Proceedings of Asia International Conference on Tribology 2018, pp. 8-10, September 2018

Effect of pulse duration on tribological behavior of textured stainless steel by laser surface texturing

J.J. Zhang[1,*], D.H. Yang[1], C.W. Song[2], Y.D. Yan[1], T. Sun[1]

[1)] Center for Precision Engineering, Harbin Institute of Technology, Harbin 150001, China.
[2)] Research Center of Laser Fusion, China Academy of Engineering Physics, China.

[*]Corresponding e-mail: zhjj505@gmail.com

Keywords: Laser surface texturing; pulse duration; stainless steel; friction reduction

ABSTRACT – Laser surface texturing has been demonstrated as a powerful technique for fabrication of surface textures on solids. The accuracy of textures fabricated by laser surface texturing is greatly influenced by laser beam parameters. In the present work, we fabricate aligned grooved microstructures with the same morphology on stainless steel by laser surface texturing with different pulse durations (from nanosecond to femtosecond). It is found that both the rim structure on the crest and the ablation-induced damage on the valley are different for different pulse durations, which are attributed to both different laser-material interactions and sizes of heat affected zone. Subsequent ball-on-disk friction tests show that the presence of as-fabricated textures lowers friction coefficient and wear of textured surface compared to untextured surface. Furthermore, the pulse duration has a significant influence on the effectiveness of surface textures in friction reduction.

1. INTRODUCTION

Surface texturing is one important method of surface treatment because it can induce wear reduction and improve anti-oxidation of the surface [1-3]. Therefore, it is promising to improve the wear resistance of sliding surface between mechanical components by fabrication surface textures. While there are many techniques available for surface texturing, laser surface texturing is one of the most widely used method for the fabrication of surface textures with feature size in the range of a few to tens of micrometers [1-2].

Laser ablation dominates the material removal in laser surface texturing process, which can be described by the two-temperature model. First, laser energy is absorbed by electrons. Then electrons collide with nuclei to transfer absorbed energy, which finally leads to escape of nuclei from the surface [2]. It is demonstrated that the efficiency and accuracy of using laser photons to remove material is different for different pulse duration. The absorption of optical energy by electrons is in a ladder like manner and direct multi-photon process for longer pulse and short pulse, respectively. Furthermore, the multi-photon absorption leads to escaping of nuclei at room temperatures because leave of enormous electrons, which leads to small heat affected zone. Consequently, both rim structures and ablation-induced damage are less pronounced for shorter pulse.

The effect of surface texturing in friction reduction is attributed to that textures can generate hydrodynamic pressure, or trap wear debris, or acts as reservoir for lubrication retention. It is also indicated that the texture morphology has a significant influence on the friction reduction [4]. Therefore, it is interesting to investigate the influence of pulse duration on the machining accuracy of surface textures and subsequent tribological properties of as-fabricated textured surface.

2. METHODOLOGY

We use the SUS420J2 stainless steel, and the sample size is 25×25×10mm. After heat treatment the sample is mechanically grinded with a surface roughness of 0.1μm. Then the sample is subjected to laser texturing to fabricate aligned groove structures on the surface. Three laser durations, as nanosecond, picosecond and femtosecond, are considered. For each pulse duration, the wavelength and the height of the groove is 90 μm and 8 μm, respectively. Figure 1 shows the fabricated morphology of groove textures under picosecond laser texturing.

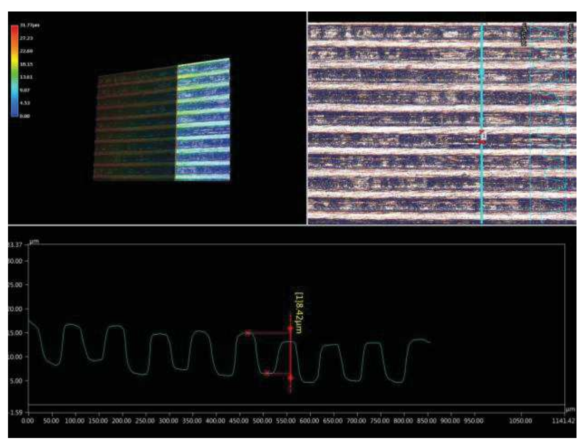

Figure 1 Morphology of surface texture by picosecond laser texturing.

Currently we are planning the machining of surface textures with both nanosecond laser and femtosecond laser on the same stainless steel. We will provide more details about the machining accuracy in the near future. So, the current results are mainly obtained with textured surface by picosecond laser surface texturing and untextured surface.

After the surface texturing, the samples are subjected to a ball-on-disk friction test using the UMT3, as illustrated in Figure 2. The ball of GCr15 has a diameter of 4 mm. The friction tests are performed in room temperature and with oil lubricant.

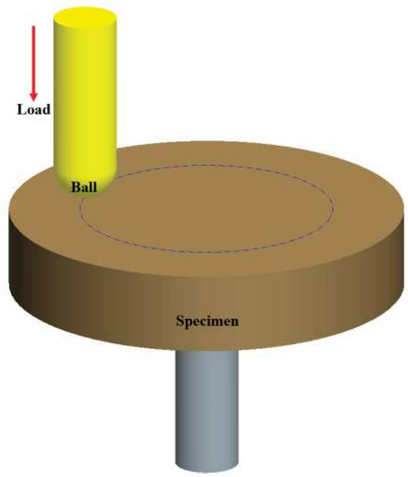

Figure 2 Illustration of ball-on-disk friction test.

3. RESULTS AND DISCUSSION

We first perform friction experiments to investigate the influence of pressure and sliding velocity on the friction of un-textured surface, as shown in Figure 3(a) and (b), respectively. Figure 3(a) shows that the friction coefficient decreases with increasing pressure, which can be attributed to the transition in lubrication status. Figure 3(b) shows that the friction coefficient decreases with increasing sliding velocity.

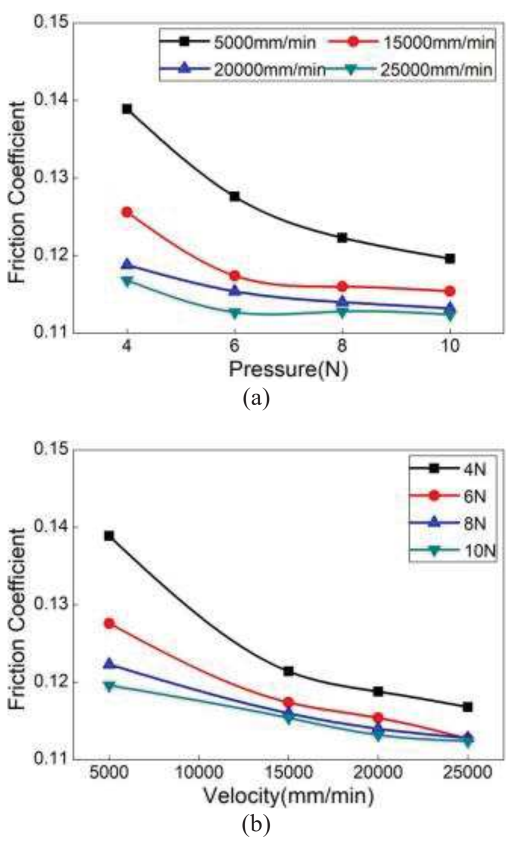

Figure 3 Parameter dependence of friction of un-textured strainlesssteel. (a) Pressure and (b) velocity.

Figure 3 shows that the dependence of friction coefficient of un-textured surface on both pressure and sliding velocity is monotonous. However, this is not the same case for the textured surface. Figure 4 plots the variations of friction coefficient with pressure and sliding velocity, respectively. Although the friction coefficient of textured surface decreases with increasing pressure, the friction reduction is more pronounced than un-textured surface.

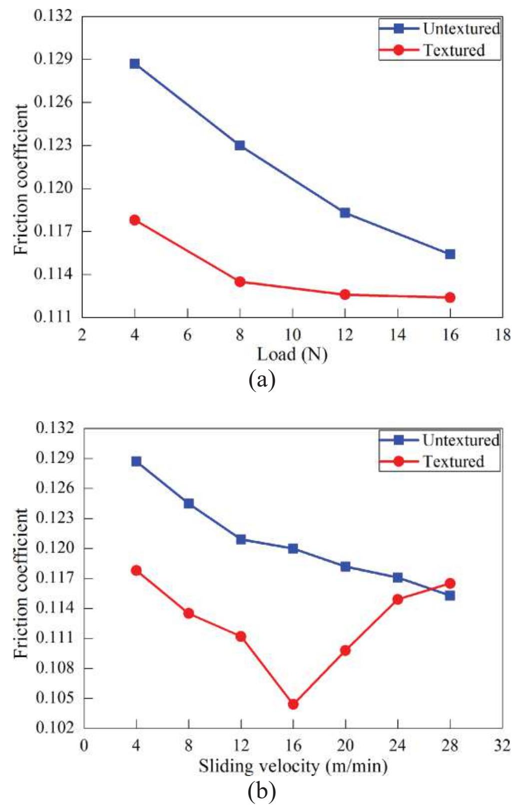

Figure 4 Influence of surface texturing on the frictional properties of stainless steel. (a) Pressure and (b) velocity.

Figure 5 present wear morphology of textured and untextured surfaces after the friction tests under the same friction consideration. It is found that the wear scar of textured is significantly less pronounced than that on untextured surface, indicating a wear reduction by the as-fabricated textures.

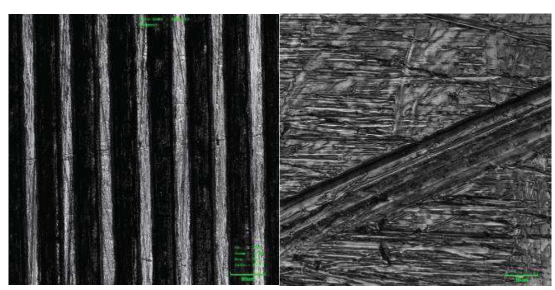

Figure 5 Wear morphology of textured (left) and untextured (right) surfaces.

4. SUMMARY

In summary, we fabricate surface textures on stainless steel by laser surface texturing with different pulse duration. For each pulse duration, the wavelength and height of the aligned groove textures are the same as 90 µm and 8 µm, respectively. Laser ablation results show that the rim structure and ablation-induced damage are strongly affected by the pulse width. Subsequent ball-on-disk friction tests indicate that the presence of as-fabricated textures significantly lower friction coefficient and wear of textured surface, i.e., friction reduction occurs. However, the effectiveness of surface textures in friction reduction is strongly dependent on the morphology of surface textures, which is dominated by different laser-material interactions under different pulse durations.

ACKNOWLEDGEMENT

The authors greatly acknowledge support from Postdoctoral Scientific Research Development Fund of Heilongjiang Province (LBH-Q16094).

REFERENCES

[1] Etsion, I. (2005). State of the art in laser surface texturing. *Journal of Tribology*, *127*(1), 248-253.

[2] Rosenkranz, A., Pangraz, J. C., Gachot, C., & Mücklich, F. (2016). Load-dependent run-in and wear behaviour of line-like surface patterns produced by direct laser interference patterning. *Wear*, *368*, 350-357.

[3] Reif, J. (2010). Basic physics of femtosecond laser ablation. In *Laser-Surface Interactions for New Materials Production* (pp. 19-41). Springer, Berlin, Heidelberg.

[4] Arslan, A., Masjuki, H. H., Kalam, M. A., Varman, M., Mufti, R. A., Mosarof, M. H., ... & Quazi, M. M. (2016). Surface texture manufacturing techniques and tribological effect of surface texturing on cutting tool performance: a review. *Critical Reviews in Solid State and Materials Sciences*, *41*(6), 447-481.