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Reducing the energy capacity of the cutting of stem fodder

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Abstract. In the paper provided efficiency analysis different types of feed processing with purpose decreasing energy use in cutting stalk crops and creating appropriate cutting units, also study results in assescment energy use in cutting with a rectangular knife and received formulation cutting strength change, the results of a change of knife for case in cutting of pre-bend stalk of various sizes. Results of theoretical research of catting work, the tensile stress of the upper fiber, stresses on the blade of the knife which is necessary for the destruction of the fiber. The use of pre-bending during the cutting of cutter material reduces the cutting work in comparison with the cutting work is 201.12 N cm this is compared to the chopping 290 N cm reduces cutting performance by 35.05 percent.

1. Introduction

The technological processes of feed processing are based on metal-consuming and energy-consuming machines. Preparing feed for feeding significantly increases the nutritional value, eatability of feeds, and animal productivity, which creates a significant economic effect in the production of livestock products. There are problems in solving such problems: the intensification of the grinding process, reducing energy costs, hardening of the working bodies. The creation of highly effective, competitive means of small-scale mechanization for the preparation of feed on small commodity farms is one of the urgent tasks in the field of mechanization of agricultural production of the Republic of Uzbekistan.

At the same time, the effectiveness of various methods of processing feed (crushing, cutting, etc.) depends mainly on the ability to best use the physical and mechanical properties of the feedstock in the development of parameters and operating modes of the corresponding working bodies of machines and equipment.

Features of the architectonics of plant raw materials, pronounced anisotropic properties, the presence of intercellular moisture, the nonlinearity of strength characteristics, and their dependence on high-speed loading conditions determine the complexity of the description of deformation processes.

The study of the physicomechanical properties of agricultural materials has been the subject of a large number of works in the main experimental plan. Fundamental include the works of Rittinger P.R., Goryachkin V.P., Zheligovsky V.A., Rebinder P.A., Gutiar E.M., Reznik N.E., Bosogo E.S., Melnikova S.V. ., Bakhareva G.F., Demidova A.R., Eliseeva V.A., Kukty G.M., Kupritz Y.I., Leontiev P.I., Rumpf G., Sablikova M.V., Alijanova D [1 – 18].

A large number of works are known on particular aspects of deformations and strength characteristics of agricultural materials, various methods and processes of cutting, crushing, pressing, etc. A distinctive feature of them is that they were carried out concerning a pre-selected working body and method of processing the material. A very promising area is the direction of modeling the processes of deformation and fracture of materials. For example, in the works of Reznik N.E.

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considered in general terms, the methodology of modeling the process of compression of a material by applying mechanical analogs of deformations ("Hooke body", "Maxwell body", "Kelvin body", etc.).

This approach, with various combinations of mechanical analogs, allows one to model the deformation of materials with rather complex combinations of elastic-viscous-plastic properties, while the mathematical interpretation of the processes is greatly simplified. A high theoretical level is distinguished by work in the field of mathematical physics, devoted to the study of complex stress states of various solids. It should also be noted the inadequacy of work on modeling deformations of stem and grain materials, the results of which are presented in the form of probabilistic models.

The lack of work also on the study of the strength characteristics of the main types of feed, their narrow focus does not allow to obtain a complete and clear picture of the processes of deformation and fracture. This situation creates significant difficulties in improving the working bodies and processes of feed preparation machines, and developers are forced to focus more on intuition and hebrew abilities than on accurate analytical methods.

The solution to the urgent problem is possible by conducting fundamental theoretical and experimental studies of the processes of deformation and destruction of feed materials that prevail in the existing feed diets of animals.

One of the urgent problems for the farm is the electro mechanization and automation of labor-intensive processes on farms. In a market economy, the most promising developments and the creation of individual samples of shredders with low power consumption. When cutting with a blade, great efforts and energy intensity of the cutting process arise due to the significant amount of breaking stress on the knife blade and the efforts of the material to compress the edges of the knife. The proposed studies are aimed at reducing the energy intensity of the process of cutting stem materials.

In [18, 19], the problems of obtaining the stress equation of a cantilever-bent rod of the rectangular cross-section were considered, which made it possible to determine the amount of bending to ensure the cutting process with a knife without violating the elastic properties of the material. This work is a continuation of them and is aimed at assessing the energy intensity of the cutting process. In the theoretical part of the study, methods of mathematical modeling and analysis, statistical processing of research results are applied. To study the influence of stem bending on cutting work, we have compiled a computational rule implemented on FDA in the MATLAB system.

2. Methods

First of all, we will evaluate the maximum work of cutting a rod of the rectangular cross-section with a knife moving at low speed, which allows us to consider the process as static.

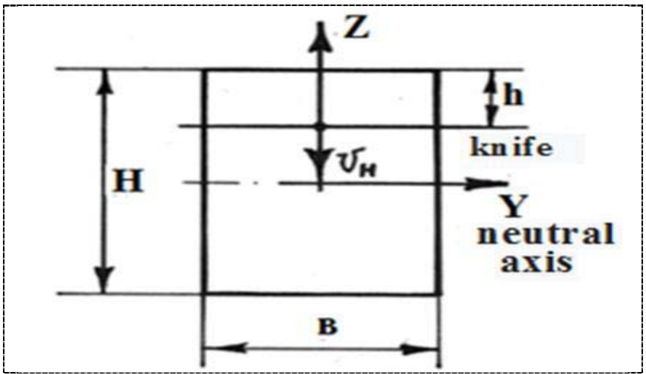

Figure 1. To determine the maximum cutting performance

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Following [13], we take the elastic modulus $E = 3300\ \mathrm{H}/cm^2$ and the tensile stress of the fiber $\sigma_{max} = 1450H/cm^2$, which corresponds to the stalks of corn. Having adopted H = 5 cm, b = 4 cm, the blade thickness $\sigma = 100\ mk$, we obtain the maximum possible cutting work

$$A_{max} = b \cdot H \cdot \delta \cdot \sigma_{max} = 2.9Dj \quad (1)$$

If cantilever bending of the rod relative to the cutting plane is performed, then a tensile stressσ_p, occurs in the upper fiber, which reduces the stress necessary for breaking on the knife blade (Fig. 2)

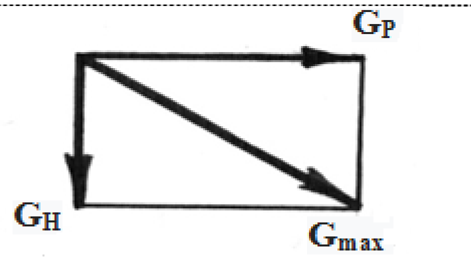

Figure 2. To the determination of the voltage on the knife blade σ_H necessary for the destruction of the fiber

$$\sigma_H = \sqrt{\sigma_{max}^2 - \sigma_P^2} \quad (2)$$

If at the beginning of cutting apply the limiting limb of the rod

$$f_{max} = \frac{P_{\text{от}} \cdot l^3}{3EJ} \quad (3)$$

where P_{ot} is the bending force applied at the end of the cantilever with its length l, which provides a stress σ_{max} in the outer fiber;

E is the modulus of elasticity $P_{\text{ot}} = \frac{\sigma_{max} \cdot J}{l \cdot z}$ (4)

here $z = \frac{H}{2}$ is the distance from the neutral axis OY to the outer fiber;

$J = \frac{bH^3}{12}$ is the moment of inertia of the section

If during the cutting process the bending value is not changed, i.e. take $f_{max} = const$, then from (3) and (4) we get

$$\sigma_P = \frac{3 \cdot f_{max} \cdot E \cdot z'}{l^2} \quad (5)$$

here $z' = \frac{H-h}{2}$ h is the depth of the knife blade into the body of the rod, E is the elastic modulus is the same for stretched and compressed fibers.

It can be seen from (5) that in the case of cutting at $f_{max} = const$, the stretching of the upper stretched fiber varies linearly as a function of the depth of the knife h, and varies from $\sigma_P = \sigma_{max}$ to $\sigma_P = 0$. However, it can be seen from (2) that the stress on the knife blade σ is non-linear with respect to h and varies from 0 – at the beginning of the cutting process to σ_{max}- at the end of the process.

Knife blade force

$$P_H = b \cdot \delta \cdot \sigma_H$$

and cutting work, respectively

$$A_H = \int_0^H P_H dh \tag{6}$$

3. Results and Discussion

The following is a computational rule implemented on FDA in the MATLAB system [20] to study the effect of stem bending on cutting work:

$\gg b = 4; H = 5; S_m = 1450; d = 0.01; E = 3300; h = (0{:}\,0.5{:}\,5); L = 10;$ $\gg I = b * (H^3)/12;$
$\gg P_{om} = S_m * 2 * I/(L * H);$
$\gg F_m = P_{om} * \frac{L.^3}{3*E*I};$
$\gg Z1 = \frac{H-h}{2};$
$\gg S_P = 3 * F_m * E * \frac{z1}{L.^2};$
$\gg S_n = \left((S^2_{m.}) - (S^2_{P.})\right).^{0.5};$
$\gg P_P = b * d * S_n;$
$\gg A1 = 0.5 * P_P;$
$\gg sum(A1)$
ans = 239.5776

In figure 3 shows the change in cutting force on the blade of the knife during its movement from the moment of contact with the stem to the end of cutting. In the beginning, cutting at maximum bending and $\sigma_p = \sigma_{max}$in the upper fiber of the stem has a knife force $P_H = 0$, and at the end, cutting stress in the stretched fiber is $\sigma_P = 0$ and $P_H = 58H$. The nonlinear nature of the change in a curve (2) is explained by a decrease in stress σ_{max}. The straight line (1) characterizes the invariability of the cutting force $P_H = 58\,H$, because To destroy the fiber on the knife blade, it is necessary to create a voltage $\sigma_{max} = 1450$ H/sm^2.

Table 1 shows the results of calculations of the work of cutting A, tensile stress σ_P of the upper fiber, stress on the knife blade σ_H, which is necessary for the destruction of the fiber. The calculation was carried out for two cases: 1 - when cutting the stem with an initial limb $f_{max} = const$, providing the initial stress σ_{max}, that is, the beginning of cutting with a force on the knife $P_H = 0$; 2-when cutting with a limb $f = f_{max} + h$, that is, the bending is first performed at f_{max}, and then increases following the movement of the knife. In the first case, the work of cutting $A_1 = 239.5776\,H\,sm$, the second $A_2 = 201.1229$ H sm , which reduces the cutting work compared to the cutting $A_{max} =$ 290 H sm (2.9 Dj) by 22.39% and 35.65%, respectively.

Theoretically, it is possible to achieve cutting work $A_H$tending to zero if, at each position of the knife h, the tension of the stretched fiber is $\sigma_{max} = \sigma_P$. In this case

$$f = \frac{\sigma_{max} \cdot l^2}{3 \cdot E \cdot z'} \tag{7}$$

where $z' = \frac{H-h}{2}$ is the distance from the neutral axis to the maximum stretched fiber.

In the table. 1, the last line shows the results of *f* for each step of the knife movement. If we subtract the value of the previous f_{i-1} from each subsequent f_i, then we obtain the increment vector Δf, which determines the theoretical control law for the considered example:

$$\Delta f = [0; 0.640; 0.814; 1.066; 1.390; 1.950; 2.93; 4.850; 9.760; 29.230;\ \infty]$$

The full implementation of such control of the limb arrow f is, of course, impossible. The technical implementation of the control even of the Δf part is complicated. Therefore, the result obtained by a concrete example is more likely to have theoretical significance.

Figure 3 Efforts on a knife without bending (1), with a maximum bending $f_{max} = 5.85\ cm$ at the beginning of cutting (2). 3 is the nature of the difference between efforts (1) and (2).

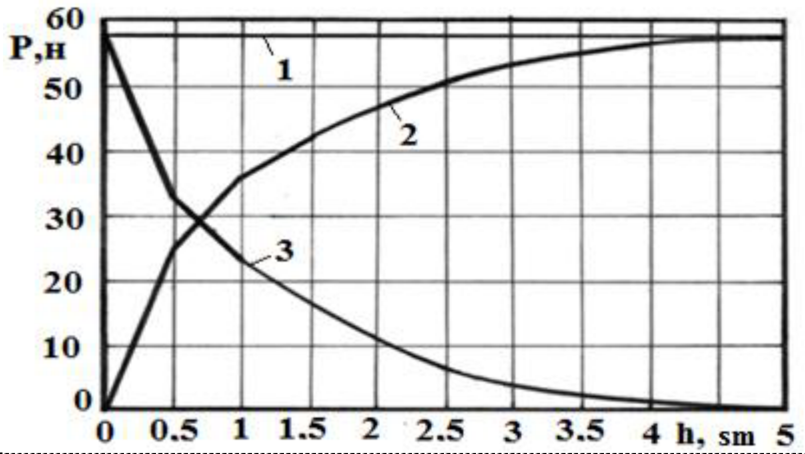

Figure 3. The force on the blade of the knife with various values of preliminary bends lower than the limiting $f_{max} = 5.85\ sm$

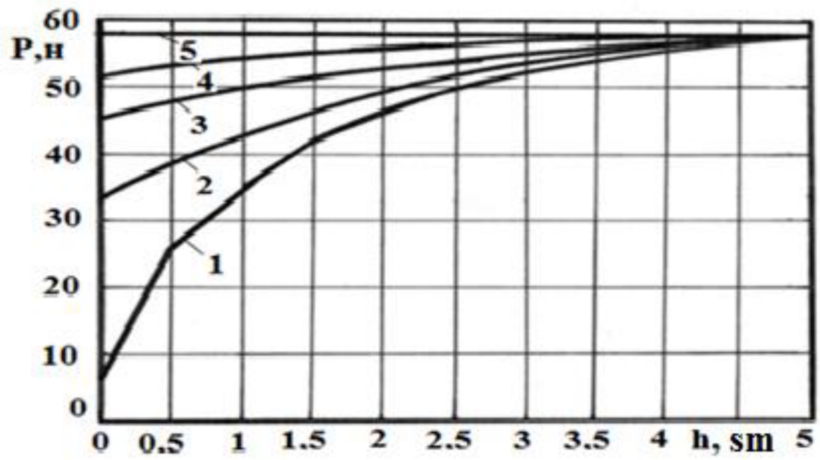

Figure 4. $1 - f = 5$ cm; $2 - f = 4$ cm; $3 - f = 3$ cm; $4 - f = 2$ cm; $5 - f = 0.0$

In this paper, we do not calculate the energy loss due to crushing the fiber of the chamfer of the knife blade from the assumption that the destructible fiber instantly restores its shape and that the fiber does not practically compress.

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Table 1. The calculation results, the tensile stress of the fiber σ_P, the required stress on the knife blade to destroy the fiber σ_H, the corresponding force on the knife blade P_H and the cutting work A when dividing the total displacement H at intervals of 0.5 cm

The position of the knife in the cutting process, cm	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
Fiber tensile stress $\sigma_{P_1} \cdot 10^3$, H/cm^2	1.45	1.305	1.160	1.015	0.83	0.725	0.58	0.435	0.29	0.145	0.0	
Fiber tensile stress $\sigma_{P_2} \cdot 10^3$, H/cm^2	1.45	1.416	1.358	1.275	1.092	1.034	0.877	0.695	0.488	0.256	0.0	
The necessary voltage on the knife to destroy the fiber $\sigma_{H_1} \cdot 10^3$, H/cm^2	0	0.630	0.870	1.030	1.16	1.25	1.37	1.38	1.48	1.44	1.45	
he necessary voltage on the knife to destroy the fiber $\sigma_{H_2} \cdot 10$; H/cm^2	0	0,310	0.510	0.690	0.86	1.01	1.15	1.27	1.36	1.42	1.45	
Effort on the knife P_{H_1}, H	0	25.780	34.8	41.4	46.4	50.23	53.2	55.2	56.2	57.6	58.0	
Effort on the knife P_{H_2}, H	0	12.40	20.40	27.64	34.4	40.64	46.18	50.88	54.6	57.08	58.0	
Work of cutting on a site 0.5 cm, $A_1, H \cdot sm$	0	12.64	17.40	20.71	23.2	25.11	26.57	27.66	28.41	28.85	29.0	$\sum A_1$=239.5776
Work of cutting on a site 0.5 cm, $A_2, H \cdot sm$	0	6.210	10.16	13.81	17.21	20.32	23.09	25.45	27.3	28.54	29.0	$\sum A_2$=201.1239
The magnitude of the limb f_1 at each step of the movement of the knife necessary to obtain $\sigma_P = \sigma_{max}$	5.86	6.509	7.323	8.369	9.764	11.71	14.646	19.528	29.29	58.59	∞	

Note: the top line corresponds to the cutting process with a constant bending value f_{max}; the bottom line corresponds to the cutting process with a variable amount of limb $f = f_{max} + h$.

4. Conclusions

For the practical implementation of the process of cutting stems with preliminary bending, it is preferable to use the second method, which gives the greatest reduction in cutting work. In the constructive plan, the chopper device with a bending device, adjustable relative to the knife, is simplified, which will allow to maximize the use of the pre-bending effect for various types of stem material.

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