EFFECT OF LASER SURFACE TEXTURING ON FRICTION AND WEAR PERFORMANCE OF 15-5 PH STEEL

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Abstract – *Laser surface texturing is used to improve tribological characteristics of material by creating microstructure pattern on mechanical contact surfaces, but lack of technical complexities in lasers texturing process are restricting use of laser surface texturing. In this context, many research works focused to develop laser surface texturing on different grades of steels with different texture, but few researchers investigated laser surface texturing with hexagonal shape pattern of 15-5 PH steel material with nanosecond fiber laser. The objective of work was to achieve potential reduction in coefficient of friction and wear rate of 15-5 PH steel by laser surface texturing. The 15-5 PH steel material pins were prepared of size 30 mm length and 10 mm diameter and EN 31 steel material disk specimens were prepared of size 80 mm diameter and 5 mm thickness. Hexagonal shape patterns of textured density 10, 15 and 20% were chosen for laser surface texturing. Laser surface texturing done on pin specimen surface with power 10 w, scanning speed 300 mm/s, and hatch spacing 0.01 mm using nanosecond fiber laser. Optical image of textured specimen was taken at 200 X magnification using optical microscope for microstructure analysis. Surface roughness and texture depth was analyzed using surface roughness tester. Friction and wear test were carried out using pin-on-disk tribometer under dry condition for different sliding speed 300, 350 and 400 RPM and different loads 3,4 and 5 kg. Microstructure of specimen was analyzed using scanning electron microscope after friction and wear test.*

***Key Words*: Laser, texturing, 15-5 PH steel, tribometer, pin, disk, friction, wear, etc.**

1. INTRODUCTION

Surface engineering is a common application for high power Lasers and a significant amount of research is currently taking place in this field. This is partly driven by the benefits, particularly for Industrial applications, that can be gained from improvements in the surface properties of engineering materials. Lasers have many properties which are advantageous for use in surface engineering such as their flexibility, accuracy, speed, lack of tool wear as well as then negligible effect the processes have on the properties of the bulk material [1,2]. There are other methods which have been used to modify the surface properties, such as electron beam treatment [3,4], chemical treatment [5], plasma treatment [6], electric discharge [7] and sand blasting [8], each of which are used for a variety of applications with in surface engineering. Most commonly, simple 'dimples' are generated in an array by ablation at discrete locations, with dimensions varying from 50–300 μm diameter with 5–80 μm depth [11,12]. Other feature geometries may also be used such as micro-grooves, which can be manufactured by the ablation of a series of parallel lines [13]. Another approach is the generation of a 'cross-like' structure using laser interference metallurgy [14]. The key parameters for generating a low friction surface appear to be the dimple density, diameter and depth [13,15,16]. In most cases, a dimple density in the region of 5–10% appears to be most effective at reducing the friction coefficient [13,16], however dimple dimensions are more dependent on the contact regime [15]. As a result, with the selection of the correct parameters for the desired application, laser surface texturing can lower the coefficient of friction by 20% or more [13,14].

2. EXPERIMENTAL PROCEDURE

2.1 Specimen Preparation

The disk specimens are machined to get fine surface finish and required dimension of 80mm diameter and 5 mm thickness length as shown in fig. 1a). 15 disk specimens are prepared for Experiment.

The pin specimens are machined to get fine surface finish and required dimension of 10 mm diameter and 30 mm length as shown in fig.1b). 30 pin specimens are prepared for conduction of friction and wear Experiment.

Fig.1 a) Disk specimen b) Pin specimen

2.2 Laser texturing 15-5 PH steel material

OR MAG 20 fibre laser setup is used to perform laser surface texturing as shown in Fig.2. The Laser parameters such as laser Power, scanning speed, line spacing and no. of passes is fixed to perform laser surface texturing as shown in Table 1.

Table 1. Laser Process parameter

Sr.No.	Specifications	Range
1	Scanning speed (mm/s)	300
2	Power (w)	15
3	Modulation frequency (KHz)	20
4	No. of passes	1
5	Line spacing (unidirectional hatching) (mm)	0.01

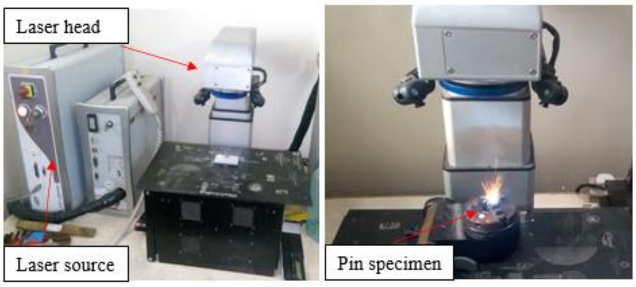

Fig. 2 OR MAG 20 Fiber laser setup

Laser surface texturing is done on surface of pin specimens of 10 mm diameter of various texture density 10%, 15%, 20%. Laser surface texturing is done on total 9 specimens that is 18 surfaces of pin specimens.

2.3 Friction and wear test

Friction and wear test were performed by using Ducom® pin on disk tribometer as shown in fig.3. Pin was fixed in holder of setup and disk was rotated for particular period of time according to experimental design. Graph was plotted for COF and wear rate v/s time from data point obtained after conducting test.

Before conducting friction and wear test pin and disk are cleaned with acetone chemical, then disk is fixed on the rotating base disk of setup with help of superglue. Pin is fixed in holder, then holder with pin is fixed to arm with help of screws. Before starting the experiment, readings are set to zero and wit the help of winducom software results were analyzed. Then experiments are conducted as per experimental design layout.

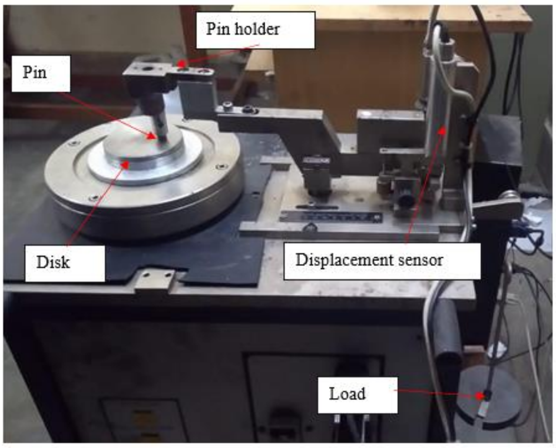

Fig.3 Ducom® Pin on disk tribometer

Experimental calculation were made for different sliding speed 300, 350 and 400 Rpm, Where sliding distance 500 meter, wear track diameter 23mm kept constant and sliding time (sec) is calculated for each sliding speed by using mathematical relations.

Sliding distance (s) = linear velocity (v) × sliding time (t)

Linear velocity (v) = wear track radius (r) × angular velocity (ω)

Angular velocity (ω) = $2\pi N/60$

Where:

N = Sliding speed (Rpm)

t = Sliding time (sec)

The 12 Experiments were conducted with help of experimental design technique for different sliding speed 300, 350 and 400 Rpm for sliding time 692, 593 and 519 sec. sliding distance 500 m, wear track diameter 23 mm were kept constant. 3 pin specimens are taken for each 10%, 15%, 20% texture density and untextured for conduction of friction and wear test. Friction and wear rate results data points were generated in friction and wear monitor Winducom software.

The next 12 Experiments were conducted with help of experimental design technique for different loads 3,4,5 kg for sliding time 519 sec. sliding distance 500 m, wear track diameter 23 mm were kept constant.3 pin specimens are taken for each 10%, 15%,20% texture density and untextured for conduction of friction and wear test. Friction and wear rate results data points were generated in friction and wear monitor winducom software.

3. RESULTS AND DISCUSSIONS

3.1 Morphology of textured and untextured surface

Fig.4 shows the optical micro-photograph of laser texture patterns (hexagonal shape) for 10%,15% and 20% texture density respectively before friction and wear test. It can be seen that the heat affected zone is formed around the hexagonal dimple due to laser with high energy density and vapor blast ejection. The bulges around dimple are little higher than plan area which increases the surface roughness of textured specimens.

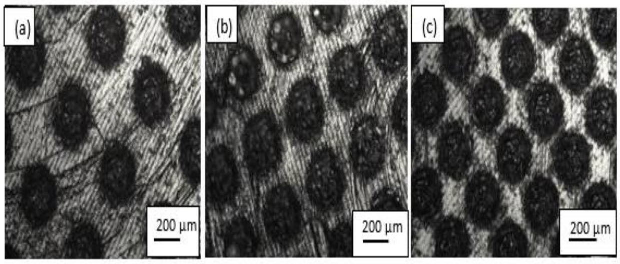

Fig. 4. Optical micro-photograph of laser textured patterns (a) 10% texture density (b) 15% texture density (c) 20% texture density

Fig. 5 shows SEM microphotograph of 20% texture density specimens taken after friction and wear test. Fig. 5 (a) and (b) shows minimum COF 0.27 and wear 5.2 µm for 20% texture density for Rpm change at 400 Rpm. Wear track can be seen in Fig.5(a) and single hexagonal pattern can be seen in Fig. 5 (b) and (d). Fig. (c) and (d) shows minimum COF 0.34 and wear 6 µm for 20% texture density for load change at 3 kg load.

Fig. 6 shows SEM microphotograph of 10% texture density specimens taken after friction and wear test. Fig. 6 (a) and (b) shows maximum COF 0.55 and wear 12.2 µm for 10% texture density for load change at 5 kg.

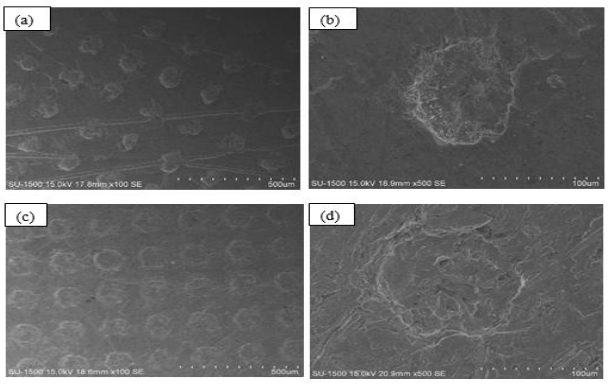

Fig. 5. SEM microphotograph minimum COF and wear of 20 % texture density specimens (a) & (b) different sliding speed (c) & (d) different load

6.(a) and (c) and single weard out hexagonal pattern can be seen in Fig. 6 (b) and (d). Figure (c) and (d) shows maximum COF 0.39 and wear 9.5 µm for 10% texture density for Rpm change at 300 Rpm. severe wear was observed in this specimen as compare to other specimens.

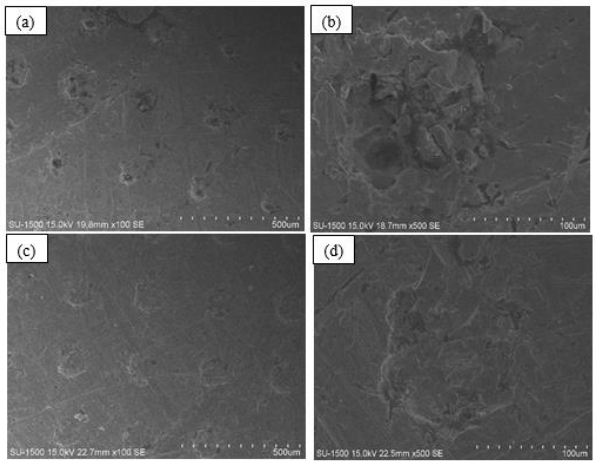

Fig.6. SEM microphotograph of maximum COF and wear of 10 % texture density specimens (a) & (b) different load (c) & (d) different sliding speed

3.2 Analysis of friction and wear results

Tribological properties of laser textured surfaces and untextured surfaces of 15-5 PH steel material were characterized under unidirectional sliding conditions in order to investigate the effect of sliding speed and load on coefficient of friction and wear rate performance of 15-5 PH steel material. Results of coefficient of friction and wear rate with sliding time was plotted for change in sliding speed and change in loading condition.

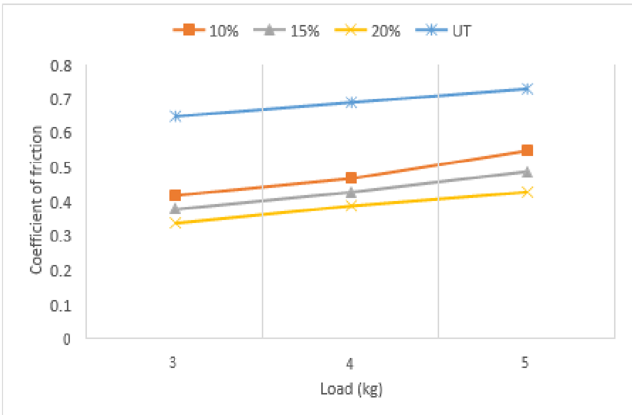

Fig.7. Comparison of COF for texture density 10%, 15%, 20% and untextured specimens at different load 3,4 and 5 kg

From Fig.7 as load is increased coefficient of friction also increases this is due to when normal load is increased which increases resistance for movement of pin over disk surface thus leads to increase in frictional force between pin and disk surface. Coefficient of friction of untextured specimen is higher than textured specimen this is due to as pin moves over disk due to friction wear of pin and disk occurs. In textured specimen wear debris present between pin disk filled into hexagonal shape dimple cavity due to which friction between pin and disk is reduced as compare to untextured specimen wear debris present between pin and disk gets trapped between pin and disk and due to this fictional force is increased which increases coefficient of friction.

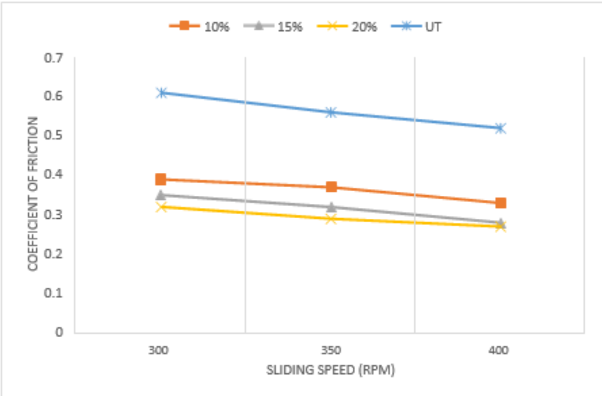

Fig.8. Comparison of COF for texture density 10%, 15%, 20% and untextured specimens at different sliding speed 300, 350 and 400 rpm

From Fig.8 as sliding speed is increased coefficient of friction decreases this is due as sliding speed increases contact between pin and disk reduced which decreases the resistance for movement of pin over disk surface thus leads to decrease in frictional force between pin and disk surface. Coefficient of friction of untextured specimen is higher than textured specimen this is due to as pin moves over disk due to friction wear of pin and disk occurs. In textured specimen wear debris present between pin disk filled into hexagonal shape dimple cavity due to which friction between pin and disk is reduced as compare to untextured specimen.

From Fig. 9 as sliding speed is increased wear rate of pin decreases this is due as sliding speed increases contact between pin and disk reduced which decreases the resistance for movement of pin over disk surface thus leads to decrease in frictional force between pin and disk surface. Wear rate of untextured specimen is higher than textured specimen this is due to as pin moves over disk due to friction the wear of pin and disk occurs. In textured specimen wear debris present between pin disk filled into hexagonal shape dimple cavity due to which friction between pin and disk is reduced as compare to untextured specimen.

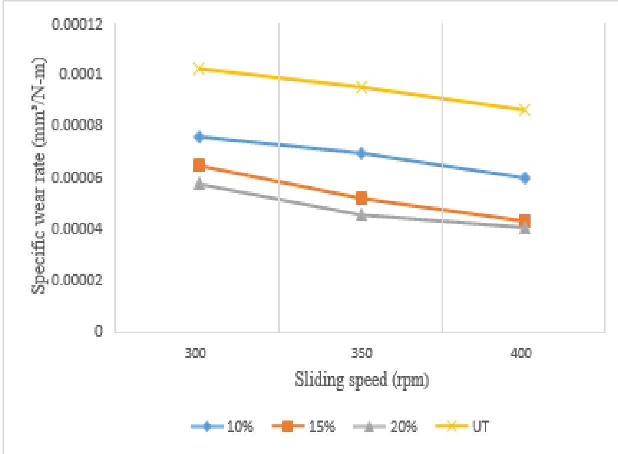

Fig.9 Comparison of specific wear rate for texture density 10%,15%, 20% and untextured specimens at different sliding speed 300, 350 and 400 rpm

Maximum specific wear rate of pin observed for untextured specimen was 10.33× 10^{-5} mm3/N-m at 300 rpm and minimum wear observed 4.09× 10^{-5} mm3/N-m for 20% textured density specimen at 400 rpm so 20% textured density specimens show minimum wear rate compare to other specimens.

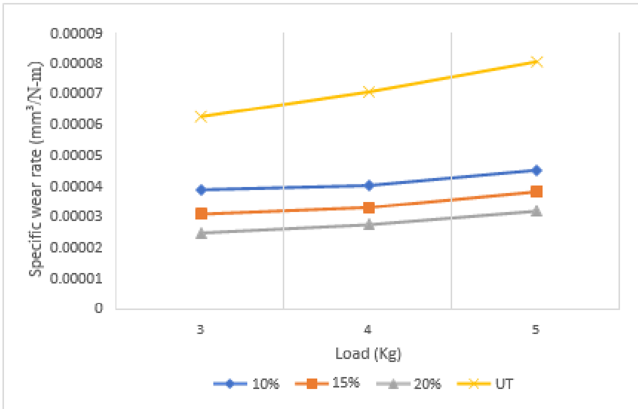

Fig. 10. Comparison of Specific wear rate for texture density 10%, 15%, 20% and untextured specimens at different loads 3,4 and 5 kg

As load is increased wear of pin also increases this is due to when normal load is increased which increases resistance for movement of pin over disk surface thus leads to increase in frictional force between pin and disk surface. Wear rate of untextured specimen is higher than textured specimen this is due to as pin moves over disk due to friction the wear of pin and disk occurs. In textured specimen wear debris present between pin and disk filled into hexagonal shape dimple cavity due to which friction between pin and disk is reduced as compare to untextured specimen. From Fig.10 maximum wear rate of pin observed 8.06361× 10^{-5} mm3 /N-m for untextured specimen at 5 kg load and minimum wear rate observed 2.49 × 10^{-5} mm^3 /N-m for 20% textured density specimen at 3 kg load so 20% textured density specimens show minimum wear rate compare to other specimens.

4. CONCLUSIONS

The effect of laser surface texturing by hexagonal shape micro-texture shows significant effect on friction and wear performance of 15-5 PH steel specimens was studied by means unidirectional pin on disc friction and wear tester.

The results of the coefficient of friction and wear rate show high dependence on the geometry of textured surface. As texture density is increased coefficient of friction and wear rate decreases. Friction and wear performance are strongly influenced by the change in sliding speed and load. As sliding speed is increased friction and wear rate decreases, when load is increased friction and wear rate also increases. From this research results conclude that potential reduction was observed in coefficient of friction and wear rate for laser textured specimens compared to untextured specimens and 20% textured density specimens found to have lowest coefficient and friction and wear rate.

For untextured specimen for different sliding speed maximum coefficient of friction and wear rate observed was 0.61 and 10.33× 10^{-5} mm3/N-m for sliding speed 300rpm at 2 kg load. For change in loads maximum coefficient of friction and wear rate observed was 0.73 and 8.06361× 10^{-5} mm3/N-m for sliding speed 400 rpm at 5 kg load. For 20% texture density specimens for different sliding speed minimum coefficient of friction and wear rate observed was 0.27 and 4.09× 10^{-5} mm3/N-m for sliding speed 400 rpm at 2 kg load and for change in load minimum coefficient of friction and wear rate observed was 0.34 and 2.49 × 10^{-5} mm3/N-m for sliding speed 400 rpm at 3 kg load.

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