ABRASION WEAR RESISTANCE OF SELECTED HVOF SPRAYED WCCoCr COATINGS

[1]Sofia KŠIŇANOVÁ, [2]Marek VOSTŘÁK, [3]Žaneta DLOUHÁ

[1,2,3]Research and Testing Institute Plzeň, Pilsen, Czech Republic, EU,
ksinanova@vzuplzen.cz, votrak@vzuplzen.cz, dlouha@vzuplzen.cz

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Abstract

The HVOF (high-velocity oxygen fuel) technology is one of the most used processes for carbide-based coatings application. These coatings are suitable, for example, to replace hard chromium plating. In order to select the right coating for a given application, it is necessary to know the key properties. The aim of this study is to analyze and compare the abrasion wear resistance of HVOF sprayed coatings based on tungsten carbide (WC-CoCr). The structure of the coatings and their resistance to abrasive wear are analyzed and discussed.

Keywords: HVOF, thermal spraying, Abrasion resistance, Abrasion wear, WCCoCr coatings

1. INTRODUCTION

With thermal spraying technology, it is possible to increase the functional properties of the surface of various components. The wear and corrosion resistance, thermal insulation or biocompatibility can be affected by using the right coating material. High velocity oxy-fuel (HVOF) thermal spraying is often used in industry for components heavily stressed for wear or corrosion. Thanks to their high speed and temperature of up to 5500 K, they are used for spraying metals, metallic alloys and especially cermets and superalloys. Low porosity, compact and dense microstructure, moderate oxidation level and high bonding strength is typical for coatings made by HVOF. Cermets and superalloys are most often sprayed with this technology. [1] The aim of this study is to compare microstructure and abrasion wear resistance of selected HVOF sprayed WC-CoCr coatings. This type of coatings has ceramic tungsten monocarbide phase (WC) and a softer metal binder phase (CoCr). Thanks to this, WC cermet coatings show excellent resistance to abrasive and erosive wear. These coatings could be suitable replacement for hard chromium plating. Properties of the coating are influenced by properties of the used powder (material composition, grain size, size of carbides) and used spray parameters. [2] [3] The aim of this study is to compare commercially used powders of the same chemical composition but with different properties such as particle size, primary carbide particle size or method of production and to determine their resistance to abrasion.

2. EXPERIMENTAL PROCEDURE

2.1. Material characteristics

Three materials from different companies or with different size of particles were tested. The chemical composition of all materials is shown in **Table 1**. All other information such as the name of the producer, particle size, primary size of carbide particles and method of production of the powder are showed in (**Table 2**).

Table 1 Chemical composition of tested materials [5] [6] [7] [8] [9] [10]

	Weight Percent (nominal)					
Material	**W**	**Co**	**C (total)**	**Cr**	**Fe max**	**Total all other**
WC-731/1350VF	Bal.	9.0 – 11.0	5.0 – 5.5	3.0 – 5.0	0.4	1.5
WC-731/1350VM	Bal.	9.5 – 10.5	5.0 – 5.5	3.5 – 4.5	0.4	1.5
Amperit 507.074	Bal.	9.0 – 11.0	5.2 – 6.2	3.5 – 5.0	0.3	0.2
Amperit 508.072	Bal.	9.0 – 11.0	5.3 – 6.2	3.5 – 5.0	0.3	0.2
Woka 3652 FC	Bal.	8.5 – 11.5	3.4 – 4.6	4.8 – 5.6	0.2	
Amdry 5843	Bal.	9.0 – 11.0	4.9 – 6.0	3.1 – 4.9	1.0	1.0

Table 2 Information about tested materials [5] [6] [7] [8] [9] [10]

Material	Producer	Particle size	Primary Carbide Particle Size	Method of production
WC-731/1350VF	Praxair	-38 +11 µm	Fine	Agglomerated and sintered
WC-731/1350VM		-38 +11 µm	Medium	
Amperit 507.074	Höganäs	-45 +15 µm	Fine	
Amperit 508.072		-38 +10 µm	Medium	
Woka 3652 FC	Oerlikon Metco	-45 +15 µm	Fine	
Amdry 5843		-45 +16 µm	Medium	Sintered and crushed

2.2. Spraying parameters

All materials were sprayed by HVOF thermal spraying technology (used gun: Tafa JP 5220). Spraying parameters are showed in (**Table 3**). Deposition distance was 380 mm, amount of the powder was 2x80 g/min (80 g/min for each feeder). The parameters were chosen on the basis of previous optimalization, where samples from each material were sprayed with different parameters.

Table 3 Spraying parameters of tested materials

Material	Equivalence ratio	Combustion chamber pressure [bar]
WC-731/1350VF	0.75	8.6
WC-731/1350VM	0.85	7.2
Amperit 507.074	0.75	8.6
Amperit 508.072	0.66	8.1
Woka 3652 FC	0.75	8.6
Amdry 5843	0.75	8.6

2.3. Evaluation methods

2.3.1. Abrasion wear resistance

The abrasive wear is an intensive degradation process. Experimental results of laboratory tests can help with the selection of the best material for parts that are working in conditions of abrasion. To test the abrasive resistance of coatings, a dry sand rubber wheel testing machine according to ASTM G-65 standard was used. This test includes the so-called three-body (sample - abrasive - disc) abrasion. The test conditions are called "Low stress abrasion", which means that the abrasive grains do not break or crush during the test. The planar specimen is pressed with a constant force against a rotating disk with a rubber rim. A constant amount of abrasive is poured between the sample and the disc, which causes wear. Three samples from each coating were tested and the results are the average of these three measurements. Parameters of this method are shown in (**Table 4**). Because tested materials have similar composition, the evaluation factor is the accumulated weight loss. [10] [11]

Table 4 Parameters of abrasion wear resistance test

Compression force [N]	22
Abrasive material	White corundum with a grain size of F70 (212-250 µm)
Total abrasive path [m]	718 (Divided into five identical cycles)

2.3.2. Microstructure

The microstructure of the coatings was evaluated on the coating cross-section prepared according to the standard method for metallographic sample preparation. The coatings were evaluated on the Arsenal AM 2203-T optical microscope. The evaluation factors are the occurrence of cracks and fissures, the homogeneity of the coating, the shape, size and distribution of the mats, the porosity, the content and distribution of oxide inclusions or other impurities.

3. RESULTS

3.1. Microstructure

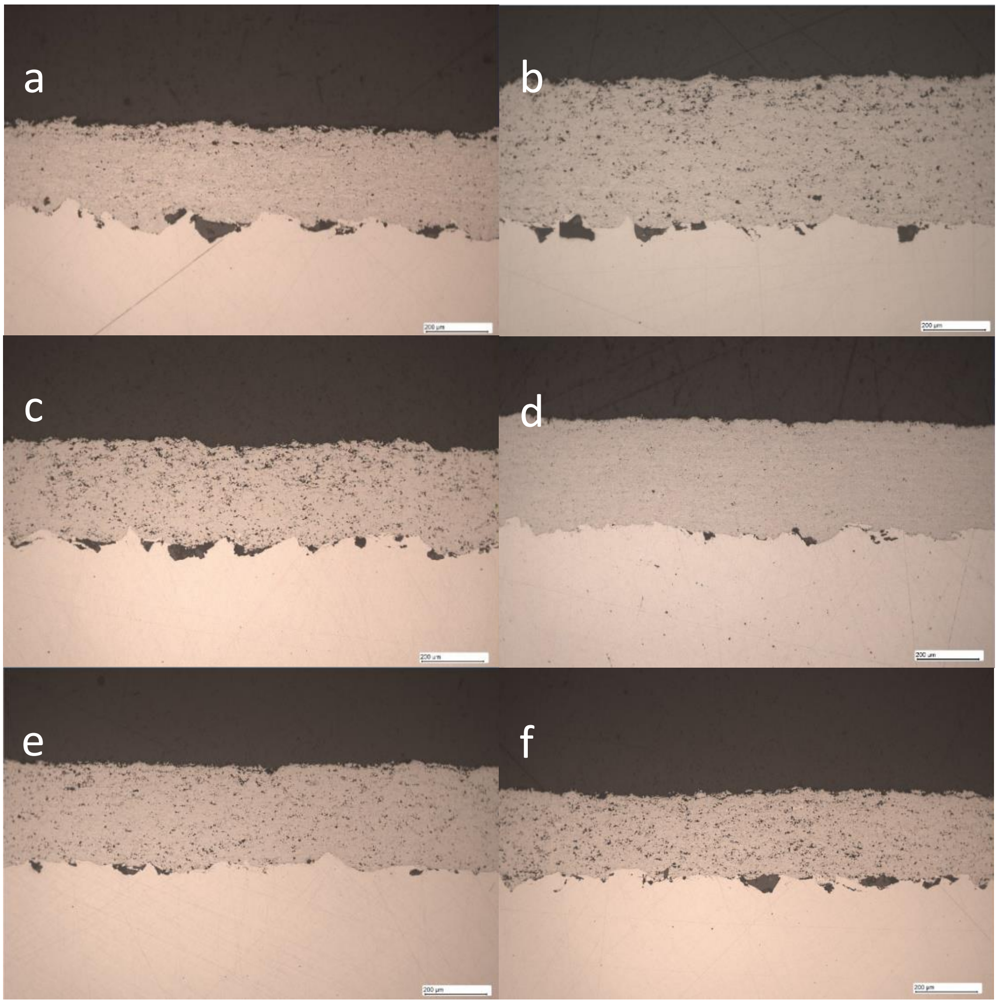

Figure 1 Microstructure of tested materials:

a) WC-731/1350VF,
b) WC-731/1350VM,
c) Amperit 507.074,
d) Amperit 508.072,
e) Woka 3652 FC,
f) Amdry 5843

Photos of microstructure are shown in (**Figures 1a-1f**). For all coatings is microstructure typical for WC-CoCr coatings prepared by HVOF. There are typical pores, patches, corundum stuck at the interface as it is usual for those types of coating. The lower layer is denser, the upper layers are more porous. The grain size of the Amperit 508.072 (**Figure 1d**) is slightly different from the others, seems more dense and solid.

3.2. Abrasion wear resistence

Slope of abrasive line of cumulative mass loss of each tested material is showed in (**Figure 2**).

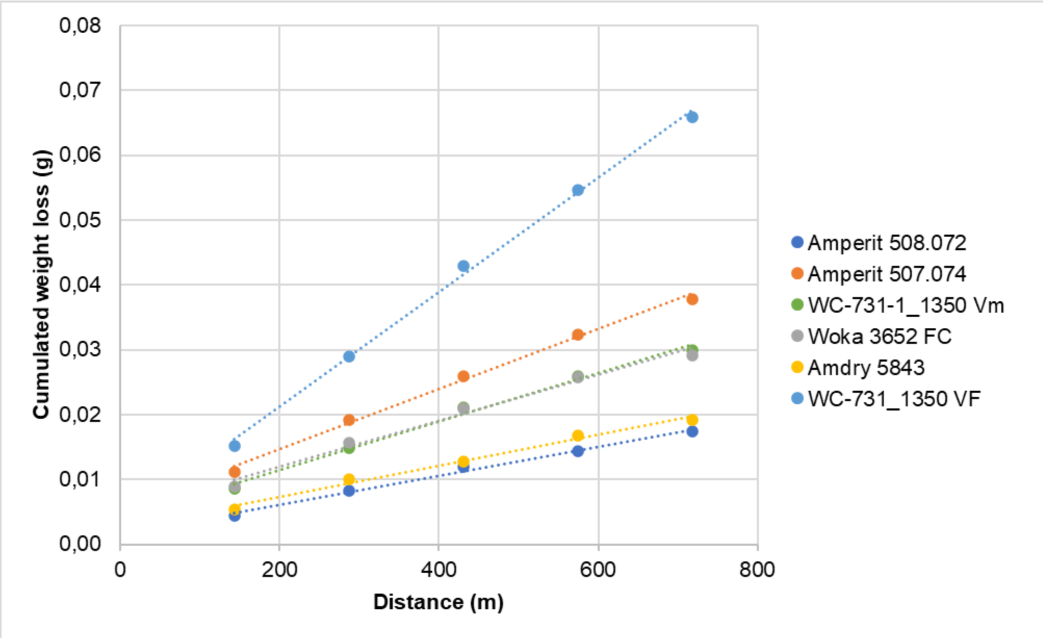

Figure 2 Abrasion wear resistance of tested materials

In **Table 5**, the powders are sorted according to the results of abrasive testing (from the best results - Amperit 508.072, to the worst - WC-731 / 1350VF). It can be seen from the table that both size of the parts and primary carbide particle size affects the results of abrasive wear.

Table 5 Material characteristics according to abrasion results sorted from best to worst

Material	Abrasive mass loss line slope	Particle size	Method of production	Primary Carbide Particle Size
Amperit 508.072	2.23615E-05	-38 +10 µm	Agglomerated and sintered	Medium
Amdry 5843	2.39554E-05	-45 +16 µm	Sintered and crushed	Medium
Woka 3652 FC	3.53064E-05	-45 +15 µm	Agglomerated and sintered	Fine
WC-731/1350VM	3.75348E-05	-38 +11 µm		Medium
Amperit 507.074	4.63788E-05	-45 +15 µm		Fine
WC-731/1350VF	8.83008E-05	-38 +11 µm		Fine

4. CONCLUSION

A total of 6 WC-CoCr commercial powders, which are commonly used in production, were tested. All coatings were prepared by HVOF technology. Subsequently, the microstructure of the coating was evaluated and the samples were subjected to an abrasion resistance test according to ASTM G-65.

According to the results of abrasive testing, it can be stated that the size of the parts affects the results of abrasive wear as much as the primary carbide particle size. It could be interesting to investigate the behaviour of coatings when changing the grain size of the used abrasive material.

The WC-731/1350 VF has the worst results (highest slope of the abrasive wear curve). This can be caused by both the properties of the powder or through human fault. Therefore, it is recommended to repeat for further research.

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T A C R

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