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RESEARCH CONCERNING THE INFLUENCE OF LASER CLADDING ON THE OPERATING CHARACTERSITICS OF THE SURFACE LAYERS OBTAINED FROM HIGH-SPEED STEEL POWDER

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ABSTRACT

The paper presents the corrosion behavior of laser cladding layers in 0.5 M NaCl along with a durability test, compared with samples made of clasically hardened HS6-5-2 steel. The higher characteristics of the laser deposited layers have been underlined while recommending the procedure of parts highly required to wear and corrosion.

KEYWORDS: laser cladding, high-speed steel, tool, powder injection, corrosion

1. Introduction

Theoretical and practical studies have lately been established to implement new surface hardening techniques associated with a corresponding increase in resistance to corrosion. Out of them, laser cladding captures the experts' attention as it was found that this leads to ultrafine structures, extremely hard and tenacious, characterized by a mix of properties superior to those obtained by conventional treatments.

In case of making the lathe tool of high-speed steel, an important part of tool body is not used during the facing process but only for setting it into the tool machine. A solution that removes this disadvantage is represented by cladding [1, 2, 3, 4, 5, 6] the high - speed steel in the active area of lathe tool made by carbon steel.

Therefore, the multilayer cladding was made by high-speed steel powder injection in melt bath by CO_2 continuous wave laser connected to x-y-z coordinate table. High-speed steel powder as addition material mainly with 0.82%C, 4.7%Mo, 6.4%W, 4.1%Cr, 2.02%V, 0.3%Mn was used as prior researches emphasized a higher capacity of this material to be quenched since liquid phase, like specific case in laser cladding. Carbon steel with 0.45% C was used like base material. Optimal running found by laboratory testes were used in order to make several lather tools by laser cladding. These lathe tools presented a good behavior when steel facing.

To provide a complete characterization of the laser claddind layers with high-speed steel powder, corrosion behavior was studied using the potentiodynamic method (polarization curves plotting) for determining the corrosion potential (Ecor), maximum corrosion current intensity (Icor) and polarization resistance (Rp).

The potentiodynamic tests aim to plot the polarization curves by varying the current density according to the potential. Proportionality between potential and current density arises from the overlap of the two cathodic and anodic processes, both obeying the logarithmic laws. In a corrosion process, the two reactions occur on the same metal surface, equipotential, so that the experimental measurements will give values that correspond to the potential and anodic and cathodic current density, i.e. mixed values. Mixed potential and corresponding current intensity are also called corrosion potential, and corrosion current density respectively. The potentiodynamic method implies modification of the electrode potential continuously at a preset scanning speed. The paper presents the behavior of laser deposited layers of high-speed steel powder type HS6-5-2 - M2 to corrosion in 0.5 M NaCl solution and a durability test using longitudinal turning with constant cutting speed without using cooling.

The researches were carried out to compare with high-speed steel samples classically treated in volume.

2. Experimental conditions

„M2 Coldstream B-7800, Sweden" powder with 0.82%C, 4.7%Mo, 6.4%W, 0.3%Mn, 4.1%Cr, 0.32%Si, 2.02%V, Fe balance, as chemical composition for cladding was used. By sieving the granulometric fractions, inside the 80÷90µm range, were separated in order to be used as addition material. Powder had spherical shape, therefore, it provided a fluid floating of addition material through the injection system. Powder dried at 110^{o}C for 15 minutes before addition material feeding inside the injection system tank.

Laboratory trials were performed in a CO_2 continuous wave laser installation as GT type of 1400 W (made in Romania), with coordinate working table and running computer program, provided by dust injection system onto laser melted surface.

For laser cladding it was used a 1.8mm diameter laser beam with 1100 W power, 7mm/s sweeping speed, which cladded parallel overlapped stripes with 1.5mm cross travel pass. Addition material flow was 251mg/s. Final thickness of the cladding layer was 3.5 mm resulted by 5 layers overlapping.

Determining susceptibility to corrosion was achieved at room temperature (24°C) using a Voltalab 21 system connected to a computer using a VoltaMaster 4 software for exprimental data processing.

The potentiostate is connected to the electrochemical cell by three electrodes: reference electrode, auxiliary electrode and working electrode. In the experimental determinations as reference electrode was used a saturated calomel electrode Hg/Hg_2Cl_2/ saturated K_2SO_4, (SCE = +241 mV/EHS), and as auxiliary electrode (counterelectrod) a platinum electrode.

The working electrode, that is the laser cladding samples on nickel base have been previouly prepared, polished, made shiny and degreased in accordance with ASTM G1 standard. To study only the behavior of the laser deposited layers, non treated areas were covered with a protective lacquer. Also, the surface submerged into solution was measured and data were entered in program.

Thus polarization curves were obtained to assess the corrosion behavior of the high-speed steel powder laser - cladded layer and volume - thermally treated sample.

For the experimental research to determine the durability of the lathe tool on which powder laser deposition of high - speed was carried out, the method of longitudinal turning with constant cutting speed without cooling was applied. Its behavior was studied in comparison with a lathe tool made from HS6-5-2 steel subjected to special treatment in volume.

The laser deposition with high - speed steel on the lathe leading edge was achieved by a laboratory technology according to the required geometry. After the high - speed steel deposition in a 3.5mm thick layer on each cutting tool, a cooling treatment at -60°C was aplied to reduce the amount of residual austenite. The treatment of double annealing to 550°C was eliminated.

Testings were conducted at three different speeds 40, 60, 80m/min to see how the cutting speed influences the lathe tools durability.

The material subject to cutting was steel 1C45, Ǿ 42mm diameter, 340mm length, and 2011MPa hardness.

Longitudinal turning test was performed in following conditions: cutting depth t = 0.5mm, feed 0.075mm/rot, speed modified during the test to ensure a constant cutting speed was of the order of 250, 400, 500, 630, 1250rpm.

3. Experimental results and discussions

Corrosion results of the laser cladded layers of high speed steel M2 powder and those classically treated in volume are given in Table 1.

Table 1. *Results of corrosion of the samples*

Samples	Corrosion environment	Parameters achieved							
		E (i=0)	Rp	Icor	Ba	Bc	Corossion	Initial mass	Final mass
		[mV]	[Ω.cm^2]	[mA/cm^2]	[mV]		[mm/an]	[g]	
laser	NaCl, 0.5M	-774.4	12.97	0.0036	199.3	- 144.0	0.04257	2.9565	2.9526
classic	NaCl, 0.5M	-767.8	5980	0.0032	190.4	-133.3	0.03740	2.7708	2.7685

Note: E – corrosion potential; Rp – polarization rezistance; Icor – intensity of corrosion current; Ba, Bc – correspond to constants Tafel for anodic and cathodic reaction

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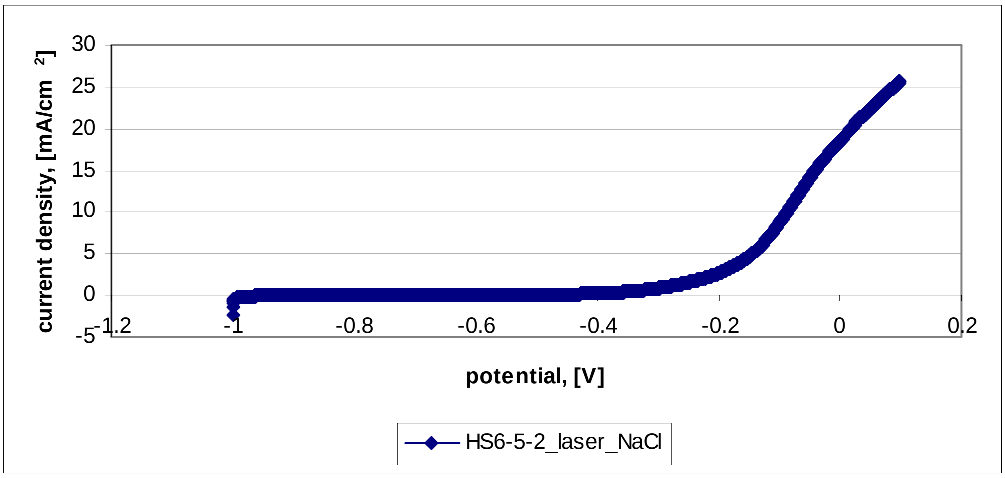
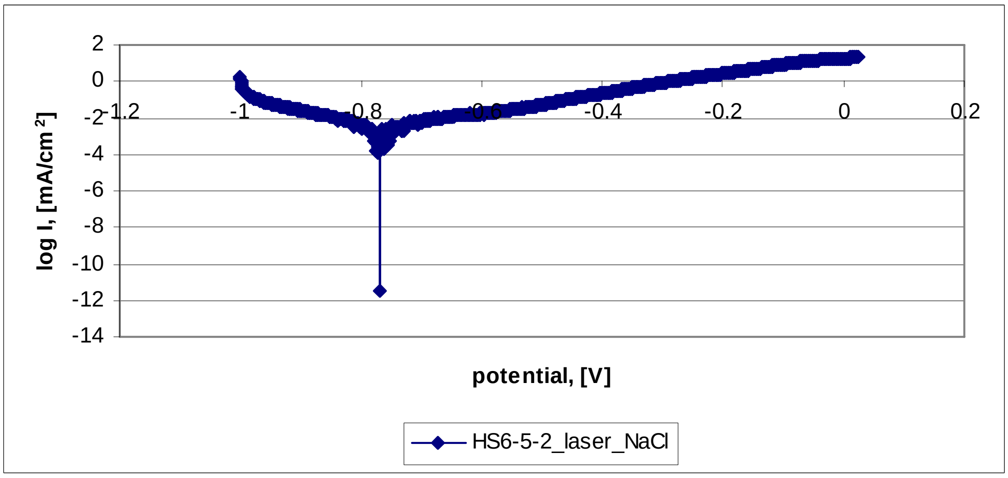


a.



b.

Fig.1. *The potentiodynamic curve – a) and Tafel curve - b) NaCl, 0,5 M environment*

Looking at Figure 1 it can be seen the presence of a passivation sector from potential - 0.9875 V – to potential -0.3844V. Thus the M2 high - speed steel powder deposition resists to corrosion over a wide range of potential. This could be subjected to localized corrosion (pitting) caused by the chloride ions.

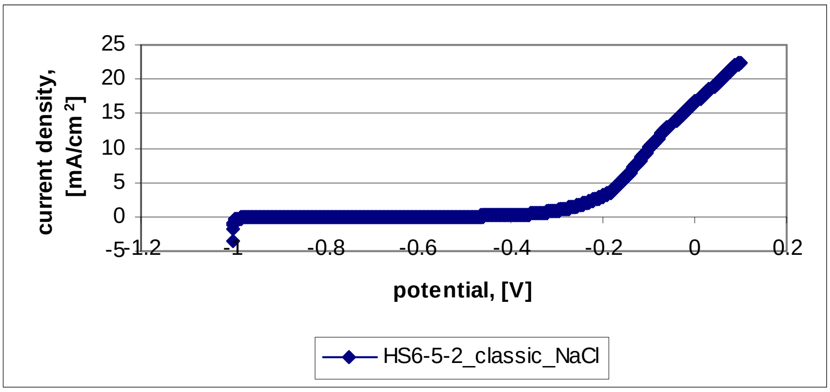
Analyzing Table 1 and Figure 1 b we can conclude that the laser deposited alloy is stable to corrosion in NaCl 0.5 M which is also indicated by the corrosion rate obtained.

Polarization resistance Rp is representative for the degree of protection provided by the layer deposited on the steel surface. The higher the polarization resistance, the more resistant the alloy and lower the $I_{cor.}$ Thus we can see that the polarization resistance is higher and the Icor is lower for the volume-treated quick steel sample which indicates that this presents a slightly better corrosion behavior compared with the laser deposited sample which, due to the presence of pores, is more susceptible to corrosion.

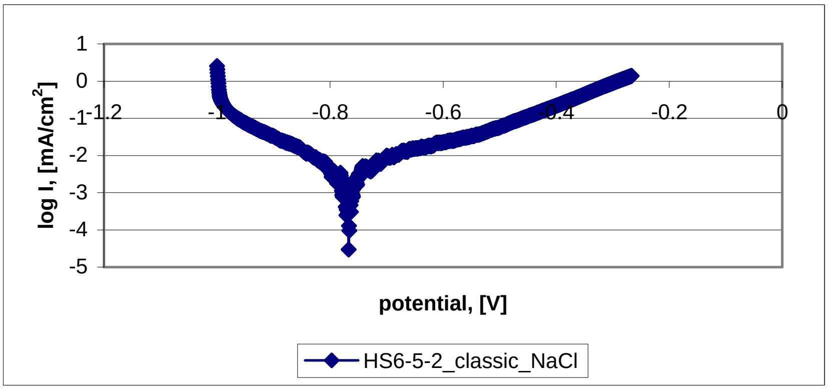
However differences between the corrosion rates are relatively small, therefore we can appreciate that the ultra fine structure of the laser deposit provides good corrosion behavior in NaCl 0.5M, medium, which is also seen in Figs. 3 and 4.

Looking at figure 2 it can be seen the presence of a passivation sector from potential from -0.959V – to -0.4282V.

Thus the M2 high -speed powder deposition resists to corrosion over a wide range of potential. This could be subjected to the pitting caused by chloride ions.



a.



b.

Fig. 2. *The potentiodynamic curve – a) and Tafel curve - b) NaCl, 0,5 M environment*

Analyzing Table 1 and Figure 2 b we can conclude that the high – speed steel classically hardened is stable to corrosion in NaCl 0.5 M which is also indicated by the corrosion rate obtained. Microstructures of the layers subjected to corrosion are given in Figs. 3 and 4.

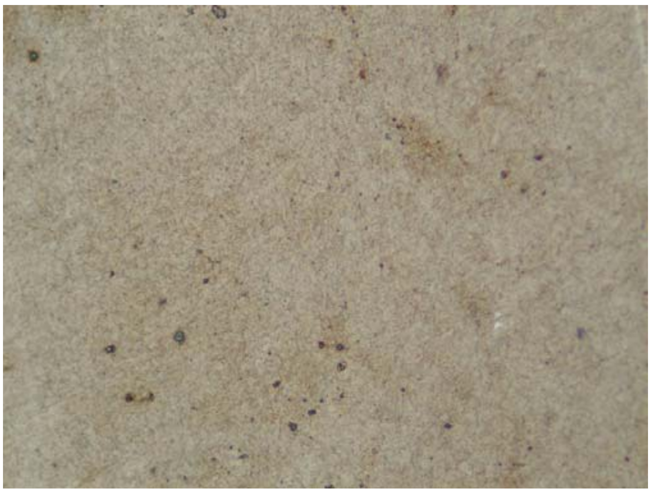


Fig. 3. *Microstructure of the laser cladding layer with powder of high-speed steel, subjected to corrosion in NaCl 0.5 M; (x500), nital attack 2%*

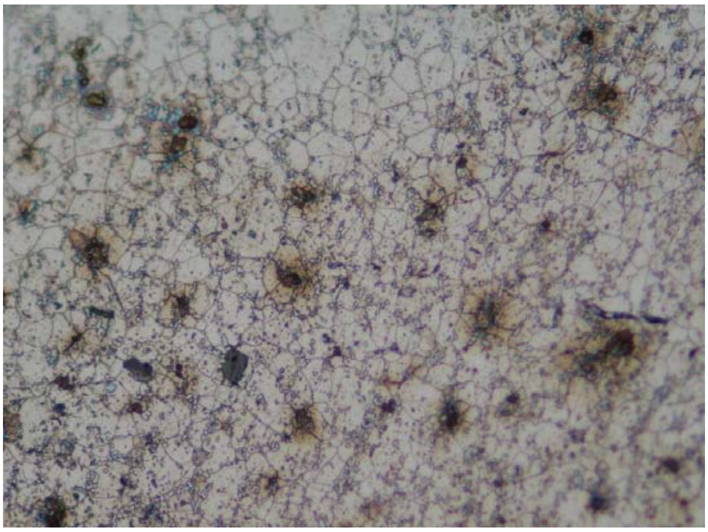


Fig. 4. *Microstructure of the classically treated high speed steel, subjected to corrosion in NaCl, 0.5 M; (x500), nital attack 2%*

Thus we can conclude that the results are comparable to the samples which show stable behavior to corrosion.

As regards durability test, the results provided by wear measurements on the lathe tool seat face are given in Table 2.

Table 2. *Results of durability tests*

No.	Cutting speed, v=40m/min	
	wear of classically quenching tool	**wear of laser cladded lathe tool**
	[μm]	
1.	49	31
2.	212	107
3.	231	120
4.	267	120
5.	280	136
6.	312	140
7.	488	266
	Cutting speed, v=60m/min	
1.	132	77
2.	180	104
3.	222	137
4.	365	231
5.	420	320
	Cutting speed, v=80m/min	
1.	333	280
2.	440	360
3.	500	420

It should be noted that for every change of speed, the lathe tool were resharpened.

Fig. 5 shows the lathe cutting edge on which laser deposition was conducted, in roughness state, after grinding (Fig. 6) and the longitudinal turning test (Fig. 7).

Fig. 8 illustrates the test results.

Fig. 5. *Semi-product after laser cladding*

Fig. 6. *Lathe tool after sharpening*

Fig. 7. *Longitudinal turning test*

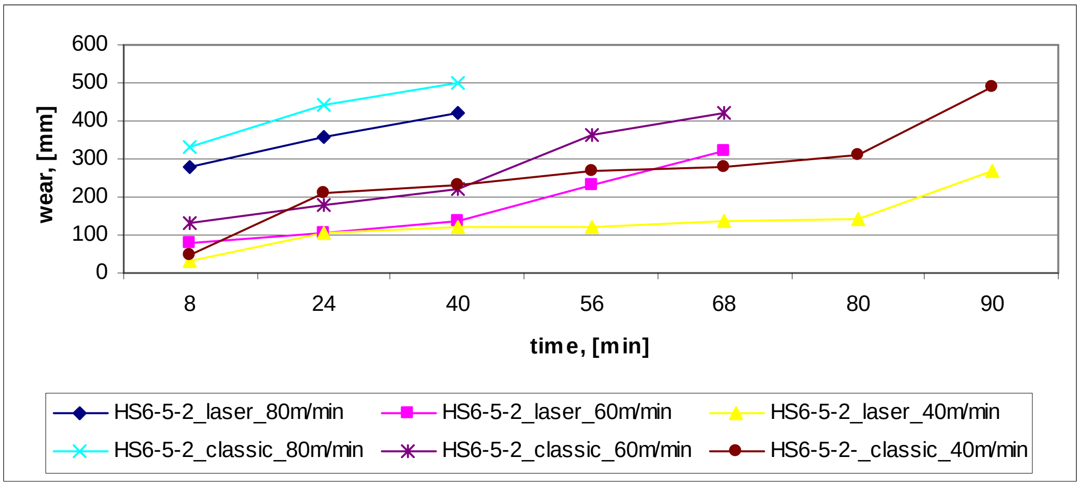


Fig. 8. *Wear vs. time variation of the blades tested to the speeds used during the test*

From Table 2 and Figure 8 the following can be concluded:

- for all speeds achieved the laser deposited lathe tool features higher durability than that of the volume heat-treated lathe tool;
- lathe tool wear increases with higer cutting speed, even more pregnant at 80m/min;
- the higher durability of the high - speed steel powder laser cladded lathe tool is due , on the one hand, to superior hardness to the volume treated lathe tool and on the other hand, due to the highest capacity of the lathe tool body (made from carbon steel) to dissipate heat from the active zone (heat conductivity of steel decreases with increasing alloying);
- the high hardness of the laser deposited lathe tool is due to the structure consisting of ultrafine, tough, tenacious, oversaturated martensite with no chemical non uniformities and a well developed substructure;
- the wear visible on the lathe tool surface concerned is of threshold type.

4. Conclusions

The corrosion behavior of the volume treated samples on which laser cladding was carried out showed that the results obtained are comparable to the samples showing a similarly stable behavior to corrosion.

Comparative durability test carried out on lathe tools classically treated and laser cladded reveals the following: the durability of the laser deposited lathe tool is superior to the classically treated one due to, on the one hand, its high hardness provided by the structure consisting of ultra-fine, tough, tenacious, oversaturated martnesite with no chemical uniformities and a well developed substructure, and on the other hand due to the highest capacity of the lathe tool body (made from carbon steel) to dissipate heat from the active zone (heat conductivity of steel decreases with increasing alloying).

Thus the laser deposition of the M2 high - speed steel powder is intended for parts highly required to wear and corrosion, as it provides a good mix of properties, superior to those obtained by volume heat treatments on the same steel grade (HS6-5-2).

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