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Increase in the Durability of the Tool, Utilized in Aviation Machine Building and with the Reconditioning of the Air Vessels

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Abstract **– This article presents the results of a study of the impact of pulsating gas flow treatment on the durability of the tool used in the production and repair of structural elements of aircraft and aircraft engines.**

Keywords – aircraft engineeri; repair; tools.

I. Introduction

High-carbon steel, alloy and carbon, having a high hardness, and, in the case of alloy tool steels and high heat resistance are traditionally used as a material for the tool used in the manufacture and repair of parts and structural elements of aircraft equipment, such as die tools, cutting tools to remove nicks on the blades of compressors aircraft engines, excess metal formed during the repair of surfacing, including parts with holes, as well as measuring tool with increased requirements for wear resistance.

Currently, the most common hardening heat treatment of carbon tool steels consists of martensite quenching with maximum presence, along with martensite quenching, secondary cementite (incomplete quenching of hypereutectoid steels), providing increased hardness and wear resistance and subsequent low tempering not exceeding 200 °C for manual and 250 °C for machine tools (low tempering). The purpose of low tempering of hardened tool steel is, in addition to ensuring the stability of the properties within the tempering temperature, to reduce unwanted residual stresses and increase the viscosity that prevents chipping of the cutting edge and brittle destruction of the tool itself. At the same time, due to the low temperature of the tempering heating, neither complete removal of residual stresses nor sufficient viscosity and stability of properties are provided, even with the duration of the tempering heating up to 2 hours, associated with significant energy costs.

The task of increasing the tool life is relevant, as its solution allows intensifying the processes of repair of structural elements of aircraft and aircraft engines.

II. Results and Discussion

The aim of the study was to improve the performance of the tool used in the manufacture and repair of parts and structural elements of aircraft while reducing the duration of hardening heat treatment by replacing the tempering heating tool after quenching treatment pulsating subsonic gas flow (gas pulse treatment) [1–2].

Metal-cutting tool made of steel U12 (1.1–1.29 % C, 0.17–0.33 % Si, 0.17–0.33 % Mn, up to 0.25 % Ni, up to 0.028 % S, up to 0.03 % P, up to 0.2 % Cr, up to 0.25 Cu) after traditional quenching on martensite-cementite structure was, as an alternative to low tempering, processed by pulsating gas flow having subsonic speed, oscillation frequency varying in the range from 1 to 2 kilohertz. As a result of treatment with a pulsating gas flow, a duration not exceeding 15 min in the tool material, processes similar to tempering occur, providing a complete removal of residual stresses, increasing hardness and heat resistance in comparison with standard quenching and low tempering.

The results of studies of the metal-cutting tool made of carbon steel У12 demonstrate an increase in hardness as a result of the described treatment, in comparison with the standard at the values of resistance to dynamic effects corresponding to those for the standard heat-strengthened steel У12, which is associated with the achievement of lower values of structural and thermal stresses as a result of gas pulse treatment.

The above method, in particular, provides the possibility of gas-pulse processing of the cutting tool, both manual and machine, as well as the tool for plastic forming, subjected, in the case of traditional hardening heat treatment, incomplete hardening followed by low tempering.

As a result of the application of this processing method, the total duration of thermal hardening of the tool intended for the manufacture and repair of parts and structural elements of aircraft from carbon tool steel is reduced to 4 times. At the same time, the increase in hardness and wear resistance reduces the time for replacement or regrinding of the tool, contributing, in particular, to the continuity of the process of maintenance and repair of aircraft.

We also studied the effects of treatment with pulsating gas flows to the heat resistance of hardened carbon tool steels, for example of steel У8 (0.75 to 0.84 % C, 0.17–0.33 % Si, 0.17–0.33 % Mn, up to 0.25 % Ni, up to 0.028 % of S, up to 0.03% P, up to 0.2 % Cr, up to 0.25 % Cu).

The quenching process of the samples was carried out in a standard way for eutectoid steels using water as a cooling medium in order to obtain the high quenching hardness required for the tool. After quenching, the steel samples, as an alternative to the traditional low tempering, were treated with a pulsating gas flow with a pulsation frequency of the order of kilohertz. The level of the resulting sound pressure was 130 dB. The duration of gas pulse treatment was 15 min.

According to the results of hardness measurement, it was found that it decreased by 2 HRC units, just as it occurs when tempering heating to low tempering temperatures. After heat resistance tests by heating to temperatures of 200-300 °C in 25-degree increments, the samples subjected to gas-pulse treatment and the standard released samples have a higher heat resistance of the samples subjected to pulsating gas flow instead of tempering heating (figure 1).

A higher resistance to heating of products treated with a pulsating gas flow is associated with smaller sizes of secondary carbides released from martensite in comparison with those formed in the process of standard low tempering and their growth, and consequently a decrease in the hardness of the tool is shifted to higher temperatures.

Was launched further investigation of the effect gatenoise processing on performance properties of the finished cutting tool, widely used in the manufacture of parts of motor vehicles, household machines and appliances and their repair, for example, to restore the holes of the stator rings after welding.

Wear of a cutting edge of the metal-cutting tool is carried out as a result of impact and thermal influences and also setting of the tool with the processed product.

The resistance of the cutting edge of the cutting tool to wear is determined by the wear of the front and rear surfaces of the cutting edge.

The tests were carried out with drills with a diameter of 7.6 mm of tool steel 9XC (0.85–0.95 % C, 1.2 –1.6 % of Si, 0.3–0.6 % Mn, up to 0.4 % Ni, up to 0.03 % S, up to 0.03 % P, 0.95–1.25 % Cr-0.2 % Mo, up to 0.2 % W, up to 0.15 % V, up to 0.3 % Ti, up to 0.3 % Cu), which has, after standard heat treatment heat resistance up to 260 °C, its value depending on the heating temperature is shown in table 1.

TABLE I. COMPARATIVE HEAT RESISTANCE OF ALLOY TOOL STEELS IN 9XC

Heating temperature, °C	Heating time, min	Value HRC
150–160	60	63
240-250	60	59

Additional processing of drills by the pulsing gas stream was carried out within 20 min at the amplitude-frequency characteristics of the stream flowing on the cutting edge of the drill corresponding to the above.

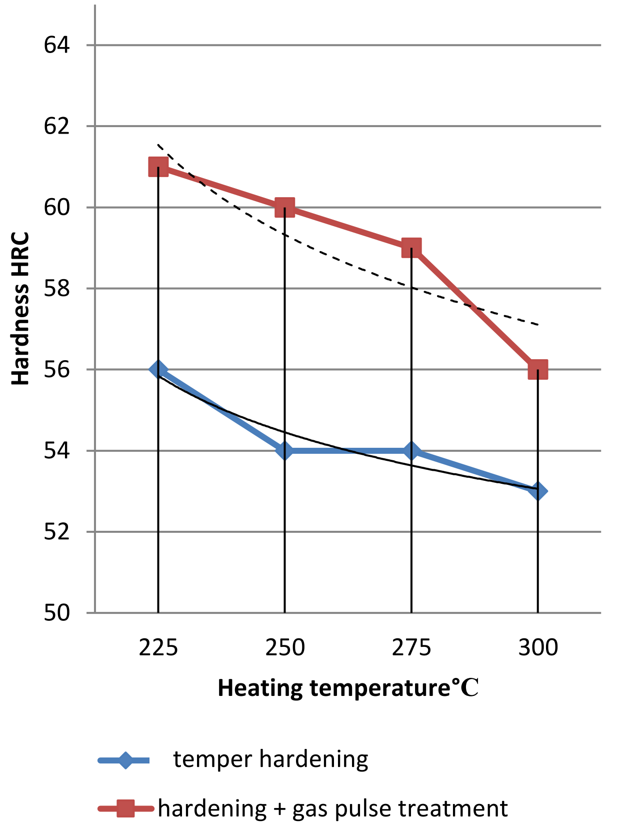


Fig. 1. Impact of pulsating gas flow treatment on the heat resistance of steel tools У8

As a result, the wear of the cutting edge is 1.5 times less in the tool subjected to pulsating gas flow (table. 2, Fig. 3). Higher resistance of the tool subjected to gas-pulse treatment is achieved due to more intensive relaxation of micro-stresses and the formation of a dislocation structure that prevents the growth of carbide inclusions when heated during the tool operation.

Further, a study was conducted of the treatment of the pulsing gas stream on the performance characteristics of cutting tools having high heat resistance (high speed) steel R6M5 (0.82–0.9 % C, 0.2–0.5 % Si, 0.2–0.5 % Mn, up to 0.6 % Ni, up to 0.025 % S, up to 0.03 % P, 3.8–4.4 % Cr, 4.8 - 5.3% Mo, 5.5–6.5 % W, 1.7–2.1 % V, up to 0.5 % Co, up to 0.25 % Cu) used for cutting tool working in conditions of heating temperature up to 600 ° C, and for punching tools.

TABLE II. COMPARATIVE WEAR OF THE CUTTING EDGE OF 9XC STEEL DRILLS AFTER STANDARD HEAT TREATMENT AND SUBJECTED TO ADDITIONAL TREATMENT BY PULSATING GAS FLOW

Processing	The amount of wear of the front surface of cutting head, mm	Wear value of the back surface of the cutting edge, mm
Standard heat treatment	2.5	2.6
Gas pulse treatment	1.5	1.6

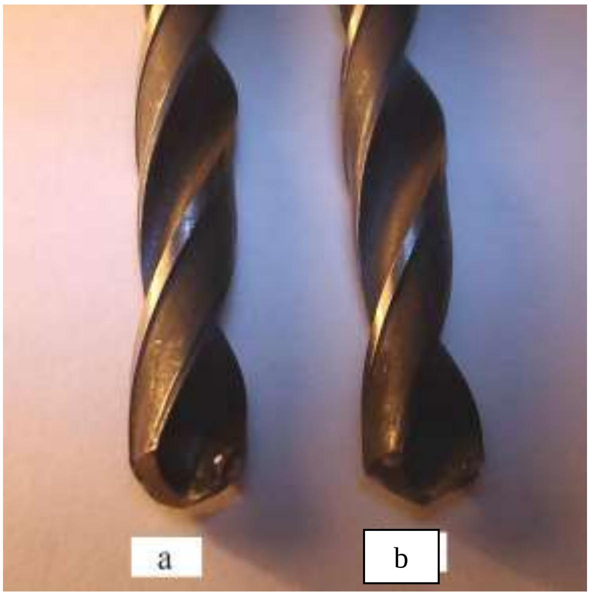


Fig. 2. Comparative wear of the cutting edge of the drill made of alloy tool steel 9XC: a – standard processed, b – additionally processed by pulsating air flow

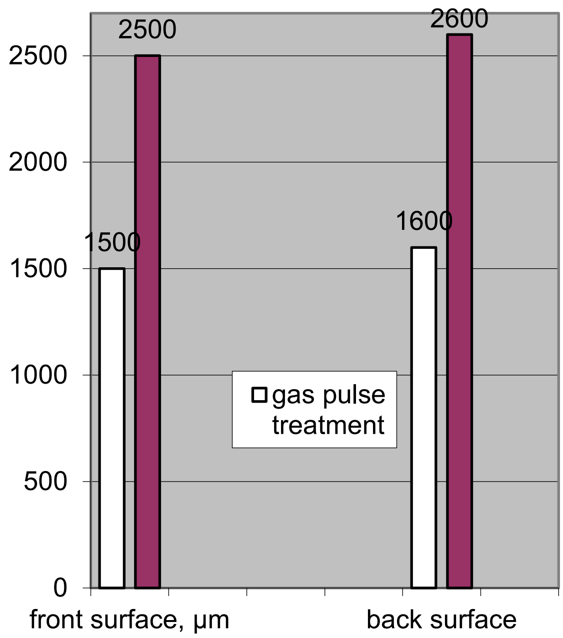


Fig. 3. Wear for an identical time interval of the front and rear surfaces of the cutting edge of the standard thermally hardened drill bits of tool alloy steel 9XC similar drills subjected to additional processing pulsating air flow.

Standard heat treatment of steel P6M5 includes quenching temperatures of the order of 1230-1250 °C and subsequent two-fold or three-fold vacation at a temperature of 570 ° C in течение1 hours.

As a result of gas-pulse treatment, the structure of steel P6M5 has the form of doped heat-resistant martensite tempering, released from it secondary carbides, primary carbides, primarily tungsten, together allowing the tool to maintain high hardness to a temperature of 600 °C.

Treatment of pulsating gas flow tool of steel P6M5 is a drill with a diameter of 9.5 mm technologically implemented similar to the processing tool of steel 9XC by blowing without heating the cutting edge of 15 minutes. the Temperature in the processing area thus falls significantly below the room. Placement of the tool was also carried out along the longitudinal axis of the flow, so that the pulsating gas flow flowed on its cutting edge.

When processing a pulsating gas flow was carried out varying the pressure in the supply line in the range of 0.5-0.9 atmosphere with the aim of identifying the dependence of the technical result of the speed of gas flow. The increase in pressure led to an increase in the flow rate, as well as a slight (from 1130 to 1200 Hz) increase in the frequency of oscillations of the flow parameters. The sound pressure level increased from 120 to 130 dB.

In comparative tests of standard processed drills and drills, additionally treated with pulsating gas flow for performance properties, drilling of rolled sheets of low-carbon steel and high-strength titanium alloy was carried out. The wear of the cutting edge on the back surface for the standard tool was more than half a millimeter, which is close to its complete wear. In the case of using additional gas-pulse processing, the wear of the cutting edge at the amplitude-frequency characteristics of the pulsating gas flow flowing on the cutting edge of 1130 Hz and 120 dB was 0.25 mm, and at the frequency characteristics of the flow of 1200 Hz and the sound pressure up to 130 dB was only 0.2 mm (table 3, Fig. 4,5), which corresponds to an increase in the resistance of metal-cutting tools made of high-speed steel 2.5 times

It can be concluded that the direct dependence of the speed of the gas flow flowing to the cutting edge, taking into account the increase in the level of sound pressure and the achieved technical result – the increase in the durability of the high-speed tool.

As a result of the influence of gas pulses on the structure of hardened steel, processes occur in it that coincide with the processes implemented during the tempering heating of hardened steel, while ensuring the durability of the tool used in the manufacture and repair of parts and structural elements of aircraft, and also allows to increase the hardening heat treatment to be less prolonged and more productive.

TABLE III. COMPARATIVE WEAR OF THE CUTTING EDGE OF P6M5 STEEL DRILLS AFTER STANDARD HEAT TREATMENT AND SUBJECTED TO ADDITIONAL TREATMENT BY PULSATING GAS FLOW

Type of treatment	Wear of the cutting edge, mm
Standard heat treatment	0.5
Treatment of pulsating a gas flow with oscillation frequency of 1130 Hz, and sound pressure level up to 120 dB	0.25
Treatment of pulsating a gas flow 1200 Hz, and sound pressure level up to 130 dB	0.2

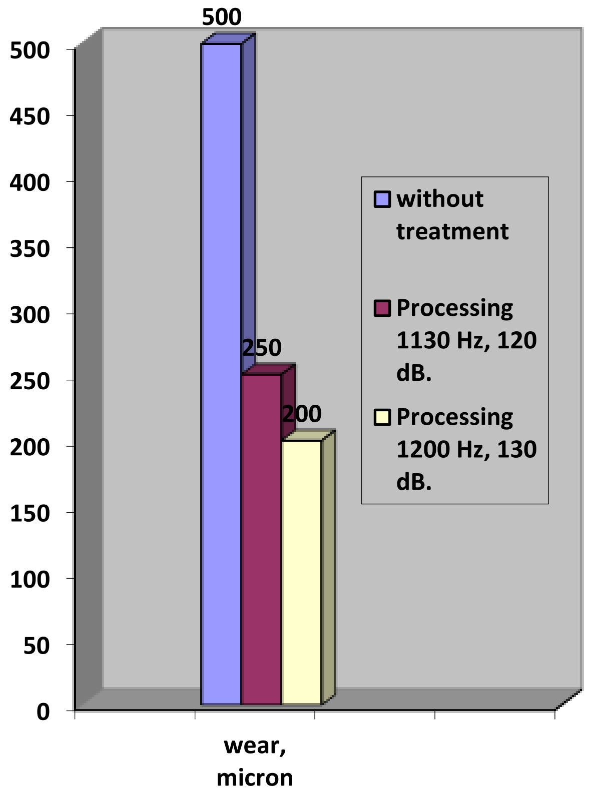


Fig. 4. Wear of the cutting edge of traditionally heat-treated high-speed steel drills P6M5 and drills of the same steel, additionally subjected to gas-pulse treatment

Were also tested for resistance to wear native cloth around the metal material Bi-Metal and fabric-to-metal hacksaw for steel У10A (0.96–1.03 % C, 0.17–0.33 % Si, 0.17–0.28 % Mn, up to 0.2 % Ni, up to 0.018 % of S, up to 0.025% P, up to 0.2 % Cr, up to 0.2 % Cu) subjected to gatenoise processing without the use of heat. Such a tool in the repair can serve, for example, to cut the corners of the pen on the fan blades.

The flat surface of the canvas was blown by a pulsating air flow for 15 minutes at a pulsation frequency of about 1130 Hz and a sound pressure of up to 120 dB.

During the test, the wear after cutting of a plate made of high-strength titanium alloy with a thickness of 10 mm to a depth of 8.5 mm for Bi-Metal and 4 mm for У10A was estimated.

To determine the resistance, a method of measuring wear on the rear surface was used. As a result of tests, the size of the wear pad f for blown for Bi-Metal and У10A was 0.1 mm, and without blowing 0.2 mm or 2 times more (Fig. 6).

a

b

Fig. 5. Wear of a cutting edge of a drill from high-speed steel P6M5: a – standard treatment, b – additional gas pulse treatment.

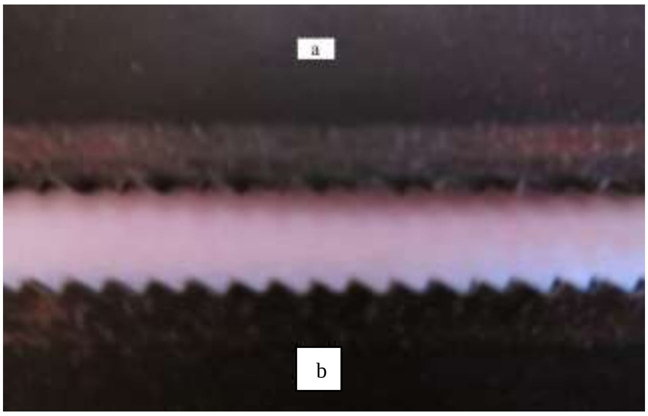
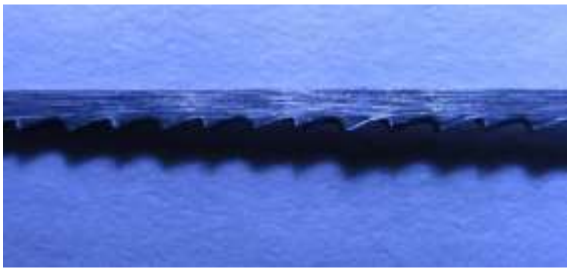
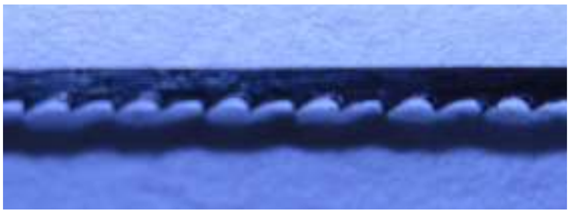


Fig. 6. Blade for hacksaw of steel У10A after the test: a – without blowing, b – with blowing

a



b



c

Fig. 7. The blade for the jig saw of steel У10А after the test and – without blowing, b – blowout of the plane, c – air cooling at 45 degrees

Treatment with a pulsating airflow with similar parameters was subjected for 15 minutes without heating the blade of the У10А steel jig from the flat surface and rotated under 45 degrees (teeth from the side of the flowing flow). During the tests, austenitic steel was sawn, the sheet thickness was 1.8 mm, the cutting depth was 4 mm. f for the blown blade was up to 0.1 mm, both in the first and in the second version of the blade positions during blowing. The value of f for the non-deflated web was 0.2 mm or 2 times more (Fig. 7).

Also, 3Х3М3Ф die steel (0.27–0.32 % C, 0.1–0.4 % Si, 0.2–0.5 % Mn, up to 0.4 % Ni, up to 0.03 % S, up to 0.03 % P, 2.8–3.5 % Cr, 2.5–3 % Mo, 0.4–0.8 % V, up to 0.3 % Cu)

Heat treatment before gas pulse treatment included quenching from 1040–1080 °C and subsequent tempering at 660 °C. the Average hardness value after heat treatment was 34 HRC. Blowing in the installation without heating for 15 minutes was carried out at the same parameters of the air flow as in the previous study. The heat resistance test was carried out at 700 °C. After testing the average hardness value neobiotic samples amounted to 24 units of HRC, and processed – 29 HRC, or 5 units more, which indicates increase heat resistance in the result gatenoise processing.

Gas-pulse processing of cutting and stamping tools made of hard alloys, such as BK8, BK15, T15K6 did not give a noticeable increase in its resistance, probably because mechanical waves have an impact mainly on the cobalt binder.

Conclusion: the Studies have shown high efficiency of the impact of pulsating gas flow on the performance properties of tool steels and, including the finished tool used in the repair of structural elements of aircraft and aircraft engines.

III. Conclusion

The studies have shown high efficiency of the impact of pulsating gas flow on the performance properties of tool steels and, including the finished tool used in the repair of structural elements of aircraft and aircraft engines.

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