

Increasing the operational life of the cutting tool based on stress relieving

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Abstract. The paper covers the results of studying the influence of internal stresses arising in the manufacture of changeable polygonal plates of TC type hard alloys on the resistance of the cutting tool and the possibility of relieving them by preheating the cutting plates before cutting. A method and a special design are proposed for preheating changeable polygonal plates in order to relieve internal stresses in tool hard alloys and increase the resistance of the cutting tool.

At the present stage of development of industrial production, cutting tools with replaceable polygonal hard-alloy plates (RPP) are the most widely used for processing of various types of difficult-to-process materials, therefore, the task of increasing their durability while solving the global problem of production resource efficiency is very urgent. Resistance of cutting tools with RPP was traditionally increased mainly by improving the RPP structure of and RPP sintering modes [1].

Minimization or complete relieving of internal stresses occurring in the RPP during sintering of a hard alloy and its subsequent heat treatment can be a fresh perspective on the solution to the problem of increasing the resistance of cutting tools with hard-alloy RPP. Studies conducted by employees of the Machines and Tools Department of the Tyumen Industrial University, suggest that the complete destruction, pitting and chipping of individual RPP elements are often caused by the presence of internal stresses. Based on the Shpet's theory [2], Professor Evgeny Vladimirovich Artamonov [3] substantiated the hypothesis about the possibility of relaxation of internal stresses by preheating them before cutting, which should increase their performance. However, the mechanism of internal stresses in titanium-tungsten-cobalt (TC) hard alloys affecting the performance of interlocking side cutting tools with RPP and the relaxation techniques have been poorly studied.

The studies conducted helped to determine the mechanism and the degree of influence of temperature on the degree 2 internal stresses in the plates of an interlocking side cutting tool with TC hard-alloy RPPs [4], a summary of all the materials studied is presented in Figure 1.

In order to minimize or completely relieve grade 2 residual stresses by preheating a cutting plate to the maximum working temperature, an engineering solution based on the Pelti-

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er effect was proposed wherein electrons of electric current passing through the boundary region between two contacting plates of a TC (TiC-CO) hard alloy and titanium (Ti) will, depending on the direction of the current, either be accelerated or decelerated by the contact field. In the first case, heat generation is observed in the boundary layer, and in the second, heat absorption.

A known method [5], wherein in order to intensify heat transfer between the plates, a binder layer was introduced, which consists of molybdenum disulfide and liquid glass, which allowed to raise the heating temperature of the carbide plate to 600°C. In this case, relying on experimental data on the effect of temperature on grade 2 internal stresses in the TC hard alloys, it was found that when the temperature is increased by heating the plates to 700°C, the grade 2 internal stresses in the hard alloys can be reduced to almost zero. Therefore, this model was modified by changing the percentage of components of the composition of the binder layer, which allowed to intensify the heat transfer process between the plates.

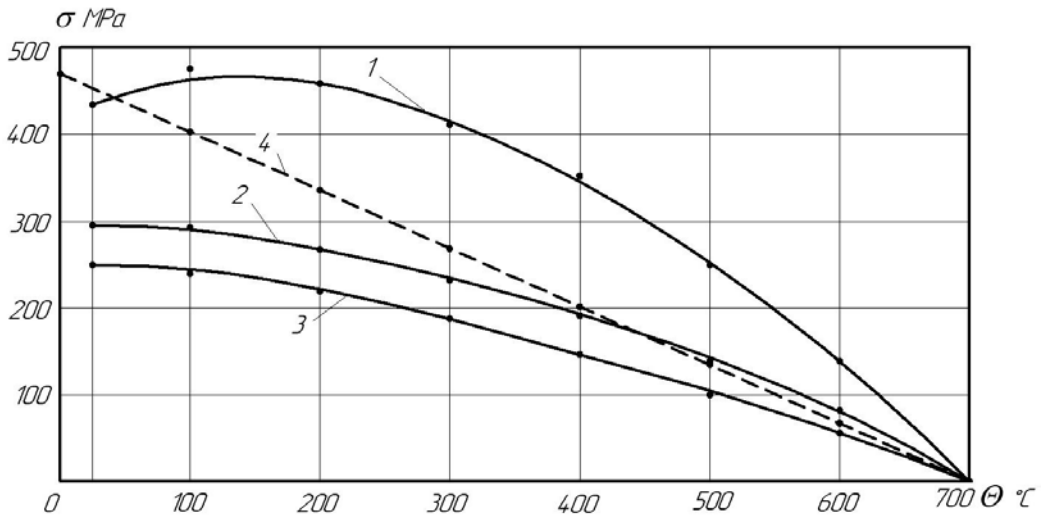


Fig. 1. Dependence of internal microstresses on the temperature of the RPP for different TC alloys: 1 – T30C4, 2 – T15C6, 3 – T5C10, 4 – according to the updated mathematical model

According to the proposed physical model of the heating process of the RPP of TC hard alloys based on the Peltier effect, the amount of heat released in the RPP of TC hard alloys can be determined from the expression:

$$\sum Q'_i = \Delta\varphi \cdot I \cdot \Delta t \tag{1}$$

where $\sum Q'_i$ – the amount of heat in the RPP; I – is amperage; $\Delta\varphi$ – the potential difference between the plates, which is determined from the expression $\Delta\varphi = (\varphi_1 - \varphi_2)$; Δt – a time interval.

The amount of heat that is required to heat the plate by ΔT can be found using the formula

$$\sum Q''_i = \Delta T \cdot C, \tag{2}$$

where ΔT – the temperature; C – the heat capacity of the replaceable polygonal plate, which is equal to $C = m \cdot c$, where m – is the weight of a RPP; c is specific heat.

If we consider that the heat removal from the RPP of the TC group into the air is insignificant, then we can assume:

$$\sum Q'_i = \sum Q''_i \quad (3)$$

By transforming formulas (1), (2), (3), we obtain an expression for the physical model, which allows you to determine the change in the temperature of ΔT the RPP at set amperage I :

$$\Delta T = \frac{\Delta \varphi \cdot I \cdot \Delta t}{C} \quad (4)$$

In order to determine amperage in the final version, the following formula can be used:

$$I = \frac{\Delta T}{\Delta t} \cdot \frac{C}{\Delta \varphi} \quad (5)$$

In order to increase the performance of a TC hard-alloy cutting tool (CT), it is necessary to relieve the internal stresses of the hard alloy. For this, before starting cutting of a part, it is necessary to preheat the cutting plate to a temperature at which the alloy undergoes transition from the brittle to the brittle-ductile state. This unit (Fig. 2) with preliminary adjustable heating of the RPP of TC hard alloys is designed to provide such a combination of strength and crack resistance of the material of the cutting part of CT, which will increase its performance.

In addition, this unit allows us to solve the problem of increasing the wear resistance of RPP of TC hard alloys by reducing grade 2 stresses when they are preheated to a temperature of 700°C before processing, which significantly reduces the likelihood of microchips and micropitting of the cutting edge of the RPP by transiting them in the brittle-ductile zone. Thus, the period of CT cold running-in is reduced or almost completely eliminated. Adjustment of the operating temperature during preliminary heating of the RPP of TC hard alloys allows to configure the unit for the processing (heating) modes for hard-alloy plates of various grades. The design of the tool is entirely a work of authorship, which is confirmed by filing a patent application for a utility model.

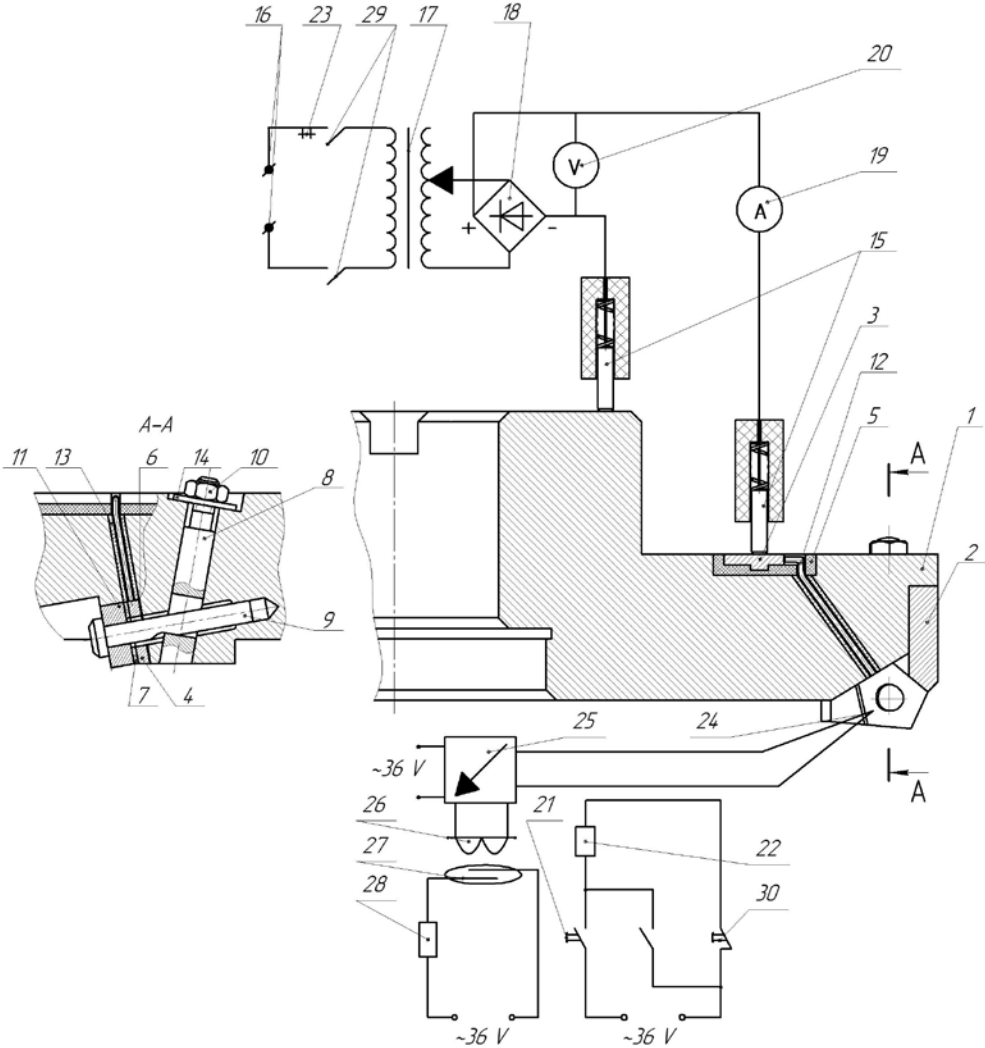


Fig. 2. A metal cutting tool with a preheating circuit diagram:
1 – housing, 2 – ring, 3 – current supply ring, 4 – current supply plate, 5 – textolite gasket, 6 – insulating gasket, 7 – binder layer, 8 – rod, 9 – fixing pin, 10 – nut, 11 – cutting plate 12 – wire, 13 – quartz glass tube, 14 – washer, 15 – graphite brushes, 16 – power supply, 17 – autotransformer, 18 – rectifier, 19 – voltmeter, 20 – ammeter, 21 – “start” button, 22 – starter, 23 – contacts of the starter, 24 – thermocouple, 25 – adjustable gain unit, 26 – electromagnet with a core, 27 – reed switch, 28 – relay, 29 – contact, 30 – “stop” button

The unit operates as follows.

Before the start of milling, the start button 21 is pushed, the starter 22 starts. As soon as the contacts 23 of the starter 22 begin to close the heating electric circuit, the hard-alloy cutting plate 11 is heated. In order to ensure the required heating parameters of the cutting plate 11 made of hard carbide, an ammeter 19 and a DC voltmeter 20 are included in the output circuit of the rectifier 18. One of the poles of the rectifier 18 is connected to the housing 1, and the second pole is connected to the current-conducting plate 4. When an electric current passes through the tool carbide cutting plate 11 and the bonding layer 7, a significant amount of heat is generated between them based on the Peltier effect and directly in the cutting plate 11 itself based on the Joule-Lenz law. The temperature range during

the cutting process is maintained during the processing of the part due to heat generation during cutting, as well as controlled heating, which is carried out by switching on the heating circuit 27 and the relay 28.

When the unit is turned on before milling, a direct electric current is passed from the RPP of TC hard alloys and the titanium plate at the interface between the RPP of TC hard alloys and the titanium plate, which passes through a binder layer consisting of molybdenum disulfide and liquid glass. Based on the Peltier effect, the RPP is heated to a temperature of 700°C, which ensures the removal of internal stresses in them and, accordingly, increases the resistance of the interlocking side tool. During the further machining process, the required temperature range is maintained due to heat generation during milling. 150 A is enough to heat the cutting plate to 700°C.

Production tests (Fig. 3) of a prototype of an interlocking side milling cutter with an RPP of T15C6, where the dependences of the influence of the cutting speed V on the cutting path L , cutting temperature Θ and surface relative wear h_{on} were studied, showed that pre-heating the RPP to a temperature of 700°C before processing of the workpiece, it significantly increases the performance of the tool, namely, the cutting path increases by 30-35% due to the removal of the internal stresses of the alloy plate and provides the stable minimum wear zone within a speed range of 85÷110 m/min.

During resistance tests of an interlocking side mill, standard methods [6] and calibrated instruments were used.

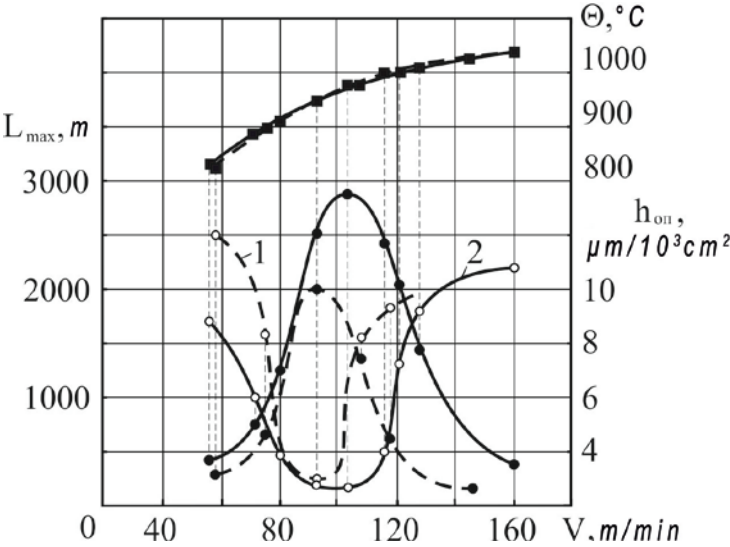


Fig. 3. Dependence of the influence of cutting speed on the cutting path, cutting temperature and relative surface wear during milling of parts of 5KhGM alloy; a mill with RPP of T15C6 ($S_z=0.1$ mm/tooth, $t=1$ mm, $V=0\div160$ m/min)
1 – without heating, 2 – with preliminary heating of the RPP (● – cutting path; ○ – relative surface wear; ■ – cutting temperature)

Thus, it was found that the removal of grade 2 internal stresses in the RPP of TC hard alloys by preheating increases the resistance of the cutting tool by 30-40%, and a device for controlled heating of hard-alloy plates [7] that increases the resistance of RPP of TC hard alloys has been developed and patented.

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