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Justification Of Edge Sharpness.

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ABSTRACT

When performing technological processes in agricultural production, it is necessary to separate the source material into parts. This is done by the working bodies, which are in the form of blades for grinding materials and separation by impact, as well as in the form of a wedge for various operations of soil cultivation and metal processing. Of the main parameters of the blade, the most important is the sharpness of its edge δ. This parameter has a significant effect on the energy intensity of the process, as well as on the quality of the surface obtained. But at present there is no unanimity on the assessment of this parameter. The most common are 5 methods for estimating the blade edge, four of which assume that its profile has the shape of an inscribed circle with the parameters δ_1, δ_2, δ_3, δ_4 numerically determining this value. But in fact, in all cases, not an arc, but a chord of an inscribed circle, is taken as the sharpness of δ. This assumption distorts the physical picture of the contact interaction of the blade with the material, especially when considering a blade with a large value of δ. In calculating the actual destructive stresses in the contact of the working element and the material, the value that estimates the sharpness of the blade, in our opinion, should be expressed not by the length of the chord, but by the length of the arc that comes into contact. The performed studies show the sharpness of the blade sharpness δ = 0,5r. The obtained dependence can reduce the error in calculating the energy parameters in 1.8 ... 15.2 times depending on the central angle of the blade.

Keywords: blade, edge sharpness, cutting force.

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INTRODUCTION

When performing almost any technological process in agricultural production, it is necessary to divide the source material into parts. This type of operation is carried out by the working bodies, which directly interact with the material being processed and form the final result. Depending on the functional purpose, they can be in the form of blades for grinding materials and separation by impact, as well as in the form of a wedge for various operations of soil cultivation and metal processing [1].

Of all the geometric parameters of the blade in a plane perpendicular to the cutting plane, the sharpness of the edge наиболее is most important. This is due to the fact that when the cutting tool interacts with the material, this parameter has a significant effect on the energy intensity of the process, as well as on the quality of the cut surface obtained [2, 3, 4]. But there is no consensus on the assessment of this parameter.

MATERIALS AND METHODS

When measuring the geometry of the blade, it is assumed that its profile has a shape into which a circle with parameters δ_1, δ_2, δ_3, δ_4 estimating the numerical value of sharpness can be inscribed (Figure 1).

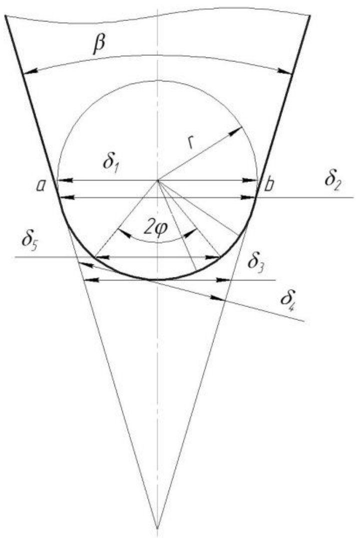

Figure 1: Scheme for determining the sharpness of the blade edge δ

In their works, many scientists [3, 5, 6] propose the sharp edge radius δ_1 for the sharpness of the blade, indicating that all analytic expressions of this parameter (Table 1) almost equally characterize each other. Also, there are recommendations for the sharpness of the blade to take the chord δ_2, pulling the arc at the points of contact of the chamfers of the blade with the inscribed circle. V.P. Goryachkin suggested measuring the sharpness of the blade with a segment δ_3 of the tangent to the inscribed circle perpendicular to the bisector, cut off by the lines of chamfer continuation. The sharpness of an asymmetrically worn blade N.V. Klementyev suggests measuring by a tangent segment v to the inscribed circle perpendicular to the line of continuation of the least worn chamfer. In turn, V.A. Zheligovskii proposes to measure the sharpness of the blade with a chord δ_5, pulling down the arc of the central angle of the inscribed circle, equal to two angles of friction 2φ.

Table 1: Edge blade parameters, taken as the sharpness index

Parameter δ_i	Formula for parameter definition δ_i	Absolute value in µm at r = 50 µm	Index β and φ
Double arc radius of blade edge	$\delta_1 = 2r$	100	β = 30°
Chord edge edge blades	$\delta_2 = 2r \cdot \cos\frac{\beta}{2}$	96,59	
The segment of the tangent to the blade edge perpendicular to the bisector of the grinding angle, limited by the continuation of its chamfers	$\delta_3 = 2r\frac{1-\sin\frac{\beta}{2}}{\cos\frac{\beta}{2}}$	76,7	
The segment tangent to the edge of the blade perpendicular to the least worn out chamfer	$\delta_4 = r\left[1 + tg\frac{(90-\beta)}{2}\right]$	78,87	
Chord, pulling an arc of a double angle of friction of the material about the edge of the blade	$\delta_5 = 2r \cdot \cos\varphi$	66,9	φ = 42°

In all the cases considered, the chord of the inscribed circle is taken as the sharpness of δ. This assumption in our opinion is not legitimate, especially when considering a blade with a large value of δ, as the physical picture of the contact interaction of the blade with the material is distorted.

When the working element interacts with the material, lateral and longitudinal deformations develop in it. For a rod, according to the theory of impact, V.P. Goryachkin [2], transverse deformations cause its bending. As a result, if we accept the existing interpretation of the severity of the blade as a chord, then under its base a space is formed that redistributes the pressure from the entire contact area to the limited parts of the blade. The cutting force is transmitted by points with both a chamfer and a free-cutting blade. Reaction forces arising from the resistance of the material with repeated contact, wear edges at these points, and the blade acquires a rounded shape. In this case, wear should be accompanied by an increase in sharpness of the edge, which in practice does not occur. Hence, in calculating the actual destructive stresses in the contact between the working element and the material, the value that estimates the sharpness of the blade, in our opinion, should be expressed not by the length of the chord, but by the length of the arc that comes into contact.

RESULTS AND DISCUSSION

Let us consider how the conditions of the cutting process will vary depending on the accepted parameter of blade sharpness presented in the work of N.E. Resnick [3]. For this, the initial acuity is taken δ_1=100 µm, and the remaining variants of the values of this parameter, we represent in fractions of it. Then δ_2 = 0,97δ_1, δ_3 = 0,767 δ_1, δ_4 = 0,789 δ_1 and δ_5 = 0,669 δ_1 respectively. Destructive contact force σ_d, arising at the edge of the blade, is defined as the ratio of the force applied to the knife P_{cut} to the area F_{ed} blades in contact with the material:

$$\sigma_d = \frac{P_{cut}}{F_{ed}} = \frac{P_{cut}}{\delta \cdot \Delta l},$$

where Δl – blade length equal to one, m; δ – edge sharpness, m.
Let us assume that in all experiments the cutting force remains constant P_{cut} = *const*, when

$$\sigma_d = \frac{P_{cut}}{\delta}.$$

The obtained values of tension σ_d are presented in table 2.

Table 2: Implications of the edge sharpness of the blade and the breaking contact voltage

	δ_1	δ_2	δ_3	δ_4	δ_5
δ_1	100	96,59	76,7	78,87	66,9
δ_i/δ_1	1,0	0,966	0,767	0,789	0,669
σ_{pi}	σ_{p1}	$1{,}034\sigma_{p1}$	$1{,}233\sigma_{p1}$	$1{,}267\sigma_{p1}$	$1{,}495\sigma_{p1}$

From Table 2 it follows that the difference in voltage values reaches 49.5% for parameter δ_5 in comparison with δ_1. In our opinion, this difference in results is essential in determining the cutting force. Therefore, in order to correctly assess the sharpness of the blade, it is required to further clarify and refine the choice of the analytical expression for its definition. This is especially important when choosing approaches to improving the efficiency of technological operations from the position of key processes that are united by a single final objective function [1]. Then the validity of the received indicators will be determined by the difference between the length of the arc and the length of the chords to which it relies.

As noted above, the length of the arc that contacts the material should serve as an estimate of the severity.

To establish the difference between the chord and the length of the arcs, known mathematical dependencies were used:

$$l = 0{,}01745 r \cdot \alpha$$

$$a = 2r \cdot \sin\alpha/2$$

where l – arc length, m; a – chord size equal to δ, m; α – value of the angle on which the chord of the circle rests, deg; r – radius of inscribed circle, m.

Table 3 shows the values of the parameters α, l and a in fractions of the radius r and their ratio as a function of the central angle α.

Table 3: The values of the parameters α, l and a in fractions of the radius r

α	10°	20°	30°	40°	50°	60°	70°	80°	90°	180°
l	0,174r	0,349r	0,523r	0,698r	0,872r	1,047r	1,221r	1,396r	1,571r	3,14r
a	0,174r	0,343r	0,517 r	0,684r	0,845r	1,0r	1,147r	1,285r	1,414r	2r
l/a	1,0011	1,0049	1,0114	1,0205	1,0323	1,0470	1,0648	1,085	1,110	1,57

According to the obtained data, a graphical dependence of the change in arc and chord magnitude on the value of the central angle in fractions of the radius of the circle, indirectly characterizing the severity of the blade, was constructed (Fig. 2).

Postponing the obtained values δ_i and determining the corresponding values l_i along a curve $l/a = f(\alpha)$ we find the degree of increment of the value of the arc l from the chord a, regardless of the value of the radius r of the inscribed circle, which limits the contour of the blade. Considering from this position the difference between the chord a and the arc length l, in determining the sharpness in terms of the parameters δ_1 and δ_2 we obtain the relation $l_1/a_1 = 1{,}57$ and $l_2/a_2 = 1{,}355$.

If you take the sharp edge of the blade δ_3 or δ_4, then this corresponds to the angle $\alpha_3 \approx 100°$ and $\alpha_4 \approx 104°$. The difference of relations $l_3/a_3 = 1{,}138$, and $l_4/a_4 = 1{,}151$, those within 13,8…15,1%. Such a value of the value proposed to determine V.P. Goryachkin.

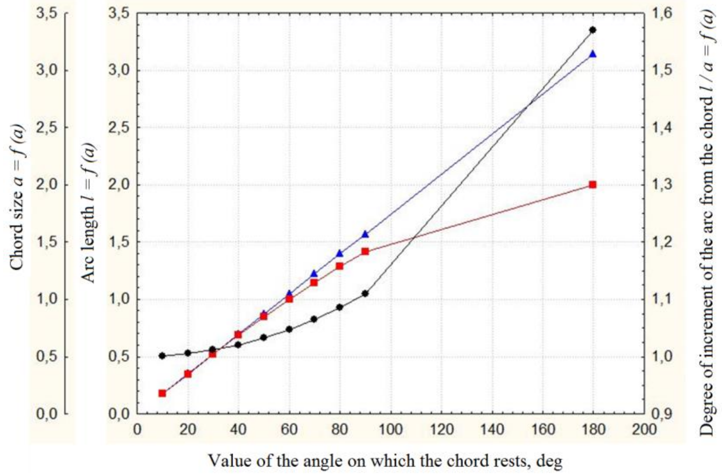

Figure 2: Dependence of the change in arc and chord magnitude on the value of the central angle in fractions of the radius of the circle

V.A. Zheligovsky proposed to determine the magnitude of the severity of the expression δ_5. For this example, the relation l_5/a_5=1,095 and corresponds to the central angle of the circle α_5=84°, that the dependence is equal to the two angles of friction of the material 2φ. The difference in the initial values is 9.5%.

Analysis of the obtained data and graphical dependencies presented in Figure 3 show that when choosing the criterion for estimating the sharpness of the blade, the statement of N.E. Reznik that this parameter should not be dependent on the physical and mechanical properties of the material and on the working conditions of the blade.

In our calculations it is recommended to take the sharpness value in the form of a chord or an arc enclosed between the central angle α, value of which does not exceed 30°. In this case, the growth rate of the arc and chord is most similar, and the discrepancy between these values is 1.14%.

In the final version, we can write down the refined dependence for determining the sharpness of the blade in the following form:

$$\delta = 0{,}5r. \qquad (3)$$

The acceptance of such a value for the true magnitude of the sharpness of the blade is fully justified, especially when considering the cutting processes of agricultural materials, the working surfaces of which differ in significant variations in the shape and roughness parameters, and this parameter will allow more accurate determination of the duration of effective operation of modern cutting and cutting machines.

CONCLUSION

Thus, the presented analytical studies due to the sharpening of the sharpness of the blade, allow to reduce the error in calculating the energy parameters in 1.8 ... 15.2 times depending on the central angle of the blade.

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