GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Quarter 1997

Tribology
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

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GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENGINEEERING
Ph.D. QUALIFYING EXAM-TRIBOLOGY
SPRING QUARTER 1997

1. According to the adhesion theory of friction, the friction coefficient is given by

$$\mu_{adh} = \frac{s_o}{H}$$

where s_o and H are the shear strength and hardness, respectively, of the softer material. On the other hand, when a hard conical, asperity plows into a softer material, the friction coefficient (due to "deformation") is given by

$$\mu_{def} = \frac{2}{\pi}\cot\theta$$

where θ is the interior cone angle measure from the axis of the cone.

(a) For each of these models list the key assumptions used in deriving the models.

(b) Since a given interface may exhibit both adhesion and ploughing, it is sometimes assumed the overall friction coefficient may be written:

$$\mu = \mu_{adh} + \mu_{def}$$

Is this equation valid? If so, give a mathematical justification. If not, show mathematically, why it is invalid.

2. This problem addresses the heat generated at sliding interfaces.

The coefficient of friction for copper on copper is 0.9. Assuming that asperities can be represented by cores of base and height each about 10^{-3} cm, and taking the yield stress of copper to be 30 MPa, calculate the local temperature that should be produced when rubbing a cooper pin on a copper plate. Suppose that the frictional heat is coined to the asperities and take the sliding speed to be 10 cm/s and the load to be 15 kg.

Hint: The heat generated per unit area per second is given by $q = \frac{\mu F \upsilon}{A}$. Use this in conjunction with a linearized Fick's First Law (heat flux equation) to relate the temperature to the experimental variables.

μ	=	coefficient of friction
A	=	contact area
F	=	normal force
υ	=	sliding velocity
K_m	=	thermal conductivity = $0.94 \dfrac{cal\ cm}{cm^2 \cdot s \cdot {}^\circ C}$
1 cal.	=	4.2 Joules

3. Car skidding on a wet pavement is a problem that can be analyzed by the lubrication theory. This is because the ratio of the minimum film thickness, C, and the tire radius, R, is of the order of 10^{-5}. The real problem involves, of course, the solution of the Reynolds Equation along with the elasticity equation since the tires will deform under the weight of the car and the hydrodynamic pressure the is being built between the tire surfaces and the pavement. For simplicity (and a first approximation) we shall neglect here all elastic deformations and assume the pavement and the tires to be perfectly rigid. We shall also assume that because the tire is much wider than the film thickness, then all pressure gradients along the tire axis are negligible compared to the pressure gradients that develop along the direction of motion.

   a. Form the problem mathematically and state the boundary conditions.

   b. Solve for the pressure between the tire and the pavement. Carry the solution as far as you can mathematically, and schematically plot the pressure profile under the tire.

   c. New cars are being built today with anti-lock breaking systems (ABS). Explain how such a system may (or may not) help in reducing the skidding problem. You must support your arguments with the math involved in the problem, and engineering concepts that you know. For example, pure rolling has no friction losses, whereas friction caused by sliding in rubbing contact is much higher than viscous friction.