COMPARISON OF MECHANICAL PROPERTIES OF LASER CLADDED WC AND (TiW)C_{1-x} IN Ni-BASED ALLOY COATINGS

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Abstract

For wear demanding applications, the metal matrix composites (MMC) are often used due to their high wear resistance, and the tungsten carbide is often used as hard reinforcing particles. Nevertheless, there are still some limits of WC, mainly its deterioration due to heat load during laser cladding. Therefore, there is an effort to develop a new type of reinforcing particles with superior properties to WC. This study focus on analyzing microstructure and mechanical properties of laser cladded Ni-based coating reinforced with a new (TiW)C_{1-x} carbide and compare it with the usual one with WC. In the new (TiW)C_{1-x} based coating a higher amount of carbide particles remain undissolved thus providing with higher hardness and improved wear resistance.

Keywords: Laser cladding, wear resistance, MMC coatings

1. INTRODUCTION

One of the best coatings for application requiring high hardness and wear resistance are materials combining tough matrix and hard reinforcing carbide particles, the MMC (metal matrix composites). And laser cladding is a possible technology to apply these coatings [1]. The commonly used coating is tungsten carbide (WC) in Ni-based alloy. The properties of this coating as well as the influence of laser cladding parameters or the amount or shape of used carbides have already been documented in the literature [2–6]. Nevertheless, there are still limits of this material because WC can be negatively affected by extensive degradation during the laser cladding process and has inferior thermodynamic stability compared to many other carbides [7]. New types of carbides and MMC coatings are being developed to overcome the limitations associated with tungsten carbide-based coatings [7]. The goal of this work is the analysis of the microstructure and mechanical properties of the experimental coating based on (TiW)C_{1-x} carbides. The results are compared with the properties of WC-based laser cladded by similar conditions and analyzed in our previous study [8].

2. EXPERIMENTAL PROCEDURE

The new experimental powder from the Oerlikon Metco company composed of 60 wt% of angularly shaped (TiW)C_{1-x} carbides blended with gas atomized NiCrBSi (8.0Cr3.5Si1.6B0.3C Ni bal.) particles were used. For the WC based coating, the powder designated as MetcoClad 52052 was used, this powder is composed of 60 wt% of WC spherical particles blended with 40 wt% of the NiCrBSi. The WC was manufactured in a unique way, resulting in a non-acicular shape with higher hardness than conventional fused and crushed WC [9]. The density of (TiW)C_{1-x} carbide is 10.1 g/cm^3, lower than the density of WC which is 15,63 g/cm^3 [7]. This means, that the volume percent-age of carbides in the new powder is higher than in MetcoClad 52052. Laser cladding was executed using the solid-state laser Trumpf TruDisk 8002 with Precitec coaxial 4-way cladding head YC52. Two variants of the coating from the experimental powder were selected for this study – one with high heat input and one with low heat input. The laser cladding process parameters were chosen as follows: powder feed rate F = 540 mg/s, process speed S = 8.3 mm/s and laser power for variant 1 P = 2400 W and for variant 2 P = 1400 W. The overlapping ratio was 50% of the single bead width. For the WC based coating – a more detailed study on influence on process parameters was presented in a previous study [8], in this study only the results for comparison are presented. The coatings were deposited onto plates of carbon steel (EN10083 2:C45) with dimensions 100 × 100 × 20 mm to ensure sufficient heat dissipation. Substrates were pre-heated to 350 °C prior to deposition to avoid cracking of the coating due to the high thermal gradient. After the deposition, the samples were left to cool down at room temperature. The microstructure was evaluated on the coatings´ cross-sections (ground and polished by automatic Leco grinding and polishing equipment) using optical microscope Nikon Epiphot 200 and Scanning electron microscope EVO MA25, Zeiss, (with LaB6 thermal filament). The thickness of the coating was measured on the cross-section and was averaged at least 10 measurements. The microhardness HV0.1 was evaluated on the coating the cross-section perpendicularly and longitudinally to cladding direction. The matrix of indents' locations (5 x 10) was designed to cover the area of the two overlapping tracks. The abrasive wear resistance was evaluated by the Dry Sand Rubber Wheel Test, in accordance with ASTM G-65. Test parameters were as follows: 22 N Load; Al_2O_3 abrasive media (F70: 200-300 µm grain size); AG 29 rubber counterpart; 718 m total abrasive distance. The surface of the coatings was left in the as-clad state, not to exclude the upper coatings layers from the evaluation. The samples were weighed after each 143 m. Using the 11.236 g/cm^3 specific density, determined by Archimedes' low method, the cumulative volume loss [mm^3] was calculated. The wear coefficient K [mm^3/Nm] was averaged from two independent measurements.

3. RESULTS AND DISCUSSION

The Microstructure of coatings containing new $(TiW)C_{1-x}$ carbides is presented in **Figures 1 and 2**. **Figure 1** shows the coating cladded with process parameters variant 1, the overall cross-section in longitudinaly to the direction of the cladding is in **Figure 1a** and perpendicularly to the direction of cladding – across the individual cladding bead in **Figure 1b**. It can be seen that near the surface, near the interface with the substrate and in the overlap of clad beads, there is the majority of undissolved carbide particles. These locations exhibit higher cooling rates and therefore the carbides remain undissolved. The details of the interface are in **Figure 1c** and the surface area is in **Figure 1d**. **Figures 1e and 1f** show details in the middle of the coating – where the carbides are dissolved in the matrix. This variant of the coating is without significant porosity or other structural imperfections. The dilution of the coating material o the coating is sufficient but there is not undesirably increased mixture of substrate material to the coating.

The microstructure of the coating cladded with process parameters variant 2 is presented in **Figures 2 a-f**, with the same order as the previous one. It can be seen that this variant of the coating contains many voids and pores with dimensions up to 500 µm, mainly near the substrate. This is due to significantly lower heat input, and therefore insufficient melting of powder and substrate material. It would affect the adhesion of the coating slightly, but on the majority of the interface there is a sufficient mixture of both materials and the adhesion should be good. The adhesion of the coating was not measured for this study. Contrary, this coating contains significantly more undissolved carbide particles than the variant 1 which will positively affect the hardness of the coating and wear performance as the undissolved carbides have significantly higher hardness than the matrix, as noted in the previous chapter.

Figure 3 represents the coating based on WC carbides. It can be seen that the majority of the carbides is dissolved in the matrix. Few undissolved carbide particles remain near the surface, interface with the substrate, and overlap of beads. But it is significantly less than in the case of coating based on new carbides, even if the cladding conditions were similar. The WC carbides are more prone to dissolution than the $(TiW)C_{1-x}$ carbides. More, the WC carbides have higher specific density, and because the powders contain the same weight percentage of carbide, the WC coating contains less volume percentage of carbides. Also, WC carbides have lower micro-hardness than the new $(TiW)C_{1-x}$ carbides[8]. These factors significantly affect the wear behavior of WC based coting, which is mainly discussed in the previous study [8].

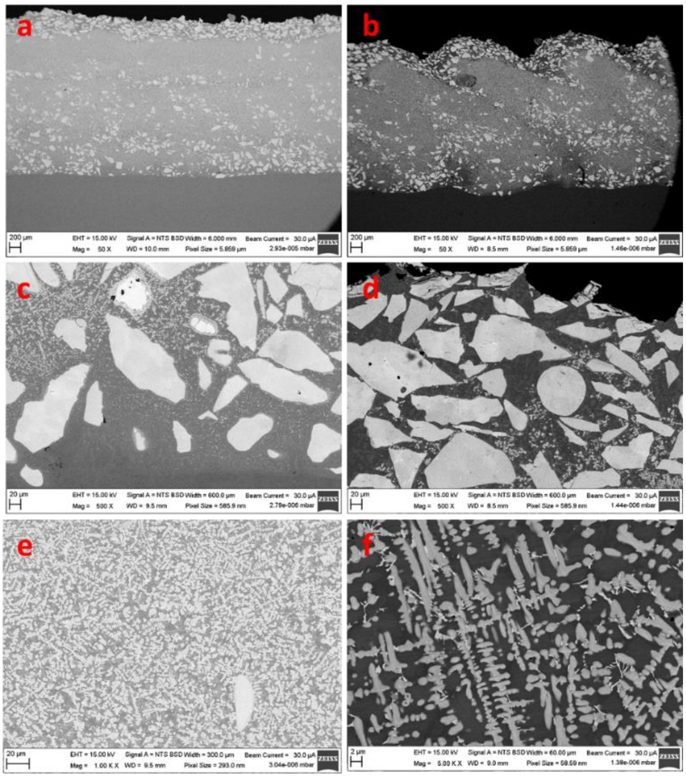

Figure 1 The microstructure of $(TiW)C_{1-x}$ coating variant 1: a) longitudinal cross-section, b) transverse cross-section, c) detail of interface with the substrate, d) detail of coating surface, e, f) details of diluted carbides

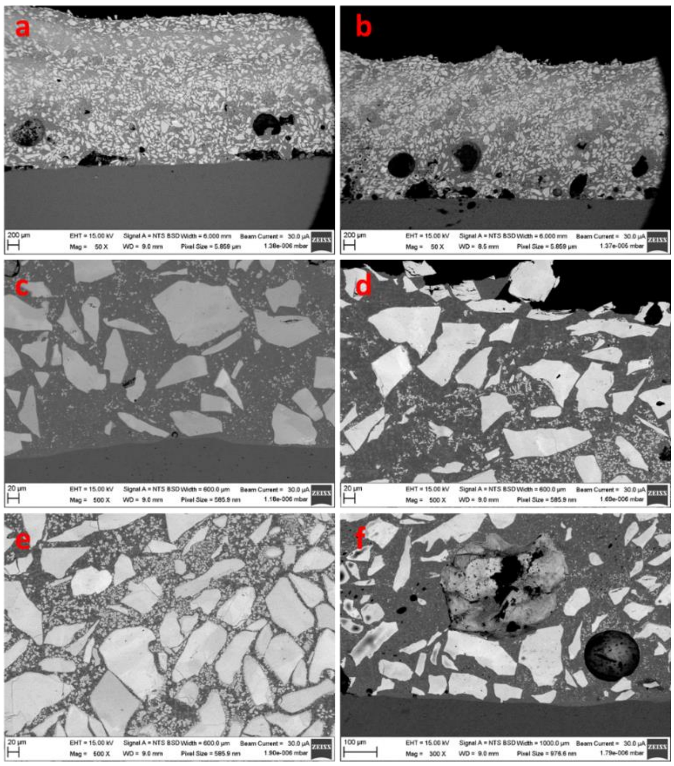

Figure 2 The microstructure of $(TiW)C_{1-x}$ coating variant 1: a) longitudinal cross-section, b) transverse cross-section, c) detail of interface with the substrate, d) detail of coating surface, e) inner structure, f) detail of pores

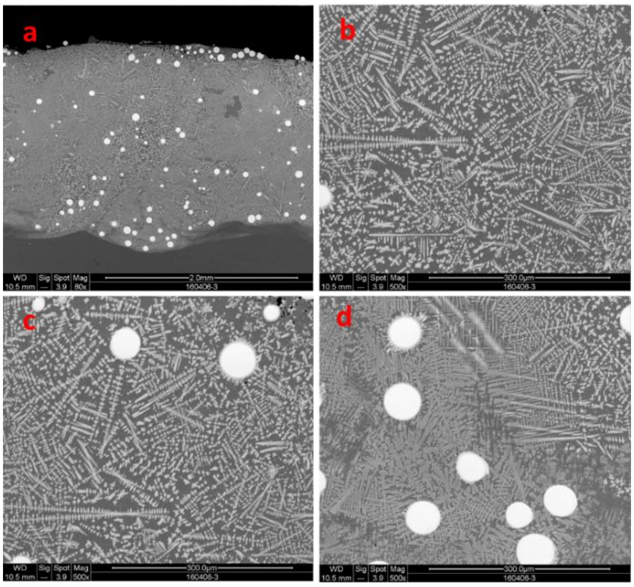

Figure 3 The microstructure of WC coating: a) transverse cross section, b, c, d) details of inner structure and dissolved carbides

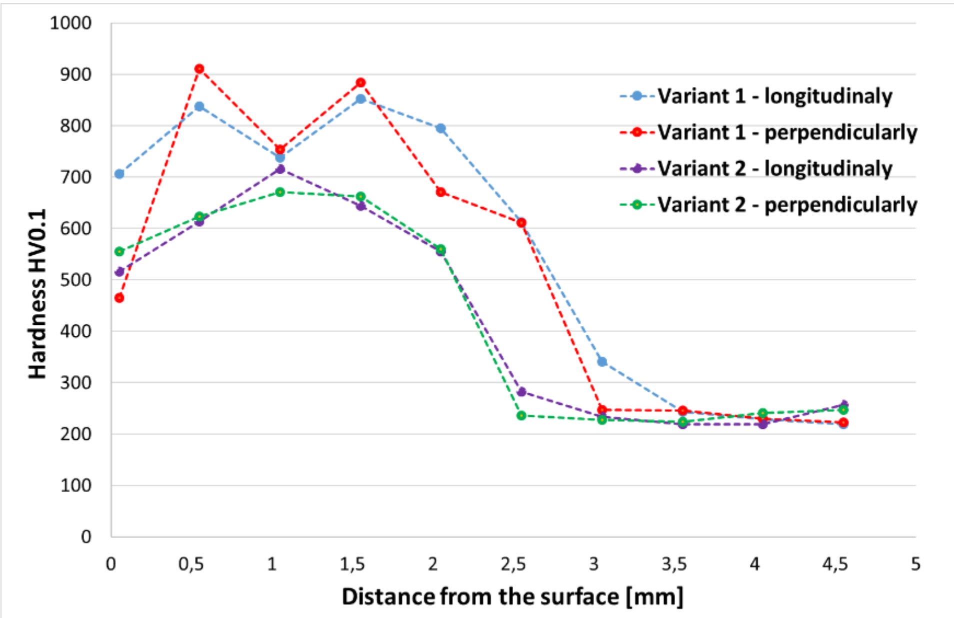

Figure 4 The average micro-hardness HV0.1 in dependence on distance from the coating surface

The microhardness measurement is presented in **Figure 4**, the indentations are performed in the matrix with dissolved carbides. The hardness measurement of undissolved carbide particles is out of range of used method and it is not part of this study. However, the presented micro harness measurement HV0,1 represents the toughening of the matrix by carbide dissolution. Therefore the higher average hardness is measured for the coating variant 1, especially in the middle of the coating. In the coating 2, the majority of the carbides remain undissolved therefore the matrix exhibit lower hardness but it remains tougher. The tough matrix with the majority of undissolved hard particles is a desirable microstructure.

The **Figure 5** represents shows the abrasion wear test results. The surface of the coating shows some marks of abrasion wear tracks, but the corresponding cross-sections show utterly minimal wear degradation of the coating material.

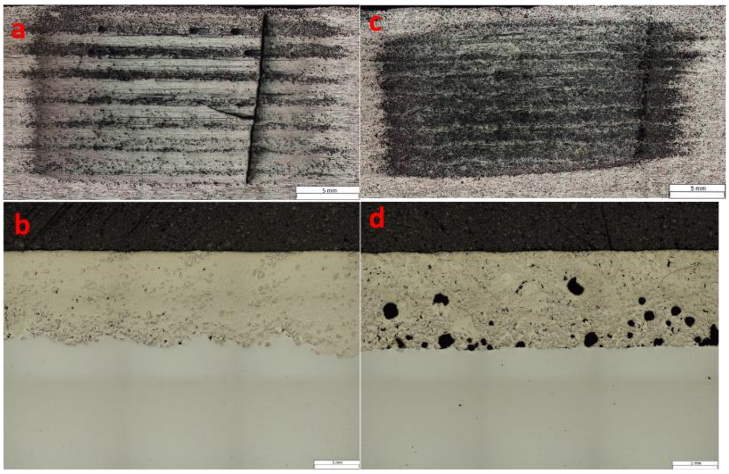

Figure 5 The abrasion test wear tracks, a, b) the coating variant 1 surface (a) cross-section (b); the coating variant 2 surface (c), cross-section (d)

4. CONCLUSION

The study shows microstructure, microhardness, and wear resistance test of laser cladded coating based on new experimental powder containing the $(TiW)C_{1-x}$ carbides. Two variants of the coating were cladded, with high and low heat input. The coating cladded with higher heat input does not contain any structural imperfections, but the carbides in the coating remain undissolved only near-surface and interface with the substrate, In the middle of the coating the carbides are dissolved in the matrix. Contrary, coating cladded with low heat input contains undissolved particles in the whole coating, but especially near the interface, there is high amount of pores due to lack of fusion with the substrate. The desired structure of the coating would be somewhere between these two variants, maintaining the majority of carbides undissolved but achieve homogenous coating without pores.

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