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Interactive methods for increasing wear resistance of cutting tool blades

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Abstract. In the scientific work, the features of the structure of the near-surface layer of high-speed steel R6M5, complex processing modified by the methods of the first ion-nitriding, ion alloying of the surface, and wear-resistant coating, its effect on the wear resistance of the tool during dry cutting of hard-to-cut chromium and its alloys are considered. One of the promising directions for hardening tools made of high-speed steel is the creation of layered structures on their surface with a gradient of physical and chemical properties between wear-resistant coatings and the base material. Among the methods for such surface modification is a special process based on the use of high-intensity pulsed beams of charged particles. Ion-nitriding treatment was carried out on the APP-2 unit, ion-alloying treatment was carried out on the unit, the latter with low friction coating. The advantage of this device is that it coats the Nb and Hf elements on the surface of the cutting tool, heats up to 10 6 deg/s in 5 µs, causing the two elements to diffuse into the cutting tool. The last treatment on the basis of reinforced cutting tools is coated with PLATIT π311 (TiAl)N. As a result, the stability of the cutting tool has increased by 3-4 times. The study was conducted at the Navoi Machine-Building Plant and conclusions were drawn.

1 Introduction

Today, high demands are placed on carbide and high-speed cutting tools when working with them. For example, solid carbide end mills have characteristics such as high wear resistance, but over time or technological root causes, they are subject to wear and breakage. But it should be borne in mind that up to 80% of failures occur due to chipping, mowing and malfunctions that cut the wedge. The quality of the cutting tool, in this case, largely determines the productivity of the processing process and is the determining factor for obtaining parts of the required shape and size. Therefore, improving the quality of the cutting tool is the most important task. As is known, there is a relationship between physical and mechanical properties and cutting conditions. The emerging problems are solved in modern technologies through the use of high-speed steels, which have increased heat resistance. As a rule, these steels are obtained on the basis of powder metallurgy technologies. Their use allows to partially solve the problem, that is, on their basis, further intensification of processing is possible. So, this intensification requires the introduction of new structural materials with increased heat resistance. However, it can be stated that when implementing

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them, developers are faced with additional requirements that apply to instrumental material. It is noted in [1, 2] that today there are a number of advanced technologies that make it possible to manufacture tools from high-speed steel with various wear-resistant coatings. These technologies, as a rule, provide the formation of wear-resistant coatings based on refractory metal nitrides, while these nitrides are obtained by physical deposition.

A cutting tool designed for machining heat-resistant, difficult-to-cut materials requires special characteristics. In this case, it is advisable to apply several successive treatments to the surface of the cutting tools. The use of a single chemical-thermal treatment or coating of a metal-cutting tool under heavy load conditions does not give good results.

The introduction of elements such as N_2 and C affects the mechanical surface properties of cutting tools. In this case, the crystal lattice is distorted and the microhardness increases. The grain boundaries of oxides and the boundaries of dislocation blocks are fast diffusion channels for implanted atoms. Ion implantation - when oxidation occurs simultaneously in the material and stresses appear. The complex compositions presented in this paper are intended for obtaining modified surface layers. A method is proposed that provides increased wear resistance of cutting tools that are made of relatively high-speed steel of medium heat resistance. The advantages of this method are demonstrated during horizontal milling of a strong, hard-to-machine 34KhN1MA chromium alloy [3, 4].

2 Materials and methods

In the study of the durability of the cutting tool for milling, specially designed cutting end mills with various options for combined ion-plasma surface treatment were used (Fig. 1). The end mills were made of high-speed steel and subjected to standard heat treatment. Ion-nitriding of machined and sharpened cutting end mills was carried out on an APP-2 type installation using a two-stage vacuum-arc gas discharge. This treatment was carried out at a temperature of 490°C for 45 min, which made it possible to create a thermochemically hardened layer on the surface with a thickness of up to 60–80 μm and a microhardness of up to HV_{60} = 120 MPa. The final resistant coating (TiAl)N, (TiAl)N + ion-nitriding, (TiAl)N + ion-nitriding + ion-alloying (NbHf), with microhardness HV_{60} = 350 MPa was applied on a Platit π311 installation. This processing is a combination of the adhesive layer of the composition with a (TiAl)N gradient coating [5, 6].

Fig. 1. High-speed R6M5 cutters.

Two- and three-phase coating layer with grain size (TiAl)N, (TiAl)N + ion-nitriding, (TiAl)N + ion-nitriding + ion-doping (NbHf) up to 5 nm, on the boundary of which the amorphous phase Si 3 N is located 4 suppresses the coagulation of grains of the main phase both during the coating process and during tool operation. Interfacial boundaries, which are zones of intense energy dissipation, deflect emerging cracks from the direction of propagation, partially or completely slowing them down. The layout of this equipment is as follows. The combined placement of the NSEP source together with several magnetron sputtering systems was performed in one powerful vacuum chamber. This combined installation allows processing, as a result of which a wear-resistant coating is fused onto the surface of the sample. Moreover, this coating has a given chemical composition. Characteristically, during processing, the sharp interfacial boundary that exists between the film and the substrate is blurred. At the same time, an extended transition layer with a variable elemental composition is formed. The thickness of the transition layer is several micrometers. This transition layer ensures that the highest level of adhesion of the coating to the substrate is achieved. The presence of a high level of adhesion has been demonstrated previously on numerous systems, including a metal film and a substrate. In particular, this effect was achieved on such a system as stainless steel - copper. As noted earlier, there are quite a few, already traditional, ways to improve the surface properties of a metal cutting tool that are used before a resistant coating is applied. However, there are alternatives to traditional methods. We note the possibility of creating an alloyed surface layer of micron thickness with increased wear resistance. Such a layer is created on steel or carbide tools using a low-energy high-current electron beam (HEB). The area of a single treatment is about 50-100 cm^2. As a result of exposure of the sintered high-speed alloy to beams of charged particles by plasma flows, we obtain heating of the surface layer of the alloy at a high rate (up to 106 deg / s) to temperatures exceeding the melting temperature of the remaining ones, followed by cooling at an extremely high rate (104 -109 deg/s) [7, 8]. The extreme temperature here should be understood as the equivalent of the thermal energy corresponding to the energy of the ions incident on the surface.

$$\mathrm{KT} = \mathrm{E}_{\boldsymbol{ion}}$$

If here $\mathrm{T} = 1 * 10^6\ K$ then we put the value

$$\mathrm{E}_{ion} = 1.38 * 10^{-23} \cdot 1 * 10^6 = 1.38 * 10^{-17};$$

$$Energy = \frac{1.38}{1.6*10^{-19}} * 10^{-17} \approx 8.625 * 10\ eV \approx 86\ eV.$$

As can be seen from the last cipher, it corresponds to an energy of 86 eV.

A multiphase structure using doping in the process of an exothermic chemical reaction occurring between the metal of the film and nitrogen was obtained by depositing a thin layer of nitride-forming elements (targets from the $Nb_{72}Hf_{28}$ alloy were used) on the tool surface before its treatment with an electron beam [9, 10].

A wide range of wear-resistant coatings has been developed that are resistant to various types of wear (abrasive, adhesive, oxidative, fatigue, dust and cavitation erosion, etc.). All of them have high hardness (25–35 GPa and more) and lower coefficients of friction than steels. However, all these coatings, which have excellent service characteristics, are intensively destroyed during plastic deformation of the base under high load. It has been established that, in most cases, the destruction of the coating-substrate system begins with plastic deformation of the substrate near the interface, when this system is subjected to relatively high loading. Thus, the load resistance in the coating-substrate system also depends on the properties of the substrate. It is clear that a sufficiently thick layer with high hardness, heat resistance and crack resistance will increase the load resistance. Creating such a layer with subsequent application of a harder coating is one of the options for combined surface treatment [11, 12].

3 Results

The device allows the deposition of films of different materials on the surface of the desired cutting tool and subsequent liquid-phase mixing of the materials of the film and the NSEP substrate in a single vacuum cycle.

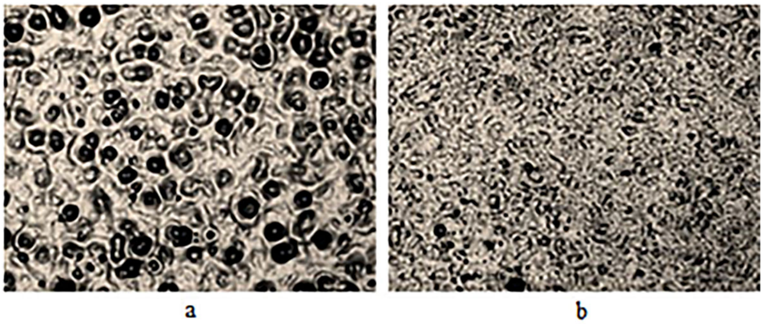


Fig. 2. Surface structure of the cutting tool. a) The structure of the surface of nitride high-speed steel R6M5 after exposure to NESP, b) The same after electron-beam doping with.

Irradiation with NSEB causes dissociation of iron nitrides, especially the e-phase; a large amount of residual austenite is formed on the surface (Fig. 3b). After applying a thin film with a thickness of about 0.2 μm to the samples using a magnetron sputterer and subsequent exposure to an electron beam, exothermic chemical reactions of the formation of the nitride phase can be initiated [13, 14].

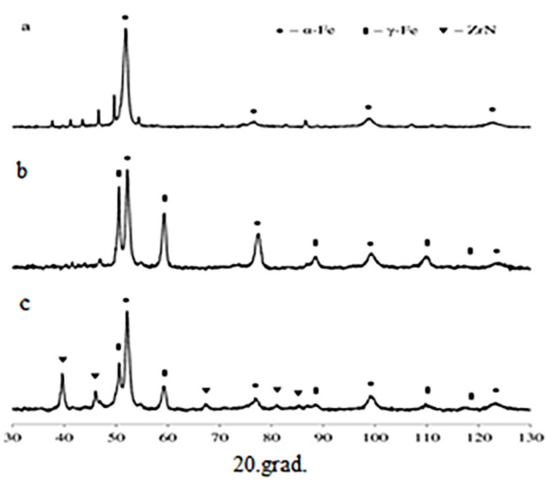
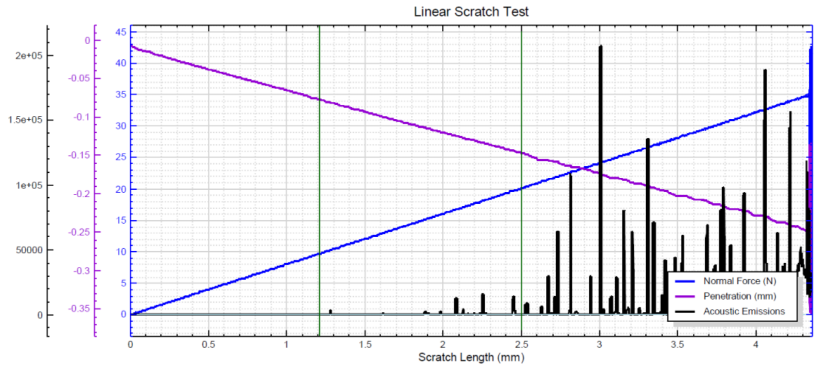


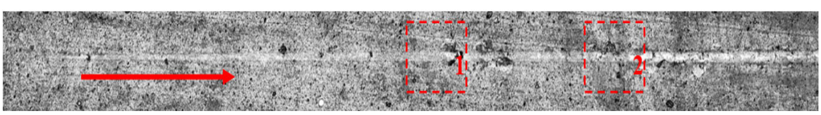
Fig. 3. Diffraction appearance of the alloy surface a) Diffraction (CoK α) from the surface of a sample of nitride steel R6M5, b) the same after exposure to NESP, c) the same after applying NbHf film to the surface before irradiation.

As shown in Fig. 2b, there is a significant reduction in metal evaporation. It should also be noted a change in the structure, which becomes finely dispersed. This is due to the fact that a refractory nitride film is formed on the surface, which reduces the evaporation of the metal and affects the structure. Figure 3c illustrates the formation of the nitride phase. These data are confirmed by the results of X-ray diffraction analysis, which are presented in this figure. An important result is that in this case the content of retained austenite in the surface layer is much lower. In our case, this is the result of strain hardening. This hardening is due to the passage of an elastic wave that arises under the pulse action of an electron beam [15, 16]. However, short process times and thermal inertia must be taken into account. Then the heating caused by compression and internal friction cannot be a physical factor that determines the behavior of the material under such conditions. In this case, a key role should be played. Mechanical activation of fast physical and chemical processes is a key factor. It is important that these processes occur in both liquid and solid phases. Figures 4 show the test results of cutting tool samples with different (TiAl)N coatings, respectively. Numerical values of adhesive strength values are presented. Each of the figures shows load and acoustic emission graphs, a panorama of a scratch, the beginning of the destruction of the coating ×1500 and the complete destruction of the coating ×1500.

a



b



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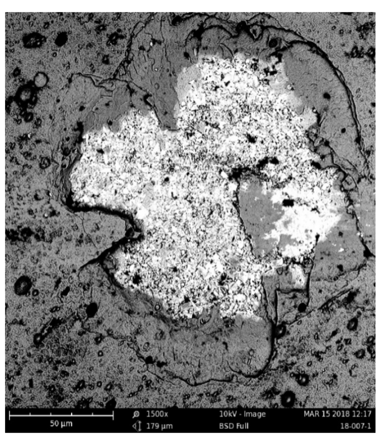

Fig. 4. Results of testing the cutting tool of the sample coated with ion-nitriding +(TiCr)N-(TiAl)N-(CrAlSi)N): a - graphs of the load and acoustic emission on the cutting tool; b – scratch panorama; c – complete destruction of the coating ×1500.

4 Discussion

Multiple starts of the process practically do not change the initial microstructure. As a rule, a series of five or six LHEP pulses is sufficient to complete the microalloying process. The rational thickness of the wear-resistant layer of a multicomponent composite coating is determined for end milling of titanium-aluminum alloys under given cutting conditions. It was found that the coating with a wear layer of 4 μm showed the best value in terms of wear resistance period. The conducted studies showed that the cracks formed did not completely cut through the structure of this coating and did not damage the surface layer, in contrast to coatings with a wear-resistant layer of greater or lesser thickness [17, 18] (Fig. 5).

pass number	Coated cutter (Platit)
37	84.626 μm.
37+35	91.774 μm

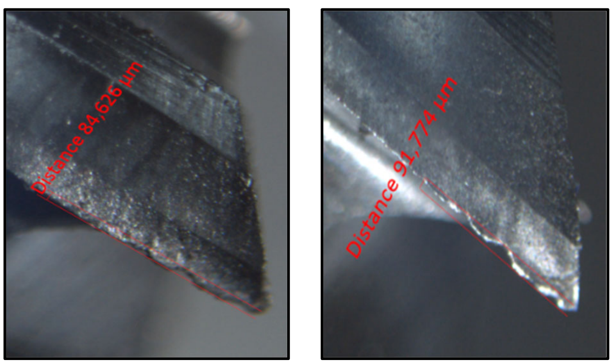

Fig. 5. Wear is visible on the tool after machining.

Carried out at NMMC PO "NMZ" for wear resistance tests were carried out when turning a forged, heat-resistant alloy 34XH1MA at a cutting speed n=10000 rp/m, Sz=0.037 mm/tooth, Sm=1500 m/min, B=5 mm, t =0.6mm. The rate of wear of the rear and front surfaces of 0.4 mm was chosen as the failure criterion [19-24] (Fig. 6).

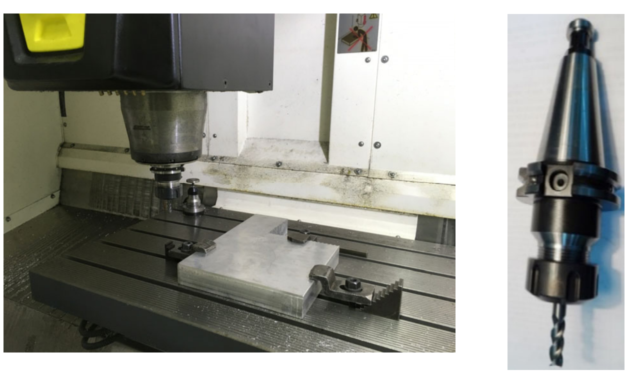

Fig. 6. Machined by milling machine.

Changing the geometry of the results of the partial results tool after processing the results of calculations of the results of measurements ρ of rounding the results of the edges with the calculation of values with the value of the initial radius of action, which are the result of the results of processing the results of cutting. The results obtained are presented in the table below. Forged ingot brand 34HN1MA, hardness HB375 workpiece processing was carried out on a milling machine FUS-32 (Fig. 7).

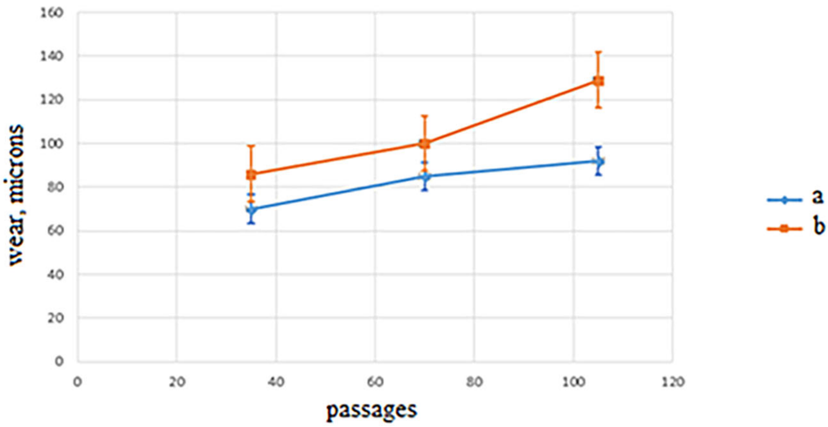

Fig. 7. Graph of tool flank wear versus number of passes (250 mm). (a) with a coating applied by New Plasma Technologies using vacuum-arc technology. (b) uncoated.

When cutting with a raw tool, the characteristic point of wear was the tip of the end mill.

5 Conclusion

The results of the experiments indicate the possibility of obtaining layers modified by surface alloying on the surface of the tool's high-speed steel. Obviously, if exothermic chemical reactions are initiated between the substrate and the thin film deposited on it, then such layers can be obtained. The study of the reaction products made it possible to discover the effect of the formation of new phase components.

Note the use of prototypes of cutting tools in production conditions. Prototypes of the cutting tool underwent complex surface treatment. Trial operation shows that there is an increase in tool life. It is noted that on average this is an increase of 1.5-2.5 times. This makes it possible to obtain a faster cutting base, since the increase in tool life obtained in trial operation is fixed as a result of a change in microhardness. In addition, the heat resistance of the surface layer of the original tool material is increased.

In a scientific study, the actual scientific and practical problem of increasing the wear resistance of a cutting tool during milling of a chromium-titanium hard-to-machine alloy through the use of multicomponent composite nanostructured coatings was solved. This structure of the coating makes it possible to effectively resist cyclic force and thermal loads, which are typical for intermittent processes, and in particular for the milling process;

In conclusion, we note the possibility of using such a process as microalloying. The microalloying treatment is generally carried out in advance, that is, before the wear-resistant coating is applied. This treatment also has a positive effect on tool life. It is possible to achieve an increase in the durability of a high-speed tool by 2-3 times, significantly reducing its wear.

References

1. Z. Fang, et al., Coatings **9(11)**, 765 (2019)
2. S.N. Grigoriev et al, Procedia CIRP **1**, 318-323 (2012)
3. Y.X. Xu et al, Surface and Coatings Technology **324**, 47-57 (2017)
4. I. Shin et al, E3S Web of Conférences **304**, 03033 (2021)
5. Y. Birol, Tribology International **57**, 101-106 (2013)
6. Holec D. et al, Surface & Coatings Technology **206**, 1698-1704 (2011)
7. V.P. Tabakov, Key Engineering Materials **496**, 80-85 (2012)
8. V.P. Tabakov, A.V. Chikhranov, Vestnik TSU **18(4)**, 1916-1917 (2013)
9. A.A Vereschaka et al, Journal of Nano Research **40**, 90-98 (2016)
10. M.G. Faga et al, Wear **263**, 1306-1314 (2007)
11. V. Gerashchenko et al., Materials Science Forum **1031**, 184-189 (2021)
12. N. Testoyedov et al, Materials Science Forum **1031**, 97-102 (2021)
13. G.G. Fuentes et al, Thin Solid Films **517(20)**, 5894-5899 (2009)
14. I.A Shulepov et al, Metals **7(11)**, 497 (2017)
15. Z.B. Zhao et al, Journal of Applied Physics **92(12)**, 7183-7192 (2002)
16. D.J. Quinn et al, Journal of Materials Research **23(3)**, 609-618 (2008)
17. A.J. Detor et al., Acta Materialia **57(7),** 2055-2065 (2009)
18. O.V. Krysina et al., J. Phys.: Conf. Ser. **669**, 012032 (2016)
19. I.V. Kovalev et al., IOP Conf. Ser.: Mater. Sci. Eng. **1227**, 011001 (2022)
20. D. Mukhammadiev et al., Modern Innovations, Systems and Technologies **3(1)**, 0101-0111 (2023)
21. J. Sharipov et al., AIP Conference Proceedings **2432**, 050042 (2022)
22. A. Abrorov et al., Modern Innovations, Systems and Technologies **2(4)**, 0331-0338 (2022)
23. A. Khojiyev, R. Muradov, S. Khojiyeva, K. Yakubova, E3S Web of Conferences, **264,** 04068 (2021)
24. A. Khojiyev, R. Muradov, T. Khaydarov, J. Pulatov, IOP Conference Series: Materials Science and Engineering, **883(1),** 012090 (2020)