-in period, where surfaces adapt to each other and the wear-rate might vary between high and low; secondary stage or mid-age process, where a steady rate of wearing is in motion. Lastly, roll-on and detachment process.

(a) Describe **TWO (2)** main types of wear in industrial applications.

(10 marks)

(b) With the help of diagram in Figure 4 (b) on mechanisms of rubber wear, explain using your own words on the mechanisms involved.

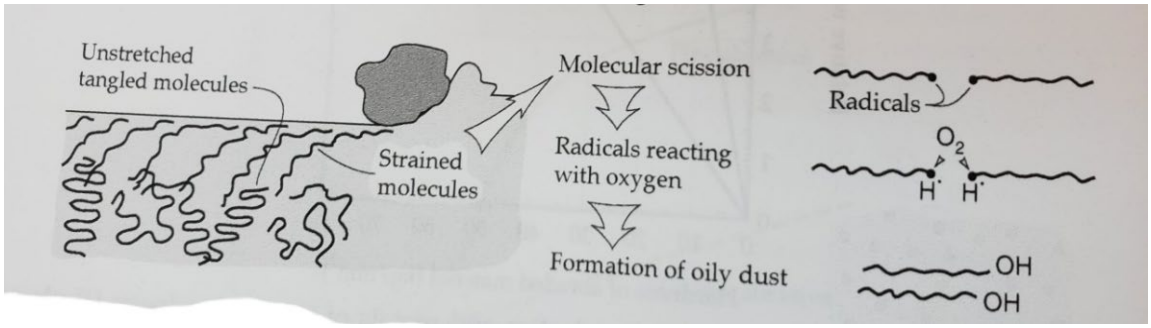

Figure 4 (b)

(20 marks)

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(c) In aerospace applications, rubber lining has become an essential in many components. Using the diagram on Schallamach waves effect on abraded rubber, describe the phenomenon that led to the waves effect as shown in Figure 4 (c) below.

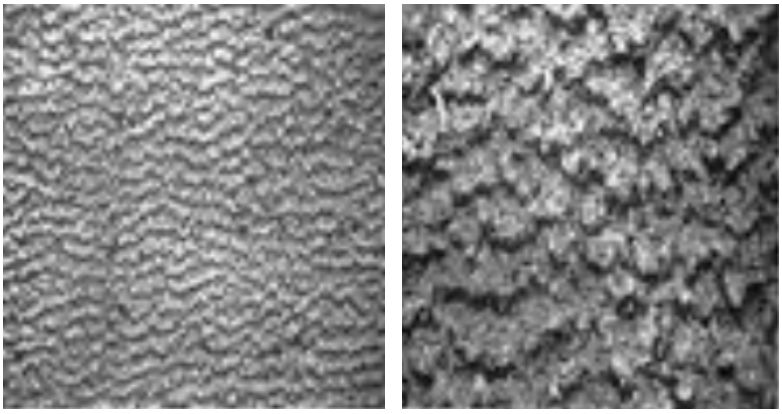

Figure 4 (c)

(20 marks)

(d) Give TWO (2) examples on the applications of rubber that is crucial in transportation and ports.

(20 marks)

(e) A fixed-inclined-pad thrust bearing of length 100 mm and width 500 mm, with a minimum film thickness of 50 μm, operates at a sliding velocity of 1 m/s with a mineral oil of absolute kinematic viscosity of 30 cP (0.03 Pa.s). Film thickness ratio is adjusted to produce the maximum load capacity. With the help of formulas given from Equations (4.1 to 4.4) answer the question given below:

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

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

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

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

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

(ii) Determine the coefficient of friction, the power loss and the average temperature rise of the fluid. Comment.

It is given that the mass density and specific heat of oil are 880 kg/m^3 and 1.88 J/g K, respectively.

(30 marks)

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