Results of formation of knife blade

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Abstract. This work presents the results of the formation of the blade due to the intersection of microreliefs of the side surfaces, moreover, the microgeometry influenced by not only the technological parameters of the grinding, but also the physical and mechanical properties of the material, as well as the forces that arise during grinding.

The formation of the blade occurs due to the intersection of the microreliefs of the side surfaces (bevels), and the microgeometry is influenced by not only the technological parameters of the grinding and physical-mechanical properties of the material, as well as the forces arising during the grinding process, and their direction. The significance of various factors characterizing the shaping of the blades was checked by disperse analysis methods [7].

The test results of knives, the blanks of which are made of steel U8A, 65G, 85XF and having a microhardness corresponding to 48-52 HRC units in particular, showed that the material of the blank has practically no effect on microgeometry indicators. Therefore, in a preliminary series of experiments, the following factors were studied as research factors: the angle of grinding, the direction of grinding, and the graininess of the circle. An analysis of the obtained regression equation shows that the angle and direction of sharpening slightly affect the microgeometry of the blade. The granularity of the abrasive wheel has the greatest influence. The distribution curves Rmax and S for one knife based on the results of experimental measurements of microgeometry of the blades are close to the shape of the normal distribution curves, which confirms the uniform nature of the influence of random independent primary factors in the absence of sharply dominant [4].

The results of preliminary experiments and analysis of the literature data [3,5,6] allow us to take as the most significant factors affecting the microgeometry of the cutting edge the characteristics of the abrasive wheel (grain and hardness); sharpening mode (longitudinal feed), hardness of the blank material. The aim of the main series of experiments was to obtain a mathematical model of the grinding process, which describes the influence of the listed factors on the microgeometry of the cutting edge. In this series of studies, methods of mathematical design of the experiment were also used [4]. The choice of levels and intervals of variation of factors (table 1) was made based on published data and the results of preliminary experiments.

According to existing recommendations [1], the cutting depth was taken equal to 0.04x10^-3 m. In the experiments, blanks of plate knives from cold-rolled strips were used. The blanks were made of tool carbon steels U8A, 85KhF, 65G and were subjected to heat treatment, after which the hardness by
Rockwell scale was ranged from 54 to 64 units. Sizes of blanks: length 0.25 m; width - 0.02 m; thickness - \(0.5 \times 10^{-3}\) m.

Table 1. The choice of levels and intervals of variation of factors.

| Level of planning | X₁  | X₂  | X₃  | X₄  |
|------------------|-----|-----|-----|-----|
| Name of the indicators | Circle granularity, \(10^{-6}\) m | Circle hardness, standard unit. | Length feed, mm/turn | Blank hardness, standard unit |
| Main level       | 230 | 3   | 0.0005 | 56  |
| Range of variation | 20  | 1   | 0.0005 | 4   |
| Upper level      | 60  | 5   | 0.001  | 64  |
| Lower level      | 60  | 1   | 0.0001 | 48  |

For sharpening, grinding wheels made of electrocorundum on a ceramic bond were used. Sharpening of the samples was carried out on a special device with the following characteristics: circle speed - 20 m/s; type of sharpening: the periphery of the circle; direction - running across the blade; sharpening angle 17°.

As the measured parameters characterizing the microrelief and the width of the cutting edge, we used: \(R_{\text{max}}\) – the highest height of the profile irregularities; \(R_a\) – the arithmetic mean deviation of the profile; \(R_p\) – the largest height of the protrusion; \(r\) – the average radius of the protrusion; \(l\) – the relative reference length along the midline; \(S_m\) – the step of microroughnesses along the midline; \(a\) – the width of the cutting edge.

In the main series of experiments, the samples were studied on an automatic microscopic system, which includes, in addition to a microscope with a photo attachment, a control panel with a screen, a display, a computer with a set of programs, and a digital printing device. The studies used two programs:

1) To determine the average static width of the cutting edge;
2) To determine the parameters of the microrelief of the blade.

The measurements were carried out at 3–5 points along the length of the blade at a 500-multiple increase for the edge thickness and 1000-multiple increase for the microrelief parameters, while the field of view of the microscope was from 160 to 380 μm, respectively. The average values of the quantities were determined by 180 points for the edge thickness and 370 points for the microrelief indicators.

An attempt to obtain a linear equation from the results of a four-factor experiment showed that an equation of this kind inadequately describes the process. Therefore, a mathematical model of the influence of the above factors on the microgeometry of the cutting edge was presented as a power function:

\[ y = b_0 \cdot t_1^{b_1} \cdot t_2^{b_2} \cdot t_3^{b_3} \cdot t_4^{b_4} \]  

where:

\[ t_1 = \ln x_1; \quad t_2 = \ln x_2 \]
\[ t_3 = \ln x_3; \quad t_4 = \ln x_4 \]

If to designate \(\ln x = Z\), then equation (1) take:

\[ Z = b_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_3 \ln x_3 + b_4 \ln x_4 \]  

The calculation of the coefficients of this equation and its static analysis were performed by known methods [4].

As a result of processing the experimental data and reducing the coefficients to dimensional form, the following regression equations were obtained:
An analysis of the equations obtained shows that the most significant factor affecting the microgeometry of the cutting edge is the granularity of the grinding wheel. Further, according to the degree of significance, the input factors can be arranged in the following order: the hardness of the material of the knives, the hardness of the grinding wheel and the magnitude of the longitudinal feed.

A graphical interpretation of the equations obtained shows that an increase in the granularity and hardness of the grinding wheel leads to a noticeable increase in all parameters except \( r \) and \( h \). In this case, sharpening defects may appear - burns, twists of the blade, burr. An increase in the granularity of the grinding wheel from 60×10^{-6} to 400×10^{-6} m leads to an increase in the width of the cutting edge by 30–40%. The hardness of the grinding wheel practically does not affect this parameter.

All controlled parameters, except the width of the cutting edge, decrease with an increase in the initial hardness of the knives. Finishing the blade with a leather circle, with GOI paste applied to it, showed good results. The finishing operation allows reducing the height and step parameters of microgeometry, reducing the width of the cutting edge by 10 - 15%. A change in the angle of sharpening in the range of 12-35\(^\circ\) does not have a noticeable effect on the parameters of knife microgeometry.

As a result of the experiments, it was found that the dominant effect on the parameters of the blade microgeometry is exerted by the granularity and hardness of the grinding wheel. As the rational characteristics of the abrasive tool can be recommended grit 6, 10, 12, and hardness M1 and M2. Finishing the blade with leather circles can significantly improve the performance of \( h \) and \( a \). This operation proceeds with minimal heat, as a result of which hardening of the treated surface occurs due to peening. Finishing on one edge can cause distortion (bending) of the blade top due to the processing forces, which is especially important at small sharpening angles. With double-sided finishing, the geometry improves.

In general, it can be stated that blade sharpening with an abrasive tool under the above conditions corresponds to 7–8 accuracy and surface roughness \( R_s = 2.0-3.5 \mu m \). By finishing, accuracy of 5–6 quality and roughness \( R_a = 0.4-1.0 \mu m \) are achieved. In subsequent series of experiments, the influence of the cutting tool finishing and the possibility of using modern abrasive materials for sharpening thin plate knives was studied.

At present, for sharpening a cutting tool, an el’bor is used more and more widely, which in hardness is close to diamond, but more heat-resistant [2]. The use of el’bor for sharpening knives is especially promising, as their grindability, due to the increased content of vanadium and chromium with a conventional abrasive tool, is significantly deteriorated: the carbides of these elements have the same order of hardness as electro - and monocrandum. Therefore, for sharpening knives, circles were also used from elbor PP 250x76x16x5 LOL 16S1K7 100%
The object of research in this section were knife plates (d = 0.4 mm) made of 85XF steel, heat-treated to a hardness of 46–48 HRC. The angle of double-sided sharpening was 15°. Grinding was carried out on a model 3G71 machine with an E840CM26K circle without coolant and straightening the circle with a diamond pencil of type C. Lapping (finishing) of the bevels was carried out with leather circles using GOI paste. The initial grinding parameters were: grinding speed – 30 m/s; granularity of an abrasive wheel – 10–40 microns; hardness – M1; the speed of movement of the blank – 6 m/min, the grinding depth – 0.08 mm.

The results of the measurement of microgeometry parameters of plate knives are presented in table 2. These data are arithmetic mean values and are characterized by variation coefficients: for parameters $a, R_a, R_p, R_{\text{max}}$ – 10–12 %, for $S_m$ – 15–20%.

Table 2. The results of the measurement of microgeometry parameters of plate knives.

| $a$ (мкм) | $R_a$ (мкм) | $R_p$ (мкм) | $R_{\text{max}}$ (мкм) | $S_m$ (мкм) | $b$ | $N$ |
|-----------|-------------|-------------|------------------------|-------------|-----|-----|
| 18.8      | 2.1         | 4.8         | 8.7                    | 15.7        | 2.2 | 1.9 |
| 7.8       | 8.3         | 1.5         | 24.5                   | 82.1        | 2.5 | 3.1 |
| 12.9      | 5.7         | 9.0         | 19.2                   | 127.9       | 1.7 | 3.1 |
| 4.3       | 3.2         | 4.5         | 12.9                   | 173.4       | 0.4 | 5.2 |

For these blades, the values of the coefficients of the rectilinear portion of the reference curve $K$ and $C$ are given.

The samples indicated in the first column of the table under the numbers 1,2,3, etc., were obtained under the following conditions: 1 - the bevel of the knife sharpened under the above conditions; 2 - a blade of the same sample; 3 - a blade sharpened by a circle of el’bor under the above modes; 4 - a blade sharpened and brought along one face; 5 - blade sharpened and finished along two faces.

The data in table 2 indicate that sharpening without finishing gives the width of the cutting edge $a$ several times greater than that of a blade brought along two faces. This is noticeable when studying microphotographs, where the dark strip corresponds to the width of the cutting edge, and the micro-teeth are arranged in two parallel lines. As finishing work is done, the micro-teeth are constantly displayed in a single line along the blade. There is an unambiguous correspondence between the altitude parameters of the microrelief ($R_a, R_p, R_{\text{max}}$) when varying the modes of blade formation.

The maximum height of the $R_{\text{max}}$ micro-teeth on the blade is 2–2.5 times higher than on the bevel. This, in our opinion, is explained by the imposition of two lateral microreliefs on the blade, formed separately when grinding the bevels. The magnitude of the longitudinal pitch $S_m$ of the microroughness of the blade on the bevel is 5–8 times smaller than on the cutting edge. The use of a wedge on one and two bevels contributes to an increase in $S_m$.

Comparison of the microgeometry indices of sample N3 with other samples shows that the el’bor sharpening, in comparison with the abrasive grinding of bevels, provides a thinner cutting edge and lower values of the parameters of the height group.

At the same time, according to individual indicators, a close approximation to the microrelief of the finished blades is visible. Subsequent experiments showed that the finishing of the faces of the cutting edge after el’bor sharpening results in blades that differ insignificantly (within the experimental error) from specimen N5, the blade of which was sharpened and adjusted according to the above modes.

The most informative from the point of view of describing the location of the blade micro-teeth is the structural characteristic curve of the supporting surface. An analysis of the experimental reference curves shows that it seems possible to divide the entire range of measurement $b$ into three characteristic sections. Section 1 corresponds to the most prominent micro-teeth and can be described by the expression:

$$\eta = b \cdot \varepsilon^\nu$$

(9)
where \( b \) and \( n \) – constant coefficients.

The microteeth of this section carry out cutting at high \( K_c \) values and can wear out during the burn-in period of the blade. This section is practically absent in finished blades.

Section 2 covers the most numerous group of microteeth, and when reaching a certain approach \( \varepsilon = h/\max R \), the section of the actual contact linearly depends on it:

\[
\eta = K \left( 1 - \frac{h}{\max R} \right) + C
\]

(10)

where \( K, C \) – constant coefficients.

The transition point of the curved section 1 to straight 2 corresponds to the moment the material touches the apex of a smaller microtooth. Microteeth of section 2 perform the main work of microcutting, because have greater strength and sufficient height. Moreover, the larger the interval the rectilinear part takes and the smaller its angle of inclination to the horizontal, the more effectively the formation of the initial micronotch occurs, because microteeth in this case are characterized by greater uniformity in height. Section 3 of the reference curve characterizes a small part of the deepest troughs, which, in the presence of a tangent speed component, may not participate in the cutting process.

Finishing and el’bor sharpening change the form of the reference curve of the blade, in which the first curved section is practically absent, and the dependences \( h = f(\varepsilon) \) for such blades are higher on the second straight section, which provides a large actual contact area with the same approach. The coefficients of the curve of the supporting surface (table 2) vary in a wide range. Values close to optimal were recorded for samples N4.5.

An analysis of the experimental data showed a consistent decrease in the roughness of the cutting edge when fine-tuning along one or two faces. Therefore, after fine-tuning along two faces, the height parameters of the cutting edge are reduced by 1.8-2.0 times. Results close to fine-tuning can be obtained using el’bor wheels, due to the high cutting properties and hardness of boron nitride. In this case, it is especially important to form the microteeth of the blade in one line with a zero transverse step. El’bor grinding is more efficient than finishing on one face.

References

[1] Armarego I J and Brown R H 1977 Processing of metal by cutting (Moscow: Mechanical Engineering)
[2] Baykalov A K 1978 Introduction to the theory of grinding materials (Kiev: Naukova Dumka)
[3] Blinov A V 1995 Improving the process of sharpening cutting tools for sausage production (Moscow: MGAPB) p 24
[4] Grachev Yu P 1978 Mathematical methods of experiment planning (Moscow: Food Industry)
[5] Dumanchuk B V, Kulak A P and Scherbakov A M 1977 Machines and devices for cutting sugar beets (Moscow: TsNIITEIPischeprom)
[6] Mutsianko V I 1987 The basics of choosing grinding wheels and preparing them for operation (Leningrad: Mechanical engineering)
[7] Krutov V I and Popov V V 1989 Fundamentals of scientific research (Moscow: Higher school)