Determining parameters of grinder rotor and its blades

Sh. X. Gapparov[1*] and *R. R.* Karimov[2], *R. M.* Choriyev[2], and *I. E.* Musurmonov[2]

[1]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, 100000, Uzbekistan
[2]Termez Engineering and Technological Institute, Termez, 190100, Uzbekistan

Abstract. The rotary crusher allows you to qualitatively grind pressed roughage. The authors proposed and developed an improved technological scheme of an impact crusher equipped with two beaters for dosed transfer to the grinding chamber. The impact crusher consists of a transfer chute, metering beaters, a chopping chamber, a rotor, chopping knives, fixed knives, an exit chute, a feed bin, and an electric motor. Work efficiency is determined by the following parameters: length, width, and thickness of knives, rotor speed. The purpose of the work is to substantiate the parameters of the rotor and its knives. Analytical dependencies are obtained to determine the parameters of the knife. Theoretical studies have established that the minimum length of the knife should be 6.9 cm, the width of the knife should be 50 mm, and its thickness should be 4 mm. A model for the theoretical calculation of the probability of grinding roughage of the required size within the limits of zootechnical requirements has been obtained. Based on the calculations, the probability of cutting the feed of the required size, depending on the number of rotations of the rotors, was established.

1 Introduction

Creating a solid feed base for livestock requires special attention to roughage and liquid and concentrated feeds. With the development of animal husbandry, the demand for roughage and concentrated feeds is increasing yearly. In Uzbekistan, coarse and concentrated feed is obtained mainly from wheat, soybean, corn, and safflower [1-3]. Wheat and corn grains, as well as corn cobs after grinding, are used in concentrated feed, and wheat straw and corn stalks after harvesting are used in roughage [4-6] because roughage is the most important source of feed protein for livestock [7-10].

In Uzbekistan today, due to the lack of small-sized grinding devices for grinding pressed and other forms of feed for small farms, feed is fed to livestock without grinding. In some farms, feed grinding is done using manual feed grinding machines due to the lack of grinding machines. Due to these feed grinding machines' high power, metal, and material volume, their use dramatically increases energy consumption and other costs [11-17].

*Corresponding author: shokir_gapparov@mail.ru

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The above-mentioned shortcomings indicate the need to develop an efficient and energy-efficient crushing device for crushing pressed roughage for small farms, especially for crushing press-harvested pods. Since the number of cattle in peasant and family livestock farms is small, a small-sized, medium-capacity crusher is sufficient [18-23].

The type, quantity, mutual orientation, sharpness, resource, and other parameters of the rotor and stator flutes of a horizontal impact crusher have a key effect on the quality side of grinding, which determines the final efficiency of this technological process in modern feed production. Zhang M, Sword M L, Buckmaster D R, Sadri H, Ghorbani G R, Alikhani M, Babaei M, Nikkhah A, Ferreira F A, Passini R, Borgatti L M O, De Souza R T Y B, Meyer P M, Rodrigues P H M, and others carried out scientific research abroad on methods of grinding coarse feed, creating devices, researching their performance and justifying their parameters [24-26].

2 Materials and methods

Based on the study of the construction and technological work processes of various types of grinders used in coarse feed grinding, the following technological scheme of the improved pressed coarse feed grinder was developed (Figure 1).

The technological operation of the device is as follows: the pressed coarse feed intended for crushing 1 move freely through the transfer chute 2 and falls on the transfer biters 3. The first pair of conveying biters 3 separates the necessary amount of pieces from the incoming pressed coarse feed with the help of its plates, and with the help of the second pair of biters rotating towards itself; it conveys the feed to the crushing chamber 4 at a certain speed.

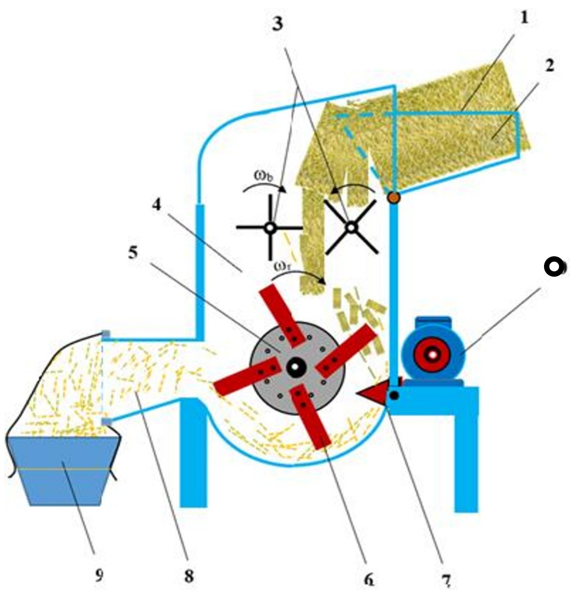

Fig. 1. Technological scheme of feed grinding machine: 1 is pressed coarse feed; 2nd transmission line; 3 is standard transmission bits; 4 is grinding chamber; 5 is rotor; 6 is grinding blades; 7 is fixed blades; 8 is product output channel; 9 is food container; 10 is electric motor.

The coarse feedstuffs entering the grinding chamber are covered by the blades 6 installed on the rotor 5 and are crushed by passing through the space of counter-sharp blades 7. Under the influence of the rotor blades and the airflow created by their rotation, the crushed mass moves towards the exit chute 8, and through it, it goes out and falls into the feed tank 9.

The device's standard transmission bits 3 and rotor 5 are driven by the electric motor 10 with belt and chain transmissions.

To conduct pilot tests of the device according to the developed technological scheme, a pilot copy of the device was prepared and economic tests were conducted.

3 Results and Discussion

The parameters of the grinder rotor blades are of great importance when grinding coarse feed. The main parameters of the blade are its length $l_п$, width bп and thickness δп (Fig. 2).

Grinder blades consist of sharp and blunt parts, and we define the active ΔS part of the blade.

$$\Delta S = z l_{c.f} \quad (1)$$

where z is the number of revolutions of the rotor required to crush the straw mass in the required dimensions; $l_{c.f}$ is the length of the piece of coarse feed being sent for grinding, m.

$$l_{c.f} = V_{t.s} t_{t.t} \quad (2)$$

where $V_{t.s}$ is transmission speed, m/s; $t_{t.t}$ is transmission time, s.
The feed rate depends on the biter speed, which can be determined as follows

$$V_{t.s} = k_m R_b \omega_b \quad (3)$$

where k_m is slip coefficient; R_b is biter radius, m; ω_b is biter angular velocity, s^{-1} .

For the convenience of calculations, we assume that the feed transfer time is equal to the time of one exchange of the rows of the rotor blade:

$$t_{t.t} = \frac{\varphi_n}{\omega_p} \quad (4)$$

where φ_n is the angle between the rows of blades on the rotor, radian; ω_p is the number of revolutions of the rotor, s^{-1}.

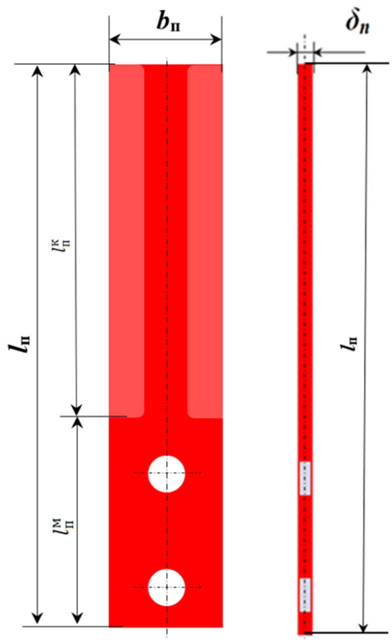

Fig. 2. Diagram of blade dimensions

The angle between the rows of blades on the grinder rotor is determined as follows

$$\varphi_n = \frac{2\pi}{z_n} \tag{5}$$

where z_n is the number of rows of blades in the rotor.

Then, according to (3), (4), and (5), expression (2) means

$$l_{c.f} = \frac{2\pi k_m R_b \omega_b}{\omega_p z_n} \tag{6}$$

If $k_m = 0.4 \div 0.5$; $R_b = 0.08$ m; $n_b = 240 \div 350$ r/min; $\omega_b = 25.1 \div 36.7$ s^{-1}; $n_p = 1600$ r/min; $\omega_p = 167.7$ s^{-1}; $z_n = 4$; $z = 2 \div 5$; taking into account that it is in the range, $l_{\partial.o.} = 0{,}008 - 0{,}014$ m the piece of coarse feed being sent to grinding is $\Delta S = 0.015 \div 0.069$ m, and the active part of the blade of the grinder is $\Delta S = 1.5 \div 6.9$ cm.

It can be seen that the length of the cutting part of the knife is required to be greater than $l_{к.п.} \geq 6.9$ cm.

The grinder rotor is required to grind coarse feed in size specified by zoo technical requirements. Suppose, on demand, it is necessary to cut the stem into a length of $\Delta_к$ cm. How many rotations of the bladed rotor must be made to do this job with 99% reliability?

We determine the probability that the stalk will be cut to the required size in one rotation of the blade rotor. The left-hand blade cuts the stem between two adjacent blades at point A. The other end is located at point *B* and at a distance *BC* from the left blade.

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We find the probability for the point *B* that the cut stem piece *AB* is of the required size. If it's $\Delta_k \geq \Delta_n$, it should be $AB \leq \Delta_k$. It, in turn, has $\beta = \arccos\frac{BC}{AB} \leq \arccos\frac{BC}{\Delta_k}$

In this case, if we specify BC=X, the required size is found as follows

$$P(AB \leq \Delta_K) = \frac{\arccos\frac{x}{\Delta_k}}{\pi/2} \tag{7}$$

For all locations of point B, that is, when point B is located at all points from point C to point D, that is, the total probability can be determined as follows.

$$p = \frac{\int_0^{\Delta_n} \frac{\arccos\frac{x}{\Delta_k}}{\pi/2} dx}{\Delta_n} = \frac{2}{\pi\Delta_n}\int_0^{\Delta_n} \arccos\frac{x}{\Delta_k} dx \tag{8}$$

We will make the following $\frac{x}{\Delta_k} = y$ replacement.

$$p = \frac{2}{\pi\Delta_n}\int_0^{\frac{\Delta_n}{\Delta_k}} \arccos y dy \cdot \Delta_k = \frac{2\Delta_k}{\pi\Delta_n}\left(y\arccos y - \sqrt{1-y^2}\right)\Big|_0^{\frac{\Delta_n}{\Delta_k}} =$$

$$= \frac{2\Delta_k}{\pi\Delta_n}\left(\frac{\Delta_n}{\Delta_k}\arccos\frac{\Delta_n}{\Delta_k} - \sqrt{1-\left(\frac{\Delta_n}{\Delta_k}\right)^2} + 1\right) = \frac{2}{\pi}\left(\arccos\frac{\Delta_n}{\Delta_k} - \sqrt{\left(\frac{\Delta_k}{\Delta_n}\right)^2 - 1} + \frac{\Delta_k}{\Delta_n}\right) \tag{9}$$

Then the upper limit of the integral when $\Delta_k < \Delta_n$ is taken as 1 instead of $\frac{\Delta_n}{\Delta_k}$.

In this place

$$p = \frac{2}{\pi\Delta_n}\int_0^1 \arccos y dy \cdot \Delta_k = \frac{2\Delta_k}{\pi\Delta_n}\left(y\arccos y - \sqrt{1-y^2}\right)\Big|_0^1 = \frac{2\Delta_k}{\pi\Delta_n} \tag{10}$$

Realization of probability

$$q = 1 - p \tag{11}$$

The probability that the bladed rotor will cut the stalks to the required size during z rotation is $p(z) = 1 - q^z$.

From this $p(z) \geq 0.99$, $1 - q^z \geq 0.99$, $q^z \leq 0.01$, $z \geq \log_q 0.01$., $z \geq \log_{1-p} 0.01$, Calculated for 99% confidence:

Table 1. Probability of cutting stalks to required size during rotation of blade rotor z

№	Δ_n, cm	3.5	3.5	3.5
1	Δ_κ, cm	3	4	5
2	p	0.5457	0.6971	0.7663
3	$q = 1 - p$	0.4543	0.3029	0.2337
4	$z \geq$	4.5492	3.8562	3.1675
5	z	5	4	3

Now we calculate for 95% confidence: $p(z) \geq 0.95$, $z \geq \log_{1-p} 0.05$.

Table 2. Probability of cutting stalks to required size during rotation of blade rotor z

№	Δ_n, cm	3.5	3.5	3.5
1	Δ_κ, cm	3	4	5
2	p	0.5457	0.6971	0.7663
3	$q = 1 - p$	0.4543	0,3029	0.2337
4	$z \geq$	3.7972	2.5085	2.0605
5	z	4	3	2

Based on the above calculation results, we make a graph of the probability that the stalks will be cut to the required size when the rotor rotates z times (Fig. 3).

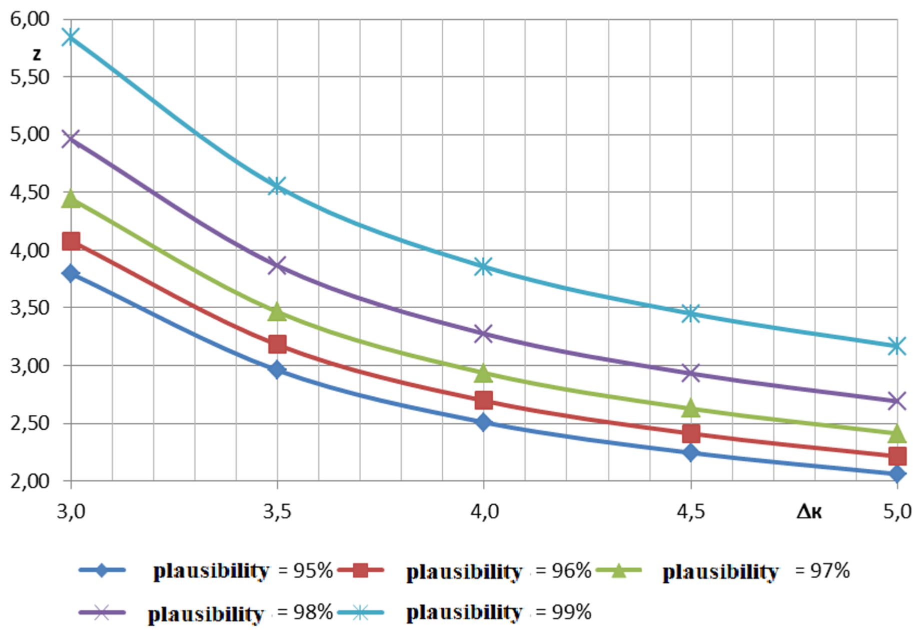

Fig. 3. Number of times rotor grinds z required to grind stalks to required Δ_κ size with adequate reliability

4 Conclusions

An improved technological scheme of an impact crusher equipped with two beaters for dosed transfer to the grinding chamber has been developed. Analytical dependencies are obtained to determine the parameters of the knife.

Theoretical studies have established that the minimum length of the knife should be 6.9 cm, the width of the knife should be 50 mm, and its thickness should be 4 mm. Based on the calculations, the probability of cutting the feed of the required size, depending on the number of rotations of the rotors, was established.

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