Second Semester Examination
2020/2021 Academic Session

July/August 2021

EME 452 – TRIBOLOGY

Duration: 2 hours

Please check that this examination paper consists of **SIX (6)** pages including appendixes before you begin the examination. A Raimondi Boyd Design Chart is given in separate file.

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

Answer to each question must begin from a new page.

Open-book
Please answer all questions. All answers must be handwritten and upon submission please safe the file as Final exam_matrix no_student's name.doc or Final exam_ matrix no_student's name.pdf
Submission via elearning or email.

1. Surface roughness is important in the formation of lubricant film in elastohydrodynamic (EHL) lubrication. Figure Q1 shows the film thickness optical interferogram, the minimum film thickness, and Hertzian stress distribution for four different surface roughness.

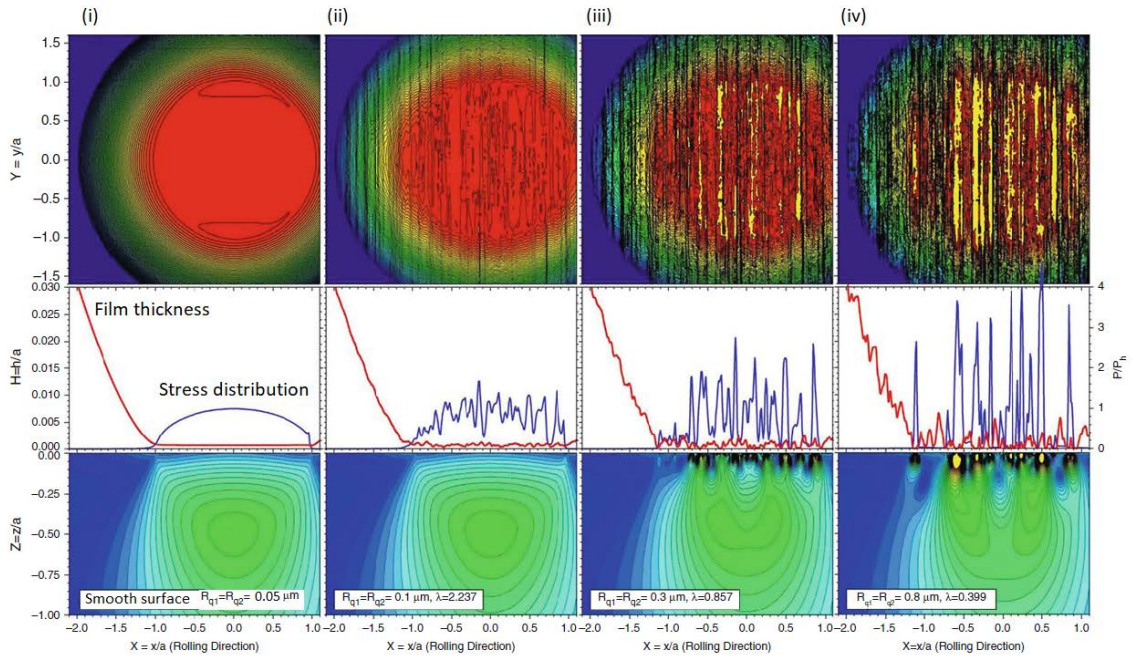

Figure Q1 Film thickness optical interferogram, a minimum film thickness and Hertzian stress distribution for surfaces with a composite roughness and λ of (i) R_{q1} = R_{q2} = 0.05 μm (ii) R_{q1} = R_{q2} = 0.1 μm, λ = 2.237 (iii) R_{q1} = R_{q2} = 0.3 μm, λ = 0.857 and (iv) R_{q1} = R_{q2} = 0.8 μm, λ = 0.399

[a] Based on Figure Q1, explain the effect of surface roughness on the formation of film thickness and stress distribution.

(20 marks)

[b] Given that the minimum film thickness formed in (i) is 0.3 μm. The surfaces are stainless steel surface with similar E1 = E2 = 200 GPa, v = 0.3 and hardness of 2 GPa. The surface roughness standard deviation is 0.025 μm and the mean radius is 0.5 mm.

(i) Determine the λ parameter.

(ii) Determine the plasticity index of this surface and explain how it contributes to the λ parameter.

(30 marks)

[c] State the lubrication regime for each surface (i), (ii), and (iii) based on the λ parameter and describe the characteristic.

(30 marks)

[d] Provide **ONE (1)** effect of the lubrication regime (iv) to the environment and propose **ONE (1)** method to solve the problem.

(20 marks)

2. [a] A journal bearing of 80 mm length and 160 mm diameter with a radial clearance of 0.05 mm is used to support a load of 82 kN when the shaft is rotating at 1800 rpm. The bearing is lubricated with oil lubrication, supplied at atmospheric pressure and the average operating temperature is maintained at 75 degrees Celsius. The lubricant is required to produce a minimum film thickness, h_o of 12 μm in order to ensure a steady-state operating condition. By using the Raimondi Boyd design chart and Appendix 1, 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.

(60 marks)

[b] With the help of a sketch, explain the generation of hydrodynamic pressure in the journal bearing.

(40 marks)

3. [a] Provide brief answers to the following questions.

(i) Define the terminology of Tribology and **SIX (6)** mode of wear.

(ii) Discuss **THREE (3)** applications with sketches on the development of wear and defects that benefitted to human or contributed an impact that could cause damages to products or machining process.

(30 marks)

[b] (i) With the help of the sketch on Stribeck's graph, explain the four phases of lamda that define the lubricants phases that applicable to the practices nowadays.

(ii) List out the **FOUR (4)** types of lubrications in everyday applications that you know.

(30 marks)

[c] A fixed-inclined-pad thrust bearing of length, $l = 100mm$ and width $b = 500\,mm$, with a minimum film thickness of $h_0 = 50\,\mu m$, operates at a sliding velocity of 1 m/s with a mineral oil of absolute kinematic viscosity of 30 cP ($\eta_0 = 0.003\,Pa.s$). Film thickness ratio is adjusted to produce the maximum load capacity with mass $m = 1.1889$. With the help of formulas given from Equations (3.1 to 3.5) answer the question given below:

$$p_m = \frac{\eta_o u_o l}{h_o^2}\left[\frac{3m}{2(1+m)(2+m)}\right] \quad (3.1)$$

$$x_m = l(1+m)/(2+m) \quad (3.2)$$

$$W_z = \frac{\eta_o u_o l^2 b}{h_o^2}\left[\frac{6\ln(1+m)}{m^2} - \frac{12}{m(2+m)}\right] \quad (3.3)$$

$$Q_o = u_o b h_o \left[\frac{1+m}{2+m}\right] \quad (3.4)$$

$$F_s = \frac{n_o u_o b l}{h_o}\left[\frac{4}{m}\ln(1+m) - \frac{6}{(2+m)}\right] \quad (3.5)$$

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

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

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

(40 marks)

4. [a] Tribological skin friction is a contemporary topic discussed amongst tribologists recently mainly due to its elastomeric characterization and compatibility in medical skin grafting in cosmetic surgery. Three examples of skin friction applications are (i) leg-skin surface contact with wet/swimming pool floor surfaces, (ii) skin-product interaction in shaving and (iii) touch-screen on handphone/laptops.

Select **ONE** of the examples listed above and state the essential testing characteristics. Analyse suitable parameters used to study the skin tribology.

(30 marks)

[b] Discuss the effect of moisturizer, oil, cosmetics and powdery talc smearing on skin surface tribology.

(30 marks)

[c] Skin damage is due to excessive cosmetic applications. Suggest 4 ways to prevent the pre-mature aging processes due to frequent abrasion on the skin**.**

(40 marks)

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APPENDIX 1

Absolute (dynamic viscosity) -Temperature chart

***1 Pa.s =1 Ns/m^2**