2D numerical wear model for determining change in surface topography with number of wear cycles

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ABSTRACT – This work demonstrates the evolution of surface topography with the number of cycles during running-in wear. The Archard's wear law is employed to simulate the wear depth by assuming the linear elastic behavior of materials. The numerical simulation is performed on various 2D profiles with varying RMS roughness, skewness and kurtosis. It is shown that roughness parameters significantly change with the number of wear cycles. Two different wear rates are clearly shown which correspond to running-in and mild or steady wear rates. The proposed wear model is developed for dry contacts. Furthermore, it can be extended to develop more complex wear models.

1. INTRODUCTION

Roughness characteristics of contacting surfaces significantly affect the friction and wear. Prajapati and Tiwari [1] reported the effect of lay direction on topography parameters and bearing area curve (BAC). The surface topography substantially changes during wear process due to removal of asperity peaks from one or both contacting bodies. It is necessary to investigate the change in surface roughness parameters with increase in wear cycles. Ghosh and Sadeghi [2] developed a novel approach to model the wear mechanisms mainly accelerated by micro-cutting. They showed the change in roughness parameters with number of cycles for various 2D profiles having different RMS roughness, skewness and kurtosis. They found same trend for wear depth on comparing with experimental result published by Masouros et al. [3]. In this work, a different approach is used to model the initial and steady state wear regimes. Archard's wear law [4] is used to calculate the wear depth at micro level. The asperity tips shape is assumed to spherical and Hertzian contact theory is employed at micro-level to calculate the asperity radius, deformation and mean contact pressure. The roughness parameters and topography parameters (summit radius and number of contacting asperity) variation with number of cycles are and discussed in detail.

2. WEAR MODELING

The simulation starts by setting the value of applied F_{app}. After that, a smooth surface is displaced (d_i) and deformation, asperity radius and means contact pressure is calculated until summation of the asperity load (F_{sum}) is equal to applied load (F_{app}). The Archard's wear law is then applied at micro-level to calculate the average wear depth. After calculating the average wear depth for a particular number of cycles, the contacting nodes is displaced by 'h' and worn surface topography is obtained. The wear cycles are updated until ratio of real to nominal contact area (A_{real}/A_{nom}) is greater than 0.5. The wear simulation is terminated when the real contact area is more 50% of nominal area. The nominal contact area (A_{nom}) in this work is assumed to 10 mm^2.

$$h = \text{mean}\left(\frac{kP_j\delta\Delta N}{H}\right) \quad .....(1)$$

Where, h is the average wear depth, P_j is contact pressure at jth contacting asperity, ΔN is the incremental wear cycles, H is the hardness of the material, δ is the horizontal displacement which is assumed to be constant, k is the wear coefficient.

3. RESULTS AND DISCUSSION

In this section, simulation is performed on various 2D profiles having different RMS roughness (S_q), skewness (S_{sk}) and kurtosis (S_{ku}) values. The simulated result for isotropic 2D profile is presented in Figure 2-4. The input parameters listed in Table 1 are used in numerical wear model (see Figure 1).

Figure 2 shows the evolution of 2D profile after 19,000 cycles. In Figure 2, black and red line represents the roughness data of isotropic 2D profile before and after 19000 number wear cycles. It can be seen from Figure 2 that significant peaks are removed after 19000 wear cycles. It is happening due to decrease in contact pressure per cycles. Figure 3 represents the bearing area curve (BAC) of isotropic 2D profile before and after 19,000 number of cycles. From Figure 3 it can be seen that almost 50% material (roughness peaks) are removed from the profile after 19,000 number of cycles. It is happening due to simultaneously change in wear depth (h), summit radius, asperity area, and asperity contact pressure per cycles. Figure 4 shows the change in RMS roughness (S_q) and wear depth with number of cycles. RMS roughness (S_q) decreases with increase in number of cycles. Whereas, wear depth increases with increase in number of cycles. Two different wear rate (running-in and steady wear rate) can be seen from Figure 4. These wear rates are obtained according to procedure outlined in Ghosh and Sadeghi [2]. It can be seen from Figure 4 that running-in (or severe wear) rate ($k_{running\text{-}in}$) is higher than steady wear (or mild wear) rate (k_{steady}). It is happening due to removal of asperity at very higher rate during initial wear cycles (N_1 = 3800 cycles in Figure 4).

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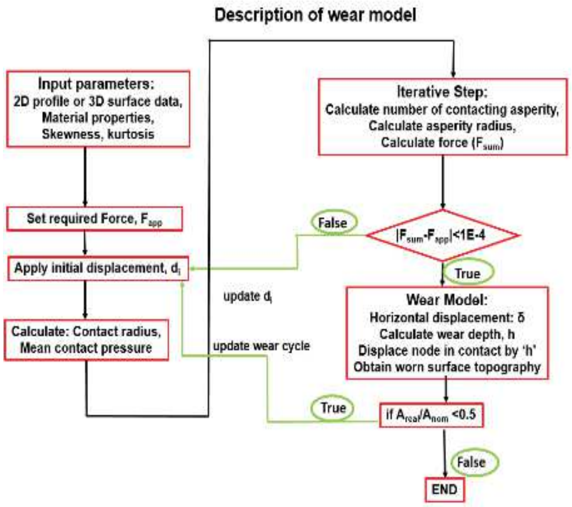

Figure 1 Flow diagram for wear simulation.

Table 1 Input parameters used in wear simulation.

Parameters	Constant Value
Applied load, F_{app}	2×10^3 N
Horizontal displacement, δ	200 µm
Hardness, H	2.07 GPa
Elastic modulus, $E_1 = E_2 = E$	210 GPa
Poisson ratio, ν	0.3
Skewness, R_{sk}	0.0010
Kurtosis, R_{ku}	2.912
Wear coefficient, k	5×10^{-4}
RMS roughness, R_q	9×10^{-4} mm

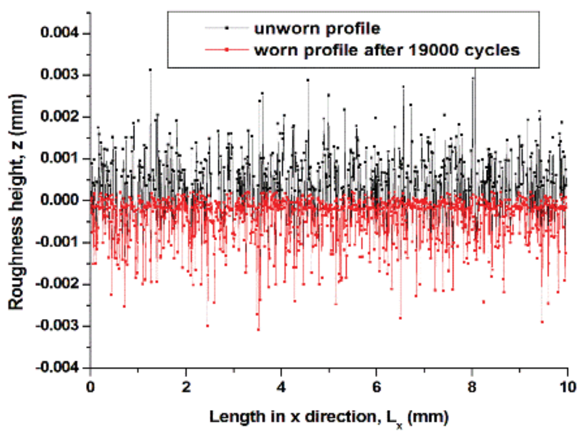

Figure 2 Unworn profile and worn profile after 19000 wear cycles.

4. CONCLUSION

The develop wear model is successfully applied to determine the change in topography parameters with number of wear cycles. It can be seen from Figure 3 that almost all roughness peaks are worn off as the real contact area (A_{real}) increases up to 50 % of the nominal contact area (A_{nom}). Two distinct wear rates can be seen form Figure. 4. The wear rates are determined by linear fitting of wear depth with number of cycles. It can be seen that initial or running wear rate is higher than mild or steady wear rate due to decrease in contact pressure or increase in real contact area at higher number of cycles.

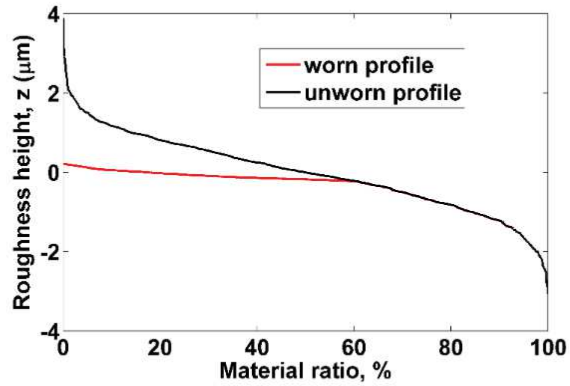

Figure 3 Bearing area curve (BAC) for unworn and worn profiles.

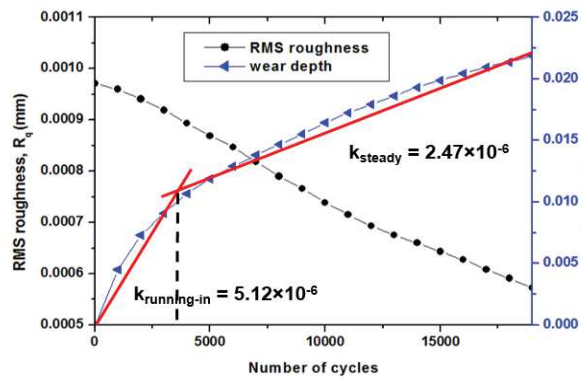

Figure 4 Change in RMS roughness and wear depth with number of cycles.

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