Tribology International 118 (2018) 37–45

Contents lists available at ScienceDirect

Tribology International

journal homepage: www.elsevier.com/locate/triboint

Effect of laser surface texture on CuSn6 bronze sliding against PTFE material under dry friction

Jinbang Li *, Shuo Liu, Aibing Yu, Sitong Xiang

Faculty of Mechanical Engineering and Mechanics, Ningbo University, Ningbo 315211, China

ARTICLE INFO

Keywords:
Bronze
Surface texture
Friction
Wear

ABSTRACT

Three kinds surface texture was fabricated on CuSn6 bronze disc by laser texturing. The tests of textured disc sliding against PTFE material were carried out in dry friction condition using a pin-on-disc tester. The results shown that the projected ridge has a strong effect on friction and wear performance. The non-polished textured surface could reduce friction coefficient and increase wear rate of PTFE. Compared with smooth surface, the friction coefficient of grid groove surface, asterisk groove surface and circle groove surface decreased by 10.55%, 6.03% and 9.50% while the wear rate of PTFE increased by 47.05%, 41.48% and 27.21%, respectively. After being polished, both the friction coefficient and wear rate of PTFE are larger compared with smooth surface.

1. Introduction

Surface texturing is an attractive approach to change the friction and wear properties of sliding contact elements [1–3]. Dimples, grooves or other depressions are usually fabricated on the sliding surface to improve its tribological properties. The functions of the depression are widely recognized as: (a) the assistance in trapping wear debris, the elimination of wear debris from the interface reduces the ploughing and deformation components of friction [4–7]; (b) act as reservoirs for lubricants, capable of feeding the lubricant directly between the two contacting surfaces [8–10]; (c) increase the load carrying capacity, the depressions could create micro hydrodynamic action [11–13]. The first function usually works in boundary lubrication and dry friction conditions. The second and third functions work in lubrication and boundary lubrication conditions.

In recent years, surface texture is still an attractive field and many interest results were obtained. Zhang et al. [14] developed an analytical numerical model to understand the tribological behavior of textured surface in the mixed lubrication regime. Wos et al. [15] investigated the tribological behavior of four types of textured steel discs sliding against pin in conformal starved lubricated conditions. They found that tribological performances of disc with spiral dimples pattern were better than that with radial rows. Zhang et al. [16] investigated the tribological behaviors of the multi-layer textured Babbitt alloys disc sliding against 45# steel pin under oil lubrication condition, they found the improvement effect may be more sensitive to the groove area density and the sliding speed. Wang et al. [17] researched the tribological properties of textured stainless-steel surface with micro-grooves by reciprocating ball-on-flat tests against Al2O3 ceramic balls under starved oil lubricated conditions. The results shown that the tribological property is significantly affected by the spacing of micro-grooves. Vlădescu et al. [18,19] investigated the friction and wear of textured fused silica and a convex steel pad, they found that individual pocket width and depth values can largely be ignored, because both friction and wear reduce monotonically as the sum of the pocket volumes along the stroke increases. The lubricant film thickness was also measured to explain the friction mechanisms. Saeidi et al. [20] investigated the effect of laser surface texturing on the friction behavior and the lifetime of grey cast iron against steel reciprocating under starved lubrication conditions. The results shown that the interactions of geometrical parameters have significant impact on the coefficient of friction. Gropper et al. [21] summarized the modeling techniques and key findings of hydrodynamic lubrication of textured surfaces, provided a comparative summary of different modeling techniques for fluid flow, cavitation and micro-hydrodynamic effects. Xing et al. [22] investigated effect of laser surface texturing on Si3N4/TiC ceramic sliding against steel under dry friction, the results shown the grooves can capture the debris effectively, when wear particles escape from the contact zone into the grooves, the friction and wear are decreased. Therefore, the tribological properties depended greatly on the size and density of the micro-grooves. Cho et al. [23] introduced a new form hybrid texturing by filling the pores on steel with PPS powder, the results shown that hybrid texturing protected the metal surfaces by

* Corresponding author.
E-mail address: lijinbang@nbu.edu.cn (J. Li).

https://doi.org/10.1016/j.triboint.2017.09.007
Received 26 June 2017; Received in revised form 29 August 2017; Accepted 9 September 2017
Available online 23 September 2017

Table 1
Properties of CuSn6 bronze and PTFE material.

Material	Density (g/cm^3)	Hardness	Young's modulus (GPa)	Poisson's ratio
CuSn6	8.8	167.6 (HV)	103	0.3
PTFE	2.16	57.73 (Shore D)	1.28	0.46

forming a polymer transfer layer.

As described above, under certain conditions, surface texturing could be beneficial to the tribological properties of the sliding surface. However, under other conditions, the same texture may impair the friction and wear [24,25]. How to design the surface texture for specific conditions needs more research and the research on textured metal surface sliding against plastic material is limited.

Because of high strength, excellent wear resistance and good corrosion properties bronze is extensively used for gears, bearings and contactors [26,27]. Polytetrafluoroethylene (PTFE) and PTFE-based polymeric materials possesses some unique self-lubricating properties, low friction coefficients, good thermal stabilities and high resistance to different chemicals [28–30]. These two materials are usually used together as friction pairs, such as in some piezoelectric actuators and some special bearings.

In this study, the tests of textured CuSn6 bronze disc sliding against PTFE material were carried out in dry friction condition using a pin-on-disc tester. The aim is to explore the tribology behavior of PTFE material, which is relatively soft, sliding against textured bronze surface. We hope that this will provide fundamental insights which could inform how to design the surface texture for friction pairs composed of plastic and metal, such as some bearings. Furthermore, our findings may also be applied to actuators driven by frictional force, such as piezoelectric ultrasonic motors.

2. Experimental details

2.1. Specimens and surface texturing

The materials used for the tests were CuSn6 bronze and PTFE material. The main mechanical properties of the samples were listed in Table 1. The values in the table are the averages of several tests. The CuSn6 bronze was made as the disc and PTFE was made as the pin.

Three kinds of surface textures which are grid grooves, asterisk grooves and circle grooves were fabricated on the CuSn6 bronze disc, as shown in Fig. 1. The size of grid is 1 mm × 1 mm, the distance between two circle grooves is 1 mm and the angle between two asterisk grooves is 10°. The blue area on the disc is the contact area, with width of 6 mm and maximum diameter of 18 mm. Laser grooves on the specimen surface were fabricated in air with Nd: YAG laser. Laser processing parameters were electric current of 220A, pulse width of 0.2 ms, laser frequency of 100 Hz and feed speed of 0.3 mm/s. The purple arrows in Fig. 1 represent the sliding direction. The circle groove is parallel to the sliding direction, the asterisk groove is perpendicular to sliding direction and the angle between grid groove and sliding direction changes with different positions of pin in the range of 0°–90°.

The surface topography of textured groove before polishing was examined, as shown in Fig. 2. Fig. 2 (a) shows three-dimensional topography of the textured groove. It could be seen that the projected ridge made up of melted bronze was formed on one side of the groove due to re-solidification of the molten and pushed up material. From Fig. 2 (b), it can be seen clearly that the projected ridge is higher than the initial surface. From Fig. 2 (c), it can be found that the depth of the groove is about 10 μm, the high of the ridge is about 15 μm, the width of the groove and ridge are 150 μm and 300 μm, respectively.

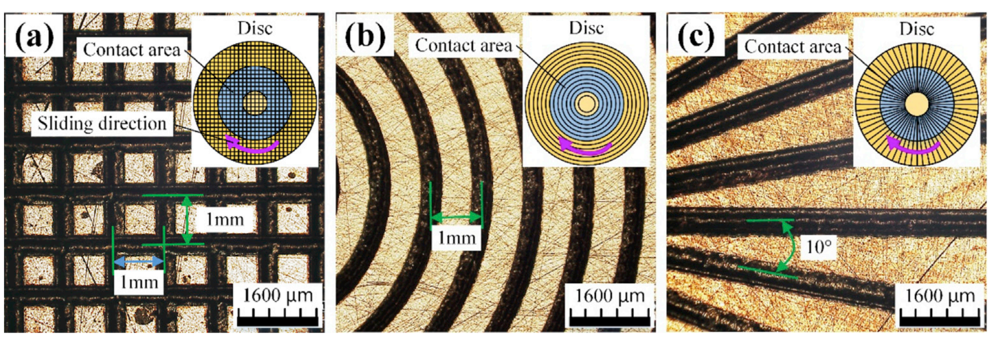

Fig. 1. Optical micrographs of textured surface: (a) grid groove, (b) circle groove, (c) asterisk groove.

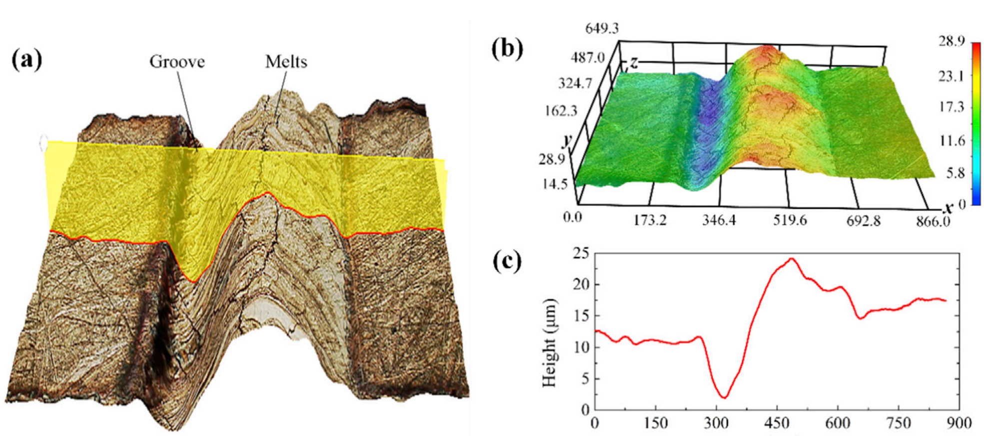

Fig. 2. Surface topography of textured groove before polishing: (a) three-dimensional topography, (b) pseudo color figure and (c) surface profile of the marked line.