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Friction and wear performance of laser peen textured surface under starved lubrication

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ABSTRACT

Laser peen texturing (LPT), which is a new surface texturing technology, was proposed to fabricate micro-dimple arrays on copper surface. Pin-on-disk experiments were conducted under different normal loads and sliding speeds to investigate friction and wear behaviors of untextured and textured samples in starved lubrication. It was found that friction performance of the surface is improved significantly after LPT. Microscope observation and EDS analysis showed that textured surface could reduce both abrasive and adhesive wear as compared to untextured surface. Results also indicated that an optimum texture density might exist at which surface shows the best friction and wear behavior.

1. Introduction

Surface texturing as an approach for controlling the friction and wear behavior of tribological components is well known for many years. As early as 1966, the effect of surface texturing on lubrication was studied by Hamilton et al. [1]. Now surface texturing has been widely recognized as a viable means to reduce friction coefficient, improve load carrying capacity and wear resistance of tribological systems. Micro-dimple array is a typical kind of texture and plays an important part in improving tribological performance. In starved lubrication, dimples act as reservoirs of lubricant, which supply back-up lubricant when lubricant film is broken down [2]. In hydrodynamic lubrication, dimples are utilized as micro-hydrodynamic bearings to help improve load carrying capacity of the lubricant film [3]. Dimples could also serve as traps for wear debris in both lubricated and dry sliding [4].

Many studies on various forms, sizes and shapes of micro-dimples on sliding surfaces for tribological applications have been reported over the last two decades [2,5–11]. Ryk et al. [2] studied the effect of surface texturing under starved lubrication conditions, and found that with optimum dimple depth and low lubricant viscosity the texturing was beneficial over the entire range of tested flow rates. However, with the deepest dimples or with high lubricant viscosity the surface texturing may be detrimental under certain operating conditions. Galda et al. [8] studied the effect of surface texturing on lubrication regime transitions from mixed to hydrodynamic and found that the shape and distribution of oil pockets are the main factors affecting the lubrication kinds. Higuera Garrido [10] studied tribological behavior of laser-textured NiCrBSi coatings. Results demonstrated the strong correlation among texture density, dimple diameter and contact area for reduction of the friction coefficient. Tang et al. [11] fabricated multi-dimples using a miniature engraving and studied the effect of surface texturing on friction and wear under hydrodynamic lubrication, they concluded that a 5% optimal dimple area

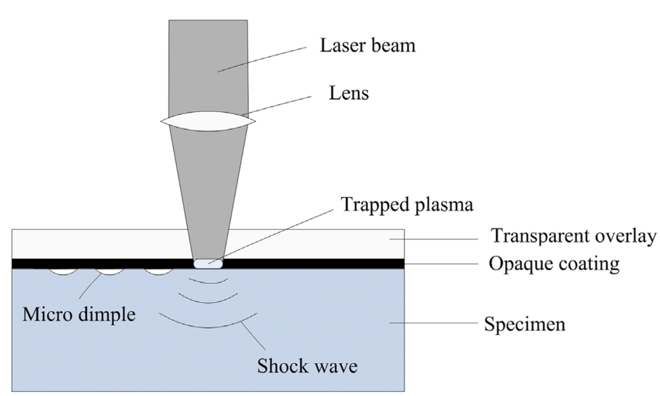

Fig. 1. Schematic of laser peen texturing.

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Table 1
Texture parameters used in this study.

Specimen no.	0	1	2	3
Texture density, ρ_t (%)	–	5	13	35
Dimple depth, h (μm)	–	10	10	10
Dimple diameter, d (μm)	–	1100	1100	1100

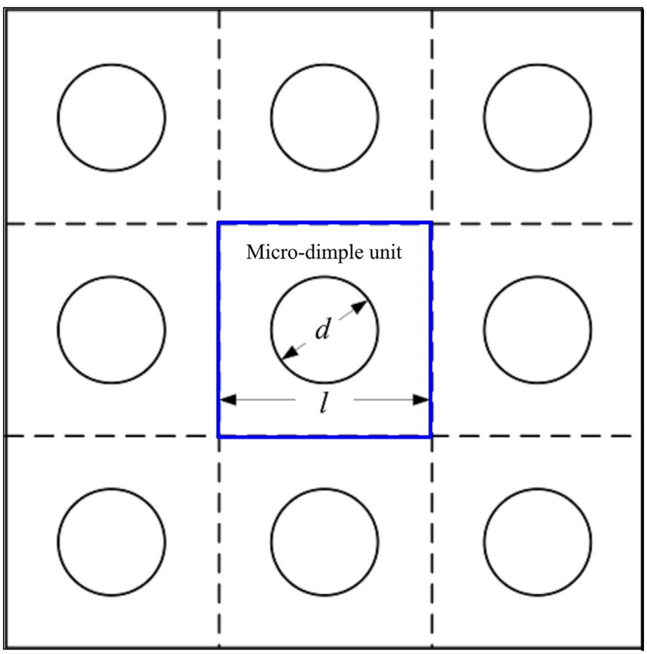

Fig. 2. Schematic of micro-dimple array.

fraction can generate the greatest hydrodynamic pressure compared with other fractions and can reduce friction and wear up to 38% and 72%, respectively.

Nowadays, methods to fabricate surface textures could be generally classified into mechanical [12–16], ion beam texturing [17,18], etching [19–22] and energy beam techniques [23–29]. Among these methods, laser surface texturing (LST) is considered as the most promising texturing technology. The main reason is that textures fabricated by LST could be precisely controlled and this process is friendly to the environment [7]. In last few years, many studies have focused on LST, and it has been successfully applied on piston rings [24,25], mechanical seals [26,27], hydrostatic gas seals [28], journal bearings [29], thrust bearings [30], and soft elasto-hydrodynamic lubrication [23,31,32]. However, laser peen texturing (LPT), which is another energy beam technology for surface texturing, has been given little attention.

Compared with LST, besides the merits of LST mentioned above, LPT has more advantages: Firstly, LPT utilizes laser-shock-induced mechanical effect rather than thermal effect, so it could effectively avoid the negative influence of ablation in material surface integrity. However, during LST, micro-dimples are fabricated by a laser ablation mechanism. Tensile residual stress may occur in material due to the high temperature during ablation [33]. This change in surface integrity will shorten the fatigue life of the material [34]; Secondly, after LPT, there is no apparent pile-up around the micro-dimple which is generally detrimental to the tribological performance, thus post-texturing lapping process for the purpose of removing pile-up could be omitted. Nevertheless, the lapping process is usually needed for LST according to the studies of Etsion [8], Yu et al. [27] and Kovalchenko et al. [35]. Thirdly, the great shock pressure of LPT can induce deep compressive residual stress and hardened layer in material surface and subsurface, which can improve fatigue life of the material dramatically [36,37]. The disadvantage of LPT compared with LST may be that the equipments and the process procedures of LPT are more complex.

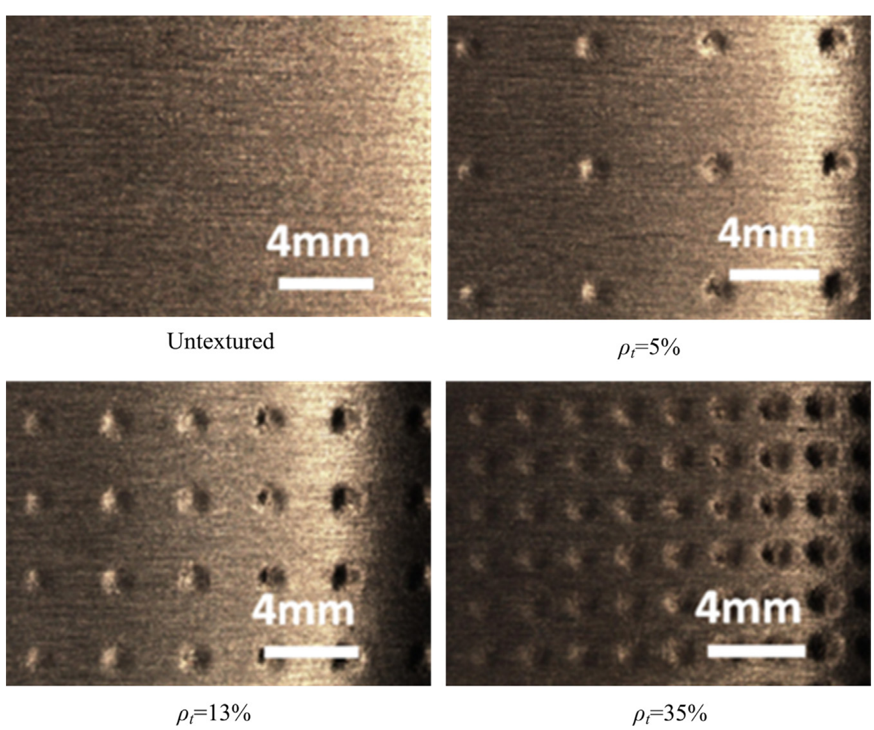

Fig. 3. Surfaces of the specimens.