On the peculiarities of wear-resistant nanocoatings research under production conditions. Obtaining calculated dependencies

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Abstract. In this paper, we consider the main types of wear-resistant nanocoatings application, a method for determining the wear resistance is presented, which was developed based on experimental data on the wear resistance of cutting tools, with the deposition of a wear-resistant coating of titanium nitride. This article discusses the increase of the cutting tools effectiveness with the use of the cutting parts deposition with wear-resistant coating of titanium nitride. Axial tools, as well as cutters with wear-resistant coatings and without were studied within the framework of the PJSC “KAMAZ” production process. The data obtained from the studies of all groups of instruments are shown in the tables, they are presented in graphs and diagrams. Recommendations are given to increase the durability of the cutting tools, as well as to optimize the tool turnover in the production process.

1. Introduction

In this article, the issue of methodical support for the use of cutting tools (CT) with wear-resistant coatings in the existing section of PJSC KAMAZ has been investigated. The first part of the article deals with the development of tool wear calculated dependences in production conditions. The main supplier of CT for machining areas is the PJSC "KAMAZ" repair and tool plant. The instrumental production facilities include a tools central storage, a site for sharpening and restoring of tools and attachments, a warehouse for abrasives, and shop tool dispensing pantries (figure 1).

The tool dispensing pantry is used to provide working places for the machining shop with tools and production tooling. In production, a complex delivery of the tooling for permanent use is organized with the subsequent replacement of the worn-out equipment surrendered by the worker. In the tool dispensing pantry, the drills are given out to auxiliary shops after being used in the main production. Planning and maintenance of issued tools from the main production to auxiliary shops is not carried out. To the sharpening shop, the tool does not come from the work places, but from the tool pantry. In most cases, the input wear control is carried out by an external inspection, the output control is made by templates. Sharpening of reamers and drills is done manually, without the use of tools, because of which a considerable part of the cutting part of the tool is removed. All these factors do not allow organizing effective management of the tool turnover in production.
2. Statement of the problem
Without changing the nomenclature of the tools and the methods of the part processing, it is required to develop a technique for determining the wear resistance of a tool with nanocoatings in production conditions, by optimizing the organization of the tooling. It is necessary to reduce the consumption of CT, by applying special methods to improve the cutting properties of the tool.

3. The main part
It is known that the main direction of increasing wear resistance of tool materials while maintaining their strength is the development and introduction of new technological methods for creating wear-resistant coatings, primarily refractory coatings, that is, coatings based on metal-like and nonmetallic compounds such as carbides, nitrides, borides and oxide films of high-strength materials thickness of which is not more than 0.02 mm (Figure 2).

Coating materials have high hardness and wear resistance. The application of thin hard coatings to the working surfaces of CT made from tool steels and hard alloys (HA) allows to reduce the frictional force when cutting structural steels by 20-50%, to reduce the chip shrinkage and cutting force by 15-20%, to reduce the cutting temperature and significantly (3-5 times) to increase the resistance of CT.

At present, many variants of coatings differing in composition (carbides, nitrides and carbonitrides of titanium, molybdenum, zirconium, hafnium, vanadium, niobium, chromium, aluminium oxide, cubic boron nitrides, etc.) are known, the number and thickness of the layers (one, two and multi-layer thickness from 3 to 15 μm), coating technology. When choosing the coating material, in addition to its physico-mechanical properties, depending mainly on the crystalline structure of the compounds, the application methods play an important role.
Currently, the most widely used methods are: chemical vapor deposition; physical vapor deposition; thermodiffusion; ion alloying; ion saturation; vacuum ion-plasma.

The methods of the plasma flow condensation generated by an electric arc evaporator with simultaneous ion bombardment of the tool surface are widely used in industry. This method, in comparison with gas-phase, activated reactive atomization (KIB), reactive electron beam plasma deposition (REP) provides a higher degree of the plasma flow ionization, reaching 80-100%, which allows for effective ion bombardment of the surface when applying accelerating voltage to the parts 1 sq. m. The presence of this factor provides high adhesion properties of the vacuum condensate, and the bombardment of the formed coating with ions having an energy of 100 ... 200 eV makes it possible to control the condensation process and ensures the formation of refractory metal nitrides at a relatively low temperature on the surface of the CT (300-400 °C).

Coatings are characterized by high hardness HV 4000 and adhesion strength. Roughness of the CT surface with wear-resistant coating does not deteriorate. The most stable results of increasing the CT and tooling resistance were obtained by coating them with titanium nitride based coatings. Essential in the coating technological process is its condensation on a stationary or rotating substrate. With the same condensation time, in the latter case, uniform coating is obtained over all working surfaces, but half the thickness in comparison with deposition on a stationary substrate. The entire cycle of deposition (CT loading, vacuuming the vacuum chamber, complete cleaning, deposition, unloading) takes 30-40 minutes.

4. Calculating scheme, accepted assumptions
The application of the CIB coating method to the CT chosen as the object of the study was organized. To clarify the fact of increasing the CT resource, it is necessary to carry out the durability tests with a comparative study of the intensity and wear dynamics of the CT with and without coating (with a basic CT).

Tests were carried out in production conditions. Production tests are characterized by limitations in the choice of conditions and test procedures under the conditions of this operation; impossibility to change parameters of CT and cutting modes in the required limits; instability of equipment and blanks properties, of cooling, etc., the main advantage is the determination of objective operational characteristics of the CT.

The following test sequence was adopted:
- Choice of research objects.
- Determination of the required number of tests.
- Selection of tools for research.
- Study of the basic tool.
- Organization of deposition works.
- Quality control of coatings.
- Testing of coated tools.
- Analysis of research results.
- Conclusions on the tests.

On the machining site of part No. 5320-2902445, mainly cutters, drills, countersinks and reamers are used (Table 1) [1]. All the CTs listed in the table have no coating. Machines, which are used in the experiment, are summarized in Table 2 [1].

Replacement and control of CTs on the line is carried out in shifts by two adjusters. The instruments on the line are changed according to the CT replacement card. After removal, CT is surrendered to the tool pantry. Most often, compared to other CTs, drills, reamers, sinkers are changed. The approximate total idle time for replacing the above CTs and adjusting the machines is 2 hours per shift, hence the significant annual expenses. For example, 1120 pcs. new drills Ø 16.5 per year for 4480 rubles were given out.

The most laborious, for the adjusters is the change of polyhedral non-re-sharpened plates (CPNRP) on mills. For example, only on the machine 9A315 to replace or reinstall PNP set (90 pcs.) it is necessary to stop the machine for 3-4 hours. One plate costs 254.7 rubles, and the annual expenses is about 60 thousand rubles (for 2014).

As the research object, CTs with a relatively short period of durability were chosen. When choosing the research object, the following factors were considered:
- technical possibilities of installing a wear-resistant coating;
- period of tool life between the re-sharpening;
- labor-consuming replacement of tools and setting up of machines;
- technical condition of machine tools;
- the state of the workpieces to be processed;
- line load during the planned testing period;
- labor intensity of sharpening;
- the applicability of tools for processing other similar parts in the same shop;
- number of simultaneously working tools;
- the ability of the tool service to provide the required number of tools for testing;
- the ability of production personnel to assist in conducting production tests.

The tools for testing were taken from the pantry, each lot tested for compliance with the requirements of the drawing and divided into 2 parts, one part was coated, the other was left unchanged. The quality of the coatings was determined visually. Coatings were applied according to the following scheme:
- reamers and drills - from the rear surface without rotation;
- plates - from the front surface, without rotation.

Tests of the basic CTs and CTs with coating were carried out simultaneously. During the tests, the time of installation and the time of removal of the CT were recorded. Experiments were conducted under constant cutting conditions.

It is known that during the operation of CT as it wears out there comes a point when further CT cutting should be terminated, and CT sent to re-sharpening or replaced with a new one. The moment of the CT blunting is established by means of the wear criterion. As a rule, linear wear on the rear surface is taken as a criterion of wear, as the rear surface of the CT wears out when processing any materials and under any cutting conditions and measuring the width of the wear area is not very difficult. Studies of the CT rear surface wear were carried out for 1.5 months. During this period, the wear of the CTs without coating and with TiN coating was constantly measured in different periods of operation.

In total, more than 60 CT wear measurements for hole processing (drill, reamer) and more than 400 measurements of carbide non-permeable plates were made. In the work, the wear measurement was
carried out using a microscope of the MPB microscope 2 type and a Brinell magnifier with a 0.05 mm dividing point. The results of the measurements were recorded in tables.

To properly assign a wear criterion, you need to know the dynamics of its change. The study of the dynamics of wear was carried out on TiN-coated drills Ø 14.5; Ø 16.5; Ø 17 (Figures 3-8 [1]) at operations 030 and 070 of the machining line in hole drilling (operating modes of drills are listed in Table 3 [1]), reamers with TiN coating Ø 17 and Ø 40 (Figures 9-12 [1]) at operations 030 and 070 (the operating modes of the reamers are indicated in Table 4 [1]) and cutting plates at operations 010 and 050 in the face milling (the operation modes of the plates are indicated in Table 5, Figures 13-15 [1]). Measurements were made periodically every 10-20 processed parts by means of a Brinell magnifier.

In parallel with the study of wear, the quality of the coating was researched. The most high-quality coating was obtained on plates. The worst coating is on drills. The thickness of the coating was determined approximately on tools (by acid etching). On plates it is 2-3 microns; on reamers it is of 1.5-2 microns, on repair tool plant drill bits it is 1-1.5 microns on press-frame plant drills it is 1.5-2 microns. On the plates and reamers, detachment was not observed. On the drills, the detachment began after processing 8-10 parts; all the coating was removed after 60-100 parts along the margin - completely, on the back and front surface - in part.

Because of the tests, the following data were obtained:
• values and number of wear measurements;
• durability, expressed in the number of processed parts in the period between re-sharpening.

5. Preliminary conclusions
A theoretical part of the method for determining the wear durability of a cutting tool was developed based on experimental data on the wear durability of a cutting tool with a deposition of a titanium nitride wear-resistant coating.

Based on the results of experimental studies, a decision will be made about the possibility of using the developed methodology in production conditions.

References
[1] Chemboriso N A and Vysogorets Ya V 2015 Research of the effect of applying wear-resistant nanocoatings on the cutting tool durability Modern Equipment and Technology 8