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Structure of the gradient carbide steels of HS 6-5-2 high-speed steel matrix

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ABSTRACT

Purpose: The goal of this work is to obtain gradient carbide steels based on a high-speed steel reinforced with tungsten carbide.

Design/methodology/approach: The materials were fabricated using the conventional powder metallurgy method. The gradient carbide steels was fabricated by mixing high-speed steel with WC powders. The uniaxial pressing before sintering was used for manufacturing the materials, consisting in compacting the powder in a closed die, and subsequent sintering. The sintered test pieces observations were also made using the scanning electron microscope (SEM), equipped with the back-scatter electrons detector (BSE) and the dispersive energy analyser (EDAX D4).

Findings: It was observed that the as-sintered properties of gradient carbide steels are strongly affected by the tungsten carbide content.

Practical implications: Developed material is tested for cutting tools.

Originality/value: The material presented in this paper has layers, at one side consisting of the high-speed steel, characterized by a high ductility and at the other side the carbide steel characterized by a higher hardness. A forming methods were developed for high-speed and WC powders, making it possible to obtain materials with seven layers in their structure.

Keywords: Tool materials; Uniaxial pressing; Sintering, High-speed steel; Tungsten carbide

MATERIALS

1. Introduction

Functionally graded materials (FGMs) are a new generation of engineered materials of which the composition and structure gradually change over volume, resulting in corresponding changes in properties of the materials [1-4].

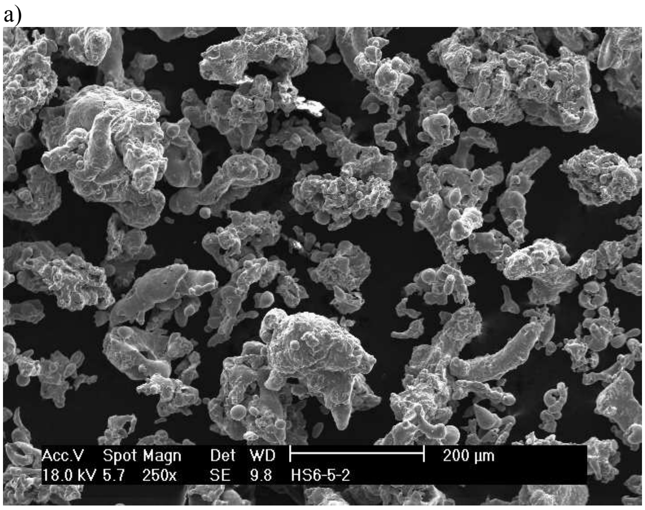
Techniques for producing functionally graded materials (FGM) have been investigated by many researchers. A monolithic material can be created with layers of materials which vary in composition. For example, a shaped body of material can have an initial layer of steel, a final top layer of carbide steel, and a number of layers of carbide steel-metal materials between the top and bottom layers [5-12].

The main objective of this work concerns the research on the structure of a sintered gradient carbide steel with the HS6-5-2 high-speed steel matrix reinforced by the tungsten carbide WC.

2. Materials for research

The investigations were made using the test pieces made of the high speed steel type HS6-5-2 and tungsten carbide (WC) powders, fabricated by the conventional powder metallurgy method consisting in compacting the powder in a closed die, and subsequent sintering. The particles of the HS6-5-2 high-speed steel and tungsten carbide WC powders particles are shown in Fig. 1. The properties and the chemical compositions of the powders are listed in Table 1.

a)



b)

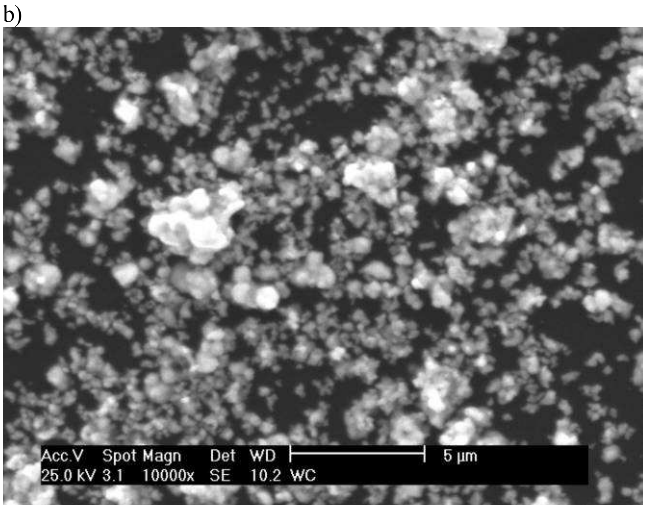


Fig. 1. Scanning electron micrographs of: a) HS6-5-2 water atomized, b) tungsten carbide WC powders.

The high speed steel and tungsten carbide WC powders were mixed at the ambient temperature for 60 min in the special agitator (WAB–TURBULA–typeT2F). The test piece is composed of the mix of the HS6-5-2 and WC in relevant proportions: HS6-5-2 + 10%WC, HS6-5-2 +7%WC, HS6-5-2 +4%WC.

Table 1.
Properties and chemical composition of powders

Element	Mass concentration, [%]	
	HS 6-5-2	WC
C	0.75÷0.90	6.11
Mn	0.20÷0,45	-
Si	≤ 0.45	≤ 0.002
P	≤ 0.04	-
S	≤ 0.04	0.003
Cr	3.75÷4.5	-
Ni	0.2	-
Mo	4.5÷5.5	≤ 0.001
W	5.50÷6.75	rest
V	1.6÷2.2	0.19
Co	0.1	-
Cu	0.1	-
Fe	rest	0.003
Ca	-	0.003
Al	-	≤ 0.002
Mg	-	≤ 0,001
K	-	≤ 0.001
Na	-	≤ 0.001
C free	-	0.02
Grain size, µm	> 150	> 0,86
Additional information	High-speed steel powder, atomised with water, made by HOEGANAES	Tungsten carbide powder made by Baildonit

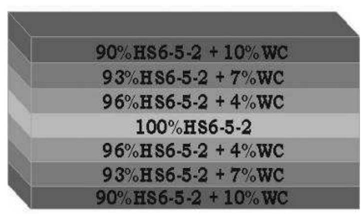


Fig. 2. The proportions of the constituents of the compacted and sintered seven-layer test pieces.

The 10%WC content is the maximum WC percentages in the surface layer for the pieces. The WC percentages for the remaining layers were chosen experimentally. The proportions of the constituents for the seven-layer test pieces are presented in Fig. 2.

The mixtures were compacted in the uniaxial unilateral die, under the pressure of 500 MPa. The test pieces were sintered in the vacuum furnace at the temperature of 1230°C for 30 minutes.

The sintered test pieces were observations using the scanning electron microscope (SEM), equipped with the back-scatter electrons detector (BSE) and the dispersive energy analyser (EDAX D4), were also made.

3. Description of achieved results of own research

A SEM BSE micrograph of the sintered test specimens with 10% content of WC in the surface layer is shown in Figure 3, whereas the EDX microanalysis results of this layer are illustrated in Table 2. The microstructures of the compacted and sintered test pieces at the temperature of 1230°C for 30 min in the vacuum furnace are presented in Figure 4. The grey colour represents the matrix of the HS 6-5-2 high-speed steel, whereas the white colour corresponds to the tungsten carbides (WC) contained in the steel. The bright precipitate rich in tungsten, molybdenum and iron is the carbide M_6C, which was confirmed in prior research [12-15].

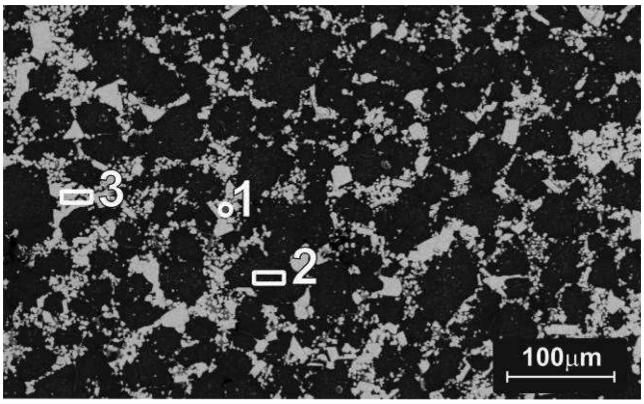


Fig. 3. SEM (BSE) micrograph of the test specimens with 10% content of WC in the surface layer

Table 2.
The EDX microanalysis results of this layer

Points	Element	wt %	at %
1	C	8.06	38.87
	W	46.64	14.7
	Mo	9.01	5.44
	V	30.6	34.8
	Cr	3.8	4.24
	Fe	1.89	1.96
	Total	100	100
2	C	2.47	11.02
	W	6.93	2.02
	Mo	1.09	0.61
	Cr	3.72	3.85
	Fe	85.79	82.5
	Total	100	100
3	C	4.44	29.55
	W	62.44	27.16
	Mo	7.71	6.42
	V	1.95	3.07
	Cr	1.85	2.85
	Fe	21.61	30.94
	Total	100	100

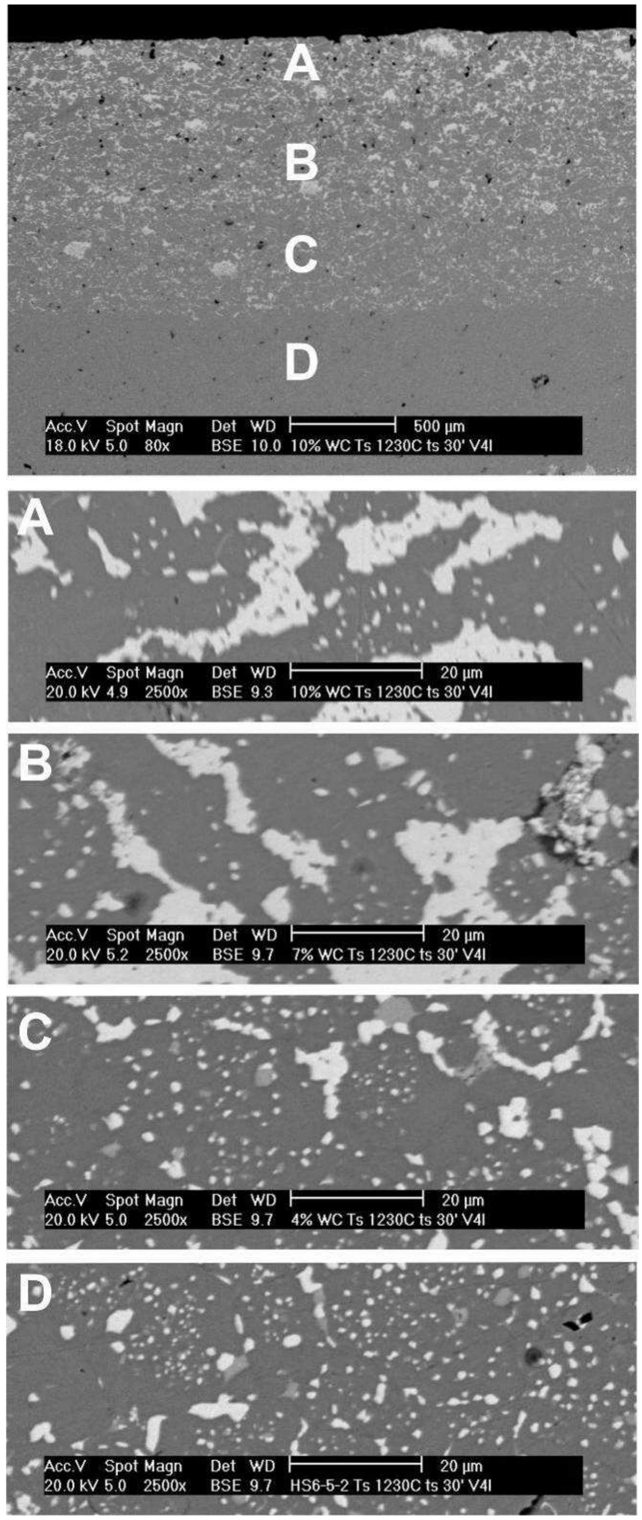


Fig. 4. Microstructure of gradient carbide steel reinforced by WC sintered in vacuum furnace at the 1250°C with 10% content of WC in the surface layer: A-HS6-5-2+10%WC, B-HS6-5-2+7%WC, C-HS6-5-2 +4%WC, D-HS6-5-2

4. Summary

From the analysis of the obtained experimental data and microstructural observation it can be concluded, that the as-sintered properties of gradient carbide steels are strongly affected by the tungsten carbide content. In the case small quantity carbide WC, he is entirely dissolved. The growth of the WC carbide causes formation of its local clusters, which do not dissolve in the matrix. Also it was noticed that the boundaries between layers with WC concentration are no longer visible. The visible pores in the layers indicate to the incomplete sintering process. The pores disappear along with the high speed steel content growth in the particular layers.

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