The balance of power consumption of the process of grain grinding

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The balance of power consumption of the process of grain grinding

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Abstract. The purpose of the research is to determine the power consumption of the process of grain grinding with a grinder. When conducting theoretical studies to determine the amount of energy spent on grinding grain during the operation of the grinder, the physical and mechanical properties of the grain, the parameters and mode of operation of the grinder, the energy consumption to overcome harmful resistances, to grind grain and to discard the crushed mass were taken into account. The technological scheme of the grain grinder is given. A mathematical dependence is proposed to determine the power consumption of the grain grinding process by a grinder. It has been established that the power consumption of a hammer grinder is mainly influenced by the number of hammers, the angular velocity of the hammer, the area of the front part of the hammer, the radius of the grinding chamber, and the physical and mechanical properties of the grain. As a result of the research, graphical dependences of power consumption and productivity on the number of revolutions of the hammer propeller were built.

1. Introduction

Studies to determine the amount of energy spent on grinding grain during the operation of the grinder were carried out by M.J. Odogherty, H. Tavakoli, Y. Jekendra, R. P. Prince, V.P. Yanovich, M. Azadbakht, M.I. Dabbour, W.J. Chancellor, G.E. Gale, P. Singh, I.M. Kupchuk, F.M. Mamatov, K.D. Astanakulov, J. Alijanov and others [1-10].

The authors have developed a grain grinder, which consists of a grain hopper, a dosing tray, a grinding chamber, a propeller, an output tray for products and an electric motor (figure 1). The grain entering the crushing chamber through the entrance window from the top first meets the rotating lever hammer and receives its impact, i.e. the "first impact".

Grains are placed in the hopper 1, and they are thrown into the chamber 3 for the purpose of uniform grinding through the standard conveying chute 2. In the grinding chamber, the grains are initially crushed by means of hammers fixed to the handle 4, and the crushed grain passes through the sieve installed in the hole opened from the wall of the lower part of the chamber and is placed in the bags through the outlet 5 (Figure 1).

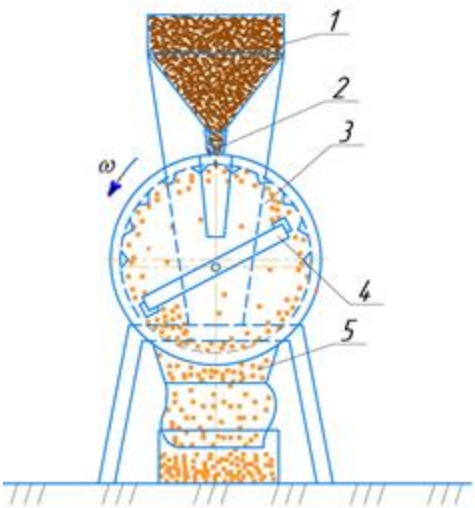

Figure 1. Technological scheme of the grain grinder.

The grain grinder rotates the rotor through an electric motor. Starting the grain grinder is done by pressing the black and red button of the stop control.

The purpose of the study is to determine the power consumption of the process of grinding grain with a grinder.

2. Materials and methods

When conducting theoretical studies to determine the amount of energy spent on grinding grain during the operation of the grinder, the physical and mechanical properties of the grain were taken into account, the parameters and mode of operation were crushed, the energy consumption to overcome harmful resistances, to grind grain and to discard the crushed mass [11-13].

In order to determine the required power of the developed grinding device and to determine its optimal technological mode, we will formulate the expression for determining the total amount of work in the grinding process [14-15]

$$A = A_1 + A_2 + A_3, \tag{1}$$

here A1 is the work spent on the mere operation of the working organs, that is, the energy spent on overcoming harmful resistances, J; A2 - the work or energy spent on grain grinding by the working bodies, J; A3 is the work or energy spent on throwing out the crushed product, J.

3. Results and discussion

The first component of the expression for determining the total amount of work spent in the technological process of the grinding device represents the frictions of the shafts in the bearings and the resistances used to overcome the air resistance (Figure 2).

The energy spent on single rotations during the operation of the grinding device is equal to the following.

$$N_{sr} = R_{rs} f_b r_s \omega + \frac{\gamma_d S_f z r_d^3 \omega^3}{2}, \tag{2}$$

here R_{rs} – the sum of the reactions at the supports, N; f_b – coefficient of friction in bearings; r_s – the radius of the shaft on which the bearings are mounted, m; ω – the angular velocity of the blades in rotation, s^{-1}; z – the number of tufts; γ_d – air density (usually $\gamma_d = 1{,}2 kg/m^3$); S_f – the surface of the front part of the tuft, m^2; r_d – the distance from the center of the front surface of the mallet to the center of its rotation, m.

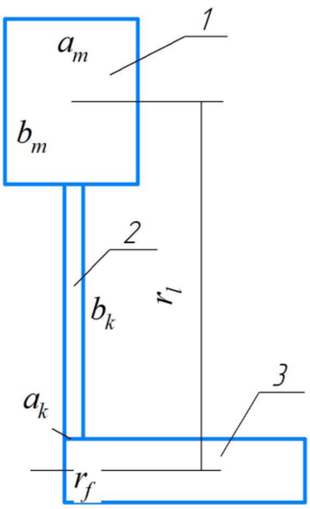

Figure 2. The front surface of the hammer and handle: 1 – hammer, 2 – prop, 3 – roller.

If $a_m b_m >> a_k b_k$, then $S_f = a_m b_m$ and $r_d = r - b_m / 2$ can be accepted. In order to evaluate the influence of mechanical and structural factors on the grinding process, we determine the amount of useful work spent on impact grinding the product of m_s mass of the shards in the grinding chamber during the period of t hours of being in the grinding chamber as follows

$$A_2 = (ztn/60)(m_s v_p{}^2/2), \tag{3}$$

In this n – the frequency of rotation of the tufts, min^{-1}; z – the number of tufts; υ_p – the speed of the hammers relative to the layer of crushed product (impact speed), m/s.

Hammers crush grains by friction as well as impact. The energy spent on grinding the product by friction on the surface of the grinding chamber when the hammers move the grains between the grain itself and the grain of the grinding chamber can be determined as follows

$$A_2 = (ztn/60)(m_s v_p{}^2/2)(1 + f_f). \tag{4}$$

In this f_f – coefficient of friction of the product to the surface of the roller.

If we take into account that the impact of the hammer working body on the product to be crushed occurs mainly in sections II and III of the grinding chamber, then the work spent on the impact of the lever hammer on the product moving inside the grinding chamber

$$A_2 = (ztn/60)(m_s v_p{}^2/2)(1 + f_f)/2. \tag{5}$$

Based on the above, the energy used to crush the product in the crushing chamber under impact and friction is as follows

$$N_g = A_2 / t, \tag{6}$$

or (4) given the expression

$$N_g = (zn/60)\left(m_s v_p^{\ 2}/2\right)(1+f_f)/2. \tag{7}$$

If we take into account that $v_p = u/2 = \omega r/2$ and $n = 30\omega/\pi$, then the expression (7) in the final state will look like this.

$$N_g = z m_s r^2 \omega^3 (1+f_f)/(32\pi). \tag{8}$$

The power used to move the product inside the grinding chamber can be considered as the work done by the force used to rub the product against the inner surface of the grinding chamber

$$N_{um} = f_{is} m_s v_p^{\ 3}/R, \tag{9}$$

where R - is the radius of the crushing chamber, m; f_{is} – is the coefficient of friction of the product to be crushed on the inner surface of the grinding chamber; v_p – the speed of the crushed product, m/s.

As can be seen from the expression, only the effect of centrifugal force is taken into account here, and the effect of gravity is not taken into account since it is $\frac{v_p^{\ 2}}{R} >> g$.

Given that $v_p = u/2 = \omega r/2$, the final expression is:

$$N_{um} = f_{is} m_s r^3 \omega^3/(8R). \tag{10}$$

The total power requirement of the grinder.

$$N = N_{sr} + N_g + N_{um}. \tag{11}$$

If we put the constituents of expressions (2), (8) and (10) into expression (11), then the total required power of the crusher

$$N = R_{rs} f_b r_s \omega + \frac{\gamma_в S_f z r_d^{\ 3} \omega^3}{2} + z m_s r^2 \omega^3 (1+f_f)/(32\pi) + f_{is} m_s r^3 \omega^3/(8R). \tag{12}$$

The efficiency coefficient of the electric motor and the total required power taking into account the losses is $N_{rp}=N/0,64$.

For developed grain grinders, the amount of energy used to grind grains during their work is also an important indicator. The relative energy consumption (j/kg) used to grind 1 kg of grain in the grinder is as follows

$$N_r = \left[R_{rs} f_b r_s \omega + \frac{\gamma_в S_f z r_d^{\ 3} \omega^3}{2} + z m_s r^2 \omega^3 (1+f_f)/(32\pi) + f_{is} m_s r^3 \omega^3/(8R)\right]/q. \tag{13}$$

here q – is the work output of the crusher, kg/s.

Optimum technological operation mode of the grain crusher device can be achieved by minimizing relative energy consumption.

Since expression (13) also contains transcendental functions, it is not possible to solve this problem analytically. Therefore, we solve it numerically.

At r=0,215 m; R=0,24 m; q=0,03 kg/s, ω=288 rad/s, m_s=0,006 kg, z=2, R_{rs}=21,2 n, f_b=0,1, r_s=0,01 m, $\gamma_в$=1,2 kg/m^3, S_f=0,000675 m^2, r_d=0,2025 m, f_f=0,3 ва f_{is} =0,2 the specific energy consumption of the grinder is N_r =16745 J/kg.

The total power required by the grinder serves as a basis for choosing an electric motor for it (Figure 3).

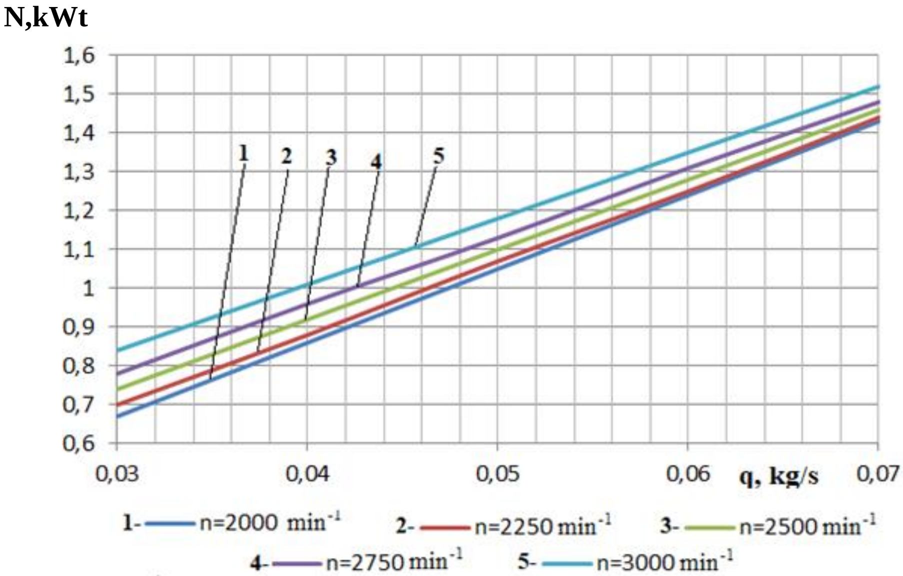

Figure 3. The effect of the number of revolutions of the grinder hammer on power and performance.

The calculations performed showed that the power spent on grinding increases with the increase in the speed of the fabric working body. The increase for energy spent on grinding the product with the same amount of the product sent for grinding is explained by the increase in the rotational speed of the textile working body, and the achievement of fine grinding of the grains at a high rotation speed of the textile handle.

4. Conclusions

When determining the amount of energy spent on grinding grain during the operation of the grinder, the energy costs for overcoming harmful resistances, for grinding grain and for discarding the crushed mass were taken into account. A mathematical dependence is proposed for determining the power consumption of the process of grinding grain by a grinder. It has been established that the power consumption of a hammer grinder is mainly influenced by the number of hammers, the angular velocity of the hammer, the area of the front part of the hammer, the radius of the grinding chamber, and the physical and mechanical properties of the grain. As a result of the research, graphical dependences of power consumption and productivity on the number of revolutions of the hammer propeller were built.

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