Determination of grinding condition by grain elasticity and hammer width for sustainable feed production in livestock farming

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Abstract. Livestock farming is one of the important sectors of Uzbekistan that provides food. An integral part of livestock farming is feed production. Grinding grain is a very important stage in the preparation of complete feed. The study aims to justify the hammer's width and theoretically investigate the parameters for grinding grain. Technical mechanics fundamentals were used in theoretical investigations. There is a schematic showing how the grain is ground in the grinding chamber. Theoretical studies indicate that for grain crushing, the internal loading resulting from grain particle compression should exceed the grain loading strength limit. According to the analytical relationship analysis to determine the width of the crusher, the width of the crusher depends on the strength limit and modulus of elasticity of the grains, the radius of rotation of the crusher, the number of blows and the diameter of the hole of the grinding chamber. In order to ensure that the grains are crushed at the required level, the width of the crusher hammer is greater than 1 cm, the radius of rotation is 21.5 cm, the number of blows is 25 times, the diameter of the hole of the grinding chamber is equal to or less than 0.0019 m.

1 Introduction

Worldwide, efforts are being made in science and research to create new, resource-efficient technologies for the preparation and distribution of full-value feed made from ground grain and coarse feed, as well as the technological means to put these solutions into practice [1-11]. In particular, special attention is paid to the creation of energy and resource-saving devices that will grind straw, alfalfa hay and other coarse feed and grain feed such as wheat,

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barley, corn grains and bran into the same granulometric content, and then distribute their mixture to livestock according to the established standards [12-14]. In this regard, it is important to process coarse and grain feeds by mechanical grinding, and then to develop devices that distribute feed prepared from their mixture to livestock in the same amount, justifying their technological process and parameters of working parts [15-18].

Development and improvement of theories and methods of shearing and grinding of grain and coarse feed, creation of drum, rotor and disc grinding devices, vertical and horizontal types of feed distributors, which shear and cut coarse feed, and grind grains by hammering and crushing, as well as the construction of their working bodies and studies on the basis of parameters Rittinger, Rebinder, V.L. Kiripichev, M.M. Gernet, V.A. Goransky, S.M. Melnikov, N.E. Reznik, V.I. Perednaya, S.I. Nazarov, W. J. Chancellor, M. J. Odogherty, G. E. Gale, P. Singh, Y. Jekendra, V. G. Malkov, T. Abiljanov, J. C. E. Quist, S. Kwofie, P. Toneva, I. M. Kupchuk, M. I. Dabbour, D. Dziki, J. Zhao, F. M. Mamatov, K. D. Astanakulov, Dj. Alijanov and others [15-20].

Concentrated feed grinders are mainly grain grinders, and they are divided into grain grinders for industrial production, large farms and small farms.

DDO, DM-440U, A1-BD2-M, DDM, A-1-DDP, A-1-DDR, A1-DMR-6/12/20, MM-100, SBCD-40/80, Neuero's RVO and Buller grain grinders are industrial grain grinders, designed for feed mills.

Until recently, grain crushers DKU-1.0, DKU-M, KDU-2.0, DB-5 and KD-2.0 of average size and productivity, intended for large farms, with a half or full cycle of work, were used in livestock farms. These grinders are designed for grinding corn husks, hay and root crops in addition to whole grains.

The technical description of these shredders shows that their productivity and required power are high, and they are intended for use in large livestock farms and complexes from 200 to 1000 heads. This shows that they are ineffective when used in small livestock farms.

In practice, several small-sized, low-performance shredders have been developed for use in individual farms, small livestock and poultry farms. Examples of such grinders include MELASTY produced in Turkey, DKU-03/04, D-2, IZ-10 produced in Russia, Elikor produced in Bulgaria, DTZ KR 20 produced in Ukraine, and RD-100 disc grinders produced abroad and in Uzbekistan.

According to the results of studies, grain grinders are single-rotor (the most common) and double-rotor according to their construction scheme, radial, central and lateral depending on the transmission of the crushed product, depending on the output of the crushed product - with a fan, without a fan and conveyor, depending on the implementation, mobile and stationary, according to their use, they are divided into grinders designed for large livestock complexes, large farms and small farms [21-25].

According to the analysis of the grinders presented above, it is advisable to use a ram grain grinder with a capacity of up to 200 kg/h and 220 V voltage for grinding grain for farmers and small livestock farms with a small number of livestock.

In the grinder, the movement from the electric motor is transmitted directly to the grinder working part, which reduces its metal volume and cost, while the placement of all parts in the frame increases its stability.

Based on this, the development of equipment that allows low-cost grinding of grain feed to the required level in livestock farms, as well as the justification of their parameters and operating modes, research is being conducted on the development of a small-sized grain crusher design for grinding nutritious grains and the justification of its parameters and operating modes [19, 20].

2 Materials and methods

According to the research methodology for theoretical studies of the technological process of a hammer grinder, the interaction of the hammer and grain inside the grinding chamber must be brought to a certain model.

Therefore, we imagine the hammer working body of a crusher as a material body with its dimensions and properties not changing. We do not take into account the increase in hammer temperature during operation. We will take the grains before destruction as a plastic ball, and after destruction into pieces as a particle. We will take all the crushed mass that moves inside the crushing chamber as an annular layer with a closed end.

In this case, we assume that the hammer rotor rotates at a constant frequency, and the gap between the hammer and the crushing chamber in the first quarter is constantly decreasing, and in the second quarter it is increasing. At the same time, this improves the separation of the crushed product in the crushing chamber.

The grinding drum pushes, strikes, and compresses the grain particle that is traveling in the "air-particle ring" inside the grinding chamber. Grain particles are crushed in the grinding chamber because the hammers' speed is higher than the particle's velocity within the "air-particle ring." In this instance, rolling friction results from the hammer's speed differential with the grain particle, which in turn generates friction as the hammer passes over the grain.

3 Results and discussion

The hammers' center of rotation is moved lower in the grinding chamber to accelerate friction and grinding. Consequently, when the hammer drops and rises, the space between the crushing chamber wall and its trajectory gets crushed (Figure 1).

Therefore, all particles larger than the smallest size of the gap between the friction and compression of the drums crush the wall of the grinding chamber and the drum. We determine the relationship between the angle θ at which the compression of grain particles begins in the grinding chamber and the diameter d of the particle from the theorem of cosines

$$d = R - \sqrt{r^2 - b^2 - 2rb\, cos\, cos\, \theta}\,. \quad (1)$$

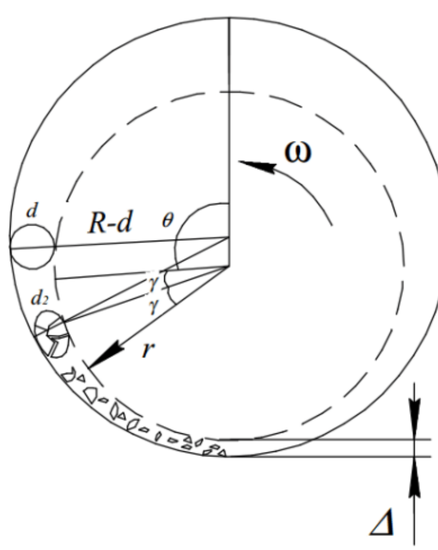

Fig. 1. The scheme of the compression of grain particles against the wall of the grinding chamber.

As previously indicated, the grain particles in the "air-particle ring" that are moving have 50% of the speed of the hammer, so the hammer is cornered at 2γ point.

The size of the undeformed grain particles at the end of the compression process in the grinding chamber can be determined from the following expression:

$$d_2 = R - \sqrt{r^2 + l_b^2 + b^2 - 2rb\cos\cos(\theta + \gamma)}. \tag{2}$$

here $l_б$ – width of the bundle in the longitudinal direction, m.

The angle of impact on the width of the beam depending on the width of the beam and its radius of rotation

$$\gamma = arcsin\, arcsin\, \frac{l_b}{r}. \tag{3}$$

In that case, the relative deformation of grain particles during compression is as follows

$$\varepsilon = \frac{d - d_2}{d}. \tag{4}$$

or

$$\varepsilon = \frac{\sqrt{r^2 + l_b^2 b^2 - 2}\sqrt{r2 + l_b^2 bcoscos(\theta + \gamma)} - \sqrt{r^2 + b^2 - 2rbcoscos\,\theta}}{R - \sqrt{r^2 + b^2 - 2rbcoscos\,\theta}}. \tag{5}$$

According to Hooke's law, the internal load that appears in grain particles when they are compressed is as follows

$$\sigma = E\varepsilon, \tag{6}$$

As in the above cases, during compression of grain particles, the internal load σ that occurs in them should exceed the grain loading's strength limit $\sigma_ч$, that is, $\sigma \geq \sigma_ч$. Otherwise, grain grinding will not occur.

According to the above, it is the condition of relative deformation that ensures the crushing of the grain

$$\frac{\sqrt{r^2 + l_b^2 b^2 - 2}\sqrt{r2 + l_b^2 bcoscos(\theta + \gamma)} - \sqrt{r^2 + b^2 - 2rbcoscos\,\theta}}{R - \sqrt{r^2 + b^2 - 2rbcoscos\,\theta}} \geq \frac{\sigma_c}{E} \tag{7}$$

In this case, the absolute deformation of the grain, taking into account some allowances, is approximately equal to the following

$$d - d_2 \approx \sqrt{r^2 + l_b^2 - r}. \tag{8}$$

If, the compression of grain particles begins in the III quarter of the grinding chamber, and the maximum the particle diameter is equivalent to the following

$$R - \sqrt{r^2 + b^2}. \tag{9}$$

Therefore, the relative deformation condition of grain particles can be written as follows

$$\frac{\sqrt{r^2 + l_b^2 - r}}{R - \sqrt{r^2 + b^2}} \geq \frac{\sigma_c}{E}. \tag{10}$$

From this condition, it is possible to determine the width that ensures the deformation of the crusher hammer during the compression of grain particles as follows

$$l_b \geq \sqrt{\left[\frac{\sigma_c}{E} \cdot \left(R - \sqrt{r^2 + b^2}\right) + r\right]^2 - r^2}. \tag{11}$$

If the strength limit and modulus of elasticity of barley grains σ_c=7MPa and E=840 MPa, as well as the radius of rotation of the grinding chamber and hammer, and the displacement of the center of rotation of the handle below the center of the grinding chamber R=0.24 m; r=0.215m; b=0.023m. If we make calculations according to the expression (11) taking into account, the width of the chopper will be $l_b \geq 0.01$ m.

4 Conclusion

The internal load created by the compression of the grain particles must be greater than the grain load's strength limit in order for the grain to be crushed.

An analytical relationship was obtained for the determination of the width of the grinding wheel. According to it, the width of the dough depends on the strength limit and modulus of elasticity of the grains, the radius of rotation of the dough, the number of blows and the diameter of the hole of the grinding chamber.

In order to ensure that the grains are crushed at the required level, the width of the crusher hammer is greater than 1 cm, the radius of rotation is 21.5 cm, the number of blows is 25 times, the diameter of the hole of the grinding chamber should be equal to or smaller than 0.0019 m.

References

1. K.D. Astanakulov, A.T. Umirov, P.S. Sultanbekova, G.B. Alpamyssova, IOP Conference Series: Earth and Environmental Science **839(5)** 052048 (2021)
2. K.D. Astanakulov, K.A. Baimakhanov, G.B. Alpamyssova, A.B. Babojanov, IOP Conference Series: Earth and Environmental Science **839(5)** 052062 (2021)
3. I.V. Kovalev, D.I. Kovalev, K.D. Astanakulov, V.A. Podoplelova, D.V. Borovinsky, Z.E. Shaporova, IOP Conference Series: Earth and Environmental Science **1284** 012026 (2023)
4. I. Kovalev, D. Kovalev, K. Astanakulov, A. Podoplelova, A. Voroshilova, Z. Shaporova, E3S Web of Conferences **471** 04017 (2024)
5. I.V. Kovalev, D.I. Kovalev, K.D. Astanakulov, A.A. Voroshilova, V.A. Podoplelova, D.V. Borovinsky, IOP Conference Series: Earth and Environmental Science **1284** 012030 (2023)
6. K.D. Astanakulov, N.A. Ashurov, A.R. Turdibekov, IOP Conference Series: Earth and Environmental Science **1231(1)** 012023 (2023)
7. K.D. Astanakulov, Kh.M. Babaev, Kh.M. Eshankulov, I.M. Turdibekov, IOP Conference Series: Earth and Environmental Science **1112** 012008 (2022)
8. Igor Kovalev, Dmitry Kovalev, Komil Astanakulov, Valerya Podoplelova, Dmitry Borovinsky, and Svetlana Efa, E3S Web of Conferences **443** 06014 (2023)
9. M. Ikonnikova, D. Kovalev, K. Astanakulov, A. Voroshilova, E3S Web of Conferences **390** 03024 (2023)
10. Igor Kovalev, Dmitry Kovalev, Komil Astanakulov, Valerya Podoplelova, Dmitry Borovinsky, Zinaida Shaporova, Svetlana Efa, E3S Web of Conferences **390** 03014 (2023)
11. A. Yablokova, D. Kovalev, I. Kovalev, V. Podoplelova, K. Astanakulov, E3S Web of Conferences **471** 04018 (2024)
12. N.E. Sattarov, A.N. Borotov, R.K. Choriev, IOP Conference Series: Earth and Environmental Science **1231(1)** 012036 (2023)
13. A. Borotov, R. Choriev, U. Boykulov, A. Khatamov, E3S Web of Conferences **390** 04038 (2023)
14. A. Borotov, S. Bekzhanov, D. Nurjan, J. Tursunov, Sh. Tursunov, U. Boykulov, K. Ernazarov et al., IOP Conference Series: Earth and Environmental Science **1284(1)** 012013 (2023)

15. M.Kh. Shomirzaev, K.D. Astanakulov, Kh.M. Babaev, IOP Conference Series: Earth and Environmental Science **1076** 012035 (2022)
16. F Mamato, Sh. G`apparov et al., IOP Conference Series: Earth and Environmental Science **1076** 012024 (2022)
17. K.D. Astanakulov, F.K. Kurbonov, M.Kh. Shomirzaev, IOP Conference Series: Earth and Environmental Science **1076** 012032 (2022)
18. F.U. Karshiev, Sh.Ch. Tursunov, A.D. Rasulov, D. Khudaynazarov, IOP Conference Series: Earth and Environmental Science **1112** 012054 (2022)
19. F.M. Mamatov, F.U. Karshiev, A.N. Borotov, A.D. Rasulov, Y.J. Shamayev, IOP Conference Series: Earth and Environmental Science **1231(1)** 012008 (2023)
20. F.U. Karshiev, M.K. Shomirzaev, S.C. Tursunov, Y.J. Shamaev, E3S Web of Conferences **390** 03030 (2023)
21. D.S. Kobylkin, *Study of the process of grain grinding when changing the air pressure in the working chamber of an impact crusher*: Abstract of thesis. diss. ...cand. tech. Sci. (Orenburg, 2009), p. 21
22. S.V. Zolotarev, *Mechanical and technological basis for the creation of impact-centrifugal grinders of feed grain*: dissertation.... doc. tech. Sci. (Barnaul, 2002), p. 385
23. M.B. Baldanov, *Justification of the parameters of a small-sized hammer grinder of feed grain* (Novosbrsk, 2008), p. 136
24. D. Dziki, Powder Technology **185(2)**, 181-186 (2008)
25. M.I. Dabbour, A. Bahnasawy, S. Ali, Z. El-Haddad, Journal of Fodder Processing Technology **69**, 100-108 (2015)