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Influence of hard ceramic particles on structure and properties of TGM

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Properties

ABSTRACT

Purpose: The Powder Metallurgy route has been chosen to fabricate tool gradient materials with high disproportion of cobalt matrix portion between core and surface layer. In the paper structure and properties of TGM have been shown.
Design/methodology/approach: SEM, light microscope, microhardness tests, density examination.
Findings: According to carried out researches it could be stated, that forming the gradient materials with highest amount of complex carbide (W,Ti)C 90-95%, using uniaxial unilateral pressing, could be possible after adding into each layer of mixes 2 % of paraffin lubricant. High diversification of cobalt matrix ratio in comparison to 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 brought values about 1450 HV1 and increased up to 1800 HV1 for lower layer of material rich with hard carbide phases.
Practical implications: Material presented in this paper is characterized by very high hardness of the surface and relative ductility of core. TGM is a smoothly varying distribution of phases element composition.
Originality/value: In the paper the manufacturing of TGM on basis of different portion of cobalt 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; Sintering

1. Introduction

The processes of powder metallurgy belong to one of the main groups of obtaining materials and metal matrix composites. These processes are implemented in solid state, minimalizing reactions of creating brittle interfacial boundaries. Materials obtained with powder metallurgy processes are characterized with properties, which are impossible to achieve with other methods [1-4].

Powder metallurgy technique allows producing tool materials with high mechanical properties using almost whole material, without scrap. Produced and subsequently formed powders make materials with high mechanical strength, hardness and low abrasive wear [3, 4].

The tool industry still tends to increase properties and life of tools. Many researches, that have been carried out prove that it's possible, when implementing controlled manufacturing processes and modification of chemical and phase composition. Therefore, one of the new directions of sintered tool materials development are materials with gradient microstructure [10-16].

Gradient materials are formed as a result of changes in phase or chemical composition of input material, in order to achieve a material with linear, stepped or parabolic changes of microstructure and properties, what is shown in Fig. 1 [4, 8, 9].

Obtained gradient materials should be characterized by increased mechanical properties, diversified on the cross section of material. The role of hard surface layer is to increase the abrasive resistance while the ductile core influences resistance

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to dynamic loads [6]. In order to produce a material, that fulfils requirements mentioned above, the work has been undertaken to determine optimal portion of cobalt in the core and surface layers of gradient sintered carbides, with the difference not higher than 17% of amount.

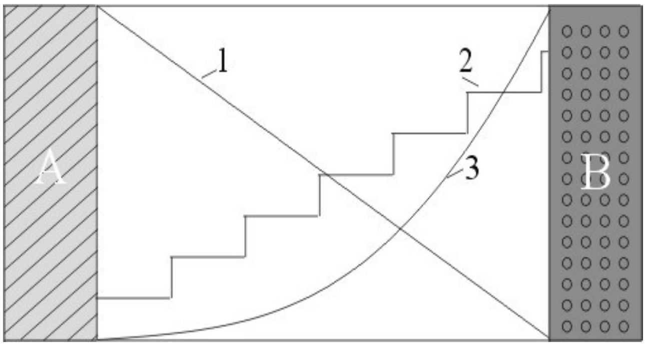

Fig. 1 Type of gradient: 1- linear; 2- stepped; 3- parabolical

2. Materials and methods

According to tests carried out in experimental mode, hardening phases have been chosen through their percentage determination in proportions to cobalt matrix. The investigated powders used for researches were those of VC carbide with density of 5,71 g/cm^3 (fig. 2), complex carbide (W,Ti)C with density 9,57 g/cm^3 (fig. 3) and cobalt (fig. 4) with density of 8,8 g/cm^3. The properties of powders used for present study are shown in Table 1.

Table 1
Proprties of materials used for the research

Powder type	Apparent density	Grain size	Total C [%]
(W, Ti)C	2.0728	3,35 µm	12,62
VC	2.668	1,8 µm	16,94
Co	3.0064	1,5 µm	250[ppm]

The researches have been carried out on samples obtained with conventional power metallurgy method, which consists in uniaxial pressing in unilateral die, and following sintering in vacuum furnace. Powders were weighted in proper proportions and mixed dry. In order to obtain the gradient material with increasing share of hard ceramic phases in the direction of surface, adequate powder mixes were prepared and poured into die, leveling each time the surface of charge. The composition of powder mixes, containing decreasing amount of cobalt in the surface direction of compact, were additionally enriched with hard phases of VC type. Connection of layers is achieved through uniaxial and unilateral pressing under pressure about of 340MPa, for 1 min.

Into such prepared power mixes of hard phases and cobalt, in order to increase gliding between grains and the grains and die during pressing, 2% of paraffin has been added. Compacts with dimensions 25mm x 5mm were sintered in vacuum furnace, in the temperature of 1450^{o}C.

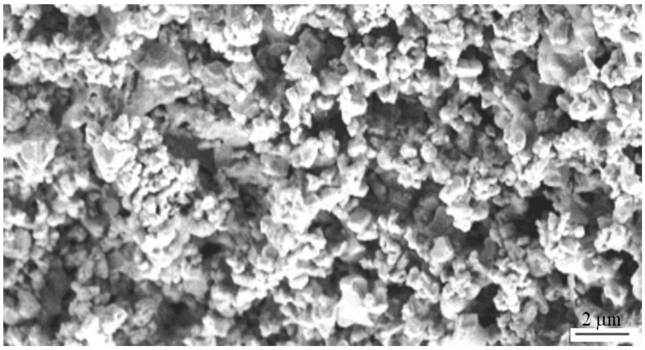

Fig. 2 VC powder

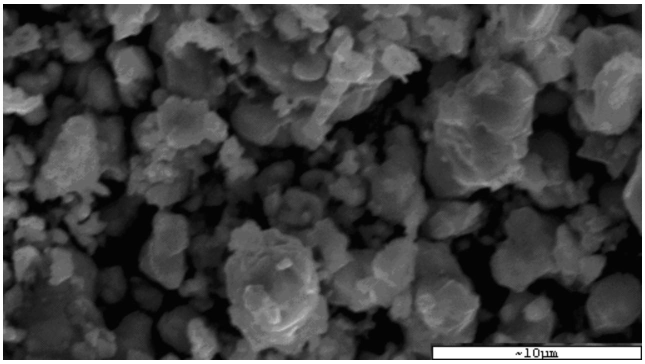

Fig. 3 Powder of (W, Ti)C with cobalt

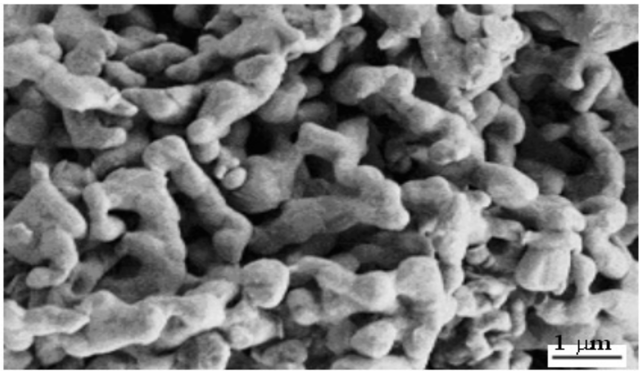

Fig. 4 Cobalt powder

Obtained samples of gradient materials were then tested with:

- hardness test (Vickers),
- light and scanning microscopy for microstructure studies,
- pore participation in layers.

Investigation of pore participation in case of gradient materials is more well-grounded for density researches, regarding to changes of density in cross section of sample.

3. Results

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.

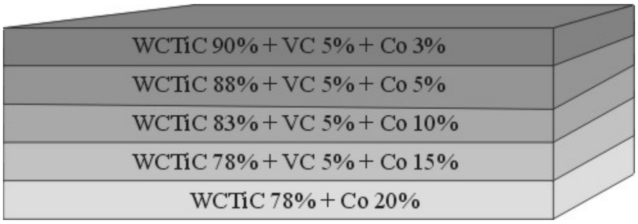

Fig. 5 Scheme of TGM sample type A

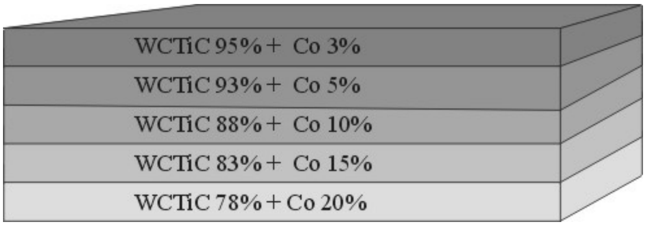

Fig. 6 Scheme of TGM sample type B

In both gradient materials, in TGM A type (fig. 5) and B type (fig. 6), was observed The shrinkage, caused by high participation of cobalt in comparison to hard carbide phases (fig. 7 and 8).

The shrinkage is an unwanted phenomenon, because it causes deformation of material. Hence, gradient materials should be designed in a way that doesn't allow the disproportion in participation of cobalt between layers and creating local shrinkage and deformation of sinters.

Fig. 7 Sample of A type after sintering

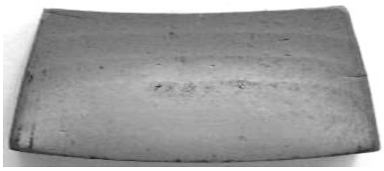

Fig. 8 Sample of B type after sintering

The participation of hard phases, present in gradient material, has also an influence on porosity (Fig. 9). The higher is percentage participation of hard phase the lower is the porosity of material. According to metallographic testing on light microscope with image analysis of sintered samples of gradient materials it was stated, that low porosity was obtained for layers (W, Ti)C 90% + Co 3%.

Large and heterogeneous pores in gradient material, are present only locally and can be created because of improper samples preparation, i.e. inappropriate process conditions of powder mixes obtaining. Gradient material was obtained using dry method, which led to connection of powder mixes with paraffin in a wrong way. The degradation of paraffin causes formation of big pore, not possible to remove during sintering process. Basing on Vickers hardness testing it was revealed, that the highest hardness was achieved for sinter (W, Ti)C +Co.

This layer is characterized by great amount of pores, but with small sizes, what influences the increase of hardness. Generally, as a result of hardness and porosity, it was found that there is a correlation between hardness and porosity. Layers with highest porosity and layers with pores with large surfaces obtained low hardness values.

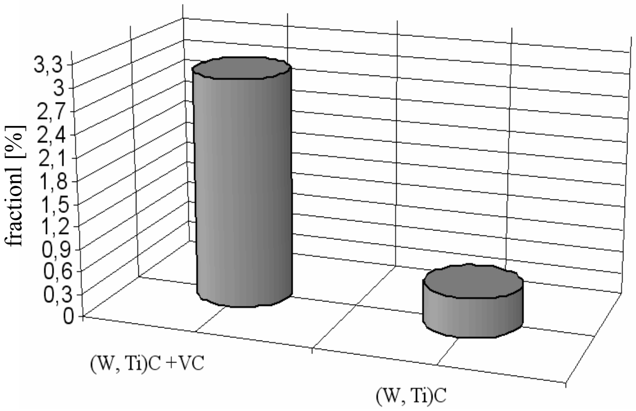

Fig. 9 Mean percentage participation of pores for sample

After carried out investigation of hardness, it was found that hardness for A type samples is above 1500 HV1 and 1400 HV1 in case of B type sample. The highest hardness, 1668 HV1, was observed for sample (W, Ti)C +Co, with 3% of Co in upper layer. Summarizing, the lower is the amount of pores and cobalt in a layer, the higher hardness of gradient material layer can be achieved.

The last step of researches for produced material was microstructure evaluation. This was carried out in scanning microscope. Analysis of gradient material microstructure has shown, that the carbide, composed of (W, Ti)C had the biggest structural participation. The presence of separate VC phases, divided with clear grain boundaries between (W, Ti)C and VC particles were not noted. The grains create on coherent carbide phase, rich with tungsten, titanium and vanadium (fig. 10).

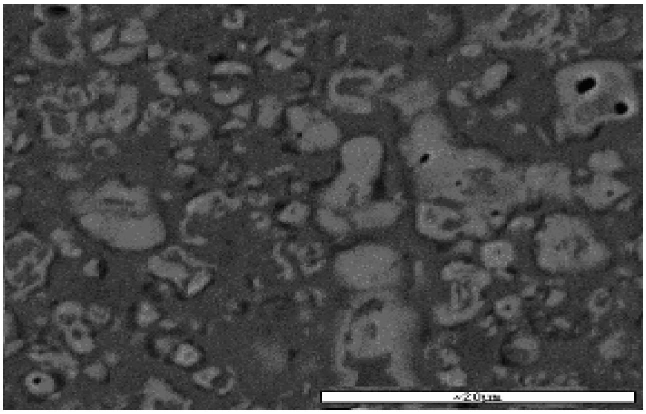

Fig. 10 Microstructue of WCTiC+VC+Co gradient material, central layer

4. Conclusions

The goal of this work was to produce gradient material using traditional powder method. Prepared powder mixes were uniaxially and unilaterally pressed. Mixes with highest amount (90-95%) of complex carbide (W, Ti)C could be pressed after adding 2% of paraffin into each layer of mixes. Non-uniform distribution of paraffin in powder mixes is a cause of pores creating during sintering. In order to prevent this phenomenon, the mixing time of powders should be increased, that certainly will improve the formability of mixtures and decrease pore share after sintering.

Too strong diversification of cobalt matrix regarding to hard phases in subsequent layers of gradient materials, causes their deformation in a sintered state. The mean hardness, in the case of all investigated gradient materials, was equal about 1600 HV1. The hardness of lower layers, rich with cobalt matrix, was equal about 1450 HV1 and increased up to 1800 HV1 in upper layer of material rich with hard carbide phases.

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References

[1] S. Luyckx, C.N. Machio, Characterization of WC–VC–Co thermal spray powders and coatings, Journal of Refractory Metals and Hard Metals 25, 1 (2007) 11-15.

[2] G. Matula, L.A. Dobrzański, Structure and properties of FGM manufactured on the basis of HS6-5-2, Journal of Achievements in Materials and Manufacturing Engineering 17, 1-2 (2006) 101-104.

[3] N.G. Hashe, J.H. Neethling, P.R. Berndt, H.O. Andrén, S. Norgren, A comparison of the microstructures of WC–VC–TiC–Co and WC–VC–Co cemented carbides, Journal of Refractory Metals and Hard Metals 20, 1 (2002) 51-60.

[4] H. Saito, A. Iwabuchi, T. Shimizu, Effects of Co content and WC grain size on wear of WC cemented carbide, Wear 261 (2006) 126-132.

[5] M. Rosso, Ceramic and metal matrix composites: Routes and properties, Journal of Materials Processing Technology 175 (2006) 364–375.

[6] Y. Liu, H. Wang, Z. Long, P.K. Liaw, J. Yang, B. Huang, Microstructural evolution and mechanical behaviors of graded cemented carbides, Materials Science and Engineering, A 426 (2006) 346–354.

[7] L.A. Dobrzański, A. Kloc, G. Matula, J. Domagała, J.M. Torralba, Effect of carbon concentration on structure and propertiws of the gradient tool materials, Journal of Achievements in Materials and Manufacturing Engineering 17, 1-2 (2006) 45-48.

[8] W. Lengauer, K. Dreyer, Functionally Graded hardmetals, Journal of Alloys and Compounds 338 (2002) 194-212.

[9] B. Krebach, A. Neubrand, H. Reidel, Processing techniques for functionally graded materials, Materials Science and Engineering A362 (2003) 81-105.

[10] L.A. Dobrzański, A. Kloc-Ptaszna, A. Dybowska, G. Matula, E. Gordo, J.M. Torralba, Effect of WC concentration on structure and properties of the gradient tool materials, Journal of Achievements in Materials and Manufacturing Engineering 20, 1-2 (2007) 91-94.

[11] J. Ma, G.E.B. Tan, Processing and characterization of metal-ceramics functionally gradient materials, Journal of Materials Processing Technology 113 (2001) 446-449.

[12] W. Acchor, C. Zollfrank, P. Greil, Mickrostructure and mechanical properties of WC-Co rainforced with NbC, Materials Research 7, 3 (2004) 445-450.

[13] J.L. Johnson, R.M. German, Liquid Phase Sintering of Functionally Graded W-Cu Composites, 16th International Plansee Seminar, 2 (2005) 116-130.

[14] G. Matula, L.A. Dobrzański, B. Dołżańska, Structure and properties of TGM manufactured on the basis of cobalt, Journal of Achievements in Materials and Manufacturing Engineering 20, 1-2 (2007) 151-154.

[15] A. Kawasaki, R. Watanabe, Concept and P/M fabrication of functionally gradient materials, Ceramics International, 23 (1997) 73-83.

[16] L.A. Dobrzański, A. Kloc, G. Matula, J.M. Torralba, Structure and properties of the gradient tool materials of unalloyed steel matrix reinforced with HS6-5-2 high-speed steel, Archives of Materials Science and Engineering, 28, 4 (2007) 197-202.