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Alternative Strengthening of Jewelry Tools Using Chemical-Thermal and Local Surface Treatments

VOLKOV Oleg[1,a], KNYAZEV Sergey[1,b], VASILCHENKO Alexey[2,c], DORONIN Evgen[3, d *]

[1]National Technical University «Kharkiv Polytechnic Institute», 2, Kyrpychova str., 61002, Kharkiv,Ukraine

[2]National University of Civil Defence of Ukraine, 94, Chernishevska st., Kharkov, Ukraine, 61023

[3]Simon Kuznets Kharkiv National University of Economics, Department of labour protection, Nauki av. 9-a, 61166, Kharkiv, Ukraine

[a]volkovoleg1978@gmail.com, [b]obmeninfoserg@ukr.net, [c]avas2006@ukr.net, [d]avas.2012.06@gmail.com

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Abstract. The study is aimed at surface strengthening of jewelry tools. Samples in the form of a tool with a flat and curved surface profile are considered. Macrophotographs of jewelry korneisen at different stages of wear, as well as after restoration and strengthening are given. The results of the influence of chemical-thermal and thermo-friction treatments on the structure and properties of U7 and U8A steels used for jewelry tools are presented. The methodology of experimental researches is given. The equipment used for each of the hardening methods investigated in this work is considered. Auxiliary media and features of sample preparation for the experiment are also described. Photos of samples and some equipment at different stages of the study are given. Data on the distribution of microhardness, photographs of microstructures in cross section of samples after different types of hardening are presented. A comparison of the strengthening efficiency of the samples after the use of different processing methods is performed.

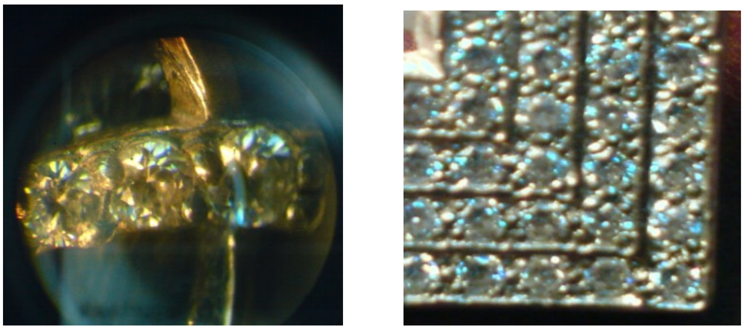
Introduction

The performance of a jewelry tool mainly depends on its ability to maintain cutting or other performance properties for a sufficient time. The wear resistance of the tool is measured by the time during which such properties are maintained under certain operating conditions. Therefore, materials for the tool, regardless of their chemical composition and method of production, must have: high hardness and wear resistance of the surface in combination with sufficient plasticity or elasticity of the main part of the tool.

Strengthening the surface of steel products using various methods has been known for many decades. However, today non-standard approaches to the strengthening of materials, including friction and deformation [1], chemical-thermal treatment [2–6] and others, are becoming increasingly important, especially if it does not require significant economic costs. Such atypical methods as local microwave hardening with borating [7–10] and additional carburization with hardening of steels with high carbon content, or hardening with the use of friction and deformation, as considered in this study, are gaining some scientific interest. Jewelry korneisen, which must have sharp edges of the working part, were chosen as an experimental tool. They have a curved surface profile surface. In addition, samples in the form of a jewelry tool with a straight surface profile were examined.

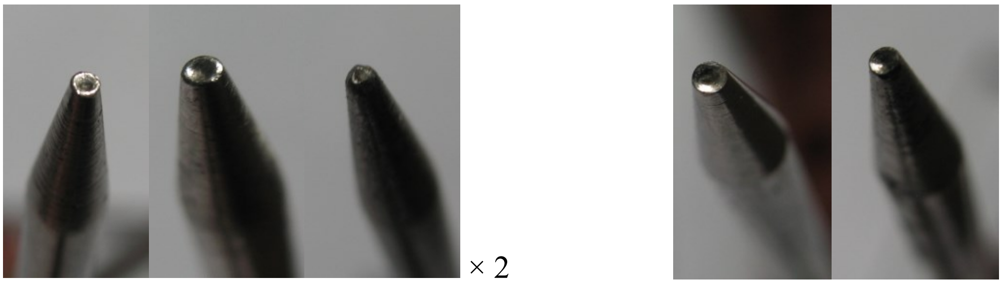
Main Part

Korneisen is designed to secure jewelry stones by creating metal corners that hold the stone in the jewelry (Fig. 1). The macrostructure of the working part of korneisens at different stages of wear is shown in Fig. 2, a. A new or restored korneisen should have a sharp edge of the working part, which forms a uniform extreme boundary of the hemispherical or cone-shaped hole located in the nasal part of the korneisen (Fig. 2, b). This configuration of the working part of the korneisen allows, in the process of fixing the stone in the jewelry, to get the right shape with a high quality surface.



× 1

Fig. 1. Jewelry with stones, which are fixed with a korneisen



× 2 × 2

a b

Fig. 2. Different stages of wear of korneisen and - korneisen after operation; b - new or refurbished korneisen

The aim of this study was to study the change in the structure and properties of jewelry tools after restoration and strengthening of its working part by local microwave hardening with borating, additional carburization with hardening, as well as surface hardening using friction and deformation.

To achieve this goal, a set of metallographic, mechanical and analytical studies of tool samples was conducted, which includes:

1. Preparation of samples for hardening.
2. Carrying out surface hardening.
3. Carrying out of metallographic analysis in section of samples with measurement of microhardness and depth of the strengthened layer.
4. Evaluation of hardening efficiency in local microwave hardening with borating, additional carburization with hardening and processing using friction and deformation.

Two samples were used for local microwave hardening with boring - jewelry rods made of U8A steel in the initial state after hardening and low-temperature tempering, which are used to fix jewelry stones in the products.

Selected korneisen were coated with a boron coating consisting of boron carbide powder with a dispersion of 60 μm and a binder in the form of CMC glue. Before applying the coating, the surface of the samples was treated with fine sandpaper and degreased with an alcohol solution to improve the adhesion of the coating to the samples and the effective passage of diffusion processes. After drying the coating, the samples were hardened in a microwave unit according to the mode: heating rate V_{nagr} = 500 °C/s; heating time τ_{nagr} = 3 s; specific power of processing 0.7 kW/mm^2; cooling rate V_{ohol} = 600 °C/s (water).

Because the heating rate during microwave tempering is much higher than that of the furnace, the recording of heating curves requires faster devices. That is why separate thermocouples with recording of the heating curve in a computer via an analog-to-digital converter (ADC) were used to determine the temperature of the sample during microwave heating. The ADC is required to convert the analog TEDS signal from the thermocouple to digital form and to form an array of data.

Schematic diagram of the ADC is shown in Fig. 3.

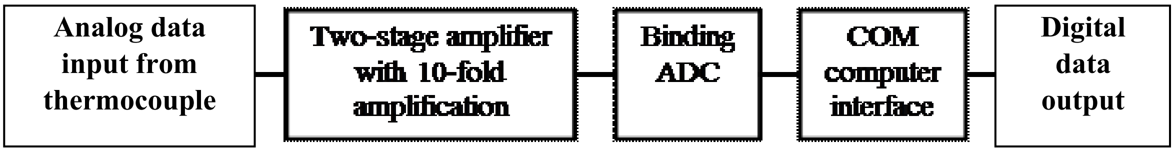


Fig. 3. Schematic diagram of the ADC

The driver and program for collecting and outputting data was written in the Visual Basic package. Structurally, the software consists of: input and output data exchange settings and description of variables; it is the driver for the ADC; the apparatus of means of transfer of TEDS in degrees taking into account amendments; software for outputting an array of data to a separate file (Microsoft Excel).

After recording the data set, a graph of temperature and time dependence was constructed, followed by processing in the MatLab7 package. The analysis of these graphs allowed us to draw conclusions about the temperature and heating rate.

The control and regulation of the temperature in the furnace took place according to the standard scheme of furnace automation, which consisted of a thermoelectric sensor (thermocouple) and a secondary actuator.

For carrying out additional carburization with hardening, 2 samples were also used - jewelry rods made of U8A steel in the initial state after hardening and low-temperature tempering. The samples were placed in a container in which the prepared carbonizer (50 % graphite and 50 % soda ash) was filled (Fig. 4). Laying the samples was carried out so that they were covered with carbonizer on all sides, not in contact with each other and the walls of the protective container. Next, the edge of the container was sealed with refractory clay (clay gate, Fig. 5) and loaded into the oven for 3.5 hours. The temperature of additional carburization with quenching was 920 °C.

× 1

Fig. 4. Samples – korneisen placed in container with carbonizer composition of 50 % graphite and 50 % soda ash

× 1

Fig. 5. The samples in container with airtight clay gate

In order to facilitate the metallographic analysis, the above samples were installed in cylindrical polymer containers and filled with epoxy glue (Fig. 6) after complete curing of which microsections by standard methods were made (Fig. 7).

Fig. 6. Filling the samples with epoxy glue

To detect the combined effect of factors in local microwave hardening with borating and additional carburization with hardening on the structure of the samples and their properties were carried out measure of microhardness using a microhardness tester PMT-3 according to standard methods at static load of diamond indenter indentation P = 100 g. Microhardness measurements were performed on all experimental samples (Fig. 8).

Based on the visible changes in the microstructure and microhardness data on the cross section of the samples, we determined the depth of strengthening, which was obtained under the influence of local microwave hardening with borating, additional carburization with hardening and surface treatment using friction and deformation.

Fig. 7. Microsection prepared for metallographic analysis

As shown by metallographic studies of the cross-section of the sample of the korneisen, on which the local microwave hardening with borating was carried out, according to the method described above, there is a formation of a surface layer with a changed structure. When analyzing the change in microhardness in the cross section of this sample, it was found that the microhardness increases from the core to the surface (Fig. 9, a, b). Therefore, on the basis of these data, we can conditionally divide the surface layer into two characteristic zones. The first is the surface zone (L_1), visually manifested in the form of a white stripe up to 30 μm thick. The microhardness of this zone reaches 8,570–9,000 MPa. It was formed by the penetration of boron atoms from the boron coating, which formed a solid solution of boron in iron, and Fe_2B borides.

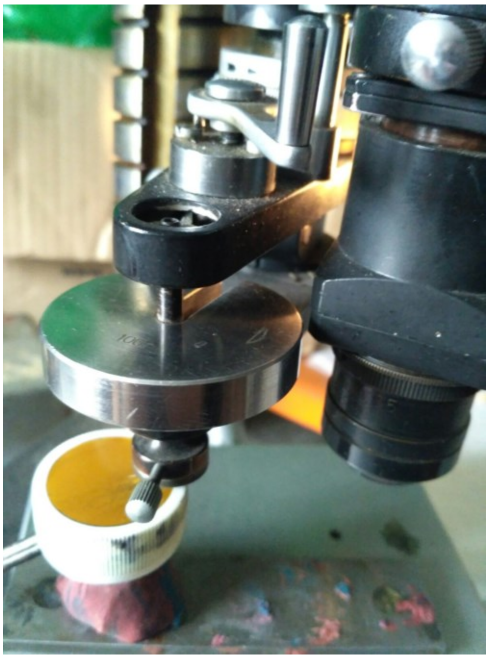
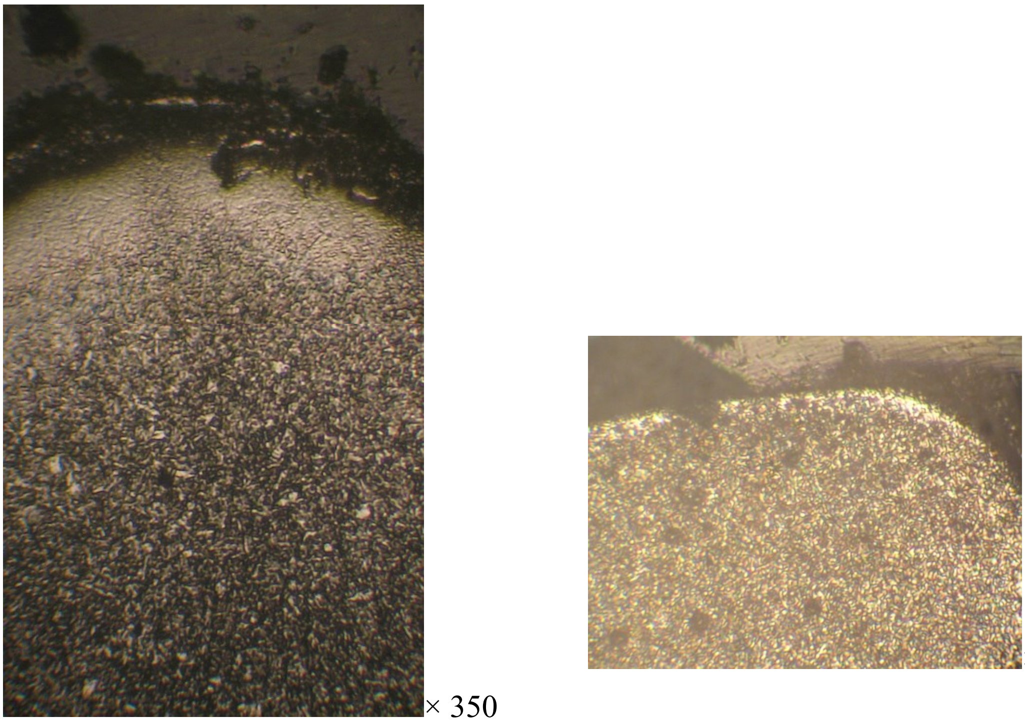


Fig. 8. Measurement of microhardness on samples

Below it is the second zone (L_2) with a thickness of 60 μm, which was formed due to the hardening of the microwave of this layer and some penetration of Fe_2B borides. The microhardness of this zone reaches 6,800–7,060 MPa.



× 350 × 350

a b

Fig. 9. The structure of the sample – korneisen, after a local microwave hardening with borating: a – nasal part; b – side part with prints from the measurement of microhardness

Under the second zone is the main part of the sample in which the influence of local microwave hardening with borating has not spread and its structure has not changed. The microhardness of this zone reaches 6,000-6,300 MPa. The dependence of the hardness of the sample on the depth of the layer after local microwave hardening with borating is shown in Fig. 10.

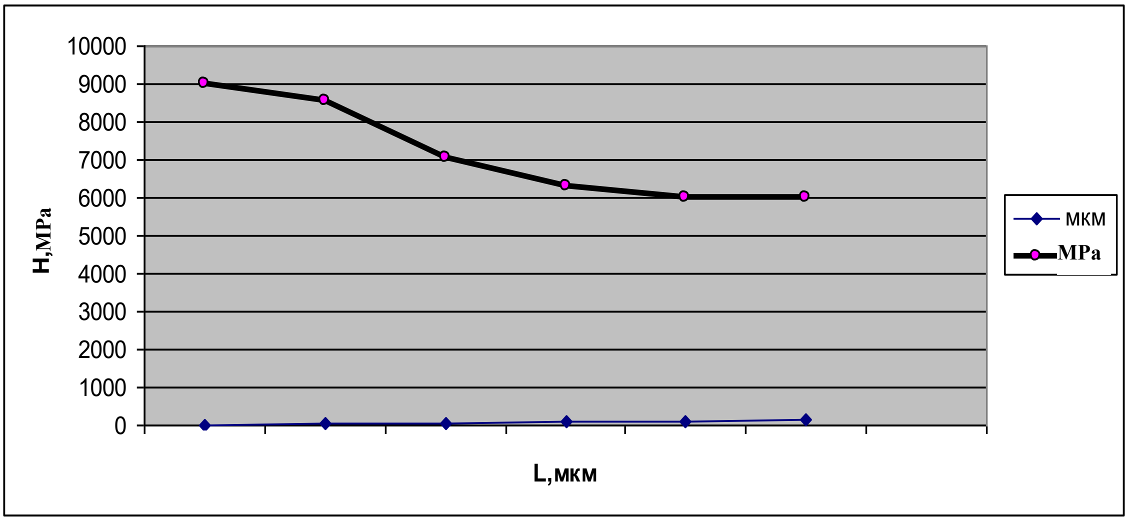
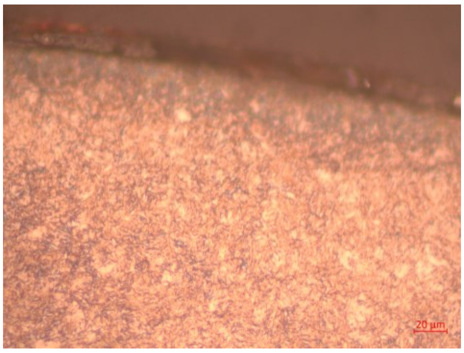
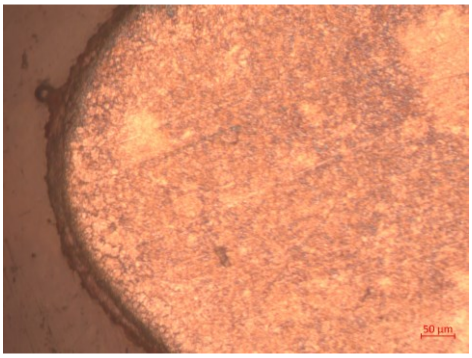


Fig. 10. Graph of the microhardness of the sample from the depth of the layer after local microwave hardening with borating

Metallographic studies of cross-sections of samples – korneisen made of U8A steel after carburization with hardening, according to the method described above, showed that there were some changes in their surface layer (Fig. 11 a, b, c, d).



(× 350)
a



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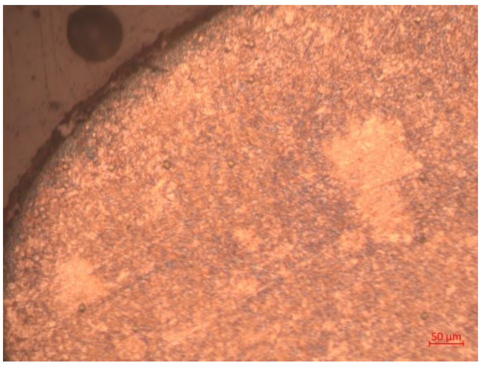
b



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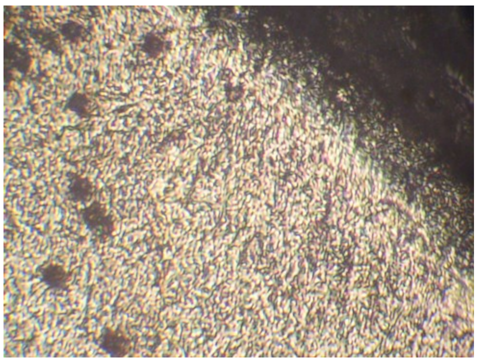
c



(× 500)
d

Fig. 11. The microstructure of the cross section of the sample - korneisen, after carburization with hardening: a – side part; b – nasal part; c – a nasal part with prints from measurement of microhardness; d – a nasal part with prints from measurement of microhardness

When analyzing the microhardness of the cross section of the samples, it was found that it gradually increases from the core to the surface. The formed surface layer (first zone) with a depth of up to 70 μm has a microhardness in the range of 8,250–8,540 MPa. Below is a layer with a microhardness of 6,350–6,800 MPa (second zone). Under the second zone is the main part of the sample where the microhardness is 6,000–6,300 MPa (Fig. 11, c). The dependence of the microhardness of the sample on the depth of hardening after carburization with hardening of its nose is shown in Fig. 12.

Analysis of these factors suggests that carburization with hardening not only helps to protect the surface from carbon depletion, but, conversely, slightly increases the concentration of carbon in the surface layer. This is confirmed by a gradual increase in the microhardness of the surface and less intense etching, as increasing the amount of carbon in the surface during hardening contributes to better hardening. In addition, the increase in carbon content may be accompanied by the appearance of a certain amount of residual austenite during quenching, which is associated with a decrease in the temperature of the point M_k. And the structure of residual austenite is able to effectively accept cold hardening during operation, which helps to increase the operational stability of this tool during its operation.

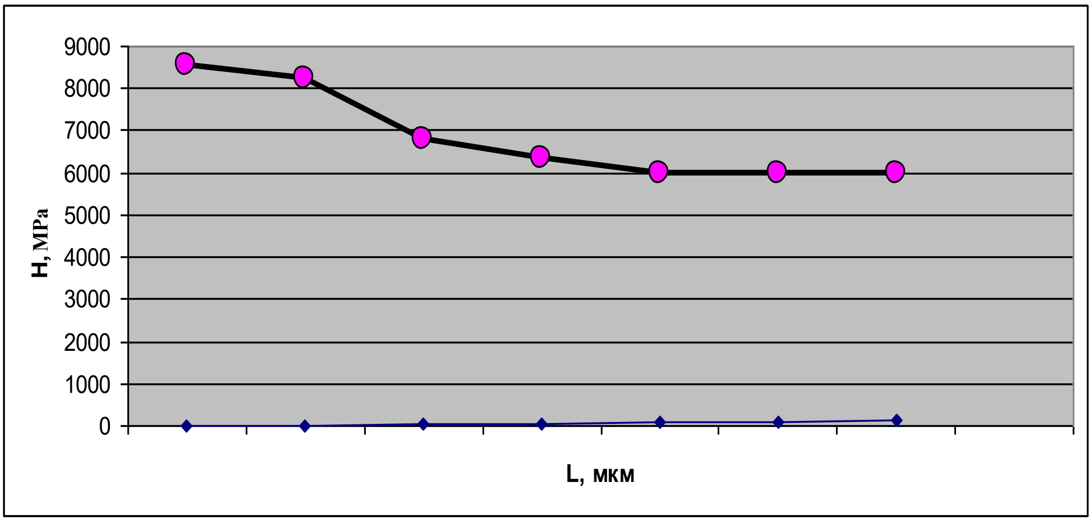


Fig. 12. Graph of the dependence of the microhardness of the sample on the depth of hardening after carburization with hardening of its nose

For a tool with a flat surface, and especially when it is necessary to carry out local hardening, it is possible to use an alternative treatment that includes thermal and deformation effects in the presence of friction. Many studies have already been conducted, which considered similar methods of strengthening. This issue is considered quite fully in [1]. Since there is a wide range of types of cutting tools that require strengthening of the working part, it was advisable to conduct research aimed at obtaining local hardening on full-scale samples of U7 steel, which mimic certain types of such tools.

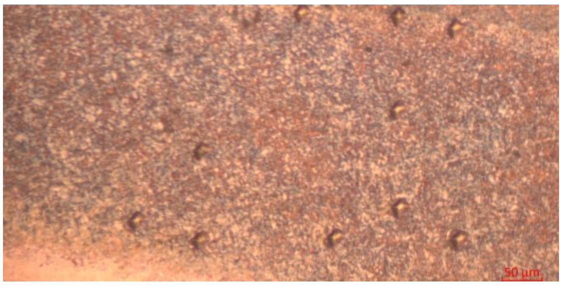
It should be noted that a method such as thermofrictional hardening (TFH) involves the simultaneous effect of friction and deformation on the surface being treated, which allows you to quickly change its structural state and properties.

The samples for the experiment were initialized after quenching at a temperature of 800 °C (water) and tempering at 180 °C, ie were hardened in the standard way for a cutting tool. Machining was performed on a surface grinding machine according to the optimal mode and scheme, which is described in [1].

In the course of previous research, it was found that jewelry tools often have low service life, and certain approaches to its surface hardening, allow to increase the life of the tool during operation. Therefore, in order to obtain a more perfect structure of the working part of such a tool and the optimal level of its performance characteristics, the considered full-scale specimens were strengthened in the manner described above. It should be noted that with TFH under different modes it is possible to obtain different depths of hardening, which can be chosen depending on the operating conditions of the jewelry tool. In Fig. 13, 14, which shows the microstructure of the sample of steel U7 after TFH, shows the structural heterogeneity. Thus, the maximum microhardness obtained in the so-called "white layer", which was formed by TFH directly in the surface to be treated. Its level is H100 = 12,200 MPa at a depth of hardening l = 170 μm, which is twice the microhardness of the sample before TFH, which is about 6,000 MPa. The structure of this layer corresponds to the deformed martensite, which underwent deformation with hardening at the time of short-term heating at TFH [1].

× 200

Fig. 13. The microstructure of the working part of the sample of steel U7 after TFH with prints from the measurement of microhardness



× 200

Fig. 14. The microstructure of the main body of the sample of steel U7 after TFH with imprints from the measurement of microhardness

Conclusion

Thus, with the help of the above results, the effectiveness of different technological approaches for surface hardening is proved and demonstrated, which is relevant, for example, for jewelry tools with different surface profiles.

This study showed the possibility of obtaining in the local areas of research objects a reinforced layer with a high level of physical and mechanical properties, which, of course, can increase the durability and wear resistance of jewelry or other tools.

Thus, the results obtained using atypical methods for surface hardening of jewelry tools, such as: local microwave hardening with borating, additional carburization with hardening, as well as TFH, confirmed their high efficiency. The possibility of restoring the working part of a jewelry tool with a different surface profile, after its preliminary wear, has been scientifically shown. In addition, it was demonstrated to obtain a reinforced surface layer in all considered samples of the tool, with a significant increase in surface hardness.

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