Effect of end sieves on the energy and quantitative indicators of a grain crusher with an increased separating surface

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Abstract. Cereals are an integral part of the feed rations of farm animals. When dry feeding, the grains are crushed. Grain grinding can be performed in various ways, such as crushing, splitting, abrasion, and impact. Different equipment is used for this purpose: roller machines, mills, gear, disk and hammer crushers, etc. In Russia, the most common method of grinding grain in hammer crushers. The advantages of hammer crushers include their high reliability, simplicity of design and maintenance, while the disadvantages are high energy consumption for grain grinding and uneven granulometric composition of the finished product. Due to these shortcomings, it is important to improve the design of crushers in order to increase their productivity and reduce specific energy consumption. We have proposed a grain crusher with an increased separating surface. To study the crusher, its structural and logical scheme and research methodology were developed. In accordance with the developed scheme, the influence of the sieve area on the quantitative and energy performance of the crusher was studied, which is the purpose of this work. The research methodology was developed and a prototype of the crusher was made. The conducted research allows us to conclude that it is necessary to change the conditions for entering grain into the grinding chamber by increasing the area of the loading window, installing a mechanism for forced grain feeding or feeding grain through the center of the rotor. The throughput of end sieves when using a rotor with straight hammers is by 2...38% higher than that of peripheral sieves.

1. Introduction

Cereals are an integral part of the feed rations of farm animals. Currently, the most common method of feeding full-fledged feed. With proper pre-treatment, the proportion of nutrients assimilated from the feed mixture is higher, which has a positive effect on the productivity of farm animals and reduces the amount of feed consumed [1, 2, 3, 4, 5]. At the same time, cereals can be added to such feed mixes as molasses or in dry form.

Molasses is a high-energy product necessary for the enrichment of coarse feed with easily digestible carbohydrates, which is aimed at reducing the consumption of amino acids for energy needs and, as a result, reducing the need for protein in animals [6, 7, 8]. With a constant reduction in the area occupied
by root crops and small production of molasses, the introduction of grain molasses into the diet of farm animals becomes relevant. In the production of molasses, the destruction of grains in disintegrators can occur due to chipping when they are pinched between the teeth of the rotor and counter-cuts, or by hitting the blades of the disintegrator impeller [9, 10, 11]. However, it should be noted that grain molasses is a high-carbohydrates additive and cannot replace a full-fledged feed.

When dry feeding, grains are crushed, since the size of grain particles has a significant impact on the digestibility of the feed mixture. Grain grinding can be performed in various ways, such as crushing, splitting, abrasion, and impact [12]. Different equipment is used for this purpose: roller machines, mills, gear, disk and hammer crushers, etc. [13]. In Russia, the most common method of grinding grain in hammer crushers [14, 15, 16, 17]. The advantages of hammer crushers include their high reliability, simplicity of design and maintenance, while the disadvantages are high energy consumption for grain grinding and uneven granulometric composition of the finished product. Due to these shortcomings, it is important to improve the design of crushers in order to increase their productivity and reduce specific energy consumption. The performance of crushers is affected by the area of the separating surface. We have proposed a grain crusher with an increased separating surface [18]. To study the crusher, its structural and logical scheme and research methodology were developed [19]. In accordance with the developed scheme, the influence of the sieve area on the quantitative and energy performance of the crusher was studied, which is the purpose of this work.

2. Materials and methods
The tests were conducted in the laboratory of the Nizhny Novgorod state engineering and economic university. A prototype of the crusher was made for research (figure 1). The crusher consists of a loading hopper 1 and a housing 5, in which a hammer rotor 4 with straight hammers is installed. The rotor is surrounded by two end 3 and one peripheral 2 sieves. The throughput capacity of the peripheral and end sieves was determined. For this purpose, the peripheral and end sieves were separated by partitions 6. Between the partitions 6, the crushed grain that passed through the peripheral sieve 2 fell into the container 7. The crushed grain passed through the end sieves 3, passed in the space limited by the partitions 6 and the body 5 of the crusher, and fell into the container 8.

![Figure 1. Laboratory installation: a – general view; b – scheme; 1 – loading hopper; 2 – peripheral sieve; 3 – end sieves; 4 – rotor; 5 – housing; 6 – partitions; 7 – container for collecting crushed grain that passed through the peripheral sieve; 8 – container for collecting crushed grain that passed through the end sieves; 9 – the handle flap.](image_url)

The influence of sieves on the energy and quantitative indicators of the crusher was studied. The experiment was performed in the following sequence. Grain was filled into hopper 1, the required rotor speed was set, set the desired angle of the flap 9. The crusher was turned on, the device for measuring the power of the electric motor was turned on, the hopper flap was opened and the stopwatch was turned on.
During the operation of the crusher, the power consumed by the electric motor was recorded. After the set time, the flap was closed and the crusher was turned off. The crushed grain was weighed in containers 7 and 8, the throughput capacity Q of the sieves and the overall productivity of the crusher, the specific energy consumption \( w \) were calculated according to the well-known method [20]. After that, angle of the flap 9 and the rotor speed was changed. The experiment was repeated again. Experiments were carried out for two cases: in the first case, only the peripheral sieve was installed, and blind walls were installed instead of the end walls; in the second case, the peripheral and end sieves were installed.

3. Results and discussion

The results of the research are presented in the form of graphs shown in figure 2. Regardless of the speed of rotation of the rotor, with increasing productivity, there is an increase in power consumption and a decrease in specific energy consumption. In most cases the dependences of power consumption \( P \) and specific energy consumption \( w \) were described by second degree polynomials (\( P\_p \) and \( W\_p \) – designation for the case of installation of a peripheral sieve only and \( P\_p+t \) and \( W\_p+t \) – designation for the case of installation of peripheral and end sieves):

\[
\text{a)
\begin{align*}
\text{w, (W-h)/kg} & = 45 - 0.5Q & \text{P, kW} & = 2.5 - 1.5Q \\
\text{Q, kg/h} & = 0 & \text{P, kW} & = 2.5 - 1.5Q \\
\end{align*}
\]

\[
\text{b)
\begin{align*}
\text{w, (W-h)/kg} & = 30 - 1.5Q & \text{P, kW} & = 2 - 1Q \\
\text{Q, kg/h} & = 0 & \text{P, kW} & = 2 - 1Q \\
\end{align*}
\]
Figure 2. Change in specific energy consumption and power consumption when grinding grain with a crusher with an increased separating surface at the rotor speed: а – 4250 min⁻¹; b – 4000 min⁻¹; c – 3750 min⁻¹; d – 3500 min⁻¹; 1, 2 – designation for the case of installation of a peripheral sieve only; 3, 4 – designation for the case of installation of peripheral and end sieves.

The graphs show that in general, the productivity of the crusher and the power consumption of its electric motor, both when using only the peripheral sieve, and when installing both the peripheral and end sieves at the same time, are almost identical. The minimum energy consumption is about 5 (W*h)/kg. At the same time, the maximum productivity of the crusher is observed, which is in the region of 320 kg/h.

At the same time, it should be noted that the power consumption does not exceed 2 kW when the installed power of the electric motor is 3 kW. This fact indicates that the engine is not fully loaded. In other words, to use the full potential of the crusher, it is necessary to change the conditions for entering grain. Based on the design of the crusher, three options are possible: increasing the area of the loading window, installing a mechanism for forced grain supply, and feeding grain through the center of the rotor.

The distribution of crushed particles between the peripheral and end sieves is analyzed. The results are presented as histograms showing the throughput of the peripheral and end sieves depending on the angle of the handle (figure 3).
The histograms show that in all modes the throughput of the end sieves is higher than the peripheral one by 2...38%.

In accordance with the structural and logical scheme developed by us, it is possible to increase the throughput of sieves by creating a directed air flow in the grinding chamber. This can be achieved by installing special shaped hammers on the rotor [21].

4. Conclusion

The conducted research allows us to conclude that it is necessary to change the conditions for entering grain into the grinding chamber by increasing the area of the loading window, installing a mechanism for forced grain feeding or feeding grain through the center of the rotor. The throughput of end sieves when using a rotor with straight hammers is by 2...38% higher than that of peripheral sieves.

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