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Novel Hardmetal with Nano-Strengthened Binder

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Abstract—The novel nano-structured hardmetal with nano-strengthened binder was developed. The microstructure of modern alloy consists of the rounded grains of tungsten carbide and the cobalt-based binder, which is reinforced by nanoscaled particles of the θ phase (Co_2W_4C). The microhardness of binder for the novel hardmetal exceeds significantly the values of this parameter for usual hardmetals due to reinforcement by nanoscaled particles. The simultaneous combination of microstructural features and nanograin reinforced binder leads to the fact that the novel alloy is characterized by large value of service durability, which is substantially higher than that in usual alloys with similar grain size and identical cobalt content.

Key words: hardmetal, nano-grain reinforced binder, microstructure.

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INTRODUCTION

The need for improved hardmetals for construction and mining tools increases continuously. At present time the wear and breakages of hardmetal inserts in the road and the coal peaks appear to be the main factors, which determine the tool lifetime. The road, coal and mining peaks are exploited in the conditions of high contact temperatures (above 1000°C), high impact loads, thermal shock, intensive abrasive damage and fatigue loads. WC–Co hardmetals represent a unique material, which can be used at the conditions described above due to unique combination of physical-mechanical and operational properties. At the same time, in most cases the usual hardmetals work on the edge of intrinsic properties. As consequence, this aspect makes the elaboration of modern alloys with improved physical-mechanical and operational properties to be especially actual.

One of the important ways for serious improvement of physical-mechanical and operational properties of different materials is nanostructuring. There exist the numerous papers, which are devoted to the improvement of hardmetal properties using the elaboration of nano-grained alloys on the base of tungsten carbide nanopowder (see, for example, [1–3]). However, all studies in this field have no positive results. This circumstance for such hardmetals is explained by the presence of quite large grains of tungsten carbide, which are formed as a result of intensive nanopowder growth owing to the dissolution and the recrystallization processes in the presence of liquid phase.

This report is devoted to the studies of structure and properties of novel hardmetal with the nano-strengthened binder. The binder of this alloy is reinforced by by nanoscaled particles of the θ phase (Co_2W_4C).

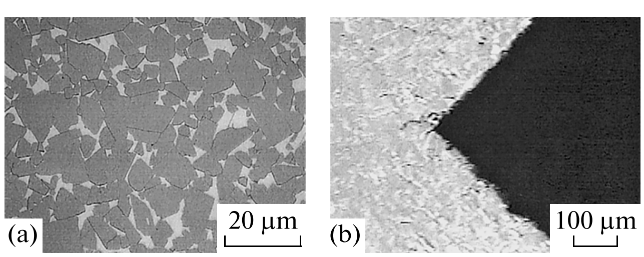

Fig. 1. The microstructures of novel alloy for mining and coal peaks: (a) Co content is 9.5%; (b) The Vickers indentation on a cross section of the novel hard metal obtained at the load of 1000 N.

EXPERIMENTAL METHODICS

The current studies were carried out by optical microscopy and high-resolution transmission electron microscopy methods by means of transmission electron microscope JEOL-2000FX. The crack growth resistance of hardmetals was determined by Palmquist method using the cross sections at the load of 1000 N. The microhardness of binder was defined by Leitz 7862 equipment using the special model samples WC–70% Co, which are characterized by thick binder layers at the load of 3000 N.

The operational tests for mining peaks equipped by the novel and the standard alloys were carried out during the sandstone cutting process.

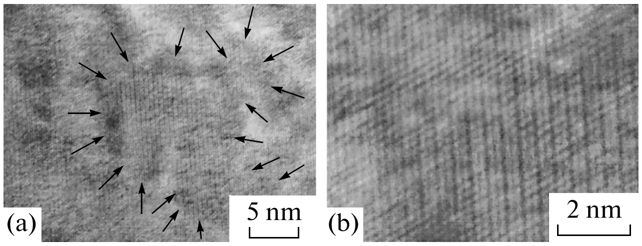

Fig. 2. The binder structure of the novel alloy with nano-strengthened binder (high-resolution transmission electron microscopy): (a) few nanoscaled particles, which form the agglomerate, are located in the matrix on the basis of Co face-centered cubic lattice; (b) The grain boundary between the nanoscaled particles and the matrix.

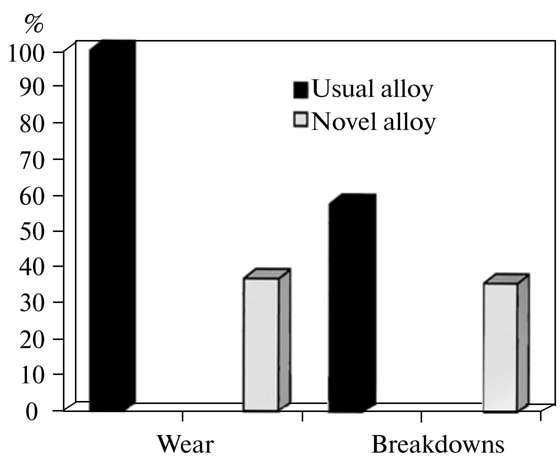

Fig. 3. Results of field tests of picks with usual and novel alloys after the tunneling (sandstone cutting).

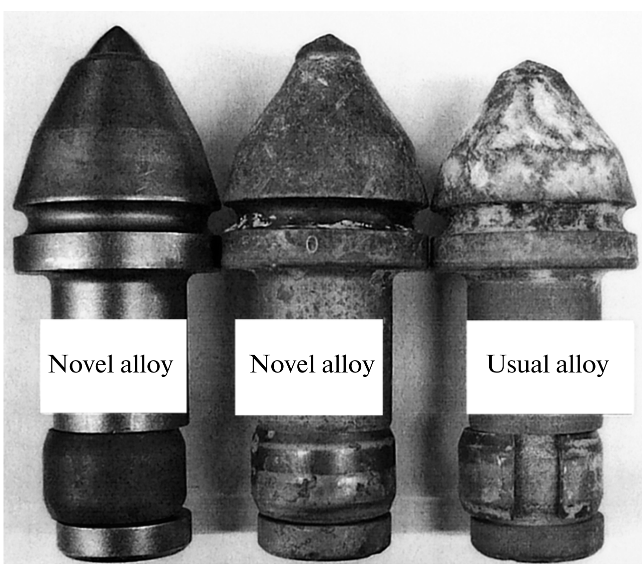

Fig. 4. The peaks with usual and novel alloys before and after service tests obtained during the tunneling (sandstone cutting).

RESULTS AND DISCUSSION

Figure 1a shows the microstructure of novel alloy with the nano-strengthened binder for coal and mining picks. The microstructure consists of the large rounded grains of tungsten carbide and the binder layers on the base of cobalt between them. The thickness of binder layers is several microns. This aspect provides the appearance of the high value of crack growth resistance in novel alloy. The indentation of cross section leads to the formation of extremely short Palmquist cracks in hardmetal. As one can see in Fig. 1b, this circumstance is an evidence for high crack growth resistance, which exceeds the value of 20 MPa $m^{1/2}$. The crack growth resistance for sample depicted in Fig. 1 equals to 20.4 MPa $m^{1/2}$ at the hardness HV_{10} of 1050. It is necessary to note that the energy imposed to the cross section surface during the indentation has a good distribution along the indenter surface. This takes place due to formation of numerous microscaled cracks, the dimensions of which is comparable with sizes of 2–3 carbide grains. As a result, the processes of formation and propagation of cracks in the novel alloy can be suppressed effectively owing to the existence of thick binder layers between the grains of tungsten carbide. The relatively high values of hardness and crack growth resistance for the novel alloy in combination with the nano-strengthened binder ought to provide high durability for instrument supplied with this alloy.

Figure 2 demonstrates the binder structure for the novel alloy, which was obtained by high-resolution transmission electron microscopy. It is evident that the binder contains the nanostructured particles, which, as it should be from [4, 5], consists of the hard θ phase (Co_2W_4C). As one can see from Fig. 2, the nanoscaled particles have no sizes, which exceed the value of 10 nm, and form the agglomerates in some cases. In accordance with basic principles of nano-strengthening [6], the binder of the novel alloy should be characterized by the hardness, which is substantially higher than that in usual Co-based binders. The measurements of microhardness for nano-strengthening binder and their comparison with the data for usual binders in hardmetals show that this microhardness, $HV_{0.3}$, equals to 790, whereas the values of microhardness for usual binders depend on the carbon concentration and lie between 350 and 450.

The nano-strengthened binders in the modern hardmetals lead to the significant improvement of picks durability at the sandstone cutting process. The results of field tests, which were obtained for novel alloy, and their comparison with the characteristics of usual alloy, having the same average size of WC phase and Co content, are illustrated in Fig. 3. As one can see from Fig. 3, the novel alloy with nano-strengthened binder is characterized by both the substantially higher durability and the larger resistance to brittle failure. Figure 4 shows the picks, which were produced using the usual and novel hardmetals, before and after field tests. As one can see, the picks provided with novel alloy are characterized by substantially less extent of deterioration.

CONCLUSIONS

The novel hardmetal with nano-strengthened binder is characterized by a tailored coarse-grained microstructure, which is represented by rounded WC grains and large Co layers between them. As a result, the novel alloy has the high hardness in combination with the high fracture toughness. The microhardness of binder in the novel alloy exceeds substantially the microhardness of binders in usual hardmetals owing to the strengthening by nanoscaled particles of the θ phase (Co_2W_4C). The combination of microstructure features and nano-strengthened binder leads to the fact that the novel alloy is characterized by service durability, which is substantially higher than that in usual alloy with the similar average size of WC grain and the same Co content.

REFERENCES

1. Shao, G., Duan, X., Xie, J. et al., Sintering of Nanocrystalline WC—Co Composite Powder, *Rev. Adv. Mater. Sci.*, 2003, vol. 5, pp. 281–286.
2. Tan, X., Qiu, S., He, W., Lei, D., Functionally Graded Nano Hardmetal Materials Made by Spark Plasma Sintering Technology, *J. Metastble Nanocrystalline Mater.*, 2005. vol. 23, pp. 179–182.
3. Lin, C., Yuan, G., Effects of Rare Earths on the Microstructure of Nano-Grained WC—VC—10Co Hardmetals, *Proc. 16th Int. Plansee Seminar (Ed. by Kneringer, G., Rödhammer, P., and Wildner, H.)*, 2005. vol. 2, p. 363.
4. Konyashin, I., Schäfer, F., Cooper, R. et al., Novel Ultra-Coarse Hardmetal Grades with Reinforced Binder for Mining and Construction, *Int. J. Refratory Met. Hard Mater.*, 2005. vol. 23, pp. 225–232.
5. Konyashin, I., Ries, B., Lachmann, F. et al, Hardmetals with Nanograined Reinforced Binder: Binder Fine Structure and Hardness, *Int. J. Refratory Met. Hard Mater.*, 2008. vol. 26, pp. 583–588.
6. Hornbogen, E., Warlimont, H., *Metallkunde*: *Aufbau und Eigenschaften von Metallen und Legierungen. 4. Aufl., Berlin, Heidelberg,* New York: Springer Vlg., 2001.