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A study on effect of laser textured cast iron surfaces on reducing friction and wear

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ABSTRACT – The purpose of this study is to investigate the effects of the geometry and distributions of dimples on the frictional behavior of cast iron surfaces for applications in automotive engines under lubricated condition. Laser surface texturing method will be used to create micro dimples with various dimensions on cast iron surface. The pin on disc tester will be used to measure the friction and sliding wear properties. A comparison will be made between the performance of reference non-textured piston rings and optimum surface textured of piston rings. The density area of dimple is expected to reduce friction and wear up to certain value.

1. INTRODUCTION

To improve fuel consumption, wear and friction must be reduced since it causes approximately 40% energy losses from wear losses and engine friction [1]. Surface texturing is a widely known as a method to improve the load capacity, the wear resistance, and the friction coefficient of tribological mechanical components [2]. Laser surface texturing offer the most suitable concept since the technique is very fast; allows short processing times, and provides a good control of the shape and size of the micro dimples [3]. Wakuda et al. [4] has found that the tribological characteristics depend highly on the size and density of the micro dimples. However, the dimples shape does affect just a little for the friction coefficient either rounded or angular profiles. A comparison has been made between a non-textured conventional barrel shape rings and optimum partial laser surface texture cylindrical shape rings and the performance shows an optimum value of the micro dimples depth over diameter ratio yields a minimum friction force about 25% [5]. A few researches had been done to directly relate the influence of the surface texturing of aluminum alloy on the efficiency of an IC engine. Therefore, this study will evaluate the effects of surface texturing with a variety of dimensions of dimples to acquire a guide to optimal dimple pattern.

2. METHODOLOGY

2.1 Experimental design

In this study, dimples on cast iron specimen is going to be produced using laser surface texturing since it has been previously reported that the low friction coefficient can be obtained using this technique. A 2^3 factorial experimental design will be used to evaluate the effect of three independent variables, namely; dimples geometry, depth to diameter ratio and surface area density ration on the surface roughness and friction coefficient of the surface, using the Design-Expert software. All factors comprising low (-) and high level (+) factors are shown in Table 1. The effect of the process factors on the responses will be calculated by following valid model in the experimental space (Montgomery 1997):

$$Y_m = B_o + \sum B_i X_i + \sum B_{ij} X_i * X_j + B_{ijk} X_i * X_j * X_k \quad (1)$$

Where *i, j, k* are equal to 1, 2, 3 and *m* equal to either 1 or 2. The coefficient B_0 is the mean of responses of all experiments; B_i coefficient represents the effect of variableX_i, whereas B_{ij} and B_{ijk} are coefficients which represent the effect of interactions of variables $X_i * X_j$ and $X_i * X_j * X_k$ respectively.

Table 1 Proposed factorial design matrix.

Std	Run	Diameter of dimples (µm)	Depth of dimples (µm)	Surface area density (%)
8	1	-	-	-
2	2	-	-	+
5	3	+	-	-
1	4	+	-	+
3	5	-	+	-
6	6	-	+	+
4	7	+	+	-
7	8	+	+	+

Table 2 Three proposed factor for DOE.

Factor	Unit	Low (-)	High (+)
Diameter of dimples	µm	70	130
Depth of dimples	µm	5	13
Surface area density	%	5	15

2.2 Optimization

The same Design Expert software will be used to analyze the data collected from tribological tests and in the selection of appropriate model to be used. Analysis of variance (ANOVA) will be performed for analysis of residuals and outlier detection. Finally, model validation and multiple response optimizations will be performed.

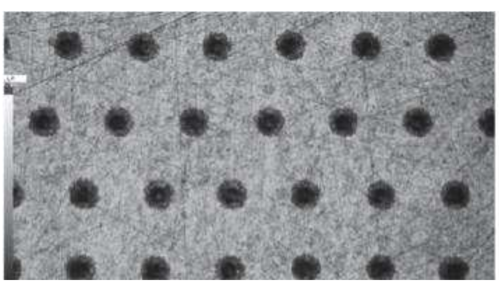
2.3 Wear Test

Tribological test is carried out on the textured and non-textured specimens using a pin-on-disc tribotester. The pin-on-disc tester measures the friction and sliding wear properties on dry and lubricated surfaces of a variety of bulk materials and coating. Tests were performed according to an ASTM G99-90 standard. Test parameters such as the speed (rpm), time (t), sliding distance (L), friction coefficient (μ), frictional force and wear (δz) will be recorded using *Winducom* software. A minimum of three samples is going to be tested for every set of experiments to minimize data scattering.

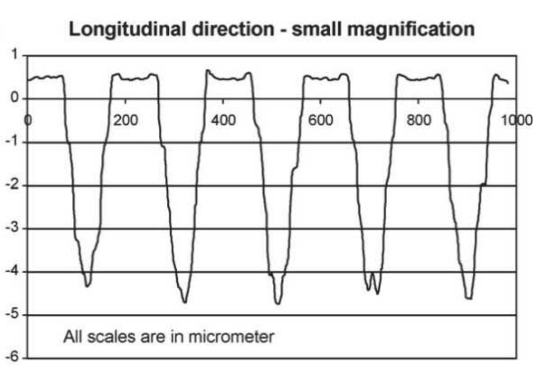
3. RESULTS AND DISCUSSION

3.1 Microstructure

Review of engineered tribological interfaces for improved boundary lubrication by A. Erdemir [6] reported that shallow pits produced on the surface have altered the hydrodynamic efficiency. These dimples can act as reservoir for lubricants and can trap wear debris to reduce wear due to third bodies trapped at the sliding interfaces. Similar microstructure as shown in Figure 1 is predicted in this study.



(a)



(b)

Figure 1 a) Plane view and b) 2D image of a laser dimpled steel sample. Dimples are typically 4 to 5 µm deep and 100 µm in diameter [6].

Manabu Wakuda et al. [4] has compared the results of friction surface between non-textured and textured surfaces. The expected result will show that all textured samples will have a lower coefficient of friction than the non-textured samples.

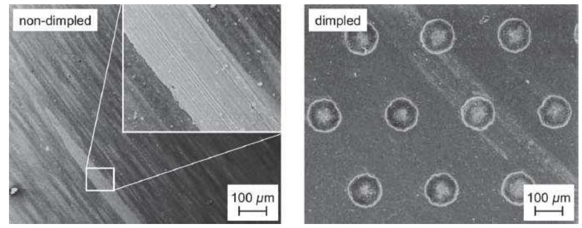


Figure 2 SEM observation of the friction surface following the long sliding test [4].

The similar result is predicted with the experiment done by Beomkeun Kim et al. [7] as friction test revealed that the measured coefficients of friction for the non-textured plates plotted as functions of the lubrication parameter, where it shows the low coefficients of friction were maintained for the textured surface throughout the entire range of lubrication parameter values.

4. CONCLUSION

In this present study, with all the parameters, the function of micro dimples on the cast iron surfaces is highly expected to reduce the friction coefficient and wear in the engine performance. The micro-trap for wear and debris and the micro-reservoirs for lubricant are the main factors for the reduction in the friction and wear of the surface texturing.

5. REFERENCES

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