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Surface Texture Influences on the Running-in Behavior and Friction Reduction

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Abstract. For improving automobile fuel efficiency, the internal combustion engines must be required to reduce the friction and wear. Changing viscosity of lubricant and surface pressure could succeed, but the seizure is easy to happen in engines. However, the surface texture can solve those problems. The running-in behavior affects friction and wear on whole combustion engines. If the running-in is not carefully designed, catastrophic accident can happen. This experiment investigates that the running-in behavior is influenced by textured surfaces and the tested materials are the cast iron and the different area ratio of dimple of aluminum alloy combination. The friction coefficient and the number and size of wear particles are measured by the friction sensor and particle counter. After the tests, the worn surfaces are measured through using surface profile measurement systems, and some significant phenomena are observed and analyzed. The textured surface verifies good consequence and tribological advantages.

1 Introduction

At present, global warming has become increasingly serious. Reducing the exhaust emissions and improving the efficiency of the internal combustion engine have become primary task [1]. Via decreasing the friction and wear can improve these, usually we could succeed to change the viscosity of lubricant and surface pressure, but the seizure is easy to appear on the contact surface, such as a piston and cylinder in the engine, while surface texture can solve those problems [2-3]. In tribology, the advantages of surface texture have been reported by many researchers since 1960s and they also get same conclusion that the utilization of textured surface can improve the tribological performances of rubbing surfaces [4]. In this study, the aluminum alloy and the cast iron combination are tested in the experiment, micro concaving areas called dimples have been machined on the material.

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surface, which is the surface texturing technology. In addition, the surfaces of the aluminum alloy have been machined with a different area ratio of dimples. Meanwhile, the friction coefficient and the number and size of wear particles are measured by the friction sensor and particle counter. After the experiment, the worn surfaces are also observed through using surface profile measurement systems, and some significant phenomena are analyzed.

2 Experiment

2.1 Experimental procedure

The schematic diagram of the tribometer is shown in Fig.1, in this experiment. The annular surface of a ring (FC230) was rubbed against the plate (AC8A) under a contact load of 800N as well as sliding velocity of 2.0 m/s. Micro debris was produced during the wear tests, because specimen surfaces were scratched during running-in tests. The sliding distance was 10000 m. The testing surface was immersed in lubricating oil, which is no additive and its viscosity at 60 ℃ is about 14.98 mm^2/s. The lubricating oil was circulated. The particle counter was used to measure the size and distribution of wear particles. During wear tests, the plate was fixed on the free revolution axis in order to transmit friction force to load cell and collected the data of friction force, and then the friction coefficient was calculated.

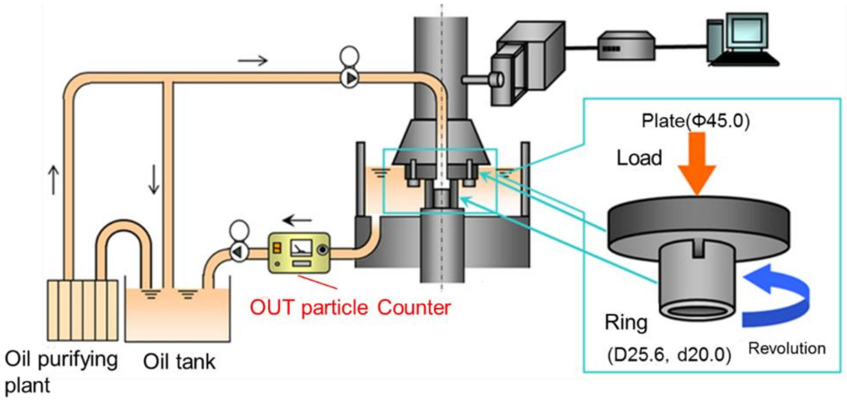


Fig.1 Schematic of wear test apparatus

2.2 Experiment material

Aluminum alloy has been widely used in the automobile industry because of its light weight and mechanical properties [5]. In the experiment, the specimen of the ring (FC230) is cast iron and the aluminum alloy is the plate of AC8A which highly contains Si as shown in Table 1, so that the AC8A has high wear resistance and low thermal expansion in high temperature [6]. As shown in Table 2, the surface texture is applied on the surface of AC8A through machining a great amount of micro concaving areas. For each specimen of AC8A, area ratio of dimples is different from 10 % to 40 %, but the surface roughness of the flat area is same. The Vickers hardness of AC8A and FC230 is 147 HV and 415 HV. Meanwhile, optical microscope images of the original surface are shown in Fig.2.

Table 1 Chemical composition of AC8A (mass%).

	Si	Cu	Mg	Zn	Fe	Mn	Ni	Ti
AC8A	11.0-3.0	0.8-1.3	0.7-1.3	<0.15	<0.8	<0.15	0.2-0.8	<0.2

Table 2 Properties of test materials

Material		AC8A(Plate)					FC230 (Ring)
		A	B	C	D	E	
Arithmetic mean roughness *Ra*, μm		0.050					0.008
Dimple	Diameter, μm	150	175	204	247	302	-
	Depth, μm	2.8	3.9	4.6	6.3	10.0	
	Area ratio, %	10	13	18	28	40	
Vickers hardness HV		147					415

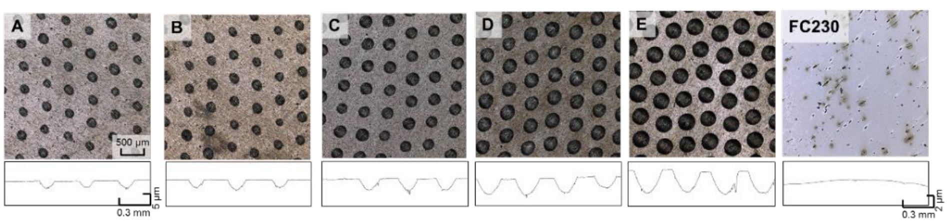


Fig.2 Optical microscope images of the specimens.

3 Results and discussion

3.1 Variations of friction coefficient with sliding distance

During the wear test (see Table 3), the friction coefficient as a function of sliding distance is also shown in the Fig.3 and the AC8A-A, AC8A-C, AC8A-D and AC8A-E show almost similar with friction coefficient, as well as all of them are higher, but AC8A-B shows the lowest friction coefficient in all of the specimens. Running-in distance of AC8A-B is lower than most specimens except for AC8A-E. Compared with the process of running-in, the AC8A-D and the AC8A-E whose dimple area ratios are large early occur the solid contact because of high contact pressure, but the AC8A-A and AC8A-B showed that the running-in distance is different. In addition, AC8A-B is superior to AC8A-A and AC8A-C reducing the distance of running-in [7]. (see Fig.4)

Table 3 Friction coefficient and running-in distance

	A	B	C	D	E
Steady-state friction coefficient μ	0.010	0.006	0.011	0.010	0.011
Running-in distance, m	736	707	794	718	693

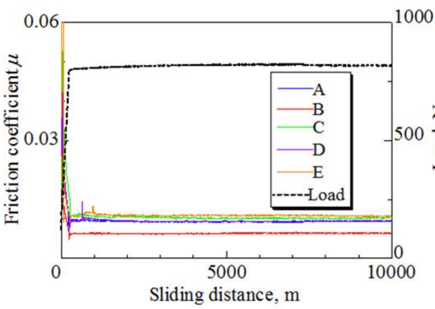


Fig.3 Variation of friction coefficient as a function of sliding distance

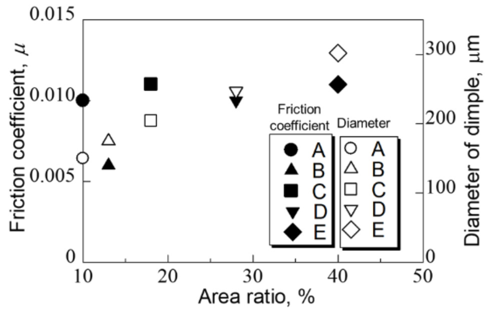
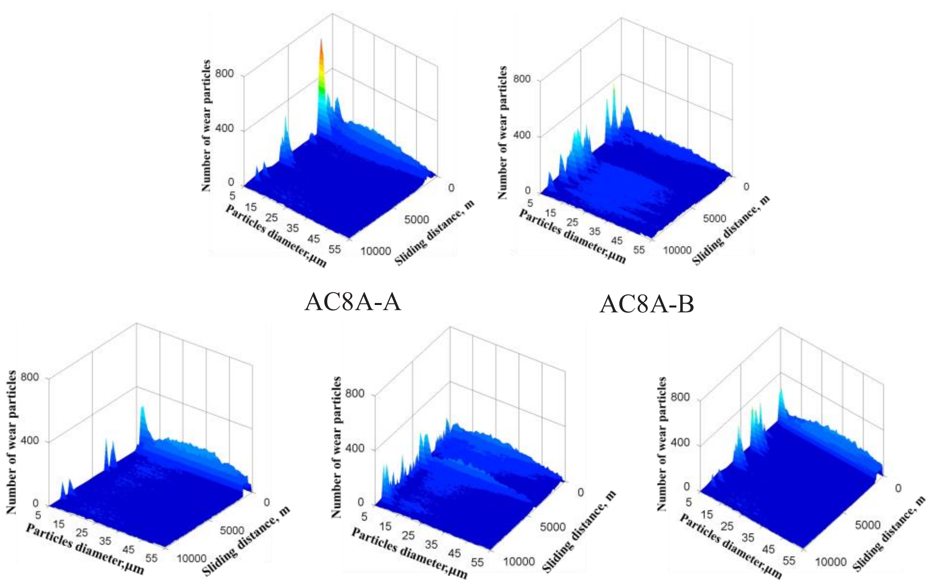


Fig.4 Friction coefficient vs. area ratio

3.2 Distribution of wear particles

In wear tests, the wear particles could include some significant information to realizing more about scuffing and wear. Figure 5 show the variation of the number and size of wear particles as a function of sliding distance. The size of wear particles from 5 μm to 55 μm were measured during the wear test and the number of wear particles at the size of 5-15μm increases during the initial stage of the test, but those of 15-55 μm are far inferior to those of 5-15 μm in the number after the running-in test. From Fig.5, through the variation of wear particles, we can know that plastic deformation takes place at the beginning of the wear test because the real contact area is very small. As we know, the contact pressure at this area is large beyond the yield strength of the AC8A [8-9]. Surface asperities detach and scratch each other. At the running-in process, two-body abrasive wear mainly occurred. However, after the running-in, two-body abrasive wear and three-body abrasive wear occurred concurrently.



AC8A-A AC8A-B

AC8A-C AC8A-D AC8A-E

Fig.5 Variation of the number and size of wear particles

3.3 Observation of the specimen surface

Figure 6 presents the variation surface roughness in the plate of AC8A and the ring of FC230 through optical microscope observation. The combination of AC8A plate and FC230 ring, the AC8A-C, AC8A-D and AC8A-E show slighter wear scars than the AC8A-A and AC8A-B. Roughness of the AC8A-C, AC8A-D and AC8A-E are smaller than that of the AC8A-A and AC8A-B. The dimple area ratio of AC8A-A and AC8A-B is small as well as surface contact is large, because of wear particles becoming large, which result to three-body abrasive wear easily appearing and lead to surface becoming rough and surface roughness getting bigger. However, the dimple area ratio of AC8A-C, AC8A-D and AC8A-E is large and the wear particles are easily collected in the dimples so three-body abrasive wear hardly happens. Therefore, surface roughness becomes small.

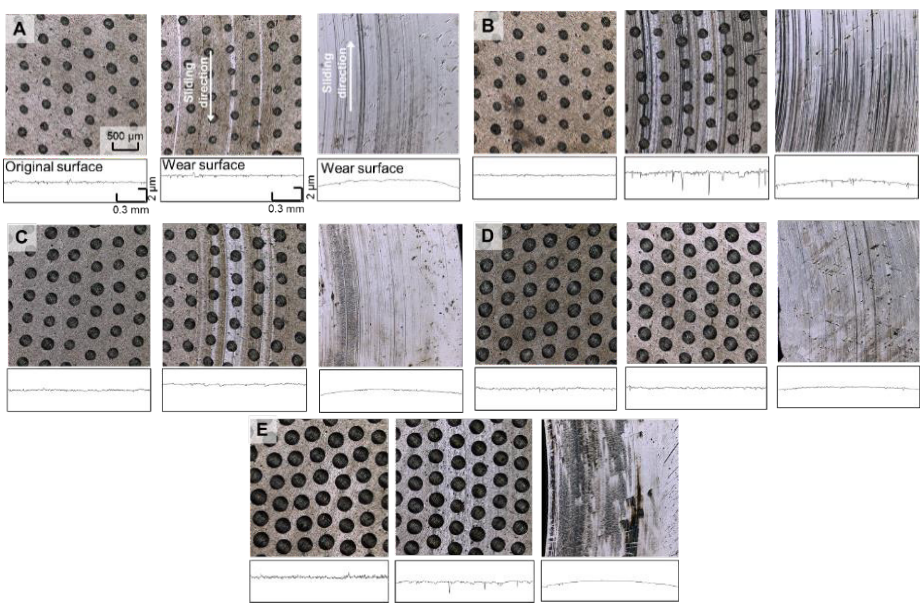


Fig.6 Optical microscope images of AC8A plate and FC230 ring

4 Conclusions

The influence of surface texture on the running-in behavior and friction reduction was investigated. In this study, the wear resistance of AC8A-B specimens performance is better than that of the other specimen. The AC8A-B has also achieved low friction coefficient under the same tribological conditions. Regarding the combination of AC8A and FC230, when the area ratio of dimple becomes large and the contact pressure becomes high, the friction coefficient becomes large because severe plastic deformation and abrasion happen in the interface. So, friction coefficient becomes higher. Meanwhile, regarding the combination of AC8A and FC230, when the area ratio of dimple of specimen is small and contact area increases, the opportunities of surface asperities contact increase as well as the plastic deformation and abrasion easily happen leading to the high friction coefficient. The area ratio of dimple of specimen is large and wear particles are so easy to be collected in the dimple that wear particles are small. So, the friction coefficient becomes low. Besides, at the beginning of running-in test, the number of wear particles whose size is from 5 μm to 15 μm is always large; After the completion of running-in, the numbers of wear particles whose size is from 15 μm to 55 μm steadily decrease. In the process of wear test, two-body abrasion and three-body abrasion occur in the interface and severe plastic deformation also appears. Therefore, regarding the combination of AC8A and FC230, the small area ratio of dimple of specimen leads to large surface roughness. While, the large area ratio of dimple of specimens leads to small surface roughness because the solid contact easily occur, and adhesion as well as abrasion easily happen in the interface. In other words, the study has proved tribological advantage obtained from textured surface. The experiment also proved textured surface is more superior property from the view of the optimal value of the dimple area ratio, it turned out that the dimples lead to the wear reduction and low friction coefficient in the contact surface.

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