Experimental study of friction reduction of micro dimples on cylindrical surface

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Keywords: micro dimples, surface texture, friction coefficient

Abstract

This paper presents our recent work of experimental investigation of friction reduction by making micro dimples on outer cylindrical surfaces. The micro dimples on cylindrical surface have been produced by piezoelectric tool holder actuator (PTHA) which was assembled in conventional two-axis lathe machine. These experiments have been carried out to insvetigate whether the micro dimples are able to improve the lubrication performance of cylindrical contact planar surface or not. The micro dimples are machined by using the PTHA on Al 6061 and carbon steel 1045 using frequency vibration ranging 50 Hz to about 200 Hz. The normal load of 50 N was applied and the rotation speeds between 100 rpm and 1000 rpm were applied in tribology tests. The experimental results show an evidence that the micro dimples reduce the friction coefficient ranging 20% to 40% in these trials.

1. Introduction

Micro dimples in term of a surface texture have gained great attention of tribology scholars due to a benefit to increase energy efficiency. This kind of application can be implemented in engine, ring pistons, cam mechanism, or mechanical bearing seals which need lubrication conditions to improve the energy efficiency.

Based on various tribology studies, micro dimples improve the frictional performance of sliding contact of planar surfaces under wet lubrication condition. Scientists argued that the micro dimples act as oil reservoir as well as micro-bearing in which the lubricant is supplied into the two sliding contact surfaces producing micro fluid film. As a result, the micro dimples enhance the load carrying capacity of the lubricant film between planar surfaces in term of the hydrodynamic pressure.

The friction reduction depends on the tribological test and the surface texture shapes either its parameters or texture orientations of the sliding contact. Y. Uehara et. al investigated the effect of dimpling on the tribological properties of a silicon nitride ceramic against hardened bearing steel under lubricated oil, planar to curved surface contact conditions.[1] In this paper, we present our recent experimental work of friction reduction on cylindrical surface with the existence of micro dimples under wet lubrication and validating which one of the surface textures gives a better performance compared to the other textured surfaces.

2. Fabrication of micro dimples and experimental setup

The micro dimples were manufactured by using PTHA on both Al 6061 and carbon steel AISI 1045 with using vibration frequencies ranging from 50 Hz - 260 Hz, as shown in Table 1. This dimpling method is very simple, cost effective and does not need expensive equipment. In this method micro dimples were built by relative sinusoidal movement between the cutting tool and the workpiece.

The block on ring method of tribology was used, as shown in Figure 1. The normal load of 50N was applied, considering the maximum load of the tribometer tester is 80 N. The rotational speeds of Al 6061 samples and carbon steel sample in tribology tests were ranging from 100 rpm to 1000 rpm and 100 rpm to 1500 rpm respectively as shown in Table 1.

Table 1: Summary description of experimental setup

Micro dimples fabrication	
Vibration frequencies:	f_m: 50 Hz – 260 Hz (Al 6061) using PCD tool f_m: 50 Hz – 200 Hz (AISI 1045) using CBN tool
Sample dimension:	DIA: 25 mm (Al 6061) DIA: 27 mm (AISI 1045) Length: 45 mm (Both)
Micro dimple dimensions:	Length: 60 µm – 300 µm Width: 80 µm – 120 µm Depth: 8 µm – 15 µm Distribution: 12 dimples (in 1 µm x 1µm area, depends on ratio vibration frequency and rotational speed) in this case f_m: 120 Hz and N: 30 rpm
Tribology test	
Condition:	Block on ring test (wet lubrication)
Oil:	Engine oil 5W-30 (T = room temperature)
Normal load:	F_N: 50 N
Rotational speed:	ω_N: 100 rpm to 1000 rpm (Al 6061) ω_N: 100 rpm to 1500 rpm (AISI 1045)

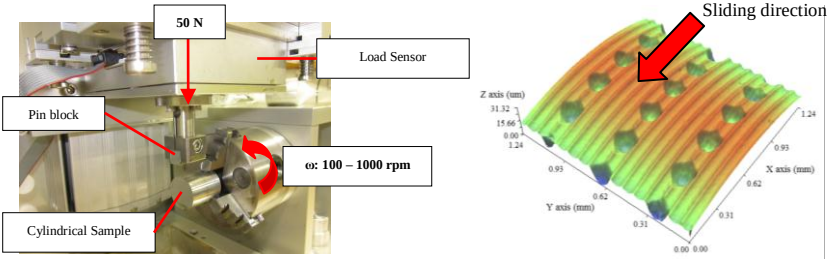

Figure 1: Block on ring test and a textured surface topography

3. Results and discussion

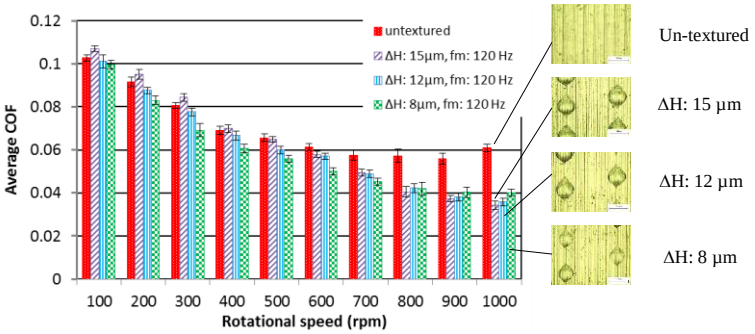

Figure 2: Average coefficient of friction with various depths (Al 6061 contacts Al 6061)

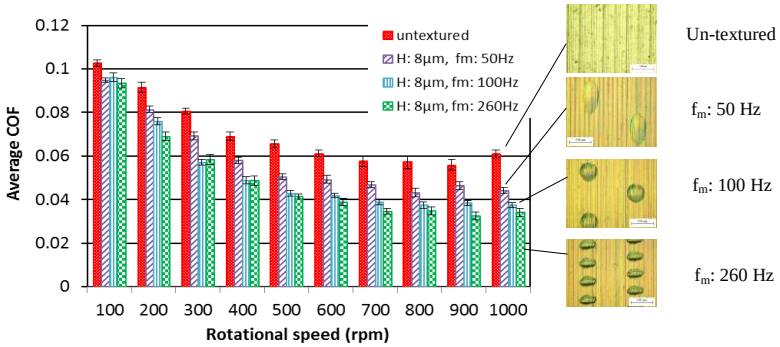

Figure 3: Average coefficient of friction with various topographies (Al 6061 contacts Al 6061)

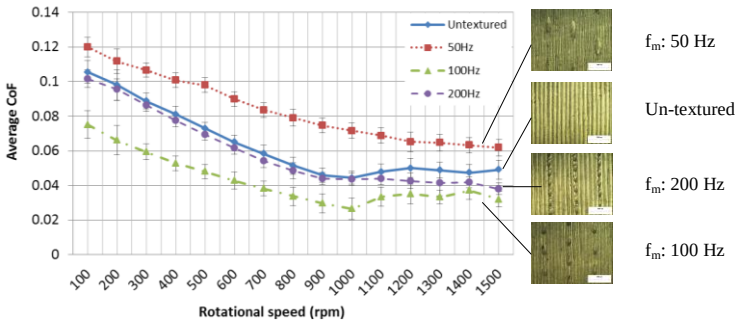

Figure 4: Average coefficient of friction with various topograhies (AISI 1045 contacts SKD 11)

As above results show that the average COF gradually decreases when the rotational speed increases. As shown in the Figure 2, the textured surfaces with micro dimples having a depth of 8 µm are more effective, especially in lower speeds, however the average COF of depth of 15 µm leads in higher speeds. Figure 3 shows the average COF comparison between un-textured and textured surfaces that have been made at various vibration frequencies from 50 Hz to 260 Hz range. This investigation shows that the textured surface made at f_m = 260 Hz has best performance resulting up to 40 % efficiency. On the other hand, as shown in Figure 4, the textured surface on carbon steel made at f_m = 50 Hz does not give any benefit in friction reduction. It is probably caused by the longer dimension (300 µm) at the AISI 1045.

4. Conclusion

The recapitulate of above experimental investigations is that textured cylindrical surface with micro-dimple improves the lubrication performance under block on ring test under wet lubrication condition. The textured surfaces having a depth of 8 µm or less and made at f_m= 100 Hz – 200 Hz are recommended for lower rpm.

Reference:

[1] Y. Uehara, M. Wakuda, Y. Yamauchi, S. Kanzaki, and S. Sakaguchi, “Tribological properties of dimpled silicon nitride under oil lubrication,” *J. Eur. Ceram. Soc.*, vol. 24, no. 2, pp. 369–373, Jan. 2004.