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NANOSTRUCTURED SURFACE FOR 38MoCrAl09 STEEL BY NITRIDING IN NITROGEN ATMOSPHERE AND YAG:Nd PULSE LASER ACTIVATION

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ABSTRACT

YAG:Nd pulse laser is usually used for cutting and welding. The paper is based by experiments using YAG:Nd pulse laser (KVANT 17-CIS made). Technological modules were assembled for laser beam deviation and for relative sample moving to manual controlled focused laser beam. In experiments was used a personal computer with adequate program for x-y sample moving (stepper system) and correlation with laser pulse. Steel sample (nitralloy steel) was fixed in nitriding chamber in a nitrogen flow. Defocused, laser beam energy and nitrogen pressure were modified. Hardness (HV5), macrostructure and microstructure were used for surface properties investigations.

KEYWORDS: *pulse laser, YAG:Nd, nitriding, steel*

1. Introduction

Thermo chemical treatment is based an surface chemical compositions changes under specific thermodynamic conditions only for surface layer. A duplex treatment CVD and diffusion are usually used for increasing surface concentration with one or more alloying elements. Processes activation (CVD and diffusion) are energetically made. Heating in a chemical active media is a common procedure. Laser radiation interaction with surface is a complex process in that thermal effect is important. Usual laser applications are based on intense thermal effect characterised by higher heating speed and lower heated surface. Laser cutting and welding describe these local and intense energetic interactions. This interaction may be converted in large surface interactions through additive procedure that represents a successive and relative moving of laser beam over material surface.

2. Experimental conditions

Nitriding experiments were based on KVANT 17 YAG:Nd pulse laser (CIS designed for cutting in oxygen plasma and point to point welding). Some important characteristics are: two units with solid dopped glass YAG:Nd (6.3 mm diameter, 100 mm long), homogeneus and heterogeneous metallic cutting up to 0.8 mm thickness, total power 12kW, double cooling system, 0...1000V voltage for optical pumping system, variable pulse frequency system, max. 0.5% pulse to pulse energy difference, interactions trace 0. 2...1.2 mm, circular deviations on trace max. 20%, inert gas (Ar, He) adding system, efficiency 2...5%. Laser energy was controlled by dc suply voltage in range 0...1000 V. An additional technological module (Fig. 1) was manufactured for x-y sample moving in range 20x20 mm and total interaction surface 400 mm^2. For KVANT 17 YAG:Nd pulse laser different pulse regime is valuable: variable frequency (fixed preset values), giant pulse and external command pulse. The technological unit was designed and manufactured by Dept. of Metallurgy and Materials Science, Dunărea de Jos University of Galaţi, for surface engeneering aplications, other like cutting and welding (Fig. 2). The technological unit was designed for: laser beam deviation (45^o), manual focused and step by step sample moving in Ox or Oy axes. The result of samples moves is a large surface of interactions. For nitriding a lower weight chamber was designed for local interactions media (air, nitrogen and other gases and gas mixture.

Laser beam is focused to sample surface through glass window.

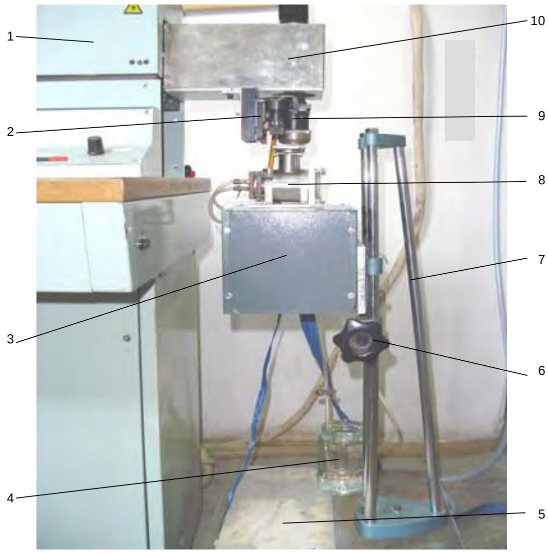


***Fig. 1**. Technological unit: 1 - laser; 2 – screw defocused; 3 – x/y plate; 4 - water; 5 – concrete block; 6 – screw x-y gross control ; 7 - support; 8 – nitriding space; 9 - objective; 10 – laser beam deviation mirror.*

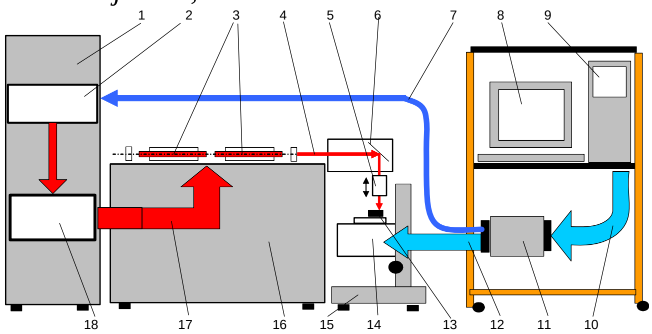


***Fig. 2**. PC controlled sample x-y moving a laser pulse: 1-SPIK force module, 2-Pulse control module, 3-laser units, 4-laser beam, 5-objective, 6-45^{o}deflection mirror, 7-frequency pulse control line, 8-display-9-PC, 10-parralel port communication, 11-optoisolator, 12-stepper line impulse, 13-x-y table, 14-steppers module, 15-concrete block, 16-laser module, 17-optical pumping connection, 18-high voltage optical pumping supply*

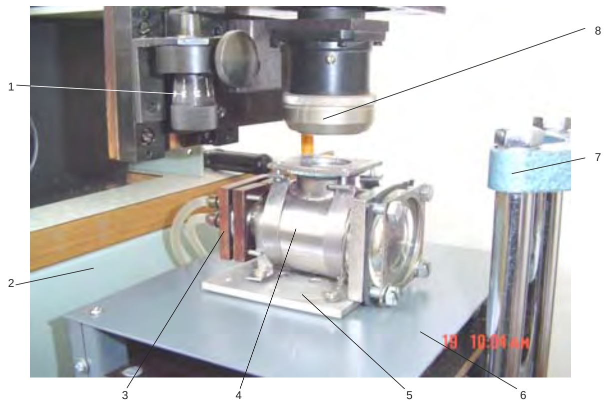


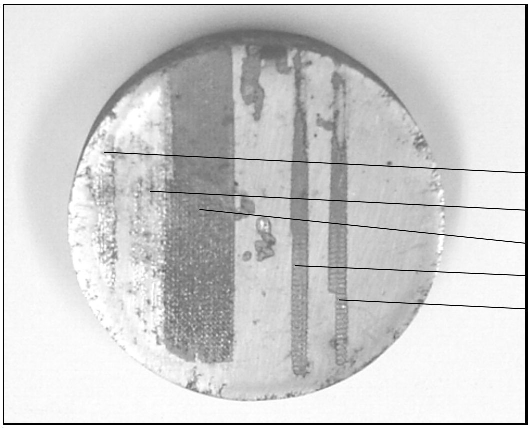
***Fig. 3**. Nitriding in nitrogen chamber and pulse laser activation: 1 – screw defocused control; 2 – laser module; 3 – nitrogen inlet and outlet; 4 – nitriding chamber; 5 – x-y table; 6 – x-y stepper module; 7 - support; 8 – IR objective*

Table 1. *Nitralloy steel (38MoCrNi Al09) chemical composition (mass%)*

C	Mn	Si	Cr	Ni	Mo	Al
0,35--0,42	0,30--0,6	0,17--0,37	1,35--1,65	-	0,15--0,3	Al=0,70…1,

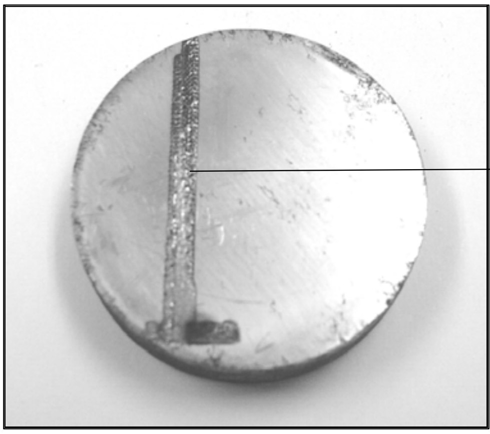
Another window is present for visual control of interactions. A computer program was designed for scanning sample surface through correlated pulses for x-y table and laser pulse command.

For experiments were used samples from 38MoCrAl09 (nitralloy steel class). This steel having and excelent behavior over gas nitriding treatment for part machine steel (850…1050, HV after nitriding at 500…600°C). Surface properties like hardness, fatigue and corrosion increasing and that induces good properties and performances (hardness, fatigue and corrosion).



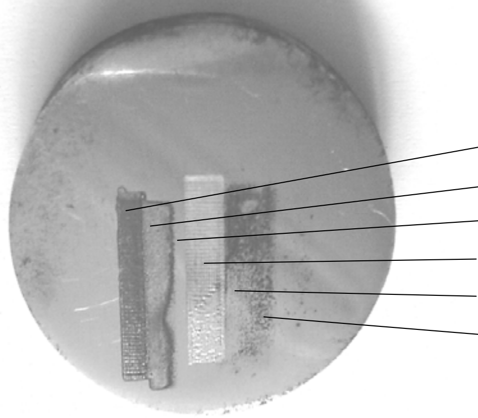
experiment	tensiune de acumulare	presiune N2
um	V	bar
1	700	-
2	750	-
3	750	0,5
4	800	0,5
5	850	-

Fig. 4 *Interaction surfaces for Disk 1- side 1 (experiments no.1 to no.5)*



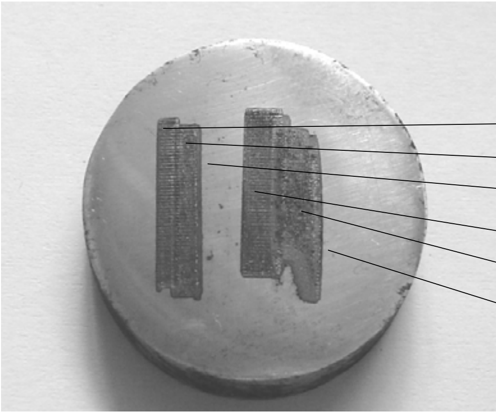
experiment	tensiune de acumulare	presiune N2
um	V	bar
6	700	-

Fig. 5 *Interaction surfaces for Disk 1- side 2 (experiment no.6)*



experiment	tensiune de acumulare	defocalizare	presiune N2
um	V	mm	bar
1	700	0	0,5
2	700	5	0,5
3	700	10	0,5
4	800	0	0,5
5	800	5	0,5
6	800	10	0,5

Fig. 6 *Interaction surfaces for Disk 2- side 2 (experiment no.1 to no.6)*



experiment	tensiune de acumulare	defocalizare	presiune N2
um	V	mm	bar
7	700	0	aer
8	700	5	aer
9	700	10	aer
10	800	0	aer
11	800	5	aer
12	800	10	aer

Fig. 7*. Interaction surfaces for Disk 2- side 2 (experiment no.6 to no.12)*

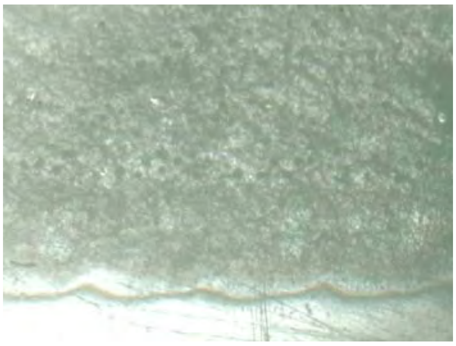


Fig. 8*. Macrograph samples surface for experiment 3-disk 1, magnitude 100x*

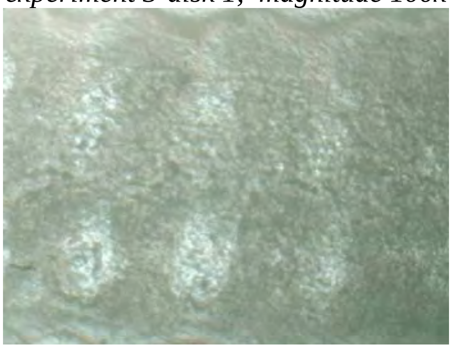


Fig. 9*. Macrograph samples surface for experiment 4-disk 1, magnitude 100x*

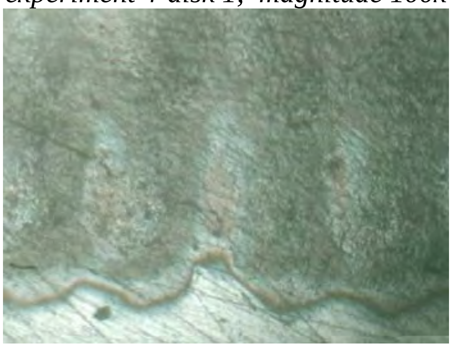


Fig. 10*. Macrograph samples surface for experiment 5-disk 1, magnitude 100x*

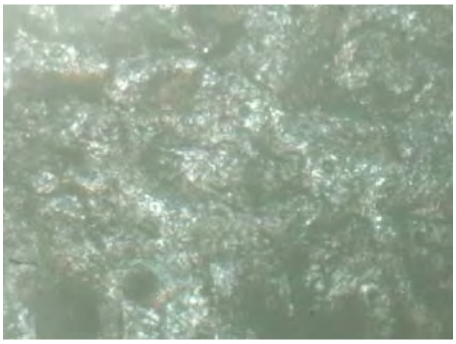


Fig. 11*. Macrograph samples surface for (experiment 6- disk 1), magnitude 100x*

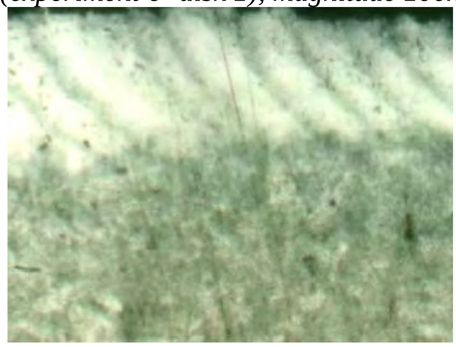


Fig. 12*. Micrograph samples surface for experiment 1, disk 1, and magnitude 300x.*

Fig. 13*. Micrograph samples surface for experiment 10, disk 2 and magnitude 100x.*

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Table 2. *Experimental conditions and surface hardness after experiments*

Sample		Experiment	Charging voltage	Defocused	N_2 pressure/ air	Hardness (HV_5)	Observation
		um	V	mm	Pa	daN/mm^2	-
disk 1	surface 1	1	700	0	$1{,}013x10^5$	381	
		2	750	0	$1{,}013x10^5$	532	
		3	750	0	$1{,}513x10^5$	303	no interaction
		4	800	0	$1{,}513x10^5$	418	
		5	850	0	$1{,}013x10^5$	441	
	surface 2	6	700	0	$1{,}013x10^5$	303	
disk 2	surface 1	1	700	0	$1{,}513x10^5$	381	
		2	700	5	$1{,}513x10^5$	532	
		3	700	10	$1{,}513x10^5$	303	no interaction
		4	800	0	$1{,}513x10^5$	289	
		5	800	5	$1{,}513x10^5$	441	
		6	800	10	$1{,}513x10^5$	303	no interaction
	surface 2	7	700	0	$1{,}013x10^5$	429	
		8	700	5	$1{,}013x10^5$	391	
		9	700	10	$1{,}013x10^5$	303	no interaction
		10	800	0	$1{,}013x10^5$	623	
		11	800	5	$1{,}013x10^5$	325	
		12	800	10	$1{,}013x10^5$	303	no interaction

Chemical composition for steel samples is shown in Table 1. Samples surface after nitriding treatments in nitrogen and laser pulse activation is shown in Fig.4...Fig.7.

2. Results

After *laser/samples surface interactions*, superficial morphologies have different changes depending on values of control factors. For each experiment, interaction conditions and results are shown in *Table 2.* Superficial properties changes after nitriding experiments were go through Vickers hardness (HV_5, load 5kgf) and results are shown in Fig 14 and Fig 15. Micrographs of 38MoCrAl0 steel after nitriding in nitrogen atmosphere activated by YAG:Nd are shown in Fig.12 and Fig.13. A specific superposition structure is present as a result of intense laser beam surface interactions, bigger than 10% (recommended value).

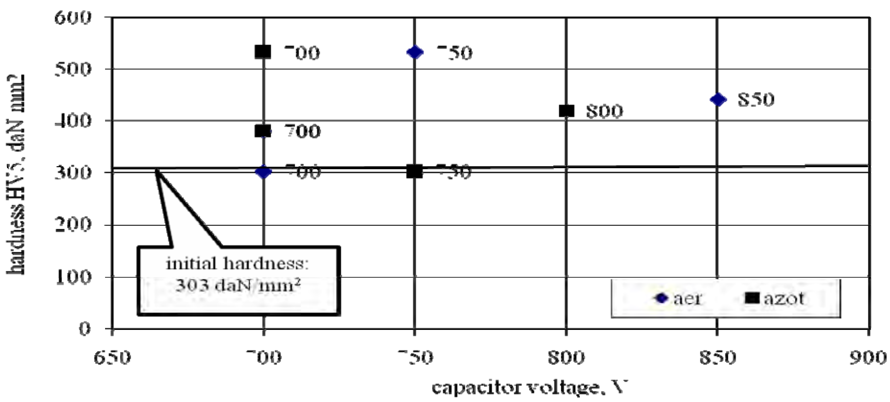

Fig 14. *Surface hardness HV_5 after nitriding experiments no.1 to no.6 (disk1)*

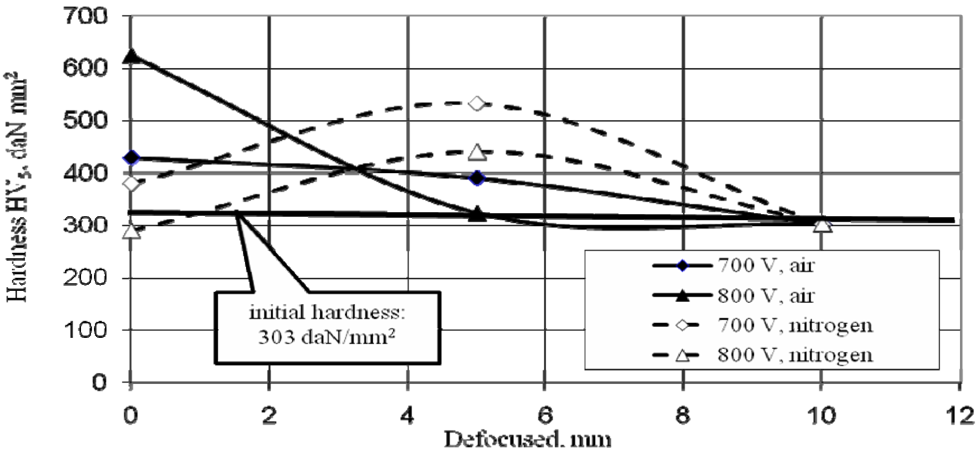

***Fig.15**. Surface hardness HV_5 for experiments no.1 to no.12 (disk 2).*

A white nanostructured layer was formed by fine dispersed martensite (Fig 12 and Fig 12). Heating and cooling processes with high speed in layer determined higher nucleation speed and lower increasing speed.

Conclusions

Laser beam interactions with 38MoCrAl09 depend on pulse radiation energy (indirect measurement from optical pumping high voltage), defocused, chemical composition of chamber atmosphere, atmosphere pressure and optical surface properties of sample steel.

For identical values of influence factors, less chemical composition of chamber atmosphere, an increasing surface hardness were obtained because nitrogen atmosphere was activated locally in interactions volume and nitriding treatment was present (experiments 2, 5, 8 and 11, disk 2). For a higher defocused the specific local density of energy was lower and interactions are lower (surface hardness is comparable with initial values (303 daN/mm^2). PC control of scanning and laser pulse determined a higher surface uniformity after local nitriding treatment. Interactions magnitude was influenced by laser energy and defocused laser beam. For 5 mm defocused and e laser energy in correspondence with 700V …800 V condensator voltages a maximum were obtained. The hardness difference was determined by nitrogen pressure that implied a complex *carbone-nitrogen- alloying elements* formations.

The nitriding process in nitrogen atmosphere may be applied for small surface treatments designed for over demand values in exploitation of machine parts.

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