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Numerical Simulation of Tribological Phenomena Using Stochastic Models

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Tribological phenomena such as wear or transfer are influenced by various factors and have complicated behavior. Therefore, it is difficult to predict the behavior of the tribological phenomena because of their complexity. But, those tribological phenomena can be considered simply as to transfer micro material particles from the sliding interface. Then, we proposed the numerical simulation method for tribological phenomena such as wear or transfer using stochastic process models. This numerical simulation shows the change of the 3-D surface topography. In this numerical simulation, initial 3-D surface roughness data are generated by the method of non-causal 2-D AR (autoregressive) model. Processes of wear and transfer for some generated initial 3-D surface data are simulated. Simulation results show successfully the change of the 3-D surface topography.

Keywords : Wear, Transfer, Surface Topograph, Numerical Simulation, Stochastic Model, Poisson Process

1. INTRODUCTION

Predictions of wear or transfer are expected in various conditions as a result of the tribo l ogical researches. But, it is not easy to predict the behavior of the tribological phenomena because of their complexity. Wear and transfer are phenomena with movements of material particles. So, authors propose a model of such movements of material particle as stochastic process. Numerical simulations about the proposed model show successfully the change of the 3-D surface topography.

2. MODELING

Consider a contact surfaces system with sliding motion such as Fig.1. Let occurrence probability of a moving particle (i.e. a unit of wear or transfer) be n_0 at real contact point for unit time t_0 and unit area. And let total projection area against sliding surface of occurred moving particle be s_0. Namely n_0 express the occurrence frequency and s_0 express the occurrence density.

In this report we assume the model for moving particle as shown in Fig.2. The moving particles have semiellipsoidal shape.

Average of projection area $\bar{s}$ for a moving particle is

$$\bar{s} = E[s] = s_0 / n_0 \tag{1}$$

where $E[]$ expresses expected value. Variance of s, σ_s^2 is

$$\sigma_s^2 = E[(s-\bar{s})^2] \tag{2}$$

Consider small area l^2 ($l^2 >> \bar{s}$) on the contact surface. When sliding velocity is V, the appearance contact area on this small area become lVt_0 during unit time t_0. Let the number of wear or transfer occurrence be k. So, the expected value of k can be expressed by following equation.

$$E[k] = lVt_0 n_0 \tag{3}$$

Considering here probability of occurrence wear or transfer is a Poisson process, probability density p_k can be written by following equation.

$$p_k(t_0) = (\lambda t_0)^k e^{-\lambda t_0} / k! \tag{4}$$

The average (expected value) of p_k is expressed by the following equation.

$$E[p_k(t_0)] = \lambda t_0 \tag{5}$$

Because eq.(3) is equal to eq.(5), we obtain the following equation.

$$\lambda = lVn_0 \tag{6}$$

The physical meaning of the parameter λ is given by eq.(6).

The parameter λ is varied with various tribological factors such as affinity of materials, surface topography, mechanical and chemical properties, lubricating condition, sliding direction and velocity, contact condition, and so on. Assuming λ can be expressed by the function of such factors, the value of λ is decided. So, we can simulate the occurrence of wear or transfer from eq.(4).

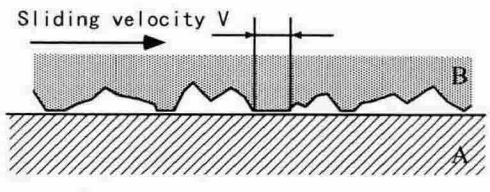


Fig.1 Schematic diagram of contact surfaces

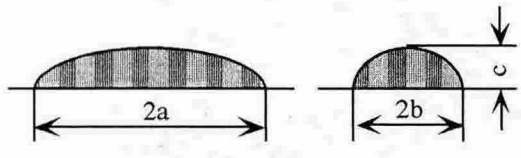


Fig.2 Model of moving material particle (wear or transfer particle)

3. SIMULATION PROCEDURE

Initial 3-D surface topography is generated with the method proposed by authors [1] using non-causal 2-D AR model. The size of moving material particles follows a stochastic model of the exponential distribution. Considering the coordinates for 3-D simulation as shown in Fig.3, the changes of surface topography are simulated as a Monte Carlo simulation.

4. SIMULATION RESULTS

Figure 4 is an example of simulation of transfer. The initial 3-D surface topography used in Fig.4 is isotropic surface.

A simulation of abrasive wear for anisotropic surface is shown in Fig.5.

5. CONCLUSIONS

Processes of wear and transfer for generated initial 3-D surface topography data were simulated. Simulation results could show successfully the change of the 3-D surface topography.

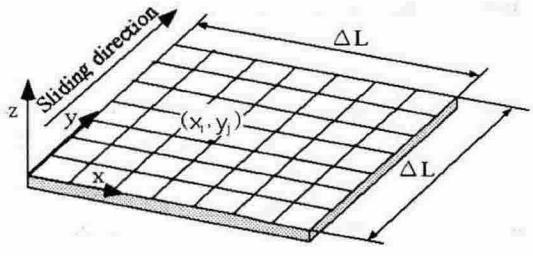
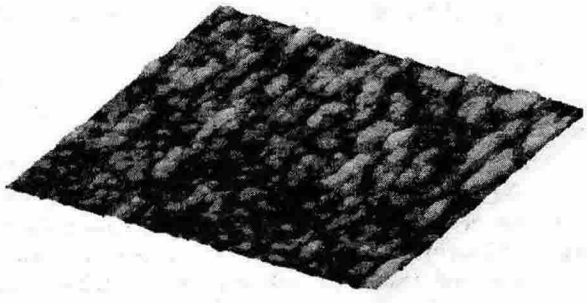
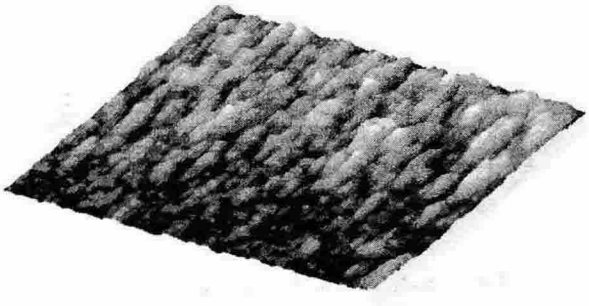


Fig.3 Coordinates for 3D simulation



(a) 1st step

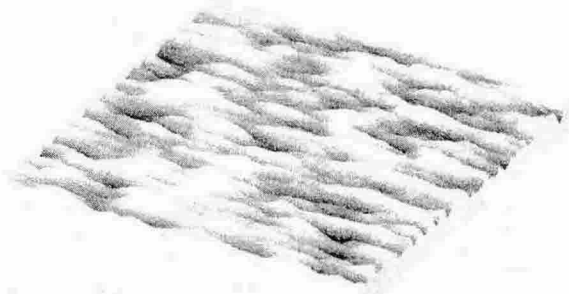


(b) 2nd step

Fig.4 Simulation results of transfer

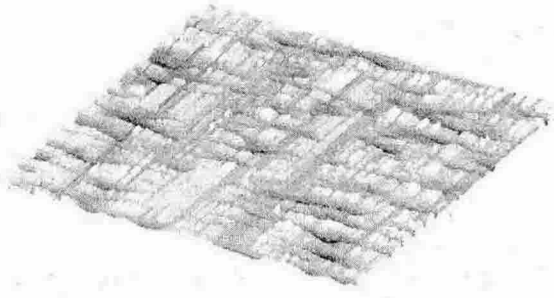
6. REFERENCE

[1] Uchidate, M., Shimizu, T. and Iwabuchi, A., "Generation of Three Dimensional Surface Topography Using Non-Causal Two Dimensional AR Model," Int. Tribol. Cof. Nagasaki 2000, pp. 223-228, 2001.

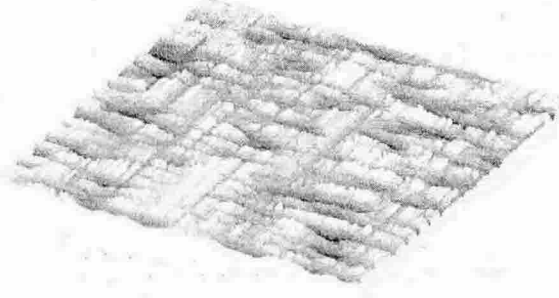


(a) Initial surface

(b) 1st step



(c) 2nd step



(d) 3rd step

Fig.5 Simulation results of abrasive wear for anisotropic surface