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Recent Development In Laser Hardening

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ABSTRACT

In recent years Laser hardening become most popular and widely used surface modification process. It is effective technique used to improve the tribological properties and also to increase the service life of component to be harden. Surface modification Industry now day's use surface hardening process which can be applied to almost the whole range of metallic materials in today's applications. Laser beam is focused to the localized region for hardening the required portion of the material. High intensity laser radiation is involved for heating the surface of steel into the austenitic region. Steep temperature gradient arises, due to high rates of heat transformation that results in instant cooling by conduction. It causes the phase conversion from austenite to martensite without the need for external quenching. This review paper is a summary of the basic fundamentals of laser hardening, and figuring some of its benefits compared with past laser hardening process and recent upgradation in laser hardening technique. The works published by various researchers by experimentation and by numerical approach are presented.

Keywords: Laser Hardening; Recent Trends In LH; Laser Surface Hardening.

1. INTRODUCTION

Laser is one of the most important inventions of the 20th century. Rapid advances in laser technology in the 21st century made it possible to perform various operations, resulting in better physical properties of the surface and improved performance in the given environment. It is effective technique used to improve the tribological properties and also to increase the service life of component to be harden. Laser hardening is one of the most widely used surface hardening process which can be applied to almost the whole range of metallic materials in today's applications. Laser beam is focused to the localized region for hardening the required portion of the material. High intensity laser radiation is involved for heating the surface of steel into the austenitic region. Steep temperature gradient arises, due to high rates of heat transformation that results in instant cooling by conduction. It causes the phase conversion from austenite to martensite without the need for external quenching. Laser surface treatment became most popular due to the recent development of high power, neodymium yttrium-aluminium-garnet (Nd: YAG) solid type, CO2 and diode lasers. These lasers may have pulsed or continuous output power. One important area of surface-treatment is surface hardening. This is an extensively used process in the treatment of surfaces on mechanical parts [1]. also new principles like the disk and fiber laser and even femto second laser are coming up for materials processing. These developments show that there is still a huge potential for new beam sources, which of course set the demand for additional system technology developments [2]. In conventional methods of heat treatment, the component is heated to the required temperature and then quenched in oil or water to achieve the desired hardness at the surface. In most industrial applications, wear occurs only in selected areas of the component; hence, it is sufficient to harden these areas to enhance the performance of the component. The advantages of using laser for surface processing results from its highly directional nature and the ability to deliver controlled amounts of energy to desired regions [3]. The energy input is dependent on the absorptivity of the material. Only a fraction of the laser energy is absorbed by the material and the remaining portion is reflected from the surface. The absorption of a polished metal surface depends strongly on the wavelength of irradiation. In the case of steels, the absorptivity increases when the wavelength is short. The wave length of Nd: YAG laser beam is 1.064 μm where the CO2 laser beam is 10.6 μm. So the Nd: YAG laser which is having short wave length is suitable for surface hardening of steel Due to higher wavelength, CO2 laser offers a low coupling interaction with metallic substances. Before CO2 laser hardening (LH), painting or coating has to be applied on the base metal to increase the absorption rate. The used paint or coating causes pollution and hazardous effects to the environment. In contrast, Nd: YAG laser is emerging as a competitive tool in surface modification due to the short wavelength and high absorbing rate of the materials and coating of base material is not needed which is the advantage compared to CO2 laser. [3]

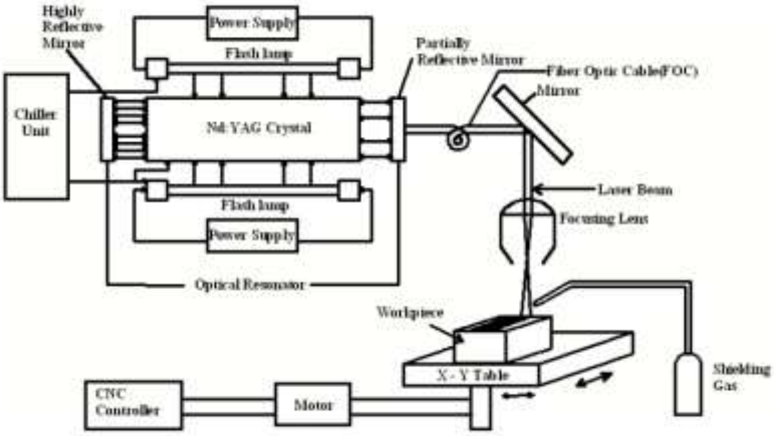

FIGURE 1. Schematic sketch of Nd: YAG laser system.

1.1. Laser Surface Hardening

In laser surface hardening laser is used as a heat source where the beam energy is applied to harden a surface on a localised region with the rest of the component acting as a heat sink. high heat fluxes generated by lasers are most suitable to heat the surface layer to austenitisation level without affecting the bulk temperature of the component. The ensuing self-quenching is rapid enough to eliminate the need for external quenching to produce the hard martensite in the heated surface. Thus, a highly wear resistant surface with the desired core properties of the component can be obtained. Components that have undergone LSH treatments include such highly stressed machine parts such as gears, gear teeth, camshafts, gear housing shafts, cylinder liners, axles, and exhaust valves and valve guides [3].

The LSH process is highly suitable for medium carbon steel and this technique is used to process the precised areas, which mainly depends on the laser beam size, since the processed area is much localised and the conduction of heat transfer into the bulk material that allows the critical cooling rate for the martensitic transformation, without the requirement of a cooling medium. Due to high rate of cooling, hardness rate is also high. For these reasons, LH is becoming the optimal technological solution for the surface heat treatment of small and complex components

1.2. Material Hardness and Wear

To obtain high hardness and wear resistance of the working surface layers of machine components, it is necessary to use treatment with high concentration energy sources, in particular, laser treatment. The tribological properties and the durability of component were improved by this method. One of the traditional methods to increase the wear resistance is induction hardening, which gives a homogenous microstructure with good wear resistance but expensive to implement. To cancel out wear in tribological systems it is not always necessary to provide the entire surface with a wear resistant layer. Depending upon the application, it is sufficient to harden locally the load bearing areas which are subjected to wear. Such areas can be treated properly by a laser, either totally or partially. With the effective use of high power laser sources the peak point of hardenability and fineness in microstructure can be obtained [7] LH of En18 steel with CO2 laser with laser power of 1.3 and 1.5 kW, scan velocity 1 m min–1 and a beam diameter of 3 mm increased the hardness of the base metal from 250 to 900 HV0.2 and a two-fold increase in wear resistance [8]. Hence, the laser surface-hardening technique can be used in the automobile industries to increase the service life of camshafts and crankshafts made of En18 steel.

The effect of the Nd: YAG millisecond pulsed laser on the surface morphologies of the irradiated area of DF-2 cold work tool steel using scanning electron microscopy (SEM), EDX and three-dimensional talysurf surface profilometer was investigated [11]. Results showed that the variation of surface morphology depend on the interaction condition of the laser and the surface during and after surface modification. Furthermore, it has been observed that surface melting or phase transformation occurs due to change in feed rate.

the influence of laser process parameters on the hardness of carbon steel specimen with varying carbon percentage. It was found that when the power is at the intermediate level and the traverse speed is at an optimum value, there was an increase in the hardness. Also, the hardness value increases with decrease in spot laser beam size with slight surface melting, due to enhanced power density which exceeds the critical value. The spot size depends on the width of the hardened zone (HZ) and beam power [10].

The schematic illustration of laser transformation hardening is shown in Figure 2. The zones between two tracks were considered to be overlapping zones. When the laser heat treatment is required for a large surface area, the overlapping method is used. Optimization of overlapping of laser HZ was performed. [9] Conventional overlapping method results in adverse tempering effect and an irregular surface hardness. Softening in overlapping passes by laser scanning is a complex problem studied the optimum gap between center-to-center distances between the beam overlap regions of laser scanning. They observed that the 2 mm gap between laser beams is more appropriate. There is no significance in reducing the gap below 2 mm in multi-pass laser scanning

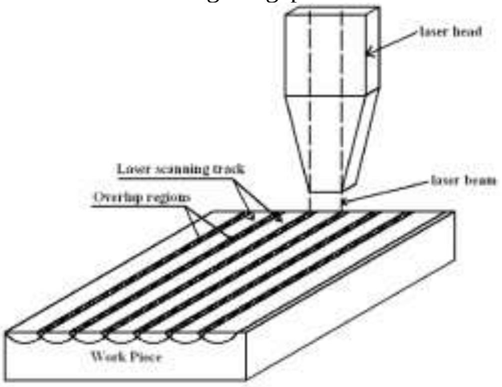

FIGURE 2. Schematic illustration of laser transformation hardening.

A coupled heat transfer-hardening-tempering model develop by Lakhkar et al. to predict the performance attributes of laser in AISI 4140 steel. The modelling results were validated experimentally. Their work showed that the variation in hardness could be controlled by changing the extent of overlapping of the tracks. Figure 5 shows the result of wear tests made on laser treated and untreated En18 steel specimen employing the pin-on-disc wear testing machine with various sliding forces of 10, 20 and 30 N at room temperature without applying any lubricant. An En24 disc, hardened to 65 Rc, of diameter 150 mm was made to slide against the laser hardened fixed pin, at constant rpm for several hours. The distance travelled by the pin against the rotating disc, that is the change in wear length is converted into sliding distance.

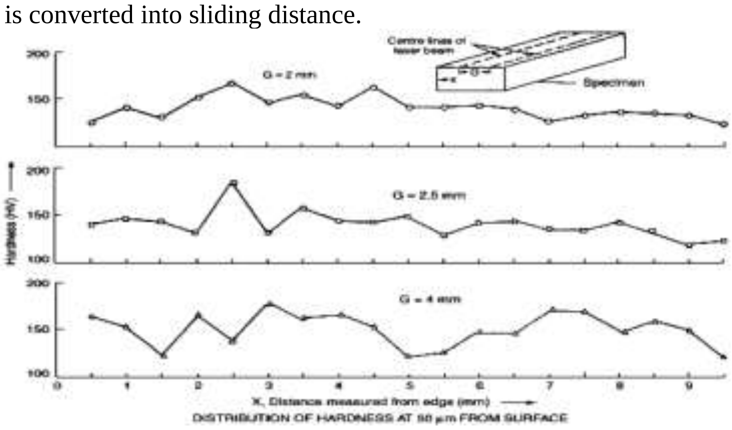

FIGURE 3. Effect of different multi-pass distances on the variation of micro hardness across a transverse section

In the experimental studies of J. Ranaaa (2007) An experimental investigation with 5 kW CW CO2 laser system was carried out to study the effects of different laser and process parameters on the microstructure and hardness of carbon steel specimen with varying carbon percentage. The laser beam is allowed to scan on the surface of the work piece varying the power (1.1–2.5 kW) and traverse speed (6–15 mm/s) at two different spot sizes using TEM01* mode laser beam they recommend an appropriate gap between consecutive passes Three types of double passes (multipasses) are taken varying the center-to-center distance between the beam such as 2, 2.5 and 4 mm. From the measured values of hardness variation at a particular depth along the width (Fig. 3), it is observed that the 2mm gap is the more appropriate gap, where the tempering effect is insignificant, corresponding to a particular beam diameter (D0 ¼ 5:47 mm, Di ¼ 1:735 mm). Also it is observed that as the gap increases, the hardness in between the passes reduces to a greater extent. Decreasing the gap below 2mm will not serve the purpose of multipass. Hence for the above beam size, the optimum gap in case of multipass can be considered to be 2.0 mm [10].

B.Q. Yang (2006) studied A quantitative analysis of the effect of laser transformation hardening on crack driving force in steels it can be seen that the crack driving force decreases with the increase of the residual compressive stress. the crack driving force is very sensitive to the residual compressive stress, and the crack driving force decreases significantly with the increase of residual compressive stress. On the contrary, if the residual stress is tensile, the crack driving force will increase significantly with the increase of residual tensile stress, and it will adversely facilitate the crack propagation [9].

1.4 Effect of Laser Power

The effect of power on the variation of hardness is shown in Fig.4. At an exceptional high power, there is a high hardness value with surface melting. But in general, there is no much rise of hardness with rise of power as noticed from these figures. So in order to increase the hardness in an economic way, the power should be maintained at an intermediate value and the traverse speed should be at an optimum value resulting high hardness at reasonable power level [10].

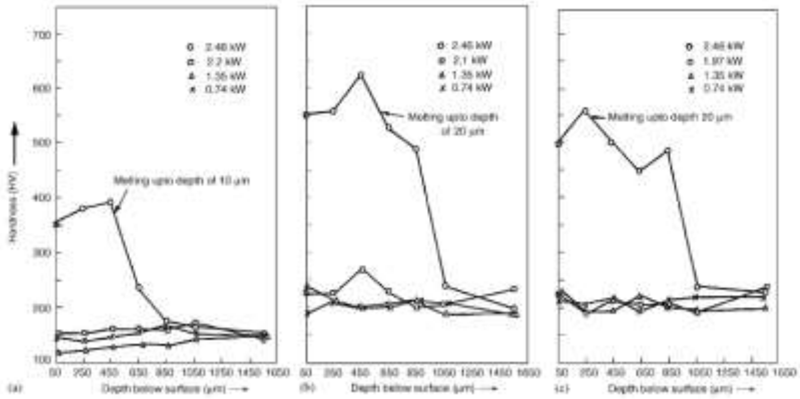

FIGURE 4. Effect of different multipass distances on the variation of micro hardness across a transverse section.

Mahmoud Moradi1 (2018) studied diode laser surface hardening of AISI 4130 is improved by carbon coating via electrophoretic deposition technique electrophoretic deposition technique. A uniform layer of carbon was deposited on the surface of AISI 4130 steel specimen via electrophoretic deposition technique using its ethanoic suspension and the effect of this film on the laser surface hardening was investigated in detail. At the same input parameters, higher hardness and larger hardened area is occurred in carbon coated samples than the bare samples due to more laser energy absorption. Electrophoretically deposited carbon coating leads to enhance laser beam absorption and therefore causes to the increased level of martensite phase and higher surface hardness. According to the obtained results for surface hardness and microstructural characteristics, it is found that laser surface hardening process is more effective than conventional furnace hardening process. The maximum hardness value for the laser hardened coated samples is 762 Vickers while this value for the laser hardened coated samples is 707 Vickers and for furnace hardened samples is 572 Vickers. Because there is lower ferrite phase in laser hardened samples compared to furnace hardened samples [12]

1.5 Effect of Spot Size

The effect of spot size on the hardness variation is shown in Fig. 5 for three different specimens. The average hardness value increases with decrease in spot size but there is slight surface melting, because the power density exceeds the critical value. The spot size is to be decided on the requirement of width of the hardened zone and power level [10].

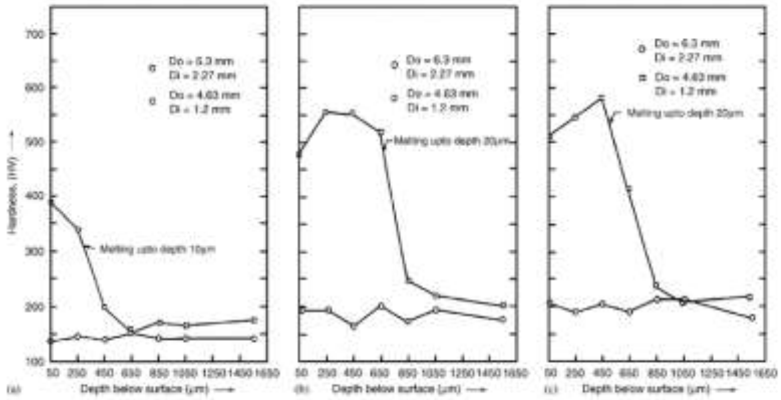

FIGURE 5. Effect of different multipass distances on the variation of micro hardness across a transverse section.

E. Kennedya (2004) studied the use of high power diode lasers in surface hardening he A describe the construction and operation of HPDLs is also presented with emphasis on the technical and economic factors which make them advantageous for surface hardening applications. Until recently, the widespread use of lasers for materials processing has been hindered by the size, complexity and high investment cost of the laser systems. These molecular and solid-state laser systems are now beginning to give way to a new generation of rapidly evolving lasers called high power diode lasers or HPDLs.

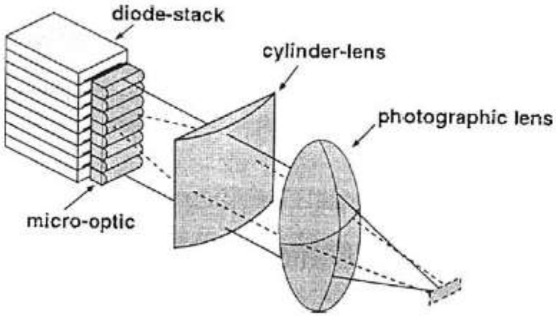

FIGURE 6. Visualization of focusing of light from a diode laser stack

The last number of years has seen the introduction of high power diode lasers with power densities in the range 104 to 105 W/cm2. For applications where moderate power density is required without the constraint of a high beam quality, today's HPDLs offer an economical, compact solution, ideal for integration into conventional machine systems and robotics. Heat treating applications are the forte of HPDL technology as their inherent beam stability and top-hat profile leads to uniform heating of the surface over a relatively large area. Although HPDLs have not yet reached sufficient beam quality or irradiance to be used in most drilling and cutting applications, their high efficiency, compact size and ever decreasing capital costs will undoubtedly drive research into conquering these applications.

CONCLUSION

In recent year laser hardening process become very popular and effective treatment for changing the tribological properties of material. Day by day there are lots of modification in the process of laser treatment as well as in the material to be harden. Now days economical and compact solution are becoming ideal for integration into conventional machine systems and robotics. There are so many improvements in lenses, laser power, laser spot size, material coating, material composition, feed rate, laser track to make laser hardening more efficient economical and compact. Researchers all over the world are working on optimization and process development in order to increase the field of applications even more. The computational modelling is very important in this development. Deeper process understanding and process optimization e.g. in terms of efficiency and process speed will help to get a wider application in industry for the laser surface treatment technologies.

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