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Authors: Dominik Soboń, Wojciech Żórawski, Medard Makrenek

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Mechanical properties of cold gas spray $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ coatings

DOMINIKA SOBOŃ
WOJCIECH ŻÓRAWSKI
MEDARD MAKRENEK*

* Mgr inż. Dominika Soboń, dsobon@tu.kielce.pl -Katedra Inżynierii Eksploatacji i Przemysłowych Systemów Laserowych Politechnika Świętokrzyska, Kielce, Polska
Dr hab. inż. Wojciech Żórawski, ktrwz@tu.kielce.pl, <https://orcid.org/0000-0003-0482-5838> - Katedra Inżynierii Eksploatacji i Przemysłowych Systemów Laserowych Politechnika Świętokrzyska, Kielce, Polska
Dr Medard Makrenek, fizmm@tu.kielce.pl, <https://orcid.org/0000-0003-4587-3027> -Katedra Matematyki i Fizyki, Politechnika Świętokrzyska, Kielce, Polska

The cold gas spraying process is the most modern method of thermal spraying. The article presents the coating produced in this process from $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ powder on the Al 7075 alloy substrate. The properties of microstructure and mechanical properties of the deposited coating are also shown. The process parameters of the applied powder allowed to obtain coatings characterized by a consistent microstructure and negligible porosity.

KEYWORDS: cold gas spraying, mechanical properties, coating, $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$

Introduction

The process of cold gas spraying makes obtaining a coating with exceptional mechanical properties and possible potential innovation. The coating properties were developed in such a way that they are not available for other methods of thermal spraying methodology [1-2].

Formation of the coating, i.e. the deposition of powder, is carried out by plastic deformation of its grains as a result of hitting the ground at high speed, at a temperature much lower than its melting point [3]. In this way, it is possible to obtain a coating with favorable compressive stresses. During the cold gas spraying process, the high energy of the powder grains when they hit the surface improves the mechanical properties of the coating [4].

The range of materials used in the cold gas spraying process includes pure metals, alloys and cermets [5-7].

Cermet coatings are made of a metal matrix and a hard reinforcing phase. They are characterized by a number of increased mechanical properties and are used in industry due to their structural integrity and high resistance to temperature and wear. The combination of ceramic and metal phases enables higher fracture toughness [8]. Cermet coatings $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$, obtained in thermal processes, have been used as anti-corrosive coatings for machine elements and increasing their wear resistance [9].

Due to the cold gas spraying process, Cr_3C_2 carbides do not degrade to their lower hardness counterparts (Cr_{23}C_6). The use of cermet powders in the form of mixtures ensures better deposition efficiency [10]. In this process, ceramic particles do not deform plastically, but deposit in the plastic phase of the metal.

The advantage of the cold gas spraying process is that the phase composition of the powder can be preserved in the deposited coating [11]. The main factors affecting the mechanical properties of the resulting coatings and their microstructure are spraying parameters and the morphology of the powder used [12-13].

Research methodology

$\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ coatings were applied using the Impact Innovations 5/8 cold gas spray system (fig. 1) and powder and Diamalloy 3004, Oerlikon Metco Inc., Westbury, NY, USA.

Fig. 1. Impact Innovations 5/7 cold gas spraying station

It is a mixture of Cr_3C_2 and Ni20Cr powders in a weight ratio of 75%/25% [14]. The coatings were sprayed on an Al 7075 alloy substrate onto samples of 30 mm × 400 mm × 6 mm. The parameters of the cold gas spraying process are presented in the tab. I.

A scanning electron microscope (SEM-E-SEM FEI XL 30) was used to characterize the powder morphology and their metallographic cross-sections. The topography of the coatings and the shape of the profile were tested using a Talysurf CCI-Lite contactless 3D profilograph. Indentations were carried out using a Nanovea device with a Berkovich indenter, at a load of 20 mN.

TABLE I. Parameters of the cold gas spraying process for Cr_3C_2 -25(Ni20Cr) coatings

Pressure, MPa	4
Temperature, °C	800
Space, mm	50
Powder feed rate, g/min	95
Technological gas	N_2
Number of layers	40

Research results and discussion

■ **Characteristics of Cr_3C_2 -25(Ni20Cr) powders.** The morphology of the Cr_3C_2 -25(Ni20Cr) powder is shown in fig. 2. The spray powder was made as a mixture of Cr_3C_2 and Ni20Cr powders. Cr_3C_2 powder particles have an irregular shape, while NiCr particles have a spherical shape. Fig. 3 shows a cross-sectional view of the grains of Cr_3C_2 -25(Ni20Cr) powder.

Powder particles Cr_3C_2 -25(Ni20Cr) are characterized by clear porosity and numerous cracks in cross-sections.

Fig. 2. Morphology of $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ powder

Fig. 3. Cross-section of the grains of $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ powder

Fig. 4. Distribution of grain size of $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ powder

The grain size distribution of the powder is presented in fig. 4. The presence of a large fraction of fine grains is noticeable in the powder.

■ **Characteristics of $\text{Cr}_3\text{C}_2\text{-NiCr}$ coatings.** Fig. 5a and 5b show the morphology of the surface of the $\text{Cr}_3\text{C}_2\text{-25(Ni20Cr)}$ coating obtained in the process of spraying with cold gas. Powder size distribution has changed, which is reflected in the morphology and surface roughness.

$\text{Cr}_3\text{C}_2\text{-}25(\text{Ni}20\text{Cr})$ coatings have a smooth surface with fine grains. Cr_3C_2 ceramic particles are much thinner on the surfaces presented than they were at the initial stage. Cracking and breaking of the Cr_3C_2 particles into smaller fragments occurred while hitting them at high speed against the embedded particles (figs. 5c and 5d). Small ceramic particles occurring in the microstructure may have the effect of limiting crack propagation [15].

Fig. 6 shows the surface topography, depth histogram and load-bearing curve. The obtained results indicate a high surface roughness (R_a of $16.3 \div 160.3 \mu\text{m}$). Surface topography parameters are summarized in the tab. II. The tested coating has asymmetry with a negative inclination of the surface height. The value of kurtosis was 3.2, which indicates that the surface is free of extreme peak and valley features. The results show compliance with the surface morphology (fig. 4).

Fig. 5. Surface microstructure (a, b) and specimen (c, d) of a $\text{Cr}_3\text{C}_2\text{-}25(\text{Ni}20\text{Cr})$ coating sprayed with cold gas

Fig. 6. Surface configuration, depth histogram with a load-bearing curve for a coating over a distance of 50 mm

Fig. 7. Distribution map and histograms for the Cr_3C_2 -25(Ni20Cr) coating: a) –b) microhardness, c) –d) Young's modulus

TABLE II. Surface topography parameters (according to ISO 25178)

Average square height S_q , μm	12.8
Asymmetry S_{sk}	-0.31
Kurtosis S_{ku}	3.2
Maximum peak height S_p , μm	43.0
Maximum cavity depth S_v , μm	69.4
Maximum height S_z , μm	112.4
Arithmetic average height S_a , μm	10.2

To confirm the mechanical properties of cold gas sprayed Cr_3C_2 -25(Ni20Cr) coatings, their hardness and Young's modulus were tested. The hardness of the obtained coating was 627 HV0.3, while the value of Young's modulus was 145.9 GPa. Fig. 7 presents the distribution map, hardness histogram and shell's Young's modulus.

Conclusions

The paper discusses the results of testing the mechanical properties and microstructure of the Cr_3C_2 -25(Ni20Cr) coating, sprayed with cold gas on an Al 7075 substrate. The experiment allowed obtaining a compact microstructure and negligible porosity coating.

During the process, plastic deformation of Ni20Cr grains occurred, while Cr_3C_2 particles were partially defragmented due to a strong impact. The surface of the obtained coating shows a noticeable roughness, which is caused by the extensive granulometric distribution of the powders used, as well as the diverse interaction of Cr_3C_2 particles on the sprayed surface.

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