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STUDY AND ANALYSIS OF WEAR AND MICRO STRUCTURAL CHANGES ON CAST IRON UNDER LASER TREATMENT

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ABSTRACT

In this thesis Fiber laser techniques are used for the surface engineering of engine cylinder liner. Laser hardening produces wear resistant tracks by microstructural transformations. In this work application of the laser hardening process on gray cast iron cylinder liner, a material that is widely used in automotive engine, is investigated based on the observations of microstructure transformations in the influence of the process parameter. An important conclusion is that the surface quality of gray cast iron can be enhanced by Power density controlled laser surface hardening. The average microhardness of cylinder liner laser treated tracks increased from 250 to 400-700 HV in the transformed zone that consisted mainly of martensite, retained austenite and remaining cementite lamellae and undisclosed graphite flakes. Finally, the wear behavior of laser hardened cylinder liner is tested by dry sliding in a varying load condition.

KEYWORDS: Need of Surface Conditioning, Wear in IC engine cylinder liner, Surface hardening technique, Laser surface Hardening, Wear properties of laser hardened cylinder liner surfaces

INTRODUCTION

The surface condition of a component is usually the most important engineering factor. Almost inevitably the outer surface of a workpiece is subjected to wear and corrosion while it is in use. In IC engine, piston, piston rings, piston pin, cylinder liner, cylinder head, valves, connecting rod, crankshaft, bearings are having relative motion with each other so they cause different types of friction and wear. Because of wear the overall efficiency and life of an IC engine is reduced.The most important tropological system of an internal combustion engine is piston-piston ring-cylinder liner. The surface of the cylinder bores is one of the most significant features affecting the compatibility of the sliding surface within the cylinders. The most important role for the piston assembly is to provide a dynamic seal between combustion chamber and crank case. This seal minimises the expansion-stage power loss due to pressure escape from combustion chamber. For long seal life, wear between piston ring and cylinder liner wall has to be controlled. Therefore, in recent years, the design of piston, piston rings and cylinder liners has received much attention in Automobile. It has become vital to reduce the wear mechanism of IC engine cylinder liner. In order to achieve minimum wear rates, the much more attention gives towards the parameters like surface hardness of cylinder liner materials, their microstructure, surface topography and lubrication. There are various methods for surface hardening, methods that involve an intentional buildup or addition of a new layer, methods that involve surface and subsurface modification without any intentional buildup or increase in part dimensions. In this thesis high-power laser technique are used for the surface engineering of engine cylinder liner. Here, experimentation is done by laser transformation, varying the process parameters like power, velocity and beam diameter of laser and the reduction of wear is demonstrated.

MATERIALS AND METHODS

EXPERIMENTAL TECHNIQUES

It summarizes the basic concepts of the principal techniques that are used in this works. The focus of the chapter is on microscopy techniques, hardness and wear tests that are employed for the investigation of laser hardened cylinder liner surfaces.

1. Vickers indentation hardness test

Hardness measurements are used in this work to obtain information on the mechanical properties of the substrate and hardened material. The Vickers hardness test method consists of indenting the test specimen by the diamond indenter, in the form of a pyramid with a square base and a top angle of 136 degrees between opposite faces subjected to a load of 5 gm to 1kg. Here, the full load is applied for 10 to 15 seconds normally.

The two diagonals of the indentation formed in the surface of the material are measured after removal of the load using a microscope and its average is calculated. Then, the area of the sloping surface of the indentation is calculated. Further, the Vickers hardness is the quotient calculated by dividing the load by the area squared of indentation. The measurements are performed in cross sections of the materials that have been ground and polished to eliminate the macroroughness. Depth of the work hardened zone is negligibly small as compared to the depth of the indentation so that it does not influence the measurement.

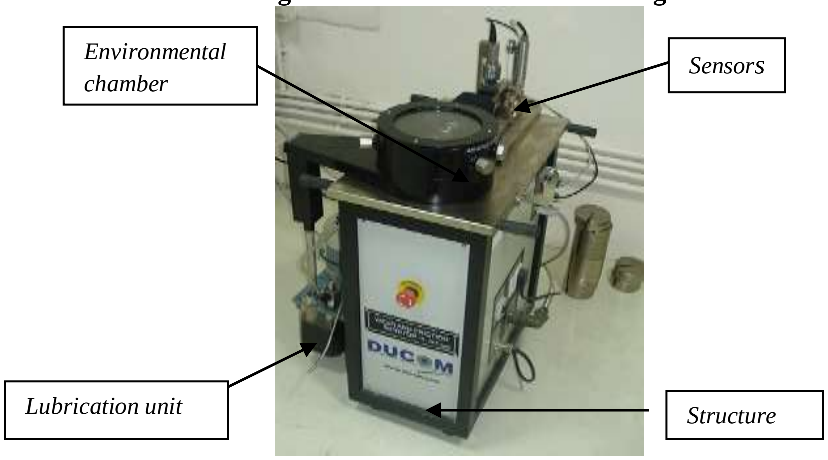
2. Microscopy

Leica Microsystems is the high pace of technology; digital recording is getting increasingly important for many microphotography applications. The Leica DFC-280 is a powerful color digital camera system which offers real-time imaging. The camera conveniently integrates to any microscope system. The camera lens and software are intended specially for microscopy. Auto white balance and brightness are regulated for the entire image and provide exact images, which provide sharp, richly contrasted images that are true down to the last detail. Image geometry, color rendering and dimensions are correct and ensure accurate results in image analysis, measurement and image processing.

3. Wear dry sliding test

In this work the Ducom Pin on Disk Test Rig Tribometer is used to perform the pin on disk test to investigate the wear properties of laser hardened cylinder liner surfaces. The instrument can perform on the following ranges of parameters: temperature, up to 800^0C; load, up to 200 N; friction force, up to 10 N; rotation speed, up to 2000 rpm and sensitivity of the lever of about 20 nm. Dry sliding test is performed with a flat or a sphere shaped indenter loaded on to the test sample.

Figure: Ducom Pin on Disk Test Rig



EXPERIMENTATION

Experimentation is done here using a continuous wave (CW) 100W Fiber Laser system. The substrate material used in this investigation was cylinder liner made from CI cut into size 7x 7x30 mm of nominal composition. There is no surface preparation for this purpose.

The setup consists of a fixed beam position with movable work table to get continuously moving laser beam. A computer interface allows the control of the laser power P during laser surface hardening.

Experimentation is carried out at different power, velocity & beam diameter combinations. Table 2 gives different combinations taken for experimentation. Experimentation was begun with few trial runs with power range between 10W to 35W. With velocity range of 0 to 0.6 mm/s, at very low powers almost no hardening effects were noticed & at high powers above 30W considerable melting & evaporation zones were observed. With these inputs appropriate combinations were chosen for experimentation.

Experimental Design

2^3 factorial design methods are used in this work for DOE. Three factors power (P), Velocity (V) and Beam diameter (D_b) each at two levels make it $2^3 = 8$ experiments. Four center points are considered thus adding the total experimental runs to 12. The conventions used in design matrix are as given in table.

Table 1: Conventions of Factors

Level	Level of Code		
	P (W)	V(mm/s)	D_b (mm)
High (+1)	24	0.66	0.234
Medium (0)	21	0.465	0.185
Low (-1)	18	0.33	0.137

RESULTS AND DISCUSSION

DOE ANALYSIS

The data obtained from DOE is used to interpret a relation between Depth of Laser Hardened Zone of workpiece and input parameters i.e. Power, Velocity and Beam Diameter. The experimental results are as shown in the Table.

Table 2: Observations

Power	Velocity	Beam Diameter	Depth	log Depth
1	1	1	40.05	1.602603
1	1	-1	91.63	1.962038
1	-1	1	72.83	1.86231
1	-1	-1	145.27	2.162176
-1	1	1	31.37	1.496515
-1	1	-1	67.69	1.830525
-1	-1	1	73.48	1.866169
-1	-1	-1	85.84	1.93369
0	0	0	63.56	1.803184
0	0	0	63.56	1.803184
0	0	0	63.56	1.803184
0	0	0	63.56	1.803184

Table 3: Regression Analysis

Regression Statistics	
Multiple R	0.948982
R Square	0.900568
Adjusted R Square	0.863281
Standard Error	0.061731
Observations	12

Table 4: Analysis of variance ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	3	0.276111	0.092037	24.15224	0.000231
Residual	8	0.030486	0.003811		
Total	11	0.306596			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.827397	0.01782	102.5466	9.13E-14	1.786303	1.86849
X Variable 1	0.057779	0.021825	2.64734	0.029377	0.00745	0.108107
X Variable 2	-0.11658	0.021825	-5.34169	0.000693	-0.16691	-0.06625
X Variable 3	-0.1326	0.021825	-6.07574	0.000297	-0.18293	-0.08228

Tables shows the results obtained from regression analysis and analysis of variance (ANOVA) for the experimental results.

Regression analysis is used to find mathematical model, which relates the independent variables with the dependent variable. In Table 3 value of multiple R is termed as regression coefficient, it indicates the acceptability of regression model. The value of R obtained is 0.948982 (the value of R should be ≥ 0.8 to accept the model); hence the regression model is acceptable. The value of R^2 decides the validity of regression model. While adjusted R^2 gives the level of validity, to use regression model. The difference between value of R^2 (0.900568) and adjusted R^2 (0.863281) is not more; hence the non-significant terms are not present in the model. Standard error gives the error in the predicted value of output. This error attributes to a set of independent variables (P, V and D_i) and the difference due to random or experimental error.

ANOVA is a statistical procedure for analyzing continuous data sample obtained from experiments in which two or more treatments are used. The value of F is determined to test the effect of treatments or regression.

$$F = \frac{MS_R}{MS_E}$$

The value of F > 1 indicates that treatments have an effect on output (Depth).

Regression Model

The relation between Depth and input parameters i.e. Power, Velocity and Beam Diameter is given as below:

$$D = K\,P^{\alpha}\,V^{\beta}\,D_b^{\gamma}$$

The above equation can be given in linear format as below:

$$\log D = \log K + \alpha \log P + \beta \log V + \gamma \log D_b$$

From the obtained results the regression model for the analysis is given as

$$\log D = 1.827397 + 0.058 \log P - -0.117 \log V - -0.133 \log D_b$$

This can be written as

$$D = 67.205\,P^{0.058}\,V^{-0.117}\,D_b^{-0.133}$$

Interpretation of Regression Model

The above equation can be written as

$$D \propto \frac{P^{0.058}}{V^{-0.117} {D_b}^{-0.133}}$$

WEAR TEST

Dry sliding tests were performed with the Magnum Engineers Tribometer with room temperature. The pin holder was loaded by a load of 3, 5 and7 kg and the rotation speed of the disk was set to a value 344 rpm which corresponds to the sliding speed of 0.811m/s. The number of rotations was fixed to reach the sliding distance of 12000 m. Both contact surfaces were polished before the test with a polish paper. The samples used were made of gray cast iron substrates that were about 7 mm thick; they were created in a base material, 3 microchanels and 5 microchanels of layer pass. These pins are mounted in a pin holder in such a way that the both pin and disc surfaces mach to each other. Table 4 shows data used for wear test.

velocity	Distance	load	load*9.81	wear	wear*density	sp wear rate
Without Hardening						
1.80118	12000	3	29.43	0.016	0.1248	3.53381E-07
1.80118	12000	5	49.05	0.086	0.6708	1.13965E-06
1.80118	12000	7	68.67	0.118	0.9204	1.11694E-06
3 Passes						
1.80118	12000	3	29.43	0.01	0.078	2.20863E-07
1.80118	12000	5	49.05	0.068	0.5304	9.01121E-07
1.80118	12000	7	68.67	0.095	0.741	8.99228E-07
5 passes						
1.80118	12000	3	29.43	0.008	0.0624	1.7669E-07
1.80118	12000	5	49.05	0.052	0.4056	6.89093E-07
1.80118	12000	7	68.67	0.062	0.4836	5.86865E-07

CONCLUSION

By observing the Regression equation we can say that the LAZ Depth is directly proportional to the Laser Power and inversely proportional to the Scan Velocity and Beam diameter. The observations of the model can be summarized as below:

- As Laser Power increases the LAZ Depth of workpiece surface will also increase. This is because the heat input to the workpiece is increasing due to increase in Energy Density.
- As the Scan Velocity decreases the temperature on workpiece surface will increase. This is because with the decrease in Scan Velocity, the Power Density increases, those results in more heat input.
- As the Beam diameter decreases the area of contact get decreases, which result in more heat input. Due to this, as Beam diameter decreases the temperature on workpiece surface will get increases.

The wear rate and the friction coefficient behave in two different regimes depending on the varying load condition of the test. From results of test wear decreases with increasing number of microchanels on cylinder liner.

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