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Experimental research of oscillation parameters of vibrating-rotor crusher

***Abstract**. In article experimental model and specifications Vibrating-Rotor Crusher for grinding feed grain are present. Crusher implements the idea of the combined interaction of vibration and rotational motion of executive bodies, which can significantly increase the power to influence material. To determine the range of the operating parameters of the machine was carried out experimental studies of the amplitude-frequency characteristics of the developed machine depending on the angular velocity of the drive shaft.*

***Streszczenie.** Przedstawiono model i badania rozdrabniacza z wibrującym wirnikiem do ziaren paszy. Rozdrabniacz łączy wibrowanie I obracanie co znacząco poprawia jakość pracy. Badano zależność częstotliwości I amplitudy od prędkości kątowej. (**Eksperymentalne badania oscylacji rozdrabniacza z wibrującym wirnikiem**)*

Keywords: impact and cutting crusher disc, oscillations amplitude, vibrovelocity, vibroacceleration, oscillation intensity.
Słowa kluczowe: rozdrabniacz paszy, wibrujący wirnik, oscylacje.

Introduction

In the technological process of feed preparation, the share of energy consumption for grinding can reach 65% [1]. Therefore, the effective functioning of farms in modern conditions requires development and implementation of technologies that meet international standards and reduce excessive energy losses [1, 2].

Thus, profitability and competitiveness of the livestock industry largely depends on the energy efficiency of this technological operation, and reducing energy intensity of the process is an urgent task.

Analysis of literary sources and problem statement

From the point of cost reduction, introduction of machines for grinding grain, proposed by Sergeev N.S. [3], Abramov A.A. [4], Nanka O.V. [5, 6], the principle of which is based on a combination of cutting and spalling methods, is quite promising. The advantage of such a combination is the local overvoltage of surface microvolumes in places of load application [7, 8]. In the process of cutting the knife blade is wedged into the product and near the contact surface a specific pressure sufficient to destroy the body is created.

On the basis of the Laboratory of Theory of Mechanisms and Machines of Vinnitsa National Agrarian University [9] a experimental model Vibrating-Rotor Crusher has been developed (Fig. 1), in which, when the electric motor 5 is turned on, the torque through the clutch 6 is transmitted to the kinematic shaft 7 with counterweights 8, the rotation of which leads to the creation of a combined power and moment imbalance of the rotor 9, placed on it, with axes and disk-shaped beaters 10 [10].

The processed material is continuously being fed through the loading neck 2 and crushed due to the rotational and oscillating motion of the disc beaters 10. With particle size reduction, the crushed material under the influence of centrifugal forces and alternating loads, through the sieve surface, undergoes intensive classification: particles equal to or smaller than the diameter of the sieve 4 holes is unloaded through the neck 3, the rest goes for re-grinding [10].

This combination of grinding methods (impact and cutting) makes it possible to process substandard raw materials with a high moisture content while reducing energy consumption for this technological operation, which was confirmed by the results of the experimental research.

However, in order to achieve high energy efficiency, it is necessary to substantiate the rational modes of operation for the suggested equipment.

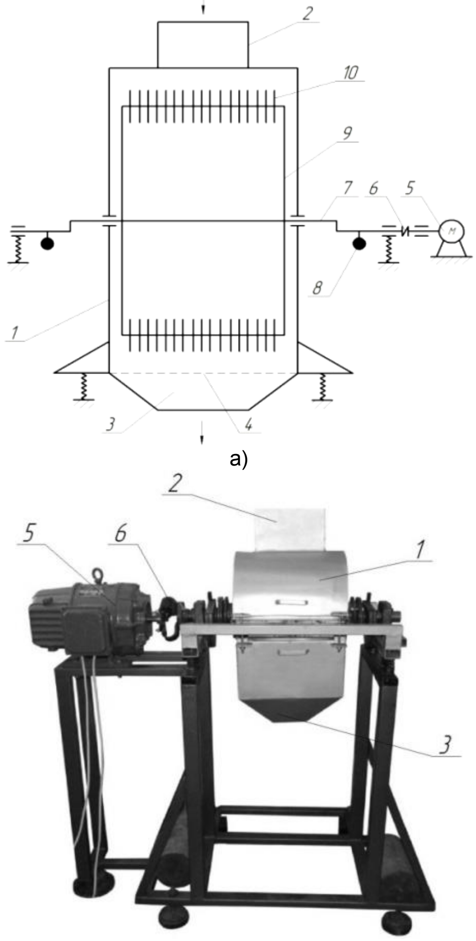


Fig. 1. Developed Vibrating-Rotor Crusher: a) Scheme of the Vibrating-Rotor Crusher; b) Experimental model: 1 – grinding chamber; 2, 3 – loading and unloading neck; 4 – sieve; 5 – electric motor; 6 – elastic clutch; 7 – kinematic shaft; 8 – counterweights; 9 – rotor; 10 – disk-type beaters.

Purpose and tasks of research

The purpose of the research is to determine the range of operating parameters of the Vibrating-Rotor Crusher for the for grinding feed grain. To achieve this goal, it is necessary to study the amplitude-frequency characteristics of the developed machine depending on the angular velocity of the drive shaft.

Materials and methods

Experimental part of the work was performed on the base of the Department of Technological Processes and Equipment for Food and Processing Industries of Vinnytsia National Agrarian University laboratories on the stand (Fig. 2) and experimental model of the vibratory crusher [11, 12] (Fig. 1). Technical and design parameters of the experimental model are given in table 1.

Table 1 – Technical characteristics of the experimental model

Parameter	Value
The operating mode	continuous
The movement of the working equipment	vibration-centrifugal
The shape of the oscillations	flat elliptical
The size of perforation of sieve surfaces, mm	1,8
Power of the electric motor, kW	1,6
Diameter of a disk whip, mm	90
Sharpening angle of the crushing disk, deg.	15
Overall dimensions, m:	
- length	1.37
- width	0.65
- height	1.35
Weight, kg	150

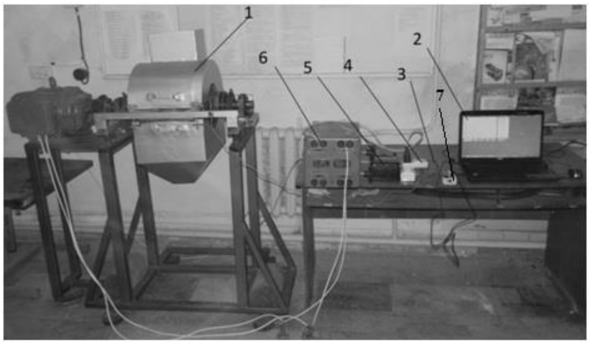


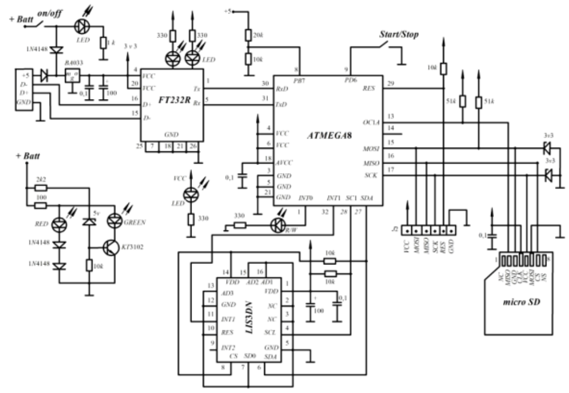
Fig. 2. Experimental stand: 1 – experimental sample of the vibratory disk crusher; 2 – personal computer; 3 – switch; 4 – EMF-1 electronic wattmeter; 5 – secondary electromechanical wattmeter; 6 – AOCH-20-220-75 laboratory transformer; 7 – accelerometer.

To record the amplitude-frequency characteristics of the vibratory disk crusher, a sensor based on the ST Microelectronics LIS3DH accelerometer was developed (Fig. 3), which has the following characteristics: ultra-low power consumption – 2 μA; voltage consumption 1.71-3.6 V; adjustable acceleration measurement range: ±4g; ±8g; ±16g; SPI/I2C interface for reading data; built-in self-testing module [12, 13].

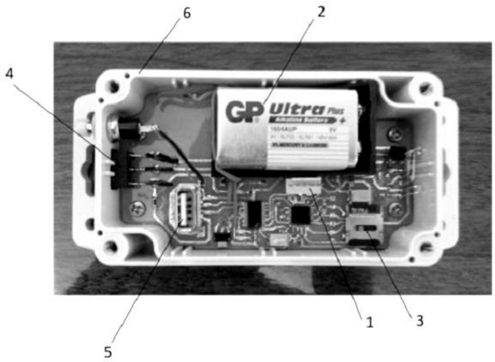
The principle of operation of the developed sensor is as follows: after connecting sensor 7 to the surface of the container (Fig. 2), the drive mechanism is to be turned on, creating alternating oscillations of the vibratory disk crusher activator, which initiates the built-in accelerometer, which starts the registration of the amplitude-frequency characteristics and through the connected adaptive cord read the amplitude frequency response, which is interpreted as graphical dependencies and data digital matrix on a personal computer 2. The developed software allows to analyze vibration acceleration, vibration velocity, vibration displacement and frequency of oscillations.

In order to register the frequency of the drive shaft a wireless tachometer UNI-T UT372 (Fig. 4a) was used, the principles and procedures of operation of which are described in the technological documents.

To control and change the rotation speed of the electric motor shaft autotransformer AOCH-20-220-75 (Fig. 4b) was used designed to work with alternating current.

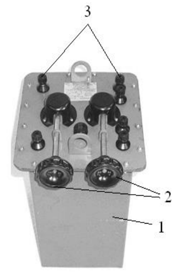


a)



b)

Fig. 3. Accelerometer: a) Apparatus-electronic circuit; b) General view of the device; 1 – microport for the accelerometer sensor connection; 2 – power supply battery; 3 – memory card; 4 – power button; 5 – adaptive microport for data reading; 6 – accelerometer housing



a) b)

Fig. 4 Devices for velocity control of the drive shaft:
a) UNI-T UT372 frequency meter: 1 – laser reader; 2 – digital indicator; 3 – control panel;
b) AOCH-20-220-75 laboratory autotransformer: 1 – outer casing; 2 – voltage regulators; 3 – input and output terminals.

The limits of experimental research are based on the design features of the machine [13, 14] and previously obtained design data (table 2).

Experimental data were processed using Excel 2010 software environment.

Taking into account the design features of the vibrating-rotor crusher and the kinematic connections between its structural elements, some assumptions were made [15, 16]:

- the laws of motion of the rotor (together with the disks) and the grinding chamber (together with the separation surface) are identical;

- the most technologically acceptable mode of operation of the machine for impulse crushing is resonant with strong impacts (velocity is constant; during the period of change of the direction of movement the acceleration changes abruptly to a maximum);

- timely removal of material from the grinding zone will occur in modes of operation with soft impacts (vibration velocity in the confidence approximation varies according to the linear law; during the period of change of the direction of movement the acceleration changes abruptly to a maximum) and in non-impact laws of motion (acceleration and velocity vary in the minimum ranges and in the confidence approximation varies according to the linear law ; change of parameters - smooth);

- the most efficient crusher operation mode is when a technical compromise is reached between the previous conditions;

- vibration intensity is a complex parameter that takes into account the vibration velocity and vibration acceleration.

Table 2 – Limits of experimental research

Parameter	Value
The angular velocity of the drive shaft, *ω*, s^{-1}	0….150
The current consumed by the motor, *I, A*	0…20
Voltage in the electrical network of the installation, U, V	0…220
Power of the electric motor, *N*, Вт	0…1600
Diameter of a disk whip, mm	90
Sharpening angle of the crushing disk, deg.	15
Overall dimensions, m:	
- length	1.37
- width	0.65
- height	1.35
Weight, kg	150

Research results

Fig. 5 demonstrates experimental dependences of the amplitude of oscillations on the angular velocity of the rotor which shows that together with angular velocity ω increase, graphical curves of the amplitude of oscillations of the container *A* become divided into three zones:

- sub-resonance, in which the amplitude A=0.004 m gradually increases in the range of values of the angular velocity ω=0… 45 s^{-1};
- resonance, where the maximum value of the amplitude A=0.0047 m at ω=45…72 s^{-1} is observed;
- post-resonance, where stabilization of the amplitude of oscillations in the range of A=0.0035…0.00385 m occurs (ω=72…150 s^{-1}).

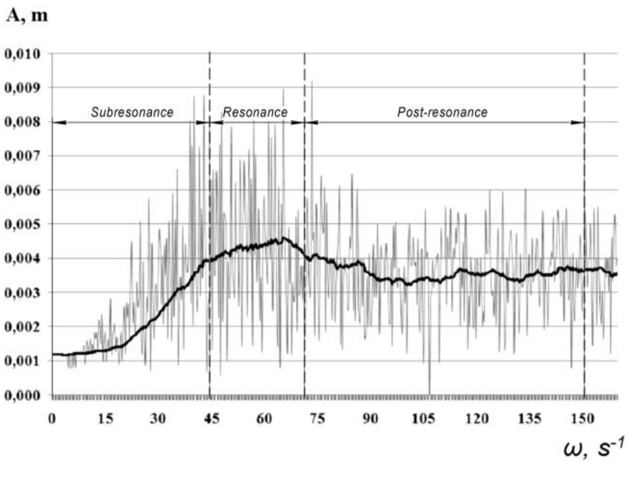


Fig. 5 Dependence of the amplitude on the angular velocity of the drive shaft

Analysis of the experimental dependence of the vibration velocity *ϑ* of the crusher actuator on the angular velocity of the rotor (Fig. 6) detected *ϑ*=0.2…0,305 m/s in the resonance zone at *ω*=45…72 s^{-1}. At an angular velocity *ω*=72…90 s^{-1} the curve is smooth with a small increase (at post-resonance zone). Also, in this range (*ω*=72…90 s^{-1}) the oscillation velocity is almost constant within *ϑ*=0.296…0,305 m/s. At the diapasons *ω*=90…150 s^{-1}, the velocity curve increases rapidly again, the oscillation velocity has a range of values *ϑ*=0.305…0,558 m/s.

The experimental dependence of vibration acceleration *a* of the of the rotor (Fig. 7) was also determined, which clearly shows that after the resonance zone above ω=90 s^{-1} the curve acquire linear character of growth, and their value are *a*=25…81 m/s^2.

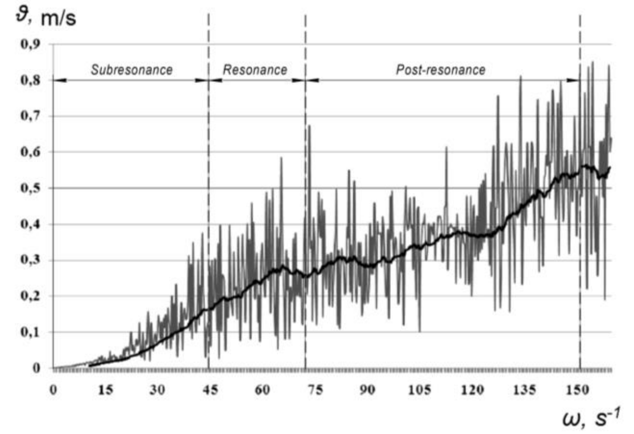


Fig. 6 Dependence of the vibration velocity on the angular velocity of the drive shaft

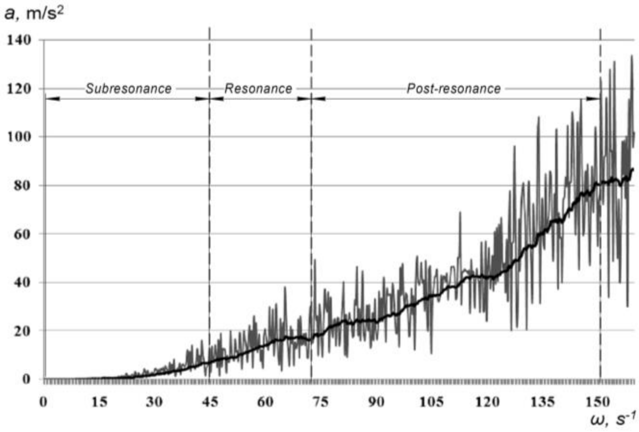


Fig. 7 Dependence of the vibration acceleration on the angular velocity of the drive shaft

In order to determine the optimal range, it is necessary to study the laws of motion in more detail (fig. 8).

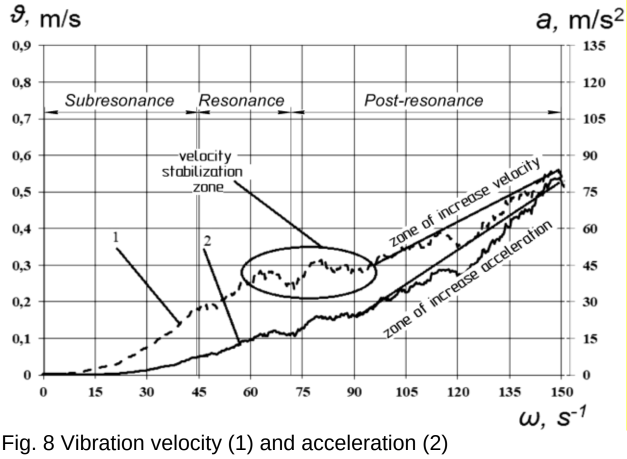


Fig. 8 Vibration velocity (1) and acceleration (2)

A compromise option is the operation of the crusher in the range ω = 75 ... 100^{-s}.

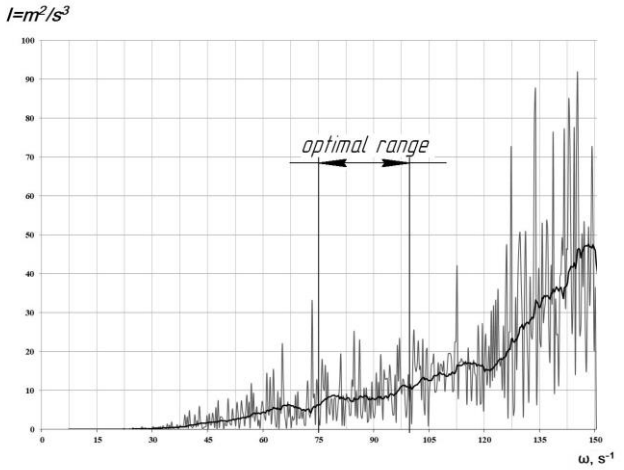


Fig. 9 Dependence of the vibration intensity on the angular velocity of the drive shaft

In this case, the crusher will operate with "soft impact" (optimal for crushing and separation). Intensity of oscillations at frequency ω = 75 ... 100^{-s} are *I=6…11* m^2/s^3 (fig. 9).

Conclusions

As a result of experimental studies, graphical dependences for the amplitude-frequency characteristics of the crusher were obtained and previous operating modes were established. Thus, it was determined that the optimal mode would be in the post-resonance zone at an angular velocity of the drive shaft ω = 75…100^{-s}. In this range of angular velocity, the kinematic parameters of vibration will have the following values: amplitude – A=0.0035…0.004 m; velocity – ϑ=0.28…0.308 m/s; acceleration – *a*=19…31 m/s^2; intensity – are *I=6…11* m^2/s^3.

Further experimental research will be established for these ranges.

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