Estimation of the throughput capacity of the core grain shredder

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Abstract. The relevance of the chosen topic is formulated in the article, a milling grain shredder is proposed. calculations of the productivity of the milling grain shredder are given. Theoretical studies have determined the grain supply through the chopper loading window during the movement of the milling cutter tooth in the loading window area. Grain feed along the milling cutter axis is calculated. It was found out that the main limiting parameter in terms of productivity is the grain supply along the axis of the milling cutter. For the developed shredder, the theoretical productivity is calculated, which varies from 90 to 100 kg/h with an increase in the angular velocity of the cutter from 185 rad/s to 206 rad/s

1 Introduction

The use in the feeding diets of farm animals has a beneficial effect on their health and productivity [1, 2]. This statement is confirmed by the results of not only Russian, but also foreign researchers [3, 4, 5.]. One of the most important components of both animals and poultry is concentrated feed. Their influence is especially noticeable in the countries of Europe and the USA, since they use a concentrate type of feeding [6, 7, 8]. In Russia, grains are traditionally crushed with hammer crushers before being fed [9, 10, 11, 12, 13, 14, 15]. However, a chipping type shredder is being developed and investigated. Which have a number of advantages over hammer crushers [16, 17, 18]. We have also developed a shredder in which the grain is destroyed by chipping, and not by a direct blow [19, 20]. This article discusses the effect of the angular velocity of the milling cutter on its performance.

2 Materials and methods

The productivity of the milling cutter was calculated, a detailed description of which is presented in the works [19]. During the calculations, mathematical methods were used in relation to the developed shredder with specific structural and technological parameters.

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The feed of the crushed material into the grinding chamber is one of the main parameters responsible for the productivity of the shredder. In the developed shredder, it is important to supply exactly the specified amount of grain, since with a small feed, all grain will be crushed at the very beginning of the milling cutter movement, and its further movement will be carried out idling. If the feed is excessive, clogging and stopping of the crusher may occur. To determine the productivity of the milling cutter, the scheme shown in figure 1 was developed.

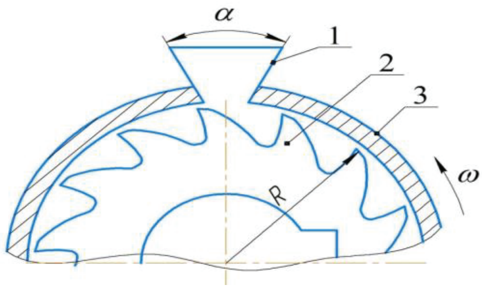

Fig. 1. Flow diagram of grain material in the developed shredder: 1 – loading window; 2 – milling cutter teeth; 3 – shredder housing.

3 Results

Grain is fed into the shredder from the storage hopper under the influence of gravity. The grain supply in this case is influenced by the area of the loading window. When the cutter rotates, the window area changes from the maximum value to 0. At the same time, the height of the loading window remains constant. Then the grain feed loading window can be expressed in terms of the width of the window, which is set by the angle α:

$$Q = f(\alpha) . \tag{1}$$

This dependence is determined empirically. We conducted experiments, as a result of which a graph of changes in grain supply through the loading window was constructed depending on its width (figure 2).

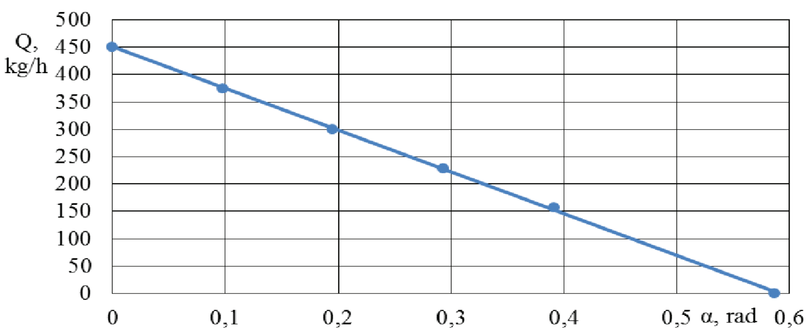

Fig. 2. Changing the grain feed through the loading window depending on the angle α.

The functional dependence for the description of the graph has the form:

$$Q = f(\alpha) = -762{,}66\alpha + 450{,}55 , \tag{2}$$

where Q – is the hourly grain feed through the loading window; α is the angle characterizing the width of the loading window.

The amount of grain that will be fed through the loading window can be calculated using the formula:

$$m = Q \cdot \Delta t = f(\alpha) \cdot \Delta t, \tag{3}$$

where m – is the mass of grain fed through the loading window; Δt is the time of movement of the milling cutter tooth in the loading window area.

The tooth of the milling cutter moves in the loading window area for a certain period of time, the value of which depends on the angular velocity of the milling cutter:

$$\Delta t = \frac{\alpha}{\omega}, \tag{4}$$

where ω – angular velocity of the milling cutter.

Substitute (4) into expression (3), taking into account (2). We get the following expression:

$$m = Q \cdot \Delta t = f(\alpha) = (-762{,}66\alpha + 450{,}55)\frac{\alpha}{\omega}. \tag{5}$$

According to equation (5), calculations were made of the mass of grain that manages to pass through the loading window of the shredder during the movement of the milling cutter tooth in the loading window area. The calculations are presented in the form of a graph shown in figure 3. It can be seen from the graph that the mass of grain fed through the loading window into the space between the teeth of the cutter during the movement of the tooth in the loading window area decreases with an increase in the angular velocity of the cutter along the hyperbola from 0.21 to 0.1 g. In this case, the maximum grain mass supplied cannot exceed the mass of grain that is placed in the space between the teeth of the cutter. It was experimentally determined that about 7 g of grain is placed between the teeth of the milling cutter.

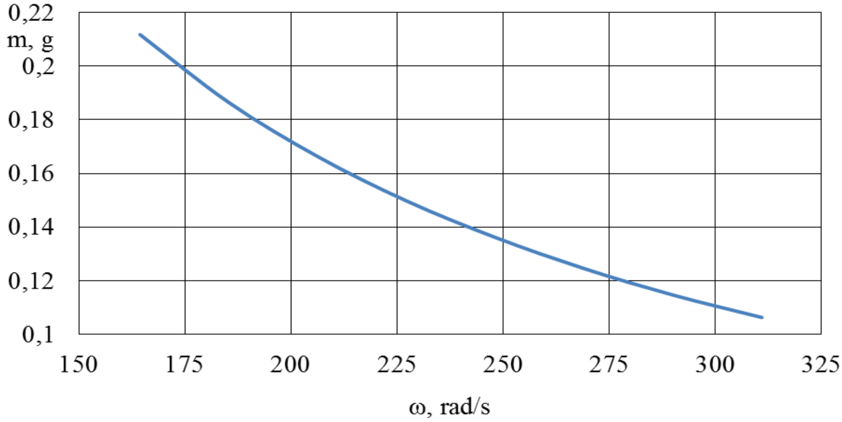

Fig. 3. Change of the fed grain mass through the loading window from the angular velocity of the milling cutter.

The productivity of the milling cutter can be calculated using the mass of the fed grain, the angular velocity of the milling cutter and the number of its teeth, using the formula:

$$Q_F = m \cdot N \cdot \frac{3{,}6 \cdot \omega}{2\pi} = 0{,}573 \cdot m \cdot N \cdot \omega, \qquad (6)$$

where N – number of milling cutter teeth.

According to the formula (6), the hourly productivity of the milling cutter was determined depending on its angular velocity. The calculation results are presented in the form of a graph (figure 4).

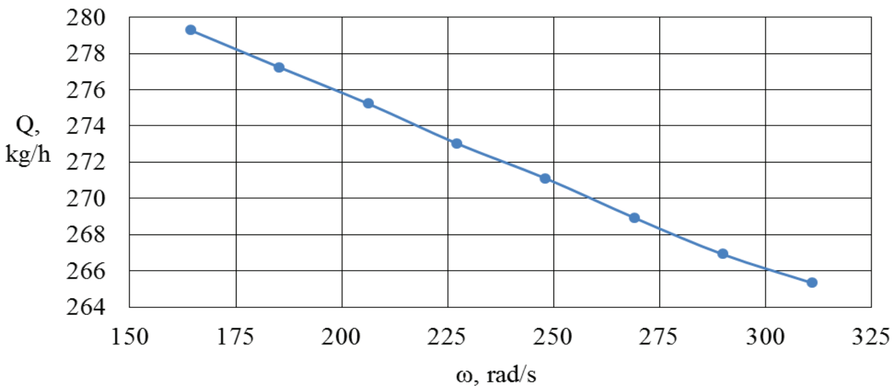

Fig. 4. Estimated maximum productivity of the milling cutter.

It can be seen from the graph that with an increase in the angular velocity of the milling cutter, its performance decreases in direct dependence. This indicates the limitations of shredders of this type in terms of manufacturability.

The second limiting factor is the axial feed of the cutter. To determine it, we assume that the grain fed through the loading window is completely distributed over the entire cross-section of the space between the teeth of the milling cutter. Then the axial feed is determined from the expression:

$$\mathrm{Q} = S \cdot \dot{z} \cdot \rho. \qquad (7)$$

where Q – axial grain feed with one tooth; S is the cross–sectional area of the space between the teeth of the cutter; $\dot{z}$ – axial velocity of grain layer movement; ρ – bulk grain density.

$$\dot{z} = z \cdot \Delta t. \qquad (8)$$

where Δt – the time of movement of the grain layer along the axis of the cutter; z – the distance traversed by the grain layer along the axis of the cutter.

Calculations have been carried out for the milling cutter under consideration with S = 101.5 mm^2. At the same time, the bulk density of grain was assumed to be equal to 480 kg / m3. The results are presented in the form of graphs of changes in the second grain feed depending on the angular velocity of the milling cutter (figure 5).

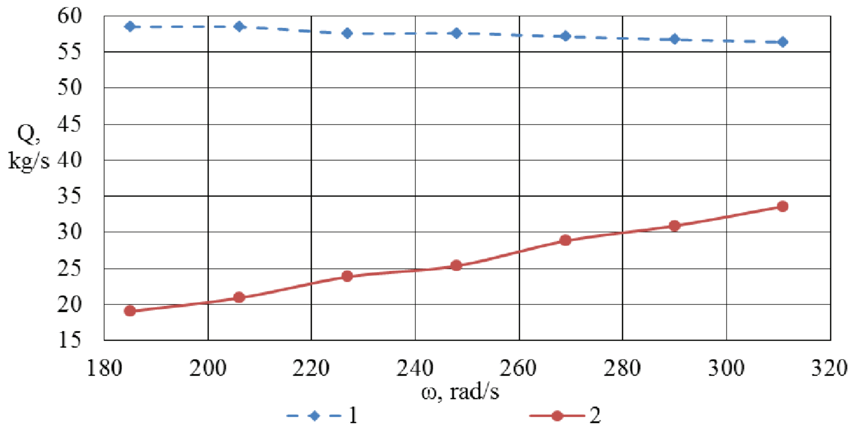

Fig. 5. The effect of the angular velocity of the milling cutter on the second grain feed: 1– grain feed through the loading window; 2 – axial grain feed with one tooth of the milling cutter.

As you can see from the graph, the axial grain feed is lower than the grain feed through the loading window and lies in the range of 19-34 kg/s. According to the expression (7), the axial hourly throughput of the milling cutter is calculated (figure 6).

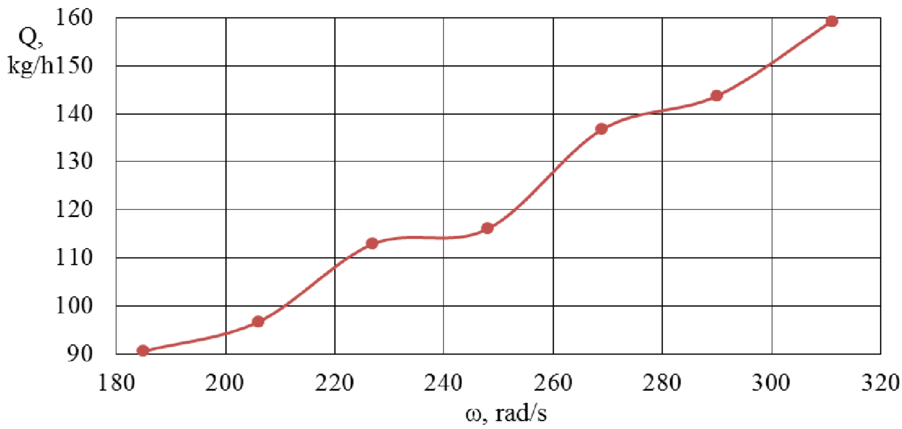

Fig. 6. The effect of the angular velocity of the milling cutter on the axial hourly throughput of the milling cutter.

4 Discussion

It can be seen from the calculations that the grain feed through the hopper of the shredder decreases with an increase in the angular velocity of the cutter, and the axial feed increases at the same time. At the same time, the axial feed at any angular velocity is lower than the grain feed through the loading window. That is, the determining limiting factor is the axial grain feed.

5 Conclusion

Thus, the conducted studies allow us to conclude that the determining limiting parameter of the milling cutter throughput is the axial grain feed along the z axis. For the milling cutter in question, the hourly throughput varies between 90-160 kg/h depending on the speed of the milling cutter. Taking into account the limiting values ω = 185 rad/s and ω = 206 rad/s obtained in Section 2.1, the maximum throughput of the milling cutter is 90-100 kg/h.

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