Theoretical determination of the speed and number of revolutions of the grain grinder hammer propeller

Fakhridin U. Karshiev[1*], *Makhmatmurod* Kh. Shomirzaev[1], *Shokir* Ch. Tursunov[1] and *Yigitali* J. Shamaev[2]

[1]Termez State University, 43, Street Barkamol avlod, Termez, 190111, Uzbekistan
[2]Termez Engineering and Technological Institute, Termez, Uzbekistan

Abstract. A mini grain grinder device was created for small farms, which is used to prepare feed by grinding grains. The main working organ of the grain grinder is a propeller with a hammer, and the grinding of grains during the work process depends on the rotation speed of the hammer and the number of revolutions of the propeller. Because when the propeller rotates, the speed of the hammer attached to it must be sufficient to crush the grains. With this in mind, theoretical studies were conducted and the rotation speed and number of rotations of the hammer propeller of the grinding device needed to grind the grains were determined. According to the research, the speed of the propeller hammer should be at least 40.2 m/s for grain crushing in the device, and this speed is ensured when the number of rotations of the hammer propeller reaches 1785 rev/min when the radius of the hammer propeller is r = 0.215 m. For rapid grinding of nutritious grains in the grinding machine, the speed of the hammer should be higher than 40.2 m/s and the number of propeller revolutions should be higher than 1785 rev/min.

1 Introduction

Milled grains are the main source of feed for livestock, poultry and fish [1-5]. Ground coarse fodder is also used for livestock feeding [6-11], but if nutritious grains are also ground and mixed with ground coarse fodder, their nutritional value and efficiency will increase. So far, many grain crushers have been developed, but some of them have high energy consumption, some of them have large metal consumption and size, and some of them cannot grind grains to the required size [12-14].

In Uzbekistan, the main part of livestock is raised in small livestock farms with 5-10 to 25-30 animals. For these farms, grain crushers for individual use with low energy consumption and low productivity are needed. Taking this into account, a mini grain grinder device was developed for small farms, which is used to prepare feed by grinding grains. The main working organ of the grain grinder is a propeller with a hammer. Grinding of grains in a grinder depends on the rotation speed of the hammer and the number of revolutions of the propeller. Because when the propeller rotates, the speed of the hammer attached to it must be

* Corresponding author: fkarshiev@mail.ru

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sufficient to crush the grains. Accordingly, theoretical studies were conducted and the rotational speed and number of rotations of the device's hammer propeller needed to grind the grains were determined.

2 Materials and methods

Theoretical studies on determining the rotational speed and number of revolutions of the hammer propeller of the grain grinder used the rules of higher mathematics and mathematical analysis, as well as the laws of shock theory in theoretical mechanics.

The grinding chamber was conventionally assumed to be a cylinder, and the grain to be a sphere. The impact of the grain received by the crushing chamber was divided into three types. In this case, the blow given to the grain falling into the grinding chamber by the rotating propeller hammer was considered as the "first blow", the impact of the grain hitting the wall of the grinding chamber after the hammer blow was the "second blow", and the blow received by the hammer from the flow of crushed grain moving inside the grinding chamber was considered the "third blow".

In theoretical studies, determining the momentum and speed of the grain after each blow was determined as the main result, and the number of revolutions of the hammer propeller was determined from the speed required to grind the grain. When determining the rotation speed and the number of revolutions of the hammer propeller of the grain grinder, the parameters of the grinder and the physical and mechanical properties of the grain to be ground were taken into account. Calculations were carried out on barley grain.

3 Results and discussions

The grain coming down from the hopper through the transfer chute into the grinding chamber receives the "first blow" from the hammer mounted on the rotating propeller. After the impact, the speed of the grain increases from u0 to the linear speed of the lever knob u=ωr (where ω is the angular velocity of the lever knob, s-1; r is the radius of the lever knob, m), it moves towards the inner wall of the grinding chamber and hits the wall at a certain angle, gets a "second shot".

According to the scheme, the angle at which the grain hits the wall can be determined as follows (Figure 1).

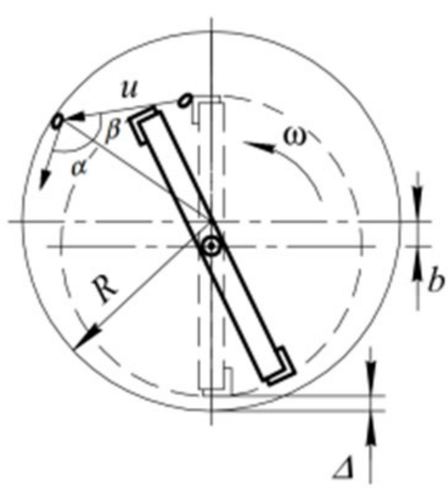

Fig. 1. Scheme of the grain hitting the crushing chamber after the hammer blow.

$$\beta = arcsin\frac{r-b}{R}, \tag{1}$$

In this b – The grinding chamber of the center of rotation of the lever is circular shift down from the center, m; R – grinding chamber radius m.

We determine the speed at which the grains hit the wall of the grinding chamber and are crushed after the impact of the hammer.

In this case, the shock pulse is as follows

$$mu\, cos\, \beta\, (1 + k_2) = F\tau, \tag{2}$$

In this m –the mass of the grain, kg; k_2– coefficient of grain recovery; F – impact force, H; τ – stroke time, c.

The grain particle is spherical and its cross-sectional surface is as follows:

$$S = \frac{\pi d^2}{4}, \tag{3}$$

In this d – diameter of the particle, m.

The mass of a grain particle can be determined as follows

$$m = \rho \cdot \frac{\pi d^3}{6}, \tag{4}$$

In this ρ – grain particle density, м.

Substituting expressions (3) and (4) into (2) yields the following

$$\frac{\rho \cdot \frac{\pi d^3}{6} \cdot u\, cos\, \beta (1+k_2)}{\frac{\pi d^2}{4}} = \frac{F}{S} \cdot \tau. \tag{5}$$

Depending on the size, density and viscosity of the grain particle, the impact time is as follows

$$\tau = 2d\sqrt{\rho/E}, \tag{6}$$

In this E – modulus of elasticity of the grain.

If we take into account that in the expression (5) $\frac{F}{S} = \sigma$, that is, it represents the loading of the grain under the impact of the impact, then according to the expression (6), the expression (5) becomes as follows

$$\frac{2}{3}\rho du\, cos\, \beta\, (1 + k_2) = \sigma \cdot 2d\sqrt{\rho/E}. \tag{7}$$

If we determine the speed of the grain after the impact of the hammer from the expression (7), then

$$u = \frac{3\sigma}{\sqrt{\rho E}\, cos\, \beta (1+k_2)}. \tag{8}$$

In order for the grains to be crushed, the load they receive as a result of the impact must be greater than the strength limit of σ grain loading, i.e. $\sigma \geq \sigma_{ch}$

Based on this, the condition for determining the limit value of the speed of the grain when it hits the grinding chamber, that is, in the "second blow", is as follows

$$u \geq \frac{3\sigma_{ch}}{\sqrt{\rho E}\, cos\, \beta (1+k_2)}. \tag{9}$$

We determine the limit value of the required speed of the grain for the "first blow", i.e., when the grain falls into the grinding chamber, when it is hit by the hammer of the handle and receives an impulse of $mu = F\tau$, it is crushed from the following condition

$$u \geq \frac{3\sigma_{ch}}{\sqrt{\rho E}}. \tag{10}$$

It is known that in order for the grain to be crushed to the required size in the grinding chamber, it needs to be hit several times in a row. After the "first blow" and the "second blow", the grain particles move in the form of an "air-particle ring" as a result of the rotary motion of the lever.

Under such conditions, it is necessary to set the actual velocity of the hammer u greater than the "air-particle loop" velocity $v_{кам}$, which ensures particle crushing.

According to V.I. Melnikov, the speed of the "air-particle ring" in the grinding chamber is 40-50% of the speed of the working bodies of the grinder.

If we assume that the speed of the "air-particle ring" in the grinding chamber is 50% of the speed of the crusher's working bodies, then in the case of the "third impact", i.e., the impulse received by the mallet when it hits a particle moving in the "air-particle ring" is equal to

$$m\frac{u}{2} = F\tau. \quad (11)$$

In this case, the grain particle fragmentation condition is based on expression (10).

$$u \geq \frac{6\sigma_{ch}}{\sqrt{\rho E}}. \quad (12)$$

The analysis of the expressions (9), (10) and (12) shows that, considering that the grain needs to be hit several times in order to grind it to the required level, it is appropriate to determine the speed of the lever hammer by the third condition.

Then for barley grain $\sigma_{ch} = 7\mathrm{M}Pa; \rho = 1300kg/m^3; E = 840MPa$, taking into account that, we perform calculations according to condition (12).

$$u \geq \frac{6 \cdot 7 \cdot 10^6 Pa}{\sqrt{1300kg/m^3 \cdot 840 \cdot 10^6 Pa}} = 40.2m/c. \quad (13)$$

It turned out that sufficient grinding of grains in the grinding chamber is ensured when the speed of the lever hammer exceeds 40.2 m/s.

When using grain grinders, it is difficult to determine the speed of its rotor or rotating parts, so it is convenient to determine the number of revolutions that provide this speed.

Based on this, from expression (12), we determine the number of revolutions of the hammer handle, which ensures the grinding of grains at the required level in the grinding chamber, as follows

$$n\frac{180\sigma_{ch}}{\pi r\sqrt{\rho E}}_{min}. \quad (14)$$

According to the calculation of the expression (14), it was found that the number of rotations of the shaft of the grinder handle should be at least 1785 rpm or more when its radius is $r = 0.215m$ to ensure the speed of the handle knob of 40.2 m/s or more.

4 Conclusions

According to theoretical studies on determining the rotational speed and number of revolutions of the hammer propeller crusher hammer developed for small livestock farms, grain crushing occurs when the speed of the propeller hammer reaches 40.2 m/s. When the radius of the hammer propeller is r = 0.215 m, the speed of its hammer is 40.2 m/s, and the number of revolutions of the propeller shaft is 1785 rpm. The speed and number of revolutions of the propeller hammer should be higher for the rapid grinding of nutritious grains in the grinding machine.

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