

DEBRIS SIZE DISTRIBUTION AND WEARING CONDITIONS

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A series of experiments on lubricated wear of steel was conducted on a three-pin-on-disk machine. A standard sliding condition (to be abbreviated as STD) was defined under which sliding was made at a sliding speed of 47.1 mm/s under a normal load of 392 N at ambient temperature of 40° C lubricated with a paraffinic base oil having viscosity of 13.3 mm²/s at 40° C and TAN of 0.01 mgKOH/g. Changes in sliding condition were made in four ways. That is, the lubricant was contaminated with 1 vol% water to form an emulsion (WC), the lubricant was previously oxidized at 150° C for 18 days to have TAN of 0.3 mgKOH/g (DET), the load was increased to 588 N (HL1) or 784 N (HL2), or the temperature was raised to 80° C (HT), in each of which the other parameters were left unchanged. Sliding was interrupted after 15 min, 30 min, 1 h, 2 h and 3 h to collect wear debris in the lubricant, and started again with new lubricant. Examples of the friction coefficient are shown in Fig. 1, and wear of the pins are shown in Fig. 2.

Wear debris were collected on a membrane filter having 0.45 μm pores to form a sample. A CCD camera mounted on an optical microscope fed images of the debris on the filter to an image analyzer; its unit frame covered an area of 736 μm x 734 μm , which was 1/1780 of the total area of the filter. For each sample, 15-25 frames were analyzed. The debris had generally flat shapes, and an equivalent diameter was defined on their projected figure on the screen; the arithmetic average of the longest cord length and the maximum length of a cord which passes the center of the figure and makes an intersection with the longest cord.

Figure 3 gives an example of the distribution of the equivalent diameter, in which the fraction of the number of the debris having larger diameter than each value of the abscissa was plotted on the ordinate in a logarithmic scale. The linear relation shows that the equivalent diameters in a sample follow an exponential distribution. It has been shown that all the samples thus prepared follow exponential distributions with certain erratic deviations for large values of the equivalent diameter. From the slope of these linear relations the average equivalent diameter was determined for each sample.

The change in the average equivalent diameter with sliding time was given for STD in Fig. 4, which shows a gradual decrease to a steady value. This is compared with those for WC, DET and HT in Fig. 5. Although initial values of the average equivalent diameter are different depending on the conditions, they have no direct correlation with the wear rate and tend to converge to a steady value which is similar to that for STD. However, the normal load was found to affect the steady value of the average equivalent diameter as shown in Fig. 6. It is clear that a higher normal load results in a larger steady value. Further, the convergence to a steady value seems to take place more rapidly for a higher load.

It is concluded that, under the conditions examined in the present experiments, only the normal load governs the steady value of the size of wear debris which follows an exponential distribution.

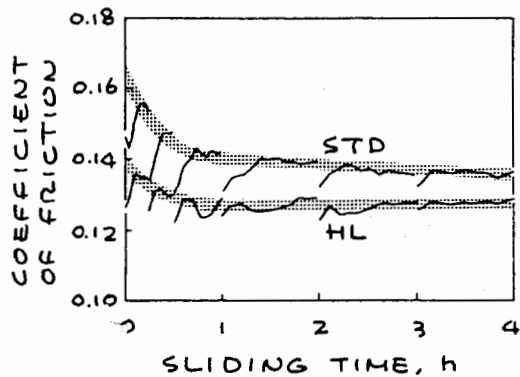


Fig. 1 Examples of friction coefficient

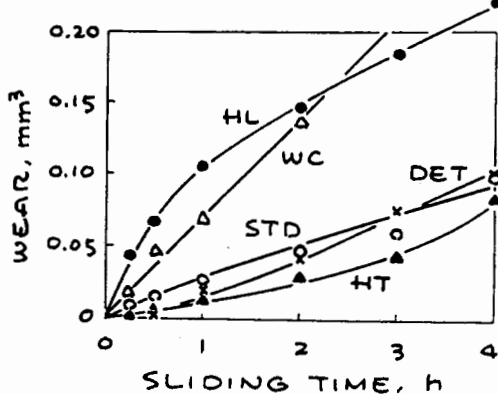


Fig. 2 Wear of three pins

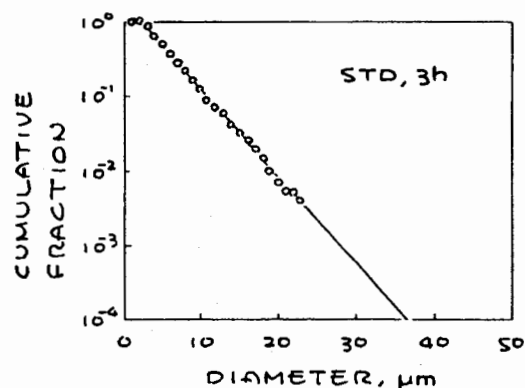


Fig. 3 Example of distribution of equivalent diameter of debris

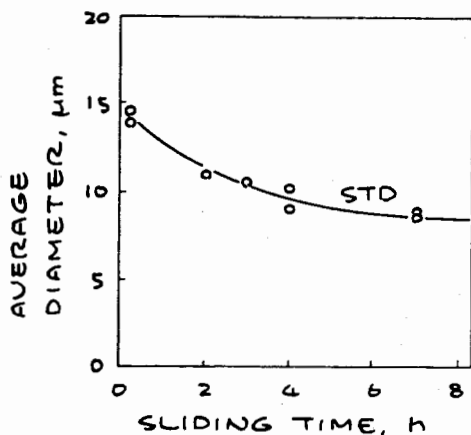


Fig. 4 Change in average equivalent diameter for STD

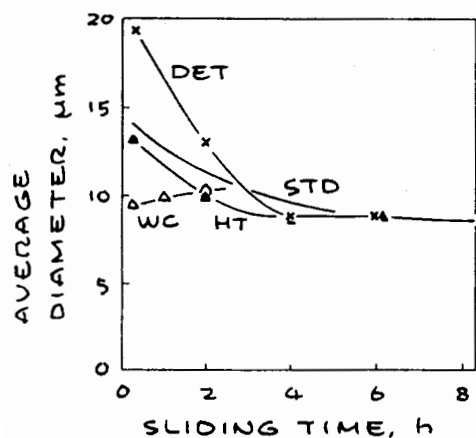


Fig. 5 Changes in average equivalent diameter for different lubricants and temperature

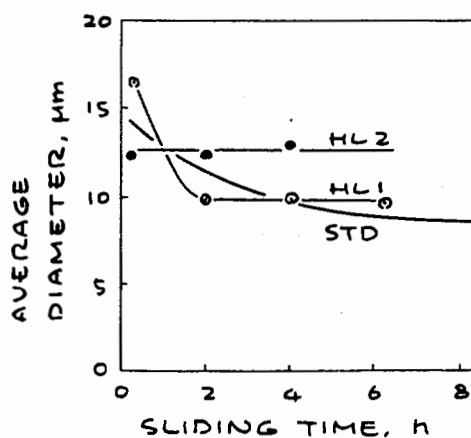


Fig. 6 Changes in average equivalent diameter for different loads