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Theoretical study of the disc chopping apparatus of the feed chopper

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Abstract. The paper presents the results of a study in the kinematics and dynamics of a multi-blade disc cutting device. In the advanced hardware scheme, the clipping process is performed as punches. We have a straight blade edge rotated 20^0 degrees back from the radial direction. As a result, the sliding motion process is reduced and the trunk is easily cut. For this reason, it is advisable to reduce the sliding process when cutting a hard stem, and it is preferable that the blade be made in the form of a hyperbolic spiral, and not an Archimedes spiral, the curvature of which is directed towards the stem, and not in a straight line.

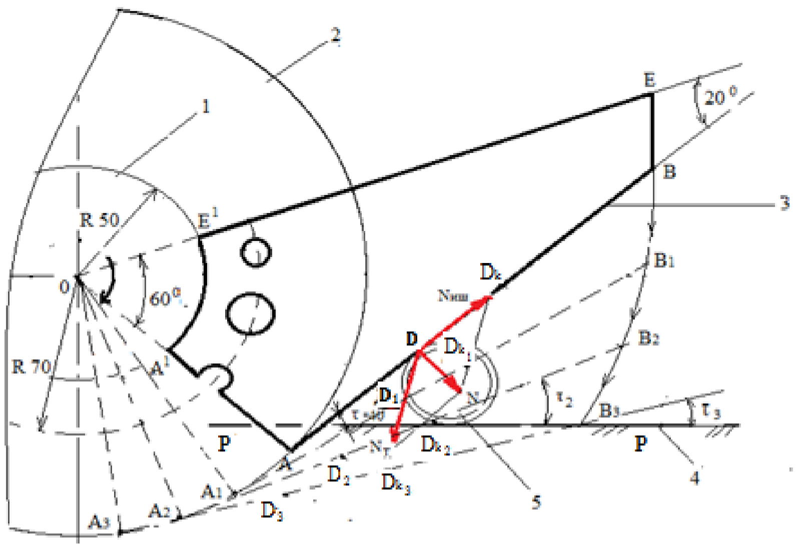
Kinematic and dynamic studies performed on a multi-knife disk shearing device accelerate the technological process of the device, increase the pressure of the blade on the trunk, and make it possible to cut it intensively.

1. Introduction

At present and in the near future, the main method of processing feed raw materials for animal husbandry will be mechanical. At the same time, the effectiveness of various methods of feed processing (grinding, cutting, crushing, etc.) depends on the most convenient use of the physical and mechanical properties of the crushed raw materials when choosing operating modes and parameters of the corresponding working bodies of machines and mechanisms. Studies of the physical and mechanical properties of fodder crops and the process of their grinding can be the basis of the works of a number of scientists [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, etc.].

2. Object and methods of research

On figure. 1 shows a diagram of the active knife 3 installed on the disk 2 of the grinding apparatus. This shows the position of the insertion of the active blade *A-B* into the gap of the fixed knife blade *P-P*.



1-drive shaft; 2-disk; 3-blade of the active knife mounted on the disk; 4-blade fixed knife; 5-initial position of the stem pinched between the blades

Figure 1. Scheme cutting a pinched stem between a fixed knife and an active knife *A-B-E-E^1-A^1* of the chopping apparatus

The angle between the blades is t=40^0, and the conditions being cut to the stem 5 are clamped in it, since the angle τ is less than the sum of the angle of friction φ_1 between the stem and the active blade and the angle of friction φ_2 between the fixed blade and the stem, that is, $t<\varphi_1+\varphi_2$.

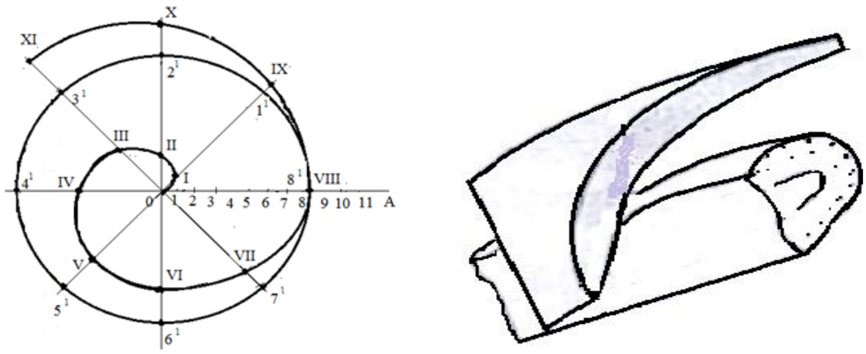
Due to the rotation of the active blade *A-B* around the center O, it sequentially assumes the position A_1-B_1; A_2-B_2; A_3-B_3. As a result, the stem slides along the blade *A-B*, cuts the bark of the stem and grinds the internal soft substances. After position A_3-B_3, the knife continues to rotate at idle and again returns to position *A-B,* the cycle repeats.

Above it was determined that the coefficient of friction on steel is lower by $\Delta\varphi$=3-4^0 due to the fact that the shell of the lower root part of the corn stalk grown in the hot weather conditions of our republic is more solid compared to the stalk ripened in European conditions.

If such a part of the stem is not immediately cut off when meeting point *D* of the knife, the knife blade slides along the surface of the stem and cuts the bark fibers one by one, like a conventional saw, creating conditions for plunging the blade into the stem and crushing it until it reaches position A_3-B_3, The stem is cut off part D-D_k of the knife blade will reach the position D_3-D_{k3}. At the point *D* of the stem, the forces N_{work} and $N\tau$ act, resulting in the offset of the action of the pressure force *N.*

The reason for the change in the shape of the knife blade is that the angle of friction of corn stalks grown in hot and dry climates is 4° less than that accepted in the literature. A stem like in Figure. 1, is pinched at τ_1=36^O instead of τ =40^O , that is, instead of the blade part D- D_κ, another part located far from the center of rotation 0 works. The lever of force *N* will be greater relative to 0, the required moment M^1b will be greater than in the first case, it will be consume more power. Therefore, we came to the conclusion that it is better to change the shape of the *D-B* section of the knife blade: the section *DB* of the knife blade after point *D* should be slightly bent towards the rod, and not be straight. Then pinching the stem is not tightened, the length of the blade will be used effectively.

In literary sources, scientists such as Melnikov S.V., Reznik N.E. [3, 4] recommended that the shape of the blade be made the optimal part of the Archimedean spiral. A. A. Vertiy [6] made a knife in the shape of an Archimedes spiral and tested it (Figure 2). The curvature of the blade is based on a full Archimedean helix, which suddenly reduces the sliding cut of the blade.



а *в*

a-standard Archimedean spiral; in-examined knife

Figure 2. Spiral of Archimedes and view on the base of his made knife

We believe that it is better to make the part of the knife blade *AD* (Figure. 1) effectively proven by many years of practice straight and keeping the inclined part by 20° in the radial direction *O-E*, only the *D-B* part to be made curvilinear. We believe that a hyperbolic spiral, rather than an Archimedes spiral, is effective for such a solution.

In figure 3, the hyperbolic spiral is drawn using a circle whose radius is equal to the radius of the disk on which the knife is mounted. The goal is to select a specific part of this curve as the shape of the knife blade._We chose its part *A-C-B*, and we believe that in this form it will be effective to use the chopper knife blade, since the straight line *A-C*, tending to the asymptote of a hyperbolic spiral, overlaps the part of the blade *A-D* in Fig. 1 that after the point *D*, the part *D-B* will be replaced by the curvilinear part of the spiral *C-B*. Most importantly, the degree of curvature of S-V does not change sharply relative to the straight line *A-C*, the tangent drawn through the point V is inclined by 4° relative to the asymptote. This is consistent with our goal of reducing the blade slip angle to 4° [6].

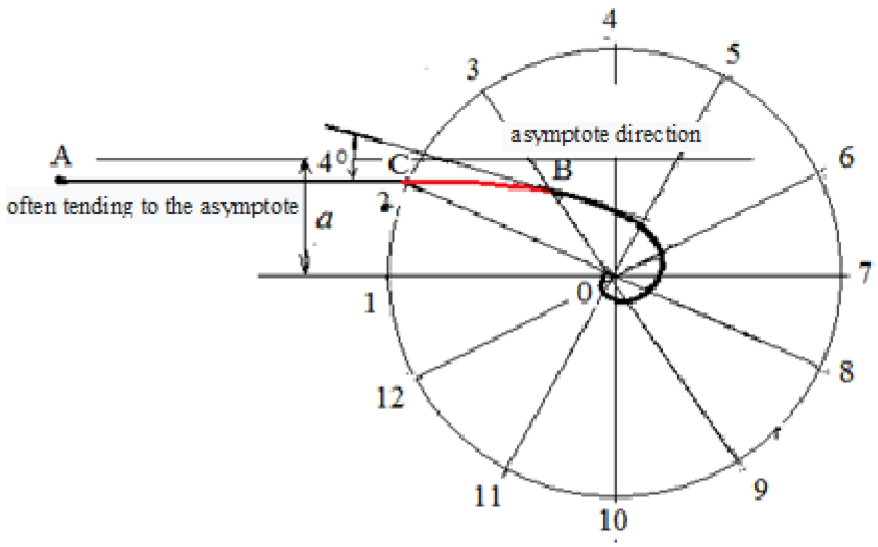


Figure 3. Scheme for constructing a curved line *A-C-B* of a hypervolic spiral

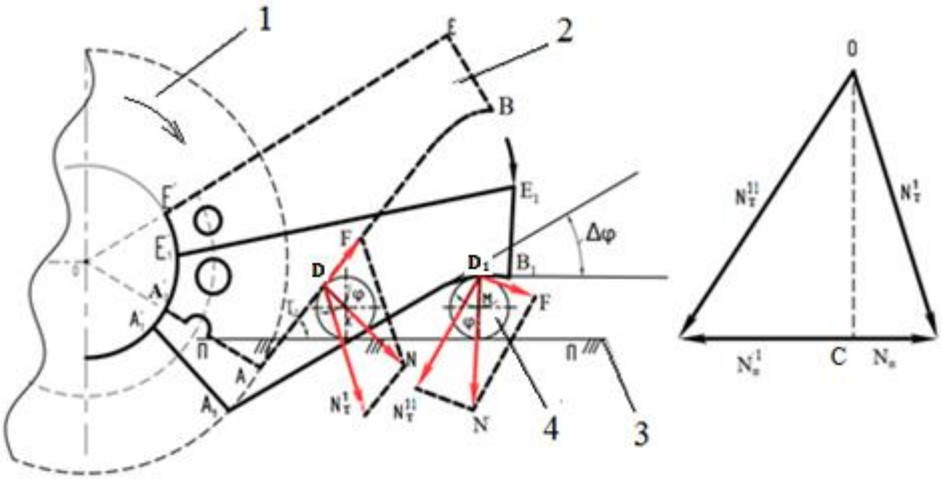
The hyperbolic spiral shape occurs when a point moves in a straight line in a circular motion, and its distance from the center of rotation varies inversely with the angle of rotation. The angle of rotation is defined relative to the starting radial line. The spiral equation is taken as $r\varphi=\alpha$. Here α is the distance of the spiral asymptote line from the center of rotation; φ-angle of rotation; r - radial arm of the point position.

For the initial case $\varphi=0$, naturally $r=0$. The asymptote line B-C is drawn from the center at a distance a parallel to r_1 (Figure 4). Point 0 is the asymptotic point of the spiral where the curved line can never reach. A circle is drawn around 0 plus the pole, which is divided into several equal parts and denoted by 1,2,3 ... and radial lines are drawn from the pole. In radial lines, the radii r_1, r_2, r_1... are calculated using the formula $r_i = \frac{an}{2\pi(i-1)}$. In this case, n is the number of parts divided around the circle; i-number of the next radius. For example, $r_1=\infty$; $r_2=\frac{an}{2\pi}$; $r_3=\frac{an}{4\pi}$ etc. With the help of radii, points I, II, III, IV and ... X of the spiral are indicated and they are connected by a curved line.

If the part E-B of the improved knife is replaced by the improved blade with the E_1-B_1 curve, the technological process performed by the knife will practically not change (Figure 4).

3. Research results and discussion

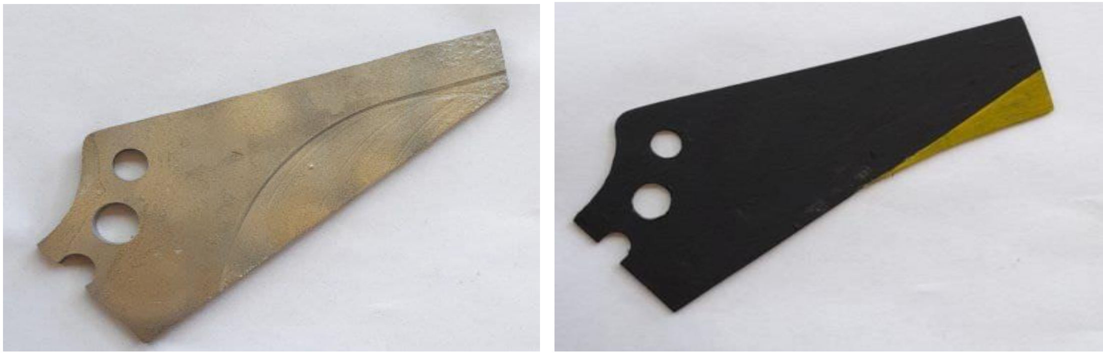
Figure 4 schematically shows the forces on the blade AB of the improved knife acting on the stem being cut. Normal pressure N (represented by dotted lines) that compresses the stem at point D on the straight part of the blade. It depends on the friction force F and the sum of the forces N and F, i.e. forces Nt, which are directed against the movement of the blade along the barrel. We assume that the stem should be pinched on the blade to point B. If we find the projections of the force vectors N_T^1 and N_T^{11} on the straight line connecting their ends, then it can be seen that the projection $N_п^1$ is longer than the projection $N_п$.



1-disk; 2-active knife; 3-fixed knife; 4-stalk sandwiched between blades

Figure 4. Scheme of forces acting on the blade of an improved knife

Figure 5 shows a drawing showing the difference between an improved knife made according to the results of research and between a real knife of the IKV-F-5A machine.



a) *в)*

a-blade of an existing knife; *в* -blade of an advanced knife

Figure 5. Drawing indicating the difference between the improved knife made according to the results of research and between the real knife of the IKV-F-5A machine

Therefore, it can be concluded that the stalk will pinch, stopping before the end of the blade B_2. Therefore, more slippery stems will not come off the fixed knife without being crushed, which has a positive effect.

4. Conclusions

The shell of the lower part of the corn stalks grown in the hot and dry climate of our republic is hard, and the friction angle with steel is 3-4^0 less than that accepted in the literature. In order to make the sliding cutting process more efficient with less energy consumption, it is recommended to change the blade shape of the moving knives.

Kinematic and dynamic studies performed on a multi-knife disc grinder made it possible to determine the parameters that must be taken into account to improve the grinder technological process.

Improving the shape of the chopper knife of the machine in the form of a hyperbolic spiral accelerates the process of sliding cutting, increases the pressure of the blade on the stalk, makes it possible to intensively chop it.

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