Microstructural characterization and friction coefficient after the laser shock processing treatment on AISI 316 L stainless steel welds

I. B. ROMAN, M. H. TIEREAN*, J. L. OCAÑA[a], C. MUNTEANU[b]
Transilvania University of Brasov, Romania
[a]*Universidad Politecnica de Madrid, Spain*
[b]*Gheorghe Asachi Technical University Iasi, Romania*

Laser shock processing (LSP) or laser shock peening is a new technique for improving the properties of materials. The aim of this paper is to analyze the influence of pulse density on friction coefficient and analyze the microstructure. The samples are made of 316 L stainless steel and chemical composition was determinate using EDX. The samples was welded by a Nd:YAG ROFIN laser using 3.3 kW power. In this experiment we use a Nd:YAG laser delivering 2.8 J, 9 ns laser pulses, operating at 10 Hz with infrared (1064 nm) radiation to treat the welded samples. The pulses are focused to a diameter of 1.5 mm. The laser welded 316 stainless steel joints were treated with different pulse density: 900 pulse/cm^2 and 1600 pulse/cm^2. Microstructures analyzes was carried out by electronic microscopy SEM. Friction test was done using a tribometer. Results reveal the influence of pulse density on friction coefficient.

(Received March 25, 2013; accepted July 11, 2013)

Keywords: Friction coefficient, Laser shock processing, Stainless steel

1. Introduction

The results of laser shock processing (LSP) technologies on various materials as aluminum, titanium, steels, successfully prove the benefits of it [6]. Compared to other similar technologies as shot peening, LSP can induce compressive residual stress deeper without damaging the surface and a minimal thermal effect. Also the mechanical properties of materials as fatigue life, hardness or corrosion resistance, wear resistance can be improved in a higher proportion [1, 2].

Welding process involves two distinct areas in the material, heat affected zone (HAZ) and weld seam. Inside the HAZ, micro-structural changes occur which can decrease the fatigue life of the welded material. The weld seam, represent the solidified material after the welding process.

Sanchez-Santana et al. [3] investigated the effect of LSP surface treatment on the wear and friction of 6061-T6 aluminum alloy. They showed that LSP reduces wear rate due to the compressive residual stress field induced. The authors demonstrated that wear rate decreased as pulse density increased. It has been observed that with LSP the time to reach the same wear depth may be increased by as much as 100%, depending on the applied load and pulse density.

The effect of LSP on 8620 steel was investigated by J.Z. Lu et al. They prove that treating the surface by laser shock processing you will decrease de friction coefficient [4].

Wang F. et al. [5] demonstrated that LSP is an effective surface treatment technique to improve the microhardness and wear resistance of H62 brass. The wear test experiment shows that the wear mass loss reduced by about 46% with the laser of 3000 pulses/cm^2. This proves that LSP technology can effectively improve the wear resistance.

Due to the composition of nickel increased and add manganese which is improving the acid and corrosion resistance the stainless steel AISI 316L could be used in more specific environment, such as strong acid and alkali chemical apparatus, construction of higher salinity regions or vessel, etc.

The aim of the paper was to investigate the influence of pulse density on friction coefficient and micro-structure for AISI 316 L stainless steel welds.

2. Experimental details

2.1. Material and samples preparation

The samples were made by stainless steel AISI 316L, 6 mm thickness. Steel chemical composition, welding technology and laser shock processing were presented in [7]. Welding process was carried out with a Nd:YAG laser with maximum power 3.3 kW, wavelength of 1064 nm, spot diameter 0.5 mm, welding speed 5 mm/s and 15-20 l/min flow gas Helium was used as a protectiv medium. During the process the room temperature was around the 20°C-25°C. The samples were treated by LSP without absorbent coating. Spot diameter for this experiment was 1.5 mm, pulse width 9 ns and 2.8 J/pulse. Density used was 900 pulse/cm^2 and 1600 pulse/cm^2 in order to observe the influence of pulse density on the properties.

The samples were polished with different sand paper grade in order to obtain a thin surface for micro-structural observation. Chemical attaching attack was obtained by mixing 15 ml glycerin, 10 ml hydrochloric acid and 5 ml nitric acid.

2.2. SEM/EDX observation

In order to have a detailed micro-structural characterization we used optical microscopy and electronic microscopy (SEM). Optical microscopy was carried out by OLIMPUS PMG3 confocal microscope using an ALTRA 20 high resolution camera, and electronics one was carried out by Quanta 200 3D scanning electron microscope coupled with energy dispersive X-ray spectrometer.

2.3. Friction test

Friction test was experimental determinate by a tribometer that works on inclined plane principle (fig. 1). This principle is the relationship between angle of inclination and friction coefficient μ:tg $\alpha = \mu$. The testing method is presented in [8].

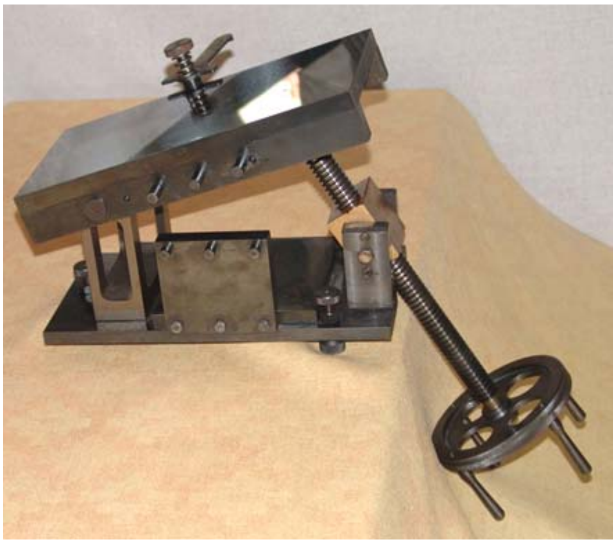
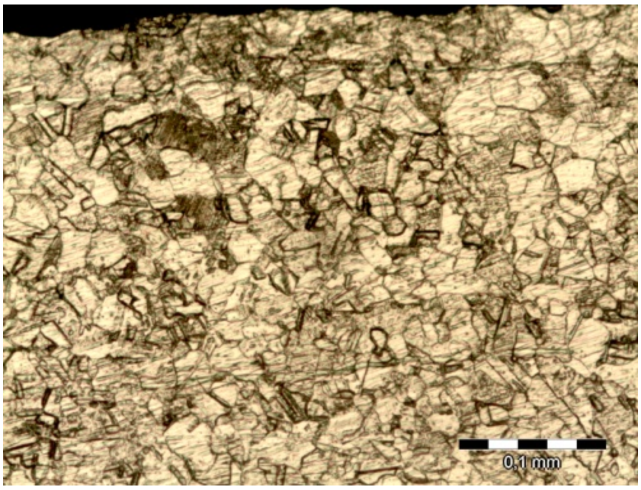


Fig. 1. Tribometer used for friction test

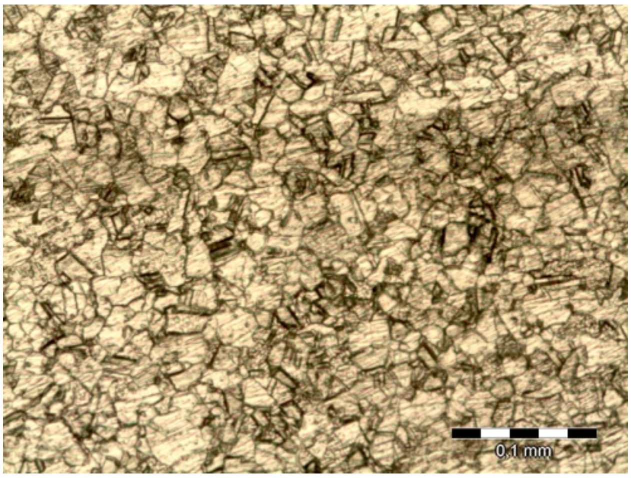
3. Results and discussion

3.1. Micro-structural characterization

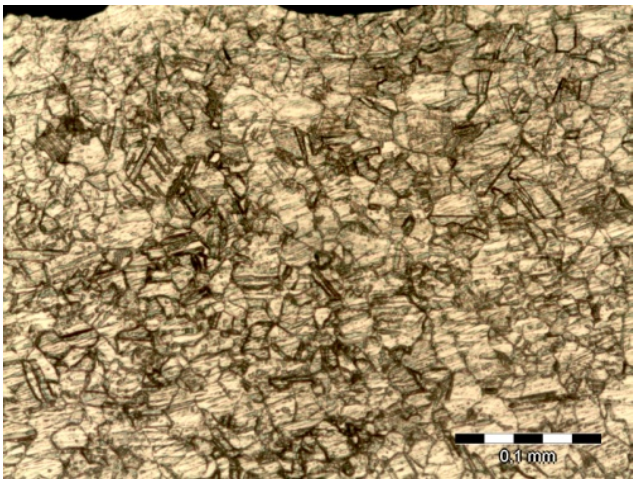
Fig. 2 presents the optical morphologies of the cross-section of the treated samples immersed in the professional etching for 20 seconds at room temperature.



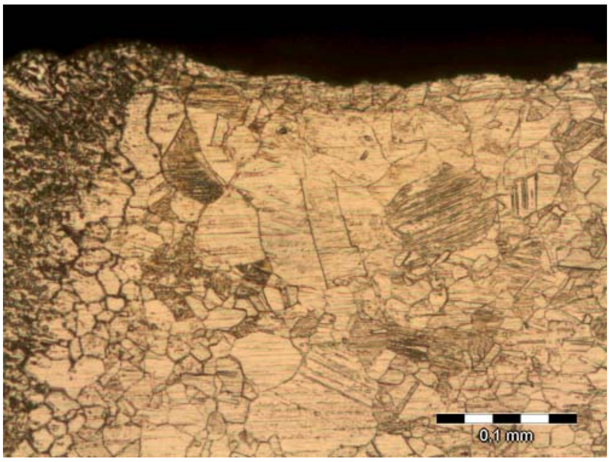
a) base material, untreated



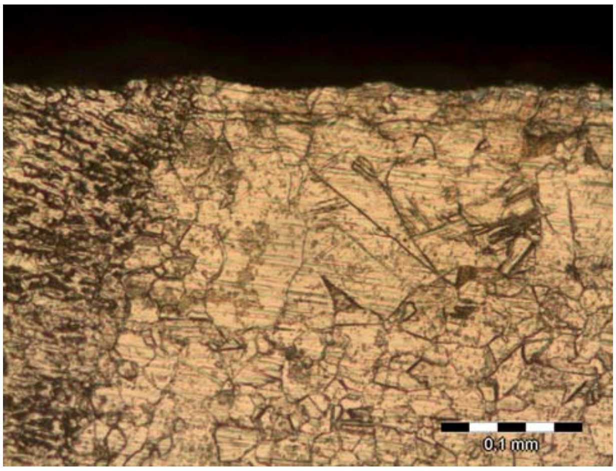
b) base material, LSP 900 pulse/cm^2



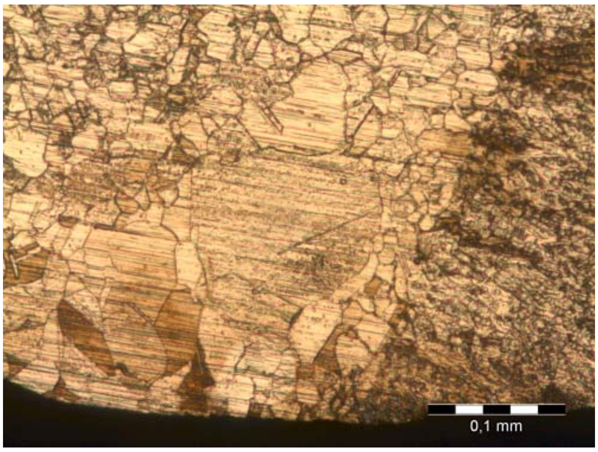
c) base material, LSP 1600 pulse/cm^2



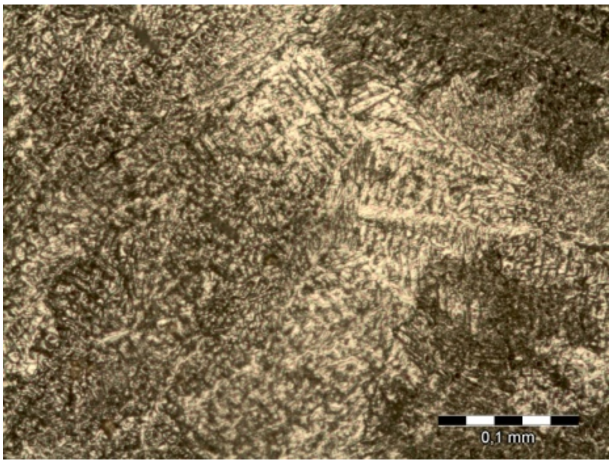
d) heat affected zone, untreated



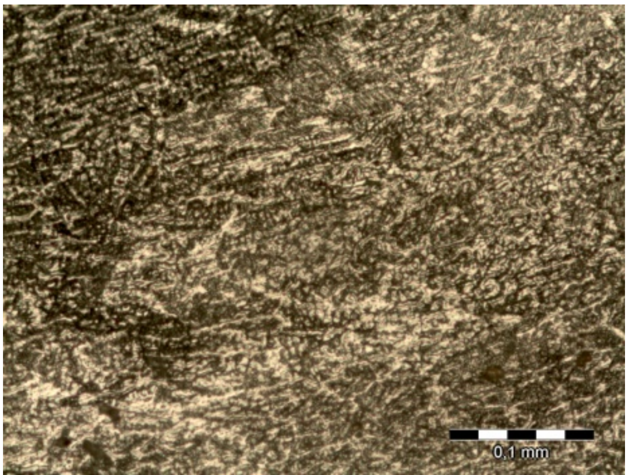
e) heat affected zone, LSP 900 pulse/cm^2



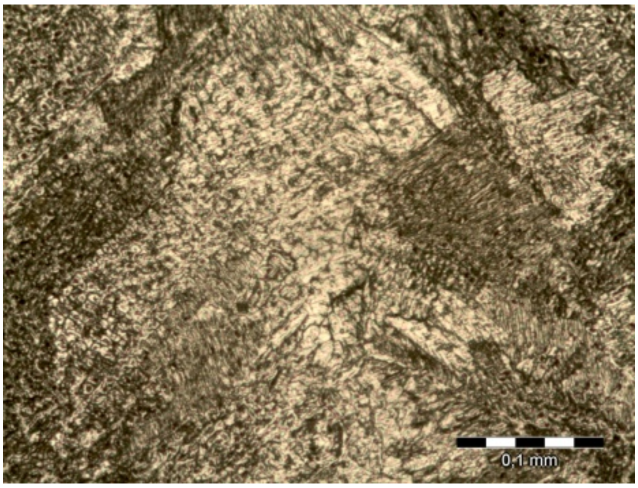
f) heat affected zone, LSP 1600 pulse/cm^2



g) weld seam, untreated



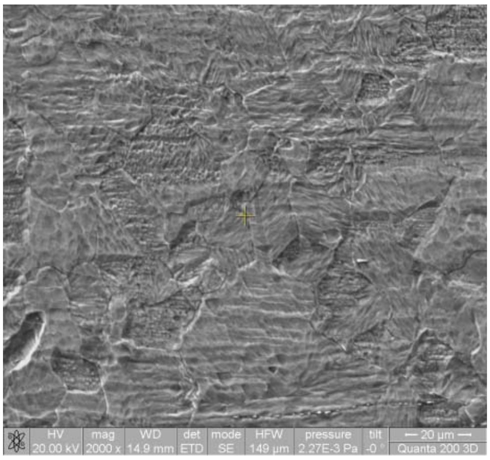
h) weld seam, LSP 900 pulse/cm^2



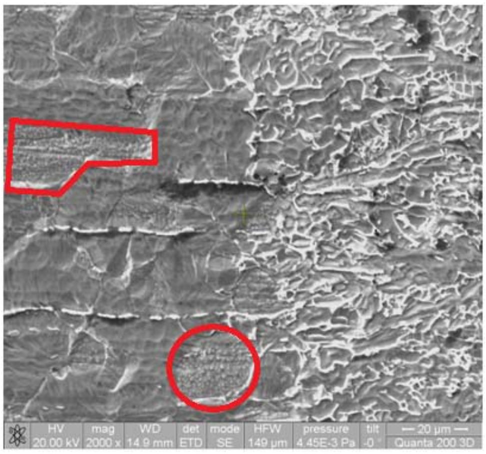
i) weld seam, LSP 1600 pulse/cm^2

Fig. 2. Optical microscopy of the cross section

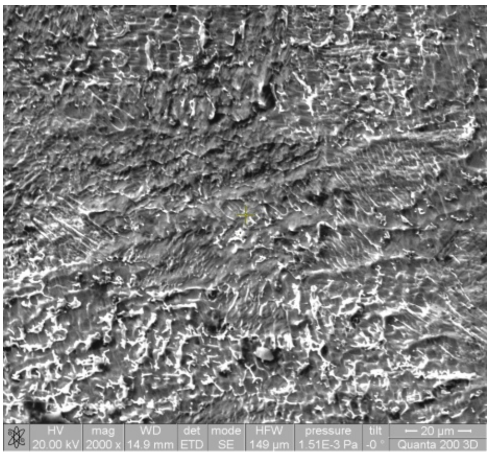
In the base material the evidence of plastic deformation is obvious. It can be seen that the average size of grains in the treated samples is about 3-5 µm, while the average size of the untreated sample is 7-10 µm. In the heat affected zone due to the welding process the grain size are increasing. Due to the shock wave induced by the LSP process the grains are refined.



a) base material



b) heat affected zone



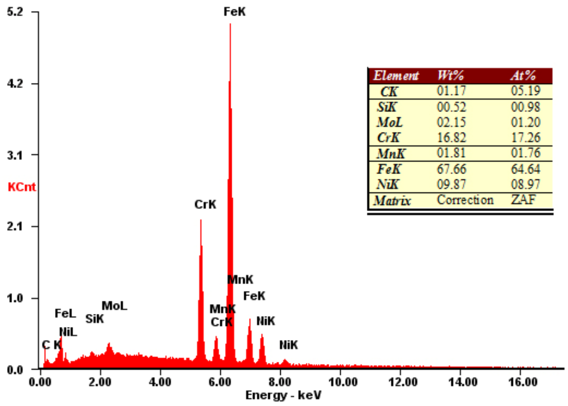
c) weld seam

Fig. 3. SEM microscopy

Fig. 3 presents the SEM microscopy at a higher magnification. It can be observed there are some grains subdivided by cell structures which are show in image corresponded to heat affected zone.

3.2. Chemical composition

Chemical composition was made by EDX in three different places, base material, heat affected zone and weld seam. The values remain constantly for all the samples. Figure 4 present the chemical composition of the sample in heat affected zone.



Element	Wt%	At%
CK	01.17	05.19
SiK	00.52	00.98
MoL	02.15	01.20
CrK	16.82	17.26
MnK	01.81	01.76
FeK	67.66	64.64
NiK	09.87	08.97
Matrix	Correction	ZAF

Fig. 4 Chemical composition

3.3. Friction coefficient

Friction coefficient measurements was made on three kinds of sample, untreated, 900 pulse/cm^2 and 1600 pulse/cm^2 density. The friction coefficient was measured 20 times. The results show that LSP can influence the friction coefficient by increasing the pulse density, figure 5.

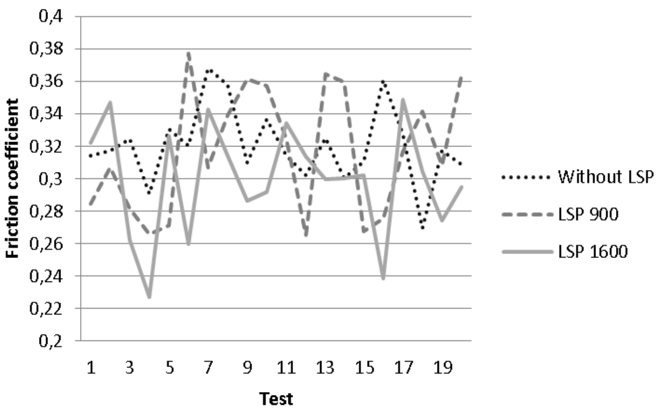


Fig. 5. Friction coefficient tests

Computing the average values, we can conclude that, increasing the pulse density the friction coefficients are decreasing. The friction coefficient of untreated sample and treated with 900 pulse/cm^2 density is almost the same, but the difference between untreated ones and treated with 1600 pulse/cm^2 density is obviously decreasing. The friction coefficient average is presented in Fig. 6.

The surface roughness was measured using a Surtroni 25 surface roughness tester (Taylor Hobson) [9]. Ra is the arithmetic mean of the absolute departures of the roughness profile from the mean line. The Ra values were: 4.14 μm for the untreated sample, 2.51 μm for the LSP 1600 pulse/cm^2, and 2.71 μm for the LSP 1600 pulse/cm^2.

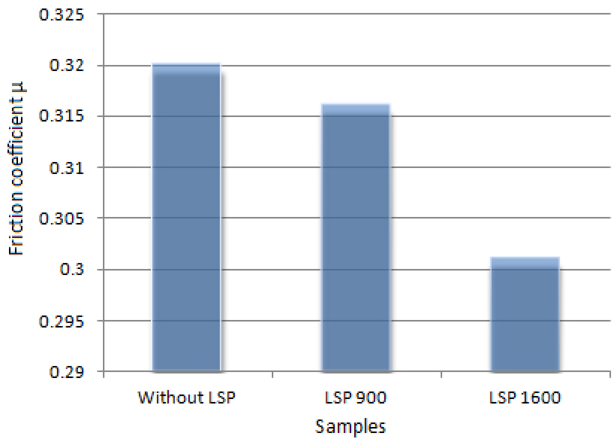


Fig. 6. Average friction coefficient

4. Conclusions

The shock waves induced by laser shock processing technologies can influence the microstructure of stainless steel AISI 316L. The microstructure is refined in the near surface of the sample which is the reason that LSP can improve the mechanical properties of the material.

The effect of pulse density on friction coefficient was also experimental investigated. We can conclude that increasing the pulse density from 900 pulse/cm^2 to 1600 pulse/cm^2, the friction coefficient is decreasing.

Acknowledgements

This paper supported by the Sectoral Operationl Programme Human Resources Development (SOP HRD), ID76945 financed from the European Social Fund and by Romanian Government. Authors are grateful to acknowledge Centro Laser, Universidad Politehnica Madrid for the fruitful collaboration and for suggestions of this study.

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* Corresponding author: mtierean@unitbv.ro