E3S Web of Conferences **401**, 04028 (2023) https://doi.org/10.1051/e3sconf/202340104028
CONMECHYDRO - 2023

Parameters of mini straw grader

F. M. Maiviatov[1], *R. R.* Karimov[2*], *I. E.* Musurmonov[2], *R. M.* Choriev[2] and *Sh. Sh.* Saparov[2]

[1]Karshi engineering-economics institute, Karshi, Uzbekistan
[2]Termiz Institute of Engineering and Technology, Termez, Uzbekistan

Abstract. The purpose study is to substantiate the parameters of a mini straw shredder. The diagram rotor of a cone-shaped shredder is given. The basic laws of theoretical mechanics and mathematical analysis were used in theoretical studies to substantiate the parameters mini shredder. Single- and multifactorial experiments were carried out when determining the optimal parameters mini shredder. In theoretical studies, analytical links were obtained to determine the length of the mini straw grader knife, the slope angle, its base, and the force required to cut the straw. According to the results of studies, the degree of grinding salmon and energy consumption depended mainly on the length blade, the mass balancing truck, and the slope angle blade. It is established that to ensure the required fullness of grinding with minimal energy consumption, the length knife should be within 87.66-88.38 mm, the weight of the balancing weight should be 0.0368-0.0536 kg, and the angle of inclination of the knife 28-48°.

1 Introduction

Animal husbandry in the Republic of Uzbekistan is one majority relevant branches of agriculture. Hence, the Government of the republic pays a large amount of information to the development of animal breeding, the implement state program, and the foundation, which is the creation of small livestock, farm, and farmer farms with a small number of cattle. The development of small breeding farms and farmer farms is closely related to providing them with technical means for grinding straw, especially the non-grain part of grain crops. At the same time, a significant reduction in operating costs and nurture in the quality straw feed preparation is possible with the enhancement grinding process, after grinding leads to an improvement in their feed qualities and a reduction in losses. At the same time, the feed qualities straw are improved, their losses are reduced, and material resources are saved. To ensure the improved quality of straw feed, we have developed a mini chopper with a knife blade tilted in the opposite direction of rotation. The theory of cutting processes of plant materials is described in sufficient detail in the classical works R Godwin [1], F Maiviatov [2, 5] V Bulgakov [3], C Gupta [4], F Mamatov [6], A Vilde [7], B Tulaganov [8], W Chancellor [9], K Astanakulov [10], K Astanakulov [11], Y Jekendra [12], V Yanovich [13], M Hers [14] and other authors. A significant part of more modern

*Corresponding author: r.nargiza@mail.ru

works is devoted to optimizing technological operations of grinding and scattering of material. These studies made it possible to improve the quality and reduce energy costs by improving the parameters of the technological process, using new materials, and improving the design of the working bodies of shredders-spreaders of the non-grain part of the crop. Among the most notable authors engaged in this field of research are W Chahecller [15], T El-Adawy [16], Y Tekin [17], H Unal [18], N Sattarov [20], and many others. However, in these works, the angle of inclination of the blade of the knife of the working organ of the mini-straw chopper, which carries out an inclined cut, has not been sufficiently studied. The purpose of the study is to substantiate the parameters of a mini straw shredder.

2 Materials and methods

The authors have developed a scheme of a mini-straw shredder with a cone-shaped working body based on existing mini-shredders. The mini chopper consists of a feeding tray, a casing, and a rotor with discs for fixing knives. Weights are installed on the knives to ensure the balancing of the rotor of the mini-chopper.

The basic laws of theoretical mechanics and mathematical analysis were used in theoretical studies to substantiate the parameters mini shredder. In experimental studies, the influence angle of the inclination knife, the degree of grinding and straw loss on the length knife, and the speed of the rotation rotor have been studied. In experiments, the straw fraction was determined on a tool with a mesh working element of different sizes, and the straw loss was determined on equipment with a size less than 3 cm in the hole.

The working body of the mini-chopper is cone-shaped, so its diameter is determined based on the following ratio

$$D_1 < D_2 < D_3 < ... < D_i. \quad (1)$$

where D_1, D_2, D_3, ... D_i are the diameters of the working body along the end part of the knife rotating with balancing weights, mm.

To prevent an imbalance of the working body, the following condition must be met

$$m_1 < m_2 < m_3 < ... < m_i. \quad (2)$$

where m_1, m_2, m_3...m_i are the weights of the loads balancing the knife, kg.

Since the sliding straw on the blade at the moment of cutting is largely due to the angle inclination of the knife blade relative to the radius working organ, we will make the following assumptions: until the straw is completely cut off, there is continuous contact between it and the blade; at the moment the beginning of cutting, the straw is at rest; under the influence knife, the straw performs an equally accelerated rotational movement with the working by the body mini-chopper (Fig.1).

From the triangle OO_1C we find

$$R = \sqrt{R_p^2 + \frac{d_c^2}{4}\cos^2\alpha - R_p d_c \cos\alpha \cos\beta},$$

where α is the straw feed angle relative to the cut plane, °.

The cutting force, without taking into account the friction force of the cut straw on the chamfer knife blade, is determined by the following well-known formula:

$$P = \mu l Q \tag{3}$$

where l is the length working part blade, mm; Q is the contact voltage, Pa; μ is the sharpness blade, mm.
The sharpness blade is determined by the following expression

$$\mu = \frac{r\cos\tau}{\sqrt{ctg2\varphi + \cos^2\alpha_H}} \tag{4}$$

where r is the radius rounding blade, mm.

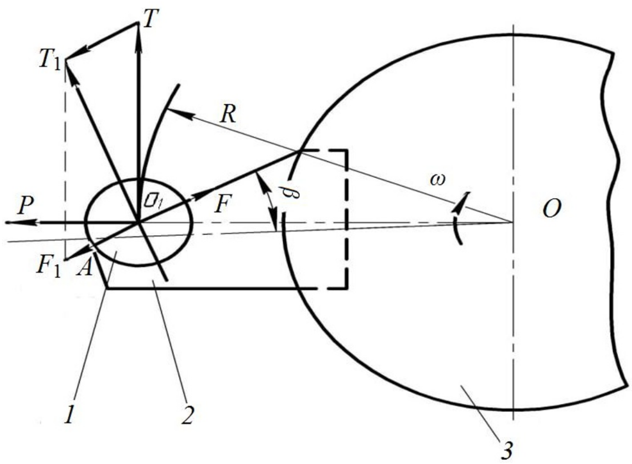

Fig. 1. Diagram for determining angle of inclination of knife blade working body mini-chopper: 1 is straw; 2 is knife; 3 is rotor

The length working part blade depends on the parameters and the relative position knife and straw. With the participation actual value l cutting force can be determined in each cutting element, including at the beginning of it. Let's say the straw's cross-section is a circle with a radius $d_c/2$; the stems do not deviate when cutting, do not flatten, and have a solid cross-section (Fig.2).

With a tilted embedding, the cross-section straw will be an ellipsis with a low axis dst. In this instance, the major and minor axes ellipse are connected by the ratio

$$a = \frac{D_C}{2\cos 2_H}, \qquad b = \frac{D_C}{2}.$$

When the straw is cut obliquely with the movement knife in the direction minor axis ellipse in coordinates aligned with its axes has the form

$$4x^2\cos^2\alpha_H + 4y^2 = d_c^2. \tag{5}$$

Equation straight edge blade in the same coordinates

$$y = (x_0 - x)ctg\tau \tag{6}$$

Solution equations (7) and (8) along, we define the coordinates intersection points ellipse with the edge blade. The distance between the coordinates points will be the working length blade

$$x_0 - x = \frac{ctg\tau}{\cos^2\alpha_H + ctg^2\tau} = \frac{\sqrt{\frac{D_C^2}{4}(\cos\alpha_H + ctg^2\tau)x_0^2 ctg^2\tau\cos^2\tau}}{\cos^2\alpha_H + ctg^2\tau} \quad (7)$$

The left part of the equation (7) is denoted by

$$l = x_0 - x\frac{ctg\tau}{\cos^2\alpha_H + ctg^2\tau}$$

Then

$$l = \frac{\sqrt{\frac{D_C^2}{4}(\cos\alpha_H + ctg^2\tau)x_0^2 ctg^2\tau\cos^2\tau}}{\cos^2\alpha_H + ctg^2\tau} \quad (8)$$

The beginning blade's contact with the stem corresponds to (l=0)

$$\max(X_0) = \frac{D_C^2}{2}\sqrt{tg^2\tau + \sec 2\alpha_H}.$$

The oblique cut of straw when the knife moves in the direction of major and minor axes ellipse, and the sum force.

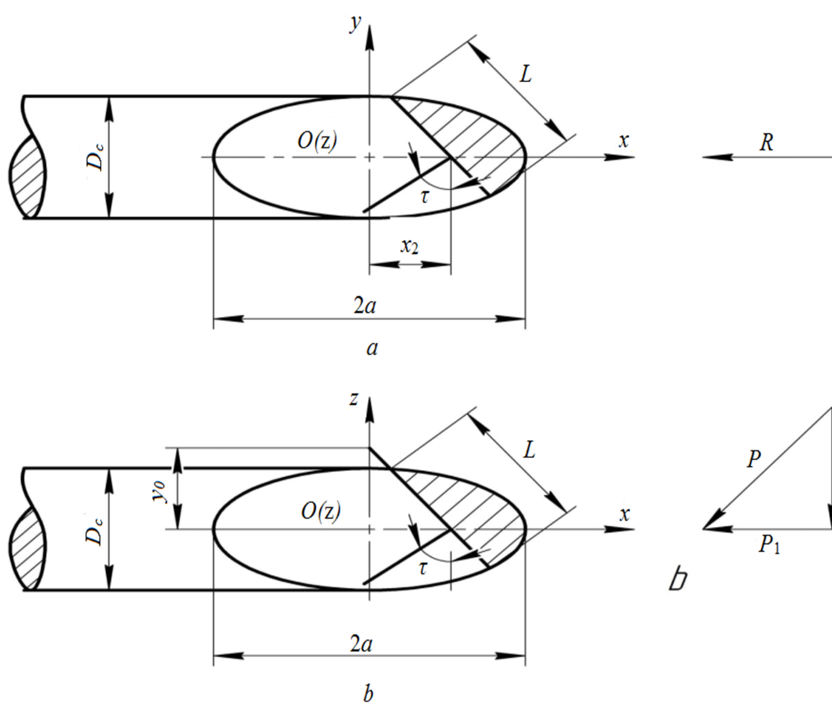

Fig. 2. Scheme oblique cut straw when knife push in direction big (*a*) and fine (*b*) axes of ellipse; (*c*) – graph of power

When the blade knife working body is located horizontally (α_H=0)

$$l = \sin\tau\sqrt{\frac{D_C^2}{4} - x_0^2\cos^2\tau}$$

By l=0

$$\max(X_0) = \frac{D_C^2}{2\cos\tau}$$

The horizontal component of the cutting force:
if the direction movement knife coincides with the large axis ellipse

$$P_1 = \frac{rG\cos\tau}{2(ctg^2\tau + \cos^2\alpha_H} \cdot \sqrt{\frac{D_C^2(ctg2\tau + \cos 2\alpha_H) - 4x_0^2 ctg^2\tau\cos^2\alpha_H}{ctg^2\varphi + \cos^2\tau}} \tag{9}$$

if the direction movement knife coincides with the small axis of the ellipse

$$P_2 = \frac{rG\cos\tau}{2(tg^2\tau + \cos^2\tau} \cdot \sqrt{\frac{D_C^2(tg2\tau + \cos 2\alpha_H) - 4y_0^2\cos^2\alpha_H}{ctg^2\varphi + \cos^2\tau}}. \tag{10}$$

Using the above expressions (7), (8), and (9) and performing simple transformations, we obtain:

$$P = \sqrt{P_1^2 + P_2^2} = \frac{rG\cos(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m})}{\sqrt{ctg^2\varphi + \cos(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m})}} x$$

$$x\left\{\frac{\frac{d_{CT}^2}{4}\left[\cos^2\alpha_H + ctg^2\left(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m}\right)\right] - x_0^2\cos^2\alpha_H ctg\left(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m}\right)}{\left[\cos^2\alpha_H + ctg^2\left(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m}\right)\right]}\right\} + \tag{11}$$

$$+\frac{\frac{d_{CT}^2}{4}\left[\cos^2\alpha_H + tg^2\left(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m}\right) - y_0^2\cos^2\alpha_H\right]}{\left[\cos^2\alpha_H + tg^2\left(\beta_H + \frac{\pi}{2} - arctg\frac{V_0}{V_m}\right)\right]^{1/2}}\Bigg\}.$$

From the expression (11), it is possible to determine the dependence angle of the inclination knife blade working body mini chopper on the parameters knife and straw. Calculations show that at R_p=0.21-0.29 m, X_1= 0.5-2 mm, φ=24-30º, a_H=0-20º, D_s=3-7 mm, the angle inclination blade mini-grinder knife is within β=28-48º, also r=0.01-0.05 mm and τ=3-50º. According to expression (11), graphical dependences of the cutting force P on the angle β knife blade inclination are constructed (Fig.3)

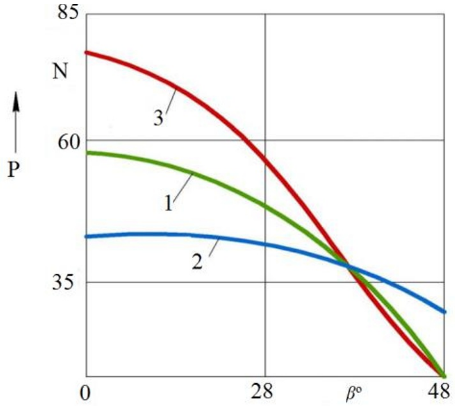

Fig. 3. Dependence cutting force on angle inclination knife blade: 1 is when cutting straw at an angle of $\alpha_H = 0$; 2 is when cutting straw in the direction major axis of section at $a_N = 15$ °; 3 is when cutting straw in the direction minor axis of section at $\alpha_H = 15°$

Figure 3 shows that at different values of a_H, the cutting force P decreases by 20-50% with an increase in the angle inclination from 28° to 48°. Based on the above, the angle of the inclination knife blade is 38°.

3 Results and discussion

In experiments, the length knife varied from 84 mm to 92 mm with an interval of 13 mm. At the same time, the rotor speed was 26, 30, and 34 c^{-1} (Table 1). From the experimental results, it can be viewed that at 26 c^{-1}, with an increase in the length knife from 84 to 92 mm, the degree of shredding of straw initially increases and then decreases, and the loss of straw increases. At 30 c^{-1}, with an increase in the length knife, the degree of grinding and straw loss initially decreases and then increases. At 34 c^{-1}, with an increase in the length knife, the degree of grinding and straw loss increases.

Table 1. Dependences degree grinding and straw loss on length knife and speed of rotation rotor

Rotor speed, c^{-1}	**Knife length, mm**				
	84	**86**	**88**	**90**	**92**
26	86.3/6.1	87.9/7.2	92.4/8.2	91.6/8.3	89.3/8.7
30	92.5/8.9	90.6/8.4	90.8/7.9	91.3/8.1	93.2/9.5
34	89.7/7.7	91.2/7.9	91.7/8.1	92.4/8.4	93.3/8.9

Table 2 shows the results of studying the influence of balancing weight and the angle of the inclination knife on the degree of grinding and straw loss. It can be viewed from the experimental results that with a knife length of 84 mm with an increase in weight from 0.02 kg to 0.1 kg, the degree of straw grinding initially decreases and then increases, while the loss of straw initially increases and then decreases. With a knife length of 88 mm, with an increase in weight, the degree of straw grinding initially increases and then decreases, and the loss of straw increases. With a knife length of 92 mm, with an increase in weight, the degree of straw grinding increases, and the loss of straw decreases.

Table 2 Dependences degree grinding and straw loss on balancing weight and length of knife

Knife length, mm	Knife weight, kg				
	0,02	**0,04**	**0,06**	**0,08**	**0,1**
84	92.4/6.1	91.8/7.2	90.5/8.2	92.3/7.9	92.8/7.2
88	81.3/7.7	82.4/7.9	83.5/8.1	82.1/8.8	81.7/9.1
92	80.1/8.2	81.9/8.4	82.4/7.9	84.1/7.3	85.5/6.8

From Table 3, it can be viewed that with a weight of 0.02 kg, with an increase in the angle inclination of the knife blade from 28° to 48° with an interval of 5°, the degree of shredding of straw initially decreases, and then increases, and the loss of straw decreases. With a weight of 0.04 kg, with an increase in the angle of inclination of the blade, the degree of straw grinding increases, and the loss of straw decreases. With a weight of 0.06 kg, with an increase in the angle inclination blade, the degree of straw grinding decreases, and the loss of straw increases.

Table 3. Dependences degree grinding and straw loss on balancing weight and angle inclination knife

Knife weight, kg	The angle inclination knife blade, deg				
	28	**33**	**36**	**40**	**48**
0.02	94.3/9.3	93.5/8.5	92.1/7.9	93.5/7.2	94.9/6.9
0.04	91.7/9.3	92.8/8.8	93.5/8.3	94.4/7.9	95.1/7.3
0.06	98.3/6.6	97.3/6.9	96.3/7.1	94.3/7.9	92.7/8.2

To determine the optimal parameters mini-grinder, the main factors influencing the optimization criteria of the process under study and the levels of their variation were determined (Table 4). The following factors were determined: X_1 (l_k, mm) is the length of the knife; X_2 (m_r, kg) is the weight of the weight; X_3 (a_H, deg) is the angle of inclination of the knife blade. The optimization criteria are Y_1 (%) is the completeness of straw grinding, Y_2 (kW/h) is the energy intensity of the crushed straw process.

Table 4. Levels and factors of their variation

Levels and interval	Factors		
	X_1 l_k, mm	**X_2 m_r, kg**	**X_3 a_H, °**
Lower level	72,0	0,02	28
Basic level	85,0	0,04	38
Upper level	98,0	0,06	48
Variation interval	13,0	0,02	9,9

The following regression equations were obtained after appropriate processing of the experimental results, adequately describing the evaluation criteria:
- following the degree of straw grinding (%)

$$Y_1=9.154-0.658X_1-1.425X_2-0.750X_1X_2+2.687X_1^2+1.163X_1^2+2.010X_3^2 \quad (12)$$

- by the energy intensity of the straw grinding process

$$Y_2=11.174-0.1474\cdot X_1+0.320X_2-0.303X_3-0.262X_1X_3+0.451X_1^2+0.959X_2^2+0.586X_3^2 \quad (13)$$

Based on the results conducted multifactorial experiments to ensure the required completeness of straw grinding with minimal energy consumption, the following optimal parameter values were determined: knife length l_k=87.66-88.38 mm; weight balancing weight m_y=0.0368-0.0536 kg; knife angle β=28-48°.

4 Conclusions

Analytical links were obtained to determine the length mini-grinder knife, the angle slope, its base, and the force required to cut the straw. According to the results of studies, the degree of grinding straw and energy consumption largely depend on the length blade, the mass of the balancing weight, and the slope angle of the blade. It is established that to ensure the required fullness grinding with minimal energy consumption, the length knife should be within 87.66-88.38 mm; the weight balancing weight is 0.0368-0.0536 kg, and the angle of the inclination knife is 28-48°.

References

1. Godwin R J and O'Dogherty M J 2007 Integrated soil tillage force prediction models *J. of Terramechanics* **44(1)** pp 3–14
2. Maiviatov F, Karshiev F, Gapparov Sh *IOP Conf. Series: Earth and Environmental Science* **868** 012060 (2021).
3. Bulgakov V, Pascuzzi S, Adamchuk V, Ivanovs S and Pylypaka S 2019 *Soil and Tillage Researc*h 195, 104406.
4. Gupta C P and Surendranath T 1989 *Soil and Tillage Research* 13(2) pp 123–149
5. Maiviatov F, Ravshanov K, Mamatov S, Temirov I, Kuvvatov D, Abdullayev A. *IOP Conf. Series: Earth and Environmental Science* **868** 012066 (2021)
6. Mamatov F, Umurzakov U, Mirzaev B, Eshchanova G, Avazov I. *E3S Web of Conferences* **264** 04065 (2021).
7. Vilde A 2008 *Engineering for Rural Development* vol 1 Issue 7 pp 141–146
8. Tulaganov B, Mirzaev B, Mamatov F, Yuldashev Sh, Rajabov N, Khudaykulov R F *IOP Conf. Series: Earth and Environmental Science* **868** 012062 (2021)
9. Chancellor W.J. Energy Requirements of Cutting Forage *Agricultural Engineering*. 1958. **39** (October): – Pp. 188.
10. Astanakulov K D, Babaev Kh M, Eshankulov Kh M, Turdibekov I M *IOP Conference Series: Earth and Environmental Science*, **1112(1)** 012008 (2022).
11. Astanakulov K D, Kurbonov F K, Shomirzaev M K *IOP Conference Series: Earth and Environmental Science*, **1076(1)** 012032 (2022)
12. Jekendra Y, Singh P, Energetics of forage chopping, AMA. 1991. **22(1):** Pp. 59-63.
13. Yanovich V P, Kupchuk I M Determination of rational Operating parameters for a vibrating dysk-type grinder used in ethanol industry. INMATEH - *Agricultural Engineering*. 2017. **52 (2).** pp. 143-148.
14. Dabbour M I, Bahnasawy A, Ali S, El-Haddad Z *Journal of Fodder Processing Technology*, 2015. **№ 69**. pp.100-108.
15. Hers R., Boyle Ch., Jutras I., Molica Ch., Ziegler E. *An Interactive Qualifying Project submitted of the faculty of Workester Polytechnic Institute*, 2012. – 48 p.
16. Chahecller W.J., Energy Reguizements forcuttungforoge Agric. Engng, 1958, № 10, - pp 68-71.
17. El-Adawy T A, Rahma E H, El-Bedawey A A and El-Beltagy A E 2004 *Plant Foods for Human Nutrition* **58** (10) 1-13
18. Tekin Y, Ishik E, Unal H and Okursoy R 2006 *Physical and mechanical properties of Turkish Goynuk bombay beans* (Phaselis vulgaris L.) J. Biol. Sci. **12** (9) 2229-2235

 https://doi.org/10.1051/e3sconf/202340104028

19. Unal H, Ishik E and Alpsoy H C 2006 Some physical and mechanical properties of black-eyed pea, (Vigna unguiclata L) grains *Journal of Biological Sciences* **9** (9) 1799-1806.
20. Sattarov N E, Borotov A N, Yunusov R F and Yangiboev A E 2022 *IOP Conference Series: Earth and Environmental Science* **1076** 012081.