

Determination of dimple distribution for laser texturing process on cast iron surface

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ABSTRACT – The aim of this research is to determine the uniformity distribution of the micro dimples to be textured on cast iron surface by using laser surface texturing method. Distribution of dimples on the surface is important in reducing wear debris amount. Imaginary grid of dimple cell was calculated and certain distance between dimples was determined in order to be located on the surface of cast iron. A uniform dimple's distribution was calculated on the sample surfaces before textured by laser treatment method.

1. INTRODUCTION

Friction and wear produced during engine operation could create heat and reduce performance of engine. Therefore, surface modifications on mechanical components had been studied for contact performance enhancement in order to reduce wear and friction. Laser Surface Texturing (LST) method will be used to create micro dimples on the cast iron surface.

Wakuda et al. [1] 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. Other than size of diameter, depth of micro dimples and shape of micro dimples, the amount of micro dimples on the sample surface also play important roles in order to help reducing wear amount. Too less or too much micro dimples might not give any effect in reducing friction and wear. Wei Tang et al. [2] reported that 5% dimple area fraction resulted 72% less than that of non-textured sample or 0% dimple area fraction after 7 hours test of sliding steel under lubricated condition. According to literature [3] the surface area to density ratio (total dimple area/total surface area) is one of the key parameters for surface texturing. The area density ratio is different according to the variety of dimple's diameter, and sample surface.

Several calculations need to be done to determine the amount and position of micro dimples on the sample surface. This paper is focusing on determination of micro dimple distribution on the cast iron sample for laser texturing. Different percentage from total surface area of sample surface was calculated to determine the volume of micro dimples and grid size on imaginary square of sample surface.

2. METHODOLOGY

2.1 Calculation

A pin sample has diameter 10mm and length of 32mm. An imaginary square is used to calculate the position of dimples on the surface of sample.

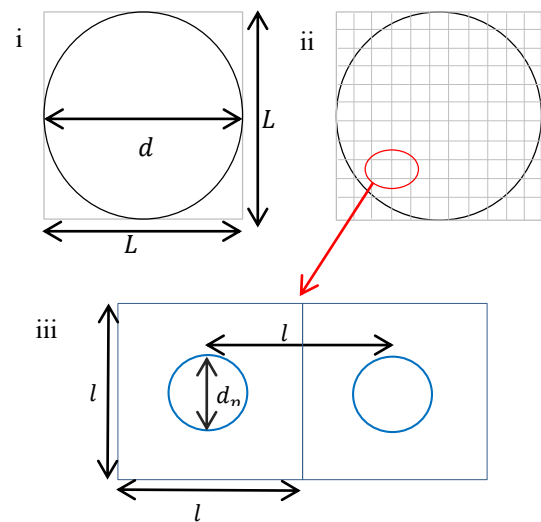


Figure 1 Schematic for (i) pin surface, (ii) imaginary grid and (iii) dimple cell.

Figure 1 (i) show the sample surface with diameter, d 10mm and figure (ii) shows the imaginary grid for $L \times L$. The geometrical model of the dimple is presented in Figure 1 (iii). Each micro dimple is modeled with a diameter, d_p and is located in the center of an imaginary square cell with the length, l which also presented the length between the adjacent cells.

In this study, Equation (1) is used to calculate total surface area of imaginary square of pin sample where L is the length of the square. Equation (2) is used to know the area of how much percentage from the total surface area. The term *value was determined by how many percentage that will be studied in this experiment. Volume of micro dimple can be determined by dividing percentage area with dimple area. Area for micro dimple can be calculated by using Equation (3) where r_p represent the radius of dimple.

$$L \times L = L^2 \quad (1)$$

$$\text{Percentage area} = \frac{\text{value}}{100} \times L^2 \quad (2)$$

$$\text{Dimple area} = \pi r_p^2 \quad (3)$$

$$\text{Grid size} = \sqrt{\frac{\text{Percentage area}}{\text{Dimple area}}} \quad (4)$$

$$l = \frac{L}{\text{Grid}} \quad (5)$$

Equation (4) is used to find the grid size on imaginary square of sample surface by square root the volume of micro dimples. After calculate for the grid size, the distance, l between the micro dimples was determined by using Equation (5) and the size of dimple size can be completed.

3. RESULT AND DISCUSSION

a. Figure of LST of dimples

A real figure of laser surface texturing of dimples by Wakuda et. al [1] and schematic diagram of dimple in this study as in the figure 2 below.

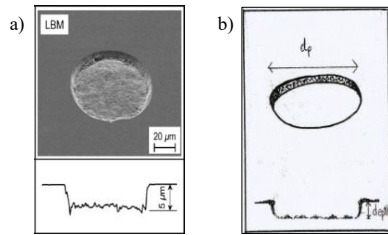


Figure 2 LST of dimple on sample surface from a) previous study [1] and b) schematic diagram.

b. Distribution of dimples

Figure 3 below shows the schematic of micro dimples on cast iron surface following the calculation from Equation (1-5) with diameter 130μm as an example.

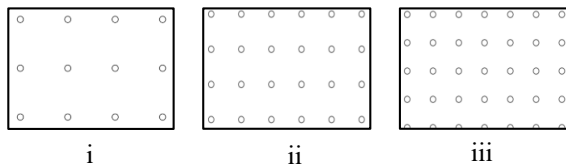


Figure 3 Dimple's distribution for diameter 130um (i) 5%, (ii) 10% and (iii) 15%.

Table 1 shows the diameter of dimples that will be textured on cast iron surface and its surface area. Table 2 shows the total surface area of the sample and area percentage to know how much dimples need to be created on the surface. Table 3 contains a data regarding the size grid on the imaginary square of the sample surface and also the distance between dimples to be located.

The uniformity of the dimple distribution was confirmed with the calculation in this study. However, it does not mean that the method from previous researchers is opposite since each study is conducted with variety

parameters and different values. A suitable amount of dimple's distribution help the existence of micro dimples to act as micro trap of the wear debris effectively during the sliding between two components under lubricated condition.

Table 1 Diameter of dimple and surface area.

Dimple	Diameter (μm)	Surface area (m ²)
d_{p1}	70	3.85×10^{-9}
d_{p2}	100	7.85×10^{-9}
d_{p3}	130	1.33×10^{-8}

Table 2 Percentage area of the sample.

Total Surface Area (100%)	$L^2 = 1 \times 10^{-4} \text{ m}^2$
5%	$5 \times 10^{-6} \text{ m}^2$
10%	$1 \times 10^{-5} \text{ m}^2$
15%	$1.5 \times 10^{-5} \text{ m}^2$

Table 3 Grid and distance for each dimples.

Diameter of dimple, d_p	Percentage area (%)	Grid, $L \times L$	Distance, l (m)
$d_{p1}, 70\mu\text{m}$	5	36×36	2.78×10^{-4}
	10	51×51	1.97×10^{-4}
	15	62×62	1.61×10^{-4}
$d_{p2}, 100\mu\text{m}$	5	25×25	4×10^{-4}
	10	36×36	2.78×10^{-4}
	15	44×44	2.27×10^{-4}
$d_{p3}, 130\mu\text{m}$	5	19×19	5.26×10^{-4}
	10	27×27	3.7×10^{-4}
	15	34×34	2.94×10^{-4}

4. CONCLUSION

From this study, the distribution of dimples on surface has successfully been determined. From the method used, the uniformity of the micro dimples is convincing to be created on the sample surface by laser texturing method. This calculation method is a part from full study on the effect of laser textured piston ring on reducing engine fuel consumption and is important for the next step in this research.

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