Experimental study results of the grinding process in a hammer-type shredder with side separating sieves

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Abstract: *The technical implementation of air-product flow control in the working chamber of a hammer mill for timely separation of conditioned particles from the main stream and their lateralization (removal to the side zones) for the purpose of evacuation from the working chamber is considered. The energy and quality indicators of the grinding process in a hammer mill with side separating sieves are determined. The obtained experimental dependences are necessary for the manufacture of hammer crushers for farms and the development of recommendations for the operation of hammer crushers with side separating sieves. Improving the conditions of the grain material separation process and timely unloading of the finished product from the grinding chamber makes it possible to achieve economic efficiency by reducing the content of the dust fraction in the finished product and reducing the specific energy costs of the grinding process.*
KEYWORDS*: GRINDING, SIEVE, SEPARATOR, GRAIN.*

1. Introduction

High requirements for the manufacturability of equipment, as well as the quality of processing feed material that meets the physiological needs of farm animals, lead to the need to expand research in the field of grinding feed grain. The most important technical and economic task of grain mass grinding is to obtain a final product with uniform grain size composition with, the required particle size and minimum energy costs.

Theoretical studies have established the possibility of correcting the trajectories of conditioned particles of crushed raw materials to the optimal location zone of the separating sieves [1]. Further experimental studies are needed to determine the adequacy of the obtained structural and geometric parameters of the grinder. The developed methodology for engineering and analytical research of the air-product flow control process (hereinafter referred to as the APF) in the working chamber of the hammer crusher made it possible to form variations of the technical solution schemes ensuring the fulfillment of the designed objective function - unloading the finished product through the side unloading zones under established technical conditions and quality indicators [1, 8].

2. Preconditions and means for resolving the problem

The complexity of mathematical formalization of the process of APF lateralization in the working chamber of the hammer crusher, as well as the presence of accepted assumptions, implies checking the operability of the detected analytical dependencies within the framework of experimental studies [1]. To determine the level of reliability of the proposed technical solution, it is necessary to evaluate the productivity and energy intensity of the grain material grinding process, as well as analysis of quality characteristics of the grinding product. This analysis is necessary to confirm the economic efficiency of the developed laboratory-production equipment and identify promising areas for further improvement of the production and technological base [4, 8].

3. Solution of the problem under consideration

To determine the rational operating parameters of the system of lateralization of conditioned particles during grinding in a hammer shredder with side separating sieves, experimental studies were conducted (Fig. 1). The program of laboratory and production tests provided for determining the productivity of the hammer crusher and the energy consumption of the grinding process, depending on the size of the feed of various components.

The tendency to increase the productivity of the crusher requires matching the energy consumption with the quality of the ground grain. To study the granulometric composition of crushed grain raw materials in production conditions, the analysis of grinding products obtained during grinding on an experimental crusher was carried out [2]. An indispensable condition for the operation of closed-type crushers is the circulation of grain material in the volume of the working space of the shredder. The energy consumption per unit of finished product, to a greater extent, depends on the amount of circulating material. Therefore, it is advisable to evaluate the energy efficiency of a shredder with a lateral arrangement of unloading zones and the APF lateralization function by an indicator that characterizes the degree of filling the volume of the working chamber with grain material [5, 6].

With an increase in the filling factor of the working volume of the chopper chamber, the load from the circulation of incoming material increases. There is a high probability of occurrence of a mode when the amount of grain material increases uncontrollably.

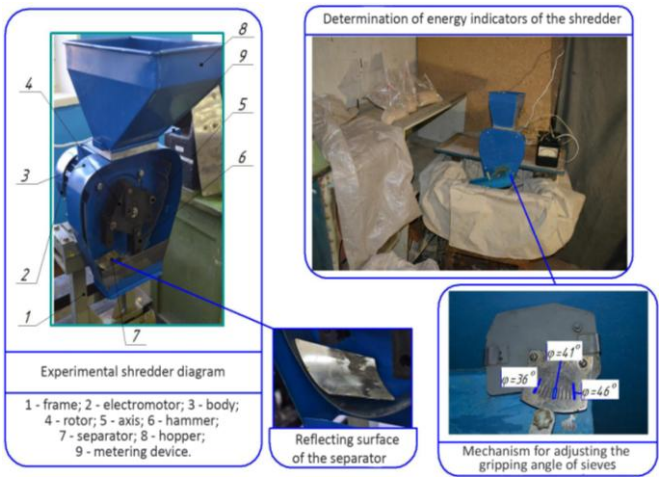


Fig. 1. *Experimental hammer-type shredder*

As a result, the shredder is overloaded. Such a marginal, non-functional state, when processing of incoming material is technologically impossible, leads to an emergency situation. The elimination of emergency mode is provided by optimizing the feed of grain raw materials to minimize the circulating load [1, 8].

Filling the volume of the working chamber is characterized by the amount of grain material constantly located in the working chamber and is determined by a coefficient that is reliably calculated using the formula:

$$\mu = \frac{q - Q}{V} \quad (1)$$

where:

μ – Fill factor of the volume of the working chamber, kg/(m^3.h);

q – Feed rate feedstock, kg/h;

Q – Total output, kg/h;

V – Working volume of the grinding chamber, m^3.

The method of optimization of elements of the working chamber of the hammer shredder was to create anomalous modes of evacuation of the conditionative product from the working chamber of the shredder. The anomalous operating mode of the unloading system was implemented by setting the capture angles of the separating sieves, which contradict the calculated results, with other adequate geometrical parameters of the separator. We varied the gripping angle of the sieves φ, in the range from 36 to 46 degrees, and recorded the specific energy consumption per unit of production and the value of the filling coefficient of the working chamber volume.

4. Results and Discussion

Rational mode of grinding is determined by dependence of capacity of experimental grinder with side separating sieves on volume of loading of ground raw material into working chamber and on degree of grinding determined by diameter of through hole of classification sieve. The dependences of productivity on the feed rate for various sieves and grain materials are shown in the figure (Fig. 2). These dependencies allow you to select the optimal values of feed volumes, which provide the highest throughput of the experimental shredder with side separating sieves.

The optimal operating modes of the experimental hammer mill (the sieve diameter is 3 mm, the crushed material is wheat) are determined by the maximum capacity of 206.5 kg/h with a supply value of 260.76 kg/h. When grinding barley, the maximum capacity of 190.3 kg/h is provided by a supply of 226.9 kg/h. When using a sieve with a cell diameter of 5 mm, the maximum capacity for barley is 217.8 kg/h, and for wheat 230 kg/h.

The quality of the finished product was evaluated using variational grinding characteristics (Fig. 3) for various grinding modules. The results show that in steady state operation the grinder produces the same particle size composition.

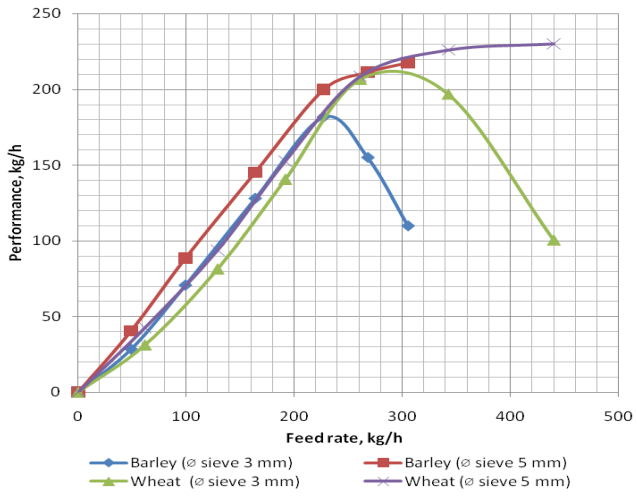


Fig. 2. *Dependence of the productivity Q of the hammer shredder on a supply value q of the crushed material*

The characteristics of barley groats obtained using a sieve with a diameter of 5 mm have a linear relationship. This indicates that their sizes are distributed fairly evenly across classes. The average particle size for a 5 mm sieve corresponds to a diameter d = 1.75 mm. When using a sieve with a diameter of 3 mm, the average particle size is d = 1.32 mm. Analysis of the total grinding characteristics (Fig. 3) showed a tendency to a downward trajectory, which indicates the uniformity of the particle size distribution. Studies have shown that increasing the diameter of the sieves holes in the crusher leads to an increase in particle size in the ground product and a decrease in the amount of fine particles [3].

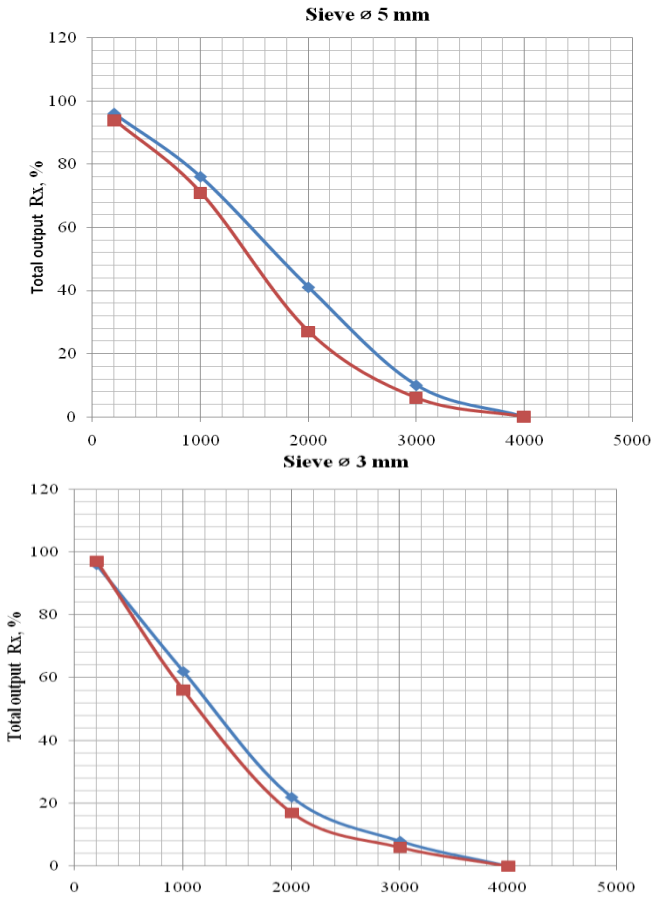
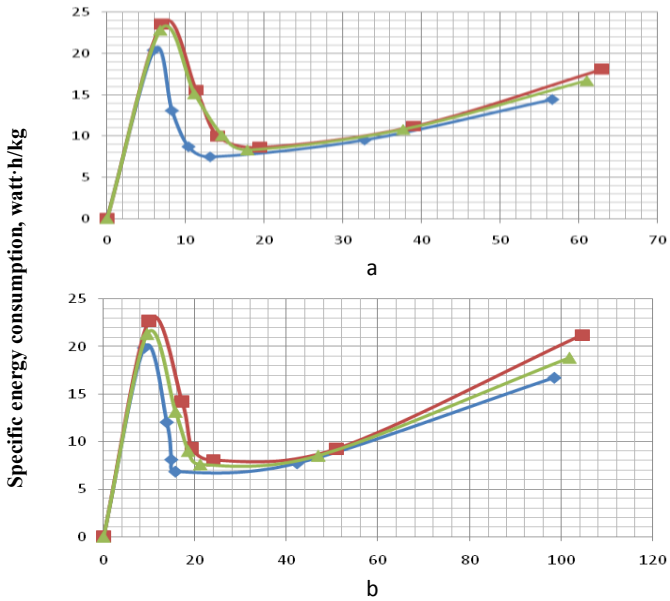


Fig. 3. *Variational grinding characteristics for various grinding modules and grain crops*

It should be noted that it is possible to obtain a ground product meeting the requirements of medium grinding (for young livestock ducks, chickens, turkeys and fattening of cattle at the age of 76 to 100 days, of early young cattle and pigs, sucked sows) when installing in a hammer crusher a sieves with a diameter of 3.0 mm. To obtain feed for calves, young cattle, young chickens, broilers, ducks, geese, meat and bacon fattings pigs, young sheep, it is necessary to install a sieve with a hole diameter of 5.0 mm [9].

The dynamics of the change in specific energy consumption from the change in the amount of grain material in the working chamber of the hammer grinder are represented by the graphs in Figure (Fig. 4).



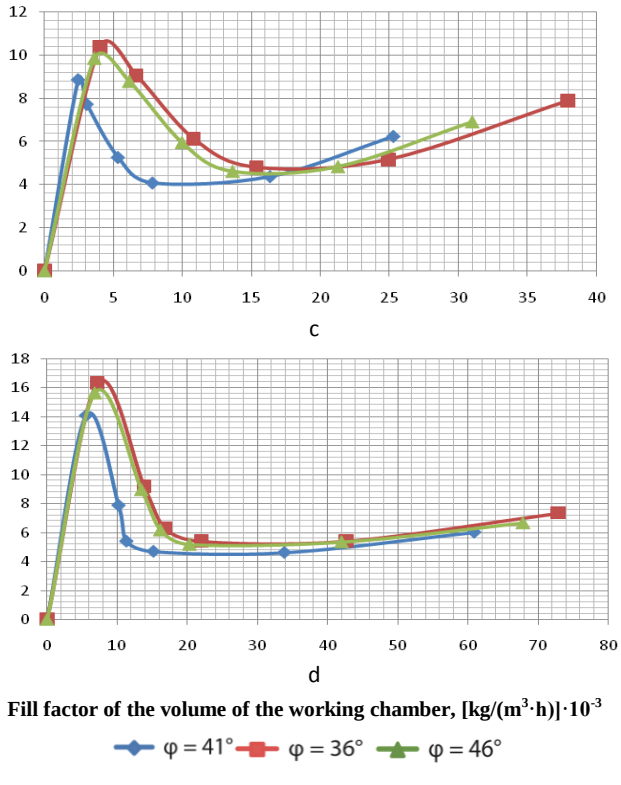


Fig. 4. *Dependencies of specific consumption of energy per unit of product from the fill factor of the volume of the working chamber: a – the grinding of barley, sieve diameter 3 mm; b – the grinding of wheat, sieve diameter 3 mm; c – milling the barley, the diameter of the sieve 5 mm; d – milling of wheat , the diameter of the sieve 5 mm*

It follows from the graphs that the specific energy consumption of grinding significantly depends on the degree of grinding controlled by the size of the sieve cell. It was found that the energy consumption of grinding barley and wheat to the degree of grinding corresponding to the caliber of the sieve with a cell ⌀3 mm is in the range of 7.48 to 20.39 watt·h/kg, and from 6.85 to 19.87 watt•h/kg. respectively. The lower limit is reached when the feed of the crushed material is 226.9 kg/h for barley and 260.76 kg/h for wheat. When using a sieve with a cell of ⌀5 mm indicators of energy consumption change slightly, in case of finding of coefficient of filling of volume of the working camera in the range of values, for barley from 7.83 to 16.35 and for wheat from 15.17 to 33.82 it testify to the nominal mode of operation of the grinder.

A comparison of the results of theoretical calculations with experimental data indicates an increase in the circulating load, which leads to an increase in specific energy costs.

The analysis of the provided schedules shows that with reduction of an angle of capture of a sieve to 36 degrees the specific power consumption of crushing of barley and wheat (to the degree of a grinding corresponding to sieve caliber with a cell of ⌀3 mm) is ranging from 8.63 up to 23.57 watt·h/kg for barley and from 8.03 to 22.76 watt·h/kg for wheat. In case of application of a sieve with a cell of ⌀5 mm specific costs of energy of crushing of barley are in range from 4.8 to 10.40 watt·h/kg. For wheat, the interval boundaries are slightly wider - from 5.40 to 16.32 watt·h/kg. The average increase in energy intensity of the process due to reduction of the capture angle is 18%.

Energy parameters in case of increase of the capture angle of the sieves to 46 degrees have similar dynamics of change. The boundaries of the interval values indicate a less critical nature of the effect of increasing the angle of capture of sieves on technical and economic indicators. For example, when using a sieve with a hole diameter of 3 mm, the energy consumption of grinding barley is in the range of 8.31 to 22.85 watts·h/kg, and for wheat from 7.6 to 21.36 watts·h/kg. At the same time, the energy consumption of grinding when using a sieve with a hole diameter of 5 mm for barley is from 4.61 to 9.86 watt·h/kg, and for wheat from 5.19 to 15.64 watt·h/kg. The average increase in the energy intensity of the process for the second anomalous mode is 12 %.

5. Conclusion

The proposed methodology of laboratory production studies allowed us to determine the main operational indicators of the designed hammer grinder with side separating sieves.

For the unloading system (a separator with an initial curvature of the reflecting surface α = 40 ° and a sieve capture angle φ = 41 °), economically feasible operating modes of the hammer grinder with side separating sieves have been established.

The values of the throughput capacity of the shredder have been reached, ensuring satisfactory quality indicators of the resulting product. When grinding wheat on a sieve with a diameter of 3 mm, the productivity was 206.5 kg/h., For barley, the productivity was 190.3 kg/h. When using a sieve with a mesh diameter of 5 mm, the productivity for barley is 217.8 kg/h, and for wheat - 230 kg/h.

The experimental dependence of the specific power consumption of grinding on the filling factor of the volume of the working chamber showed an increase in power consumption, both in case of deviation in the direction of increase and in case of deviation in the direction of decrease of the value of the grip angle of the sieves from the optimal value (41 degrees). Reducing the screen grip angle to 36 degrees increases the power consumption by 18%. Increasing the screen grip angle to 46 degrees increases the energy consumption of 12%. The results are fair for barley and wheat when ground on sieves with diameters of 3 mm and 5 mm.

Sufficient convergence of theoretical and experimental results confirms the prospects of creating a technical product – hammer-type shredder, which technologically provides for the lateralization of APF and lateral evacuation of the conditioned product.

References

[1] Ushakov Y., Shakhov V., Asmankin E., Naumov D. Theoretical study results of product flow management process in hammer-type shredder working chamber. 10.22616/ERDev2019.18.N231.

[2] Павлидис В.Д., Бурлуцкий Е.М., Чкалова М.В., Сапун О.Л. Экспериментальное исследование процесса измельчения зернового сырья (Experimental study of the process of grinding grain raw materials). Техническое обеспечение инновационных технологий в сельском хозяйстве: материалы международной научно-практической конференции (Technical support of innovative technologies in agriculture: materials of international scientificpractical conference), Minsk, Belarusian State Agrarian Technical University, 2016, pp. 103-107 (In Russian).

[3] Булатов С.Ю., Миронов К.Е., Нечаев В.Н., Савиных П.А. Разработка и использование методики определения оптимального положения загрузочного окна дробилки зерна ударно-отражательного действия (Development and application of determination method of the most suitable position for charging hole in the grain crusher of impact-rejected action). Пермский Аграрный вестник (Permskii Agrarnyi Vestnik), № 1 (21), 2018, pp. 4-14 (In Russian).

[4] Савиных П.А., Булатов С.Ю., Нечаев В.Н. Экспериментально-теоретические исследования процесса движения частицы по лопатке ротора-вентилятора (Iexperimental-theoretical studies of the process of particle movement along the blade of the rotor-fan), Научно-технический прогресс в сельскохозяйственном производстве: материалы международной научно-практической конференции (Scientific-technical progress in

agricultural production: materials of international scientificpractical conference). Minsk: SPC NAS of Belarus for mechanization of agriculture, 2014, pp. 59-65 (In Russian).

[5] Нечаев В.Н. Изучение влияния конструктивных факторов лопаток ротора-вентилятора на показатели рабочего процесса дробилки (Studying of influence of constructive factors of shovels of rotor-conditioner to the characteristics of crushing woring process). Вестник НГИЭИ (Bulletin NGIEI), № 8, 2012, pp. 12-21 (In Russian).

[6] Лебедев А.Т., Валуев Н.В., Искендеров Р.Р. Экспериментально теоретические подходы к оценке эффективности процесса измельчения зерновых материалов (Experimental theoretical approaches to estimation of efficiency of grain materials grinding process). Вестник АПК Ставрополья (Agricultural Bulletin of Stavropol Region), №2(14), 2014, pp. 61-64 (In Russian).

[7] Шахов В.А., Ушаков Ю.А., Асманкин Е.М., Наумов Д.В. Методика оценки взаимодействия ингредиентных частиц зерновой массы и воздушного потока в рабочей камере дробильных машин (Methods of assessing the interaction of the ingredient particles of the grain mass and the air flow in the working chamber of crushing machines). Научно-технический прогресс в сельскохозяйственном производстве: материалы международной научно-практической конференции, посвященной 110-летию со дня рождения академика М.Е. Мацепуро (Scientific-technical progress in agricultural production: materials of international scientificpractical conference dedicated to the 110th anniversary from the birthday of academician M.E. Matsepuro / ed. by P. Kazakevich). – Minsk: SPC NAS of Belarus for mechanization of agriculture, 2018, pp. 196-200 (In Russian).

[8] Шахов В.А., Ушаков Ю.А., Петров А.А., Абдюкаева А.Ф., Наумов Д.В. Анализ функциональной специфики дробильных устройств с боковым расположением выгрузных зон (Analysis of the functional specificity of the crushing device with lateral disposition of the unloading zones). Известия Оренбургского государственного аграрного университета (Izvestia Orenburg State Agrarian University), №4, 2018, pp. 181-184 (In Russian).

[9] Chkalova M., Shahov V., Pavlidis V. Effectiveness analysis of ways organizing production of combined feeds 110.22616/ERDev2019.18.N004.