Strengthening of metal-working tools by a method of chromium-diamond coating application on cutting edges

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Abstract. A description of SamSTU innovative product - a prototype and construction of a mechanical part of small-sized galvanic device designed for a formation of protective chromium-diamond coating on wear-subjected areas of drills, which are manufactured from high-speed steel. The new device allows to increase durability of tools with the highest energy efficiency, doesn't harm environment and does not require user to have skills in a field of electrochemical technologies.
[Gallyamov A.R., Ibatullin I.D. **Strengthening of metal-working tools by a method of chromium-diamond coating application on cutting edges.** *Life Sci J* 2014;11(12s):592-596] (ISSN:1097-8135). http://www.lifesciencesite.com. 127

Keywords: Metal-working tool, chromium-diamond coating, electrochemistry, local galvanic coatings, durability of tool, galvanic device

Introduction

It is known, that service durability of metal-working tools is affected by a variety of factors: body's geometry, properties of processed material, regimes and strategy of processing, as well as material, which tool is made from [1]. At the same time, many companies, that manufacture tools (Iscar, Arno, Mitsubishi Materials, Sandvik Coromant, Walter, etc.), recently paid great attention to an improvement of tool's quality by strengthening surface treatment of cutting edges by means of an application of thin (with thickness of few micrometers) wear-resistant coatings, which contribute to an increase of tool's durability and productivity, as well as an improvement of processed surfaces' quality [2].

One of the earliest methods of metal-working tool's strengthening by means of wear-resistant coatings is electrochemical chromium-plating, which in Russia started in 1925-1926, when "Goznak" factory in Moscow began to use chromium-plating of printing forms in order to prevent wear [3]. In addition to high hardness, chromium coatings are used for a restoration of worn surfaces and corrosion protection [4]. An increase of cutting tool's durability by means of chromium-plating method began to develop in the 1930s. At the same time chromium coatings became widely implemented in the transport industry, in manufacturing of measuring tool and in repair practice. From 1940s due to works of M.B. Cerkez, I.M. Antonov, D.N. Pletnev, V.V. Efremov, G.K. Shviryaev, L.Ya. Bogorad, M.L. Perzovski, O.A. Esin, N.D. Biryukov,V.I. Lainer, N.D. Biryukov, P.P. Belyaev and others quality of wear-resistant chromium coatings was improved, which stimulated their use in practice of service-life-increasing treatment of new products, as well as in restorative maintenance of worn parts of machines and tools [3: 21].

Chromium-plating of tool's cutting part decrease friction force during cutting, facilitates chips' escape, significantly reduces temperature of cutting and, as a result, improves durability of tool (from 2 to 10 and more times). Main features of chromium, which ensure an increase of chromium-plated tool's quality, are: high hardness, combined with sufficient plasticity, which provides high resistance of coating to fatigue, deformation and abrasion forms of wear, as well as low coefficient of friction, which ensures coating's ability to resist a formation of outgrowth of processed material on tool's body (especially in a case of nonferrous alloy processing) [5, 6].

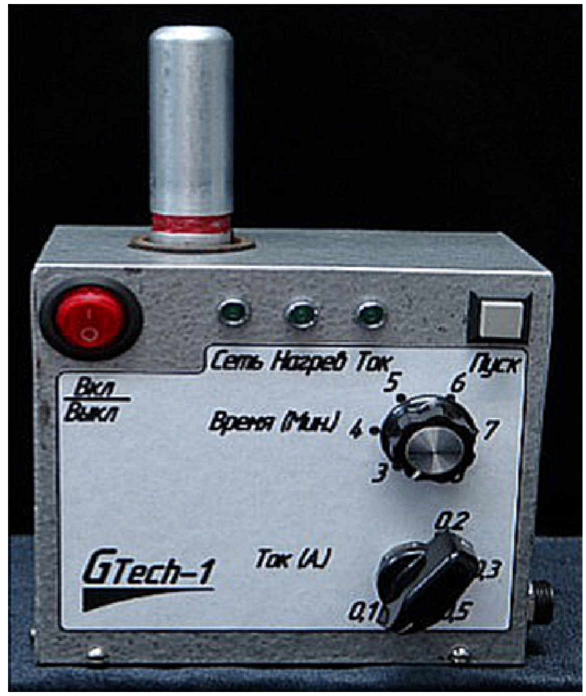
In spite of the fact, that, nowadays, chrome plating of tools is increasingly substituted with more eco-friendly methods of an application of protective ion-plasma (titanium nitride, etc.) and diamond-like coatings, [7, 8] interest for an application of chromium coatings doesn't disappear [9-10]. That fact is related with a development of new technologies of a production of cluster chromium-diamond coatings' with increased durability [11], as well as with the fact that a technology of chromium-plating remains the most simple and productive and doesn't require expensive equipment and materials. It is also important, that there is no significant heating of tool during electrochemical chromium platting [12]. However, aforementioned methods have disadvantages. First of all, because of duration and energy intensity, existing methods of coatings application are becoming cost-effective only in a case of mass production. Therefore, strengthening coatings are most commonly applied to a batch of new tools. Secondary application of coating on reground tool, as a rule, is not carried out, although tool manufacturers provide such services. For that reason, effect of applied coatings has short life. Secondly, tool's wear is uniform on body of tool and localized at a certain area (more often, on a rear surface). Therefore, an effective rework of tool requires an individual approach. For example, it is difficult to recover calibrating sizes of precision tool (drills, taps, etc.) in a case of mass processing. Also, during chromium-plating in bath it is difficult to strengthen cutting edge of tool and remain its diameter in the same time. Thirdly, electrochemical processing of tool results in a deterioration of ecological parameters in a production facility. Hermeticity of working area during processing of tool in galvanic bath is hard to ensure, therefore, ventilation is required. Disposal of spent electrolyte requires expensive waste treatment facilities. In addition, strengthening of tool requires a specialized bay and qualified personnel.

That fact led to a demand for specialized small-sized systems for local strengthening of cutting tool in a process of their operation [13]. The new product, designed in Samara State Technical University, had a purpose to provide a capability of automated electrolytic application of hard electroplating on geometrically-complex working areas of metal-working tool of specified thickness.

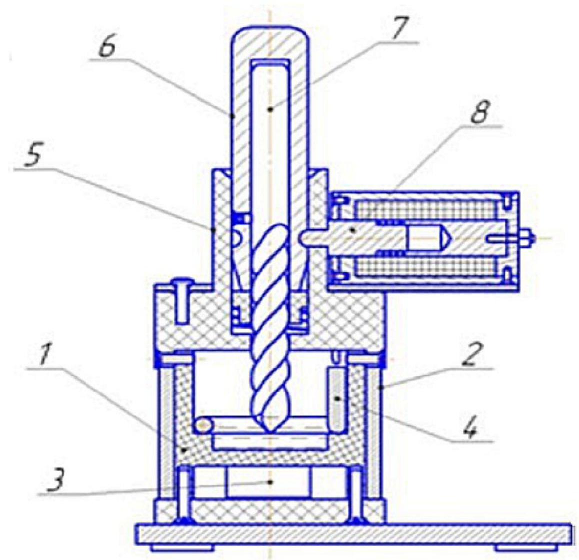
In the proposed device (fig.1) galvanic unit and the control unit are integrated into one independent monoblock. Arrangement of experimental unit is presented in figure 1. The unit is a chemically resistant plastic bucket 1, with a heat insulating casing 2. Electrolyte temperature is kept by means of heater 3. On the bottom of the bucket there is lead anode, immersed in the chromium-plating electrolyte. Positive pole of power supply is connected to anode. In lid 5 there is opening for a placement of handle 6 with processed tool 7. Handle is locked using electromagnetic fixing device 8, which is transferring current to processed tool.

Monoblock design of the device allowed to combine power supply and control unit in one casing of galvanic device. On the front panel there switches, which control technology regimes, and corresponding led indicators.

In addition, inside the bucket there is timer equipped with a mechanism designed for automatic lifting of tool after coating's deposition. Such a solution allows, immediately after resharpening, to place tool into the device and continue work, without a need to control a process of deposition. Small sizes of a device allow to avoid evaporation of harmful substances. It is practical to place the device near any each grinding machine at a production facility.



a



b

Fig.1. Galvanic device; a) overview of galvanic device; b) schematic of galvanic unit: 1– bucket; 2 – heat insulator; 3 – heater; 4 – anode; 5 – lid; 6 – handle; 7 – drill; 8 – fixing device.

A consumable material in that device is chromium-plating electrolyte, which can be supplied in a form of a syringe with a long tube instead of a needle. The simplest composition of chromium-plating electrolyte contains following components:

1. Chrome anhydride – 250-350 g/l;
2. Sulphuric acid – 2.5-3.5 g/l;
3. Nanostructured additive UDD-W (suspension of ultradispersed diamonds) – 20 g/l.

Chrome plating is performed with electrolyte temperature of 45-60 °C and current density of 15-50 A/dm^2 (current output is 12…13 %).

Special feature of the new technology is that suspension of ultradispersed diamonds, with particles sizes approximately 10 nm and concentration of 15 to 20 g/l, is introduced into standard electrolyte. Chromium-diamond coating has microhardness (1500 kg/mm^2), which is three times higher than hardness of cone drill steel and is more than twice bigger than hardness of chromium without nanostructured additives. Coating has strong adhesion with a basis (in a case of steel basis tear strength reaches 45…50 kgf/mm^2), high surface smoothness (R_a=0.2 micron) and low coefficient of friction, which reduces temperature in a friction zone and creates anti-gland effect. Chromium-diamond coating ensures a reliable operation of parts in conditions of normal and shear loads.

An implementation of UDD during an application of protective coatings, in comparison with the standard galvanic technology, allows to increase service life of products in 2.0...4.5 times [14, 15]. With use of that technology, it is possible to apply coatings on products with a complex shape. Experiments shown that wear resistance of nanostructured chrome-diamond coatings exceeds wear resistance of traditional chromium coatings (without UDD) in 6 times, titanium nitride coatings in 1.5...2 times. A significant advantage of UDD applications also a significant increase in diffusion capability of electrolyte. A physical mechanism of an increase of technological and operational characteristics chromium-diamond coatings is determined by high physical and chemical activity and low inertia of UDD, which increases effectiveness of mass transfer and results in an ability to work with high current densities up to 600 A/dm^2.

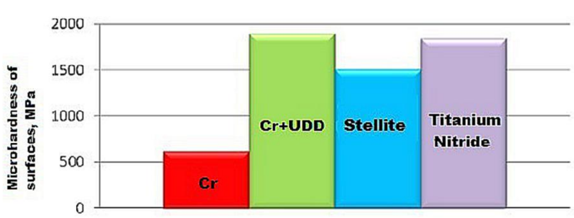


Fig.2. Comparative analysis of wear-resistant coatings' hardness

Comparative analysis of chrome-diamond coatings durability (fig.2) showed their significant advantages as compared to traditional wear resistant coatings based on titanium compounds (titanium nitride, titanium-aluminum). That technology of protective coatings' application has been successfully applied to enhance durability of cutting tool: shaped, disk and worm cutters, drills, bits, taps, screw-thread dies, equipment for deep cold drawing of metals, as well as various kinds of press-molds [16].

The method of galvanic device operation is very simple. The device is turned on and given time for electrolyte to heat up to operating temperature. New or sharpened tool is clamped in mandrel, providing the required offset (4 cm) with a special stand-stopper. Surface of cutting edges is degreased with a cloth and water suspension of chalk and alkali. The mandrel is inserted in opening (fig.3a) and a lower part of tool is kept in electrolyte for 30 seconds in order to provide activation and warming up of surface. Then, required parameters of current and processing duration are set up and the process of chromium-plating is started with Start button (fig.3b). After automated ejection of the mandrel with tool from a socket (fig.3c), tool is cleaned with a cloth and taken off from the mandrel.

a

Tests were conducted on an example of strengthening of metal drills, which had two diameters: 5 mm and 8 mm and were manufactured with high-speed steel R6M5 (initially the drill did not have protective coatings). Processing was conducted with 300 mA current, which was set in advance using control on the front panel.

b

c

Fig.3. Phases of galvanic device work (a-b-c)

Processing was carried out during 10 minutes. Chromium coating was deposited along 2 mm length from tip of drill on its working edges, thickness of coating was 5 micron, Vickers microhardness was 1200 kgf/mm^2 (fig.4). Testing processed drills shown that strengthening improves durability of tool up to 50 %.

Fig.4. Overview of drills with locally strengthen cutting zone

As compared to an application of wear-resistant coatings in the bath [3] the proposed method and the device possess following advantages:

- Mobility and small sizes of the device allow to use it in any conditions of production facilities, for example, directly near grinding machines;
- The device does not require qualification in a field of electrochemistry; local strengthening of cutting edges of tool allows to increase its durability without a change of a caliber;
- Possibility to process various cylindrical tools (drills, taps, cutters, dies, etc.);
- Possibility to process tools repeatedly and adjust thickness and hardness of deposited coating;
- Low electrolyte expenditure and absence of hazardous fumes; low power consumption and high speed of processing;
- Applied chromium-diamond coating has high hardness, wear resistance, wear resistance, heat resistance, corrosion resistance and adhesion;
- High economic efficiency in a case of single-piece processing of tool (both new and reworked).

The present study was carried out with the support of the Ministry of Education and Science of the Russian Federation in a framework of grant No. 2014/199 (project code 1585) for a conduction of state supported research within a framework of a main part of government contract from the Ministry of education and Science.

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7/28/2014