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INVESTIGATION OF THE DEPENDENCE OF BLADE MICROGEOMETRY ON GRINDING MODES AND CHARACTERISTICS OF THE ABRASIVE TOOL

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Abstract

The formation of a blade occurs due to the intersection of the micro-reliefs of the side surfaces (bevels). The blade microgeometry is influenced not only by the technological parameters of grinding and the physical and mechanical properties of the material, but also by the forces arising during the grinding process and their direction. The significance of various factors characterizing blade formation was evaluated using analysis of variance methods [1].

Introduction

The results of preliminary experiments and the analysis of literature data [2] made it possible, in the main series of experiments, to identify the most significant factors affecting the microgeometry of the cutting edge: the characteristics of the abrasive wheel (grain size and hardness), the grinding mode (longitudinal feed), and the hardness of the workpiece material.

The objective of the main series of experiments was to obtain a mathematical model of the grinding process describing the influence of the above factors on the microgeometry of the cutting edge. In this part of the study, methods of mathematical experimental design were also applied [3]. The selection of factor levels and variation intervals (Table 1) was based on literature data [4] and the results of preliminary experiments.

Table 1 Planning levels and ranges of factor variation

Factor	Parameter name	Main level	Variation interval	Upper level	Lower level
X_1	Wheel grain size, 10^{-6} m	230	20	400	60
X_2	Wheel hardness, conventional units	3	1	5	1
X_3	Longitudinal feed, m/rev	0.0005	0.0005	0.001	0.0001
X_4	Workpiece hardness, units	56	4	64	48

According to existing recommendations [2], the depth of cut was set at 0.04 × 10^{-3} m. In the experiments, blanks of plate-type knives made from cold-rolled strips were used. The blanks were produced from tool carbon steels U8A, 85KhF, and 65G and subjected to heat treatment, after which their Rockwell hardness ranged from 54 to 64 units. The dimensions of the blanks were: length – 0.25 m; width – 0.02 m; thickness – 0.5 × 10^{-3} m.

Grinding was carried out using grinding wheels made of electrocorundum with a ceramic bond.

The sharpening of samples was performed on a special device with the following characteristics: wheel speed – 20 m/s; grinding type – wheel periphery; direction – transverse to the blade, up-cutting; grinding angle – 17°.

The following parameters were used to characterize the microrelief and the width of the cutting edge: R_{max} – maximum height of profile irregularities; R_a – arithmetic mean deviation of the profile; R_p – maximum peak height; r – average radius of peaks; h – relative bearing length along the mean line; S_m – spacing of micro-irregularities along the mean line; a – cutting edge width.

In the main series of experiments, the samples were examined using an automatic microscopic system (Section 2.3), which included, in addition to a microscope with a photographic attachment, a control console with a screen, a display, a computer with a set of programs, and a digital printing device. Two software programs were used in the study:

1. For determining the average statistical width of the cutting edge;
2. For determining the microrelief parameters of the blade.

Measurements were carried out at 3–5 points along the blade length at a magnification of 500× for edge thickness and 1000× for microrelief parameters. The microscope field of view ranged from 160 to 380 μm, respectively. Average statistical values were determined based on 180 points for edge thickness and 370 points for microrelief parameters.

An attempt to obtain a linear equation based on the results of a four-factor experiment showed that such an equation does not adequately describe the process. Therefore, the mathematical model of the influence of the above factors on the microgeometry of the cutting edge was represented as a power function:

$$y = b_0 \cdot t_1^{b_1} \cdot t_2^{b_2} \cdot t_3^{b_3} \cdot t_4^{b_4} \qquad (1)$$

where:

$$t_1 = \ln x_1;\ \ t_2 = \ln x_2$$
$$t_3 = \ln x_3;\ \ t_4 = \ln x_4$$

If we denote ln x = z, then equation (1) takes the form:

$$z = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_3 \ln x_3 + b_4 \ln x_4 \qquad (2)$$

The calculation of the coefficients of this equation and its statistical analysis were performed using well-known methods [3].

As a result of processing the experimental data and converting the coefficients to dimensional form, the following regression equations were obtained:

$$\ln y_{R\max} = 3{,}216 + 1{,}157 \ln \frac{x_1}{154{,}9} + 0{,}109 \ln \frac{x_2}{2{,}236} - 0{,}005 \ln \frac{x_3}{0{,}0003} - 0{,}056 \ln \frac{x_4}{55};$$

$$\ln y_{Rp} = 2{,}575 + 1{,}031 \ln \frac{x_1}{154{,}9} + 0{,}118 \ln \frac{x_2}{2{,}236} - 0{,}020 \ln \frac{x_3}{0{,}0003} - 0{,}201 \ln \frac{x_4}{55}; \quad (3)$$

$$\ln y_{Ra} = 1{,}611 + 1{,}276 \ln \frac{x_1}{154{,}9} + 0{,}303 \ln \frac{x_2}{2{,}236} - 0{,}059 \ln \frac{x_3}{0{,}0003} - 1{,}145 \ln \frac{x_4}{55}; \quad (4)$$

$$\ln y_{Rr} = 3{,}709 + 0{,}522 \ln \frac{x_1}{154{,}9} + 0{,}113 \ln \frac{x_2}{2{,}236} - 0{,}027 \ln \frac{x_3}{0{,}0003} - 1{,}340 \ln \frac{x_4}{55}; \quad (5)$$

$$\ln y_{Rs} = 5{,}617 + 0{,}457 \ln \frac{x_1}{154{,}9} + 0{,}024 \ln \frac{x_2}{2{,}236} - 0{,}002 \ln \frac{x_3}{0{,}0003} - 0{,}194 \ln \frac{x_4}{55}; \quad (6)$$

$$\ln y_{R\eta} = 0{,}766 + 0{,}388 \ln \frac{x_1}{154{,}9} + 0{,}029 \ln \frac{x_2}{2{,}236} - 0{,}002 \ln \frac{x_3}{0{,}0003} - 0{,}688 \ln \frac{x_4}{55}; \quad (7)$$

The analysis of the obtained equations shows that the most significant factor influencing the microgeometry of the cutting edge is the grain size of the grinding wheel. In terms of significance, the input factors can be arranged in the following order: hardness of the knife material, hardness of the grinding wheel, and magnitude of the longitudinal feed.

Graphical interpretation of the obtained equations shows that an increase in the grain size and hardness of the grinding wheel leads to a noticeable increase in all parameters except *r* and *h*. At the same time, grinding defects such as burns, blade bending, and burr formation may occur. Increasing the grinding wheel grain size from 60×10^{-6} to 400×10^{-6} m results in a 30–40% increase in cutting edge width. The hardness of the grinding wheel has practically no effect on this parameter.

All controlled parameters, except the cutting edge width, decrease with an increase in the initial hardness of the knives. Good results were obtained by finishing the blade with a leather wheel coated with GOI polishing paste. The finishing operation makes it possible to reduce the height and spacing parameters of the microgeometry and to reduce the cutting edge width by 10–15%. Changing the grinding angle in the range of 12–35° does not have a noticeable effect on the microgeometry parameters of the knives.

References

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