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Tribological properties of surface dimple-textured by pellet-pressing

Wang Yan-qing[a,b*], Wu Gao-feng[a], Han Qing-gong[a], Fang Liang[a,b], Ge Shi-rong[a,b]

[a]*School of Materials Science and Engineering, China University of Mining and Technology, Xuzhou 221116, China*
[b]*College of Mechanical and Electrical Engineering, China University of Mining and Technology, Xuzhou 221116, China*

Abstract

Surface texturing is thought to be as an effective tribological method of decreasing friction coefficient of contact pairs. Firstly, AISI1045 steel surface is dimple-textured by a convenient and economical way of pellet-pressing, then, the textured and polished samples is against SiC ball lubricated by engine oil to carry out tribological tests in reciprocating mode in tribomachine type UMT-Ⅱ. It is concluded that surface dimple-texture made by pellet-pressing is beneficial to improve tribological properties lubricated by engine oil under10N load and 5mm/s sliding speed.

Keywords: pellet-pressing; dimple-textured; tribological property

1. Introduction

In recent years, the presence of artificially created micro- texture can significantly affect friction and wear behavior of lubricated surfaces[1]. Miki Nakano et al[2] reported that the friction coefficient increased or decreased depending on the geometry of the micro-texture pattern, and the dimple pattern texture led to a lower friction coefficient than the other pattern texture did, such as groove and mesh pattern textures.

Various techniques for texturing surfaces have been developed recently including mechanical means such as milling using a machine tool[3,4] or shot blasting[5], as well as photolithography and etching processes such as reactive ion etching[6–8]. An energy beam technique such as laser beam processing has been applied for texturing, and the frictional properties of these laser-textured surfaces have been investigated[9–11]. The convenient and economical way of pellet-pressing technique is also suitable for fabricating micro-textured surfaces over a large area. A key feature of the pellet-pressing technique is that it can be applied to many kinds of materials irrespective of their chemical reactivity. In this article, we fabricated bicron-sized dimples over the AISI1045 steel steel surfaces by pellet-pressing, and then investigated the effects of the texturing on reducing friction and the amount of wear, and the relationships between the geometry of the texturing and friction coefficients.

2. Experimental details

* Corresponding author. Tel.: +86-516-83591877; fax: +86-516-83591870.
E-mail address: cumtwyq@163.com.

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The friction test was performed in reciprocating mode with different loads and speeds using a ball-on-plate tribometer on UMT-Ⅱtesting machine. The upper specimens were SiC ball (Φ4 mm) and the lower specimens were AISI1045 steel steel plates (Φ40 mm×H6 mm, Figure 1).

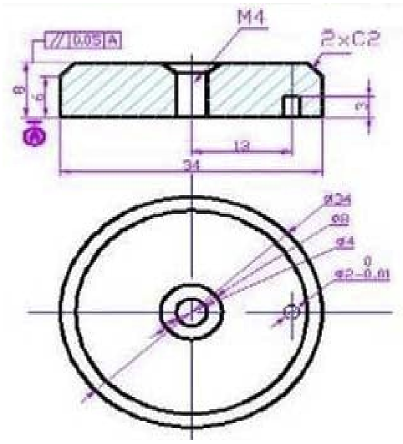

Fig. 1. Schematic diagram the lower specimen

All the plates were finished by polishing and had an average surface roughness of 0.03μm Ra. The surfaces of the lower specimens were flat or textured by pellet-pressing with three different loads depending on the pattern size. The larger-sized dimples were fabricated under larger load and the finer ones were smaller load. Table 1 shows the load of pellet-pressing and parameters of dimples. With the increase of the load, the width and depth of dimples increased, while the value of λ ratio parameter which was defined as the ratio of the width to the depth of dimples decreased. Figure 2 shows SEM micrographs of sample surface after textured by pellet-pressing, and Figure 3 shows the 3D images of a dimple. Flat plate without texturing was also used for comparison.

Table1. Load of pellet-pressing, parameters of dimples and hardness of samples

Sample number	Load (MPa)	Width (μm)	Depth (μm)	λ(Width/Depth)	Vickers hardness/HV
Sample 1	5	166	8.97	18.5	219.9
Sample 2	10	273	21.7	12.58	222.1
Sample 3	25	475	82.4	5.76	233.3
Polished sample					217.9

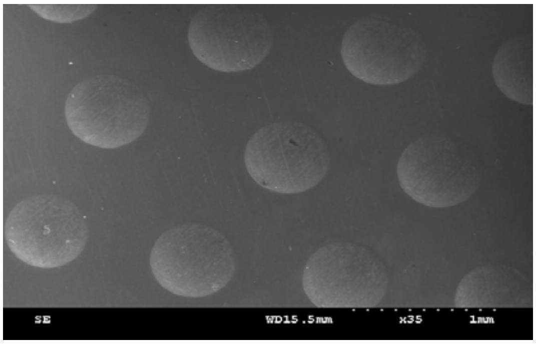

Fig. 2. SEM micrographs of sample surface after pellet-pressing

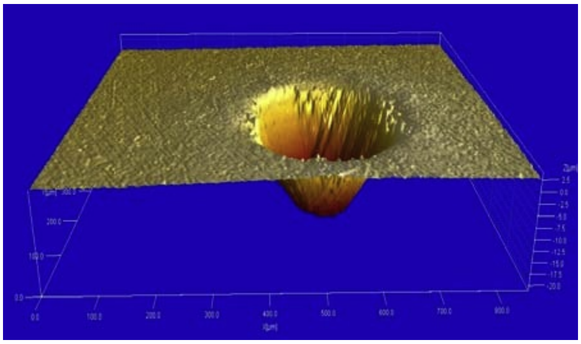

Fig. 3. 3D image of a dimple

The Vickers hardness of both polished samples and textured ones were tested, and the results showed in Table 1 indicated that pellet-pressing didn't make samples greatly harden as the Vickers hardness didn't increase greatly.

Friction tests were conducted at temperature 20□, with normal loads of 5, 10, 20, 30, 40 and 50 N, with linear sliding speeds of 1, 3, and 5 m/s respectively, and the stroke was 30 mm. Commercially available lubricant oil was used for this study, the kinetic viscosity is 406.6 mm2/s at 313 K and the density is 0.878 g/cm3.

The procedures to achieve the flat contact configuration between the upper specimen and lower specimen were as follows: (1) Cleaned upper and lower specimens were mounted on the tester. (2) 320-grit abrasive paper was adhered to the lower specimen. (3) Reciprocating motion was made at 100 N and 0.05 m/s for a few minutes. (4) Procedures (2) and (3) were repeated with 800-grit, 1200-grit, 2000-grit and 4000-grit abrasive paper respectively. After procedures (1) to (4), the shape of abrasive pattern on the abrasive paper which had the same width as the upper specimen was observred[2].

The friction coefficient was achieved directly through frictional tests, and the amount of wear was measured by width of surface wear track generated during reciprocating.

3. Results and discussions

Figure 4 shows the relationships between the average friction coefficients and loads on the three textured surfaces lubricated by engine oil, with the sliding speed of 5mm/s. The friction coefficients for all patterns decreased sharply at higher loads, reaching the lowest value under the load of 10N. This dependency of loads indicates that with the increasing of the loads, dimple-texture resulted in transformation of friction conditions, from boundary lubrication at lower loads to hydrodynamic lubrication at higher loads. Meanwhile, the fluctuation of friction coefficients for each sample or the difference of friction coefficients between all samples became tiny under the high load condition (higher than 10 N), this occurred probably because the thickness of the lubricant film was comparable to the roughness of samples at lower loads, and thus the formation of the lubricant film was not stable. Therefore, partial solid contacts always occurred between the surfaces and the friction coefficient became more fluctuant. With the increasing of loads, a sufficiently thick lubricant film was exhibited, and the load-carrying capacity of lubricant film would be improved, and the friction coefficient became more stable. So, the dimple-texture can be expected to keep the hydrodynamic pressure because of the discrete shape[12].

The fact that the friction coefficient was highest for sample 3 and lowest for sample 1 under all loads except of 5N proved that dimple-texture on the sample 1 with relative high ratio of width and depth had more obvious effect on reducing friction and wear than the texturing on the other two samples did.

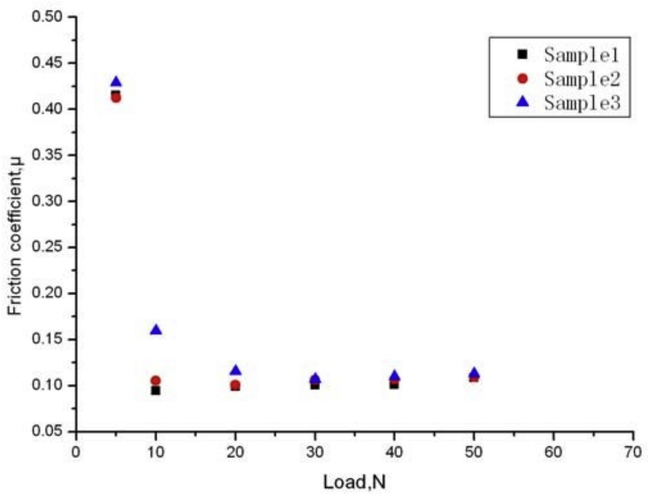

Fig. 4. Friction coefficient as a function of load for different sample surfaces (lubricated by engine oil, the sliding speed is 0.005m/s.)

Figure 5 reveals the obviously different friction coefficients of sample 1 at different sliding speeds of 0.001m/s、0.003m/s and 0.005m/s, under the same load of 10N. At the highest sliding speed of 0.005 m/s, sample 1 had the lowest friction coefficient, while the lowest sliding speed of 0.001m/s, the higtest friction coefficient. This revels that with the increasing of sliding speeds, lubricant film became thick. It could lead the increase of hydrodynamic pressure, and the load-carrying capacity of lubricant film would be improved[13].

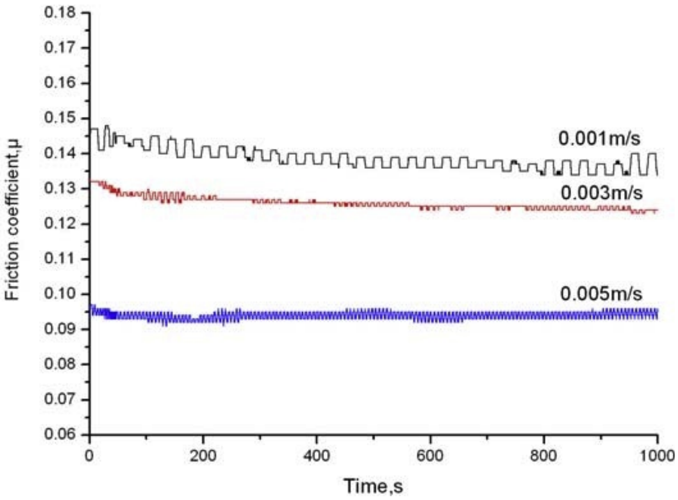

Fig. 5. Friction coefficient as a function of time for sample 1 at different speeds (lubricated by engine oil, normal load is 10N.)

Figure 6 exhibits SEM micrograph of wear track generated on sample 1 surface after different speed slide in the same time. The width of wear track generated after 0.001m/s speed slide was 592μm (cf. Fig. 6a), which was the widest. That is the amount of wear during this slide was the biggest. On the other hand, the width of wear track generated after 0.005m/s speed slide was as small as 322μm (cf. Fig. 6c), which reveals the amount of wear during this slide was the smallest. A fact could not be ignored is that the slide distance with reciprocating 0.005m/s speed is the biggest. This strongly proves the above fact that with the increasing of sliding speeds, lubricant film became thick, and the wear-reducing capacity of sliding surface would be improved.

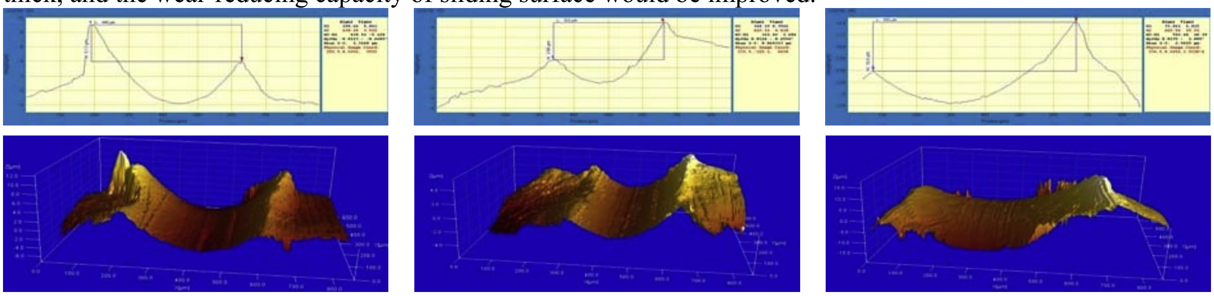

Fig. 6. 3D images of wear track generated on sample 1 surface after different speed slide in the same time, a is 0.001m/s, b is 0.003m/s and c is 0.005m/s

Further proving the beneficial influence of dimple-texture on tribological properties, the contrast test of sample 1 with dimple-texture and polished sample was conducted with the same friction condition. The reciprocating slide lubricated by engine oil under10N load and 5mm/s sliding speed. During consecutive 1000s slide time, the friction coefficient of sample1 was lower than that of polished sample (Fig. 7). Ronen et al. [14] and Burstein et al. [15] reported the surface-texturing effect on friction properties in reciprocating motion using theoretical model. They showed that the hydrodynamic pressure increased in the vicinity of the dimples and mentioned that the textured surface had the friction reduction effects. Our experimental results support their theoretical studies. At the same time, the discrete lower area could be considered to effectively keep the wearing scraps inside of the dimples and act as an oil reservoir.

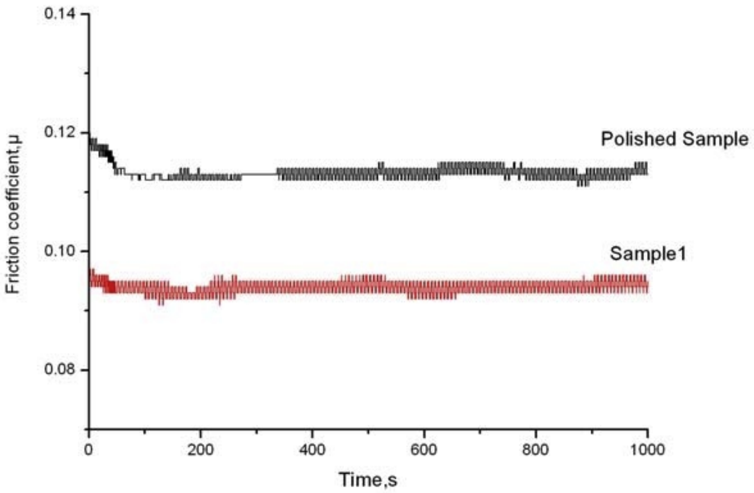

Fig. 7. Friction coefficient as a function of time for No.1 sample and polished sample (lubricated by engine oil, normal load is 10N, sliding speed is 0.005m/s.)

4. Conclusions

The frictional properties of dimple-textured AISI1045 steel surfaces are investigated and conclusions are summarized as follows:

(1) Pellet-pressing is one of the most conveniently and economically way to fabricating dimple-texture on many kinds of contact surfaces irrespective of their chemical composition or their shapes. At the same time, ratio of width to depth, which determines the geometry of the dimple-texture pattern, can be adjusted conveniently by altering the press loads.

(2) Dimple-texture results in the beneficial influence on tribological properties. It can obviously reduce friction coefficient and wear lubricated by engine oil under normal load 10N and sliding speed5mm/s.

(3) The hydrodynamic pressure is locally increased near the dimples and the load-carrying capacity of lubricant film is improved. At the same time, dimple-texture could be considered to be as a reservoir of wearing scraps and oil.

Acknowledgements

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