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Antifriction superhard coatings for drill bits and boring cutters

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Abstract

Coatings obtained by sputtering a stainless steel cathode and a plate titanium cathode cut from drill bit cutters JCS-M60 MX 172 544.00 are investigated. The measured microhardness of the plate drill bit is 1400 HV (Vickers) and that of coating 12Cr18Ni10T+Ti is 2200 HV that is significantly higher. The measured coefficient of dry friction for a drill bit plate on steel equals to 0.82, and it is 0.12 for coating 12Cr18Ni10Ti+Ti. Coating 12Cr18Ni10Ti+Ti deposited on the drill bit cutters in nitrogen gas may be used to modify the surface of drill bits and boring cutters to increase their lifetime. Such coatings, having a small friction coefficient, high hardness and low cost of production, can compete with traditionally used diamond materials.
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Keywords: drill bit; multi-element coating; X-ray analysis; microstructure; nanostructure; microhardness; nanohardness; friction

1. Introduction

At present technologies that can increase durability (life) of parts and machine units are particularly important due to limited material resources in the industrial complex. In general 90% of parts and machines go out of operation due to surface wear. This is particularly essential both for oil and gas exploration and field development.

Grain synthetic diamonds with different properties and superhard materials are used to increase the drilling rate, but the cost of their production is rather high. In recent years, the technology of applying superhard coating on various parts, including drilling tools has been developed [1]. Such coatings for drill bits and boring cutters must satisfy two principal but opposite requirements. They should have a high hardness and a low dry friction coefficient. Nanostructural coatings [2] obtain these properties.

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2. Experimental

In this paper coatings produced by sputtering of steel cathode 12Cr18Ni10Ti and plate titanium cathode cut from KNSh-M60 MX 172 544.00 cutters drill bits are investigated. The coatings were applied on unit NNV - 6.6.I1 in argon and nitrogen gas environment over a period of 40 minutes at an arc current of I_i = 80 A, the reference voltage U_{ref} = 200 V and a gas pressure in the chamber p = 5 × 10^{-3} Pa.

The microstructure of the coatings is investigated on metallographic microscope Epikvant and electron microscope JEOL JSM-5910. To measure the microhardness Micro Durometer HVS-1000A is used. To determine the coefficient of friction the system for determining the wear and sliding friction [3], being constructed in the laboratory of the University of Karaganda, is used.

The thickness of the coatings and their elemental composition is measured using an electron microscope 200 Quanta 3D. The phase composition and structural parameters of the samples were performed on diffractometer XRD-6000 in CuK_{α}-rays. An analysis of the phase composition, the size of coherent scattering regions, the internal elastic stress (Δd/d) was carried out with the use of databases and PCPDFWIN PDF4+, as well as the program of full-profile analysis POWDER CELL 2.4. The nanohardness of coatings for the samples was determined by Oliver-Pharr nanoindentation system method and using Berkovich indenter with a load of 1 g and a dwell time of 15 sec.

3. Results of experiment

Fig. 1 shows the microstructure of 12X18H10T + Ti and Table 1 represents the phase composition. A dislocation structure can be noticed.

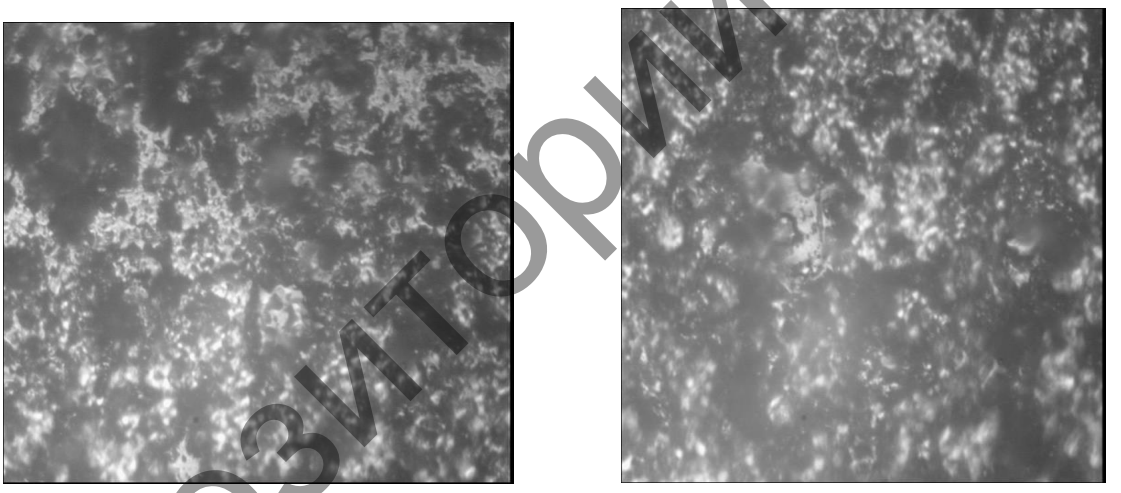

Fig. 1. Microstructure of coating 12Cr18Ni10Ti+Ti in nitrogen gas at two different points of sample (magnification ×400).

Table 1. Structural and phase composition of coating 12Cr18Ni10Ti+Ti.

Coating	Phase detection	Phase content, vol.%	Lattice parameters, Å	Size of CSR, nm
12Cr18Ni10Ti+Ti in nitrogen gas	$FeN_{0.0324}$	9.8	a=3.592	10.35
	TiN	85.5	a=4.240	14.71
	Fe-α	4.6	a=2.864	7.29

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The cover structure changes significantly in argon gas environment. Fig. 2 shows the microstructure of coating 12Cr18Ni10Ti+Ti in an argon gas environment, in Table 2 its elemental composition is presented and Fig. 3 shows the cross-section. A columnar structure can be noticed.

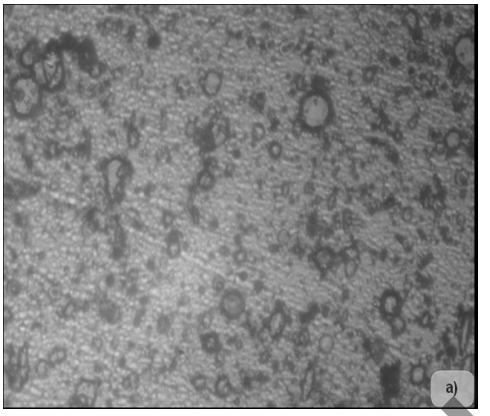

Fig. 2. Microstructure of coating 12Cr18Ni10Ti+Ti in argon gas environment.

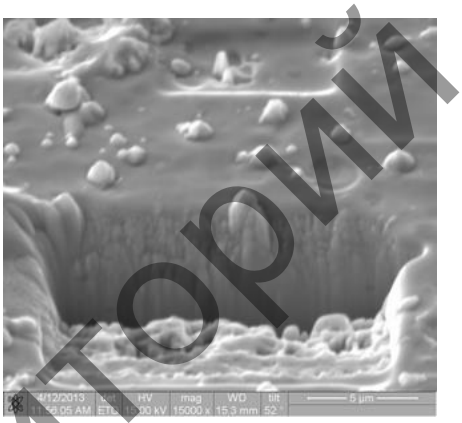

Fig. 3. Cross section of coating 12Cr18Ni10Ti+Ti in argon gas environment.

Table 2. Elemental composition of coating 12Cr18Ni10Ti+Ti in an argon gas environment.

Element	Wt %	At %	K- Ratio	Z	A	F
N K	10.26	11.68	0.1089	1.0015	0.9839	1.0765
Cr K	16.05	16.83	0.1750	0.9981	0.9836	1.1103
Fe K	64.96	63.40	0.6408	0.9980	0.9798	1.0089
Ni K	8.73	8.10	0.0840	1.0127	0.9502	1.0000
Total	100.00	100.00				

The nanohardness of coating 12Cr18Ni10Ti+Ti in the nitrogen gas environment is determined by Oliver-Pharr nanoindentation system method and using Berkovich indenter with a load of 1 g and a dwell time of 15 sec., which is equal to 35.8 GPa. Furthermore, the fluidness module of coating 12Cr18Ni10Ti is determined in the gaseous environment of nitrogen, this module being equal to 378.56 GPa. The fluidity is equal to 0.15%, and the relaxation of the coating is equal to 0.05%.

The nanohardness of coating 12Cr18Ni10Tii+Ti in an argon gas environment under a load of 1 g and dwell time of 15 sec. was determined, this nanohardness being equal to 3,339 GPa. Moreover, the fluidness module of coating 12Cr18Ni10Ti+Ti in an argon gas environment was defined, this module being equal to 111.03 GPa. The

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fluidity of 1.07% and the coating relaxation of 0.08% were defined as well.

The measured microhardness of Vickers drill bit plate is 1400 HV and those of coating 12Cr18Ni10Ti+Ti is 2200 HV, that is significantly higher. The measured ratio of dry friction for the drill bit plate for steel is 0.82, and for coating 12Cr18Ni10Tii it is 0.12.

4. Discussion

Various composition of titanium with other elements were studied in [4-8] and some other papers. The conclusion coming out of these papers is as follows: high hardness coating takes place in the process of the formation of fine-grained structure with the grain size of about 5 nm, this structure consisting of nitrides, carbides and titanium borides.

In our experiments coating 12Cr18Ni10Ti+Ti in the nitrogen gas environment comprises 73 % of Ti, and the coating 12Cr18Ni10Ti+Ti in an argon gas environment contains high assay of Fe, which is 65 %.

Coating 12Cr18Ni10Ti+Ti in the gas environment of nitrogen and argon obtains a columnar structure being characteristic of single-phase films. However, the results of radiographic tests show the presence of three phases in coatings 12Cr18Ni10Ti+Ti in the gas environment of nitrogen and argon. The explanation for the presence of the columnar structure in both cases can be in a high content of titanium nitride phase that "inhibits" the presence of other phases.

In industrial drilling processes the attempts to reduce friction were made, primarily using water or oil based drilling mud containing various types of expensive and environmentally harmful additives. Diesel oil fuel and other mineral oils are also often used as lubricants, but elimination of drilling mud is still the problem.

Coating 12Cr18Ni10Ti+Ti in nitrogen gas environment has 7 times lower coefficient of friction as compared to the material of the drill bit. Coating 12Cr18Ni10Ti+Ti in nitrogen gas environment is 1.5 times harder than the material of the drill bit. These characteristics of the resulting coatings provide a life-extension (not less than 2 times) of drill bits and boring cutters. The research at the gold deposit of Altyntau (Central Kazakhstan) for drilling and blasting holes to the depth of 4 m brings us to that finding. Uncoated drill bits JCS-172 M60 MX 544.00 and coated drill bits 12Cr18Ni10Ti+Ti were tested. The results of tests demonstrated a life-extension increase of a drill bit by a factor of 2.3.

5. Conclusion

Studies of nanostructured coatings are at the initial stage. Any quantitative theory explaining the mechanical properties of the multi-element nanocomposites has not been available yet. Nevertheless, the transition to nanoregions shows significant changes as compared to bulk samples.

Nanostructured coatings may have mutually exclusive properties, parts of mechanisms and machines having good performance due to these properties.

According to the results obtained, coating 12Cr18Ni10Ti+Ti applied to the drill bit cutters in nitrogen gas environment can be used to modify the surface of drill bits and boring cutters to increase their lifetime.

This type of coatings can compete with traditionally used diamond materials due to a small friction coefficient, high hardness and a relatively low cost of production.

References

[1] A.D. Pogrebnyak, A.A. Baghdasaryan, I.V. Yakovenko, V.M. Beresnev, Structure and properties of high entropy alloys and nitride coatings on their basis, Russian Chemical Reviews, 2014, Vol. 83, №11, pp. 1027-1061.

[2] E.N. Reshetnyak, V.E. Strel'nitskij, Synthesis of hardening of nanostructured coatings, Problems of Atomic Science and Technology, 2008, №2, pp. 119-130 (In Russian).

[3] V.A. Kolesnikov, Ya.Zh. Baysagov, V.M. Yurov, Information-measuring device for determining the coefficient of sliding friction, Basic Research, 2011, №12, pp. 121-124 (In Russian).

[4] N.J.M. Carvalho, J.Th.M. De Hosson, Deformation mechanisms in TiN/(Ti,Al)N multilayers underdepth-sensing indentation, Acta Materialia, 2006, Vol. 54, pp. 1857-1862.

Репозиторий КарГУ

[5] Chen Li, Du Yong, S.Q. Wang, Li Jia, A comparative research on physical and mechanical properties of (Ti, Al)N and (Cr, Al)N PVD coatings with high Al content, International Journal of Refractory Metals, 2007, Vol. 25, pp. 400-404.
[6] P.H. Mayrhofer, M. Stoiber, Thermal stability of superhard Ti–B–N coatings, Surface, 2007, Vol. 201, pp. 6148-6153.
[7] J.K. Park, Y.J. Baik, Increase of hardness and thermal stability of TiAlN coating by nanoscale multi-layered structurization with a BN phase, Thin Solid Films, 2008, Vol. 516, pp. 3661-3664.
[8] F. Pinakidou, E.C. Paloura, G.M. Matenoglou, P. Patsalas, Nanostructural characterization of TiN–Cu films using EXAFS spectroscopy, Surface, 2010, Vol. 204, pp. 1933-1936.

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