POLITEHNICA UNIVERSITY TIMIŞOARA
DEPARTMENT FOR MATERIALS SCIENCE AND MANUFACTURING
Materials Engineering

PHD THESIS ABSTRACT

Researches on the reinforcement of cobalt based composites coatings with tungsten carbide particles

Phd student
Eng. Iasmina-Mădălina Anghel (Petculescu)

PhD Advisor
Prof. univ. dr. ing. Ion-Dragoş Uțu

Timişoara 2026

Abstract

1. Introduction

Metal matrix composites reinforced with hard ceramic particles represent an essential research direction in the development of advanced solutions for protecting surfaces operating under extreme service conditions. Over time, various metal matrix composite systems reinforced with hard ceramic particles have been studied, including nickel, iron or aluminium-based matrices strengthened with carbides, borides or oxides, with the aim of improving wear and corrosion resistance. In this broad research context, cobalt (Co)-based composite systems reinforced with various ceramic particles such as tungsten carbide (WC), titanium carbide (TiC), chromium carbide (Cr_3C_2), and tantalum carbide (TaC) have attracted considerable interest in the scientific literature due to their superior performance in terms of wear resistance, high hardness, and favourable behaviour in aggressive corrosive environments [1, 2]. Owing to these properties, such materials are widely used in the aerospace, energy, and mining industries, as well as in the manufacture of heavy equipment, where components are subjected to severe tribological and chemical stresses.

Cobalt, as a metallic matrix, provides a good combination of toughness and thermal stability, while tungsten carbide, with its extremely high hardness, significantly contributes to enhancing wear resistance. The proportion and distribution of these particles within the matrix decisively influence the microstructure and functional properties of the coating [3, 4]. Therefore, controlling the composition and processing parameters is essential for obtaining a high-performance material.

In this context, within this doctoral thesis, Co-based composite coatings reinforced with tungsten carbide (WC) were developed using two modern deposition methods: vacuum furnace brazing and laser cladding. These techniques provide good adhesion to the substrate and precise control of the microstructure of the deposited layer, with minimal dilution and thermal distortion. Coatings with varying WC contents were investigated in order to optimize the composition for achieving the highest possible tribological and corrosion performance.

The performance evaluation of the coatings was carried out through the characterization of surface properties, with emphasis on sliding wear resistance and electrochemical corrosion resistance in aggressive environments.

The study aimed to establish the relationship between WC content, the coating microstructure and its functional behaviour, thereby providing an in-depth understanding of the role of ceramic particles in improving the durability of composite coatings [5, 6].

Coatings with optimal technological and functional properties were identified, suitable for application under real industrial conditions, thus contributing to extending the service life of components exposed to demanding environments.

2. Current state of functional coatings

Functional coatings represent a category of advanced materials used to improve the surface properties of various industrial components. Their purpose is generally to provide effective protection against wear, corrosion, high-temperature oxidation, contact fatigue, or other forms of degradation under severe operating conditions. The selection of the deposition technology and chemical composition is essential for achieving high and long-lasting performance [7, 8].

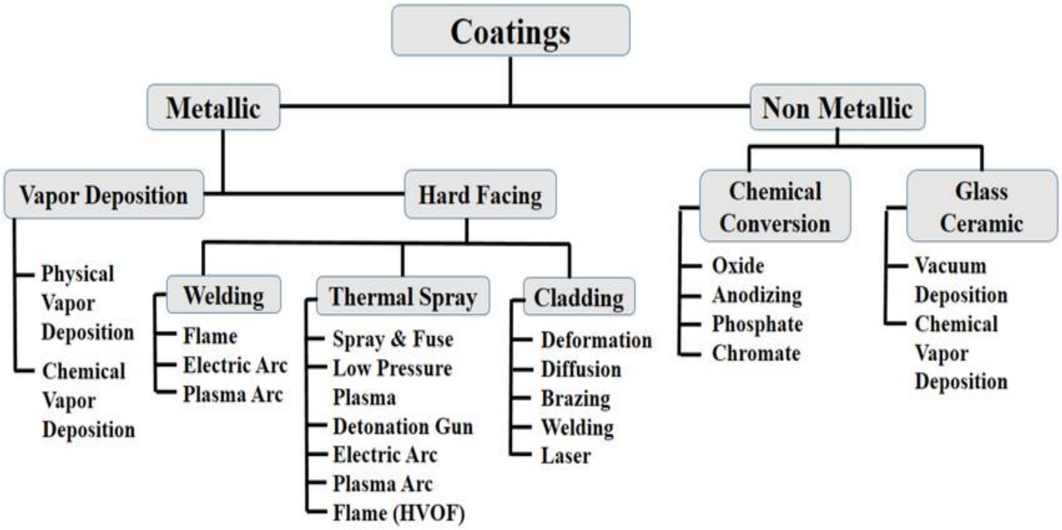

Fig. 1. Classification of coating technologies [9]

At present, a variety of methods are used to produce functional coatings (Fig. 1), including thermal spraying (HVOF, plasma), physical or chemical vapor deposition (PVD/CVD), brazing, laser cladding, sintering, and additive manufacturing technologies. Among these, laser cladding has emerged over the past decade as one of the most promising techniques due to its excellent control over the heat-affected zone, microstructure, and coating adhesion [10, 11].

In applications requiring high wear and corrosion resistance, cermet-type coatings are frequently used. The metallic matrix (often cobalt, nickel or iron) provides toughness and ductility, while the ceramic particles (WC, TiC, Al_2O_3, etc.) provide high hardness and abrasion wear resistance. Co-based composites reinforced with various ceramic particles (WC, TiC, TiN) are among the most studied and widely used for this purpose, with applications in the manufacturing of cutting tools, moulds, pumps, turbines, and other heavily loaded industrial equipment [12, 13].

Recent studies have shown that the proportion, size, and distribution of the reinforcing particles have a direct impact on coating performance. Additionally, the interface between the metallic matrix and the ceramic phase influences delamination resistance and behaviour in corrosive environments. Coatings deposited by laser cladding typically exhibit a fine microstructure, with low dilution and low porosity, which provides superior durability compared to other deposition methods [14].

In addition to wear, corrosion is a major degradation mechanism for industrial components, particularly in sectors such as chemical, marine, and energy industries. Co-based composites with WC particles provide an effective barrier against corrosive agents, especially when the coating structure is dense and homogeneous. It has been shown that WC can enhance surface passivation and reduce the corrosion rate in acidic or saline environments [15].

Current research in the field of functional coatings focuses on optimizing the composition, deposition method, and processing parameters to develop materials capable of withstanding demanding environments.

3. Materials, methodology, equipment

The base material used within the experimental program of the doctoral thesis was austenitic stainless steel AISI 904L, which was selected due to its extensive use in industrial applications subjected to severe service conditions. AISI 904L is characterized by a high nickel and molybdenum content, which provides superior resistance to general corrosion, localized corrosion (pitting), and stress corrosion cracking, as well as good structural stability at high temperatures [90].

Although AISI 904L exhibits excellent corrosion resistance and thermal stability properties, like other austenitic stainless steels, it has limitations in terms of surface tribological properties, particularly relatively low hardness and modest wear resistance [92]. These limitations justify the application of hard coatings intended to improve wear behaviour and extend the service life of components during service.

The substrate surface was processed by grinding with P150 abrasive paper in order to obtain a clean and controlled rough surface. Following this process, an average surface roughness of Ra = 4.8 µm was obtained. Prior to coating deposition, the sample surfaces were degreased with acetone to remove any impurities and contaminants.

For the experiments, a cobalt-based brazing alloy powder with the commercial name Amdry MM509B-C, produced by Oerlikon Metco, was used, with a particle size ranging between –125 and +45 µm and the chemical composition presented in Table 1. This alloy is characterized by good wetting and diffusion capability, being specifically designed for brazing applications in demanding environments. The presence of boron in the chemical composition lowers the melting temperature, facilitating thus the brazing process and ensuring the formation of high-quality metallurgical joints [93].

Tab. 1 Chemical composition of the Co based brazing alloy

	Chemical element, weight %								
Amdry MM509B-C	Co	Cr	Ni	W	Ta	B	Ti	Zr	C
	Rest	22.5 – 24.25	9.0-11.0	6.5-7.5	3.0-4.0	2.0-3.0	0.15-0.30	0.30-0.60	0.55 – 0.65

This powder was mechanically mixed, in dry condition, for 2 hours with different proportions of WC–CoCr–Ni 85–9–5–1 powder, having a particle size fraction of (–106 +45 µm), produced by Thermico GmbH, Dortmund, Germany.

Following the mixing process, three cobalt-based composite powder compositions were obtained, containing 10 wt.%, 20 wt.%, and 30 wt.% WC–CoCr–Ni (hereinafter referred to as WC).

After the homogenization stage, the resulting powders were used to obtain coatings by two modern methods, namely vacuum furnace brazing and laser cladding, in order to evaluate the material behaviour under severe loading conditions.

For vacuum furnace brazing, a HITERM 80-200 type furnace was used, and the deposition technology by this method is schematically illustrated in Figure 2.

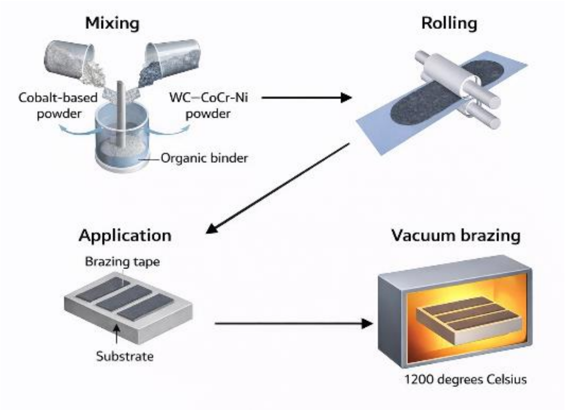

Fig. 2 Schematics of the furnace brazing process

For the laser cladding (Figure 3) a Coherent diode 100F laser was used, equipped with a Precitec YC 50 water cooled head; the system was operated by an industrial 7 axis robot produced by the CLOOS company.

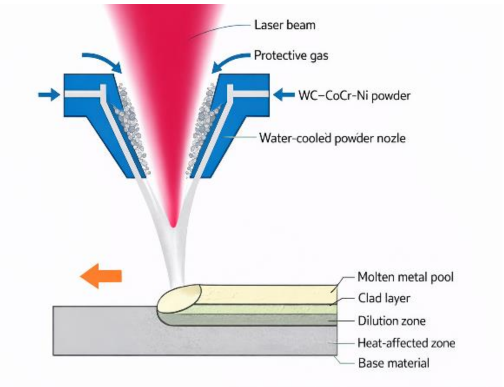

Fig. 3 Schematics of the laser cladding process

For the microscopic analysis, a Quanta FEG 250 scanning electron microscope (FEI, Hillsboro, OR, USA), equipped with an EDX system and an Apollo SSD detector (EDAX Inc., Mahwah, NJ, USA), was used. X-ray diffraction analyses were carried out using a Philips/Panalytical X’Pert diffractometer system with Cu-Kα radiation.

Hardness measurements (HV0.3) were performed using a ZHVμ Vickers microhardness tester manufactured by Zwick/Roell.

To evaluate the sliding wear behaviour of the coatings using the pin-on-disc method, a tribometer manufactured by CSM Instruments, Switzerland, was employed. After completion of the wear tests, the wear track profile for each tested sample was measured using a laser scanning microscope (Keyence VK-X260K, Osaka, Japan) in order to determine the volume of material loss.

Potentiodynamic measurements were carried out using an SP-150 galvanostat (Biologic, Seyssinet-Pariset, France) to assess the electrochemical behaviour of the coatings. For the tests, a three-electrode electrochemical cell was used, consisting of a platinum counter electrode, a saturated calomel reference electrode, and the working electrode represented by the analysed sample.

4. Results and discussions

4.1 Vacuum brazing

The deposition of the coatings by vacuum brazing was carried out at a maximum temperature of 1200 °C, with heating performed in stages and holding steps. All the obtained coatings exhibit a dense and homogeneous microstructure, without the presence of evident structural defects such as porosities or microcracks, which indicates a good quality of the deposition process. Good adhesion of the layers to the substrate is also observed, with no discontinuities at the interface. At the interface between the substrate and the deposited coating, a diffusion zone can be clearly identified (Figure 4), resulting from the thermo-chemical interactions occurring during the brazing process, which suggests the formation of an efficient metallurgical bond between the two components. This diffusion zone significantly contributes to the structural integrity and mechanical stability of the coating–substrate system.

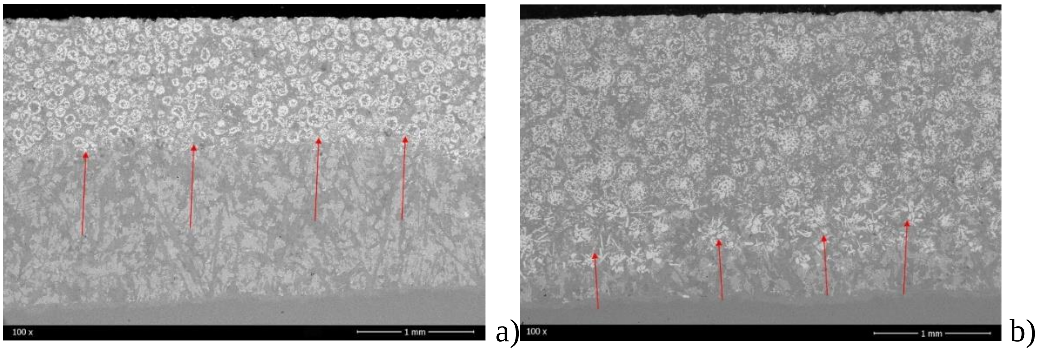

Fig. 4 SEM images of the brazed coatings: (a) Co + 20 % WC; (b) Co + 30 % WC

The addition of tungsten carbide particles had a significant positive effect on the hardness of the material. Thus, for the Co + 30% WC coating, the hardness reached values of approximately 880 HV0.3. A progressive increase in hardness was observed, directly correlated with the WC content in the deposited coating, which can be attributed to the enrichment of the cobalt-based metallic matrix in carbon and tungsten as a result of diffusion processes occurring during brazing. The partial dissolution of WC particles and the redistribution of alloying elements facilitate the formation of hard phases and solid-solution strengthening, thereby leading to improved mechanical properties of the coating.

The differences in hardness directly influenced the sliding wear behaviour, both for the analysed coatings and for the base material. Figure 5 illustrates the evolution of the friction coefficient (COF) for each tested material, while Figure 6 presents the wear rate determined based on the volume of material loss. The cobalt-based composite coating containing tungsten carbide (WC) reached a steady-state regime after approximately 35–40% of the total number of cycles, whereas the cobalt-based coating without WC addition stabilized only after 70–80% of the cycles.

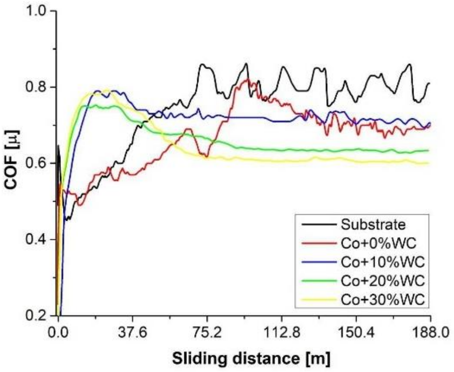

Fig. 5 Evolution of the friction coefficient (COF) of the brazed coatings

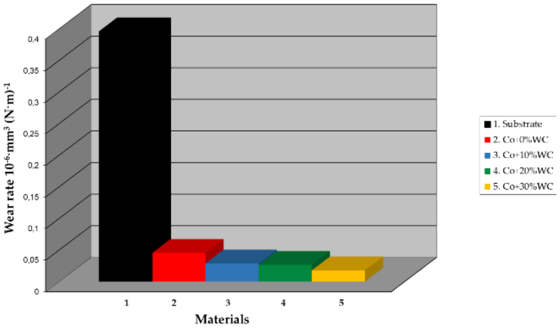

Fig. 6 Wear rate evolution of the brazed coatings

Overall, the results highlight that the addition of WC-based powder particles leads to a reduction in the coefficient of friction compared to both the substrate material and the cobalt-based coating without carbide addition. Moreover, the presence of tungsten carbide particles promotes stabilization of the coefficient of friction values throughout the sliding wear test, indicating a significant improvement in the tribological behaviour of the deposited layer. Among the analysed samples, the coating containing the highest fraction of tungsten carbide particles (30 wt.%) exhibited the lowest material loss and, consequently, the best resistance to sliding wear (Figure 7).

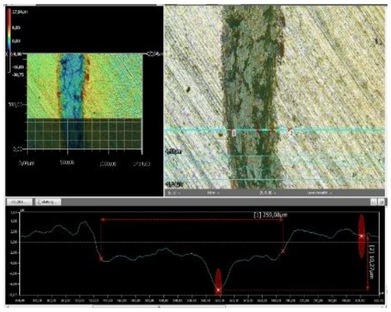

Fig. 7 Wear track profile of the brazed samples with Co + 30 wt.% WC

However, the deposition of cobalt-based composite coatings led to a significant improvement in the wear resistance of the steel substrate, regardless of the content of WC-based particles added. Compared to the stainless steel base material, material loss was reduced by up to 16 times in the case of the coating containing 30 wt.% WC, highlighting the effectiveness of this type of coating under sliding friction conditions.

Following the electrochemical corrosion measurements, it was found that the introduction of tungsten carbides into the cobalt matrix did not lead to a significant improvement in corrosion resistance. On the contrary, the highest corrosion current density value, 0.232 μA/cm², was recorded for the coating containing 30 wt.% WC, suggesting a slight increase in electrochemical activity. In the case of coatings containing WC particles, the corrosion potential values were slightly shifted toward more negative values, which may be attributed to the microstructural heterogeneity induced by the presence of ceramic particles and matrix–particle interfaces.

Overall, the results indicate that although the addition of WC significantly improves the tribological behaviour of the brazed coatings, its influence on corrosion resistance is limited, without, however, compromising the overall anticorrosive performance of the coating–substrate system.

4.2 Laser cladding

The optimised parameters presented in table 2 were used for the laser cladding coatings.

Tab. 2 Laser cladding parameters

Laser power (W)	Coating speed (cm/min)	Deposition rate (g/min)	Argon, (l/min)
720	22	6	14

The deposition of the coatings was carried out in a single layer, the resulting surface being formed by the successive and controlled overlapping of the deposited beads, thus ensuring the continuity and uniformity of the coating.

The macroscopic analysis highlights the presence of overlapping deposition beads with a parabolic shape, characteristic of the laser cladding process and resulting from the controlled overlapping of the deposition tracks. No structural defects such as porosity, cracks, lack of fusion, or delamination were identified, and the interface between the coating and the steel substrate exhibits good continuity, indicating the formation of an effective metallurgical bond. The total thickness of the obtained layers is approximately 900 µm, a value typical for single-layer laser cladding processes.

The presence of multiple phases (Figure 8) can be distinguished in the microstructure of the deposited layers: the light gray regions are attributed to a Co/Ni/Fe-based solid solution, which constitutes the metallic matrix of the coating, while the dark gray areas correspond to chromium-rich (Cr-rich) phases. The very bright regions are associated with tungsten- and silicon-enriched phases, resulting from the segregation of alloying elements during solidification.

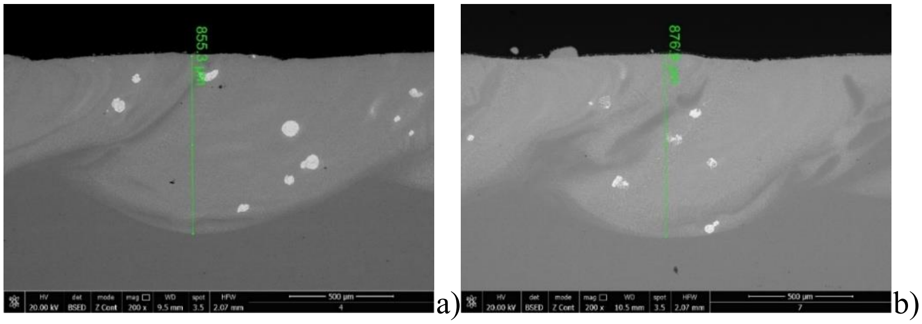

Fig. 8 SEM cross-sectional micrographs of the laser-cladded coatings:
(a) Co + 20 % WC; (b) Co + 30 % WC

At higher magnifications (Figure 9), a certain coarsening of the chromium-rich phases can be observed, as well as the partial formation of a eutectic-type microstructure, particularly in the layers containing 10% WC (Figure 9b) and 20% WC (Figure 9c). These microstructural changes are attributed to the influence of WC addition on the solidification mechanisms and on the redistribution of chemical elements within the melt pool.

As a result of the partial melting of the initial WC particles, needle-like structures can also be observed, especially in the coatings with a higher WC content (Figure 9c and 9d). The partial dissolution of carbides into the metallic matrix leads to its local enrichment in tungsten and carbon, a phenomenon that promotes the formation of hard phases and contributes to the modification of the mechanical properties of the coating.

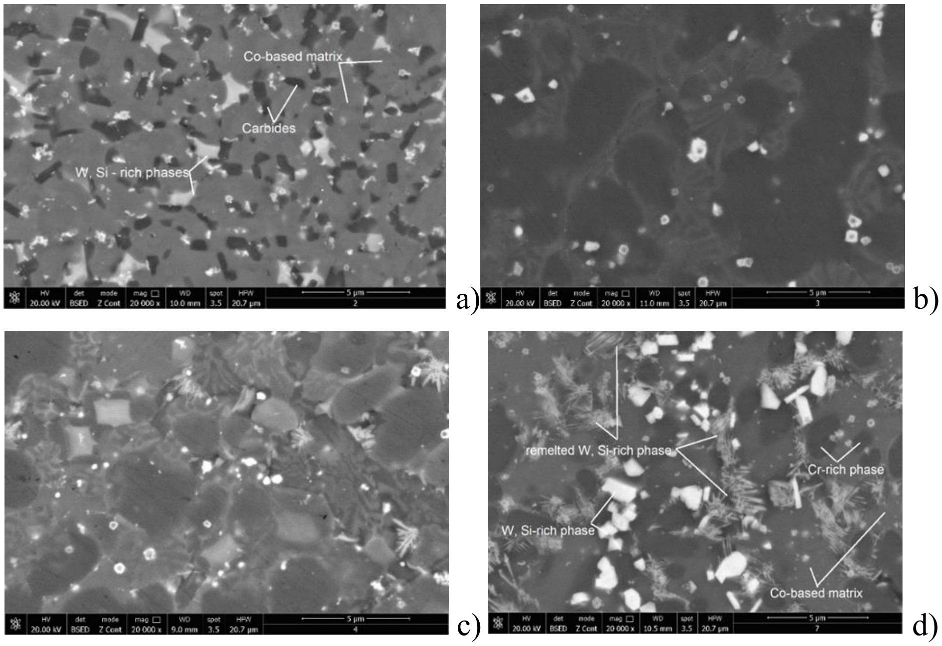

Fig. 9 Microstructure of the laser cladding deposited Co based composites:
(a) Co + 0 % WC; (b) Co + 10 % WC; (c) Co + 20 % WC; (d) Co + 30 % WC.

The hardness measured along the cross-section of the deposited layers indicates that it is not significantly influenced by the content of added WC particles (Figure 10), suggesting that in the case of laser-cladded coatings, the strengthening mechanisms are predominantly controlled by the microstructure of the metallic matrix and the degree of dilution with the substrate material, rather than by the weight fraction of WC carbides.

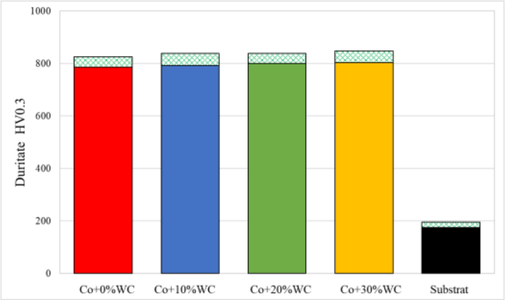

Fig. 10 Hardness values of the laser cladded coatings

The highest hardness values were measured in the regions close to the coating surface, where the dilution effect of the base material is reduced. In these areas, the chemical composition of the layer is closer to that of the feedstock powder, promoting the formation of hard phases and a more refined microstructure. As the interface with the substrate is approached, the increasing degree of dilution leads to a decrease in hardness, due to the enrichment of the metallic matrix in iron and the reduction in the concentration of alloying elements responsible for strengthening.

This variation in hardness along the thickness direction reflects the direct influence of the laser cladding process on the distribution of chemical elements and on the local mechanical properties of the deposited layers.

Following the wear resistance measurements, it was found that, in general, the addition of WC-based particles led to a slight reduction in the friction coefficient values, compared to both the substrate material and the cobalt-based coating without carbide addition (Figure 11). Furthermore, the presence of WC promoted the stabilization of the friction coefficient throughout the test, suggesting a more uniform wear mechanism and a more favorable interaction between the contacting surfaces.

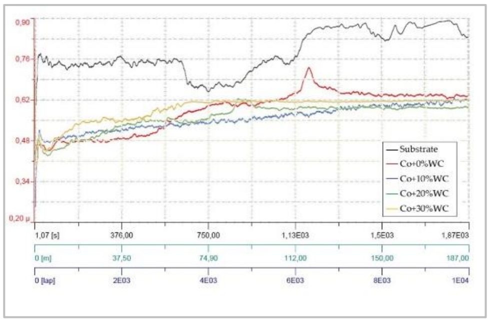

Fig. 11 Evolution of the friction coefficient (COF) for the laser cladded surfaces

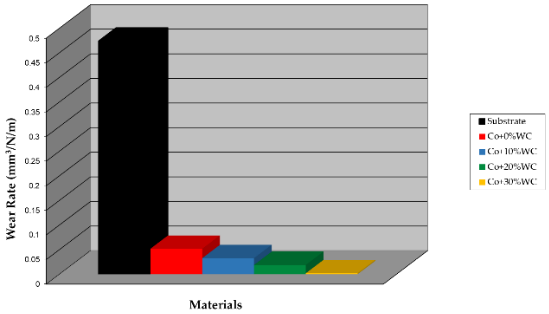

Fig. 12 Wear rate evolution of the laser cladded surfaces

The calculated wear rate values are graphically illustrated in Figure 12. The coating containing the highest weight fraction of WC particles (30 wt.%) exhibited the lowest material loss, thus demonstrating the best tribological performance among the analysed samples.

At the same time, it is noteworthy that the deposition of cobalt-based composite coatings led to a significant improvement in the wear resistance of the stainless steel substrate, regardless of the content of added WC particles. This result confirms the effectiveness of laser cladding technology in enhancing the durability of surfaces subjected to tribological stresses.

The geometric analysis of the wear tracks highlights a significant reduction in both their width and depth following the application of cobalt-based composite coatings and with increasing WC content (Figure 13).

Thus, for the stainless steel substrate, the width and depth of the wear track reached values of approximately 1185,03 µm and 59,86 µm, respectively, whereas for the Co + 30 wt.% WC composite coating these values decreased to approximately 198,87 µm in width and 1,37 µm in depth. This reduction in wear track dimensions indicates a superior resistance to friction-induced degradation of the composite coating, demonstrating the essential role of WC particles in limiting material loss and enhancing tribological performance.

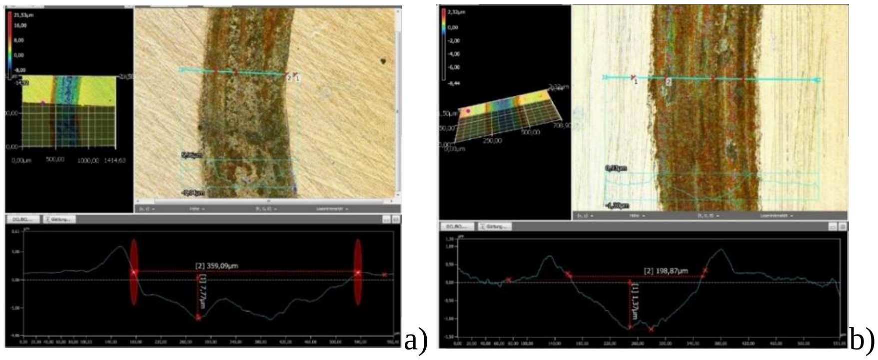

Fig. 13 Wear track profile of the laser cladded samples (selection):

(a) Co + 20 % WC; (b) Co + 30 % WC

Corrosion tests highlight that the deposition of cobalt-based composite layers does not negatively affect the corrosion resistance properties of AISI 904L steel (Figure 14). Moreover, the Co-based composite layers exhibit superior chemical stability, reflected by lower corrosion current density values compared to those of the uncoated substrate.

The addition of WC-based particles led to a shift in the corrosion current density values from 0,066 µA/cm² for the Co + 0% WC layer to 0,116 µA/cm² for the Co + 30% WC layer. However, this increase did not result in a significant reduction in corrosion resistance, even though the measured corrosion potentials showed a slight shift toward more negative values. These results indicate that the addition of ceramic WC particles into the cobalt-based matrix does not compromise the electrochemical behavior of the coatings, maintaining good corrosion resistance in a chloride-containing environment.

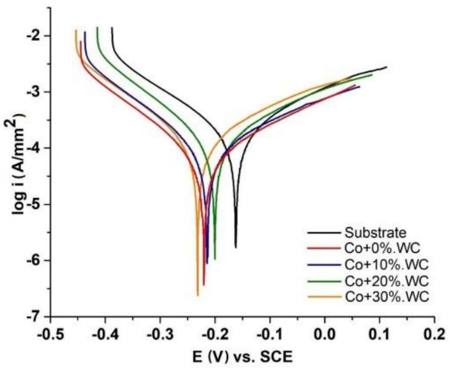

Fig. 14 Polarization curves of the laser-cladded samples

The results of the tests performed on the laser-cladded samples indicated that the Co + 30 wt.% WC layer exhibited the most balanced combination of wear resistance and chemical stability, despite a relatively high degree of iron dilution from the substrate associated with single-layer deposition. Based on these results, the optimized Co + 30 wt.% WC composition was selected for the fabrication of coatings deposited in one, two, and three successive layers using the same laser beam deposition parameters (Figure 15).

The main objective of this approach was to investigate the influence of the number of deposited layers on the degree of iron dilution in the cobalt-based matrix and, consequently, on the mechanical properties, wear behavior, and corrosion resistance of the obtained coatings.

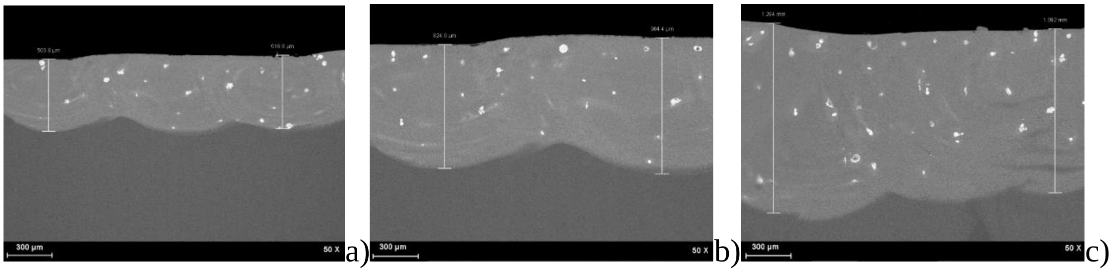

Fig. 15 Cross-sections SEM images of samples with different architectures:

(a) Sample 1 (1 layer); (b) Sample 2 (2 layers); (c) Sample 3 (3 layers)

The presence of WC carbide agglomerations can be observed, visible as white particles randomly distributed throughout the volume of the layers. These agglomerations are characteristic of composite coatings and result from the distribution of ceramic particles within the cobalt-based metallic matrix. Additionally, no macropores were identified in the coating structure, indicating proper densification of the deposited material.

Hardness measurements were carried out exclusively in the upper region of the layers, as the objective was to evaluate the variation in hardness along the cross-section at a depth of approximately 2 mm from the surface. The results highlight that an increase in the thickness of the deposited layer correlates with higher hardness values. This improvement in hardness can be attributed to the reduction of iron (Fe) content in the metallic matrix, a phenomenon that promotes grain refinement of the microstructure.

Following the wear resistance tests, it was found that the coating deposited in a single layer exhibited the highest average coefficient of friction value ($\mu_{me}d = 0{,}621$). In contrast, the coatings deposited in two layers ($\mu_{me}d = 0{,}323$) and three layers ($\mu_{me}d = 0{,}318$) showed significantly lower COF values, indicating superior tribological behaviour. The improved tribological performance of the multilayer coatings can be correlated with their enhanced structural integrity and with the reduced degree of WC carbide decomposition, a phenomenon that promotes the formation of a higher fraction of W_2C carbide.

The presence of the W_2C phase contributes to the increase in hardness and wear resistance of the coatings, leading to a more stable tribological response during testing (Figure 16). Thus, controlling the multilayer architecture and the phase transformations associated with the laser cladding process plays an essential role in optimizing the friction and wear behavior of cobalt-based composite coatings.

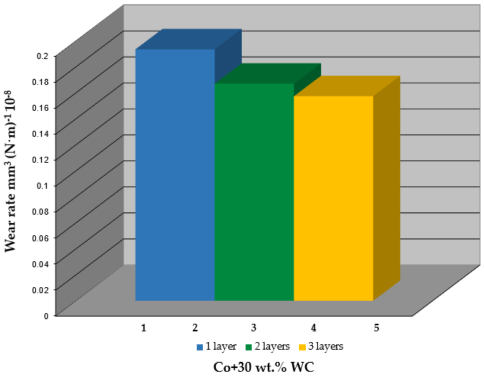

Fig. 16 Wear rate of the laser cladded coatings

The analysis of the polarization curves obtained from the corrosion tests indicates that the triple-layer coating (Sample 3) exhibited the best corrosion resistance among the investigated samples. This behavior is evidenced by the lowest corrosion current density values, approximately 0,091 $\mu A \cdot cm^{-2}$, compared to those recorded for the single-layer coating (0,105 $\mu A \cdot cm^{-2}$) and the double-layer coating (0,117 $\mu A \cdot cm^{-2}$), thus demonstrating superior protective performance. These results confirm that the multilayer architecture not only limits iron dilution from the substrate but also contributes to optimizing the corrosion behaviour of cobalt-based composite coatings produced by laser cladding.

5. Conclusions, future research perspectives and personal contributions

General conclusions

In the case of coatings obtained by vacuum brazing, it has been shown that this technology allows the formation of dense, homogeneous Co–WC layers with good adhesion to the AISI 904L stainless steel substrate, regardless of the WC content studied (0–30 % wt.). The absence of major structural defects, such as porosity or microcracks, as well as the presence of a well-defined diffusion zone at the coating–substrate interface, confirms the efficiency of the brazing process in achieving stable metallurgical bonds.

Microstructural analysis revealed the formation of a dendritic microstructure characteristic of cobalt-based coatings, with a Co/Ni solid solution matrix in which secondary phases rich in Cr and W are dispersed. The progressive addition of WC caused significant changes in the morphology and distribution of the phases, leading to the formation of an upper carbide-enriched zone, followed by a transition zone and a diffusion region at the substrate interface. These observations confirm the critical role of WC content in the solidification mechanisms and elemental segregation.

EDX and XRD investigations allowed the identification and correlation of the present phases, highlighting the formation of a Co-based solid solution, Laves-type intermetallic compounds (Cr_3Ni, Co_2W_4) and hard carbides Cr_7C_3 and W_2C. The appearance of tungsten-rich phases, particularly at high WC contents, underscores the influence of diffusion and molten-state reaction processes on the evolution of the phase structure.

From a mechanical standpoint, the brazed coatings exhibited a significant increase in hardness with increasing WC content, reaching values of up to approximately 880 HV0,3 for the Co + 30 %

WC layer. This evolution results from the combined effects of carbide dispersion strengthening and the enrichment of the metallic matrix in tungsten and carbon. The tribological performance followed the same trend, with the coating containing the highest WC content showing the lowest wear rate and material loss—up to 16 times lower than that of the substrate.

Electrochemical tests demonstrated that Co–WC coatings deposited by vacuum brazing do not compromise the corrosion resistance of AISI 904L steel. Although the addition of WC leads to a slight increase in corrosion current density at high contents, the overall anticorrosive behaviour remains stable, indicating that the microstructural heterogeneity induced by the ceramic particles does not significantly affect the performance of the coating–substrate system.

In the case of coatings obtained by laser cladding, the results highlighted the major advantages of this technology in terms of microstructure control and functional properties. Increasing the WC content up to 30 wt. % led to the formation of hard carbide phases (W_2C, Cr_7C_3), directly impacting hardness and wear behaviour. Additionally, the use of a multilayer architecture for the optimized Co + 30 % WC composition significantly reduced iron dilution from the substrate, a phenomenon that contributed to microstructure refinement and improved mechanical and tribological properties.

Compared to single-layer deposition, the coatings applied in two and three layers exhibited higher hardness values, lower friction coefficients, and reduced wear rates, confirming the essential role of a multilayer architecture in optimizing functional performance. Additionally, the multilayer coatings demonstrated the best electrochemical stability in 3.5 % NaCl solution, due to the reduced Fe content and the formation of a denser, more stable passive film.

Overall, the results demonstrate that both vacuum brazing and laser cladding are viable technologies for producing Co–WC composite coatings, each offering specific advantages. While brazing provides homogeneous coatings with balanced tribological and corrosion properties, laser cladding—particularly in a multilayer configuration—allows superior control of dilution and mechanical performance, making this approach highly suitable for demanding industrial applications.

Future research perspectives

The results obtained in this thesis open new research directions that can contribute to the knowledge and extend the applicability of the WC-Co coatings, among which the following can be mentioned:

- Investigation of the corrosion and wear behaviour in severe condition such as high temperatures, complex corrosive environments and cyclic loadings;
- Optimisation of size and distribution of the WC particles using different carbides grades or powders with controlled morphology;
- Study of the influence of post-coating heat treatments on the microstructure, residual stress and functional properties;
- Extending the concept of multi-layer architecture, obtaining functionally graded layers, with controlled content of the WC powder;
- Evaluation of the coating’s performances in conditions close to real industrial applications, on complex geometry components.

Personal contributions

A first important contribution is the development and systematic characterisation of the cobalt based composite coatings with variable wolfram carbide contents (0-30 WC wt.%) obtained using vacuum brazing, a technology less explored in the literature for this type of composite systems. Using a rigorous experimental approach, clear correlation was established between the coating composition, the resulting microstructure, phasic structure and mechanical, tribological and electrochemical properties, offering a solid base for the usage of this type of coatings in the severe condition applications.

A significant original contribution constitutes the highlighting of the role of WC addition on the microstructural evolution and strengthening mechanisms in the brazed coatings, demonstrating that the addition of wolfram and carbon in the metallic matrix together with carbide dispersion leads to a substantial increase of hardness and improves the wear behaviour, without significantly compromising the corrosion resistance.

The thesis makes a significant contribution by the comparative analysis between Co-WC coatings obtained by vacuum brazing and laser cladding, showing the advantages and limitations of each technology from a microstructural and functional point of view. This comparison offers an integrated perspective over the way in which the deposition technology influences the final performances of the coating, aspect which is rarely approached unitary in the literature.

A major original contribution is the optimisation of the chemical composition Co+30 wt.% for the laser cladded coatings, identified as an optimal solution in terms of balance between hardness, wear resistance and corrosion stability. The thesis demonstrates that this chemical composition offers superior performances compared to the coatings obtained with lower WC content, constituting a solid base for future developments.

A relevant contribution is the investigation of the multi-layer architecture (one-, two- or three-layer) over the iron dilution, microstructure and functional properties of the Co + 30 % WC deposited by laser cladding. The results clearly demonstrate that the multi-layer coating significantly decreases the iron dilution from the substrate, favours the microstructure refinement and leads to the increase of hardness, decrease of the friction coefficient and wear rate and improvement of the electrochemical behaviour.

The thesis contributes also to the clarification of the wear and corrosion mechanisms for the Co-WC coatings, correlating the tribological results with the microstructure (carbides distribution, presence of hard W_2C și Cr_7C_3 phases) and iron dilution analysis. This integrated approach facilitates a profound understanding of the way that the coating structure influences the response to mechanical and chemical stresses.

Last but not least, an important contribution is the formulating of concrete technological recommendations for the Co-WC coatings optimisation, including choosing the chemical composition, coating technology and architecture depending on the application requirements. The recommendations have a high transfer potential to the industry, especially with applications such as refurbishment, wear protection, and extending the service life of components subjected to severe stress.

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