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"AN EXPERIMENTAL INVESTIGATION ON HARDNESS OF SURFACE TEXTURED TOOL STEEL"

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ABSTRACT

Tool steel has widespread applications in tools, dies and other manufacturing industries but friction between the interacting surfaces remains a challenge for its effective performance and efficiency in different industrial applications. Laser Surface Texturing (LST) is seen as an effective solution to minimize the losses in energy due to friction and wear of substrate. Bio-inspired textures have gained popularity due to their effectiveness in reducing friction and wear on the surface which leads to savings in energy losses due to friction. The project commences with a comprehensive literature review, analyzing prior research on laser surface texturing and its potential impact on friction reduction. Honeycomb and finger print textures were fabricated on the surface of tool steel using different laser power, scanning speed and frequency of laser. Vickers's hardness test at a load of 10 N was performed to study the hardness variation in textured substrates The textured surfaces were characterized under 3D profilometer to confirm the ablation of material. The hardness results revealed a significant increase in surface hardness of substrate due to effect of laser.

Key Words: *Tool steel, Hardness, Texture, Profilometery.*

I. INTRODUCTION

Due to the addition of alloying elements, tool steels are iron-based alloys having unique features from carbon steels. They are a part of a sizable class of steels that display high strength, high hardness, and high wear resistance in comparison to other steel kinds after being heat treated. Furthermore, a variety of tool steel types maintains their qualities to a significant depth in the material and exhibit good microstructural stability at high temperatures (red hardness). Tool steels are used extensively, such as in cutting tools, dies, and molds.

Surface texturing is used to create patterns of different shape and size on the surface of the materials. It can be used to enhance the tribological behavior of the surface, improve cell attachment and bacteria adhesion reduction in bio-interfaces, and also to improve the mechanical properties like stiffness and hardness of the surface. Texture designs are also inspired from nature like honeycomb, mosquito egg surface etc. which have characteristics to reduce friction, wear and augment the mechanical properties. Texturing has prominent applications in electrical systems of automobiles, solar cells to improve light absorption, increasing the wettability of the surface and many others and thus are not restricted to only use in tribology. The different surface texturing techniques discussed may be further divided in following groups: melting and vaporization such as EDM, ablation such as LST, forced material removal such as micro grinding, VMT, dissolution such as chemical etching. Forced material removal process like micro grinding have an advantage of establishment of contact between tool and work piece resulting in an excellent geometrical contact between surface to be machined and the tool is established. Forced material removal process affects geometrical precision due to machining force and limits the texture size due to elastic deformation of work piece and cutting tool. In melting and vaporization process of texturing, very little machining force is required and machining characteristics are influenced by thermal properties like; boiling point, melting point, heat capacitance and conduction efficiency. Tool and work piece does not come in contact in this process which may lead to inaccuracy in texture dimensions and has a disadvantage of generation of heat affected zone. Ablation also generates the heat affected area on the substrate but using the femtosecond and excimer laser, heat affected area can be reduced to a larger extent producing textures with a greater accuracy. Chemical etching, another texturing process, with no requirement of machining force does not modify the mechanical characteristics of the surface. When compared to LST and other texturing methods chemical etching leaves very few irregularities along with a minimized roughness but it restricts the usage due to consumption of time in printing the mask and etching. Thus selection of a texturing technique is very important for a particular application to achieve the higher degree of accuracy with the cost in the limits. Further, compatibility with the dimensions of work piece, required shape of textures, safety of substrate material are some of the minimum criterion which needs to be satisfied while choosing the texturing technique. Among the different texturing technique discussed micro grinding is the lowest in cost and easy to operate. But a large number of researchers have used LST to create textures since the process is environment friendly and possess accuracy in shapes and size of textures. It is also taken into consideration that the surface textures are highly application dependent and firstly be evaluated for the use in the tribological system. The number of texturing parameters are huge in quantity thus they need to be simulated further under the frictional regime to optimize the texture parameters to overcome “trial and error approaches” of expensive and time consuming texturing. Due to environment friendliness and higher rate of accuracy LST edges over other techniques in various applications.

II. LITERATURE REVIEW

Goutam Mukhopadhyay et al. (2023) investigated the failure analysis of a tool steel (TOOL) beater head of an impact crusher and development of suitable heat treatment process to improve its performance have been presented. The pin-hole positions on the beater heads caused brittle fracture, which caused them to fail early. Visual inspection, fractography, chemical analysis, characterization of microstructures using optical and scanning electron microscopes (SEM), EDS analysis, and micro-hardness profile determination were all included in the inquiry. The martensite matrix had a large number of coarse continuous Cr-carbide networks, according to microstructural characterisation performed using SEM and EDS analysis. Since coarse carbide networks are extremely hard and brittle, it lowered toughness (3 J) while increasing hardness (64 HRC) and heterogeneity of the matrix as shown by the microhardness profile. The manufacturer's end heat treatment temperatures for austenitizing and tempering were determined to be lower. A decreased number of discontinuous Cr-carbides and a considerable number of fine precipitates evenly distributed throughout the matrix as a result of the new heat treatment recommendation led to the ideal balance of hardness (59 HRC) and toughness (6.5 J) needed for the application. In comparison to prior models, the beater heads produced using the suggested heat treatment performed better (life extended by 4 times).

T.VeckoPirtovsek et al. (2022) studied thatfor further increase of economy of production of TOOL tool steel, a study of possibility of expanding the hot working range and better prediction of flow stress has been carried out. Hot compression tests were used to demonstrate that initial microstructures affect the lower limit and chemical composition affects the upper limit of the hot operating range. To forecast the flow stresses for intermediate values of strain rates and temperatures, a CAE neural network was used. The hyperbolic sine function's activation energies and constants for two temperature ranges (850–1000°C and 1000–1150°C) were determined for optimization purposes.

Zhengwen Pu et al. (2021) Due to its potential for significant cost savings and productivity gain, high speed machining (HSM) of tool steels in their hardened form is emerging as an appealing approach for the mold and die sector. In order to better understand the mechanisms behind tool wear and surface integrity during high-speed ball nose end milling of hardened TOOL tool steel employing coated tungsten carbide and polycrystalline cubic boron nitride (PCBN) tools, an experimental investigation was carried out. It is discovered that high content PCBN tools are acceptable for HSM range (470 m/min), whereas coated carbide tools can only be utilized at low speed (120 m/min). A damage-free workpiece with a better surface polish and less work hardening is produced with PCBN tools. Despite the higher tool cost, HSM with PCBN tools lead to reduction in both total cost and production time per part.

Dinesh Kumar et al. (2020) studied that the electro discharge machining (EDM) is one of the non-conventional machining processes which are widely used for machining of conductive, hard and brittle work piece and TOOL steel is one of them. The current study suggested mathematical models for the modeling and analysis of Productive factors, such as Material Removal Rate (MRR), Tool Wear Rate (TWR), and Surface Roughness (SR), in the EDM process of ASI A2 steel. For modeling and elucidating the impact of four machining parameters, namely discharge current, pulse on time, duty factor, and discharge voltage on productive aspects, response surface methodology (RSM) is applied. The experiments are designed using Central Composite Design. For the purpose of analyzing the individual effects of machining settings and the interactions between these factors on the productive characteristics of an EDM-ed work piece, a mathematical model is developed. The importance of a given mathematical model is validated with a 95% confidence level using analysis of variance (ANOVA). The outcomes were then experimentally validated. The outcome of the RSM model and the actual observation collected from the experiment are found to be in considerable and valid agreement.

III. METHODOLOGY

3.1. Sample preparation

Commercially available TOOL steel was used as a substrate. A 20 mm diameter of TOOL steel rod was cut into discs of 20 mm diameter and 9 mm thickness. The surface of samples was then subjected to facing operation to ensure flat surfaces.

Table 1 Polishing time

S.No.	Emery papers Grit size
1	320
2	400
3	600
4	800
5	1000
6	1200
7	1500
8	2000

The samples were subsequently polished using emery papers to remove unwanted scratches and damages sustained during cutting operations to obtain a smooth specimen. Emery papers of grit sizes 320 to 2000 were used for the process. Polishing operation was completed on an automatic polishing machine till 600 grit size paper and after that polishing was done by hand. Diamond polishing was done with a diamond paste of grit size 0.5 micron and 0.25 micron to achieve minimum surface roughness and also to remove dirt and impurity from the surface.

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3.2 Laser surface texturing

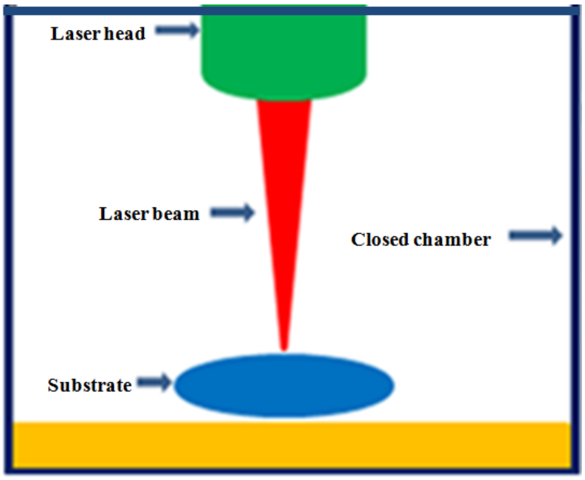

Figure 1 (a) Mechanism of Laser Surface Texturing (LST)

Inspired by the idea of strong adsorption atcontact interfacedue to the synergistic effect of mucus and surface texture in reptiles, the regular hexagonal honeycomb textures were produced on polished tool steel substrate. Textures of side 200 µm were produced using a fiber laser of 1064 nm wavelength, 5 ns time duration.

Table 2 Laser parameters for honeycomb and fingerprint textures

Texture Design	**Laser Power (% of 20 W)**	**Scanning Speed (mm/s)**	**Frequency (kHz)**
Honeycomb	30	200	30

3.3. 3-D Profilometry

A non-contact optical technique called 3D profilometry, sometimes referred to as 3D surface profiling or 3D surface measurement, is used to measure the three-dimensional shape and topography of an object or surface. To accurately depict the surface features of the item, depth information and the surface profile must be captured and examined.

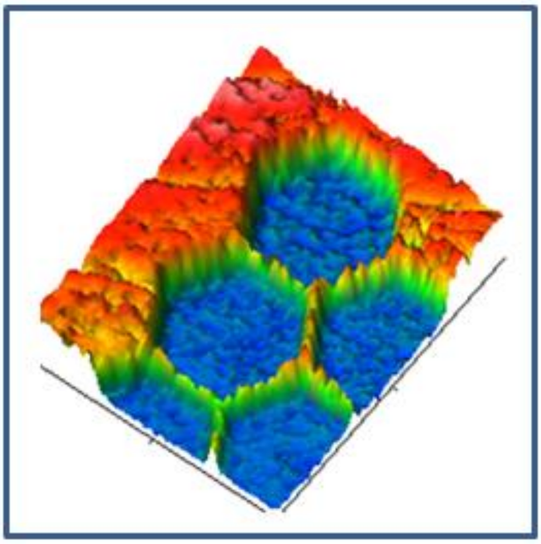

Figure 2 3D image of honeycomb textured surface

3.5 Hardness test

All metals can be tested with the Vickers test, which also has one of the broadest scales of any hardness test. The Diamond Pyramid Hardness (DPH) or Vickers Pyramid Number (HV) is the hardness measurement unit provided by the test. Although the hardness value can be expressed in pascals, pressure, which also employs the same units, should not be confused with it. Pressure is not used to describe the hardness number since it is defined by the load applied to the indentation's surface area rather than the area normal to the force.

IV. RESULT & DISCUSSION

4.1. Results of Vickers's hardness Test on samples

Hardness test is performed on Polished tool steel, Honeycomb textured and Fingerprint textured samples.

Table 3 Hardness test specifications

Load	Dwell time	Indenter
10 N	20 seconds	Diamond tip

Table 4 Results of Hardness

Sample Type	Hardness (HV)
Polished tool steel	242.9
Honey Comb Textured TOOL steel	298.2

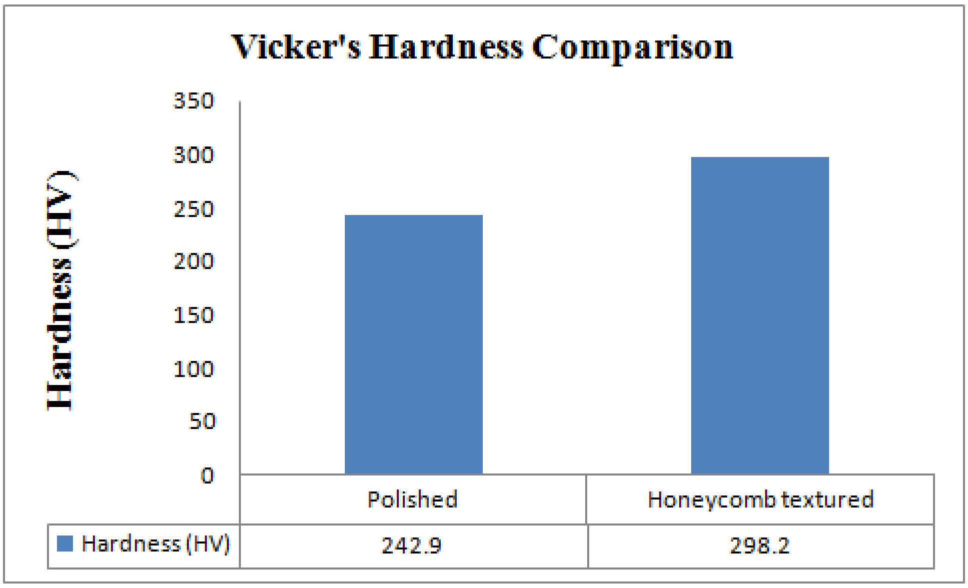

Figure 3 Graphical representation of hardness values

The hardness values you provided indicate that textured tool steel (298.2 HV) is harder than polished tool steel (242.9 HV). Hardness, typically measured using various scales such as Vickers, Rockwell, or Brinell, indicates a material's resistance to deformation, scratching, or penetration. In this case, the Vickers hardness (HV) values suggest that the textured tool steel has a higher resistance to indentation compared to the polished tool steel. Texturing the surface of the tool steel can often increase its hardness by modifying the microstructure of the material or introducing compressive stresses. This can result in improved wear resistance and overall performance in applications where hardness is critical, such as cutting, forming, or shaping operations. Therefore, in practical terms, the textured tool steel would likely offer better performance in applications where hardness and resistance to wear are important factors.

V. CONCLUSION

In conclusion, the comparison of the hardness values between polished and textured tool steel reveals significant differences in their resistance to indentation and wear. The textured tool steel, with a hardness value of 298.2 HV, demonstrates superior hardness compared to the polished tool steel, which measures 242.9 HV.

This discrepancy underscores the impact of surface treatment techniques on the mechanical properties of materials, particularly in the context of tool steel. Texturing the surface of the tool steel enhances its hardness, likely due to modifications in the microstructure or the introduction of compressive stresses during the texturing process.

The higher hardness of the textured tool steel suggests enhanced durability and resistance to deformation, making it better suited for applications where hardness and wear resistance are crucial considerations. These applications may include cutting, forming, or shaping operations where the tool steel is subjected to significant mechanical stress and abrasion.

Ultimately, the comparison highlights the importance of material selection and surface treatment techniques in optimizing the performance and longevity of tools and components in various industrial applications.

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