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Analysis of sliding contact temperature for roughness surface

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ABSTRACT – In this work, the Finite Element Method (FEM) is used to analysis contact temperature of multiply asperity sliding contact surface. The following parameters are included: pressure, roughness, sliding speed, friction coefficient, and thermal conductivity. Analysis results show that pressure and thermal conductivity play the most important role on affecting maximum temperature rise parameter. In addition, regression equations are used to study the effect of study parameters on the contact temperature for roughness surface. The effects of contact pressure and thermal conductivity on the contact temperature increases as the Peclet number increases.

1. INTRODUCTION

All engineering surfaces are rough. When two surfaces slide over each other, rough surfaces will cause contact at discrete contact spots. The contact temperature and real contact area play a significant role in contact properties since it determines the states of wear, friction, lubrication, and frictional heating and signal transmission between two rough surfaces.

Blok [1] and Jaeger [2] were pioneered to the studies of temperature rise at the contact surfaces due to moving heating source. The Fractal Method of surface roughness was firstly used for temperature analysis by Wang and Komvopoulos[3]. Lin[4] described the thermal behavior of a single asperity in an apparent area of contact. A new expression of the temperature rise parameter T/f is introduced to describe fluctuations in the thermal parameters. The Finite Element Method has been widely used to investigate the contact temperature of the deformation peak. Ye and Komvopoulos [5] show that frictional shear traction and thermal loading promote stress intensification and plasticity, especially in the case of relatively thin layers exhibiting low thermal conductivity. A series of transient three-dimensional thermo-mechanical model of single peak has been developed by Liu et al. [6,7] and Chen and Wang[8] for sliding contacts. The past experiments generally analyzed single smooth surface under various loads [9]. However, experiments for multiple peaks under various loads are limited. Only a few papers have studied temperature distribution of the peaks and valleys for multiple peaks contact conditions.

2. METHODOLOGY

The contact of a deformable rough surface and a rigid flat is shown in Fig. 1 where upper surface has five semicircle peaks. A uniform distribution pressure of P is applied at the top of the upper sliding block. Then the block moves along the smooth surface of the lower block for a distance of d, through traveling time t. The velocity of the sliding block V is then determined as d/t. The initial point-of-contact interface will become a line contact after loading, as shown in Fig. 2. Therefore, the number of elements used at the nearby area of the peaks will affect the amount of heat generated on the contact patch significantly. A finite element model of the sliding system was constructed by using 32 800 elements.

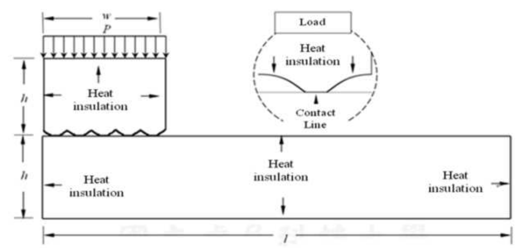

Figure 1 Physical model of the sliders.

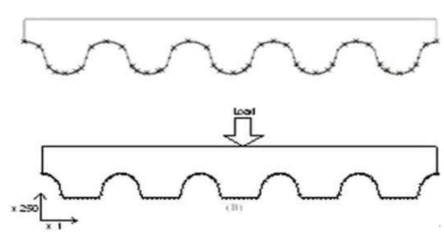

Figure 2 Deformation of the asperity contact profile (a) before and (b) after loading.

3. THEORY

The material properties of the lower block are considered the same as that of the upper sliding block. The thermal equilibrium equation can be described as follows:

$$\rho c(\partial T/\partial t)= \nabla\cdot k\nabla T + Q \quad (1)$$

where T is the temperature which is a function of the coordinate system and time t, ρ is the density, c is the specific heat, k is the conductivity, and Q is the heat generated per unit volume due to the friction work on the contact patches and is given by $Q = fPV$, where f is the coefficient of friction.

4. THEORY

In this study, a system with w = 1280 μm, h = 1280 μm, l = 5120 μm, N = 5, d = 3840 μm, ρ = 2.7 × $10^{-9} Ns^2/ mm^4$, and c = 9 × $108 mm^2/s^2k$, is considered. The study cases for calculating contact temperatures are shown in Table 1.

Table 1 Parameters of calculating contact temperatures

Properties	Data
Pressure (*MPa*)	10 ~ 300
Velocity (*m/s*)	0.512 ~ 20.48
Thermal conductivity(*N/sK*)	50 ~ 200
Average roughness(*nm*)	76.8 ~ 767.7

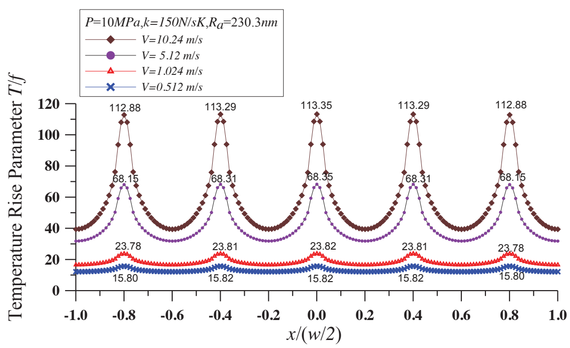

Figure 3 Temperature rise parameter vs. rough surface at various sliding speeds.

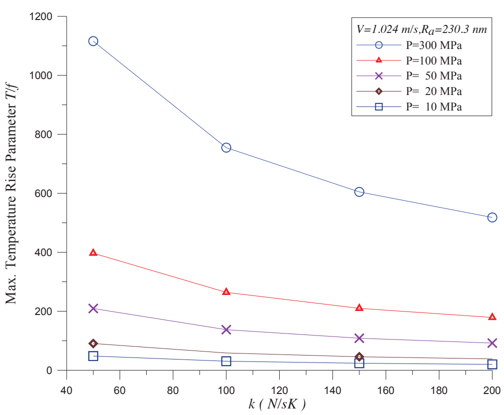

Figure 4 Temperature rise parameter vs. thermal conductivity at various contact pressures.

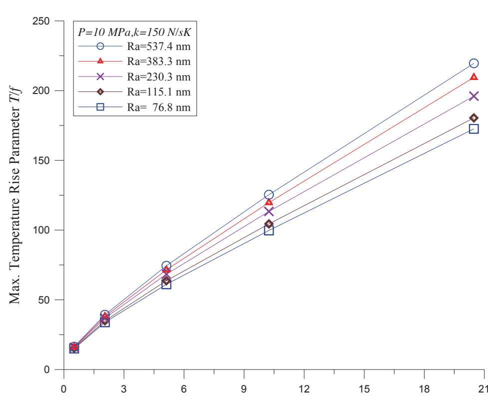

Figure 5 Temperature rise parameter vs. sliding speed at various roughness values.

As shown in Fig. 3, the temperature rise is larger at the middle peak than that of the other peaks. The temperature rise of valleys is the smallest for all rough asperities. Fig. 4 shows that, regardless of contact pressure, max temperature rise parameter decreases when the thermal conductivity increases. Fig. 5 shows that, at the same sliding speed, large roughness surface give up to larger temperature rise parameter. By means of curve fitting, three prediction formulas can be obtained as follows:

$$P_e > 5: \frac{T}{f} = 10^{2.201} \frac{P^{0.889} V^{0.775} R_a^{\ 0.113}}{k^{0.801}} \tag{2}$$

$$0.1 < P_e < 5: \frac{T}{f} = 10^{1.767} \frac{P^{0.94} V^{0.576} R_a^{\ 0.062}}{k^{0.592}} \tag{3}$$

$$P_e < 0.1: \frac{T}{f} = 10^{0.314} \frac{P^{0.99} V^{0.106} R_a^{\ 0.007}}{k^{0.137}} \tag{4}$$

5. CONCLUSIONS

A Finite Element Method model of contact temperature has been developed which incorporates the surface roughness effect. The results show that the contact temperature rise parameter increases as the contact pressure, sliding speed and average roughness increases and thermal conductivity decreases. Three prediction formulas are established to analysis the influence of pressure, sliding speed, average roughness and thermal conductivity on surface contact temperature rise parameter.

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