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# MEANS OF RAISING COMPETITIVE CAPACITY OF FOOD EQUIPMENT

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**Abstract**. The current economic state is seen as a great barrier to diversification of national goods, equipment and services outlet. Globalization processes regulate sales and deliveries priorities. At this stage European Union provides products, goods, technologies of more competitive capacity. There are a number of enterprises that produce high quality products in the Republic of Belarus. These products are in popular demand not only within the country but abroad as well. Taking into consideration these facts it should be noted that an inflow of funds from abroad is held by high prices for such products. It's connected with outdated technologies, expensive equipment being used in the production, short terms of its operation and sometimes low competitive capacity of goods.

**Keywords:** maintenance, wear, electric discharge, ultrasound, composite materials, microhardness.

## 1. Introduction

At present mainly imported equipment is being used in the food production. It meets all the necessary requirements and characteristics. Nevertheless it has terms of exploitation. Once been expired it requires a lot of funding in order to obtain either new components or the whole new equipment. Hence, the most problematic aspect of exploitation of specialized food equipment, e.g. which is used in meat production or in slicing vegetables, cheese, bread, is its fast wear of working components – knives (Fig. 1). Nowadays a lot of solutions of quality improvement of such equipment are introduced by scientists and manufacturers. Mainly the solution is seen in development of its design. Thus, as seen in Fig. 1, the design of modern food cutters can be improved by cutting meat with three different sets of knives in turns [1]. They need to be fixed in a certain order inside the cutter head. It will result in a decrease sickle curvature and length of the cutting edges of the chopping blades in the transition from one set of raw material to another. This change provides a reduction in the duration of the process of cutting, improved product quality, as well as reducing energy costs. But it remains an unresolved problem of intense wear, corrosion damage and blunting of knives, leading to loss of cut quality and reduced terms of exploitation. Another design improvement of food cutters is the introduction of a special mixer with trowels. This improvement is meant to make meat a more homogeneous mixture, which will facilitate the process of cutting and reduce its duration [2]. However, even in this embodiment, not only knives but the mixer trowels as well are subjected to various kinds of heavy wear.

**Fig. 1.** Equipment for chopping various food products

As a rule, changes in the design of any instrument or device are connected with considerable material costs – development of a new design and technological documentation, production or acquisition of new components, testing, pre-production, etc.

It is possible to keep the position on the market by carrying out competent scientific, technical and marketing policies that will improve the quality of goods produced without abnormal increase in their prices. One of the most effective solutions to this problem is innovations in the field of service and supply. The main purpose of such innovations is development of modern progressive, cost-effective technologies that will improve competitive capacity of equipment. It can be achieved by producing the equipment and its components with improved working surfaces and extended terms of exploitation. Apparently there will be no need in expensive imports and it will decrease manufacturers' dependence on suppliers. Such improvements will lead to increased terms of exploitation while producing goods of a higher quality. At the same time it's a solution to problems of supplies, energy and import substitution.

## 2. Experimental part

### *2.1. Technology and equipment*

We propose an innovation in the production of national machinery and equipment for chopping and slicing foods that lies in applying function-adapted coatings to the critical surface of such equipment.

Such coatings are not only to maintain but also to improve the basic performance of the treated surfaces by providing them with increased wear and corrosion resistance, improved anti-friction properties (such components generally operate in conditions of friction), etc. Further, such coatings must be chemically inert and harmless when in contact with food, must not disrupt the geometry of the cutting edges and degrade the cut quality.

Currently, there is a large number of such coating application technologies, such as the gas-flame method, the plasmatic method, the ion-plasmous method, laser processing, the high-current electron beams influence on the surface, etc. [3-6] However it is impossible *to maintain application* of such coatings with the required thickness and roughness levels using modern, usually stationary, expensive, energy-consuming, requiring the creation of special infrastructure processes. In most cases, the following mechanical processing of such hardened or refurbished products is needed. It is followed by additional material costs and often at the same time chipping risks of the highly-stressed coating.

Applying coatings with the desired properties can be effectively achieved through the use of low power-consuming, mobile, universal technology of electric discharge alloying with additional ultrasound exposure (EDA and UE) [7]. This method does not require the creation of the special infrastructure. The main technical characteristics of the used equipment are summarized in Table 1. It is low power consuming (powered by 220 V network), mobile thanks to small size and weight (see Fig. 2). It can be easily combined according to sequence of operations on the task, reliable and inexpensive.

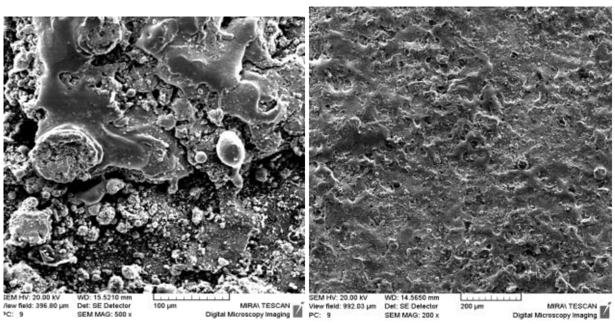
**Fig. 2.** Serial plants for electric discharge alloying and ultrasound exposure

**Table 1**
Main technical characteristics of serial plants for electric discharge alloying and ultrasound exposure

| Plant | Supply voltage, (V) | Power consumption, (kW) | Operating current, (A) | Output ($cm^2$/min) | Max. coating thickness, (μm) |
|---|---|---|---|---|---|
| UIL-2 | 200 | 0,5 | from 0.3 to 1.8 | up to 5 | up to 10 |
| Eletron-22 | 100 | 0,4 | from 0.3 to 3.6 | up to 5 | up to 120 |

As a result of this treatment it is possible to select the desired composition of the electric discharge alloying, providing a secure contact of the treated surface with nutritional environments, as well as achieving improved corrosion resistance and anti-friction properties by obtaining the hardness of the hardened surface at the level of 72-74 HRC and a decrease in the friction coefficient by 30-50% [8]. Furthermore, in most cases such treatment is complete. It eliminates additional costs for the following mechanical finishing of hardened surfaces to the required parameters in accordance with the design documentation.

Figure 3 shows the topography of the surface hardening, e.g. using gas-thermal spraying and electric discharge alloying with ultrasound exposure methods.



a) b)

**Fig. 3.** Topography of the surface hardening using gas-thermal spraying (a) and electric discharge alloying with ultrasound exposure (b) methods

*2.2. Material*

Choosing the composition of electric discharge alloying is usually guided by the requirements of operational necessity. Electric discharge alloying with the ultrasound exposure method is a significant advantage over the technologies listed above. It not only allows the use of *any* conductive material, but also to specially build composition to form a coating of the desired purpose. It can be achieved with the use of powder metallurgy methods, self-propagating high-temperature synthesis, sintering and pressing, etc.

In modern material science it is an innovative way to improve the properties of the alloys by modifying their structure. The use of materials with nanocrystalline structure is of particular interest in this sphere [9, 10]. Such composite materials are manufactured by sintering or hot pressing with the use of a nanostructured alloy consisting of tungsten carbide-cobalt with a cobalt content of 3-25% (wt.), and tungsten carbide grain sized of 2 to 120 nm, with a residual porosity of 8-40%. They are widely used at hardening of a wide range of machine parts. The result is improved performance properties of metal surfaces of machine parts operating under load in extreme conditions, increased continuity, durability, heat resistance, micro-hardness, Young's modulus, reduced surface roughness and friction coefficient. Innovative solutions are the creation and application of the electrode rods [11] made of a uniformly mixed and compressed powders of the first component comprising at least one metal from the group Fe, Co, Ni, metals of group 4a, 5a and 6a of periodic table of the elements and Si and a second component, which ensures the implementation of self-propagating high temperature synthesis (SHS) in the process of electric discharge alloying to get both first component comprising carbide, nitride, boride, silicide and intermetallic compound. Since such electrodes are made of compounds with a high melting point, such as silicon carbide and boride of a transition metal, the coated surface can exhibit a wear resistance several times higher than the wear resistance of the base metal. In order to get high quality protective layers, some authors suggest using a doped electrode of a material less pliable to oxidation processes at high temperatures [12]. At that the phase composition of the formed layers must comply with a given chemical composition of the electrode material, providing the required wear resistance, impact toughness, fatigue resistance, etc. Several scientists from Russia, the United States of America, and Japan suggest using titanium-tantalum-carbide compounds in order to maximize hardening properties [13]. A number of scientists [14] claim that the most promising solution in terms of achieving greater or lesser degree of completion in the hardening process is taking into account certain, physically conditioned time during mass transferring of alloying anodes material to the hardening surface. It is determined by the kinetics of internal processes while forming of the microstructure and phase composition of the coatings.

*2.3. Methodology*

The choice of the alloying composition of the electrode is not only limited to its properties. Erosive capacity plays an important role as well. It determines the thickness of the formed coating, which should be sufficient to ensure its protective function. The study of the effect of composition of the alloying anode on erosion activity of selected electrodes was carried out by the gravimetric method. Layerwise weighing of steel samples of the same size was carried out with the help of the atomic weights of the brand ADV-200 with an accuracy of $\pm 2 \times 10^{-4}$ g.

Cathode mass measurement was carried out every minute. The direct mass measurement indicates the direction of mass transfer and its efficiency.

The study of topography and microstructure of the coating and the diffusion zone of the sample cross-section was performed with the use of modern research equipment. The topography of the surface was photographed by the stereoscopic microscope Texnival (Carl Zeiss Iena) and by the light microscope Mef-3 (Reichert-Jung) and studied in the backscattered electron mode at an accelerating voltage of 20 kV and a magnification of 1,000 to 10,000 times.

Microhardness was measured according to the Kneipp method using a micro durometer «Micromet II» (Buehler Met) with Vickers indenter. The fingerprints obtained were studied using scanning electron microscopy and microprobe analysis.

The roughness of the coating was measured with a profilometer 296 according to State Standard 19300-86. The measurement was taken in 5 - 8 points of the surface controlling the criterion of the arithmetic average roughness Ra, which is the average value of the measured profile between points that distance to its middle line.

*2.4. Results*

Figure 4 shows graphs of the steel substrate weight gain after electric discharge alloying with different carbide compositions that enhance the wear resistance of the treated surface.

The graphs show that the group of carbide tungsten-cobalt hard alloy electrodes is the most promising for achieving the desired result. Another task is the selection of plastic compositions, in which wear-resistant substrate will have the necessary adhesion and composition of which will not interfere with their use in food production.

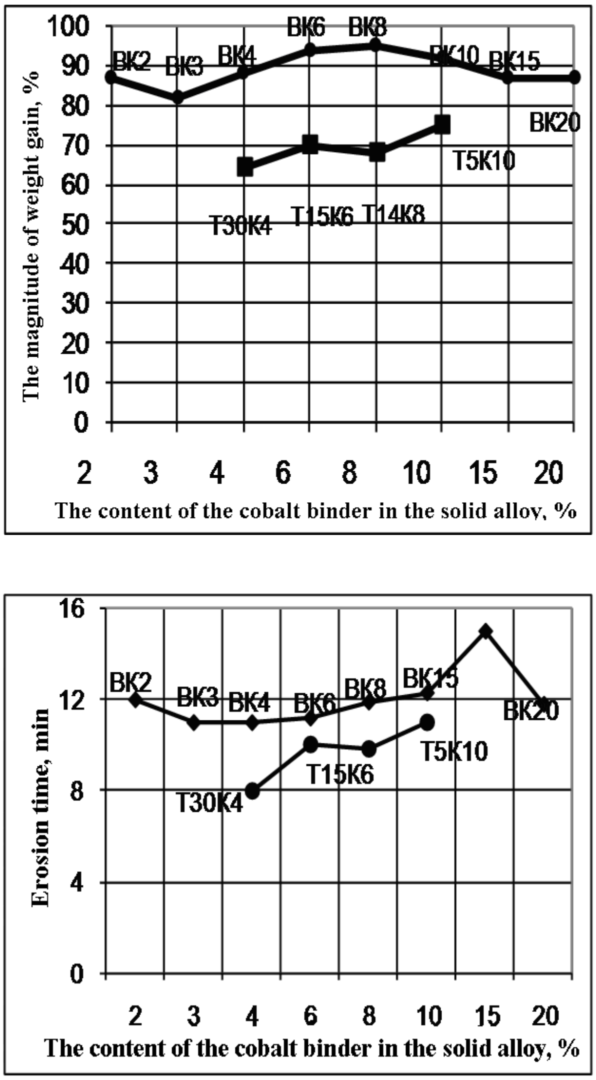



**Fig. 4.** Steel substrate weight gain after electric discharge alloying with ultrasound exposure using different electrode materials

The results of measurements of the microhardness and the roughness formed by various alloying electrode coatings are illustrated in Fig. 5 and Fig.6.

Fig. 5 shows that the highest Hμ rates are achieved by alloying the steel substrate electrodes of TK group and KXH group achieved by the help of sphere weight (see coatings with .producing good of higher quality). Throughout the whole studied area of the surface. The most uniform change of this characteristic in the depth of the hardened zone is observed after hardening with electrodes of TK group. This result and the higher microhardness are due to the greater thermal stability of titanium carbide compared to tungsten carbide and a less intensive carbon burn up while mass transferring of carbides to the surface of the metal base.

The composition of the electrode material also affects the depth of hardened zone: the widest, almost comparable to the thickness of the coating, hardened area is formed by alloying of steel cathode hard alloys, 25 - 30% less wide - in the processing by intermetallic electrode systems.

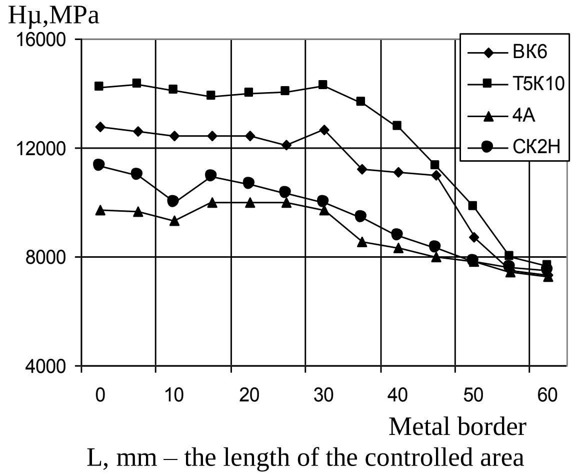



**Fig. 5.** Cross-sectional distribution of microhardness formed by various alloying electrode coatings

The roughness indicators of the formed coatings are also determined by the composition of the electrode material (see Fig. 6).

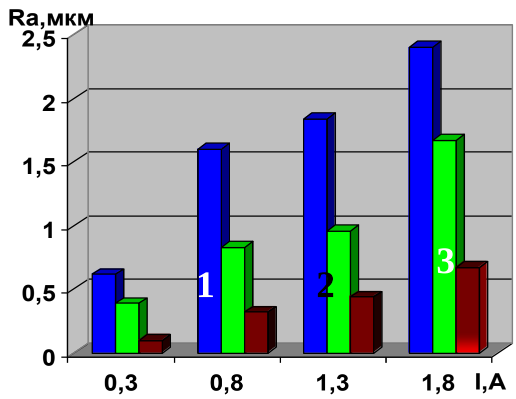



**Fig. 6.** Changing of the surface roughness of the coatings formed on the various hardening modes using different electrodes (1 – 4A; 2– BK6; 3–T15K6)

Evaluation of energy consumption, as calculated by the power consumption of equipment while alloying metal cathode with different alloying anodes, did not show significant dependence on their composition (see Fig. 7).

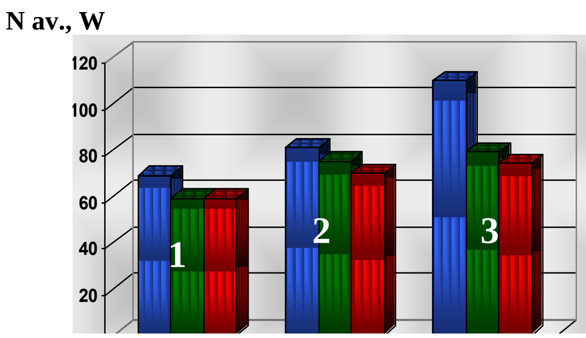



**Fig. 7.** Economical energy consumption indicators during the formation of coatings of the same thickness using electric discharge alloying with ultrasound exposure and different alloying anodes (1 – 4A; 2–T15K6; 3– BK6)

## 3. Conclusion

The result of this research shows that applying the integrated technology of hardening, such as electric discharge alloying with additional ultrasound exposure, to the formation of functional coatings on metallic surfaces ensures steady and stable mass transferring of various alloying anodes to form a coating of operational thickness, lowered surface roughness and increased hardness.

It was determined that the composition of the alloying anode had the dominant influence on the character and intensity of mass transfer with the equal electrical parameters during electric discharge alloying with additional ultrasound exposure process.

It is demonstrated that less refractory metals and more brittle hard alloys should be used in order to obtain thicker layers as alloying electrodes. Alloying layers of most even thickness with a regular microstructure can be obtained in the processing of steel cathode anodes using alloys of titanium-tungsten-cobalt. Alloying layers of least equal thickness with a large number of surface defects and increased surface roughness can be obtained using intermetallic alloy anodes.

Creating alloying coatings of different composition and the same size-parametric characteristics using alloying anodes doesn’t show significant difference in the energy consumption of the specialized equipment.

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