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MULTILAYER LASER CLADDING

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Abstract. *Laser cladding technique consists on obtaining an homogeneous surface layer with a strong metallurgical bond, a low degree of dilution and minimal distortion. The process usually involves the delivery of fine grained powders directly into the melt pool during laser irradiation. Much has been done regarding the features of the coatings produced, as a result of processing parameters for different materials. Although laser cladding processing has shown several advantages over competing techniques, such as welding or plasma coating, the vast majority of laser cladding research has been carried out on one layer cladded specimen. This can be an important limitation to the process, particularly when recovering operations are concern. During maintenance operations, most frequently material has to be added to fill up irregular surface areas that have suffered some sort of damage such as erosion. In order to be able to answer to this requirement, it is very important to know the effect of overlapping successive layers by laser cladding technique. This work, shows the effect of depositing multilayers of a cobalt based alloy, stellite 6, on the features of the coated surface. Specimen with different number of successive layer were produced with a* CO_2 *CW laser. The influence of multilayer cladding on microstructure and mechanical characteristics was study. Results are discussed bearing in mind the potential of laser cladding as a tool for repairing operations.*

Keywords: *Laser cladding, Hardfacing, Coatings, Surface treatments*

1. INTRODUCTION

Laser surface treatments have long passed the laboratory stage. Within these treatments, laser cladding has proven to be an alternative to conventional techniques, when a wear resistance surface is needed (Lugscheider and Oberlander 1992, Monson and Steen, 1987). Hardfacing with laser technologies, has been developing rapidly in recent years, and as already found many applications in industry, from moulds for plastic injection (Colaço *et al*.

1994), automotive parts (Belmondo and Castagna 1979), to steam turbine components (Coulon *et al.* 1992, Macintyre 1983).

The potential of laser cladding technique is beyond the coating of new components. The repairing of worn components is an emerging market for laser cladding. Unique characteristics can be mention, such as excellent metallurgical bonding with simultaneously little intermixing with the base material, and low distortion, hence little machining required after the deposition. These features make laser cladding an ideal procedure to restore the shape and properties of parts or components that have suffered lost of material after any type of wear mechanism. Since surfaces deteriorate in a non-uniform way, one has to be prepared to deal with different depth regions, depending on the severity of the wear. To recover these areas more than one layer would most probably be necessary. Therefore it urge to known the effect of depositing successive layers by laser processing, on the features of coatings.

2. EXPERIMENTAL PROCEDURES

A 16mm thick 304 stainless steel plate was laser cladded with a cobalt based alloy, stellite 6. Cladding was done following a modification of the one-step procedure. Instead of blowing the powder into the melt pool, it was made to fall by gravity. Powder particles were molten by the laser beam just before reaching the melt pool in the substrate. This technique allows for a reduction of the powder feed rate, and higher efficiencies. As received chemical composition of the stellite powder is shown on table 1.

Table 1 – Chemical composition of the as received powder

Element	Ni	Cr	Mo	W	Fe	Mn	Si	C	Co
%	3.0	30.0	1.5	4.5	3.0	2.0	2.0	1.1	Bal.

Cladding was done using a 3KW CO_2 laser, at the Laser Material Processing Laboratory of Instituto Superior Técnico de Lisboa, Portugal. Processing parameters are shown in table 2.

Table 2 - Laser cladding processing parameters

Power	2.2 kW
Beam diameter	3 mm
Powder feeding rate	0.2 g/s
Substrate displacement	8mm/s
Track width	3 mm
Protective gas	Argon

One layer, two layers and five successive layers, laser cladded specimen were produced, cladding parameters were kept constant for all layers. Successive layers were deposited making an angle of 90° with each other, starting always on the same side of the specimen, fig. 1.

The plate with the specimen was then submitted to mechanical machining in order to reduce the substrate thickness down to 6mm, specimens were then cut out by eletroerosion.

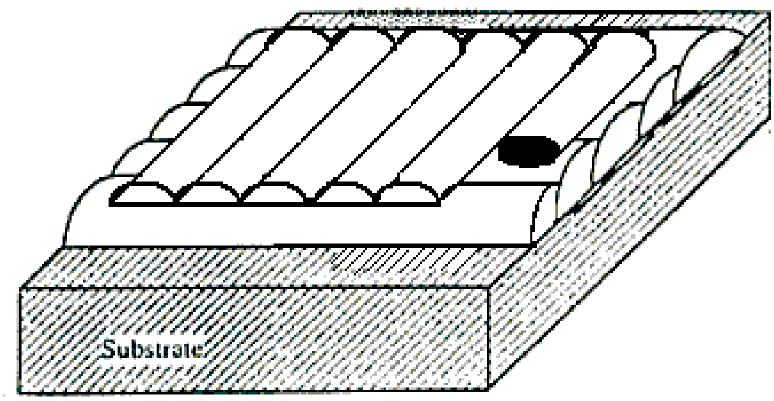


Figure 1 – Schematic representation of the multilayer deposition sequence

Microstructure characterisation was done using standard metalographic procedures for specimen preparation and etching (solution of 15ml H_2O, 15ml HNO_3, 15ml CH_3COOH and 60ml HCl), to reveal the main features of the structure for study with optical and scanning electron microscopy. Vickers microhardness profile, 100g, was done on the different specimen. Chemical composition analysis were done using EDS.

3. RESULTS AND DISCUSSION

3.1 Surface characterisation

Coatings from 1.5mm (one layer) to 4 mm (5 layers) thickness were produced. Final coating thickness is not an add up process, as a strong metallurgical bond, involving fusion, occurs between deposited layers.

Surfaces produced are very smooth, particularly when compared to other coating processes, given a competitive advantage to the laser cladding process as one could save time during the finishing stage, since very little machining is required.

Surface inspection did not reveal any relevant defects on specimen with one and two layers coats. However naked eye inspection of the thicker coated specimen, suggests that a different deposition procedure should be used when several layer are to be deposited successively, as a surface crack was observed. Intermediate annealing could be a solution, as it would allow for stress relief.

3.2 Microstructure

Transverse cross section microstructures of the laser cladded specimens are shown in fig. 2 to 4.

Compared to other coatings techniques, such as surface welding and PTA (Foltran *et al.* 1999, Lugscheider & Oberländer 1992), fine dendritic structures were produced in all specimens, one, two and five successive deposited layers. The effect of the tracks overlapping and overlayering can cleary be identified as alternated areas of fine and coarse dendritic structure are visible, showing the influence of the heating cycle on the material previously deposited; adjacent tracks and layers always present a region of coarser structure at the interface between them.

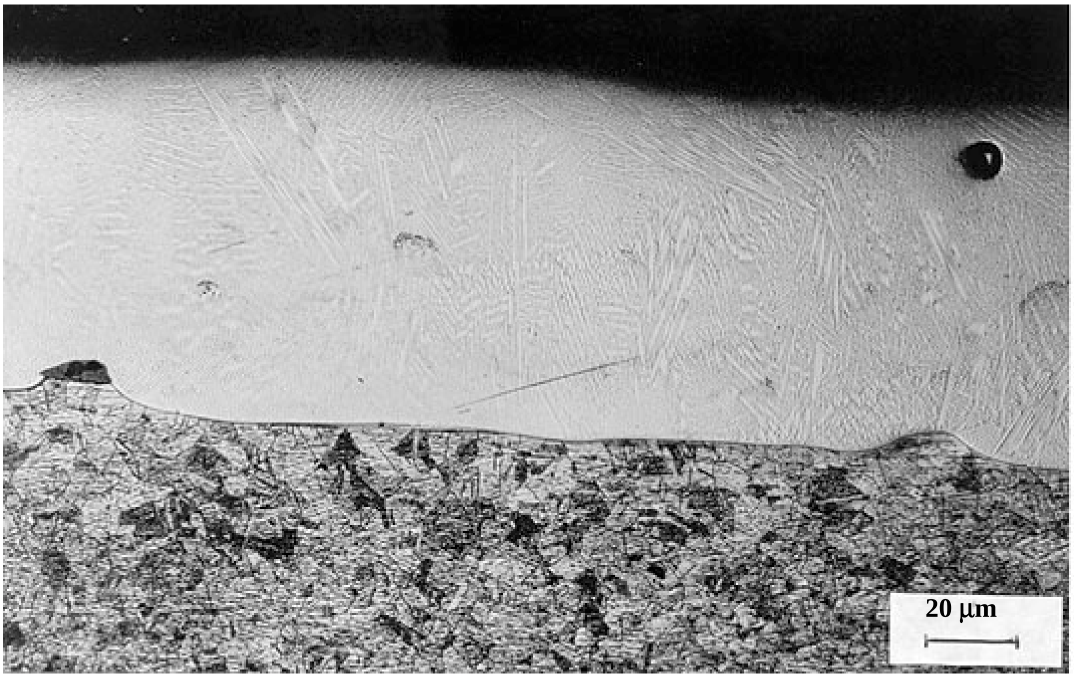


Figure 2 – Transverse cross section of a laser cladded specimen, one layer, as observed under optical microscope

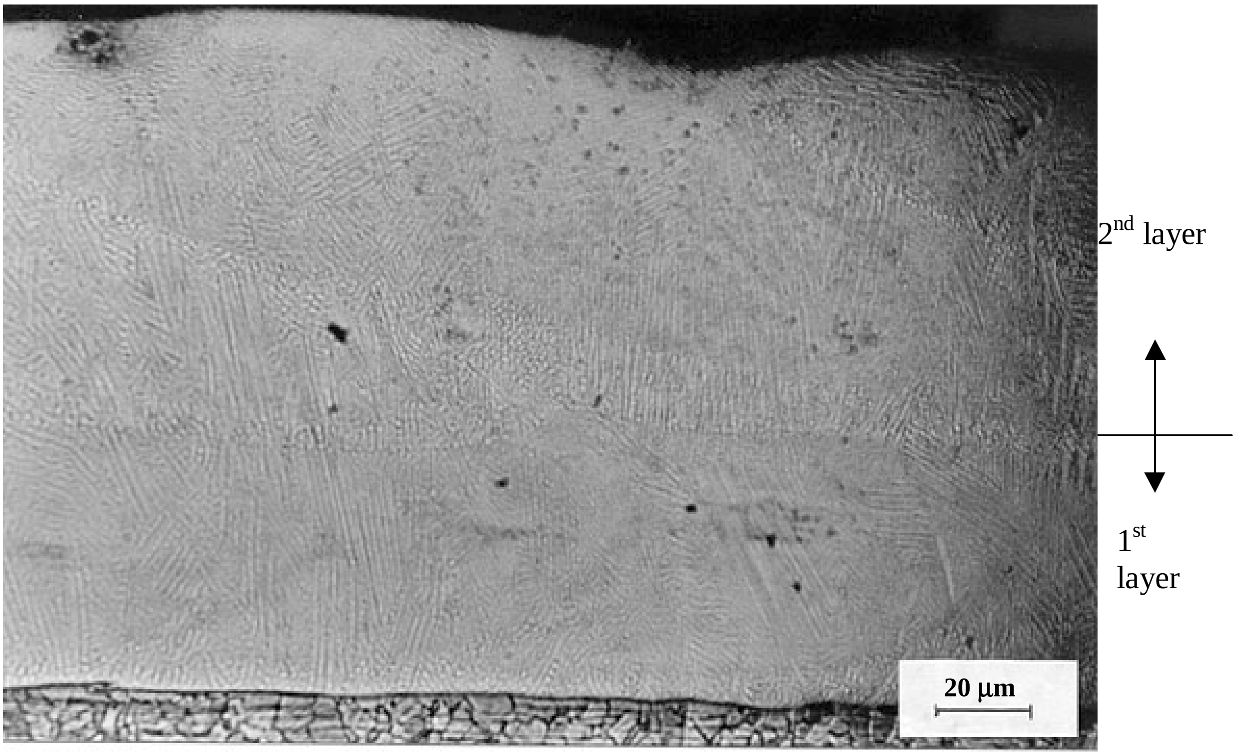


Figure 3 – Transverse cross section of the two layers laser cladded specimen, as observed under optical microscope.

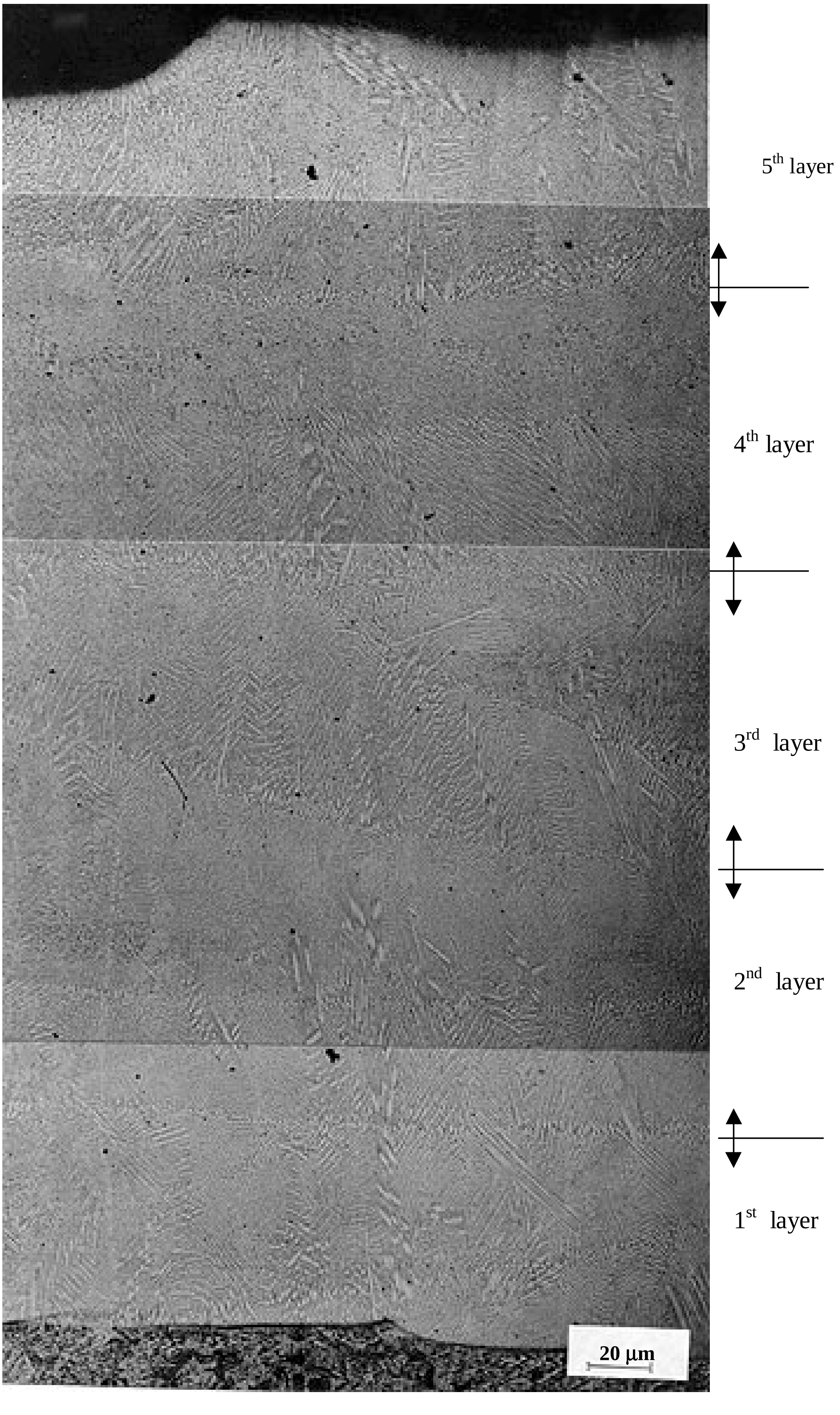
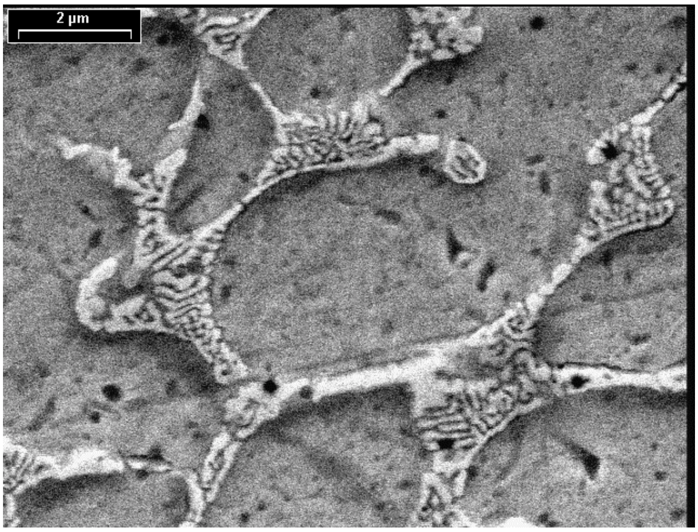


Figure 4 – Transverse cross section of the five layers laser cladded specimen, as observed under optical microscope.

Structure refinement, from interface with the base material to the external surface, became more clear, as more layers were deposited. Scanning electron microscopy analyses showed that the thicker the coat, the more significant is the coarsening of the interdendritic regions near the interface with the base material. Figure 5 shows the morphology of the interdendritic regions after depositing five successive layers, near the interface and at the external surface.

a)



b)

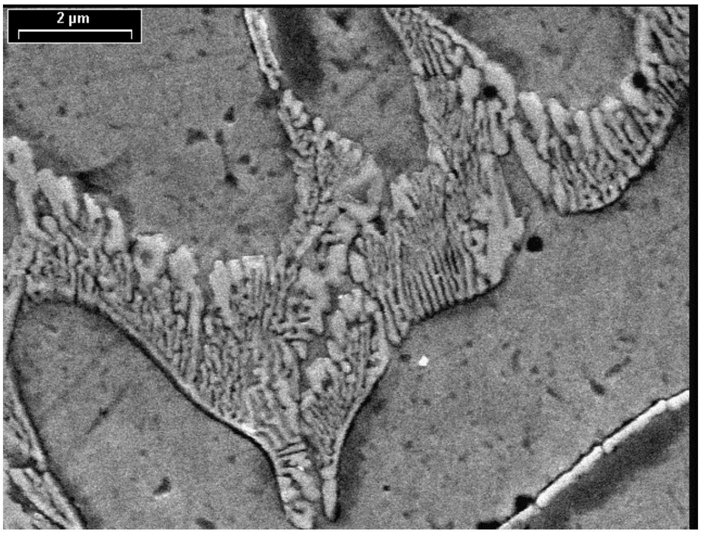
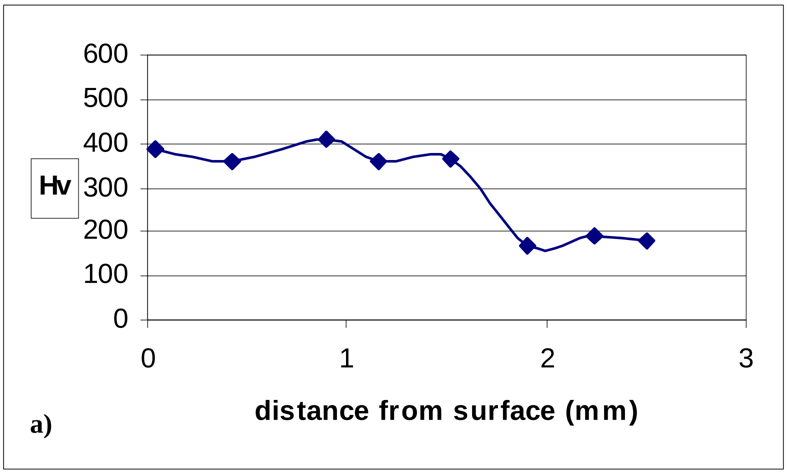


Figure 5 – Microstructure of the five layers laser cladded specimen, showing the features of the interdendritic regions a) near the external surface and b) near the interface with the substrate

3.3 Coating performance

It is well known and accepted, that hardness can express the behaviour of a surface submitted to some wear/erosion effort. Therefore microhardness profiles were used to characterise the expected performance of the different coatings produced. One and two layers laser cladded coatings did not show significant differences regarding the hardness value at the external surface. However a drop on hardness was observed as one crosses the first layer of the two layers specimen, confirming the tempering effect of the heat cycle, as observe with conventional processes (Alvarez, 1999).

Figure 6 compares hardness profiles of specimens with two and five successive laser deposited layers. An increase on hardness towards the interface with the base metal is evident on the five layer coated specimen.



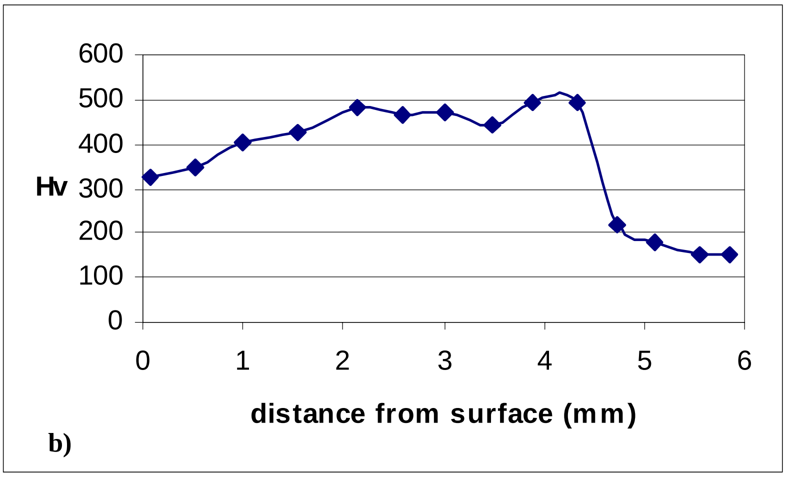


Figure 6 – Microhardness profiles of laser cladded specimen with a) two and b) five successive layer.

The understanding the measured behaviour, comes from the chemical composition analyses, done on the different regions of the microstructure (dendritic and interdendritic), at points located near the external surface and at the interface with the base material. EDS chemical composition resultsare shown in fig. 7. Comparing dendritic and interdendritic regions, the later are richer on Cr, W and Si, elements known to form very hard phases. In fact it has been observed (Osma *et al*. 1996) that after rapid solidification of cobalt base alloys, these elements form very hard intermetallic phases, such as $M_{23}C_{6,}$ Cr_7C_3, Co_7W_6, Co_3W e Co_2Si. Therefore one should expect a greater contribution to the measured hardness of the interdendritic regions which are richer on these elements, compared to dendritic regions. According to the observed microstructure, interdendritic regions near the interface with the substrate, after depositing five successive layers, are coarser than near the external surface, contributing to the increase on hardness. The drop on hardness profiles as one approaches the external surface is a consequence of the diffusion mechanisms enhanced by the overlapping process, which led to microstructure refinement and reduced chemical composition differences between dendritic and interdendritic regions.

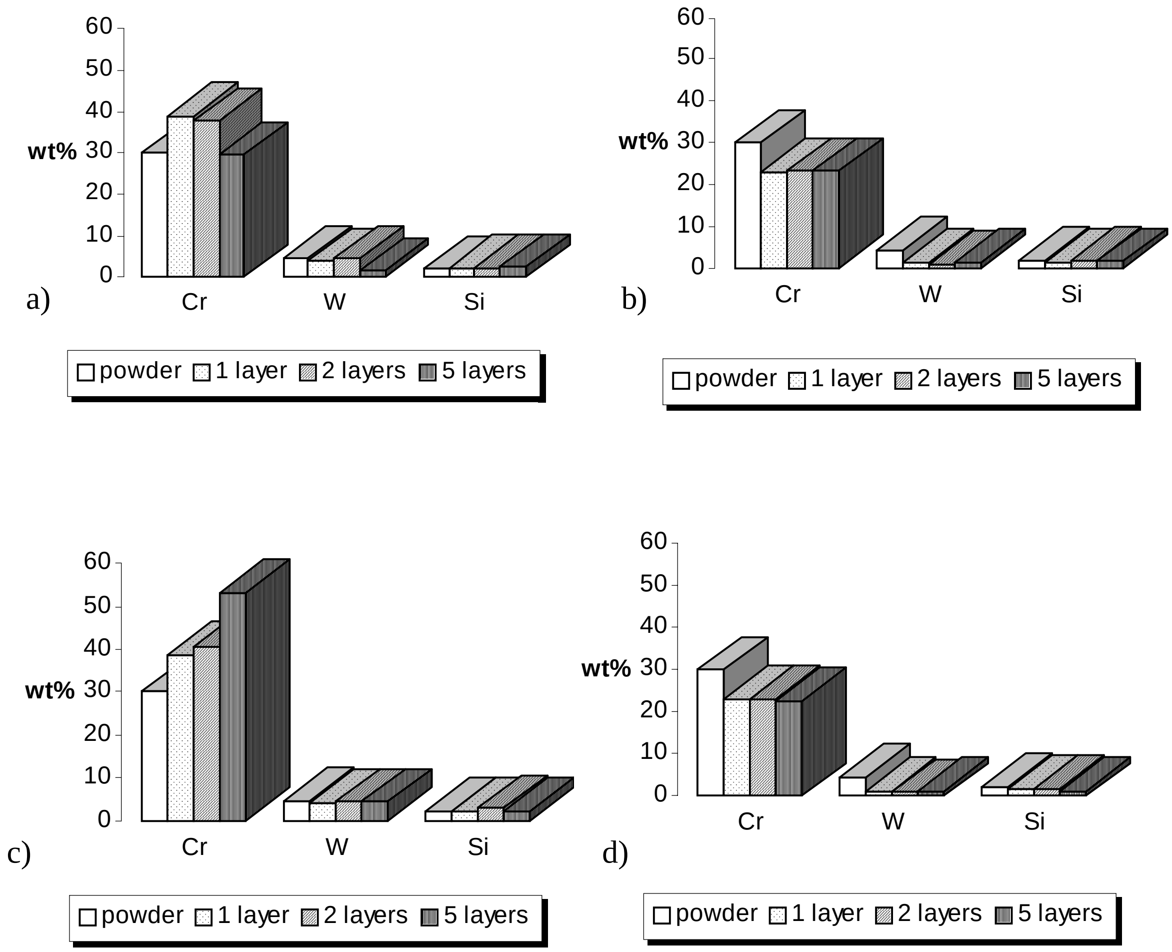


Figure 7 – Effect of overlaying on the hard phases elements diffusion at the external surface a)interdendritic region, b)dendritic region, and at the interface with the base material, c) interdendritic region, d) dendritic region.

4. CONCLUSIONS

Laser cladding leads to fine dendritic microstructures compared to those obtain after conventional coating processes. Multilayer structures showed alternate regions of fine and coarse dendrites, due the effect of deposition heat cycle, during overlapping and overlaying. Thicker coatings showed a interdendritic refinement as one approaches the external surface.

Interdendritic and dendritic regions present different chemical composition, the first one being richer on Cr, W and Si and the later on Co and Ni. Theses are reduced as a consequence of the multilayer deposìtion.

Surface performance depends on the number of deposited layers. The ticker the coat the more non-uniform are the properties.

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