Influence of cutting edge of lamellar knives on the efficiency of work when cutting food semi-finished products

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Abstract. The article discusses the problems of improving the functional quality of lamellar knives by such key indicators as cutting ability and blade resistance.

The food industry should develop based on acceleration of scientific and technological progress in the sector, optimization of the consumption and production of food products, enhancing the interaction of food and agricultural enterprises, increasing of production efficiency in a market economy, improving the structural and investment policies of Uzbekistan.

When processing food raw materials and semi-finished products, one of the most common technological operations is cutting. Food materials are characterized by a complex set of technological, structural-mechanical and adhesive characteristics; therefore, the degree of technical excellence of cutting equipment and tools largely determines the quality, appearance and yield of finished products. Currently, various designs of machines, used for cutting food products and semi-finished products, differing in the structure of the working cycle, the type and trajectory of the movement of knives, the method of supplying raw materials and other characteristics.

The semi-finished product, obtained by cutting, must meet certain requirements for the accuracy of the shape, size, and smoothness of the cut. The main factors contributing to the improvement of quality performance of cutting machines are: optimal cutting conditions and geometry of the knives, their high cutting ability, accuracy of the position and movement of the cutting and feeding working bodies during operation, adjustment and sharpening, special preparation of the semi-finished product to reduce cutting forces, crumbling and deformation of the semi-finished product.

The use of rational geometric parameters of the cutting tool helps to reduce the mechanical impact on the semi-finished product.

Improvements in the quality of work of the cutting tool should be aimed at solving the problem of improving the operational qualities of knives by such key indicators as cutting ability, resistance and stability. Finding rational ways and modes of preparing a cutting tool for work is very perspective.

For the manufacture of knives, carbon and low-alloy steels of the eutectoid and hypereutectoid class (carbon content - 0.8 - 1.2%) with alloying additives of chromium (1.0%) and vanadium (1.0%) are used. Such knives have, as shown by the experience of food enterprises, sufficient resistance at a comparatively low cost of the blank material.

The quality of the working area of sliding cutting knives can be characterized by two groups of parameters:

1. The cutting ability, which determines the ability of the knife to undergo the cutting process and transform the material into a semi-finished product.
2. The resistance of the knife, which determines the ability of the knife to withstand the mechanical impact of the cutting process.

The study of the influence of the cutting edge of lamellar knives on the efficiency of work when cutting food semi-finished products is of great importance for improving the quality of cutting equipment and tools.
- Geometric (angle of sharpening, straightness of the blade, etc.) and microgeometric parameters (thickness of the blade, height and pitch of microteeth).
- Parameters characterizing the physical and mechanical properties of the surface layers.

Common to all types of knives is its cutting side (blade) made in the form of a one-sided or two-sided wedge.

The face of a one-sided wedge, resting in the process of cutting on the main part of the product, is called the reference face, and coincides with the plane of movement of the knife.

The face, with which bending of the cut off part of the product occurs, is called the working face.

The line of intersection of the reference and working faces is called the cutting edge of the blade.

![Figure 1. Knife blade angles.](image)

The angle \( \alpha \) between the supporting and working faces is called the angle of sharpening of the blade.

A two-sided wedge has two working faces, and the sharpening angle is formed by two working faces and is equal to \( 2\alpha \).

Knives are of different types and can be made of different types of steel. They are intended for cutting various products. Despite the fact that they are different in shape and composition of steel, they all need to be sharpened from time to time. If the knives are not sharpened with prolonged use, then their blade will cease to fulfill its functions over time. To work with a blunt blade, it is needed to make more effort, and there is a greater probability of injury. In order for the blade to be quite sharp and at the same time not damaged, you need to know the rules for sharpening it.

Changing the geometry of the tool during operation leads to the loss of its cutting properties. The tool operating time before blunting, i.e. between two regrinding, is called tool life. It is considered that the total durability time consists of the time of two main periods: the initial, or burn-in period, when local breaks or bends of the blade can occur, and the second (often-main) period, which is characterized by a gradual wear of the cutting elements of the tool.

Tool resistance depends on the cutting mode, the material being processed, the type of tool and its material, as well as on the magnitude of the taper angle and the rake angle provided by the tool design.

The process of blunting the cutter consists in increasing the radius of curvature of the cutting edge; at the same time, the shape of the blunting curve - microgeometry can also change. The most typical microgeometry of the cutting edge and the nature of its change in the process of blunting of knives.

Let us consider the process of forming a cutting edge during grinding of bevels in several passes with the runaway direction of the abrasive wheel (figure 2). At the initial stage of sharpening, the blade 1 of
the tool is brought to the grinding wheel 2, while the bevel 3 of the blade 1 is ground by the periphery of the circle 2. When grinding the bevel 3, a deformed surface layer 4 is formed, and when the edge 5 of the blade 1 comes off the periphery of the circle 2, a microtooth 6 of height \( l_1 \) is formed, which is the exit of the surface layer 4 to the edge 5.

As a result, the initial width \( t_1 \) of the edge 5 in the section \( C - C \) decreases to the value \( t_2 \) (figure 2.a). The opposite bevel is ground in the same way 7. As a result, a deformed surface layer 8, a microtooth 9 of height \( l_2 \), and a gap 10 between the microteeth 6 and 9 are formed.

The width of the edge 5 in the section \( C - C \) decreases from \( t_2 \) to \( t_3 \) (figure 2.b). Upon further processing of the opposite bevel 4, a deformed layer 11, a micro-tooth 12 of height \( l_3 \) are formed.

The width of the edge 5 in the section \( C - C \) decreases from \( t_3 \) to \( t_4 \), the size of the gap 10 also decreases (figure 2.c). When grinding the bevel 8, a deformed surface layer 13 and a microtooth 14 of height \( l_4 \) are formed. The microtooth 14 is aligned, i.e. consisting of layers 11 and 13, and the gap 10 disappears. The thickness of the \( C - C \) section decreases from \( t_4 \) to \( t_5 \).

The convergence of the deformed surface layers 8 and 11 is accompanied by the formation of a boundary dividing line in the section \( C - C \).

The microtooth 14 is slightly curved towards the bevel 11, opposite to the circle 2, in the position of the last grinding pass. The thickness \( S \) of the butting boundary dividing line is directly dependent on the thickness of the microtooth and the width of the cutting edge \( a \). Figures 1.a - d show the parameters of the edge width \( a_1, a_2, a_3 \). At the last grinding pass, the microtooth 14 under the action of the radial component of the grinding force is separated from the blade 1, and a cutting edge of width \( a \) is formed.

The microteeth considered are technological irregularities (burrs) of the sharpening. After breaking off a technological microtooth (burr) during the last pass, the base of the microteeth remains on the blade, usually of a lower height and located with a certain longitudinal pitch. From this scheme, in particular, it can be seen that the transverse step of the microteeth is characteristic of insufficiently careful sharpening of the blade (figure 2.c).

![Figure 2. The formation of the cutting edge at multi-pass grinding of the bevels of a lamellar knife.](image)
\[ R_a \approx \frac{1}{n} \sum_{i=1}^{n} |y_i|; \]  

where \( n \) – number of ordinates of roughness;
\( y_i \) – single values of the ordinates of roughness;
\( R_a \) – the height of the profile roughness at ten points, i.e. the average distance between the five highest and five lowest points of the measured profile within the base length:

\[ R_e = \frac{1}{5} \left( \sum_{i=1}^{5} |H_{i_{\max}}| - \sum_{i=1}^{5} |H_{i_{\min}}| \right); \]  

where \( H_{i_{\max}} \) – ordinates of the five highest points of the profile;
\( H_{i_{\min}} \) – ordinates of the five lowest points of the profile;
\( R_{max} \) – maximum height of profile roughness, i.e. the distance between the lines of the protrusions and the lines of the hollows of the profile within the limits of the base length

\[ R_{max} = |H_{i_{\max}}| + |H_{i_{\min}}|. \]  

where \( H_{i_{\max}} \) – the distance from the midline to the line of the protrusions of the profile;
\( H_{i_{\min}} \) – the distance from the midline to the profile hollow line

Step parameters included:
\( S \) – average step of profile roughness along the vertices within the base length:

\[ S = \frac{1}{n} \sum_{i=1}^{n} S_i; \]  

where \( n \) – number of unit steps;
\( S_i \) – unit step values along the heights;
\( S_m \) – the average step of the profile roughness along the midline, i.e. arithmetic mean of the step of the profile roughness along the midline within the base length:

\[ S_m = \frac{1}{n} \sum_{i=1}^{n} S_{mi}; \]  

where \( S_{mi} \) – unit values of the step along the midline.

**Figure 3.** The longitudinal microrelief of the cutting edge.

The structure of the surface layers of the grinded part is shown in figure 4. The boundary layer 1 with a thickness of 2 - 3 \(^\circ\)A consists of an adsorbed film of gas, which can be removed only by heating the
part in vacuum. Layer 2 with a thickness of 2–80 Å is a loose deformed layer of oxides, nitrides, and metal decarburized by the action of high temperatures developing during grinding. Layer 3 with a thickness of about 5 microns (during abrasive grinding) consists of particles of highly deformed metal, as well as structurally free cementite released under the influence of high temperatures. Layer 4 is undeformed metal.

The methods of forming the cutting edge of thin lamellar knives, existing in practice now, create initial microgeometry parameters that are far from optimal. This leads to the fact that the entire period of durability or a significant part of it, the tool works in the burn-in wear mode, characterized by intense chipping of individual sections of the cutting edge and abrasion of the working surfaces of the tool.

Reducing brittle and fatigue chipping, as well as attrition rate, can be achieved, first of all, by improving the quality of sharpening and finishing, which allows to reduce the roughness of the active contour of the blade and, as a result, to reduce the coefficient of influence of stress concentration and to ensure a roughness close to equilibrium.

![Figure 4. Structure of the surface layer of the bevel of a knife.](image)

The following quality indicators are available for inspection under production conditions: sharpening angle, uniformity of width, straightness of the cutting edge, depth of chipping, absence of cracks on the cutting edge, sharpness of knives.

The point angle is measured with a goniometer of any design with an accuracy of 1°. Non-straightness of the cutting edge can be seen in the form of concavity, convexity and waviness. When checking the straightness, the knife is applied with a cutting edge to the control ruler and the largest clearance is measured with the probe.

Checking of sharpened knives is a necessary condition for timely elimination of shortcomings in sharpening and finishing, further improving their quality, as well as it is a mean of monitoring the condition of the knife grinder. The frequency of the inspection depends on the specific conditions of production and the organization of the grinding work.

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