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EDX ANALYSIS OF LASER CLADDING LAYERS WITH Ni – Cr – B – Fe – AL ALLOY

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ABSTRACT

Multilayer cladding by injection of powder with 8.9% Cr, 4.5% Fe, 5.1% B, 2.4% Al, 0.6% Cu, Ni rest as chemical composition, in melted bath by a continuous wave CO_2laser connected to x-y-z coordinate table was tested in order to increase the wear and corrosion resistance of 0.45% C superficial steel layers. Layers made by different laser running were characterized by microstructure analysis, microhardness analysis and EDS microanalysis in order to establish the optimal deposit running.

KEYWORDS: laser cladding, nickel alloy, microstructure, microhardness, EDS microanalysis

1. Introduction

Laser cladding was defined as a process used to melt a material having different metallurgical properties on a substrate by means of laser beam. In order to maintain the original properties of the material cladded, only a very thin film of the substrate must be melted in order to obtain the minimum dilution of the metallurgical bond of both material addition and substrate.

The structure and properties of the coating depend on the ratio of the melting temperatures of the support and material coat, the chemical composition and they may vary by application of cladding thermal regimes and the powder granulation.

Thus it was found that by altering the power density, duration of laser action, feed speed, powder feed speed, granulation and powder density, the complex of physical – mechanical properties within the superficial layers of preset size. Also a good quality of the layers deposited implies lack of cracks, of porosity, good bond with the substrate and a low dilution of the material covering the substrate and minimum roughness [1, 2, 3, 4, 5].

Following, laser cladding can be used to good effect in processes which require a high productivity combined with flexibility without compromising quality. A high and uniform quality with a low heat input makes this process suitable for a wide range of applications in which minimum distortion is desired. Examples of industrial laser cladding applications are [3]:

- Improved wear resistance of bearings, valves, shaft, cutting tools and other parts where the working conditions are very severe;
- Improved corrosion resistance;
- Repairing turbine parts, moulds, tools, etc;
- Building up complex geometries.

Laser cladding can be used to improve resistance to wear and corrosion of components in the metallurgical industry.

Hot-rolled band having a temperature of 550^{o}C is centered on the mandrel by means of manipulators whose plates reach the edge of the moving belt. It follows rapid wear by abrasion and oxidation of these plates. To increase their life duration, it is necessary to deposit a superficial layer of material with higher resistance to wear and oxidation.

Thermal-gas (oxy-gas flame, plasma spray) coatings made from nickel-based powders from systems of Ni-Cr-B-Si, Ni-Cr-Al, Ni-Mo-Si and others are known and used for parts running under larger thermal and mechanical loads in aggressive environments [1, 2, 3, 4, 5, 6, 7, 8]. The research carried out [2] on the thermal sprayed coatings of alloys Ni-Cr-B-Si, subsequently melted with laser, revealed increased hardness and resistance to fatigue, lower coefficient of friction, lower running-in and lower tendency to jam as compared with the deposition obtained by flame melting.

This paper presents the properties of layer deposition by laser with the nickel alloy Ni-Cr-B-Fe-Al, having the capacity of solidification from the liquid phase, specific to laser cladding.

The samples obtained were examined metallographically to see the variation of microhardness over the depth of the deposited layer; EDS microanalyses have also been carried out.

2. Experimental conditions

The basic material used in experimental research is steel 1C45, SR EN 10083-1:1994, in improved condition. The Nickel based alloy used in the laser cladding is Ni-Cr-B-Fe-Al with the following chemical composition: 8.9% Cr, 4.5% Fe, 5.1% B 2.4% Al, 0.6% Cu, rest Ni. For experiment purpose, granulometric fractions have been separated in the interval 80 – 90 μm. It is worth mentioning that before adding the material in the injection tank, the powder was dried at a temperature of 110 ° C for 15 minutes. Experiments were performed on a 1200 GT LASER W device manufactured by IFTAR Bucharest consisting of a continuous wave CO_2 laser generator connected to a work mass within a computer – controlled xyz coordinate system and updated at SC UZINSIDER ENGINEERING Galaţi. The working regimes used in the laser cladding with nickel base of Ni-Cr-B-Fe-Al are shown in Table 1. It is worth mentioning that the sample code 2 was performed by previously preheating the support to be able to monitor its effect on the layer characteristics.

***Table 1**. Working regimes in laser cladding*

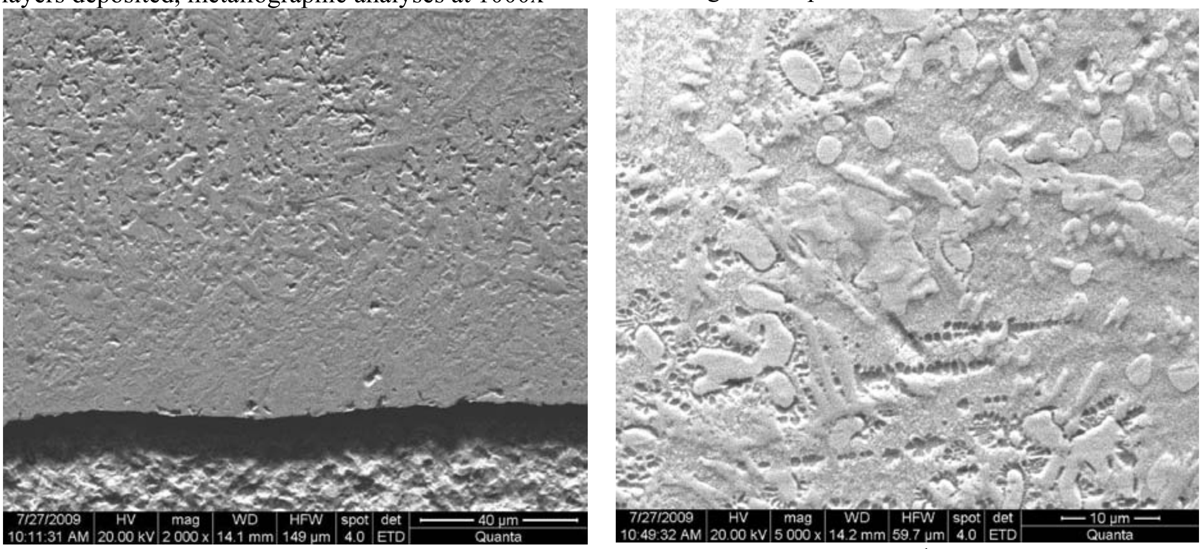
Sample code	Added material rate	No. of overlapping runs	Working regimes					
			P	v	d_s	p_{av}	Layer thickness	Hardness HV_{49}
	[mg/s]		[W]	[mm/s]	[mm]			[MPa]
1	105	4 [T_P=20°C]	1150	7.5	1.8	1.5	2.07	11450
2	63.9	4 [T_P=60°C]	1150	11	1.8	1.5	0.42	4600

NOTE: P - power of laser radiation, v – surface scanning speed of the laser beam; ds - diameter of laser beam on the surface processed; p_{av} - advance step; m_p - flow rate of material added

3. Experimental results and discussions

To highlight the microstructure aspects of the layers deposited, metallographic analyses at 1000x were performed and the metallographic attack was carried out by electrolyte way.

Fig. 1 shows the microstructure of the layer cladding for sample code 1.

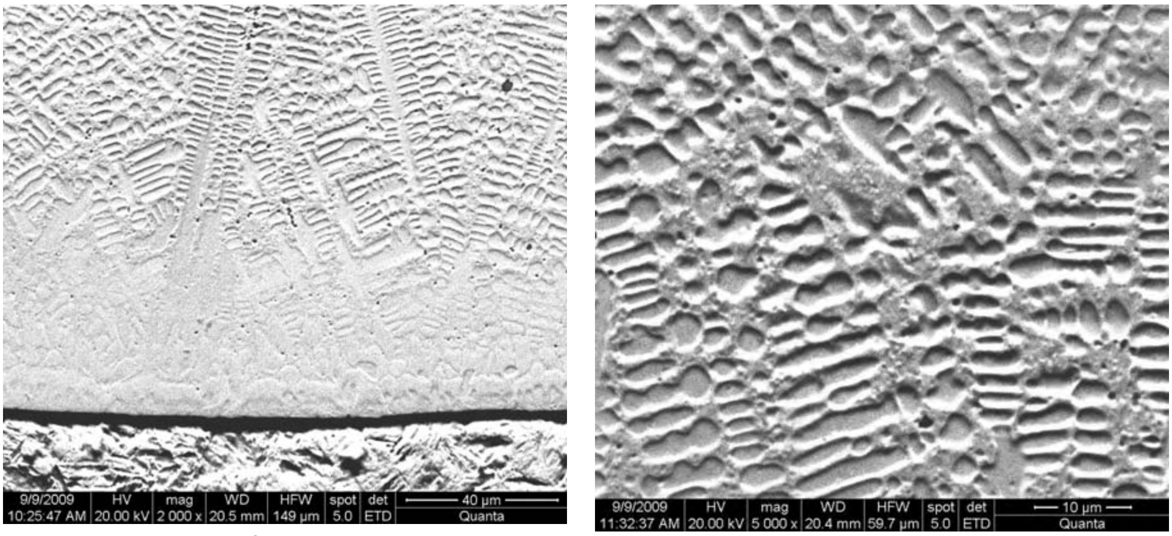


a b

***Fig. 1.** Microstructure of nickel – based alloy deposited on the sample 1*
(v = 7.5 mm /s, m_p = 105 mg /s)
a) base of layer deposited; b) layer surface(x1000). Electrolyte attack, solution 50% HNO_3

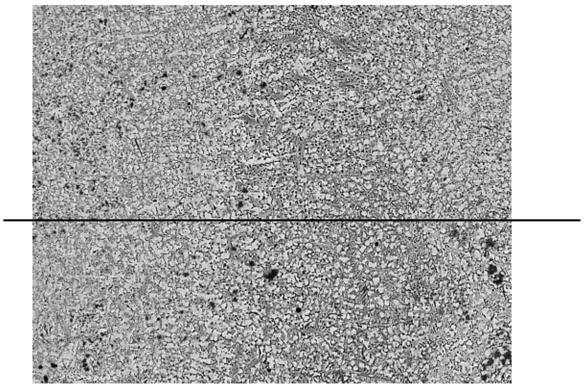
As indicated in the literature [3, 4, 5, 6, 7], the fine columnar dendritic structure of the deposit contains solid solution based on nickel and eutectic colony of borides (Ni_3B, CrB), the main hardening phase being CrB. At the layer base there is a narrow zone of nickel-iron dilution without eutectic carbides, which makes the transition to the material support and provides a good adhesion of the layer to the support. In the presence of aluminum, the nickel can form inter-metallic compounds with hardening effect: Ni_3Al, Ni_2Al_3.

Fig.2. shows microstructure of the layer deposited for sample code 2 (support preheating), electrolytic attack. In this case it can be observed a dendritic non crystallized structure without precipitated fine.

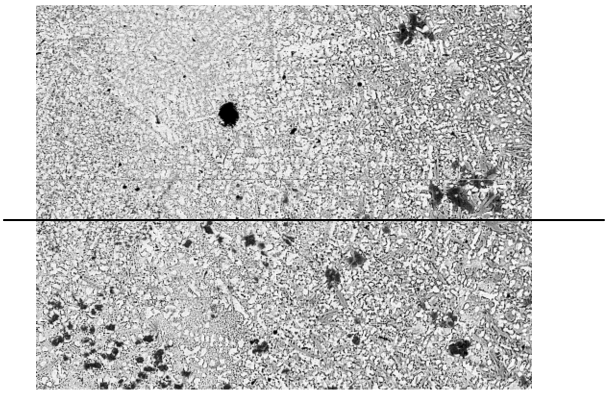


a. b.

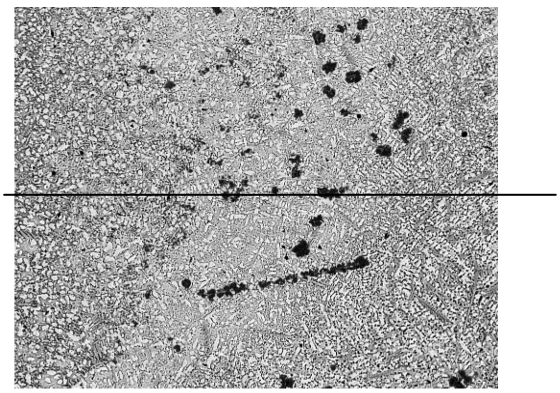
Fig. 2. *Microstructure of nickel alloy deposited on the sample code 2 (v=11 mm/s;* m_p*=63.9 mg/s) a-layer base; b- surface of the layer deposited (x2000). Electrolytic attack, solution 50%* HNO_3*.*



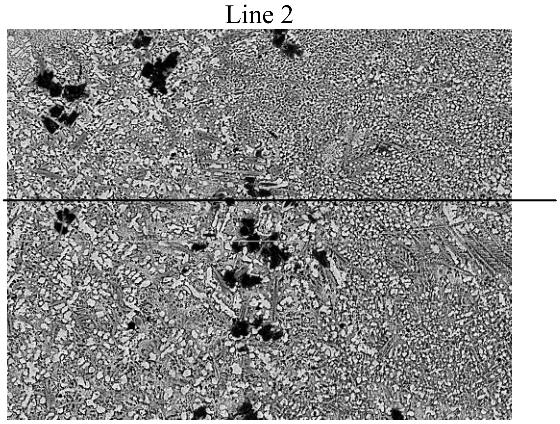
Line 1



Line 2



Line 3



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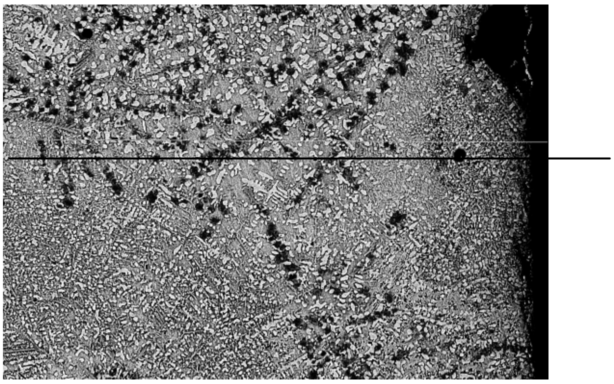
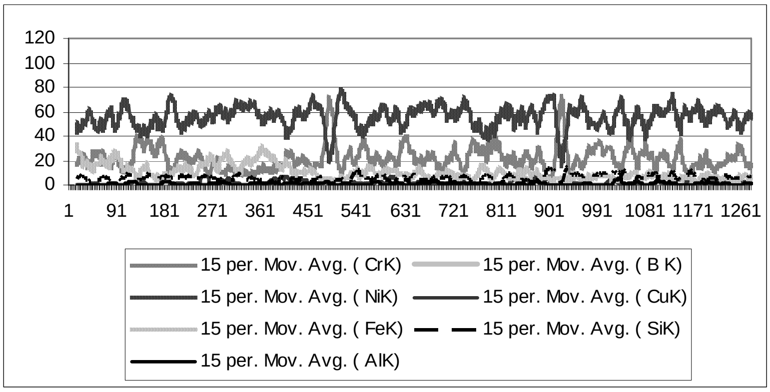


Line 5

a.



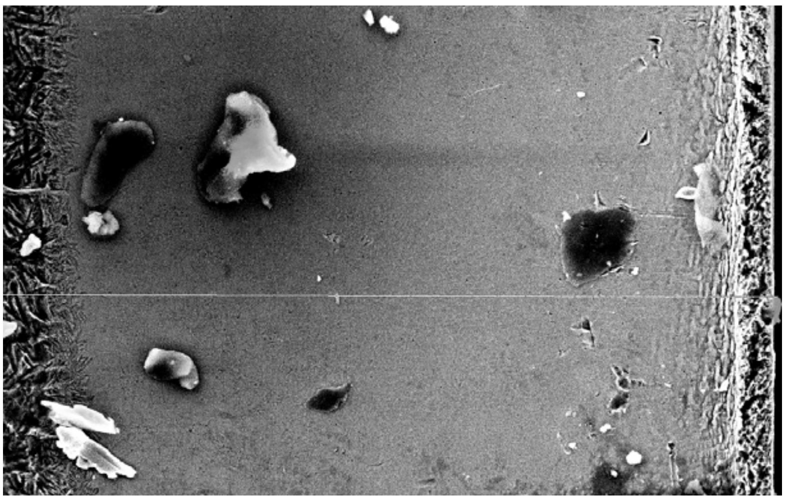
b.

Fig. 3. *Distribution on direction of the elements in the nickel based alloy by laser cladding for sample 1 – a and concentrations profile of Ni, Cr, B, Fe, Al - b*

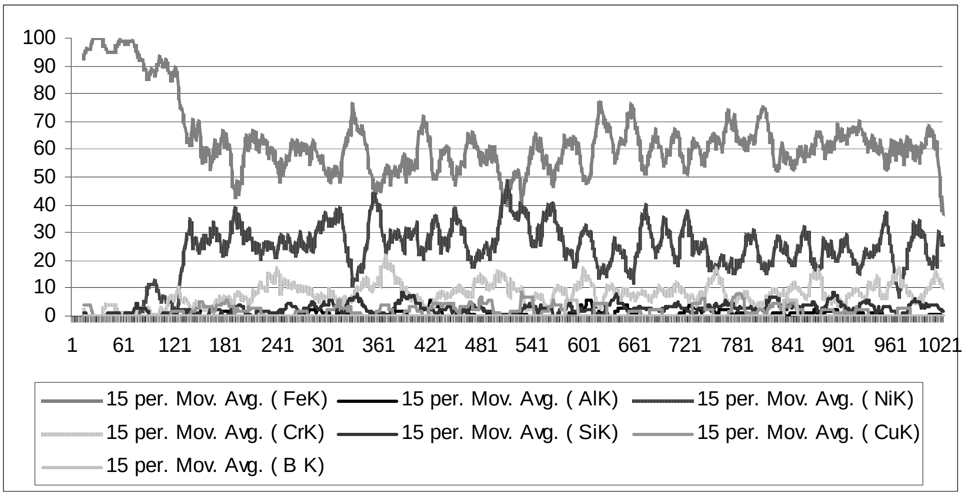
The dilution zone is larger and contains nonmetallic inclusions. Preheating the support causes thinning of the layer which further leads to inhibition of the recrystallization processes and dispersion of the hard particles [9]. Fig.3.a illustrates analysis on layer depth direction of the elements in the laser deposited layer for sample 1, the microstructures being revealed at 300x magnifying and fig. 3.b shows the concentration profile of Ni, Cr, B, Fe, Al.

To highlight the influence of the support preheating on the laser cladding, EDS investigations have been conducted on direction for sample 2. The results are presented below.

Fig. 4a: the analysis to direction over the layer depth of the layer elements for the sample 2, the microstructure being revealed at 300x fig. 4 b concentrations profile of Ni, Cr, B, Fe, Al.



a.



b.

Fig. 4. *Distribution on direction of the elements in the nickel based alloy by laser cladding for sample 2 – a and concentrations profile of Ni, Cr, B, Fe, Al - b*

If we analyze the distribution on direction of the elements in the layer deposited with the base preheated and the sample 1 we find that:

- iron disseminates much more intensely in layer of sample 2 due to its much higher concentration than in sample 1 where the iron concentration decreases from base to surface.
- chromium concentration is lower and shows a more uniform variation in sample 2 than in sample 1 where one can see a fairly intense variation along the layer depth.
- nickel concentration is lower in sample 2 than sample 1, where it is visible down to the layer base.
- aluminum concentration is lower in sample 2 than sample 1, its variation over the layer depth being similar.

Thus it may be noted the presence at the interface of an area where it practically took place an alloying process with a more intense iron diffusion from the substrate to the layer than nickel. These findings limit the possibilities to fight the fissuring tendency of the layer deposited by preheating the support and accounts for the establishment, by researches prior to manufacturing, of the optimum properties ratio: (chemical composition) - compactness (the maximum allowable size of cracks) for each pair support material – added material. Figure 5 shows the variation of $HV_{0,98}$ microhardness over the depth of the cladded layer in samples 1 and 2. The peak layer hardness and thickness are found in sample 1, where the scanning speed was minimal and the injection material flow rate was maximal.

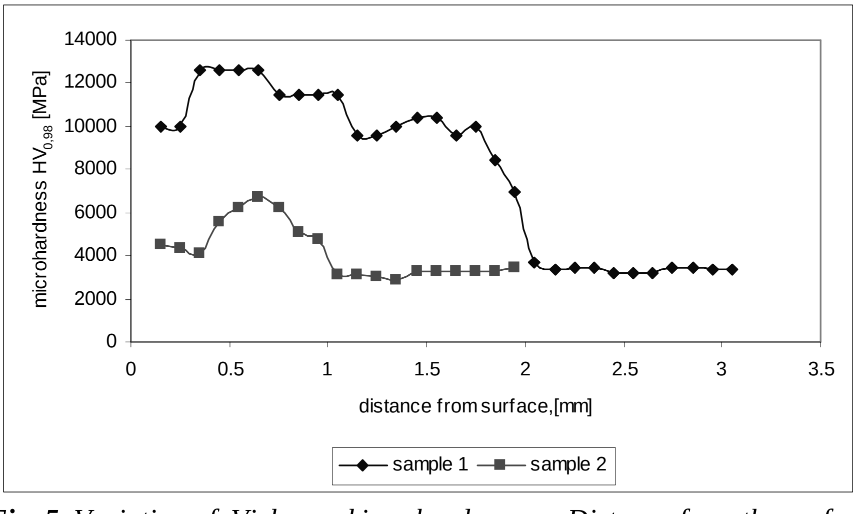


Fig. 5. *Variation of Vickers mkicro hardness vs. Distance from the surface of the deposited layer, at samples 1, 2.*

Preheating the sample to 60 ° C (sample 2) reduces hardness and thickness of the deposited layer, more pronounced with slow scanning speeds because of the increased surface temperature and more intense vaporization processes. Since the laser beam mainly provides the energy required to melt the added material, the scanning speed must be correlated with the added material flow rate. The higher the material flow rate, the lower the scanning speed, which provides maximum layer thickness.

4. Conclusions

Concerning the distribution on direction of the elements in the layer deposited with the base preheated and the sample 1, we have found that: iron disseminates much more intensely in layer of sample 2 due to its much higher concentration than in sample 1 where the iron concentration decreases from base to surface; chromium concentration is lower and shows a more uniform variation in sample 2 than in sample 1 where one can see a fairly intense variation along the layer depth; nickel concentration is lower in sample 2 than sample 1, where it is visible down to the layer base; aluminum concentration is lower in sample 2 than sample 1, its variation over the layer depth being similar.

The findings resulted from EDS microanalysis limit the possibilities to fight the cracking tendency in the layer being deposited by preheating the support and accounts for the establishment, by researches prior to manufacturing, of the optimum properties ratio: (chemical composition) - compactness (the maximum allowable size of cracks) for each pair support material – added material.

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