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Influence of intermetallic coatings of system Ti-Al on durability of slotting tool from high speed steel

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Abstract. The operation conditions and mechanism of wear of slotting tools from high-speed steel was researched. The analysis of methods increasing durability was carried out. The effect of intermetallic coatings deposited from vacuum-arc discharge plasma on the physical-mechanical high-speed steel EP657MP was discovered. The pilot batch of the slotting tool and production tests were carried out.

1. Introduction

For today aircraft engine construction sets itself the tasks of modernizing and development modern turboshafts, which have high efficiency coefficient and engine thrust due to the new heat-strength, heat-resistant and high-strength materials. For the treatment of internal slots in different products of turboshafts uses a slotting operation. In the working process, the slotting tool experiences alternating dynamical loads, wherein the greatest wear exposed the backside of tool [1].

At present time physical deposition processes [2] for different components, including cutting tool, are increasingly used due to high reliability, uniqueness, the possibility of obtaining coating of various composition, structure with high productivity of tool. For increase durability of metal-cutting tools widely applied coatings of the Ti-Al-N system [2]. For most of bulk materials with high hardness is characteristic a large value of elastic modulus E, therefor such materials are brittle. To evaluate the resistance of materials to elastic deformation uses the ratio of hardness to the elastic modulus H/E, which called the plasticity index of material [3]. It follows that to increase the resistance to elastic deformation, the material must have a high hardness with a low modulus of elasticity. Earlier, the authors [2, 4] developed a new method for obtaining coatings based on the intermetallic compound of the Ti-Al system, which based on the synchronous deposition of Ti and Al from two electric arc evaporator, by heating substrate to a temperature of 700 K. As a results of conducted researches, has been established, that with the increase the substance intermetallic phases in the coating, mechanical properties are increase.

In this way, the aim of this work is to research the influence of intermetallic coatings of the Ti-Al system on the durability of slotting tools from high-speed steel.

2. Objects and methods of research

As the object of research was chosen slotting tool made of EP657MP steel, which is a gear-cutting tool with the shape of a gear wheel. Depending on the working rime of tool, its wear can be divided on three steps (figure 1), which consistent to the three sites of wear. Area I – initial wear – burn-in period. Area II – period of normal wear. Area III – period of intense wear. In the working process slotting tool is incured a thermal wear, formed as a result of friction of the backside of the teeth of cutting tool to the surface of the workpiece.

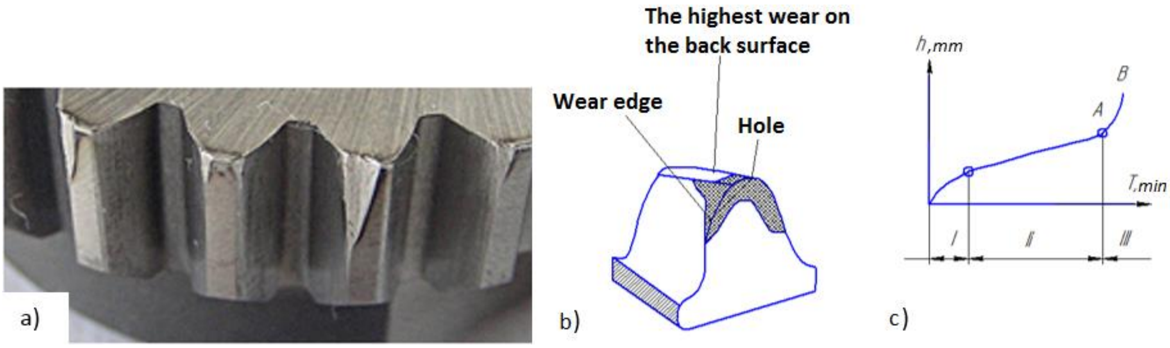

Figure 1. Wear a gear-cutting: **(a)** – catastrophic wear of the teeth of a slotting tool; **(b)** – the nature of the tooth wear; **(c)** – dependence of wear on the tool life.

The samples of EP657 material were coated intermetallic coatings of the Ti-Al system by developed technology [4]. Samples in the vacuum chamber are located as well as in parallel and perpendicular, to determine the difference of the thickness on vertical and horizontal surfaces. Coatings were covered by simultaneously spraying of two one-component cathodes of Al and Ti, and also rotating the table around itself axis. During the deposition coatings, when the samples were rotated in the chamber, intermetallic phases Ti-Al system are formed on the surface. Technological modes of the coating are varied the next limits: the pressure in the chamber $P = 10^{-1}$–10^{-2} Pa; arc current I = 60–120 A; processing time 90 min. The thickness of the samples was measured by device called CALOTEST. The microhardness, modulus of elastics were measured by using a nanodidomer called NANOVEA. The microstructure and chemical composition of the surface were determined by scanning electron microscope.

3. Experiment results

The thickness of the coating on the samples which were located parallel to the flow was 3 μm, perpendicular – 5 μm. The microstructure of the coated samples is shown in figure 2.

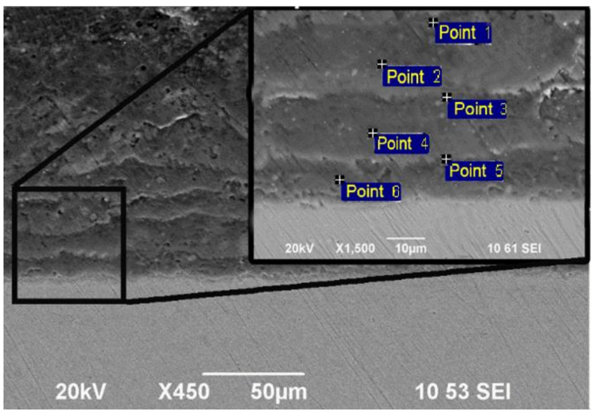

Figure 2. Microstructure of samples processed by the developed technology.

Also, using the scanning electron microscope, was researched the chemical composition of the coating layers. The microstructure of the explored area is shown in figure 2. The results on the chemical composition of the coating layers is showed in table 1. The results of measurements of the chemical composition of the layers are shows that the nitrogen content is maximal in the dark areas and decreases on the light layers, which is correspond to the intermetallic layers. In the transition from the upper layers to lower, increases the content of iron and chromium, because the depth of the layer since measuring the chemical composition is up to 3 μm.

Table 1. Chemical composition of the layers.

Point	Atomic ratio, %				
	N	Al	Ti	Cr	Fe
1	35.12	22.8	40.7	0.6	0.4
2	27.27	26.7	45.4	0.64	0.4
3	39.77	22.2	36.6	0.55	0.5
4	27.4	22.1	48.5	0.75	0.8
5	34.34	21.5	42.9	0.63	0.7
6	33.15	21.5	43.1	0.69	0.9

Also were studied the mechanical properties of coated samples. The loading and unloading curves are shown in figure 3, the hardness of the coating H was 34.75 GPa, the modulus of elasticity E = 204.17 GPa. Herewith, the elastic recovery value W_e is 62 % and the plasticity index of the material is 0.17, which made possible to provide increased mechanical properties and wear-resistant characteristics of the cutting edges of the tool.

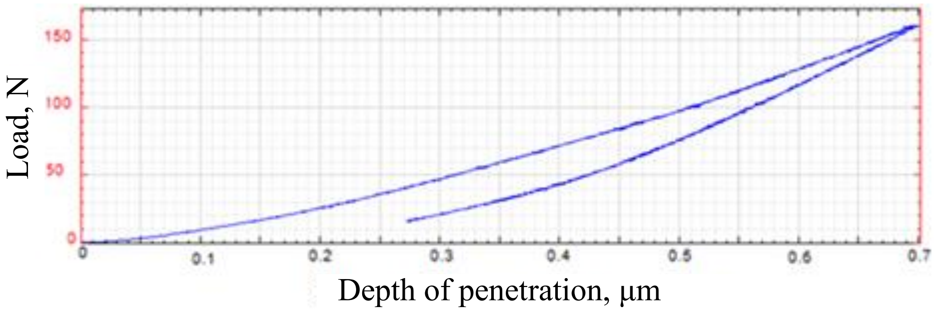

Figure 3. Microstructure of samples processed by the developed technology.

Based on the results of researches the experimental batch of the instrument was processed (figure 4) and production test were carried out.

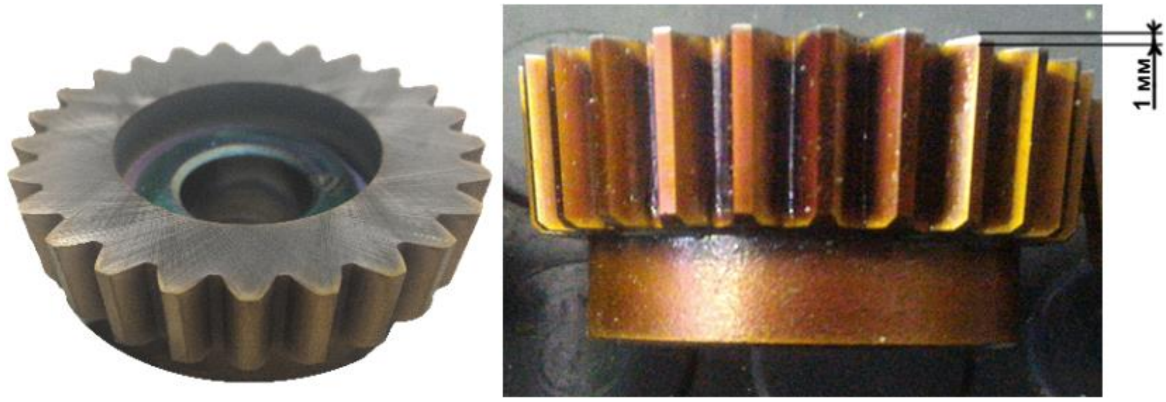

Figure 4. Slotting tool with intermetallic coating.

The results of the tests established, that the deposition of composite coatings based on intermetallic Ti-Al system on metalcutting slotting tool for involute splines allowed to process detail in size with the drawing requirements, with using a single instrument and thereby improving durability compared with regulatory 6 times (figure 4), the tool wear was not more than 1 mm, which will use the tool in future (after regrinding and repeated coating), as opposed to catastrophic wear of the teeth (figure 1(a)).

4. Conclusion

Operation conditions and the wear mechanism of slotting tools form high-speed steel are investigated. A research of mechanical properties of samples with intermetallic coatings showed, that the microhardness is 34.75 GPa and the modulus of elasticity is 204.17 GPa. Also it was found that the value of elastic recovery W_e is 62 % and the plasticity index of the material was 0.17, which allowed the increased mechanical properties. Based on the results of the researches tests it was found that the application of intermetallic coatings of the Ti-Al system made it possible to increase the tool life in comparison with the standard one by 6 times.

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