Sliding Wear Modeling of Artificial Rough Surfaces

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Abstrak - *Surface roughness plays an important role in machine design. In the micro-scale when two engineering surfaces are brought into contact, the real contact area occurs at isolated point of asperity. Wear is one of some effects of contacting surfaces. This paper presents a modeling of sliding wear at asperity level on the artificial rough surfaces. The surface roughness is represented by spherical asperities at the hemispherical pin that is developed from the existing model. The wear model is based on the simple analytical solution. The combination of Archard's wear equation and finite element simulation is performed to predict the wear. Results show that the increasing of sliding distance give the increasing of wear depth, wear scar diameter and wear volume of the asperity. Wear at the center of the contacting rough surface is higher than the its surrounding.*
[Keywords: Rough Surface; Sliding Wea;, Wear Scar Diameter; Wear Volume]

I. INTRODUCTION

The experiments and analytical studies indicate that the real area of contact between solid surfaces, for instance metals and ceramics, occur at isolated points. The real contact area is a very small portion of the apparent area for flat surfaces (conformal contacts) or curved surfaces (concentrated contacts) [1]. Regarding to the real contact area of a surface, Greenwood and Williamson [2] proposed the simplest method for modeling an irregular surface. A rough surface is represented by identical, uniformly distributed spherical asperities. They assumed that all asperities have the same radius of curvature. The height of asperity is stochastically distributed around an average value. Other models that are based on the Greenwood and Williamson model can be found in [3-6]. In most of these contact models, the asperities are assumed to be hemispherical or paraboloidal and the local contact stresses can be calculated using the Hertz solution [7].

Archard [8] was the pioneer in developing the sliding wear model. Archard's wear equation postulates that the wear rate is defined by the volume worn away per unit sliding distance and the load. The wear depth can be computed related to the wear rate, sliding distance and contact pressure.

There are many papers presented on wear modeling using Archard's equation. Podra [9] presented the sliding wear of a pin-on-disc system. He performed wear simulations to determine the contact pressure distribution and applied Archard's wear relation to calculate the wear as a function of the sliding distance. His work was further developed by Andersson and co-workers [10, 11]. A numerical simulation of the wear of a cylindrical steel roller oscillating against a flat steel surface was performed by Oqvist [12]. The simulation was done with incremental sliding distance steps and the pressure was recalculated as the surface geometry changed. The numerical simulation with updated geometry also presented by Kim et al. [13] and Mukras et al. [14].

Hegadekatte [15-17] presented a wear modeling scheme similar to Podra [9]. He performed a 3D static contact calculation with the FE analysis. The stress field and the topography were extracted from the FE results and wear was calculated (Archard's wear model) on the basis of the contact pressure obtained from the FE simulation. The geometry was updated to calculate a new stress distribution, which in turn is used to compute the updated contact pressure distribution, and so on until the sliding distance set is reached.

In this paper, sliding wear modeling is focused on the microscopic geometry change of a component that wears. In this paper, wear of a rough surface is investigated. The rough surface is represented by an artificial rough surface in which the asperities are represented by uniformly distributed spherical shaped asperities. The wear system considered is a pin-on-disc contact configuration. The general Archard's wear equation [8] is combined with FEA for predicting the wear.

II. FINITE ELEMENT MODELING AND WEAR CALCULATION

The wear simulation in this paper is conducted with the commercial package ABAQUS. Pin-on-disc contact system was selected to perform the contact configuration and wear model. A hemispherical pin of Hegadekatte et al. [17] is modified with an artificial rough surface represented by uniformly distributed spherical asperities is in contact with a smooth flat disc (see Fig. 1).

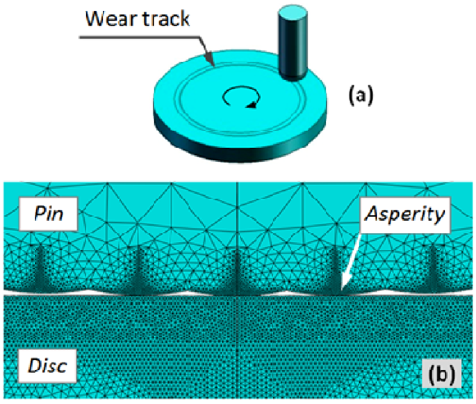

Fig. 1 (a) Pin-on-disc and (b) its asperity

The radius of pin is 0.794 mm. The asperity radius (R_{as}) of 25 μm and 50 μm was used for modeling the asperity. Poisson's ratio is 0.24, Young's modulus is 304 GPa, wear rate (k_D) is 13.5E-9 mm^3/Nmm and contact load is 0.2 N. Both pin and disc made from ceramic material, silicon nitride (Si_3N_4). The nomenclature of asperity location is the 1st asperity at the center of pin and the surrounding asperity is the 2nd, 3rd, 4th, and 5th asperity respectively. For a more detail finite element modeling, the reader is referred to [18].

In the present model the inputs for the simulation are geometry, material model, contact definition and boundary condition. The initial step of this simulation is determining the contact pressure. After this step, the geometry of the contact system is updated. This is repeated until the set sliding distance is achieved.

The local wear depth is computed from combination of the finite element calculated contact pressure and Archard's wear model [8]:

$$\Delta h_w = k_D \cdot p(x,y) \cdot \Delta s \qquad (1)$$

in which, Δh_w is the wear depth, k_D is the wear rate, $p(x,y)$ is the contact pressure distribution and Δs is the incremental sliding distance. The wear of the disc is not considered.

The wear volume is calculated by taking into account the wear depth and wear scar diameter [19] as shown in Eq. (2).

$$V_w = \frac{\pi h_w}{6} \cdot \left(\frac{3}{4} d^2 + h_w^2\right) \qquad (2)$$

where V_w is the wear volume, h_w is the wear depth, and d is the wear scar diameter. The worn volume is assumed to be a spherical shape and the wear scar diameter is similar to the diameter of contact area.

III. RESULTS AND DISCUSSIONS

The wear depth of each asperity is presented in Fig. 2. The asperity at the center of the contact is loaded more than the asperities located further away from the center, this due the geometrical setting of the asperities on a curved body. The wear of the asperity at the center of contact area is higher than the surrounding asperities. Due to the symmetric artificial rough surface wear of the 2nd, 3rd, 4th, and 5th asperity (#2, #3, #4, #5) is the same. At the start of the sliding process, the wear, reduction of the asperity height, is high (initial phase) and then tends to stabilize (final phase). In the terms of mechanical systems, the initial and the final phases are called running-in and steady-state respectively [20].

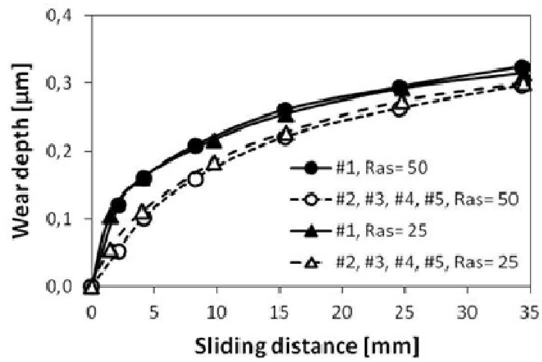

Fig. 2 Wear depth of each asperity

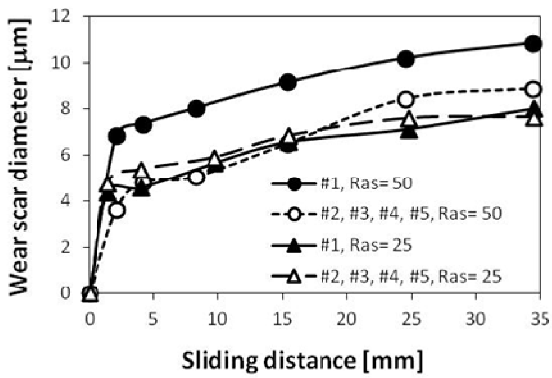

Fig. 3 Wear scar diameter of each asperity

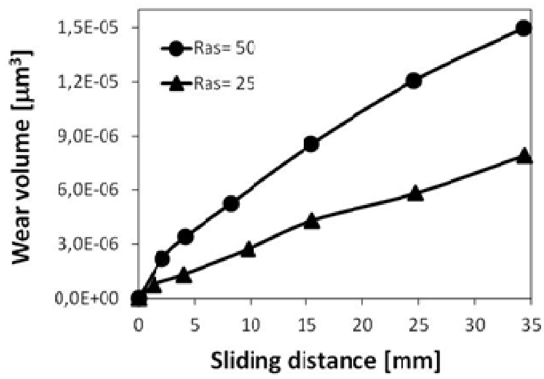

Fig. 4 Wear volume at the center of contact area

From Fig. 3 it can be noted that as the sliding distance increases, the wear and the wear scar diameter also increases. The wear scar diameter, as well as the wear depth at the initial phase of the sliding process is high and then tends to stabilize in the final phase. This behavior is due to the reduction of the asperity height.

Fig. 4 shows the wear volume at the center of contact region (1st asperity) as a function of sliding distance. As predicted the wear volume increase due to increasing the wear scar diameter and wear depth. The wear depth between two asperity models (see Fig. 2) is not so different but the results as is depicted in Fig. 4, the difference between those models is significant. It is clear that the wear (wear scare diameter and wear volume) of the asperity radius of 50 μm at the center of the contact is higher than the asperity radius of 25 μm.

IV. CONCLUSION

A model of sliding wear of artificial rough surface has been presented in this paper. A hemispherical pin, made of silicon nitride with an artificial rough surface represented by uniformly distributed spherical asperities is in contact with a smooth flat disc. Both the pin and the disc have similar mechanical properties. From the FEA, the contact pressure is obtained and then the geometry of the contact system is updated. The local wear depth is computed from combination of the finite element calculated contact pressure and Archard's wear model. It can be concluded that the wear of the asperity at the center of the contact of the rough surface is higher than the surrounding asperities.

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