Is laser surface texturing good or bad for rolling element bearings?

—Comments on: “Does laser surface texturing really have a negative impact on the fatigue lifetime of mechanical components?” by Hsu et al. and “An exploration of frictional and vibrational behaviors of textured deep groove ball bearing in the vicinity of requisite minimum load” by Vidyasagar et al.

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Received: 08 April 2021 / Accepted: 13 April 2021

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Abstract: A short commentary on the two research articles published in *Friction* in 2021 is presented. Both articles reported experimental results of applications of laser surface texturing technology to the raceway of rolling element bearings. After briefly reviewing the main findings of the articles, the arguable problems and distinctions between the two articles are pointed out.

Keywords: rolling element bearings; laser surface texturing (LST); fatigue life; wear; vibration

1 Introduction

For the past three decades, laser surface texturing (LST) has attracted a lot of attention from researchers in the field of tribology. The primary impetus behind the LST research stream comes from the following aspects. Firstly, increasing demands on the continuously reducing of friction and wear have spanned over wider and wider range of applications from machine elements to human body implants. Secondly, the rapid progress in surface finishing technologies has made engineering surfaces with the roughness of sub-micrometers or even tens of nanometers producible, and the high power picosecond and femtosecond pulsed laser tools have become affordable and popular in industry. Consequently micro-scale and nano-scale surface texturing over a macro-surface area is no longer difficult. Lastly the effects of surface textures acting as micro-bearings as well as reservoirs of lubricant oil and wear debris have been extensively

explored by means of theoretical modellings and experiments, and hence objective design and evaluation of LST have become possible. Applications of the LST technology have spread from mechanical seals, piston/cylinder bores to thrust bearings, etc. However, most of the investigations published ever on the LST are on face-to-face sliding tribosystems, and less work has been done on concentrated rolling contacts like rolling element bearings and gears. The major concern about the applicability of the LST to rolling contacts is the accelerated surface fatigue that might be caused by the deterioration of surface perfectness due to the introduction of LST.

2 Comments

In Volume 9, Issue 6 of *Friction*, two papers on the effect of LST on performance and fatigue lifetime of ball bearings are published. One is by Hsu et al., a joint team from TU Wien, Saarland University, AC2T

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Research GmbH, and RWTH Aachen, with the title “Does laser surface texturing really have a negative impact on the fatigue lifetime of mechanical components?”, on pages 1766–1775 (referred to as Austria–Germany team paper hereafter) [1]. The other is by Vidyasagar et al., a joint team from Indian Institute of Technology Delhi and Osmania University, with the title “An exploration of frictional and vibrational behaviors of textured deep groove ball bearing in the vicinity of requisite minimum load”, on pages 1749–1765 (referred to as India team paper hereafter) [2]. The Austria–Germany team paper applied two types of micro-scale LST patterns, cross and dimple, to the race of thrust ball bearings, and compared the fatigue lifetime of the textured bearings with texture-free bearings under boundary lubrication condition, while the India team paper investigated frictional and vibrational behaviors of dimpled deep groove ball bearings in the vicinity of requisite minimum load. The dimple and cross patterns on race way in the Austria–Germany team paper were made by using femtosecond pulsed laser and direct laser interference patterning (DLIP) nanosecond pulsed laser respectively, and the depth of both dimple and cross was around 1 μm , but the pitches between the dimples were different from those of the cross. The India team used a nanosecond pulsed laser to make hemispherical dimples with diameter of 28 μm in three different dimple area densities of 5%, 15%, and 25%. The dimple depth was 15 μm . The laser processing parameters used for their surface texturing were provided in the two papers. The two teams evaluated the LST effect on their rolling bearing test rigs.

The main findings reported in the Austria–Germany team paper are a three-fold increase in fatigue lifetime for the cross 30 (denoting the cross pattern with 30 μm periodicity), as shown in Fig. 8 of Ref. [1], and remarkable reduction in wear loss, reaching two orders of magnitude for the cross 30 as shown in Fig. 4 of Ref. [1], compared with the texture-free reference bearing. The authors attributed the positive impacts of LST on fatigue lifetime of thrust ball bearings and wear of thrust cylindrical roller bearings to the enhancements of antiwear tribofilms formation under higher normal pressure

and lubricant oil retaining in the richer micro-scale surface cavities in the case of textured bearings. Contact simulations for the different surface textures have been done, and the simulation results support their postulations. Positive effects of LST on tested deep groove ball bearings were also reported by the India team in Ref. [2]. Comparing with the texture-free bearing, the dimpled bearings have shown a reduction in frictional torque by 15%–47% (see Fig. 7 in Ref. [2]) and a reduction in vibration amplitude by 25%–46% (see Fig. 14 in Ref. [2]). Among the three tested dimple textures, the samples with 15% dimple area density presented the best performance. The India team did not provide the test data of fatigue lifetime and wear loss of the bearings. However, as shown in Fig. 11 of Ref. [2], there are more severe surface cracks on the textured inner race after experiment than on the texture-free conventional race, indicating a detrimental effect of LST on fatigue lifetime. This is somehow controversial to the conclusion of the Austria–Germany team.

3 Discussions

It is worth noting that there are several differences in test conditions between the two experimental studies. Besides bearing type, the lubrication, temperature, speed, and load conditions are also of big difference. The Austria–Germany team used ISO VG100 oil mixed with zinc dialkyldithiophosphate (ZDDP) additive as lubricant for wear test and fatigue lifetime measurement, while the India team used commercial lithium grease as lubricant. The Austria–Germany team performed bearing wear test under 60 $^{\circ}\text{C}$ and fatigue test under 90 $^{\circ}\text{C}$, respectively, while in the experiments by India team, the temperature of the bearing outer race was much lower, at around 26–28 $^{\circ}\text{C}$. For the conditions of speed and load, a very low speed of 20 rpm (0.04 m/s in linear speed) and a heavy load of 80 kN (corresponding to 3.5 GPa Hertzian pressure) were selected in the wear test, and a medium speed of 750 rpm (1.53 m/s in linear speed) and a heavy load of 80 kN were used in the fatigue test in the study by the Austria–Germany team. However, the load conditions used in the experiments by the India team were 20, 40, and 60 N, corresponding to Hertzian

pressures of 1.2, 1.6, and 1.9 GPa, respectively, and the test speed was changed in the range from 500 to 1,400 rpm, corresponding to linear speeds of 1.2 to 3.4 m/s, respectively. Evidently these different test conditions could lead to very different contact and lubrication states at the interfaces between the rolling elements and races of the two teams, resulting in different behaviors in friction, wear, fatigue, and dynamics of the tested bearings.

Another difference might be in the bearing materials used in the two experimental work. The bearings tested by the India team were made of EN31 bearing steel, while the bearings tested by the Austria–Germany team were made of 100Cr6 (AISI 52100). In fact, even if the same bearing steel was used, the crystal microstructures including the size and distribution of inclusions of carbides and oxides might be quite different between the tested bearings of the two teams, because they are dependent on the bearing manufacturing processes. The inclusions are of great importance for fatigue and wear of rolling bearings. Unfortunately, both papers did not provide detailed information of microstructure and inclusions of their tested bearings.

4 Conclusions

In my opinion, it is still not confident to answer the question “is laser surface texturing good or bad for rolling element bearings?” at this stage. More experimental work and detailed analyses are needed

to do on this subject in the future, and the efforts are definitely valuable for producing better bearings.

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