Second Semester Examination
Academic Session 2018/2019

June 2019

EME 452 – Tribology
[Tribologi]

Duration : 2 hours
[Masa : 2 jam]

Please check that this paper contains **SIX [6]** printed pages before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **ENAM [6]** mukasurat bercetak sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

Tribology Design Booklet is provided.
Buku Tribology adalah dibekalkan

1. **The Reynold's equation is used primarily to determine the lubrication parameters of the flow between two surfaces such as the journal bearing. Using a control volume approach and assuming a flow in the bearing is limited to the circumferentialdirection (1-D flow) and no flow in the axial direction, derive the Reynold's equation.**

   Persamaan Reynold digunakan untuk menentukan parameter-parameter pelinciran untuk aliran di antara dua permukaan yang bergerak seperti yang terdapat pada galas jurnal. Dengan menggunakan pendekatan isipadu kawalan dan membuat anggapan aliran di dalam galas jurnal adalah terhad di dalam arah ukurlilit (aliran 1-D) dan tiada aliran di dalam arah paksi, terbitkan persamaan Reynold tersebut.

   (100 marks/*markah***)**

2. **Using the Raimondi Boyd charts from the booklet given, determine the steady state operating condition of the journal bearing of 80mm long and 160mm in diameter with radial clearance of 0.12 mm. The bearing is used to support a load of 40 kN when the shaft is rotating 30 rev/s. The bearing is lubricated with SAE 40 oil supplied at atmospheric pressure and average operating temperature of 65 degree Celsius.**

   Dengan menggunakan carta Raimondi Boyd daripada buku kecil yang diberikan, kirakan keadaan operasi mantap bagi galas jurnal sepanjang 80mm dan berdiameter 160mm dengan kelegaan jejari 0.12mm. Galas itu di gunakan untuk menyokong beban 40 kN dengan aci berputar selaju 30 putaran se saat. Galas di lincirkan dengan minyak SAE 40 yang dibekalkan pada tekanan atmosfera dan dengan suhu purata 65 darjah Celsius.

   (100 marks/*markah***)**

3. **A ball bearing with the ball diameter of 10 mm and raceway diameter of 45 mm is used in machinery with a running speed of 1500 rpm. The bearing is used to support a load of 700 N. 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 and Poisson's ratio *v* = 0.3.**

   Galas dengan penggolek bola berdiameter 10 mm dan alur laluan berdiameter 45 mm digunakan di dalam mesin dengan kelajuan 1500 putaran seminit. Galas ini digunakan untuk menyokong beban 700 N. Minyak pelincir yang digunakan mempunyai kelikatan 0.01 Pa.s pada tekanan atmosfera dan pekali kelikatan-tekanan 15 GPa^{-1}*. Kedua-dua komponen diperbuat daripada keluli dengan Modulus Young 200 GPa dan nisbah Poisson v =0.3.*

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

Dengan menggunakan persamaan Pan dan Hamrock (1989), tentukan ketebalan filem minimum berdasarkan pelinciran elastohidrodinamik.

(65 marks/*markah***)**

[b] **Given the RMS roughness for ball and raceway surface is 0.018 μm and 0.022 μm respectively. Determine the lubrication film parameter, *λ*. With the help of sketch, describe TWO (2) characteristics of the calculated lubrication regime.**

Diberikan kekasaran RMS bola dan alur laluan adalah 0.018 μm dan 0.022 μm masing-masing. Tentukan parameter filem pelinciran, λ. Dengan bantuan lakaran, terangkan DUA (2) ciri rejim pelinciran yang telah dikira.

(25 marks/*markah***)**

[c] **Based on the lubrication regime obtained in 3[b], should further surface machining be carried out for the surfaces to be fully separated by the film thickness. Justify your answer.**

Berdasarkan rejim pelinciran yang diperolehi dalam 3[b], perlukah pemesinan permukaan lanjut dilakukan supaya permukaan dipisahkan sepenuhnya oleh ketebalan filem. Berikan justifikasi anda.

(10 marks/*markah***)**

4. [a] List and compare FOUR (4) type of wear mechanisms with sketches.

Senaraikan dan bandingkan EMPAT (4) jenis mekanisma haus dengan lakaran.

(20 marks/*markah***)**

[b] According to mapping in Figure 4[b], with the help of sketches, give ONE (1) example for each of the four mapping indicated in the figure.

Berpandukan pemetaan pada Gambarajah 4 [b], dengan bantuan lakaran berikan SATU (1) contoh bagi setiap satu daripada empat pemetaan yang ditunjukkan dalam gambarajah.

high friction ↑	**High Friction, Low Wear**	**High Wear, High Friction**
	Low Friction, Low Wear	**High Wear, Low Friction**
low	**low** →	**high Wear**

Figure 4[b]
Gambarajah 4[b]

List THREE (3) types of material properties to prolong the life of a tribological device.

Senaraikan TIGA (3) jenis-jenis sifat bahan untuk memanjangkan hayat alat tribologi.

(40 marks/*markah***)**

[c] 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.

Pad tetap-cenderung tujahan bergalas sepanjang 100 mm dan lebar 500 mm berketebalan filem minimum 50 μm, beroperasi pada halaju gelongsor 1 m/s dengan minyak mineral yang kelikatan mutlak 30 cP (0.03 Pa.s). Nisbah ketebalan filem dilaraskan untuk menghasilkan kapasiti maksimum beban.

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

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

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

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

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

Kirakan tekanan maksimum (seperti persamaan 4.1) dan lokasi tekanan maksimum, kapasiti muatan biasa(seperti persamaan 4.2), filem kekejangan, kadar aliran isipadu (seperti persamaan 4.3), dan daya ricih yang dialami oleh permukaan gelongsor (seperti persamaan 4.4).

Given that the mass density and specific heat of oil are 880 kg/m^3 and 1.88 kJ/kg K, respectively.

Diberi ketumpatan jisim dan haba minyak adalah 880 kg/m^3 dan 1.88 kJ/kg K, masing-masing.

(40 marks/*markah***)**

5. (a) Explain the importance of surface roughness. List and identify THREE (3) method to determine surface roughness topography experimentally.

Terangkan kepentingan kekasaran permukaan. Senarai dan kenalpasti TIGA (3) kaedah untuk menentukan topografi kekasaran permukaan secara ujikaji.

(40 marks/*markah***)**

(b) The flat face of a Titanium(Ti) annulus having an outside diameter of 20 mm and an inside diameter of 10 mm is placed on a flat Zirconium (Zr) alloy plate under a normal load of 10 N and rotates about its axis at 100 rpm for 100 hour. As a result of wear during the test, the mass losses of the Ti and Zr are 20 mg and 1 mg, respectively. Calculate and compare the wear coefficients (as in Equation 5.1) and wear depths for the Ti and Zr.

Permukaan rata anulus Ti yang mempunyai diameter luar 20 mm dan diameter dalam 10 mm diletakkan di atas plat aloi zirkonium rata di bawah beban biasa 10 N dan putar diatas paksinya pada 100 rpm selama 100 jam. Hasil daripada ujian haus, jisim yang hilang pada Ti dan Zr adalah 20 mg dan 1 mg, masing-masing. Kira dan bandingkan pekali haus (seperti di dalam persamaan 5.1) dan kedalaman haus Ti dan Zr tersebut.

$$\mathbf{k} = \frac{\mathbf{vH}}{\mathbf{Wx}} \quad (5.1)$$

It is given that the hardness of Zr = 2.5 GPa, density of Zr= 7800 kg/m^3, hardness of Ti= 0.8 GPa, and density of Ti= 7500 kg/m^3. The average contact diameter is 15 mm.

Diberi bahawa kekerasan Zr = 2.5 GPa, ketumpatan Zr = 7800 kg/m^3, kekerasan Ti = 0.8 GPa, dan ketumpatan Ti = 7500 kg/m^3. Purata diameter sentuhan adalah 15 mm.

(60 marks/*markah***)**

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