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MICROSTRUCTURE AND WEAR RESISTANCE OF MODIFIED WC-Co COATINGS

Key words

WC-Co coatings, wear resistance, modifications.

Abstract

Results Results of investigations related to microstructure and wear resistance characterization of three types of WC-17Co coatings obtained by a high velocity process were showed in this article. The first type of coating was obtained by spraying standard powders of WC-17Co types. The second one was from “superfine powder” with the same chemical composition. The third type of coating consists of standard powders, as in first case, but with additions of sub-microcrystalline carbides of different types. The process of powder modifications rely on simple mechanical blending of standard WC-17Co powder with 5% wt. of carbide modifier. The presented investigations included the characterization of the microstructure of coatings. Evaluation of porosity, thickness, and especially the morphology of the matrix of coatings were made. The matrix microstructure description was an interesting problem, especially due to the localization and morphology of modifier particles in the Co base phase. Final investigations consisted of the characterization of the wear resistance of the analysed coatings.

Introduction

WC-Co cemented carbides in the form of massive materials or in a coating's condition are widely used in areas of many different industries. Due to theirs high hardness, wear resistance, and satisfactory toughness, in comparison to other hard materials, cemented carbides are used as machining, cutting, drilling and other types of tools [1], and as a coatings working in conditions of wear destruction in corrosive environment, for example, in power plant systems [2]. The hardness, strength, and wear resistance of WC-Co materials can be improved by decreasing the WC grain size to the submicron meter or nanometre scale [3]. Investigations in this area have become one of the hot issues in the field of high-performance hard materials over the last decade, especially in application areas relegated to massive parts [4]. Very similar situations are in the case of coatings on the base of WC-Co materials where feedstock powders exist in the form of very coarse, coarse, medium, fine, superfine, or nano-sized particles [5]. WC-Co coatings deposited by thermal spraying methods from conventional (micro-sized) and nano-sized powders are described in detail in many publications [6]. From the other side, the problem of WC-Co coatings modifications by other hard phase types, especially in the form of nano-sized additions, is not widely presented in literature.

Experimental

Four types of coatings are investigated. All of them were deposited by the HVOV method on carbon steel. The first type is a coating deposited from conventional powder of the WC-17Co type (Amperit 526.074). The second one is the coatings deposited from superfine powder by Inframat (Infralloy^{TM} S7400). The another two are coatings deposited from a mixture of standard Amperit 526.074 with 5% wt. additions of nano-size powders of B_4C and Cr_3C_2 carbides. The modifier powders were applied to modify the microstructure and properties of standard WC-Co coatings and compared them to properties of coatings obtained from superfine powder. The microstructure characterization of the obtained coatings was carried out with a light microscope, Nikon Eclipse MA 200, and scanning microscopy of the HITACHI S-4200 type. Coating porosity was calculated on cross-sectioned samples by quantitative evaluation with Met-Ilo software [7]. The micro-hardness of the coatings was also determined on cross-sectioned samples by Vicker's method with a SM-800 tester under an indentation of 100 g. Dry air erosion testing was carried out using an air jet test rig. Erosion tests were performed on coated samples with the following test parameters: particles velocity 30 m/s, test time 10 min and impact angle 30, 45, and 90 degrees. The samples were initially ultrasonically cleaned in ethyl alcohol, dried until all the moisture was removed, and weighed with

± 0.1 mg precision. After cleaning, samples were dried and weighed to determine weight loss.

Results

From the overall point of view, the microstructure of deposited coatings is very similar, with the exception of course powders and the thickness of coatings, and Infralloy™ S7400 coating (Fig. 1). This parameter changes from ca. 110 to 575 µm with the same spraying process parameters (Tab. 1). It suggests that, in each case of feedstock powders, the spraying should be delineated. The smallest coating thickness was obtained for Amperit 526.074 without any modified additions. The thickest coatings were obtained using Infralloy™ S7400 superfine powder. These differences indicate that the morphologies of feedstock powders and additions of modified particles even at a value as low as 5% wt. have an influence on deposition efficiency of spraying process.

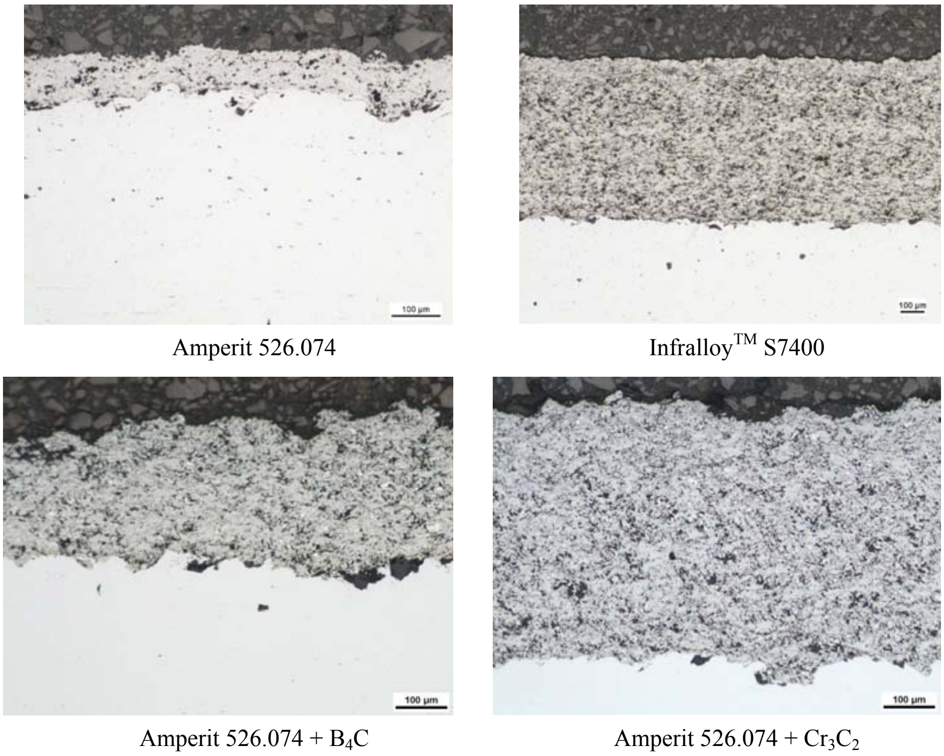

Fig. 1. Microstructure of WC-17Co coatings

Another microstructural parameter, such as porosity, is very sensitive to the spraying process parameters as well as on the feedstock powder's morphology. This fact is visible on the background of porosity measurement, where the strong effect of powder morphology is noted in the case of the micro-sized powder of conventional type Amperit 526.074 in comparison to their superfine version marked as InfralloyTM S7400. In this case, with the same spraying parameters, the porosity of coating Amperit 526.074 is lower. Of course, this result has a reflection in the hardness value. Conventional "micro-sized" coating also has a higher hardness.

Tab. 1. Microstructural parameters characterizing WC-17Co coatings

Coating	Thickness, μm	Porosity, %	Hardness, HV0.1
Amperit 526.074	108.27 ± 13.18	2.4	1398 ± 61
Infralloy™ S7400	575.48 ± 143.74	3.5	1353 ± 87
Amperit 526.074 + B_4C	247.67 ± 39.97	1.3	1130 ± 64
Amperit 526.074 + Cr_3C_2	496.89 ± 23.20	2.2	774 ± 80

A very interesting situation is observed in the case of modified conventional coatings by carbides of B_4C and Cr_3C_2 types. The expected value of hardness in these cases should be much higher or comparable to basic coating, but it was not. A logical explanation of the differences between the obtained results and expectations is related to changes in process parameters due to the applications of powder mixtures and the plausible non-uniform location of nano-sized carbides in the coating's microstructure. This reason is associated with the possibly strong tendency of modified powders to agglomeration in larger conglomerates of particles. This effect is relatively visible in Figs. 2–5.

In the case of the Amperit 526.074 (Fig. 2) coating, the distribution of phases is typical for this type of WC-Co coatings. It can find separated areas rich in Co and W, which corresponding to the Co matrix and the WC phase. The same situation is observed for the superfine coating, where the distribution of the mentioned phases is only more uniform due to the smaller size of structural elements (Fig. 3). In the case of the Amperit 526.074 coating modified by B_4C (Fig. 4), the additional visible element is porosity, which is higher than in the case of the non-modified coating. However, there is no significant difference in WC and Co phase distribution. Distribution of B_4C carbide is not detectable by this method (EDS).

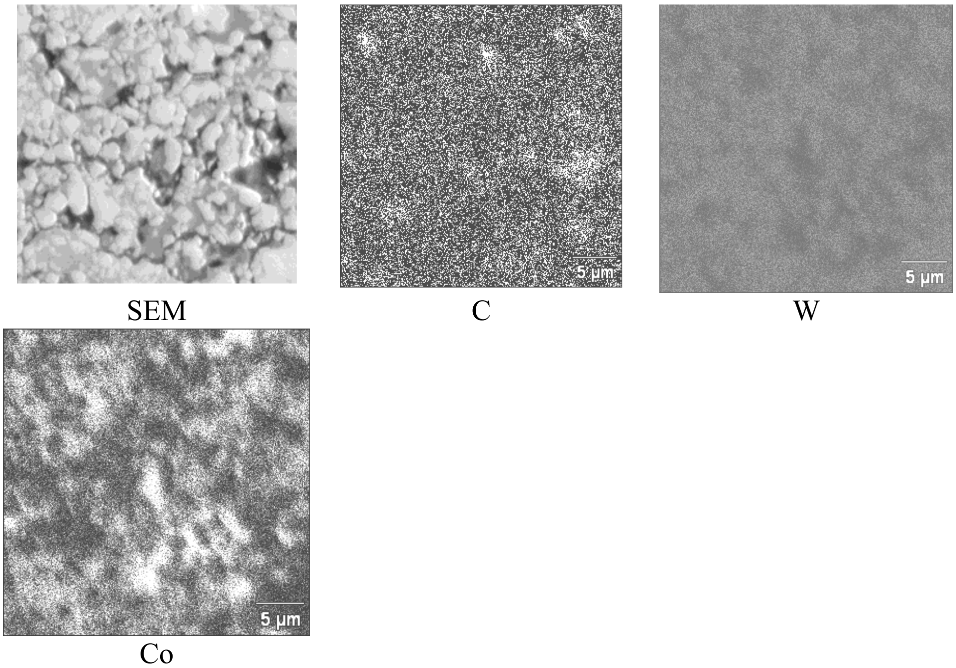

Fig. 2. Distributions of elements on cross section of Amperit 526.074 coatings

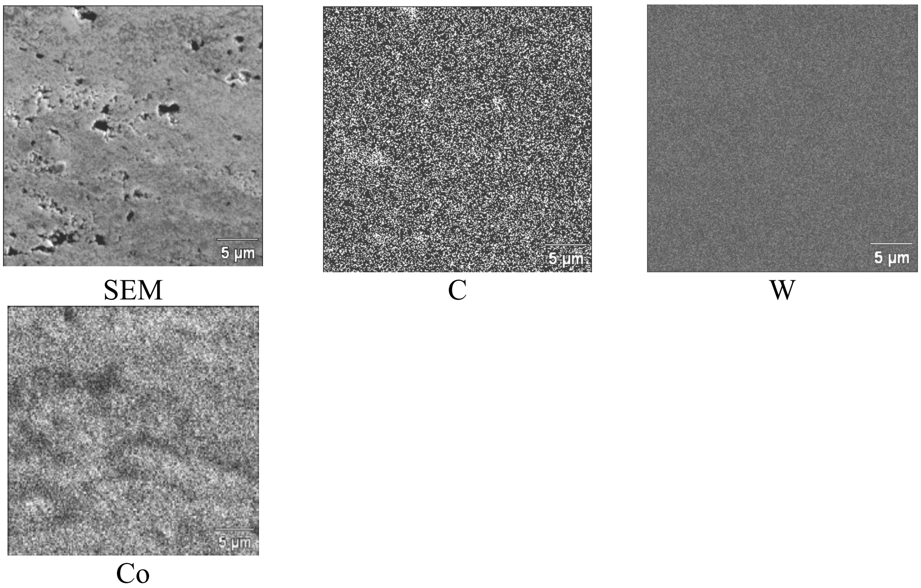

Fig. 3. Distributions of elements on cross section of Infralloy™ S7400 coatings

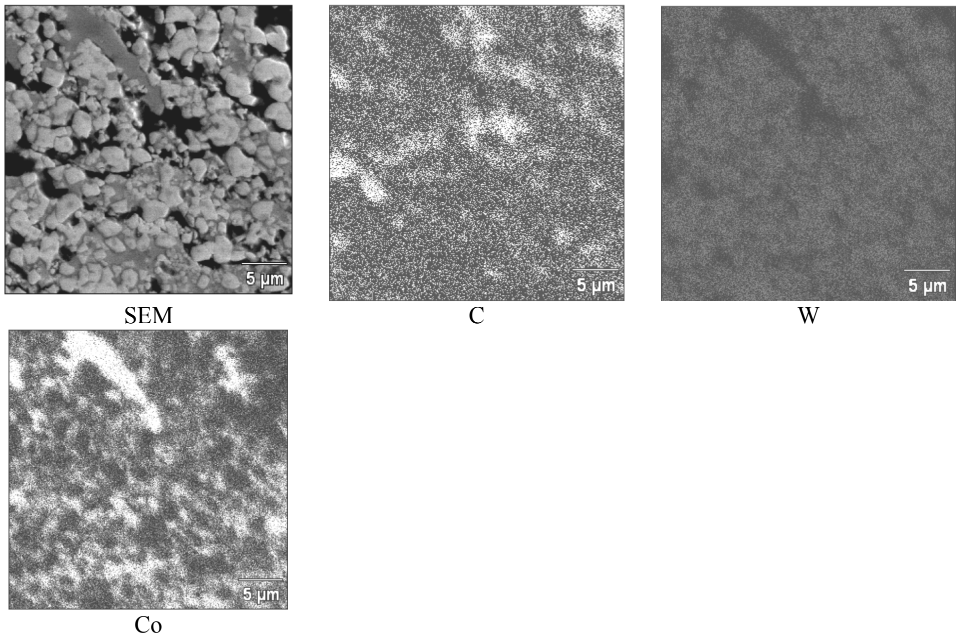

Fig. 4. Distributions of elements on cross section of Amperit 526.074 + B_4C coatings

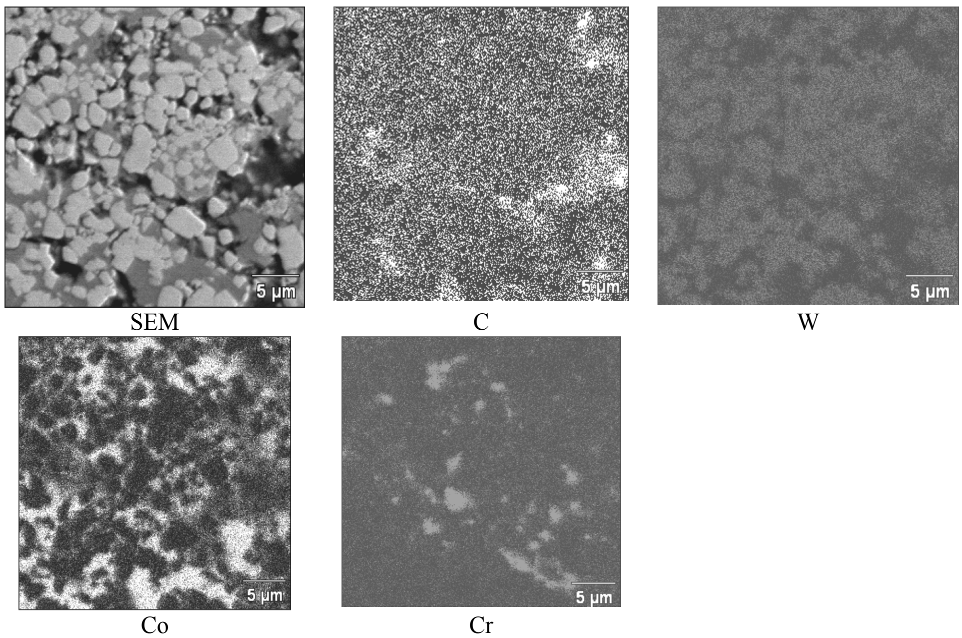

Fig. 5. Distributions of elements on cross section of Amperit 526.074 + Cr_3C_2 coatings

Another situation is in the case of a conventional coating with the addition of Cr_3C_2. In this case, the strong effect to agglomeration of feedstock-modified powder in Co matrix was observed (Fig. 5). This distribution type of modified powder in coatings is due to the loss of the beneficial effect of nano-sized hardening by carbide particles. The same situation is probably observed in the case of the B_4C modified coating. In the case of both modified coatings, the effect of higher porosity was observed, but not only. Other morphology of observed voids was detected as well. In the case of basic conventional coatings, observed pores were isolated; however, in the case of modified coatings, the effect of massive porosity was revealed. This type of microstructural defect is unacceptable in this type of coating. Erosion test results are shown in Fig. 6. In all cases, the coating of Amperit 526.074 was better independent of the angle of abrasive medium attack. These results correspond with porosity and hardness of analysed coatings. If the hardness is high, as in the case of Amperit 526.074 coating, their wear resistance is high as well.

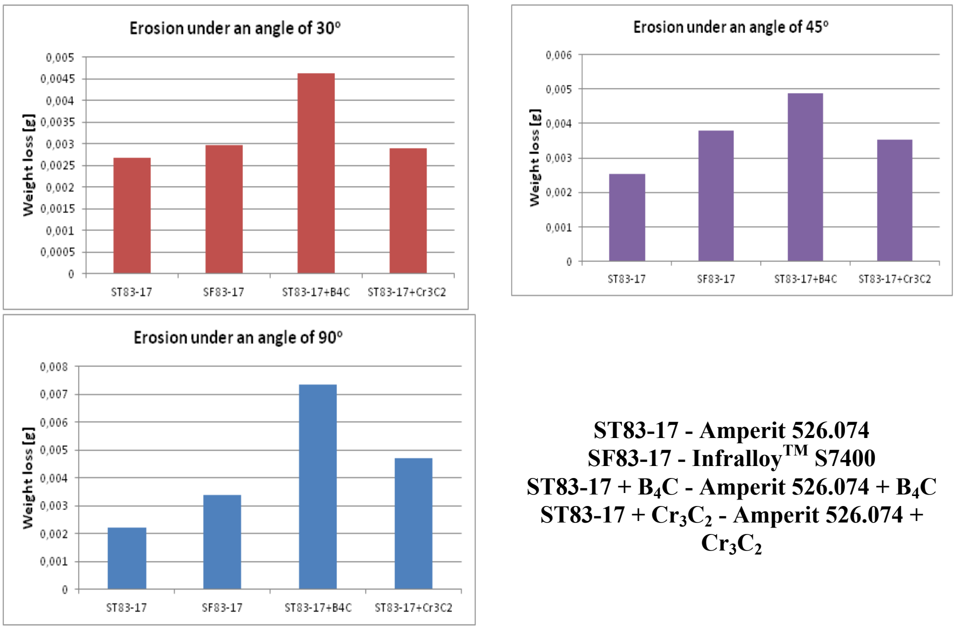

Fig. 6. Results of erosion test with different angle of abrasive media attack

Summary

Presented investigations showed that simple mixing of basic feedstock powders with modified powders of nano-sized carbides caused a loss of the beneficial effect that is related to the addition of reinforced elements such as hard carbides.

In analysed cases, nano-sized powders of B_4C and Cr_3C_2 types joined to form micro-sized agglomerates of powders. In consequence, coatings with a similar level of porosity and a lower value of hardness, in comparison to basic Amperit 526.074 coating, were obtained. Coatings with lower hardness were characterized by much lower resistance erosion in tests.

To obtain modified coatings with improved hardness and wear resistance, other methods of powder preparations than simple mechanical mixing should be used, for example, mechanical milling or ultrasonic mixing.

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