Additional Strengthening of “Screper” Jewelry Tool Using Friction

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Abstract. This study is aimed at strengthening the working surfaces of the jewelry tool - scraper. This tool is used for fine cutting work. The object of research is a method of additional thermofrictional hardening of samples of jewelry tool - scrapers made of carbon steel tool grade U8A. In the course of work the complex of metallographic, mechanical and analytical researches of samples in an initial condition after hardening and low-temperature release which includes is carried out which includes:

1) preparation of samples in the form of plates and their preliminary heat treatment;

2) surface thermofrictional strengthening (STS);

3) conducting metallographic analysis of samples; measuring the microhardness and depth of the layer with a changed cross-sectional structure of the samples after STS;

4) analysis of the influence of STS on changes in the structure and properties of steel on the basis of the obtained results, as well as identification of the degree of its strengthening and the role of deformation.

The methodology of experimental researches is presented. Photographs 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 additional strengthening are presented. The efficiency of strengthening of samples after use of additional processing is shown.

1 Introduction

The quality of work with the use of jewelry tools mainly depends on its ability to maintain cutting and other performance properties for a long time. The wear resistance of the tool is measured by the time of preservation of such properties under certain operating conditions. Therefore, materials for such a tool should provide high hardness and wear resistance of the surface in combination with a certain elasticity of the main part of the tool.

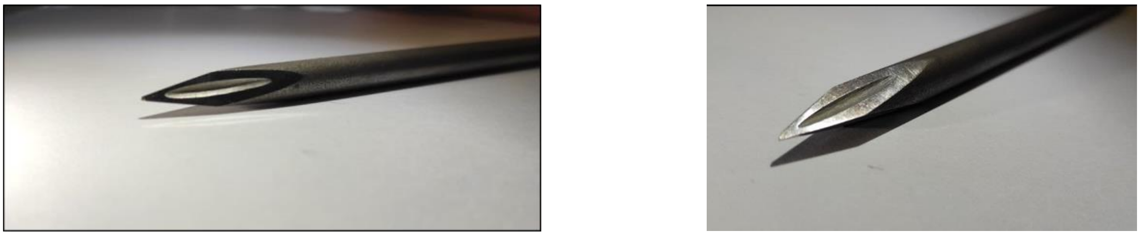
Strengthening the surface of steel products using various methods has been known for many decades. However, today non-standard approaches to the strengthening of materials, including friction and deformation [1], types of processing aimed at obtaining nanostructured states [2–7] and other methods for changing structural states [8–13] are becoming increasingly important, especially unless it requires significant economic costs. Such atypical methods as strengthening with the use of friction and deformation or additional strengthening of materials that already have a certain level of hardening are of some scientific interest, as considered in this study. The jewelry tool "scraper" type, which is intended for fine cutting works, was chosen for the research. Accordingly, it must have sharp cutting edges of the working part.

2 Experimental part

In this research work, two samples of jewelry tools were studied – a scraper 120 mm long and 7 mm in diameter with a triangular working part, made of U8A steel (Fig. 1, a).

It should be noted that the scraper is a metal-cutting tool. It has the form of a rod with cutting edges at the end, which provide the scraping process. The cutting parts of the scraper can be triangular, quadrilateral, flat or shaped, and by their design – solid and with insert cutting inserts. The peculiarities of the scraper application, due to its shape, are the need to ensure high hardness of the cutting edge and its regular restoration. This is due to the gradual wear of the cutting edge, which causes a deterioration in the quality of work and the need for frequent replacement of tools or its restoration.

Improving the wear resistance of the scraper, in addition to the economic effect, will also improve the quality of work. It is possible to offer a reliable method of increasing the efficiency of operation and restoration of this jewelry tool only on the basis of the study of structural transformations in the working area of the tool.



a) b)

Fig. 1. Scraper for jewelry work: a – in normal form; b – with traces of wear

This tool is put into operation in the state after hardening at a temperature of 800 °C with cooling in water and low-temperature tempering at a temperature of 180 °C. The intensity of its wear indicates an insufficient level of hardness and wear resistance, in connection with which it is proposed to further strengthen it using heat-friction treatment, the effect of which was confirmed in [14, 15].

Thermofrictional strengthening (TFS) was performed on a surface grinding machine. The samples were fixed on the magnetic plate of the flat grinding machine using a special device to ensure the possibility of processing the strengthening disk in the horizontal plane. The scheme of processing is presented in fig. 2.

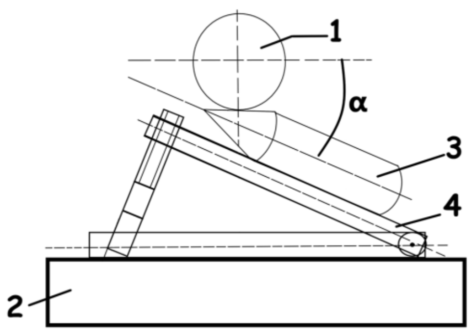


Fig. 2. Scheme of thermofrictional strengthening: 1 – cutting disk; 2 – magnetic plate of the machine; 3 – sample of scraper; 4 – device for adjusting the angle of the sample

The reinforcing disk is made of St3 steel. It was used to a depth of 0.4 mm. This choice of machining depth is made taking into account the small cross section of the tool to be strengthened.

Moving the table at a speed of 30 mm/s allowed TFS on the entire surface of the cutting edge. When making contact between the cutting disc and the sample was implemented TFS, which was carried out in conditions without lubrication. Thus, the selected TFS mode is limited by the level of rigidity. TFS was carried out on one of the three surfaces.

In order to provide metallographic analysis of steels, after TFS, micro-sections of samples with a triangular cross-section were made of U8A steels. They were placed in cylindrical polymer containers and filled with epoxy glue. In the manufacture of microsections, samples were processed on 4 numbers of sandpaper (sanding), followed by polishing by standard technology. The finished sections (Fig. 3) were etched in 4 % alcoholic solution of nitric acid (HNO_3) according to standard methods.

x2

Fig. 3. Microgrind prepared for metallographic analysis

The study of the microstructure was performed in the cross sections of the samples, which were further strengthened by friction on one of the three surfaces. The study of the microstructure was performed using a metallographic microscope ZEISS AXIO Vert. A1. Photographing of microstructures was performed using a digital camera, which is adapted to the microscope, as shown in Fig. 4.

To identify the combined effect of TFS factors on the structure of the samples and their properties, microhardness was measured using a microhardness tester PMT-3 according to standard methods (Fig. 5) at static loading by diamond indenter indentation P = 100 g. Based on visible changes in the structure and data on the microhardness of the cross section of the samples, it becomes possible to reliably determine the depth of the layer with the changed structure obtained under the influence of TFS and draw conclusions.

Fig. 4. Metallographic microscope ZEISS AXIO Vert.A1

Fig. 5. Measurement of microhardness on samples

When conducting macroscopic analysis of scraper samples of U8A steel in the state after hardening and low-temperature tempering, which were not strengthened by friction and operated under standard conditions, it is seen that the cutting edge is damaged compared to the initial state (Fig. 1, b).

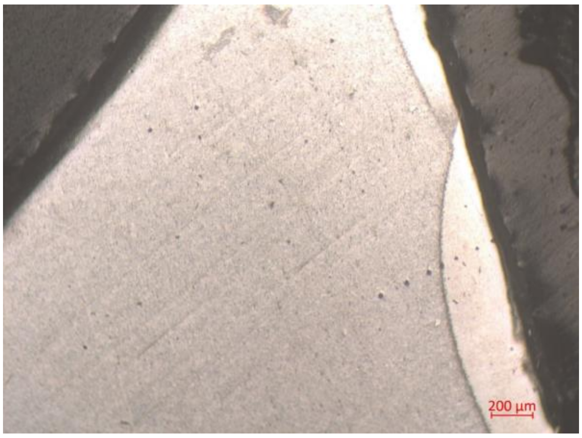
The nature of wear is the appearance of jags and blunting of the cutting edge. Local chips are also possible (mainly when the cutting edge of the scraper is in contact with hard materials or other tools, solid particles of various origins, as well as when the scraper is working on twisting or bending). Blunting occurs gradually in the process of cutting metals with this tool by wiping.

Macroanalysis of the cutting edge of the scrapers shows their low operational stability. As a result, there is a need for processing that could increase the hardness of the work surface and, consequently, the operational stability of the tool. Therefore, the prepared samples of U8A steel were thermofrictionally strengthened on one of the three surfaces. The treatment was carried out on only one surface to compare the properties obtained in one pass of TFS with the part of the tool that is strengthened only thermally. The microstructure of the experimental sample for these studies is presented in Fig. 6.

From those shown in Fig. 8, 9 and 10 photos of microstructures of the sample type "scraper" of U8A steel after additional thermofrictional strengthened, it is seen that in the cross section of the samples there are two additional zones. Thus, the cross sections of the samples include:

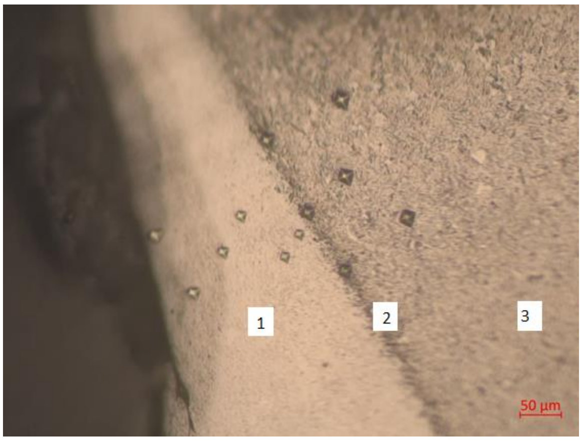
1. Strengthening zone.
2. The weakening zone.
3. The main part of the sample.

Photographs of cross-sections of structures show prints from microhardness measurements, which clearly illustrate the nature of the change in microhardness from the core to the surface.



x 50

Fig. 6. Microstructure of the cross section of the scraper sample in the triangular nasal part, reinforced by friction on one side



× 200

Fig. 7. Microstructure after measuring the microhardness in the cross section of the sample of scraper closer to the cutting edge: 1 – strengthening zone (white layer); 2 – weakening zone (transition zone); 3 – the main part of the sample (without structural changes)

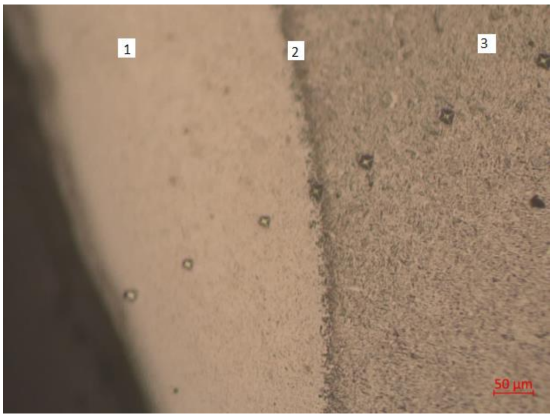


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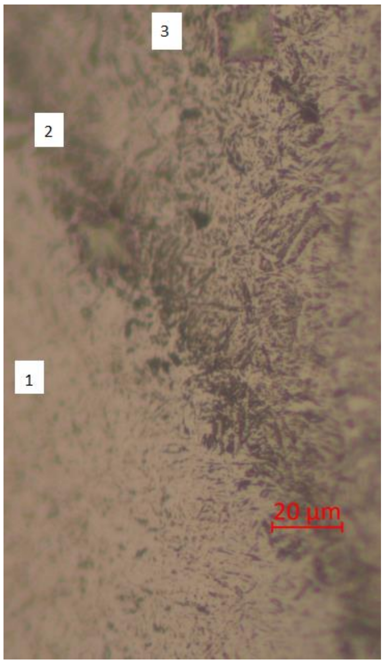
Fig. 8. Microstructure after measuring the microhardness of the section closer to the middle of the face



x500

Fig. 9. Microstructure of the transition zone in the cross section of the sample: 1 – strengthening zone (white layer); 2 – weakening zone (transition zone); 3 – the main part of the sample (without structural changes)

According to the obtained results, the maximum microhardness of the “white layer” obtained by TFS is equal to H_{100} = 12200 MPa at the depth of hardening l = 170 μm. The structure of this layer corresponds to the deformed martensite, which received deformation with hardening at the time of short-term heating at TFS to high temperatures (Fig. 10).

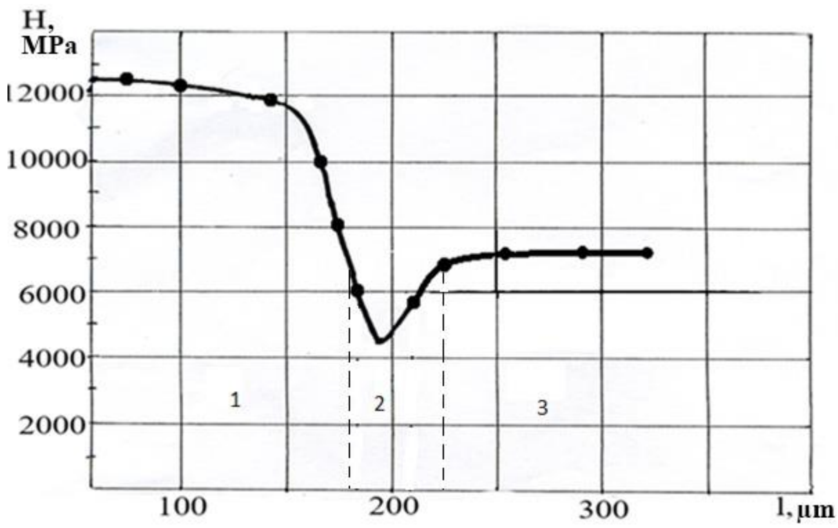


Fig. 10. Graph of microhardness distribution along the depth of the sample of U8A steel scraper after hardening, low-temperature tempering and thermo-friction strengthened: 1 – strengthened zone (white layer); 2 – weakening zone (transition zone); 3 – the main part of the sample (without structural changes)

The appearance of zone 2 (weakening) is caused by the fact that in TFS heat flow is directed from the surface into the sample and at a certain depth from the surface residual heat can cause the beginning of the decay of martensitic structure. That is, in this area, which has a small thickness, partial release processes take place. Accordingly, the microstructure in this zone has a troostite-like nature (see Fig. 9), which is explained by the partial passage of the average holiday in the local area.

Below the cross section of the sample – the heat is dissipated, but there is no effect of TFS. Accordingly, the main part of the sample has a microstructure - martensite of tempering, which is caused by pre-heat treatment.

Thus, TFS allows to obtain on the surface of the sample type "scraper" a strengthened layer with a high level of physical and mechanical properties, which of course can increase the durability and wear resistance of jewelry tool. However, it should be noted that with TFS under different modes, different depths and levels of hardening are possible, which can be chosen depending on the operating conditions of the jewelry tool for different purposes.

Analysis of all the results obtained during the study suggests that under the influence of TFS there are significant changes (Table 1). This is manifested by the formation in the surface of the products "white layer", which has a very high microhardness. The properties of this layer depend on the initial state of the material and the conditions of TFS, as shown in previous studies [14]. In this case, the considered mode of TFZ allowed to obtain in the surface of the sample type "scraper" strengthening of a sufficient level and to a sufficient thickness, which can contribute to the effective use of the tool.

Table 1. The results of the influence of TFS on the microhardness and depth of strengthening of U8A stee**l**

Steel grade	Processing scheme	TFS mode	Initial micro-hardness of the sample, [MPa]	Micro-hardness of the strengthened layer, [MPa]	Depth of strengthe-ning, [μm]	Increase of micro-hardness, [%]
Sample scraper U8A	Hardening + tempering + TFS	S = 30 mm/s, t = 0.4 mm	7300	12200	170	67

3 Conclusion

A study of the structural transformations of the cross sections of the samples, resulting in the appearance of a surface "white" layer, which differs in morphology from the structure of the main part of the instrument under study. Its appearance is caused by the conditions of TFS, namely high contact pressure with simultaneous heating due to friction in contact between the strengthening disk and the sample. The study of the microhardness of the cross-sections of the samples showed that the white layer formed under the surface to be treated has a microhardness of 12200 MPa, which is significantly higher compared to the microhardness of the main part, which is 7300 MPa. This is due to the peculiarities of the formation of the surface strengthened layer, which according to previous studies has the structure of deformed martensite.

Thus, this study allowed to choose technological aspects for additional strengthening of the tool - jewelry scraper, ie to develop a technological complex of additional strengthening of the working part of this type of jewelry tool made of U8A steel, including TFS. As a result of the offered and executed technological approaches the microhardness of a working part of the tool – a scraper is increased by 67 %.

References

[1] Joseph R., Surface Hardening of Steels: Understanding the Basics. Publisher: ASM International. (2002). 364.

[2] Wang Z.B., Tao N.R., Li S., Wang W., Liu G., Lu J., Lu K. Effect of surface nanocrystallization on friction and wear properties in low carbon steel. Materials science and engineering, A 352 (1–2) (2003) 144–149.

[3] Lu K., Lu. J. Nanostructured surface layer on metallic materials induced by surface mechanical attrition treatment. Materials science and engineering, A 375–377 (2004) 38–45.

[4] Ba D.M., Ma S.N., Meng F.J., Li C.Q. Friction and wear behaviors of nanocrystalline surface layer of chrome-silicon alloy steel. Surface and coatings technology. 202 (2) (2007) 254–260.

[5] Xu Y.H., Peng J.H., Fang L. Nano-crystallization of steel wire and its wear behavior. Materials Science and Engineering. A. 483–484 (2008) 688–691.

[6] Zhou L., Liu G., Han Z., Lu K. Grain size effect on wear resistance of a nanostructured AISI52100 steel. Scripta materialia. 58 (6) (2008) 445–448.

[7] Lv X.R., Wang S.G., Liu Y., Long K., Li S., Zhang Z.D. Effect of nanocrystallization on tribological behaviors of ingot iron. Wear. 264 (7–8) (2008) 535–541.

[8] Galvao I., Leal R.M. Loureiro A.. Influence of tool shoulder geometry on properties of friction stir welds thin copper sheets. Journal of materials processing technology. 213 (2) (2013) 129–135.

[9] Chernukha A.A., Chernukha A.N., Ostapov K., Kurska T. Investigation of the Processes of Formation of a Fire Retardant Coating. Materials Science Forum. 1038 (2021) 480–485.

[10] Rajamanickam N., Balusamy V., Magudeeswaran G., Natarajan K. Effect of process parameters on thermal history and mechanical properties of friction stir welds. Materials & Design. 30 (7) (2009) 2726–2731.

[11] Momeni A., Arabi H., Rezaei A., Badri H., Abbasi S.M. Hot deformation behavior of austenite in HSLA-100 microalloyed steel. Materials Science and Engineering. A 528 (4–5) 25 (2011) 2158–2163.

[12] Sipos K., Lopez M., Trucco M. Surface martensite white layer produced by adhesive sliding wear friction in AISI 1065 steel. Revista latinoamericana de metalurgia y materiales. 28 (1) (2008) 46–50.

[13] Yan W., Fang L., Sun K., Xu Y. Effect of surface work hardening on wear behavior of Hadfield steel. Materials science and engineering. A 460–461 2007 542–549.

[14] Volkov O.A. Study of heat deformation influence in surface strain hardening of steel by thermofriction processing. Eastern-European journal of enterprise technologies. 2 5(80) (2016) 38–44.

[15] Volkov O., Knyazev S., Vasilchenko A., Doronin E. Alternative Strengthening of Jewelry Tools Using Chemical-Thermal and Local Surface Treatments. Materials Science Forum. 1038 (2021) 68-76.