International Journal of ISSI, Vol.9 (2012), No.2, pp. 5-8

Evaluating Wear Properties of AISI 420 Martensitic Stainless Steel after Laser Transformation Hardening

Gh. Zirehpour[1]*, R. Shoja Razavi[2] and E. Moayerifar[3]
[1]Department of Materials Engineering, Iran University of Science and Technology, Tehran, Iran
[2,3]Department of Materials Engineering, Malek Ashtar University of Technology, Isfahan, Iran

Abstract

As the turbine industries need to manufacture turbine blades made of martensitic stainless steel AISI 420 with high toughness and wear resistance, local laser hardening has become more and more important. In this research, surface of the samples was initially hardened by high-power pulsed laser beam; then, optimum parameters of hardening were calculated and wear resistance of surface hardened samples were compared with the similar parameter in the surface raw samples. Scanning Electron Microscope (SEM) was used to determine microstructure and surface phases. Reciprocating wear test was also performed for surveying wear resistance of the samples. The results showed that laser surface treatment led to producing a martensitic-austenitic microstructure and dissolution and/or redistribution of carbides. Hardness of surface of hardened samples was obtained about 700 Hv after laser hardening. Wear mechanism was transformed from laminate to abrasive during the testing.

Keywords: Martensitic stainless steel AISI 420, Laser surface hardening, Wear.

1. Introduction

In cases where a combination of moderate corrosion resistance and high strength is required, martensitic stainless steels are widely used; for example, these steels are used at high and low temperatures to manufacture components such as ship propellers, pump impellers, valves and turbines [1-3]. Steel AISI 420, as a common martensitic stainless steel, is used to manufacture turbine blades in gas and combined cycle power plants [4]. These turbines usually encounter some problems such as wear, cavitation erosion and localized corrosion in certain areas. Corrosion damage in some cases is so intense that part time working is decreased to one-tenth of the time considered in its design. In order to prevent this phenomenon, certain areas of the component are hardened by laser [3-5].

Among different laser surface treatments, laser transformation hardening and laser surface melting are the simplest methods because of not requiring any additives. These methods improve wear resistance [6,7], cavitation resistance and corrosion resistance in stainless steels [1,8-10] due to the dissolution and/or refinement of carbides and increase of Cr in solid solution. Between the above mentioned methods, laser transformation hardening is more desirable because it does not require any subsequent machining; thus, processing possibility is higher on the final surface [9].

In a few studies, effect of pulsed YAG laser on steel AISI 420 has been studied, in which great hardness has not been obtained for the steel [3,4,11].

In this research, optimum parameters of laser transformation hardening on the steel AISI 420 were improved which improved hardness in this steel after laser hardening. The wear resistance of surfaces under laser hardening was compared with that of raw surfaces.

2. Material and Experimental Method

A martensitic stainless steel AISI 420 was prepared as a sheet with thickness of 10 mm. Chemical composition of the sample was specified by spectrophotometry method (Table 1). The stainless steel sheet was cut into smaller pieces to be prepared for laser test. After the same surface preparation for all the samples, surface of the samples was sand blasted in order to increase absorption coefficient of laser beam. For this purpose, pulsed Nd:YAG laser model IQL-20 with the power 700 W was used for power supply. A power meter was also applied to measure average power. Argon gas was blown with the rate of 15 lit/min during laser hardening treatment for the purpose of surface protection from oxidation.

* *Corresponding author:*
Tel: +98 913 2884003 *Fax: +98 312 5228530*
Email: gh.zirehpour@gmail.com
Address: Department of Materials Engineering, Iran University of Science and Technology, Tehran, Iran
1. M. Sc. Student
2. Associate Professor
3. M. Sc.

After laser transformation hardening, the samples were sectioned transversely, polished by diamond paste, cleaned and dried, respectively. Then, surface of the samples was etched by vilell's reagent. The microstructure was measured by a Vickers hardness test machine Zwic model 3213000 under the load of 100 g.

Sliding wear test was conducted on raw and laser treatment samples using linear reciprocating pin- on-plate contact in similar conditions at 35% humidity, temperature 27 ºC, pin speed of 0.1 m/s and different applied loads. Diagrams of load-bearing capacity and wear test were drawn for each test. The pins used in wear test had spherical convex surface which was 5 mm in diameter and 0.3 µm roughness in surface, made of steel 52100 with hardness of 800 Vickers.

3. Results and Discussion

Initial screening tests were conducted in order to obtain optimal parameters of laser transformation hardening of steel AISI 420 by pulsed Nd: YAG laser and the effect of process parameters on hardness and hardness depth were studied. Two final powers of 300w and 350w were selected for further research; in order to select one of these powers, their micro-hardness was investigated (Figure 1). As seen in Figure 1, the micro-hardness was reported more over 700 Vickers on the laser treated surface. This result was better than micro-hardness of 480 Vickers which was obtained by Mahmoudi et al. [3,4,11] in laser treated surface of steel AISI 420 by pulsed YAG laser. According to Figure 1, it can be clearly found that hardness depth was higher in the samples treated by power 350 W compared to the one in the samples treated by power 300 W, which was a more favorable result. Thus, the experiments were continued with power 350 W in order to obtain maximum harness depth by reducing travel speed to melting point. As seen in Table 2, reducing surface scan speed to 25 mm/s led to no fusion in the surface; but, dendrites of austenite appeared with further reduction in surface scan speed to 15 mm/s, which indicated surface fusion. As a result, 25 mm/s was selected as the best scan speed.

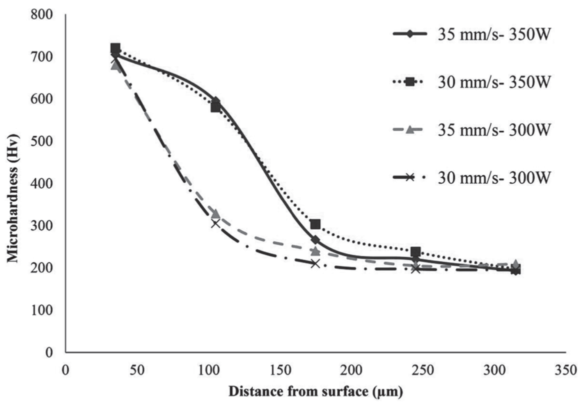

Fig. 1. Microhardness of various samples in screening tests.

The microstructure of raw sample and laser transformation hardened sample by scan speed of 25 mm/s is shown in Figure 2. The matrix of raw sample consisted of ferrite grains and dispersed carbide particles while transformation laser hardened sample in transverse section had a martensitic structure.

Table 1. Composition of steel AISI 420 used in this study

Element	C	Mn	Si	V	P	Mo	Cr	Ni	Fe
Weight percent	0.18	0.35	0.55	0.004	0.014	0.02	12.3	0.19	86.35

Table 2. Laser treatment parameters with power of 350 W in order to evaluate the optimum speed

Surface condition	Nozzle distance from surface (mm)	Scan speed (mm/s)	Frequency (Hz)	Pulse width (ms)	Current (A)	Average power (W)
Hardned	15.6	45	23	5.5	60	350
Hardned	15.6	35	23	5.5	60	350
Hardned	15.6	25	23	5.5	60	350
Surface fusion	15.6	15	23	5.5	60	350

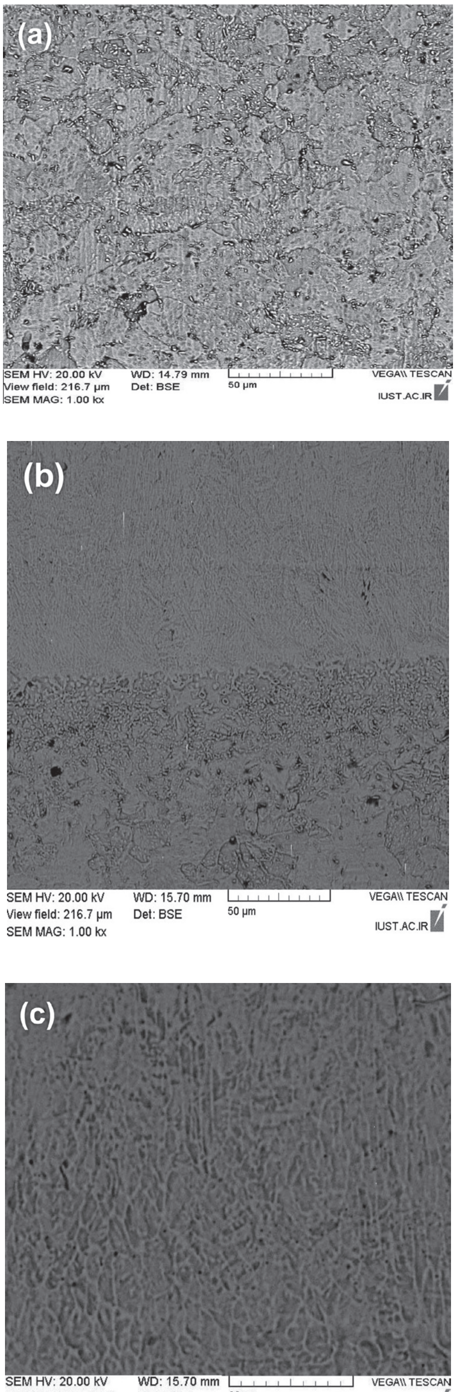

Fig. 2. SEM image of (a) raw sample, (b) and (c) laser treated zone.

Wear test was conducted on two samples mentioned in Table 3. In order to select an appropriate force, load wearing capacity test was performed. The result of this test is given in Figure 3(a). According to this figure, the loading of 70 N was selected for wear test in order to compare wear resistance in different samples; the result of this test is presented in Figure 3(b). As weight loss of laser treated sample was much less than the raw sample's, so it can be concluded that wear resistance of laser treatment hardened samples was higher than that of raw sample. Wear resistance was directly related to the microstructure and its hardness. The microstructure of surface of laser transformation hardened sample consisted of martensite, residual austenite and some unresolved carbides while microstructure of raw sample consisted of ferrite grains and dispersed carbide particles. Thus, it can be resulted that laser transformation hardened sample with the microstructure containing martensite and residual austenite and some carbide had the highest hardness among other samples mentioned in Table 3; also, it had the highest wear resistance. On the other hand, the raw sample with the microstructure containing carbide in ferrite matrix had the least hardness and wear resistance among other samples mentioned in Table 3.

Table 3. Condition of the samples used in reciprocating wear test

Sample	Surface condition	Overlap percent
Raw	Sand blasted	-
Laser treated	Transformation laser hardened	10%

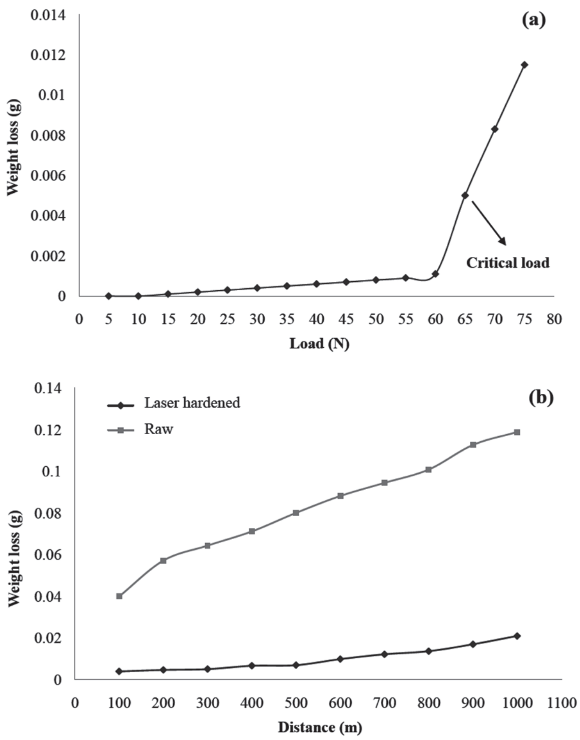

Fig. 3. (a) Diagram of load wearing capacity test for laser hardened sample and (b) wear diagram of different samples (weight loss via distance at constant load).

SEM images from wear surface are shown in Figure 4. In Figure 4(a), it can be observed that lamination wear was more than abrasive wear; it can be concluded that dominant wear mechanism in the raw sample was lamination mechanism. In Figure 4(b), various abrasions can be observed via deep craters, which could lead to propel wear mechanism to abrasive wear.

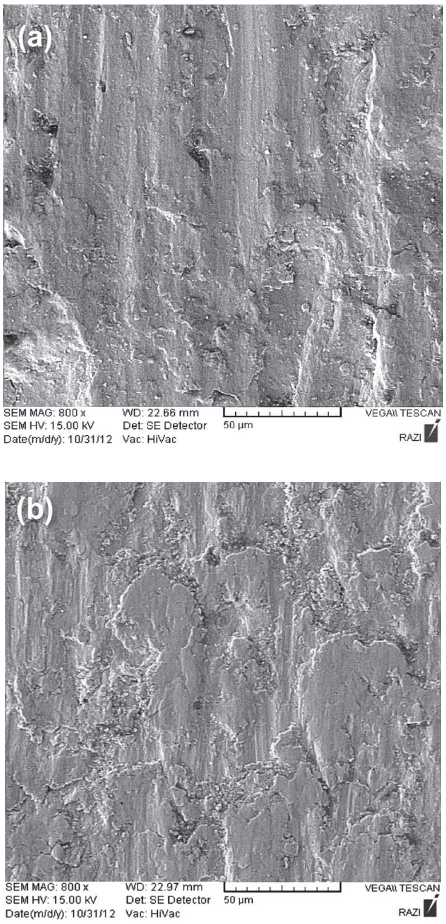

Fig. 4. SEM images from wear surfaces of (a) raw and (b) laser transformation hardened sample.

4. Conclusion

1. A structure consisting of martensite, residual austenite and a small amount of unresolved carbide was formed due to laser transformation hardening of steel AISI 420.
2. The improvement of properties in laser transformation hardening of steel AISI 420 was resulted from solid state transformation and dissolution/redispersion of carbides.
3. Microhardness of this steel was measured as 700 Vickers after laser transformation hardening with power of 350 W.
4. Wear resistance of this steel significantly improved after laser treatment.

References

[1] K. H. Lo and F. T. Cheng: Surf. Coat. Technol., 173(2003), 96.
[2] C. T. Kwok, K. H. Lo, F. T. Cheng and H. C. Man: Surf. Coat. Technol., 166(2003), 221.
[3] B. Mahmoudi, A. R. Sabour Aghdam and M. J. Torkamany: J. Electron. Sci. Technol., 8(2010), 87.
[4] B. Mahmoudi, M. J. Torkamany and J. Sabbaghzade: Mater. Des., 31(2010), 2553.
[5] M .L. Escudero and J. M. Belo: Mater. Sci. Eng. A, 158(1992), 227.
[6] R. Colaco, C. Pina and R. Vilar: Scripta Mater., 41(1999), 715.
[7] R. Colaco and R. Vilar: Wear, 258(2005), 225.
[8] A. Khajeh, B. Mahmoudi and J. A. Jahromi: Mater. Des., 34(2012), 857.
[9] K. H. Lo, F. T. Cheng, C. T. Kwok and H. C. Man: Mater. Lett., 58(2003), 88.
[10] V. Chaitanya Bommi, M. Krishna Mohan and S. Prakash: Proc. of Int. Symp. on research student on material science and engineering, India, (2004).
[11] B. Mahmoudi, M. J. Torkamany and A. R. Sabour Aghdam: Proc. of 9rd Iranian seminar on surface engineering, IUST, Tehran, (1387).