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The Reserch of the Tempereture Impact in Tool–Workpiece Contact on the Quality of the Cut at Thermofrictional Cutting

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The purpose of the given work is to describe the research methods of the temperature impact in contact on the quality of a cut. The mechanisms of the cut off process by a method of thermofrictional cutting (?FC) are revealed, the drawbacksemerging at the cutoff by a smooth disk in case of application of classical method ?FH are determined and described.
The work describesa new mode of the cutoff with a high-frequency break of the contact whose principal difference is a new scheme of heat distribution at the expense of an impulse cycle of heat and refrigeration. Photos of cutting disks made from constructional steels and special equipment mounted on the basis of a lathe are provided, as well as dependence of influence of frequency and the zone size on the mean temperature in the contact are provided.

Keywords: thermofrictional cutting, high-frequency refrigeration, impulse heat.

1. Introduction

For conditions of the mining and metallurgical complex engineering operations of Republic of Kazakhstan the application of progressive modes of cutting, such as laser, chemically-thermal, plasma and thermofrictional, turns to be unprofitable as they demand either big capital, big power expenditures or big production spaces.

Mining equipment is connected with application of special alloys with special physical properties, characterized by high corrosion and thermal resistance, cutting of which faces certain difficulties in Kazakhstan factories when cut by traditional modes (on milling and hacksaw machine tools, in dies for stumps, an abrasive and gas cutoff). These alloys, as a rule, are intractable. Deterioration of the cutting tool is rather high. In this connection working out new resource-saving technologies of a cutoff of metal preforms is an actual problem.

Condition and problems of frictional cutoff. The traditional technology of thermofrictional cutting (TFC) is grounded on the loss of strength of the processed material in the area of cutting at the expense of high speed of sliding friction. Thus, the more speed is, the bigger amount of heat is accumulated in contact tool – preform. Consequently, the processed material is exposed to a bigger loss of strength, and the cutting disk saves durability properties because of minimisation of presense of a concrete site of periphery of a disk in contact. However, the excessive increase of speed leads to toughening of the requirements set to the equipment.

The basic indexes of the process of a frictional cutoff [1, 2], as well as a possibility of its implementation, are basically defined by thermal processes. Therefore, control of the process of a frictional cutoff is, to a great extent, the control of thermal flows, contact temperature, temperature fields in the preform and the tool [3]. Thus, the ability to control the temperature field in a detail allows carrying on the process with demanded efficiency and quality. Definition of temperature is of great importance for understanding, definition and optimization of those parametres which characterize the basic stages of process of a frictional cutoff.

In cutting the thermal condition of a preform in a cutting area to a big extent defines a condition of cutting which essentially influences the quality of cutting. When cutting by a traditional mode with a smooth disk as a cutting tool, values of the disk speed and feeding should ensure the temperature that is close to a melting temperature of the cut metal [4]. Otherwise, cutting implementation is hampered. In these conditions the cut metal behaves as viscous environment. Drop-shaped metal particles are carried out from the cutting area, and flows are formedon the surface of the cut. At an exit of a disk from the cutting area burrs of very big sizes are formed. The surface of the cut is exposed to tempering on depth from 0,5 to 1,5 mm, the burr is also tempered. Durability of a cutting disk in a range $V = 35 \div 60$ m/s is low as it has no time to be cooled.

Within several seconds ($5 \div 10$) it accumulate sheat which has no time to pass into the environment at the expense of convection, as a result there is a thermal landing of a disk, and also its catastrophic deterioration. To prevent it, the speed of a disk should be increased up to $V > 75$ m/s, which leads to sharp rise in price of the equipment and demands big energy consumption for a disk drive gear.

The drawbacks given above constrain wide application of traditional technology of thermos frictional cutoff of metal preforms.

2. Experimental researches of an offered mode of a thermofrictional cutoff

One of the ways to save expensive cutting material is to apply new technologies [8, 9] one of which is thermofrictional cut off with localization of the thermal field at the expense of high-frequency refrigeration [10].

This mode of cutting with high-frequency refrigeration is resource-saving. Its implementation allows cutting down expenses on the electric power (not more than 11 kW) and on the tool (the cutting disk can be manufactured from such widespread brands of constructional steels, as a steel 45, 50, 55, 60).

For the research of the given mode of cutting, the department "Technological equipment, mechanical engineering and standardization" of the Karaganda State Technical University has worked out a special equipment on the basis of lathe 1K62. During experiments feeding of cooling fluid was carried out manually.
Fig. 1 displays a photo of the special equipment on the basis of lathe 1K62.

Figure 1 Special equipment on the basis of lathe 1K62

Fig. 2 presents a photo of the process of thermofrictional cutting.

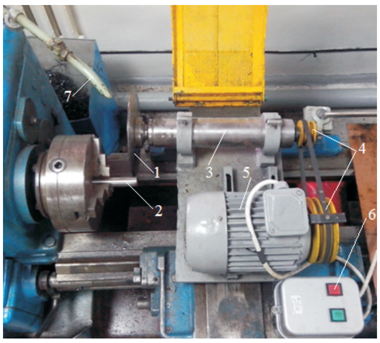

Figure 2 Process of thermofrictional cutting. 1 – processed preform, 2 – cutting disk, 3 – spindle, 4 – driving and driven pulleys, 5 – electric motor, 6 – control panel, 7 – feeding system of refrigeration fluid

For measurement of temperatures in the points lying on certain distances from the surface of cutting, semi-artificial thermocouples, the cut off sample – hard-alloyed penetrators have been used. All penetrators have been selected according to equality of their measured electrical resistance. To lead out a conductor and a copper wire, a copper clamp has been welded to the back part of the cylindrical penetrator. A lead-out has been soldered to the clamp.

Calibration tests of these pairs have been carried out in the following way. Next to apex of the hard-alloyed penetrator the ball of the exemplary artificial thermocouple was pinched. As heating was formed at the expense of work of a cutting disk, the cutting process was carried out by finishing forming of a cutting disk to a penetrator apex. Comparing indications of two thermocouples inferred on self-recording electronic devices Control Recorder-4 the calibration test of the natural thermocouple was made. The calibration test was carried out at cutting without refrigeration.

Fig. 3 displays a sketch of the basic construction of a disk.

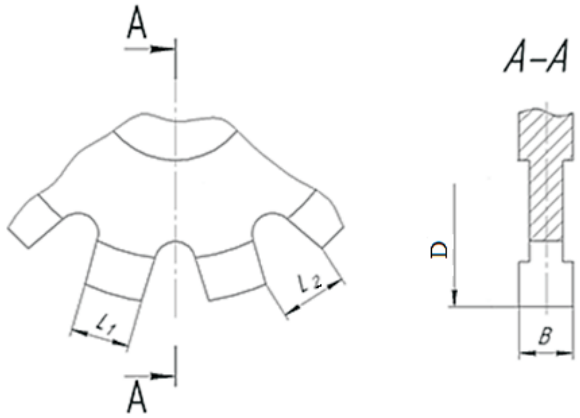

Figure 3 Sketch of the basic construction of a disk. L_1 – heating area; L_2 – refrigeration area, D – diameter of a disk, B – width of a disk

A new mode of cutting with a high-frequency break of contact, when there is an impulse cycle heat-cooling, essentially differs from a traditional technology and in the scheme of heat distribution. The issue of quality assurance comes to the adjustment of the mean temperature in contact. Thus, it is possible to adjust this temperature at the expense of the following parametres: speed of cutting V, speed of feed S, diameter of disk Du and tool geometry. As tool geometry we understand the ratio of lengths of sites L_1 and L_2, as well as a step of their arrangement.

Fig. 4 presents a photo of cutting disks made of different materials.

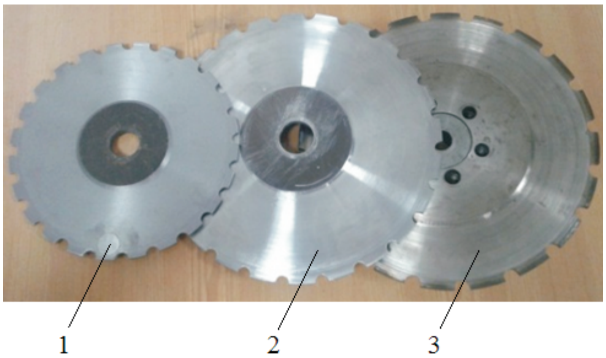

Figure 4 Cutting disks. 1 – disk made of SCH15, 2 – disk made of Hardox 450, 3 – disk made of steel 45

Having selected these parametres, further adjusting can be made by means of change of L_1, L_2 and their volumes.

But, if assigned by diameter of tool Du and assign values L_1 and L_2, their volume z comes from a ratio:

$$z = \frac{\pi D}{L_1 + L_2} \tag{1}$$

In the conditions of persistence of rotational speed the amount of cycles of heat-cooling per a unit of time will be quite definite and equal:

$$i = \frac{\pi D}{L_1 + L_2} n \tag{2}$$

The same value can be defined through the speed, i.e:

$$\frac{V_u}{L_1 + L_2} = i \tag{3}$$

Impact of frequency of cycles on this parametre can be evaluated according to the data given in Fig. 5.

The analysis of the results displays that efficiency of refrigeration increases after frequency $> 100\ 10^3$ cycles for V = 35 m/s. With the increase of speed the general level of temperatures rises. This is explained by big heat evolution. As regards efficiency boundary – It is shifted to the area of bigger i. In our case $i > 130 \cdot 10^3$ cycles.

Level of mean temperatures according to experimental data should be maintained (for steel 30) between values $250 \div 500^o$C, as increase in $T_{avg.} > 500^o$C leads to burr increase, and decrease $T_{avg.} < 250^o$C leads to considerable growth of forces of cutting.

The latter can be tracked through the character of change of a friction coefficient. In Fig. 6 dependence of mean temperature of $T_{avg.}$ of contact on the size of refrigeration area L_2 is presented.

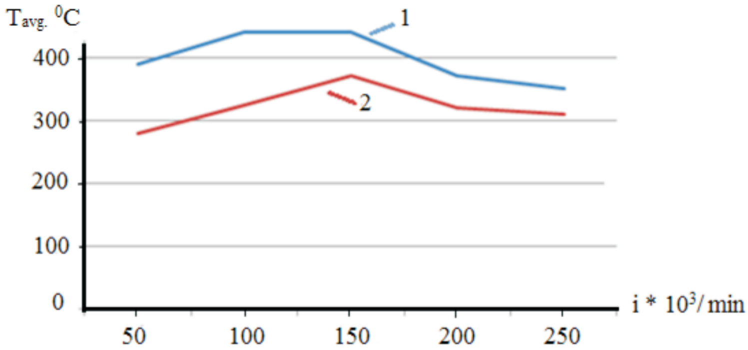

Figure 5 Impact of frequency of cycles on mean temperature in contact. $V = 35$ m/s, 1 – $L_2 = 15$ mm, 2 – $L_2 = 20$ mm

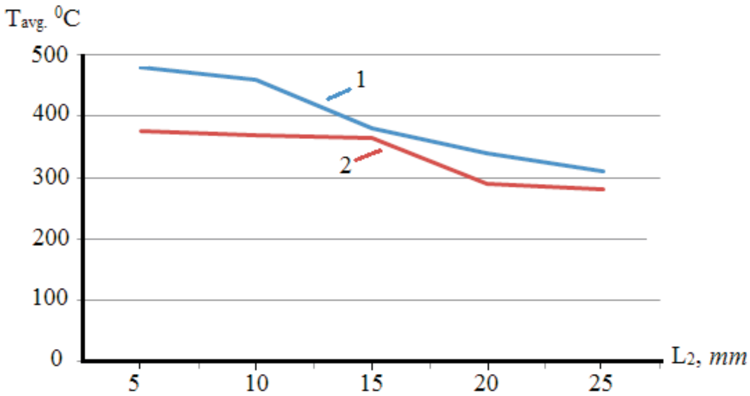

Figure 6 Impact of the size of refrigeration area on mean temperature. Steel 45, $V = 30$ m/s, $L_1 + L_2 = 40$ mm, 1 – $S = 250$ mm/min, 2 – $S = 125$ mm/min

Fig. 7 presents the dependence of the quality of the cut on the size of the refrigeration area L_2.

The data are received at a cut off steel 30 by the disk made of steel Hardox 450. The step of cycles was kept constant so that the sum of lengths ($L_1 + L_2 =$ const) was invariable. Change of length L_2 leads to the respective alteration of the heating area. But the data on the influence of L_1 on temperature specifies that at increase $L_1 > 20$ mm its influence is hardly noticeable.

As concerns the length of refrigeration area L_2 – the influence is rather considerable. Thus, increase of L_2 from 10 to 20 mm leads to the reduction of $T_{avg.}$ by 30%. This reduction is enough for a sharp decrease of roughness of the cut, and depth of the hardened layer turns to be rather small (see Fig. 6).

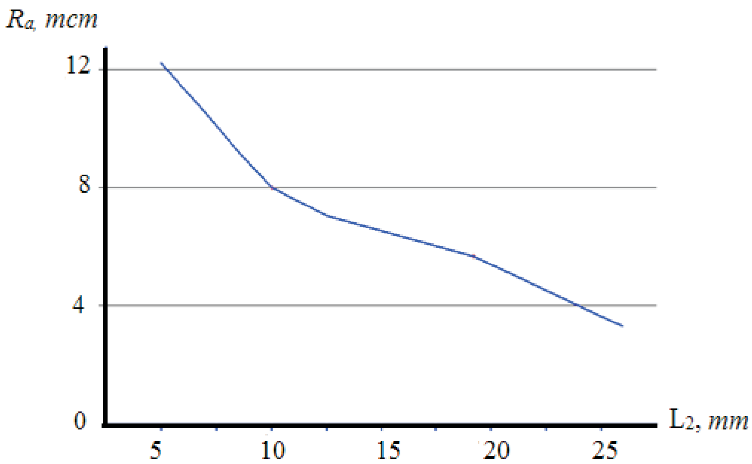

Figure 7 Impact of the size of refrigeration area on the quality of cut. Steel 45, $V = 30$ m/s, $S = 150$ mm/min

3. Conclusions

1. Using the achieved results, it is possible to offer practical recommendations for choice of the tool geometry and assignment of modes of cutting, which will ensure improvement of the quality of the treated surface, and also will allow implementing the given process in less expensive machine tools at simultaneous lowering of energy consumption and increase of durability of the tool.

2. For implementation of the mode it is enough to apply rotational speeds in a range $n = 2500 \div 3500$ rpm. Thus, needed power of the electric motor of a drive gear is not more than 10 kw. Durability of a disk till the next resharpening makes $300 \div 500$ cuts at width of the cut metal of 50 mm.

3. Experimental researches have shown that increase of the heating area for more than 20 mm is ineffective. Influence of length of the refrigeration area is more considerable, so its increase from 10 to 20 mm leads to lowering of mean temperature by 30 %. It is quite sufficient to reduce roughness of the treated surface to Ra<6,3 μm.

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