TRIBOLOGICAL STUDY FOR DEVELOPMENT OF ACCELERATED WEAR TESTING METHOD UNDER LUBRICATION

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In this work, the friction and wear behavior under various lubrication regimes were investigated. The objective of this work is to develop an Accelerated Life Test (ALT) method for the durability evaluation of a machine element which is operated under lubrication. Electric contact resistance and frictional forces were measured with respect to a wide range of the loads and speeds under various lubrication regimes using a pin-on-disk type tribotester. From the experimental results, it could be found that an effective and reliable ALT method could be achieved by controlling the lubrication regime through the measurements of friction coefficient and contact resistance with respect to load and sliding speed.

1. INTRODUCTION

It is well perceived that tribological problems affect not only the life of machine elements but also its performance. Therefore, the durability of a machine element should be carefully evaluated. To do this, ALT is generally conducted by subjecting a component to a more severe environmental operating condition [1,2]. In general, since the tribological phenomena can be changed according to numerous factors the test conditions of ALT are very important in order to evaluate the durability of a machine part appropriately. However, a systematic research on the development of ALT method has been rarely conducted [3].

Most of mechanical parts such as cylinders, bearings, and gears are operated under lubrication and experience various lubrication states [4]. It is also well known that the tribological characteristics with respect to various lubrication states are quite different [5]. In many cases, boundary lubrication is a more severe sliding condition than any other lubrication state. Especially, many machine elements experience boundary lubrication state during motion reversals or the start up phase of operation. It is known that many factors such as surface roughness and lubricant viscosity affect the tribological behavior of boundary lubricated metallic surfaces [6,7]. Under boundary lubrication, surface damage phenomena such as pitting and scuffing can occur due to the direct contact of the asperities between the two surfaces [8]. Therefore, it is regarded as the critical lubrication regime that governs the life of the sliding component.

The objective of this research was to identify the lubrication regimes and to assess the tribological properties according to the lubrication condition. The motivation was to improve the understanding of the wear characteristics in various lubrication regimes and to propose an effective ALT method under lubrication. In this work, the friction and wear properties with respect to various loads and speeds were investigated. Electric contact resistance between the pin and the disk was measured to estimate the real area of contact and predict the lubrication state [9]. Also, the relationship between wear coefficient and non-dimensional parameters was established by evaluating the acceleration effects of load and speed on wear.

2. EXPERIMENTAL DETAILS

A pin-on-disk type tribotester with lubricant vessel was used. Normal loads of 3, 5, and 10 N were applied by using a dead weight. The frictional force was sensed by using a set of strain gages mounted on the strain ring that was linked to the cantilever beam of the pin holder. The sliding speed was varied in the range of 20 to 700 rpm. In addition, a special electric circuit was designed to measure the change in the contact resistance between the pin and the disk specimen together with the frictional force during sliding.

As for the test specimens, AISI E52100 (KS STB2) ball with 6.35 mm diameter or AISI 304 (KS STS304) slider pin with wedge-shaped end was used as the pin and AISI 4140 (KS SCM4), Al, Cu, and brass were used as disk materials. The average surface roughness of all the specimens were about 0.03~0.05 μm. By using the wedge-shaped slider pin, the pressure generation can occur more easily and thereby various lubrication states including full film lubrication could be obtained. As for the lubricant, mineral oil with kinematic viscosity of 28.8~35.2 cSt (ISO VG 32, at 40℃) was used.

3. RESULTS AND DISCUSSIONS

Fig. 1 shows the friction coefficients and contact resistances of various materials with respect to the sliding speed and load. The friction coefficient tends to decrease as the sliding speed increases, while the contact resistance increases with the speed. Especially, in the case of relatively low loads the contact resistance increased abruptly. These results may be due to the fact that the real area of contact between the two surfaces is reduced as the lubricant-induced pressure increases with the sliding speed.

From the relationship between the friction coefficient and contact resistance, the lubrication regime could be classified. Fig. 2 shows the friction coefficient variation according to the contact resistance under the sliding speed range of 0~500 rpm using a wedge-shaped slider pin. From the figure, it can be found that there is no remarkable change in the friction coefficient even though the contact resistance changes with a broad range in region A, while in region B the friction coefficient decreases significantly in spite of a little change in the contact resistance. From these observations, it can be suggested that the lubrication state of region A may be boundary or mixed lubrication and that of region B may be classified as elastohydrodynamic or hydrodynamic lubrication. Thus, it can be concluded that the lubrication states may be changed from one state to another as the sliding speed varies beyond specific values as shown in Fig. 1.

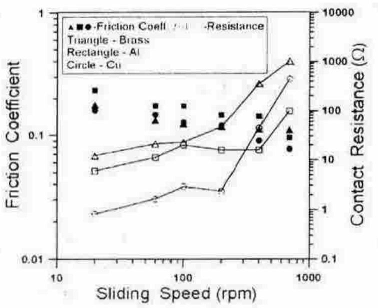

Fig. 1 Effect of speed on the friction coefficient and contact resistance of various metals (5 N load, AISI E52100 ball)

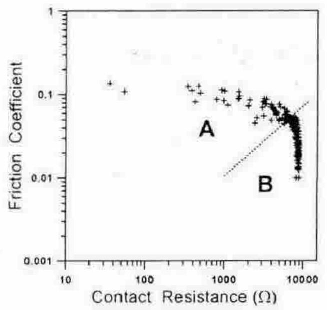

Fig. 2 Friction coefficient variation with respect to the contact resistance (5 N load, AISI E52100 ball vs. AISI 4140 disk)

In order to predict the wear coefficients according to various loads and speeds under various lubrication regimes, non-dimensional parameters were introduced. Fig. 3 shows the experimentally obtained wear coefficients with respect to the non-dimensional load and speed parameters. From this figure, it can be seen that the wear coefficient under lubrication is likely to be more affected by the speed parameter and can be derived quantitatively in terms of the speed and load parameters. This suggests that the durability of a machine element operating under a certain lubrication state can be evaluated quantitatively by using the empirical relation between the wear coefficient and the non-dimensional parameters.

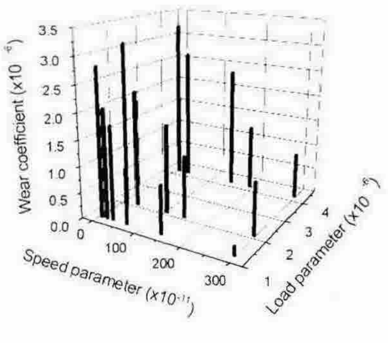

Fig. 3 Wear coefficients with respect to the non-dimensional parameters (AISI E52100 ball vs. AISI 4140 disk)

4. CONCLUSIONS

In this work, the tribological properties and contact resistance with respect to various loads and speeds were investigated to propose an ALT method under lubrication. The results from the contact resistance measurements as the ball slides on the disk covered with lubricant film correspond well with the asperity contact area and tribological properties. From this observation, it was found that the constriction resistance method was useful to identify the lubrication regimes and to quantify the friction and wear with respect to various loads and speeds. In addition, the wear coefficients could be predicted using the dimensionless parameters of load and speed.

In conclusion, the durability of a machine element can be evaluated effectively in terms of the friction and wear coefficients obtained through experiments conducted under various loads and speeds under boundary or mixed lubrication regimes which can be identified by contact resistance.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Hardy, W. B., and Doubleday, I., "Boundary Lubrication-The Paraffin Series," Proc. Roy. Soc. London Ser. A, Vol.102, pp. 550-574, 1922.

[2] Elsayed, E. A., "Reliability Engineering," Addison Wesley Longman Inc., pp. 353-390, 1996.

[3] Hirst, W., and Stafford, J. V., "Transition Temperatures in Boundary Lubrication," Proc. Instn. Mech. Engrs., Vol.186, pp. 179, 1972.

[4] Furey, M. J., and Appeldoorn, J. K., "The Effect of Lubricant Viscosity on Metallic Contact and Friction in a Sliding System," ASLE Trans., Vol.5, pp. 149-159, 1962.

[5] Komvopoulos, K., Saka, N., and Suh, N. P., "The Mechanism of Friction in Boundary Lubrication," J. Tribol.-T. ASME, Vol.107, pp. 452-462, 1985.

[6] Komvopoulos, K., Suh, N. P., and Saka, N., "Wear of Boundary-Lubricated Metal Surfaces," Wear, Vol.107, pp. 107-132, 1986.

[7] Ryu, J. K., Lee, H. C., and Kim, D. E., "Major Factors that Affect Friction and Wear of Metals in Boundary Lubrication," J. of KSTLE, Vol.15, No.2, pp. 171-177, 1999.

[8] Bowden, F. P., and Tabor, D., "The Friction and Lubrication of Solids," Clarendon Press, pp. 176-199, 1958.

[9] Lee, H. C., and Kim, D. E., "Relationship between Contact Resistance and Tribological Behavior in Boundary Lubrication," J. of KSTLE, Vol.16, No.5, pp. 381-388, 2000.