

QUANTITATIVE ANALYSIS OF RETAINED AUSTENITE IN LASER MELTED MARTENSITIC STAINLESS STEEL

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Abstract

An AISI 420 martensitic stainless steel, 0.6 mm thick was melted with a 4.4 kW continuous wave Nd: YAG laser in order to induce a certain proportion of retained austenite in a matrix. The volume percentage of the retained austenite (RA) in the melted-surface layer was investigated by irradiating the surface at different processing conditions.

Typically, the sample was melted at different nominal laser beam powers (P), beam scanning speeds (v), and shielding gases, at constant beam diameter (d).

The objective of this study was to determine if X-ray diffraction (XRD) was sufficient for quantifying the volume percentage of retained austenite. After a preliminary qualitative analysis, a Rietveld full pattern refinement program was used to quantify the volume percentage of the retained austenite in the melted-surface layer. The results show that the volume fraction of retained austenite in laser melted layer increased with decreasing energy density, when laser melting was carried out in an inert atmosphere.

Introduction

Laser surface modification plays a huge role in tailoring the near surface microstructures and hence improves surface properties. Laser surface melting (LSM) has been used in the past years to improve the mechanical and chemical properties of tool steel surfaces. LSM of tool steels involves the dissolution of carbides, refinement of the microstructure and homogenization of chemical composition. The improvement of mechanical properties includes; increased hardness and toughness, increased wear resistance, whereas chemical properties include increased corrosion resistance [1, 2]. Martensitic stainless steels are widely used in engineering

applications such as steam and water valves, pumps, cutlery, surgical tools, bearings and plastic moulds.

During laser surface melting of tool steels or martensitic stainless steels, one of the microstructural features is the large quantity of retained austenite in the laser melted surfaces. This behaviour depends on the chemical composition of the matrix and laser processing parameters. Previous research shows that the proportion of retained austenite increases with an increase in laser scanning speed [1]. Other investigators reported that a decrease in power density also increases the quantity of retained austenite during LSM of tool steels [3]. However, heating and cooling rates play a major role in predicting the proportion of certain phases.

The objective of this study is to establish an understanding behind microstructural evolution during laser surface melting of AISI 420 martensitic stainless steel and its effect on wear resistance. This involves optimization of processing parameters and quantification of resultant phases. The X-ray Diffraction (XRD) technique is used to quantify the amount of retained austenite by using the Rietveld full pattern refinement program. A wheel-on-plate abrasive wear tests were performed to study the effect of retained austenite.

Experimental procedure

A martensitic stainless steel AISI 420 in the quenched and tempered condition was used as an experimental material. This material has an average hardness of 315 HV. The chemical composition of the steel is shown in Table 1. Samples of 50 X 25 X 0.6 mm were machined from a cylindrical rod. These dimensions were chosen to conform to the specification of the wear testing facility. Prior to laser surface melting, the surfaces were shot blasted with

micro-spheres glass beads and finally cleaned with acetone.

LSM was carried out using a Rofin-Sinar 4.4 kW Nd:YAG laser. Laser processing parameters are given in Table 2. The laser beam was delivered through a 400µm diameter fibre with a 300 mm focal distance lens. The DCY ILV scanner was used to rapidly scan the laser beam across the sample in transverse direction to the feed direction. The scan width was set to 25 mm. LSM processing parameters were optimized to produce a better surface finish. Argon gas flowing at the rate of 15 l/min was applied into the melt pool to minimize oxidation.

Table 1 chemical composition of the AISI 420 steel

C	Si	Mn	Cr	Mo	Ni	S	Fe
0.38	0.30	0.65	14.30	1.0	0.84	-	Bal

After laser treatment, the samples were sectioned, polished and electrolytically etched with 10% oxalic acid for metallographic investigations. The microstructure of the starting material and laser treated was studied by using scanning electron microscope (SEM) and X-ray diffraction technique (XRD). After a preliminary qualitative analysis, a Rietveld full pattern refinement program was used to quantify the volume percentage of the retained austenite in the melted-surface layer. A Vickers micro-hardness tester was used to measure hardness changes after laser treatment.

Table 2 laser processing parameters

Sample code	Laser power (kW)	Scanning speed (mm/s)
420-untreated	-	-
420-A	1.7	3
420-B	1.7	4
420-C	1.7	6

Abrasive wear tests were carried out in a rotating wheel-on plate facility. The test rig consists of a mild steel wheel which rotates at 100 rpm, that gives a tangential speed of 0.88 m/s.

The lower half of the wheel rotates through a bucket containing the abrasive medium.

The abrasive medium used consisted of foundry silica sand from Lancaster sands, with water added to the bucket in accordance with the standard (4g of grit to 1 cm³ of water) this is significant to wet the sand without having excess water on the surface.

This sand was sub-angular (semi-rounded) sand with a sieve grading of 45 AFS. The sample (volume specification 50 X 25 X 0.6 mm³) was held against the wheel with a constant 10 Kg load for series of revolutions. These analyses are mass ratio, resistance response of materials mass loss.



Fig 1. Abrasive wear testing device with rotating wheel.

Results

The microstructure of the untreated sample designated 420-untreated is shown in Figure 2a. It shows carbides in a tempered martensite matrix. After LSM, carbides are expected to dissolve because of the melting effect. Figure 2b shows an optical micrograph of the laser melted sample with finer grain structure which confirms rapid cooling.

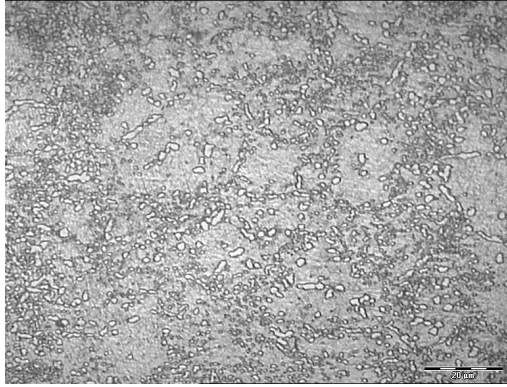


Figure 2a. A microstructure of the starting material.

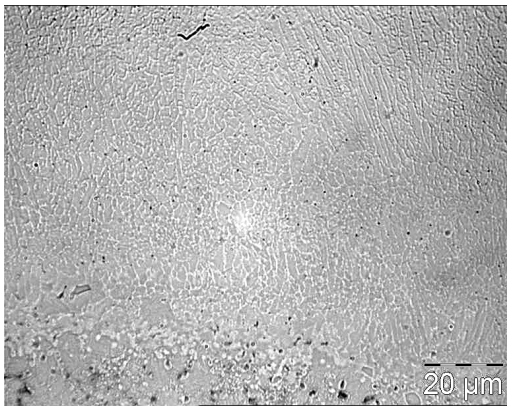


Figure 2b. Microstructure of the laser treated sample.

Figure 3 shows higher resolution SEM micrograph of the laser-melted zone. The retained austenite (RA) is outlined at the grain boundaries. The percentage of this phase increases with decreasing grain size. Figure 4 shows the XRD pattern of the sample 420-B. A Rietveld quantitative analysis method showed that at least 12% retained austenite (RA) was achieved at the higher speed.

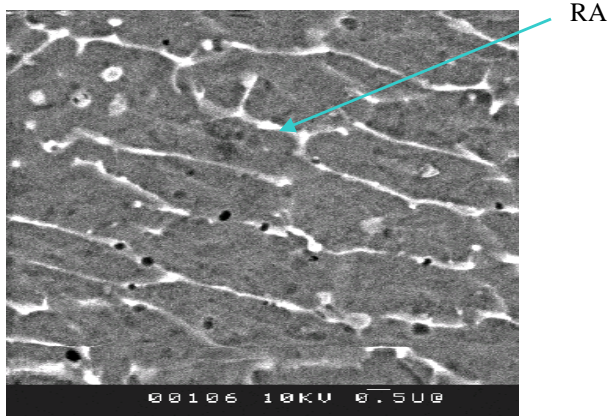


Figure 3. SEM micrograph of the laser-melted sample showing retained austenite.

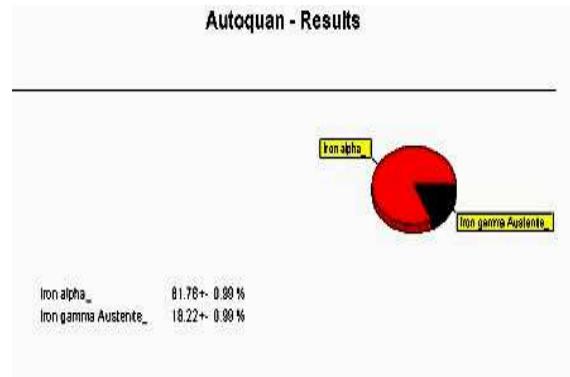
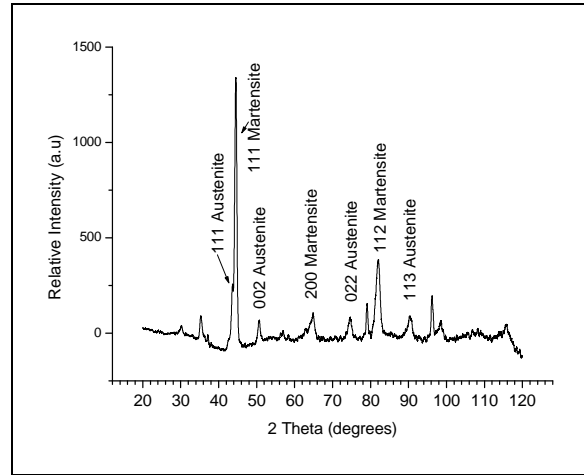


Figure 4. X-ray diffraction pattern of sample 420-B.

Abrasive wear tests showed a remarkable improvement in wear resistance comparing the untreated and laser treated samples processed at various parameters. Figure 5 shows a graphical illustration of wear rates conducted for 700 revolutions.

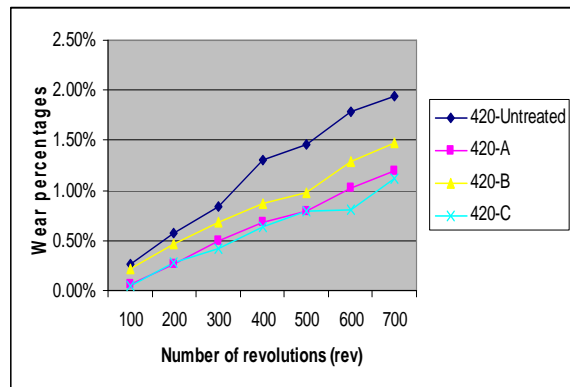


Figure 5. Wear percentage comparison for the untreated and laser melted samples.

The laser treated samples achieved wear percentages between 1.2 and 1.5 after 700 revolutions. However, the untreated samples reached higher wear percentages of approximately 2%. Sample 420-C was treated at higher scanning speed and showed better wear resistance.

Conclusions

Careful selection of laser processing parameters could lead to a controlled quantity of retained austenite. The scanning speed and laser power density play a major role.

The experiments showed that retained austenite decreased with decreasing processing speed. Sample treated at a higher scanning speed achieved better wear resistance.

Wear results showed that laser surface melting of martensitic stainless steel improved wear resistance.

References

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