LASER CLADDING OF METCO 68F-NS-1 COBALT BASED POWDER

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Abstract. This paper addresses to the laser cladding of cobalt base powder on AISI 5140 chromium steel. Experimental investigations are made to determine the influence of the scanning speed on the geometrical feature of the laser cladded tracks. An 1kW diode laser made by Coherent and a Precitec YC50 cladding head manipulated by an seven axes CLOOS robot were used for the achievement of coatings. Macroscopic and microscopic analyses of the laser cladded tracks are discussed in the article. Coarse dendrite structure and hard laves phases enclosed in a cobalt matrix characterise the microstructure of the coatings. It was determined that cladding speed has a direct influence on the clad high and melt depth.

Keywords: laser cladding, cobalt powder, scanning speed

1. Introduction

Nowadays, the laser cladding technology is widely used for wear related applications in various industrial fields. The laser cladding has several advantages compared with conventional deposition method (electro-plating, flame coating):

- good adhesion between the coating and substrate;
- highly precision process in terms of coating thickness and geometry;
- high density of coatings layer with minimal dilution.

Laser cladding by coaxial injection of the powder is the most used technique for improving or for recondition of wear components. In this technique a laser cladding head/module is used to infuse the powder with the laser beam as a coaxial cone. For the cladding process the most used powders are based on nickel or cobalt.

Cobalt based powders are specific to claddings for surfaces that will be used in rough working environments, being well known for their high wear hardness. These powders are alloys of Co with Ni, Cr, W, C and Mo. The chrome has the role to develop certain carbides which enhance the hardness of the alloy but it also has anticorrosive and antioxidant proprieties. Because they are characterized by a big/high atomic number, the wolfram and the molybdenum are also added in order to enhance the hardness of the matrix, developing very rough carbides [1]. The nickel enhances the flexibility. Co-based alloys from the Haynes Stellite family are the most popular in commercial applications [2]. From this category, Stellite 6 is used in the main applications which need high wear adhesion and abrasive resistance by cavitation or impact [3, 4].

In a recent study Kusmoto [5] investigates the process parameters domain for Stellite 6 coatings applied to the P22 and P91 steel substrate. Díaz et all [6] uses five different cobalt powders Stellites® and Tribaloys® to investigate the compatibility with low Cr-Mo steel components. It was concluded that preheating the substrate will decrease the cracking susceptibility.

Further improvement of the coated layers can be obtained by mixing in a precise ratio hard materials like carbides or borides with the cobalt based powders. Wei Zhang [7] reports good results by using TiC to reinforce the cobalt solid solution.

A metal matrix composite coating (MMC coating) in the system of Stellite-6 and tungsten carbides was used by Bartkowski [8] to improve the corrosion resistance compared to pure Stellite 6 material. The laser cladding using cobalt based powders are used for micro scale applications [9] or for recondition large components like pistons, continuous casting moulds [10], etc.

The cobalt based powders are characterized by a high hygroscopicity and form this reason a special attention must be accorded to laser cladding process parameters. In order to recondition or to improve the mechanical proprieties of a small component is necessary that a precise cladded track geometry to be achieved. Also the mechanical feature of the claddings in directly influenced by the main process parameters like: laser power, cladding speed and powder feed rate.

The purpose of this study was focused on the geometrical feature of the single track laser cladding with Metco 68F-NS-1 powder. Optimal cladding speed was determined by using different speeds and maintaining the same laser power and powder feed rate.

2. Experimental frame

The base material used for the achievement of the experimental tests is a chromium steel namely AISI 5140. This steel grade is often used in automotive industry for drive shafts, moulds, etc.

The cladding tests were carried out using

Metco 68F-NS-1commercial powder.

The coating has high corrosion resistance, oxidation resistance, excellent abrasive wear resistance and high service temperature capability with good hot hardness. Coatings exhibit a low coefficient of friction particularly suitable where lubrication is low or non-existent [11]. The chemical composition of the base material and powder is presented in Table 1.

Table 1. Chemical composition of the AISI 5140 and Metco 68F-NS-1

Material	C %	Co %	Si %	Mn %	Cr %	Ni %	Mo %
AISI 5140	0.36	-	0.22	0.65	0.98	0.09	0.01
Metco 68F-NS-1	-	49.4	3.4	-	17.5	-	28.5

The laser cladding tests were conducted using a 1 kW diode laser (Coherent F1000) and a coaxial cladding module produced by Precitec. For the movement of the cladding head was employed a seven axes CLOOS robot (figure 1).

Powder delivery to the injection unit was assured by a powder feeding device made by Termatech (AF 1000). Argon was used as carrier gas and also as shielding gas at a flow rate of 14 l/min. Single track cladding tests were performed on specimens obtained by mechanical processing (milling followed by a surface grinding) from a row material with the size of 100×100 mm. In Table 2 are presented the process parameters and the measurement of the geometrical dimension.

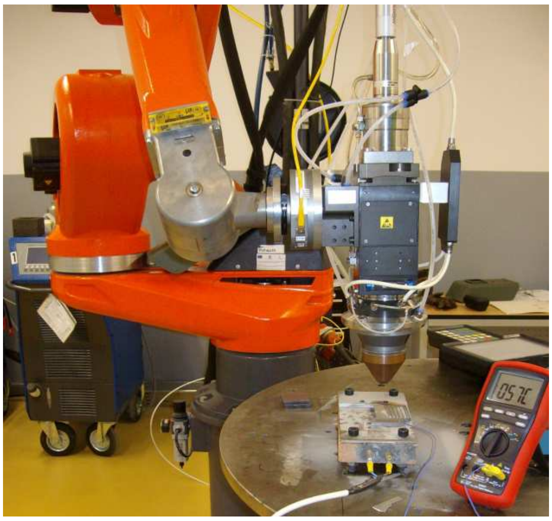

Figure 1. Experimental frame used to perform the experimental welding tests, at Transilvania University of Brasov

Table 2. Laser cladding process parameters and main geometric dimension

Sample		Sample 70	Sample 71	Sample 72	Sample 73	Sample 74	Sample 75	Sample 76
Parameters	Units							
Laser Power	W	1000	1000	1000	1000	1000	1000	1000
Powder Feed Rate	g/min	7	7	7	7	7	7	7
Cladding Speed	mm/s	3	4	5	6	7	8	9
Clad High	[µm]	1306	1194	964	858	794	750	604
Clad Area	[mm^2]	2.52	2.08	1.56	1.33	1.14	1.08	0.88
Clad With	[µm]	2352	2094	2084	2057	1951	2098	2063
Melt depth	[µm]	254	139	186	81	40	0	0
Molten Area	[mm^2]	0.23	0.08	0.12	0.04	0.02	0	0
HAZ- Depth	[µm]	1130	943	868	818	712	695	699
HAZ-Width	[µm]	3595	3431	3113	3184	2942	2960	2751
HAZ-Area	[mm^2]	2.76	2.16	1.90	1.77	1.44	1.39	1.34
Clad Angle (α)	[°]	90	90	95.5	102.1	104	113.5	122.6
Dilution	[%]	8.4	3.7	7.1	2.9	1.7	0	0

Seven single cladded tracks were performed by linear increasing of the speed and maintaining the same power and powder feed rate. In the macro examination presented in Figure 2 it is emphasized the influence of the cladding speed on the cross section profile. The visual observations during experiments characterises the process as being uniform, continuous, without drops and plasma free. The parameters that were used for the tests, power of 100 W, are recommended for low and for higher cladding speed.

Analysing the images presented in Figure 2 it is obvious that the cladding speed has a determinant role on the geometry and structure of the cladded material. The dimensional profile associated to the cladded tracks are influenced by a constant increase of the scanning speed. The same images (fig. 2) highlights that the wetting angle (α) that is essential for a good bonding with the substrate increase at higher speeds; and so it results that speeds that are superior to the value of 5 mm/s are required for obtaining high quality single or overlapped tracks.

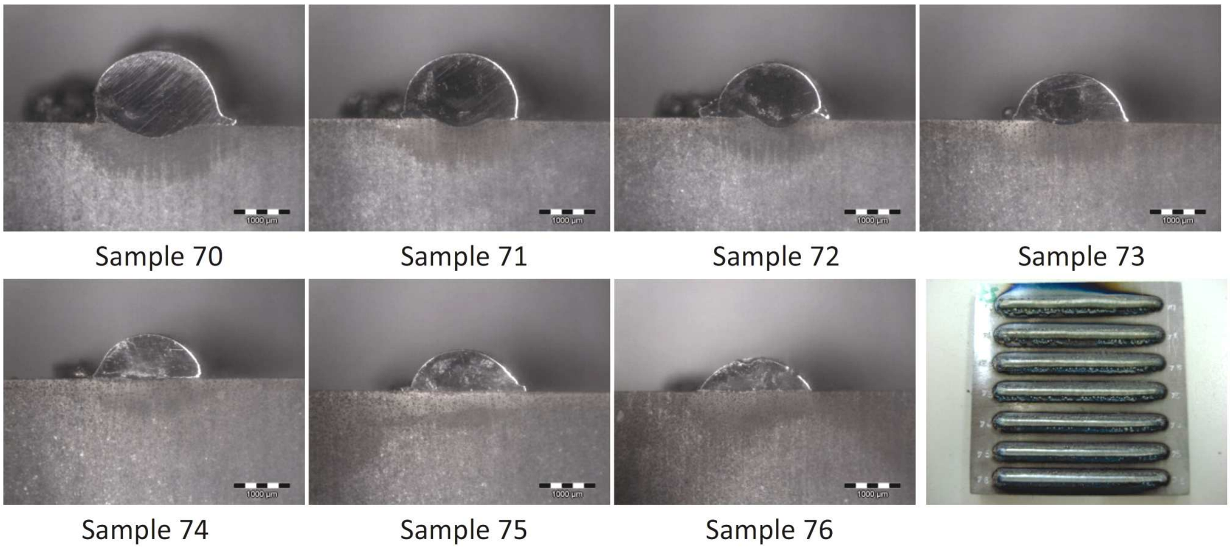

Figure 2. Cross section of the laser cladding with the Metco 68F-NS-1 (magnifications 10×)

In the Figure 3, a and b, is presented the scanning speed influence on the clad high and area. The clad high decreases with the increasing of the cladding speed.

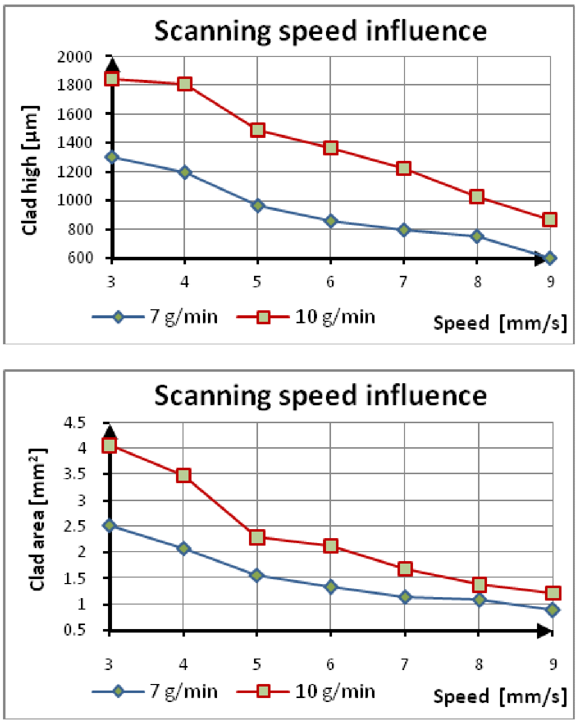

Figure 3. Relation between scanning speed and clad high / area for Metco 68F-NS-1 on AISI 5140 steel substrate

The right balance between clad high, width and melt depth must be obtained to prevent crack formation. In all laser cladding applications is very important to maintain a low as possible heat affected zone. As resulted from graphical representation from Figure 4, the heat affected zone decrease at higher cladding speeds.

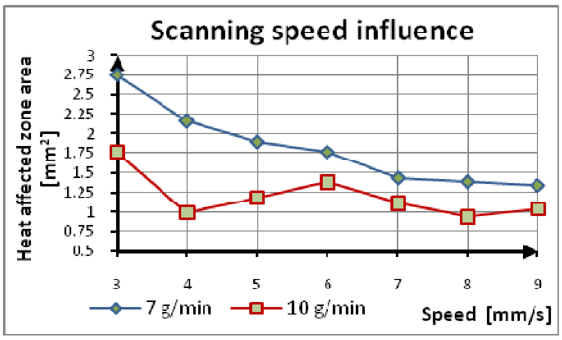

Figure 4. Relation between scanning speed and heat affected zone for Metco 68F-NS-1 on AISI 5140 steel substrate

In order to validate the cladding speed influence on the properties of the cladded layer, an additional set of experiments was performed using the same laser power, the same linear speed increase but using a bigger amount of powder, namely, 10 g/min.

In Figure 3 can be observed that by using a different powder feed rate, the cladding speed will generate the same geometrical profile.

Figure 5 shows the microstructure of the sample 75 chemically etched with reagent of HCl and HNO_3 in a ratio of 3:1 (Regal Water).

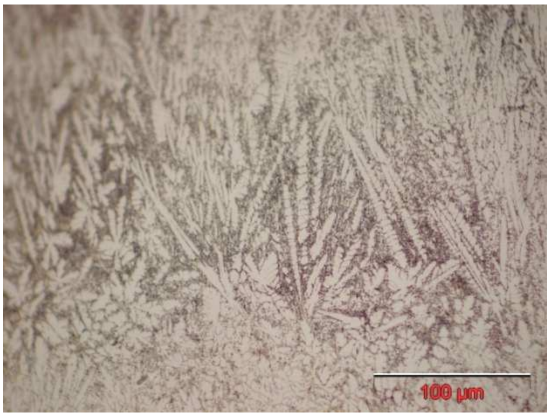

Figure 5. Microstructure of the cross-section of sample 75 (magnifications 100×)

All obtained cladded tracks have a dendritic microstructure. Hard precipitations, molybdenum - silicon based intermetallic Laves phases, are evenly dispersed in the solid solution cobalt matrix and confer the high hardness of the coating.

The dendrite formations are oriented towards to the middle of the tracks respectively to the area where the thermal gradient is more pronounced.

4. Conclusions

The present study was focused on the influence of the process parameters on the geometry of the laser cladded tracks with Metco 68F-NS-1 powder. The study evaluate the possibility of obtaining high quality laser tracks with a precise geometry for applications like reconditioning of worn parts manufactured from chromium steel.

It was determined that cladding speed has a major influence on the geometric profile of the laser cladding tracks. Clad high, width and clad area decrease at higher cladding speeds.

Optimal cladding speed was determined to be between 6 and 8 mm/s at a laser power of 1000 W.

The presented aspects indicate the fact that the optimal operational domain of the cladding process is conditioned by an exact ratio of the parameters used.

Acknowledgements

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the project number POSDRU/159/1.5/S/134378.

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Received in June 2015