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Wear Resistance Improvement of Alloy Steel Using Laser Surface Treatment

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Abstract

Laser surface heat treatment has been accepted as an effective technique of surface hardening of steels because of the converging of the laser beam by the lens on a tiny spot with a diameter near the value of the laser wavelength, laser surface heat treatment has been an effective way to improve the surface properties of. There are many applications in the industrial of the laser technique. This concentrated a lot of energy into a tiny area, resulting in a lot of heat compared to traditional heating methods. Wear resistance is a surface phenomenon, although it is influenced by elements such as surface hardening, surface condition, and microstructure. In this research, the aNd-YAG laser was used to treat the surface of alloy steel in order to investigate the effects of irradiation on the microstructure, metal surface hardening, and wear resistance. Low surface roughness and increased surface microhardness have been achieved due to the laser pulse indicated (900 Hv). The wear resistance was discovered to be higher due to laser treatment with the selected conditions.

1. Introduction

Although laser technology has been around for a long time, its application in metal processing and technology did not begin until the early 1970s. Laser surface hardening, in particular, is currently recognized as being as effective as other traditional hardening procedures. The laser has the added benefit of hardening a limited location in a complex technical component. This could be viewed as a cost-cutting measure to offset the significant initial investment in laser equipment compared to the requirements of traditional methods [1, 2].

Steel components are surface treated to improve properties that suit certain applications, laser surface hardening is one of the recently developed methods that use the principles of laser beam impingement on the steel surface, thus heating is done locally and consequently leaving it to self-quench. The laser technology provides the extra advantage of hardening localized regions in intricate engineering components [3]. The use of lasers for metal surface processing offers a number of advantages [2, 4]:

- It is less expensive than bulk alloying or hardening heat treatments.
- Surface processing can be done quickly with minimum overall shape distortion.
- A controlled amount of energy can be given to a surface with precision in both dimensions and treated time.
- Access to difficult places.
- There is no requirement for external quenching.

Laser surface hardening entails heating a steel surface with enough carbon to the austenite region, then quenching to cause the austenite to change to martensite. The mass of the material acts as a heat sink in this scenario. Many researchers have looked into transformation hardening caused by continuous scanning laser beams or pulses. The microstructure phases that result are determined by the laser beam properties on the one hand, and the resulting steel composition on the other. In a laser-treated carbon steel surface, the heat-affected zone is characterized by dendritic structure, martensite, pearlite, ferrite, and retained austenite [5, 6].

Laser surface treatment with optimum parameters resulted in a noticeable increase in microhardness. When the microstructure is not uniform and a hard compound formed owing to laser glazing, scatter in surface microhardness is expected. Steel's laser hardening reaction increases with carbon content, as expected [7]. The ND-YAG (Neodymium–Yttrium Aluminium Garnet) laser was utilized to harden the surface of low alloy steel, resulting in increased microhardness and beneficial microstructural changes. Similar treatment of tool steel resulted in chemical composition variations as well as visible surface modifications [8, 9].

The volume shift that occurs during the transformation of austenite to martensite is linked to the creation of residual stresses, also a favorable compressive stresses due to the surface transformation by laser pulses; however, when those pulses are overlapped, the microstructure in the overlapped region is tempered, and residual stresses become tensile. In the heat-impacted zone, however, overlapping laser passes resulted in a more homogeneous microhardness distribution with acceptable surface roughness [10, 11].

2. Experimental Procedure

For ideal surface conditions, ND-YAG laser pulses were delivered to alloy steel specimen surfaces, with the laser beam energy and distance between the lens and treated surfaces being adjusted. In addition, different overlapping distances between laser pulses were tested. The ideal working conditions which give the best homogeneity and the best hardness values are as follows:

The energy of the laser beam is 3.8J, pulse duration 300 microseconds, wavelength 1.06 micrometers, and spot diameter 2 mm with Gaussian laser intensity distribution.

* The optimum distance between the final lens of the laser system and the specimen is 22 cm.

* The optimum selection of the distance between two overlapped Laser pulses is 1200 µm.

Table (1) shows the chemical composition of the alloy steel, the microhardness of this steel is equal to 220 Hv. In this project, laser treatment is applied to alloy steel because it is widely used and has many applications in the industry**.**

In this study, circular alloy steel samples were submitted to a wear-testing machine before and after laser surface treatment. The test specimens had a length of 25 mm and a diameter of 10 mm. For this experiment, a pin on the disc sliding machine was used. Weight loss of samples before and after irradiation was used to determine the wear rate.

Table (1). The chemical composition of the alloy steel.

Element	C	Si	Mn	P	S
Percentage	0.37	0.15	0.79	0.036	0.038

The applied normal load was 50 N, with 1.8 m/sec linear sliding rates. The disc had an 1100 HV hardness rating. Each test lasted 10 minutes and was conducted at room temperature and in normal weather conditions. The character and microstructure of samples were examined before and after laser surface hardening using an optical microscope coupled to an automatic camera and digital controller to automatically adjust exposure time.

3. Results and Discussion

Figure (1) shows the microstructure of untreated and treated laser pulses with a power of 3.8 J and a distance of 22 cm between the lens and the specimen, this figure clearly shows that the metal has become the more fine structure.

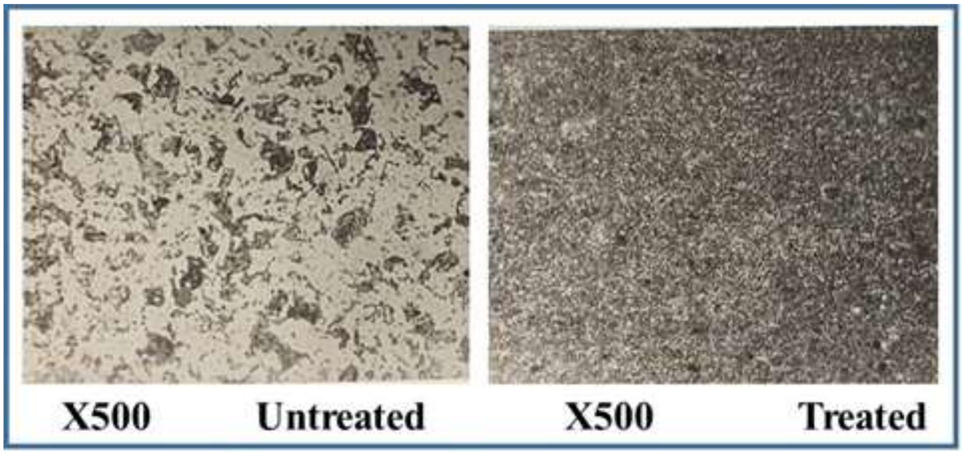

Figure (1). The microstructure of untreated and treated laser.

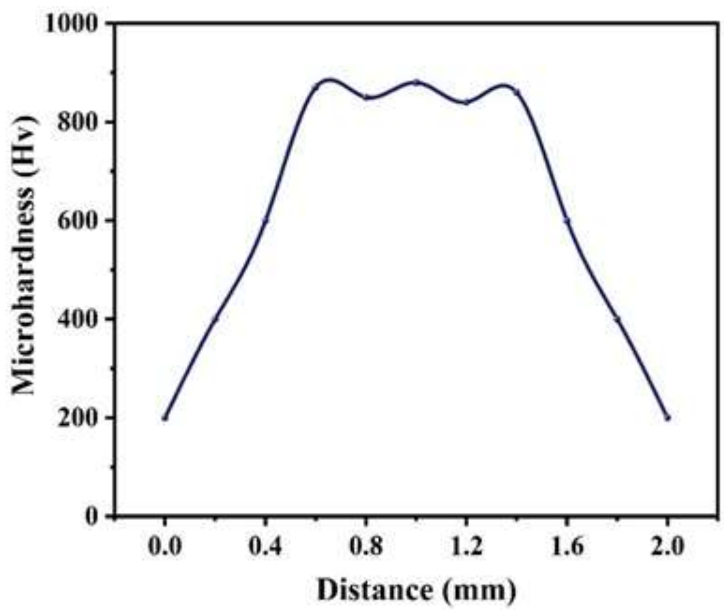

Figure (2). Micro hardness values distribution of laser pulse.

Figure (2) shows the distribution of microhardness values for laser pulses. Because the energy distribution of laser pulses is not uniform, microhardness values varied significantly, we notice from this figure that the maximum hardness value is in the middle (900 Hv) due to the thermal distribution of the spot where the laser energy is concentrated in the medium.

Figure (3) shows a cross-section view of the treated layer, we can see clearly the hardening fine layer of the metal towards the depth. The relation between the distance from the surface of the metal and microhardness (hardening depth) is shown in figure 4 this figure shows that the hardening depth is about 70 µm.

The rapid transformation of a surface from a liquid to a solid state in a short period of time may result in an increase in hardness due to laser glazing for some areas where a glazed phase was produced, as well as internal compressive stresses caused by fast heating and cooling without melting. Aside from these impacts, the production of martensite and cementite would improve the hardness.

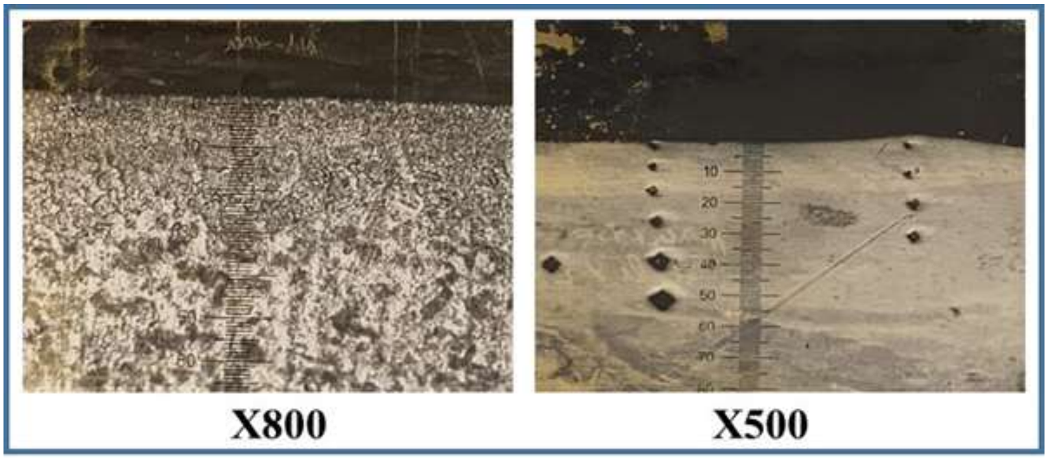

Figure (3). The cross section image of the laser treated sample.

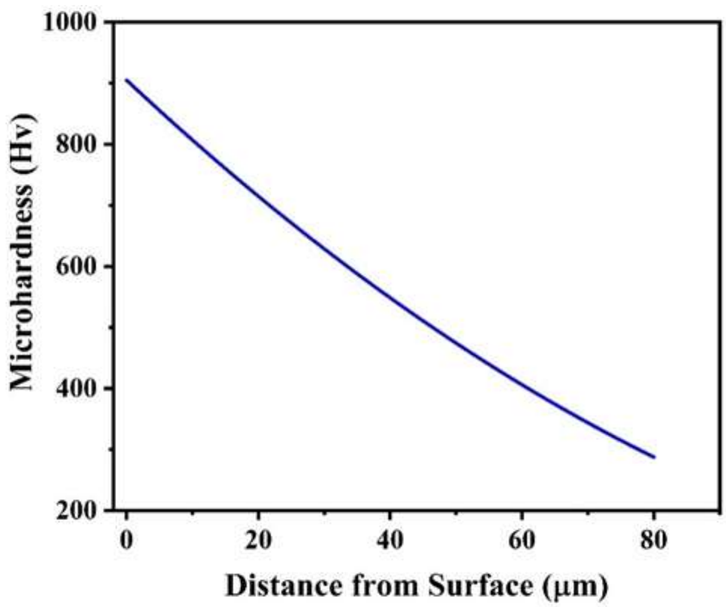

Figure (4). Depth of hardening.

The laser-treated region's microstructure figure (3) revealed a martensite phase near the surface of the specimen and a fine pearlite phase deeper in the specimen.

When compared to published references [3, 12, 13], the microhardness (about 880 Hv) results in yield favorable results. Figure (5) shows the wear resistance of untreated and treated laser pulses with 3.8 J and a 22 cm distance between the lens of the laser system and the specimen. The weight loss for treated and untreated samples increases as time is increases. Figure (6) depicts the image of untreated and laser-treated wear resistance test specimens after and before the wear test.

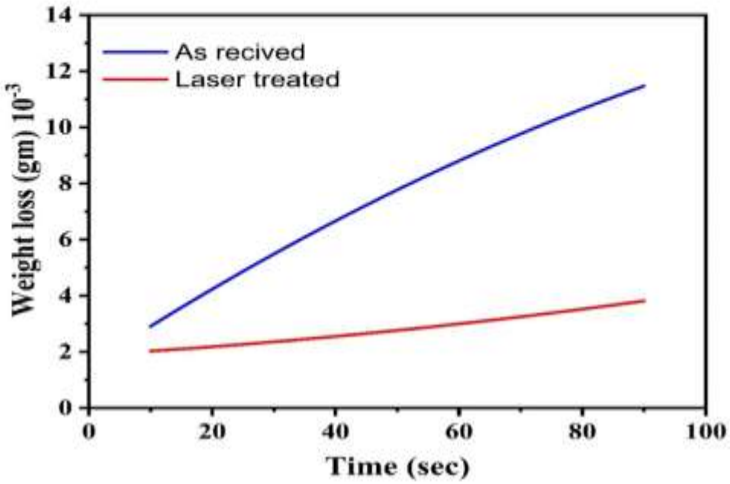

Figure (5). Wear resistance of untreated and treated laser pulses.

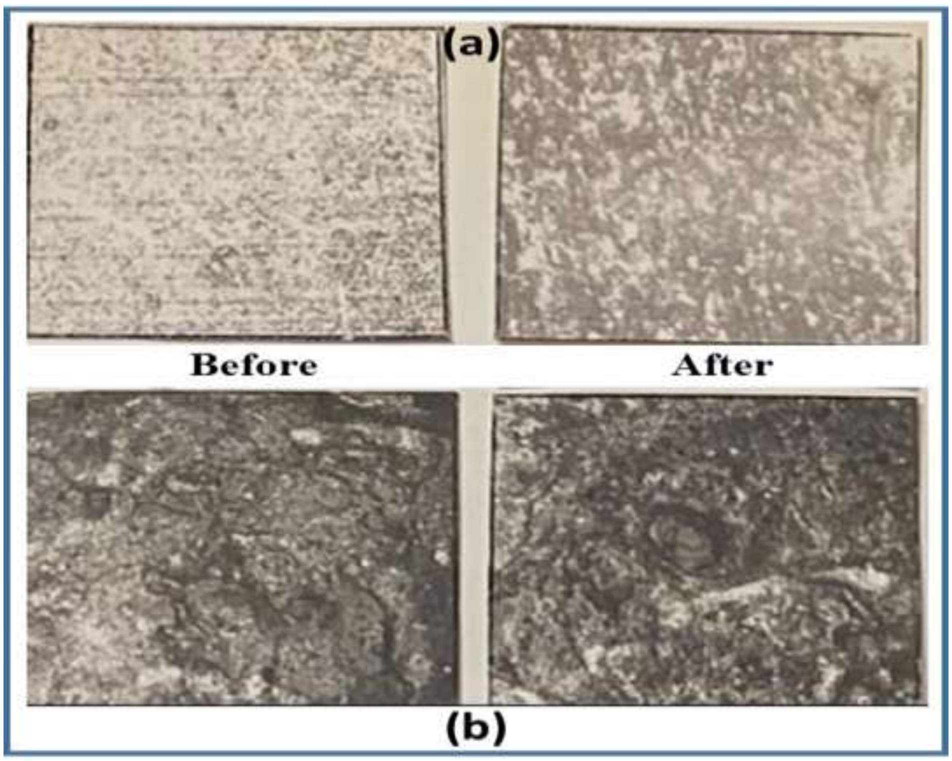

Figure (6). The image of wear resistance test specimens (Mag. X50) after and before wear test for: (a) untreated specimens. (b) Laser treated specimen.

4. Conclusions

ND-YAG laser processing on the surface of alloy steel increases the treated surface's micro hardness values (up to 880 Hv). Laser processing produces a hard martensitic structure in alloy steel. The accumulative wear rate of steel alloy grows with increasing sliding time, with the increase being more evident at the start of the test; however, after about 30 minutes, the growing ratio of the wear rate is lowered due to a work hardening phenomenon. Because of the stress-induced phase transformation of austenite to martensite, the presence of residual austenite in the treated specimen has led to improved wear resistance.

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