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Influence of carbide (W, Ti)C on the structure and properties of tool gradient materials

L.A. Dobrzański*, B. Dołżańska, G. Matula
Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: leszek.dobrzanski@polsl.pl

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ABSTRACT

Purpose: The goal of this work is to obtain the gradient materials based on the (W, Ti)C with high disproportion of cobalt matrix portion between core and surface layer. In this work is shown the structure and properties of Tool Gradient Materials (TGM).

Design/methodology/approach: In presented study (W, Ti)C powder were mixed with cobalt powder. Prepared mixtures were heaped up, pressed at 300MPa and sintered in vacuum furnace at temperatures 1450°C. Produced gradient materials were studied by scanning electron microscope (SEM), light microscope. Hardness tests and density examination were also made.

Findings: According to carried out researches it could be stated, that forming the gradient materials with highest portion of complex carbide (W,Ti)C 91-95%, using uniaxial unilateral pressing, could be possible after adding into each layer of mixtures 2 % of paraffin lubricant. High diversification of cobalt matrix ratio in comparison with hard phases in subsequent layers of gradient materials leads to their deformation in as sintered state. In case of all gradient materials, mean hardness was equal about 1600 HV1. Whereas, hardness of lower cobalt matrix rich layers has value about 1450 HV1 which increases up to 1700 HV1 for lower layer of material rich with hard carbide phases.

Practical implications: The Powder Metallurgy gives the possibility of manufacturing tools gradient materials characterised by very high hardness on the surface and relative ductility in core.

Originality/value: In the work the manufacturing of TGM on the basis of different portion of cobalt matrix reinforced with hard ceramics particles carried out in order to improve the abrasion resistance and ductility of tool cutting materials.

Keywords: Cemented carbides; Tool gradient materials; Powder metallurgy

PROPERTIES

1. Introduction

Powder metallurgy is the most important method by which Tool Gradient Materials (TGM) are produced, belonging to one of the main groups of manufacturing technologies of such materials and metal matrix composites. The powder metallurgy is implemented in solid state, minimizing the possibility of creating the brittle interfacial boundaries[2-8].

Tool Gradient Materials are composites consisting of two different materials with a gradient composition. These materials obtained with powder metallurgy processes are characterised with properties witch are impossible to achieve with other methods [1,7-11].

This group of sintered materials has outstanding properties of high values of hardness and wear resistance. Such material, no doubt, has found increased technical interest due to the advantage of special applications, but tool gradient materials made lacked the versatility of their applications. Therefore, one of the new directions of sintered tool materials development are materials with gradient microstructure [13-15].

2. Materials and methods

The investigated powders used for research were those containing the (W,Ti)C complex carbide with density of 9.57 g/cm^3 (Fig. 1) and cobalt (Fig. 2) with density of 8.8 g/cm^3. The properties of powders used for present study are shown in Table 1.

For tests in the experimental mode, hardening phases have been chosen by determining their percentage in proportion to cobalt matrix.

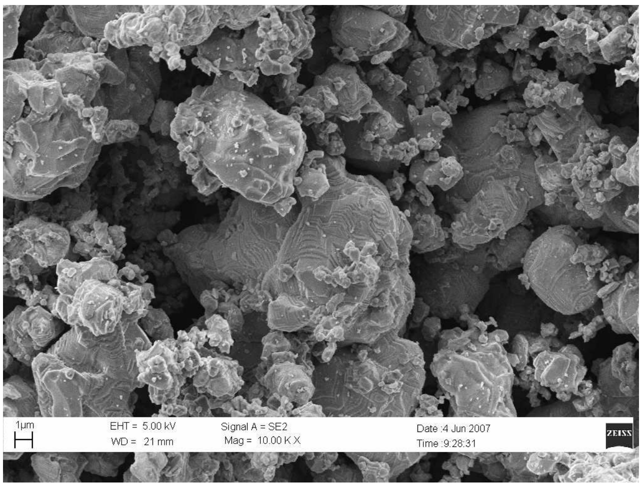

Fig. 1 Powder of (W, Ti)C

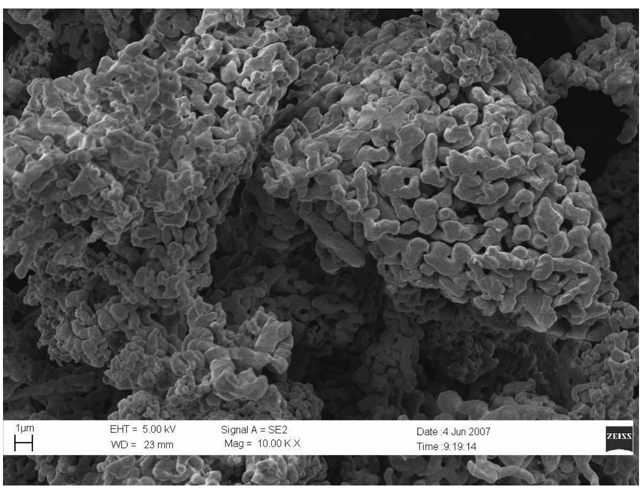

Fig. 2 Powder of (W, Ti)C with cobalt

The research has been carried out on samples obtained with conventional power metallurgy method, consisting in uniaxial pressing in a unilateral die, and following sintering in vacuum furnace. Powders were weighed in appropriate proportions and mixed dry in order to obtain the gradient material with the increasing portion of hard ceramic phases towards the surface, adequate powder mixes were prepared and poured into die, leveling each time the charge surface.

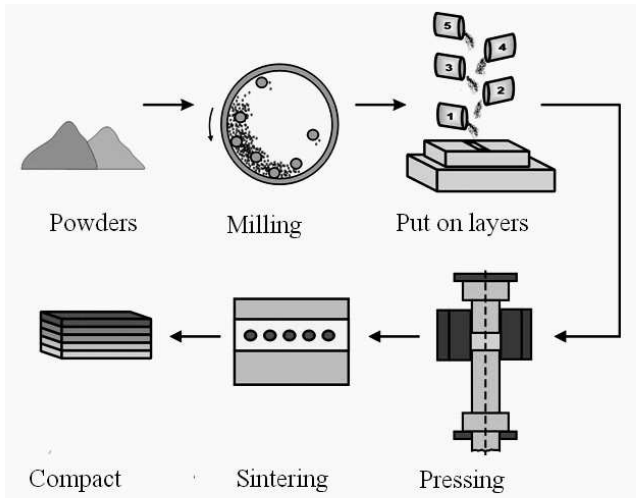

Fig. 3. Scheme of manufacturing of gradient materials (W, Ti)C with Co matrix

The composition of powder mixes, containing decreasing amount of cobalt towards the compact surface.

Bonding of layers is achieved through uniaxial and unilateral pressing under pressure about of 340MPa, for 1 min. Compacts were sintered in vacuum furnace, in the temperature of 1450^{o}C (Fig. 3). Obtained compacts were investigated by following methods:

- examinations of the gradient materials were made on the Zeiss Supra 25 and Opton DSM 940scanning electron microscopes, using the accelerating voltage of 5-20kV;
- density measurement using water displacement method;
- hardness of gradient material was tested. PMT-3 Vickers hardness indenter with load of 1,96 N was used for hardness test
- tevaluation of pore ratio was performed on unetched metallographic specimens on the Axiowert 405M light microscope;

3. Results

The macroscopic observations of gradient materials in as sintered state, revealed the non-uniform shrinkage, both in A and B samples. This undesirable phenomenon of shrinkage present in studied materials is not that strong in A type material (Fig. 4) because of smaller disproportion of cobalt content in upper and lower layer equal 4% (Fig. 5). In case of B type material (Fig. 6), the difference in cobalt content between upper and lower layer is 8% (Fig. 7) and that is why its deformation is bigger.

Table 1
Proprties of materials used for the research

Properties	Powder type	
	(W, Ti)C	Co
Apparent density	2.0728	3.0064
Grain size	3.35 μm	1.5 μm
Total C [%]	12.62	250[ppm]
[ppm] – part per milion		

Sintering process caused decay of clear boundaries between the layers. Therefore, for further researches of material, three main layers have been considered: upper layer, with maximum participation of hard ceramic phases, central and lower layer with maximum amount of cobalt.

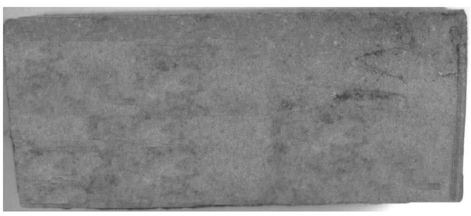

Fig. 4 Sintered sample A type

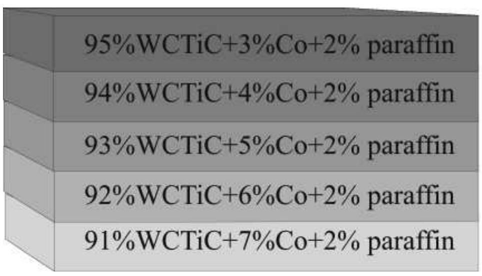

Fig. 5 Scheme of TGM sample type A

The selection of chemical composition and method of obtaining the gradient materials should take into account the presence of non-uniform shrinkage phenomenon during sintering; therefore the difference in cobalt portion should be possibly the lowest. During the pressing stage, compacts should be compacted by applying an external load.

Fig. 6 Sintered sample B type

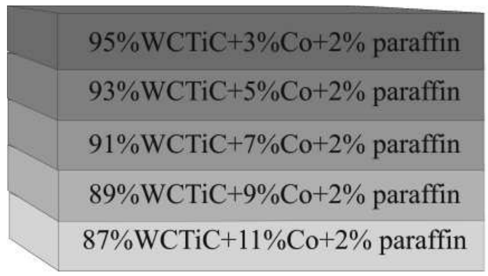

Fig. 6 Scheme of TGM sample type B

The content of hard phases, present in gradient material, has also an effect on porosity (Fig. 7). The higher is the hard phase content the lower is the material porosity.

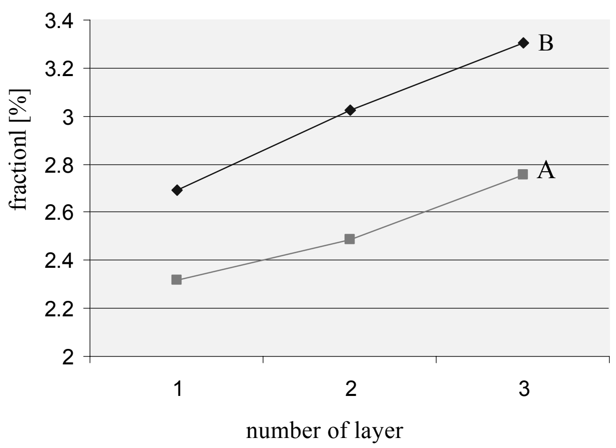

Fig.7 Average percentage content of pores for layers' samples

Layers with highest porosity and layers with pores with large surfaces demonstrated low hardness values. It was found having carried out hardness tests that hardness for the A type samples is above 1700 HV1 and 1450 HV1 in case of the B type sample.

The last stage of research for the fabricated material was microstructure evaluation (Fig. 8). In gradient materials formed from layers with increasing content of reinforcing phases in cobalt matrix, stratifications and clear boundaries of individual layers pressed in a die in as sintered state are not present.

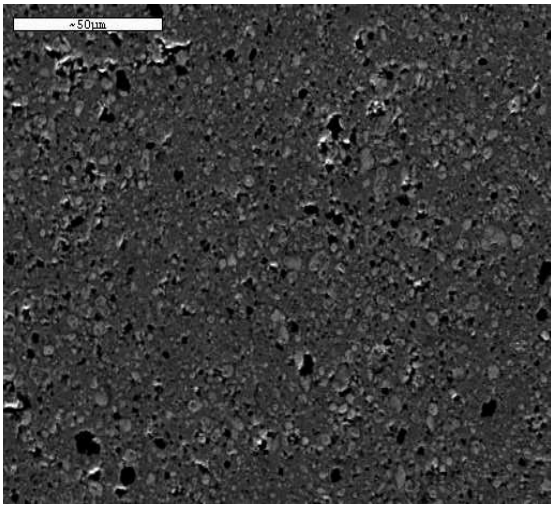

Fig. 8. Microstructure of (W, Ti)C+Co, central layer, type A

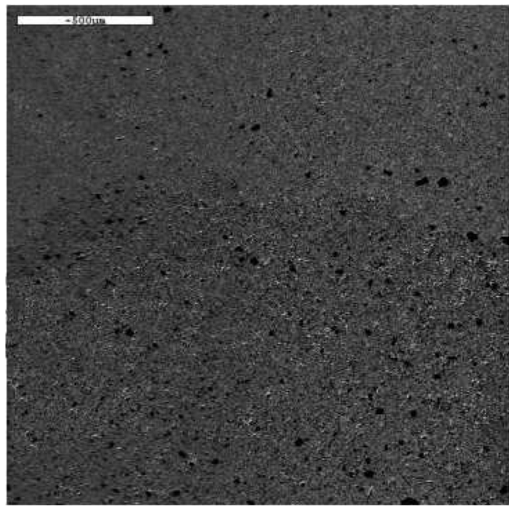

Fig. 9. Microstructure of (W, Ti)C+Co, gradient material, type A

4. Conclusions

The goal of the present work was to obtain and investigate microstructure and properties of gradient tool material with cobalt matrix. The gradient materials made with the highest amount (91-95%) of the (W, Ti)C complex carbide could be pressed after adding 2% of paraffin into each layer of mixes. The non-uniform distribution of paraffin in powder mixes is a cause of pores developing during sintering. The powders mixing time should be increased to prevent this phenomenon.

The big disproportion of hard carbide phases content between the abrasion wear resistant upper layer and the impact resistant lower layer, causes deformation of shape during free sintering.

In gradient materials formed from layers with increasing content of reinforcing phases in cobalt matrix, stratifications and clear boundaries of individual layers pressed in a die in as sintered state are not present (Fig. 9).

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