IMPROVEMENT IN CAVITATION EROSION RESISTANCE OF X2CrNiMoN22-5-3 DUPLEX STAINLESS STEEL BY LASER BEAM NITRATION

MICU Lavinia Madalina[1], MITELEA Ion[2], BORDEASU Ilare[3], CRACIUNESCU Corneliu Marius[4], OANCA Octavian Victor[5]

„Polytechnica" Universty of Timisoara, Timisoara, Romania, EU
[1] lavimicu@yahoo.com, [2] ion.mitelea@upt.ro, [3] ilarica59@gmail.com, [4] craciunescucm@yahoo.com,
[5] octavian.oanca@yahoo.com

Abstract

Currently, one of the modern techniques for improving the surface properties of the stainless steel is the nitrating thermo chemical treatment. The research conducted in this paper aims at forming coatings with high hardness on the surface of Duplex stainless steel X2CrNiMoN22-5-3. This material was subjected to laser beam nitrating by using three pulse power regimes (240 W, 180 W, and 120 W). To highlight the effect of the behavior of the thermo chemical treatment upon details functioning in cavitation, for comparisons, there were used the results on the same steel, heat-treated only by quenching. The cavitation erosion resistance was highlighted by tracing erosion diagrams (expressing the variation of mass loss in time) as well as by the images of macro - and micro-system layer - substrate. The results showed that the change in the pulse power of the laser beam from 120 W to 240 W, lead to an increase in the depth of the nitrogen-enriched layer from 0.14 to 0.20 mm, at the same time increasing the resistance to cavitation with about 42 % if it is referred to the cumulative mass loss and by 35% when the erosion rate was taken into consideration.

Keywords: Duplex stainless steel, cavitation erosion resistance**,** laser beam nitration

1. INTRODUCTION

Because X2CrNiMoN22-5-3 Duplex stainless steel is widely used in all industrial fields and especially in the construction of naval equipment, researchers [3, 4, 6] constantly sought new ways to improve the stability of these types of steels to pitting corrosion, fatigue, cavitation, etc. The research conducted in this paper has the aim to increase of the wear resistance at cavitation, applying laser beam thermo chemical nitrating treatment. To highlight the effect of this treatment on the behavior of details which are subjected to cavitation, for comparison, we used the results of the same steels, treated only by quenching (heating to 1060 °C and water cooling).

2. MATERIAL, METHODS AND APPARATUS USED FOR RESEARCH

The chemical composition of the examined steel is shown in **Table 1** and the mechanical characteristics determined by the tensile tests, at room temperature are presented in **Table 2.**

Table 1 Chemical composition of the investigated steel in mass %

C	Mn	P	S	Si	Ni	Cr	Mo	N
0.017	1.837	0.024	0.0002	0.313	5.019	22.083	2.585	0.1502

Table 2 Mechanical characteristics of the investigated steel

$YS_{p0.2}$ [MPa]	TS [MPas]	El.5 [%]
570	736	34

The specimens surfaces exposed to cavitation erosions, were subjected to a thermo chemical nitrating treatment (**Figure 1**) using a programmable pulsed Nd-YAG laser, which equips the Trumpf HL 124 P LCU device (**Figure 2**). This treatment has the purpose to form layers with high hardness, which gives an improved resistance to cavitation erosion.

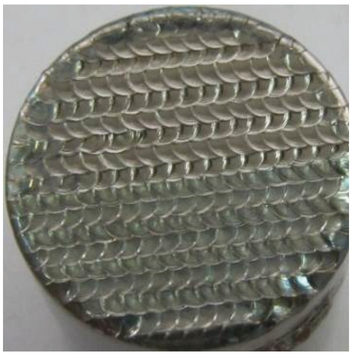

Figure 1 Specimen with a layer of nitride putted with 240 W

Figure 2 The station Trumpf HL 124 P LCU

Figure 3 T2 Standard vibration station with ceramic crystals

The laser beam moved on the sample surface at a speed of 4.07 mm/s for 10 ms, in an atmosphere of pure nitrogen with a flow capacity of 33 l / min. The pulse power was different, depending on the selected mode, as follows:

- The first set of samples was exposed to 240 W.
- The second set of samples was exposed to 180 W.
- The third set of samples was exposed to 120 W.

In order to analyze the effect of the thermo chemical treatment on the cavitation resistance, the treated samples were subjected to a controlled cavitation attack (in distinct time periods, according to Laboratory customs [1, 2, 5 and 9], for a total length of 165 minutes) in the Cavitation Laboratory of the Timisoara Polytechnic University (**Figure 3**). To obtain the cavitations erosion specific curves M (t) and v (t) after each testing period was determined the weight of eroded mass, using high precision analytical balances. To highlight the effect of laser nitrating were used for comparison, the results of investigations made on the same steel, heat treated only by quenching [6, 7].

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. Results of cavitation tests

Cumulative mass loss curves as well as the erosion rate curves are shown in **Figures 4, 5**, using the experimental values obtained for each attack period. Analyzing and comparing the mediation curves presented in **Figures 4, 5** there results the following conclusions:

- Irrespective of the laser beam regime, the scatter of the experimental points around the mediation curve is very small, indicating that the area attacked by cavitation is homogeneous in terms of mechanical properties, responsible for the behaviour to cavitation erosion resistance;
- the quenching heat treatment currently applied for this steel gives a relatively low increase to cavitation erosion resistance, the lost mass is much more intense in comparison to the nitrating laser treatment, regardless of the power values for the pulsed beam;

- the scatter of the experimental data and the shape of the curves is given not only to the mechanical characteristics of nitride layer but is also a result of the constancy of the treatment process parameters such as pulse duration, frequency and power;
- whatever is the parameter chosen for characterizing the resistance at cavitation erosion (depth cumulative average in 165 minutes of exposure to cavitation, **Figure 4**, or the rate value for which erosion become stable) is was found that nitrating at 240 W laser beam produces the most important increase (by 81% compared to the hardening heat treatment, approximately 45 % compared to 120 W nitrating and by about 31 % compared to 180 W);
- From the three sets of samples the laser nitride, performed with a pulse power of 120 W produce the lowest increase, but it remains still important in comparison with the volume quenching, the increase being of approximately 61 %.

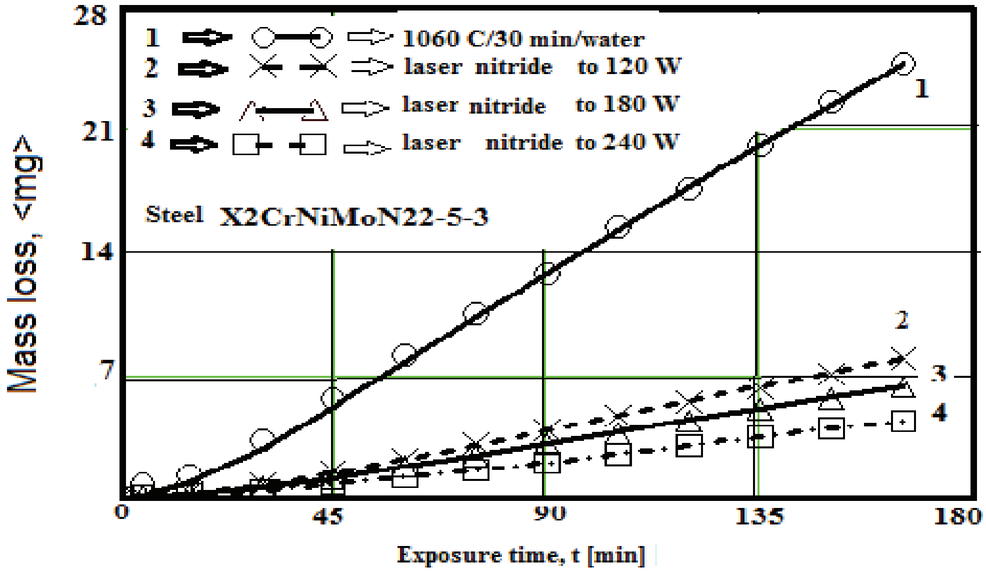

Figure 4 Mass loss variation against the exposure duration of the cavitation attack

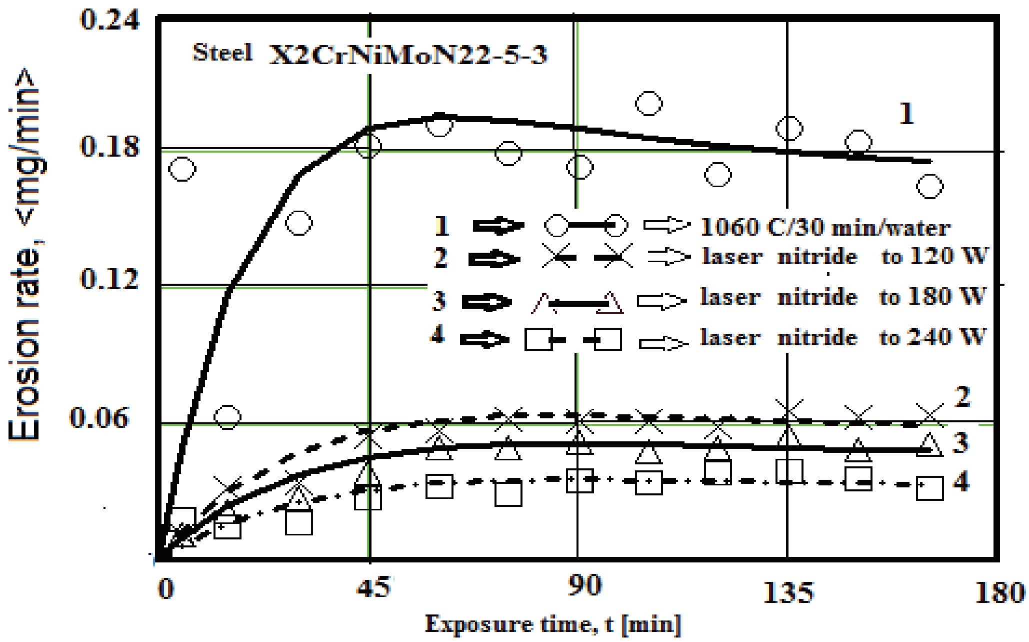

Figure 5 Rate of erosion against the exposure duration of the cavitation attack

3.2. Discussion upon the morphology of surface degradation by cavitation erosion

After each period of cavitation attack images of the surface were obtained by using a Canon Power Shot camera SX200 IS. The results are presented in **Figure 6** and they also highlight the manner in which degradation phenomena is extended on the whole exposed area. For the variants treated by laser nitrating may be noted that with increasing duration of attack the surface became dull and roughness tops are diminished. The effect of hardness created by the beam, after the 165-minute attack is very noticeable compared with circular degraded samples hardened surface, where pitting is dispersed evenly over the entire eroded surface. All the images show that using a power of 240 W generates a resistant layer to cavitation erosion.

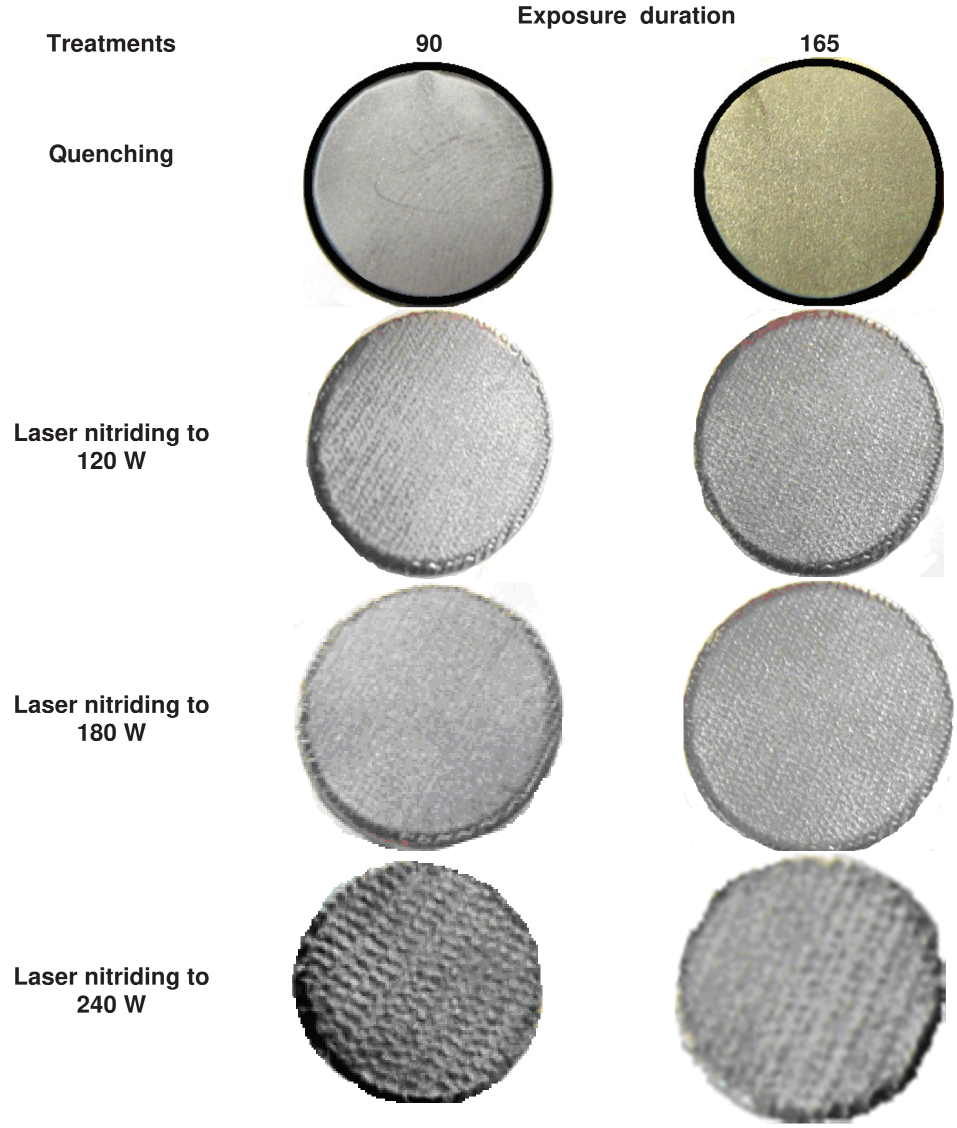

Figure 6 Macro graphic images of the surfaces tested at various time

Metallographic examination of cross-sections through cavitation test sample **(Figure 7**) shows that the surface layer has good metallurgical bond with the basic material and that there are no signals of continuity metal defects. Primary crystallization structure developed from the basic metal grains in a columnar manner. In this way is justified the epitaxial growth of crystalline grains in the melted zone by the laser beam. The material pits occur mainly at the separation limits between the two constituent phases (ferrite and austenite) and especially on the inside of ferrite grains.

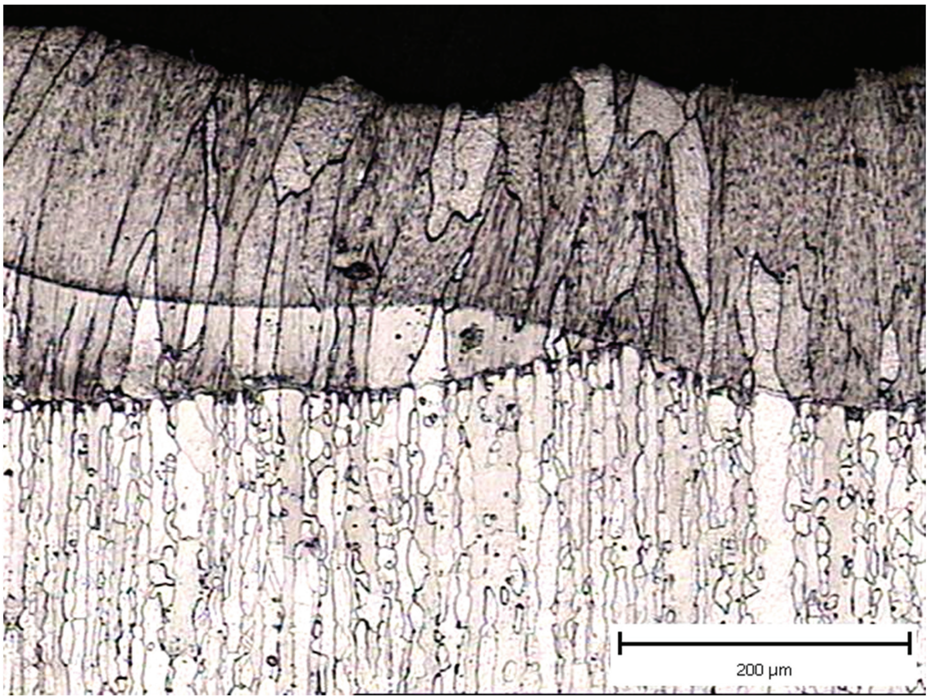

Figure 7 Micrograph image of a section through the nitride laser sample (240 W) after cavitation

4. CONCLUSIONS

Thermo chemical nitriding treatment of laser 120 W duplex stainless steels causes a decrease by approx. 61% rate of erosion for parts working under cavitation. Increasing the power of the laser impulse is manifested by a significant increase in resistance to cavitation erosion (the increase is about 31 % for 240 W in comparison with 180 W and approx. with 45 % in comparison with 120 W).

Regardless of the power pulse, the thermo chemical laser nitrating treatment provides a higher cavitation erosion resistance in comparison with volume quenching for putting into solution. For 180 W this increase is with 81 % greater than that for volume quenching.

ACKNOWLEDGEMENTS

The support from the strategic grant of the Ministry of Labor, Family and Social Protection, Romania, co-financed by the European Social Fund-Investing in People, within the Sectoral Operational Programme Human Resources Development 2007-2013 (POSDRU/159/1.5/S/137070-2014).

REFERENCES

[1] BORDEAŞU, I. Eroziunea cavitaţională a materialelo. 1st ed. Timişoara: Editura Politehnica Timişoara, 2006. 15 p.

[2] FRANK, J.P., MICHEL, J.M. Fundamentals of cavitation. 1st ed. Dordrecht/Boston/London: Kluwer Academic Publishers, 2004. 123 p.

[3] GARCIA, R., HAMMITT, F. G., NYSTROM, R.E. Corelation of cavitation damage with other material and fluid propertie. Erosion by Cavitation or Impingement. 1st ed. Atlantic City: ASTM, STP 408, 1960, 189 p.

[4] HAMMITT, F.G. Cavitation and Multiphase Flow Phenomen. 1st ed. New York: McGraw Hill International Book Company, 1980. 198 p.

[5] WARREN, A.D., GRIFFITHS, I.J. , HAMIMAN, R.L., FLEWITT, P.E.J. , SCOTT, T.B. The role of ferrite in type 316H austenitic stainless steels to creep cavitation. Materials Science and Engineering A, 2015, vol. 635, pp. 59-69.

[6] MICU, L.M., MITELEA, I., BORDEAŞU, I., CRACIUNESCU, C.M., OANCA, V.O. The transformations morphology by cavitation erosion of gas nitrited X2CrNiMoN 22-5-3 Duplex stainless steel. In METAL 2015: 24th International Conference on Metallurgy and Materials, Ostrava: TANGER, 2015, pp. 785 - 790.

[7] NIEDERHOFER, P., HUTH, S. Cavitation erosion resistance of high interstitial CrMnCN austenitic stainless steels. Wear, 2013, vol. 301, pp.457-466.

[8] TONG, W., NING, X., HANJIE, S., XINGYUE, Y. The effect of chloride ions on the corroded surface layer of 00CrNi5Mo3N Duplex stainless steel under cavitation. Ultrasonics Sonochemistry, 2016, vol. 33, pp. 1 - 9.

[9] *** Standard test method for cavitation erosion using vibratory apparatus ASTM G32-2010.