Study on Laser Surface Microtexture Processing and Friction of 45 Steel

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Keywords: laser processing; microtexture; friction.

Abstract: To study the effects of different surface microtextures on the friction and wear properties, the microtextures were processed on the 45 steel surfaces by pulsed laser. It showed that the textured surfaces with pits and grooves had an effect on the storage of lubricating oil and abrasive particles, which can improve friction and wear behavior of surface. Compared with smooth sample surface, the wear resistance and anti friction of textured surface were significantly improved; the improvement of abrasive resistance of textured surface with appropriate texture area ratio is more remarkable.

Introduction

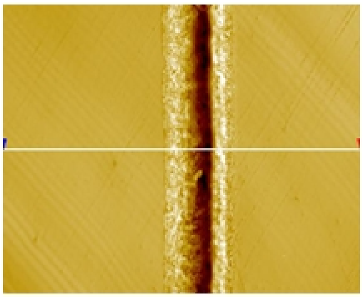
The surface performance of mechanical component plays an important role in the reliable operation thereof, and the friction wear on surface is an important reason which leads to its failure. The laser micro-processing technology plays an important role in the surface improvement of friction pairs, especially in influencing lubrication and sealing property [1-2]. Many scholars have widely done the research of tribological property of the laser micro-processing appearance, but such research is usually limited to the pit shape distribution [3] and the pit size optimization [4]. Meanwhile, many tests are mainly carried out to qualitatively explain relevant theories rather than describe the influence of the whole regular pit surface on lubrication [5]. On the basis of existing research, this article is about using 45 steel to form some typical pit textures for the sliding bearing and the research of tribological property thereof. All of the research is favorable for deeply understanding the influence of the structural features of the surface appearance on friction, wear and lubrication.

Experiment and Method

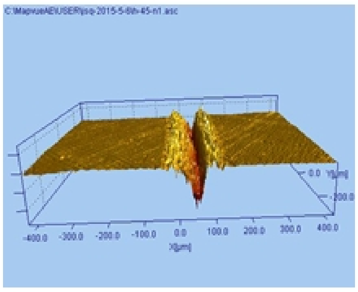
Laser microtexture experiment. The diode side pumped YAG laser machining system is adopted as the experimental equipment, and the laser mode is TEM00. This is a pulsed laser and of which the wavelength is 1064nm. The auxiliary blowing system equipped on the machining system can remove the most slags that generated during the machining process and accordingly reduce metal recasting. Micro XAM 3D non-contact surface appearance analyzer is adopted to detect the geometrical appearance of microtexture.

45 steel of Ø15mm×10mm in size was used for experimental sample, which was firstly quenched and then tempered. Specifically, the sample surface was firstly polished by the abrasive paper for metallograph and then buffed in order to make the roughness become nearly 0.2um, and before testing, the sample needs to be cleaned by ultrasonic waves and dried.

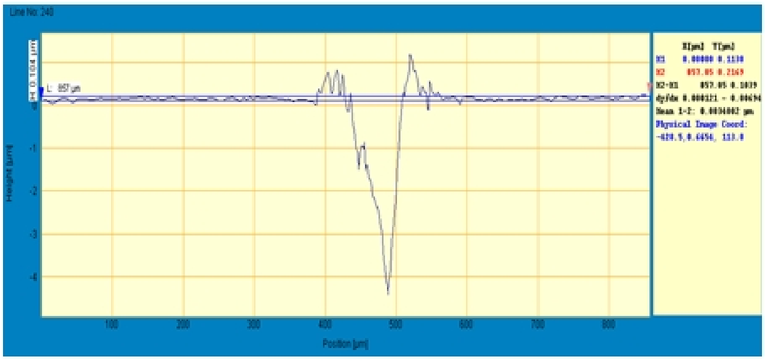
In order to obtain ideal microtexture geometrical appearance, it is necessary to machine the single line texture by laser to optimize firstly, optimize the laser processing parameters (energy, scanning speed, scanning times) secondly and finally obtain the microcosmic geometrical topography of the surface which is required in the design and then remove such residues as slags through ultrasonic cleaning treatment. The result of the single factor experiment shows that the microtexture appearance is relatively ideal when the speed is 3mm/s; the current is 14.5A and the single scan. Fig.1 shows the microcosmic geometrical appearance and the section profile of 45 steel single line microtexture, wherein the microtexture has the groove width of about 70um and the depth of 4.2um. According to the measured data, the width & depth dimension of the microtexture is the most approximate to the dimension standard of the honing reticulate pattern of the cylinder liner. According to the cross-section profile shown in Fig.1(c), the two sides of the groove are smooth and the edges have less than 1um recasting residues. Therefore, it is necessary to implement polishing treatment before its using to remove the burrs and slags which generated during the laser micromachining process.



(a) 2D topography



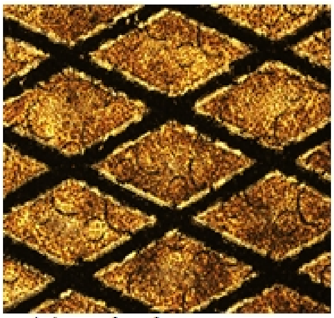
(b) 3D topography



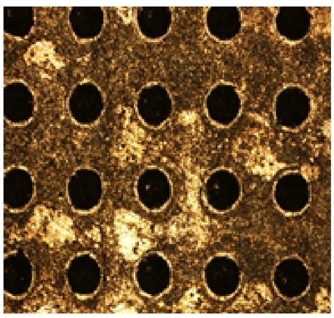
(c) cross-section profile along X direction

Fig.1 3D topography of 45 steel with single line microtexture

The above optimized parameter combination is adopted for the microtexture laser machining parameters of the friction pair surface. The reticulate pattern and pit are adopted for the profile of the microtexture. Fig.2 shows the micro-topography of microtexture of 45 steel changed by plused laser. The geometric dimensions of the two models are changed to form different microtextures, and the specific scheme i



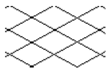
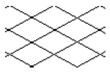
(a) reticulate pattern



(b) pit

Fig.2 The micro-topography of microtexture of 45 steel by laser

Table 1 Profile, geometrical parameters and wear microtexture surfaces by laser

Sample scheme	Geometric construction	Dent or line space /um	Pit diameter or line width	Pit depth /um	Wear loss/g
1		300	70	6-7	0.0005
2		400	70	6-7	0.0001
3		500	70	6-7	0.0004
4		300 (14.7%)	130	8-10	0.0005
5		400 (8.3%)	130	8-10	0.0003
6		500 (5.3%)	130	8-10	0.0002
7	smooth sample				0.0011

Friction wear test. In the experimental research on the point-surface contact and lubrication, UMT-2 multifunctional friction wear testing machine is adopted to test the influence of multiple laser microtextures on the surface friction wear performance of 45 steel, wherein the reciprocating low-load linear driving device is adopted for this instrument, and the stainless steel ball with the friction pair of Ø4mm is adopted for the ball-on-disc friction test. The experimental conditions are as follows: load 0.8kg; rotating speed 300r/mm; friction time 30min; room temperature; SAE20/W40 lubricating oil; and for each sample, the experiments should be repeated three times. Oil is added every 10min during the experiment process in order to ensure that the contact surface has rich oil. Before each experiment, the sample is cleaned by ultrasonic waves, dried, and weighed by an electronic balance. After the experiment, the scanning electron microscope (SEM) is adopted to analyze the worn surface of the test piece and measure the worn cracks of the surface and the profile shape thereof.

Result and Discussion

Wear resistance. The surface wearing capacities of various laser microtexture samples and smooth samples are as shown in Table 1. The experimental result shows that the surface wearing capacity of the laser microtexture sample is lower than that of the smooth sample. The reason is as follows: on the one hand, the pits or the grooves on the surface of the microtexture sample can store lubricating liquid, thus to generate certain fluid dynamic pressure lubricating effect between the upper and lower friction surfaces and accordingly separate the upper and lower contact surfaces; on the other hand, the pits or the grooves can collect the worn abrasive particles to reduce the possibility of the worn abrasive particles occurring on the contact surface. Additionally, during the laser machining process, the short-pulse high-energy laser beams can suddenly heat and cool the surface of the machining area to quench and temper the surface material and accordingly change the microstructure of the material and form the hardened layer with high hardness and superfine texture, thus to more or less improve the surface wear resistance of the sample. When the space is 400um, the wear resistance of the textured sample is satisfactory.

Tribological property. Fig.3 shows the friction wear performance test results of the cross hatch texture sample with different line space of reticulate pattern and the smooth sample. The result shows: compared with the smooth sample, the sample with cross hatch texture has a small surface friction coefficient, in other words, the line groove on the surface can store lubricating oil under lubricating state and accordingly more or less reduce the friction. When the line groove space is increased from 300~500μm, the friction coefficient is firstly reduced and then increased, but is 0.15 less than that of the smooth sample. The possible reason is as follows: when the line space is too small, the line groove on the surface has a large occupancy and the surface integrity is accordingly reduced; when the line space is too large, the line groove has a reduced occupancy and the oil film continuity and the bearing capacity are accordingly reduced. In allusion to the surface contact friction pair of the cast iron sample, Pettersson and other once pointed out that the surface friction coefficient of such texture appearance as groove or cross hatch was less than that of a smooth surface and the friction coefficient curve had small fluctuation [4]. According to relevant comparison, when the space of reticulate pattern is 400μm, the minimum friction coefficient is about 0.11 and the friction wear reduction effect is the best.

Fig.4 shows the surface friction coefficient of the pit texture sample surfaces with different spaces of pit and the smooth sample. According to the figure, compared with the smooth surface, the pit sample has a relatively small surface friction coefficient, thus indicating that under the liquid lubricating state, the surface pit can have a certain friction reduction effect. According to the comparison of the friction coefficients of the pit textures with four dimension parameters, when the space is 500μm, the minimum friction coefficient is about 0.1~0.11 and the friction wear reduction effect is the best.

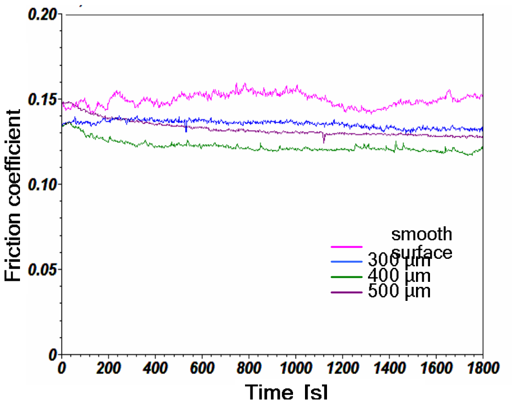


Fig.3 Friction coefficient of textured surfaces with reticulate pattern and smooth surface

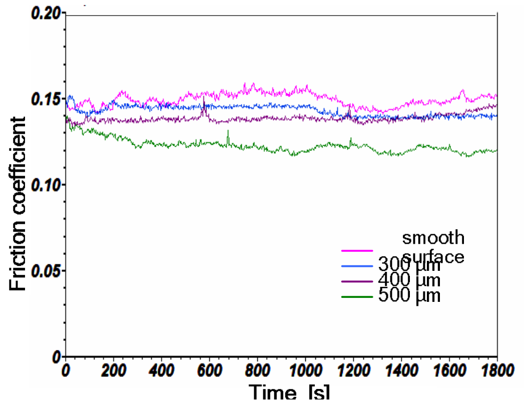


Fig.4 Friction coefficient of textured surfaces with pit and smooth surface

Viewed from the surface friction coefficient of the above two textures, both the continuous grove and the interrupted groove can increase the surface friction coefficient. The reason is as follows, on the one hand, the lubricating oil flows along the groove and accordingly causes a local low-pressure area in the texturing area to thin the oil film on the surface [5]; on the other hand, under lubrication condition, the microtexture processing can cause the original smooth and smooth sample surface to form regular uneven washboard textures, thus to not only increase the surface roughness, but also increase the surface friction drag. According to the analysis of surface occupancy S_p, when S_p is about 5%, the sample surface can have ideal tribological property.

Conclusion

(1) The microtexture surface on the 45 steel by pulsed laser has an effect on the storage of lubricating oil and wear particle, reduce the use of lubricating oil, and shorten the formation time of the lubricating film, so as to reduce the friction wear.

(2) Under lubricating condition, the wear resistance and anti friction of the material are better

when the texture area ratio is about 5%.

(3) From the curve of surface's friction coefficient, the change of that in the surface with reticulate pattern or pit is gentler, and the stability of that is better compared with smooth surface. However, the difference between friction numerical factors and smooth samples is little.

Acknowledgements

The work was financially supported by the Natural Science Foundation of the Jiangsu Higher Education Institutions (No. 13KJA460001), the Open Foundation of Jiangsu key Laboratory (No. HGDML-1101) and the Foundation of Huaiyin Institute of Technology (No. HGB1201) and the Jiangsu Student Innovation Training Program (No. 201411049036y and No. 201411049036y) .

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