LASER CLADDING OF HIGH-SPEED STEEL ON A STEEL SUPPORT

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ABSTRACT

Multilayer cladding by injection of high-speed steel powder with 0.82%C, 4.7%Mo, 6.4%W, 4.1%Cr, 2.02%V, 0.3%Mn, as chemical composition, in melted bath by CO_2 continuous wave laser connected to x-y-z coordinate table was tested in order to increase the wear resistance and heat proving of tool active surfaces made of 0.45%C steel. Layers made by different laser running were characterized by macro and microstructure analysis, as well as phase quality analysis by X ray diffractometry, microhardening analysis and hardness finding on coated layer surface in order to establish the optimal cladding run. Lathe tools made by this procedure showed a good behavior when steel shaping.

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

1. Introduction

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, 6, 7, 8] 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. [4].

Carbon steel 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.

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÷90 μm 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. Coatings were performed on 25 x 25 x 15 mm^3 samples made of 0.45% C carbon steel in improved condition.

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 laboratory tests an 1100 W power laser beam with 1.8 mm in diameter on machined surface was used, by which parallel strips partly superimposed cladded. Final cladding layer thickness resulted by superimposing of 5 layers. In order to establish the optimal laser deposit running the addition material flow and the sweeping speed of charging surface as well as transverse motion pass varied. In table 1 layers running conditions and thickness for several experimental running are given.

Table 1: *Experimental conditions and layers thickness.*

Code	AM flow [mg/s]	v [mm/s]	p [mm]	h [mm]
1	251	7	1.5	3.82
2	251	9	1.5	2.29
3	134	5	2	1.50
4	251	5	1.5	3.59
5	119	5	1.5	2.09
6	119	5	1	1.49
7	134	7	2	1.74

Note: AM - added material flow, v - sweeping speed, p - trransverse motion pass, h - layer thickness.

Cladded layers were tested by: macroscopic analysis on deposited layer surface as well as in cross section to laser processing direction after its metallographic preparation, chemical analysis by spectral methods, microstructure analysis and $HV_{0.98}$ (0.98N load) microhardness profile drafting in cross section of laser strips, phase quality analysis by X ray diffractometry to cladded layer surface using copper anticathode, single diffracted chroming beam, U=34kV, I=30mA, F_1=2mm, F_2=0.5mm, ω=1°/min, v_{strip}=720mm/h, at diffraction angle variation between 2θ = 20°....75° limits.

3. Results and Discussion

Macroscopic analysis pointed out the cladded surface quality, tightness, cladded layer thickness and its adherence onto support. Figures 1 and 2 show code 1, 2 and 3 code sample macrostructure having 3.82 mm, 2.29 mm and 1.50 mm in thickness, respectively. Thick layers with good adherence on support may be observed.

Fig. 1. *Samples cladded by thick layers of high-speed steel.*

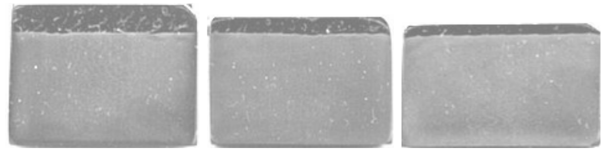

Fig. 2. *Macrostructures in cross section. Nital attack 2%.*

Chemical composition of laser claded layers surface is given in table 2 together with support composition (BM) and powder used as addition material (AM).

Table 2: *Chemical composition.*

Sample code	Chemical composition (%)				
	C	W	Mo	V	Cr
1	0.77	6.41	4.60	2.09	3.95
2	0.78	6.34	4.62	2.19	4.07
3	0.77	6.30	4.71	1.84	3.75
4	0.76	6.50	4.72	2.07	3.97
5	0.76	6.31	4.63	1.99	4.02
6	0.77	6.32	4.65	1.97	4.03
7	0.78	6.48	4.75	2.16	4.02
BM	0.49	-	-	-	0.19
AM	0.82	6.40	4.70	2.20	4.10

It was found the lack of any support influence upon chemical composition through cladded layer surface after five charging passes.

Dilution level resulted by support melting in order to achieve the support layer adherence may be found as a result of metallographic analysis by high multiplying, in orthogonal plan onto direction of strips generated by laser beam. Figure 3 shows, for sample 3, the cladded layer surface microstructure (CL), and figure 4 gives the cladded layer adherence area microstructure, of high-speed steel, on carbon steel support (BM). Throughout laser cladded cross section there is a dendrite structure with many carbides of wolfram, molybdenum, chrome and vanadium disposed between dendrites and at border of solid solution grains.

Good cladded layer adherence to support may be observed.

Tightness defects or non – metallic inclusions do not exist on diffusion border.

Dilution area (DA), resulted as a superficial support melting, which conducts to intermediary composition getting between cladded layer and support, is decreased. Measurements made by optical microscope empathized a dilution layer thickness of

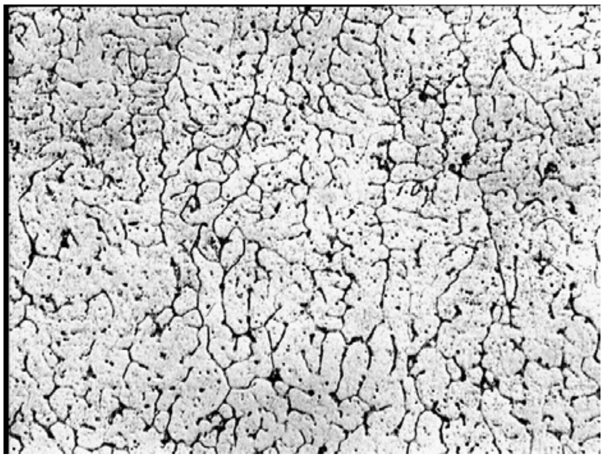

Fig. 3. *(x300) Sample 3. Laser cladded layer surface area microstructure. Nital attack 2%.*

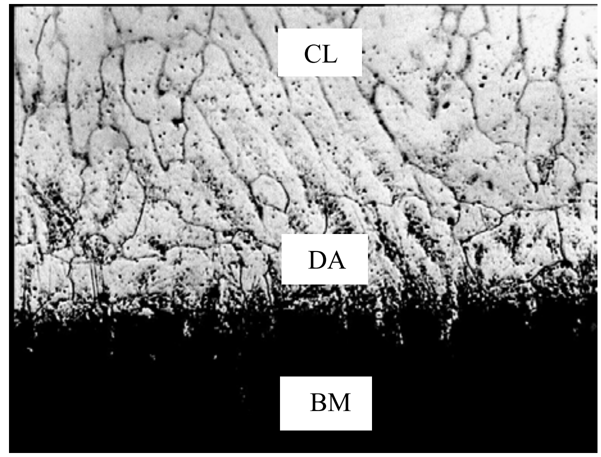

Fig. 4. *(x300) Sample 3. Adherence area microstructure of layer cladded to carbon steel support: BM - support; DA - dilution area; CL - cladded layer. Nital attack 2%.*

40 µm about. As layer was made by several passes, it was found a large granulation decreasing since fusion border toward surface, as a result of successive recrystallisation determined by repeated heating.

According to the quantity analysis (figure 5), cladding microstructure includes martensite, residual austenite and carbide eutectic colonies, main hardening base being the Cr_7C_3. In layer bottom may be seen a narrow dilution area that makes transition to the support material.

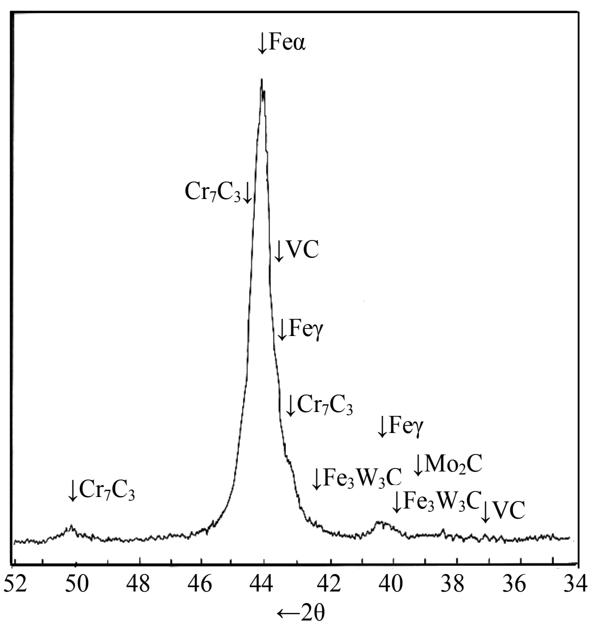

Fig. 5. *Fragment from diffractograme of high-speed*

$HV_{0.98}$ micro-hardness measurements generally confirmed the acknowledgements made on microstructure analysis, related to structural homogeneity of cladded layer and reduced dilution degree determined by the applied running. However, making a comparison between curves of micro-hardness variation on laser cladded layers depths on samples 3 and 6 (figure 6) processed by powder flow of 134 mg/s and 119 mg/s, respectively, in condition of steady keeping the other running parameters, a difference between dilution layer thickness resulted. Because of larger flow used to process sample code 3, the powder jet sucked a large quantity of laser beam energy intended to heat it up to melting. Therefore, a smaller quantity of energy was available to make melted baths that resulted with a smaller depth and found the minimum dilution.

HV_{49} hardness measurements pointed out higher hardness values than those measured on parts from same material, volume treated or superficially treated by laser [9]. Table 4 shows these measurements results.

Table 4. Cladded layer surface hardness.

Samples code	1,4, 5, 6	2, 3, 7
HV_{49} (MPa)	10130	10270

High-speed steel laser cladding on active surface of lathe tool was made by laboratory technology matching to the specific by the tool geometry assessed. A lot made of three identical tools was processed.

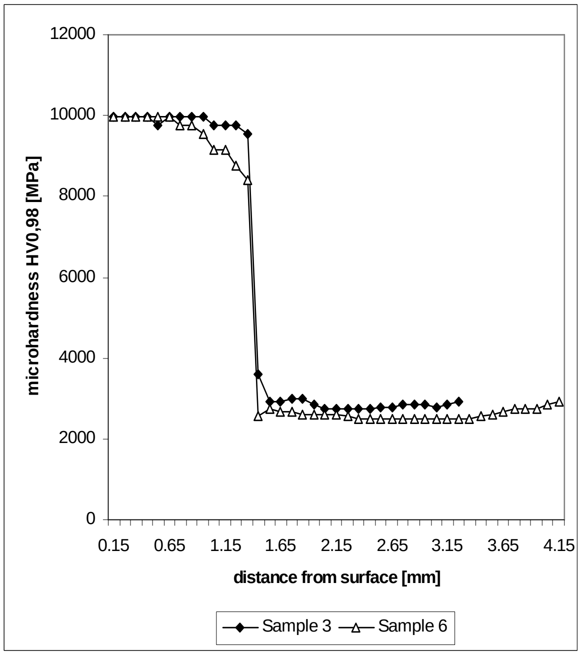

Fig. 6. *$HV_{0.98}$ hardness variation curves in laser cladded layer at samples 3 and 6.*

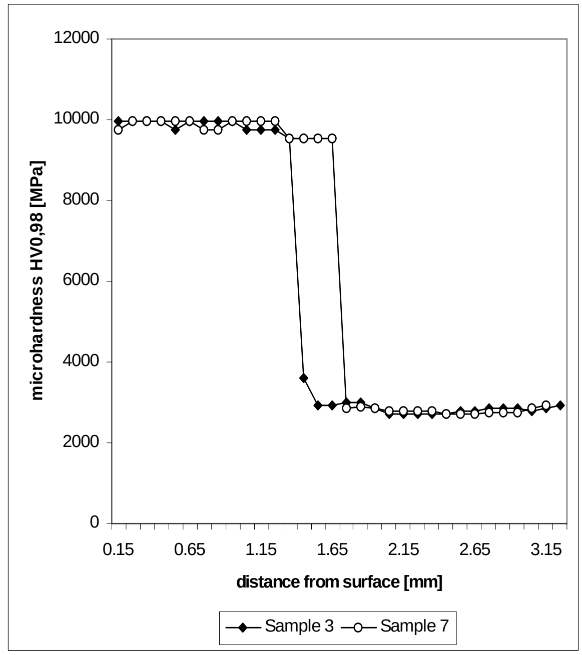

Fig. 7. *$HV_{0.98}$ hardness variation curves in laser cladded layer at samples 3 and 7.*

Fig. 8. *Semi-product after laser cladding.*

Fig. 9. *Lathe tool after sharpening.*

Fig. 10. *Longitudinal turning test.*

After cladding the high-speed steel in 3.5 mm thickness layers (figure 8) of each tool, these were submitted of a under cooling treatment to -60^oC, aiming to reduce the residual austenite quantity. 550^oC double annealing thermal treatment was eliminated.Comparation of microhardness variation curves got on samples 3 and 7 (figure7) that used the same powder volume but processed by different sample surface sweeping speeds (5mm/s on sample 3 and 7 mm/s on sample 7), confirms the structural homogeneity of laser cladded layers and the low dilution level

Different laser cladded layer thickness in this case is explained by difference between k ($k = P/v \cdot d_s$) power factor values. Thus, sample 3 was processed by k = 122,2 J/s power factor and sample 7 k = 87,3 J/s power factor, respectively. Layers cladded onto the two surfaces were made by five superimposed passes. Power factor difference resulted in different losses by vaporization. It is known that temperature in laser beam is higher then metallic material vaporization temperature. As consequence, each laser beam superimposed pass vaporized a larger material quantity of sample 3 rather than of sample 7, that made the larger layer thickness of sample 7 to be.

Each tool sharpened in order to provide the cutting capacity (figure 9).

Steel processing tests, without cooling liquids use, were accomplished by these tools (figure 10).

Comparatively speaking of a tool entirely made of the same kind of high-speed steel, submitted to specific volume treatment, laser processed tools had a higher behavior, determined by one hand of higher superficial hardness and by the other hand of larger steel carbon body capacity to spread the heat from the active area (steel thermal conductivity decreases in the same time with alloying degree increasing).

4. Conclusions

By laser clading of high-speed steel powder with 0.82%C, 4.7%Mo, 6.4%W, 0.3%Mn, 4.1%Cr, 0.32%Si, 2.02%V, Fe reminded, as chemical composition, high hardness layers with 10130 – 10270 MPa and 1.5 – 4 mm in thickness were achieved, which allow the cutting angles making and taking over of technological wear.

Laser cladding tests by different running, pointed out the fact that powder flow has an decisive influence upon dilution degree. Also, when processing the laser cladding layers by several superimposed passes, it was found that k power factor magnitude determines the losses increasing by vaporization.

Turning test pointed out the fact that laser processed tools had a higher behavior, determined by one hand of higher superficial hardness and by the other hand of larger steel carbon body capacity to spread the heat from the active area.

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