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Performance analysis of laser structured surfaces like-honing

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Abstract

This paper presents the exploratory study on the use of laser-structured with micro grooves to emulate honed surfaces to reduce the friction between relative motion parts. The objective is to analyses the effects of a Laser structured surface with patterned micro grooves, like honing, over the friction and wear resistance. Honing is a low-velocity abrading machining process used to improve the form, dimensional accuracy, and surface quality of a workpiece with an abrasive bounded tool working under constant surface contact, and it can produce patterned micro grooves. From the tribological point of view, honing can produce surfaces with unique characteristics, such as high support area, high wear resistance and low friction. Characteristics are well explored in precision positioning system. One disadvantage of the honing process is its incapacity of produce continuous micro grooves with constant geometry and dimensions, aside the metal folded and blur formation problem.

The study started with a statistical analysis of cylindrical honing surfaces to classified the micro grooves in terms of geometry and distribution over the surface. This allowed classifies the grooves into three groups: high deep, medium deep and shallow or nearly scratches groves, each group with its own spatial distribution in terms of number of lines per unit of area. Considering this and the macro geometry of grooves, four different structured surface were designed. Test parts were Laser manufactured in vermicular graphite cast iron, and its surfaces characterized. Experimental tests were performed using reciprocate test on an Optimol SRV 5 Test System, with a low viscosity oil. The results were compared to those obtained from the experiments with the conventional honing surfaces. The results show that laser-structured like honing surfaces provided friction compatible with conventional honing, and a promising solution to reduce friction and wear on parts with relative motion.

Keywords: Laser structured surface, Tribology, Honing, lubricants

1. Introduction

On the tribological point of view honing process can produce surfaces with unique characteristics as high support area, high wear resistance and patterned micro groove with capacity of retains lubricant. These characteristics are well explored on the automotive engines, and precision instruments.

One disadvantage of the honing process is its incapacity of produce continuous micro grooves with constant dimensions and geometry, aside the metal folded and blur formation problem. The folded metal and the blur formation are strongly related with the decreasing on the wear resistance, and severe damage on the surfaces. The development of Laser structured like honing surface - LSLHS allows the elimination of these problems.

2. Objectives

The objective is exploring the viability of use of a Laser structured surface with patterned micro grooves, like honing, over the friction and wear resistance.

3. Materials and methods

3.1. Laser structured surface

The design of LSLH surfaces started with performing a statistical analysis of honed surfaces, using the methodology developed by Obara [1]. This study allowed the classification of the grooves in terms of deepness, geometry, and distribution over the surface. The grooves were divided into three groups: first order grouped the high deep grooves, second order medium deep ones, and lower order the shallow or nearly scratches groves. The grooves on conventional honed surface uses an statistical approach in order to set deterministic parameters to the laser structured ones. Each group is associated with its own special distribution in terms of number of lines per area unit. Considering this and the macro geometrical pattern of grooves, four different structured surface were designed. The micro grooves had circular or V shape, with the parameter a, b, r and β are variable of investigation. The intersection angle α was 120°, Figure 1 show the main design parameter.

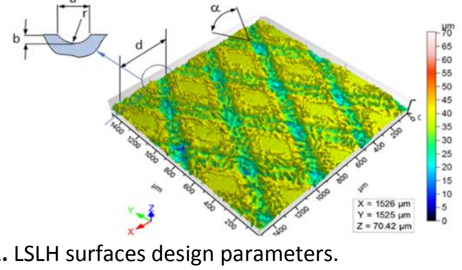


Figure 1. LSLH surfaces design parameters.

The grooves were manufactured using a Nd:YAG Short Pulse Laser, with λ 532nm, output power of 8,05W, and 5kHz frequency of pulses. Short pulse and ultra-short pulse laser has an advantage of avoiding thermal damage on the material [2]. The test body are vermicular graphite cast iron with rectangular shape 150X100X3 mm. The counter body were stainless steel ANSI 306, with 38HRC of hardness, 3 mm width and edge radius of 0,1 mm. The geometry was based on the recommendation of Stoeterau [2]. Table 1 show the patterns developed for the experiments

Table 1. Patterns developed for the experiments

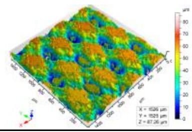
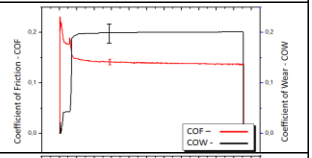
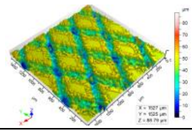
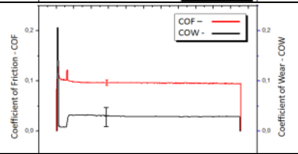
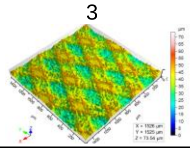
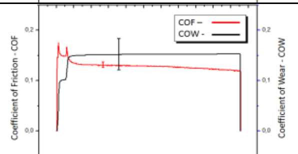
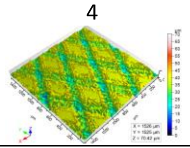
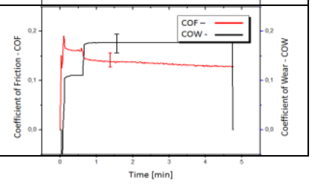
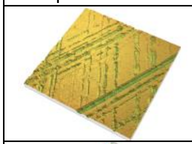
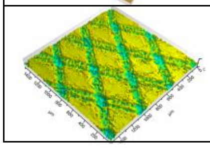
Pattern	Parameters	Results
1 	*a* = 200μm *b* = 20μm *r* = 150μm *d* = 500μm	
2 	*a* = 150μm *b* = 25μm *r* = 125μm *d* = 400μm	
3 	*a* = 200μm *b* = 10μm *r* = 250μm *d* = 500μm	
4 	*a* = 150μm *b* = 10μm *r* = 150μm *d* = 400μm	

Table 2. Conventional honed and Laser structured comparative

Sample	Height Parameters – ISO 25178	
	Sq = 0,8710 μm Ssk = -1,669 μm Sku = 5,474 μm Sp = 7,011μm	Sv = 7,316 μm Sz = 14,33 μm Sa = 0,6447 μm
	Sq = 0,7014 μm Ssk = -0,986 μm Sku = 4,786 μm Sp = 5,231μm	Sv = 5,045 μm Sz = 10,23 μm Sa = 0,4875 μm

3.1. Experiments

Reciprocate experiments were performed using an *Optimol* SRV 5 Test System, using the recommendations of ASTM D6425 – 11 1997 [8]. A synthetic low viscosity oil SAE 5W30, at a 38°C of temperature. A pre-load of 20N were applied and the experiments were performed under a constant load of 100N. The stroke was 5mm with a frequency of 33kHz, and the experiment time was 10 minutes. Figure 2 shows the experimental apparatus. Each experiment was replicated five times for each pattern, with the first and last one were set aside.

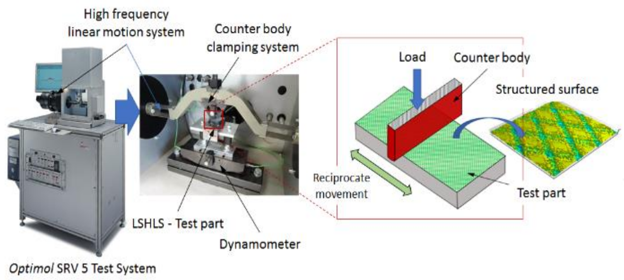


Figure 2. Reciprocate experimental apparatus.

4. Results and discussion

Based on [3] [4][5][6] and [7] a range of COF for conventional honed surfaces was set, and overlayered on the same graphic. The conventional honing COF vary per counter body material and geometry, lubricant type, temperature, velocity, load, the presence of coatings and others. Lower COF in conventional honed surfaces is also associated with the use of coatings.

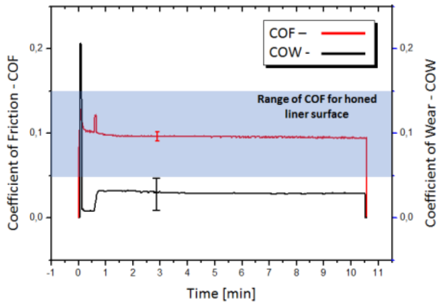


Figure 2. Average experimental results obtained for patter 2

5. Conclusions

Laser-structured like honing surfaces provided friction compatible with conventional honing, and a promising solution to reduce friction and wear on parts with relative motion. Based on the results the Laser structured like honing surface have a friction performance compatible with the conventional ones. In term of friction LSLH surfaces can be an alternative process, since the damage related with metal folded and blur formation are eliminated.

Long term experiments must be performed to support the information's regarding the wear resistance. A comparative analysis related with the support capacity of conventional and LSLH surfaces, based on Abbot-Firestone curve are going to be provided. This exploratory investigation were performed based upon first order surfaces structured with circular shape, further experiments must done to explore a combination of second order and lower other grooves, and V groove types.

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