Improvement of Devices for Cleaning Sieves of Grain Cleaning Machines

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Abstract. The article discusses the issues of reducing the productivity of grain cleaning machines as a result of clogging holes with seeds of the culture being cleaned and impurities. The analysis of indicators reflecting the clogging of sieves and their throughput is given. It is noted that the reduction of the clogging of the sieves is provided by the use of additional devices, the work of which is aimed at removing stuck seeds from the sieve cells. In order to determine the relationship between the physical and mechanical properties of seeds and the modes of operation of the sieve that affect the clogging of the sieves, an analysis of the forces holding stuck seeds in the cells of the sieve is given. Which showed that the main force holding the stuck seeds in the cells is the friction force. Gravity and elasticity have a significant influence on the amount of friction force of the seed against the cell walls. Graphs of the dependence of the change in the force pushing the grain through the hole on the angular frequency of the sieve oscillations are obtained. In addition, graphs of the dependence of the change in the force to be applied to the grain wedged in the sieve on the relative deformation of the grain are constructed. The obtained research results allow us to substantiate the parameters of devices for cleaning sieves, which will increase the productivity and quality of the products obtained.

INTRODUCTION

Increasing productivity while ensuring the desired quality of grain cleaning machines with seeds of various crops is the most important direction in improving equipment for post-harvest grain processing. The aim of the work is to determine the relationship between the physical and mechanical properties of seeds and the modes of operation of the sieve that affect the clogging of the sieves. At the present stage of development of agricultural machinery, the problem of insufficient machine productivity has not been solved. An increase in the area of sieves in order to obtain the necessary throughput leads to a disproportionate increase in material consumption and, as a result, the cost of machines. Improving the efficiency of grain separation and increasing the specific productivity of sieves is an urgent task. To assess the effectiveness of the sieves, the indicators of clogging and the coefficient of the live section of the sieve are often used. The issues of sieve clogging are considered in the works of A.M. Gievsky [1], K. N.

Tishaninov [2], L. N. Burkov [3] and other scientists. It is established that the following factors have an important influence on the clogging of the sieves: the specific load per unit area, the speed and amplitude of the vibrations of the sieve.

METHODOLOGY

The coefficient of scoring of sieves along the length is defined as the ratio of the number of scored cells to the total number of cells along the length of the sieve:

$$\Delta = n_z / n_{total}, \tag{1}$$

Where n_z is the number of scored cells, pcs.; n_{total} is the total number of cells along the length of the sieve, pcs.

The coefficient of clogging of sieves along the length is determined at steady state, passing a certain amount of grain heap through the sieve, then count the number of clogged holes. Studies conducted by A. I. Petrusov [5] have shown that with an increase in the frequency of vibrations of sieves, their clogging decreases. However, the quality of seed separation and the sieving capacity of the sieve deteriorate due to the fact that most of the grains do not have time to pass into the hole during the time between the vibrations of the sieves. In addition, modern grain cleaning machines operate with the movement frequencies of sieves in the range from 300 to 500 min^{-1}. This is due to the quality of grain separation by fractions, as well as inertial loads on the grain cleaning machine and maintenance personnel.

The next most important indicator that has a direct impact on the performance of sieves is the coefficient of the live section of the sieve, which determines the technological efficiency of the sieve and can be calculated as the ratio of the total area of the holes to the total area of the sieve [4]:

$$\Psi = S_{hole} / S_{sieve,} \tag{2}$$

Where S_{hole} is the total area of the holes, m^2; S_{sieve} is the area of the sieve, m^2.

Increasing the value of these coefficients to a possible maximum is designed to increase the specific productivity of sieves. It should also be noted that the technological efficiency of the sieve is significantly influenced by a number of factors, including: the type of material being cleaned, its properties, the patterns of movement of the sieves, the shape of the sieve holes, etc.

Reducing the clogging of sieves is provided by the use of additional devices, the work of which is aimed at removing stuck seeds from the sieve cells. When cleaning the clogged holes of the sieves, cleaning devices perform work to overcome the forces of connection of the stuck grain with the edge of the hole. According to the principle of operation, the following devices for cleaning sieves are distinguished: ejecting, squeezing, knocking out, combined. At the same time, the particles stuck in the holes of the sieve are affected by cleaning devices and mechanisms both directly from interaction with the particle and through dynamic loads on the sieve of other particles involved in the process of grain separation into fractions.

Devices using the ejection principle during operation remove grains stuck in the holes of the surface and held in it by gravity and friction of the grains against the walls of the hole. Since the grain that has sunk into the cell, as a rule, is affected by the mass of the grain layer from above, then to simplify further calculations, the gravity of the grain over the cell is determined by the expression:

$$m_z = m \cdot z \tag{3}$$

Where m is the mass of the grain, kg; z is the number of layers of material on the sieve above this hole, pcs.

Thus, the effort to remove or displace the grain sunk into the sieve hole can be determined by the expression:

$$P = m_z \cdot g \cdot \mu \, (1 + f) \tag{4}$$

Where g is the acceleration of gravity, m/s^2; μ is the coefficient of uneven loading of the sieve; f is the coefficient of friction of the sorted material on the sieve.

Here we provide some basic advice for formatting your mathematics, but we do not attempt to define detailed styles or specifications for mathematical typesetting. You should use the standard styles, symbols, and conventions for the field/discipline you are writing about.

RESULTS AND DISCUSSIONS

However, in real conditions, the grains of agricultural crops have a complex geometric shape, and the grain, entering the opening of the sieve, can take a position in which grain deformation is required to exit the hole. In this case, the grain can be considered jammed. In addition, the inertia force R_i has an alternating effect and, depending on the mechanism of the sieve drive, can be determined by the expression [6]:

$$R_i = 0.5 \, m \cdot \omega^2 \cdot A \cdot cos \, (\omega t) \qquad (5)$$

Where ω is the angular frequency of the sieve oscillations, s^{-1}; A is the amplitude of the oscillations, m; ωt is the angle of rotation of the crank, rad.

Thus, the force of inertia, varying depending on the design of the drive mechanism, in one case will facilitate the exit of the grain from the hole, in the other – the passage through the hole. Provided that the direction of movement of the drive mechanism is carried out in the vertical direction, the maximum force Fp, which pushes the grain through the holes in the sieve, must be determined as the sum of the forces acting on the grain that is in the hole and trying to push it through the hole:

$$F_n = 0.5 \, m_z \cdot \omega^2 \cdot A \cdot cos \, (\omega t) + m \cdot z \cdot g. \qquad (6)$$

The graph of the change in the maximum force F_n, which pushes the grain through the holes at cos $\omega t = 1$ and the oscillation amplitude of 5 mm, is shown in Figure 1.
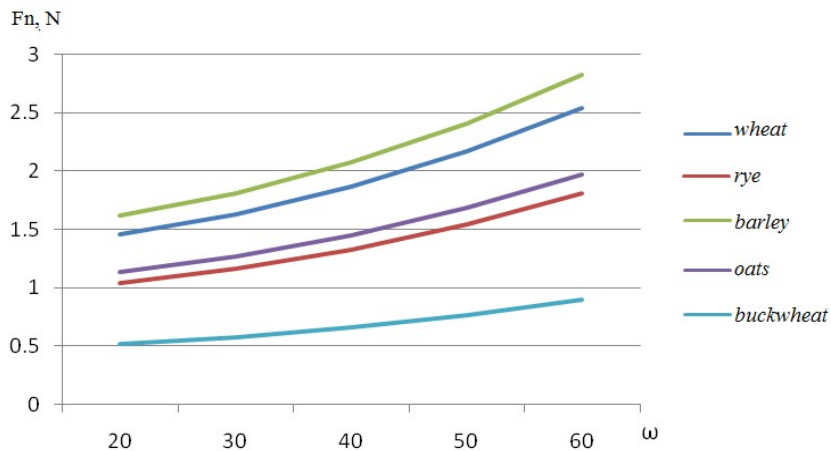

FIGURE 1. Graphs of the dependence of the change in the force F_n pushing the grain through the hole on the angular oscillation frequency of the sieve ω.

From the graph data, we see that an increase in the rotation speed leads to an increase in the force of pushing the grain into the hole. One of the factors affecting the depth of grain penetration into the hole under the action of the pushing force is the grain size by which the separation occurs, as well as the degree of deformation of this size. Prevents the grain from passing through the hole by the friction force F_{tr} of the grain against the walls of the sieve

opening, which depends on the normal reaction of the interaction of the walls and the grain, as well as the mass of the grain:

$$F_{tr} = f\,(N + m_z \cdot g \cdot cos\ \alpha) \tag{7}$$

Where N is the normal reaction from the interaction of the walls of the sieve opening and the grain, N; α is the angle of inclination of the sieve surface, rad.

In the case of jamming of the grain in the opening of the sieve, the main holding force will be the friction force, the normal reactions N to the walls of the hole will be formed due to the elastic force F, determined by Hooke's law. Thus, the normal reaction and the elastic force of the grain, taking into account its shape and size, are determined by the expression:

$$N = F_{upr} = E_z \cdot e_z \cdot \pi \cdot c \cdot b\,/\,4 \tag{8}$$

Where E_z is the modulus of elasticity (Young's modulus), MPa; e_z is the relative deformation; c is the grain thickness, mm; b is the grain width, mm.

For a more detailed analysis, let's consider the scheme of forces acting on grain stuck in a sieve (fig. 2). In most designs of modern grain cleaning machines, in order to set a certain direction of movement of the grain mass, the sieves are installed at an angle α to the horizon, the crank of the drive mechanism causes the sieve to make harmonic oscillations at an angle β. The plane of the sieve is indicated by the *LC* segment and is fixed on the *EL* and *DC* wings of the same length. Thus, the lattice mill is a parallelogram of *LEDC*. The drive is carried out by a crank mechanism with a point *A* in the center of the crank and a point *B* in the center of the suspension.

The following forces act on the grain stuck in the sieve cell: mhd – the gravity of the grain above the cell; Ri – the force of inertia; N_1 and N_2 – normal components from the cell walls; F_{t1}, F_{t2}, F'_{t1}, F'_{t2} – the friction forces of the grain against the cell walls.

To get the stuck grain out of the cell, two options for its movement are possible: up – along the +Y axis, and the grain ends up on the surface of the sieve, or down – along the –Y axis, and the grain passes through the sieve.
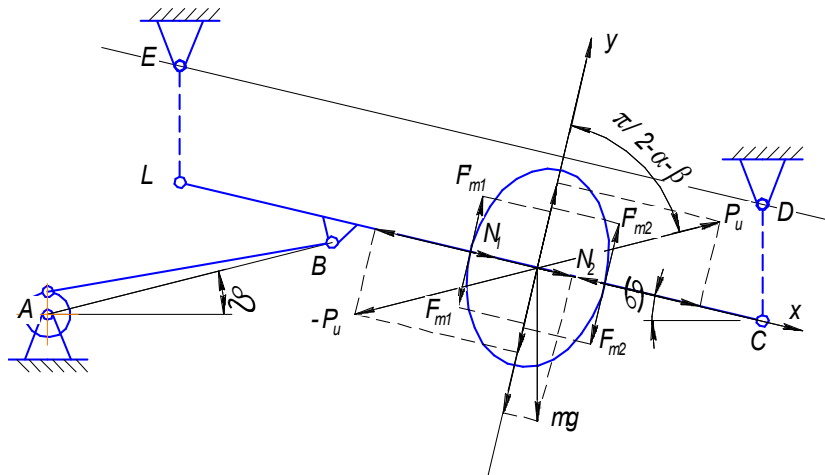

FIGURE 2. Diagram of forces acting on grain stuck in a sieve cell.

Consider the condition under which the forces acting on the grain allow it to exit the cell along the +Y axis upwards:

$$R_i \cdot cos\ \pi/2 - \alpha - \beta) > F_{t1} + F_{t2} + m_z\,g\ cos\ \alpha. \tag{9}$$

The normal reaction to the grain on the left side of the cell is as follows:

$$N_l = E_z \cdot e_z \cdot \pi \cdot c \cdot b / 8 - m_{zd} \cdot \cos \alpha - 0.5 \, m_z \cdot \omega^2 \cdot A \cdot \cos(\omega t) \sin (\pi / 2 - \beta - \alpha) \tag{10}$$

Accordingly, the thorn force on the left side of the cell is defined as:

$$F_{tl} = f \, (E_z \cdot e_z \cdot \pi \cdot c \cdot b / 8 - m_{zd} \cdot \cos \alpha - 0.5 \, m_z \cdot \omega^2 \cdot A \cdot \cos (\omega t) \sin (\pi / 2 - \beta - \alpha)) \tag{11}$$

Where f is the coefficient of friction of the grain on the sieve material.
By analogy, we determine the coefficient of friction on the right side of the cell:

$$F_{t2} = f \, (Ez \cdot ez \cdot \pi \cdot c \cdot b / 8 + mzd \cdot \cos \alpha + 0.5 \, mz \cdot \omega 2 \cdot A \cdot \cos(\omega t) \, si \, (\pi / 2 - \beta - \alpha)) \tag{12}$$

Thus, after simplification and transformation, condition (9) will take the form:

$$0.5 \, m_z \cdot \omega^2 \cdot A \cdot \cos(\omega t) \cdot \cos (\pi / 2 - \alpha - \beta) > f \cdot E_z \cdot e_z \cdot \pi \cdot c \cdot b / 4 + m_{zd} \cdot \cos \alpha. \tag{13}$$

The grain can be considered stuck in the hole, provided that the component of the inertia force will not be able to extract it from the hole:

$$0.5 \, m_z \cdot \omega^2 \cdot A \cdot \cos (\omega t) \cos (\pi / 2 - \alpha - \beta) < f \cdot E_z \cdot e_z \cdot \pi \cdot c \cdot b / 4 + m_{zd} \cdot \cos \alpha. \tag{14}$$

Consider the condition under which a grain whose dimensions are close to the size of the opening of the sieve cell passes through it (Figure 3) along the – Y axis downwards:

$$R_i \cdot \cos (\pi / 2 - \alpha - \beta) + m_{zd} \cdot \cos \alpha > F'_{tl} + F'_{t2}. \tag{15}$$

$$0.5 \, m_z \cdot \omega^2 \cdot A \cdot \cos(\omega t) \cos (\pi / 2 - \alpha - \beta) + m_{zd} \cdot \cos \alpha > f \cdot E_z \cdot e_z \cdot \pi \cdot c \cdot b / 4. \tag{16}$$

It is obvious from conditions (14) and (16) that the force to push the grain into the hole is higher than the extraction (condition (13)), therefore, the possibility of blocking the cell is higher.

In order to clean the grains stuck in the hole, additional devices are used that apply force to the grain to clean the sieve. The force that must be applied to the grain to knock it out of the cell is directed from under the bottom of the sieve and is determined by the expression:

$$R_z = f \cdot E_z \cdot e_z \cdot \pi \cdot c \cdot b / 4 \cdot 0.5 - m_z \cdot \omega^2 \cdot A \cdot \cos (\omega t) \cdot \cos (\pi / 2 - \alpha - \beta) + m_{zd} \cdot \cos \alpha \tag{17}$$

The analysis of the presented expression shows that the elastic modulus of the grain material will have a significant effect on the holding force of the grain in the sieve. In turn, the modulus of elasticity depends on the moisture content of the material. Thus, according to the data of grain strength studies given in the works of I. A. Naumov [7], the modulus of elasticity for barley at a humidity of 11.6 % was 24.8 MPa, at a humidity of 17 %, the indicator decreased to 12.7 MPa. At the same time, the tensile strength changed from 4.9 to 3.4 MPa.

It is noted that with an increase in grain moisture, the strength decreases [8]. The permissible relative deformation at which the grain is not damaged varies from 26 % to 12 % for different crops. When the grain is jammed, it is the deformation that will affect the effort to remove the grain from the sieve and damage it.

Figure 3 shows graphs of the dependence of the change in the force to be applied to the grain wedged in the sieve on the relative deformation of the grain, the values of which are determined by the expression (17).
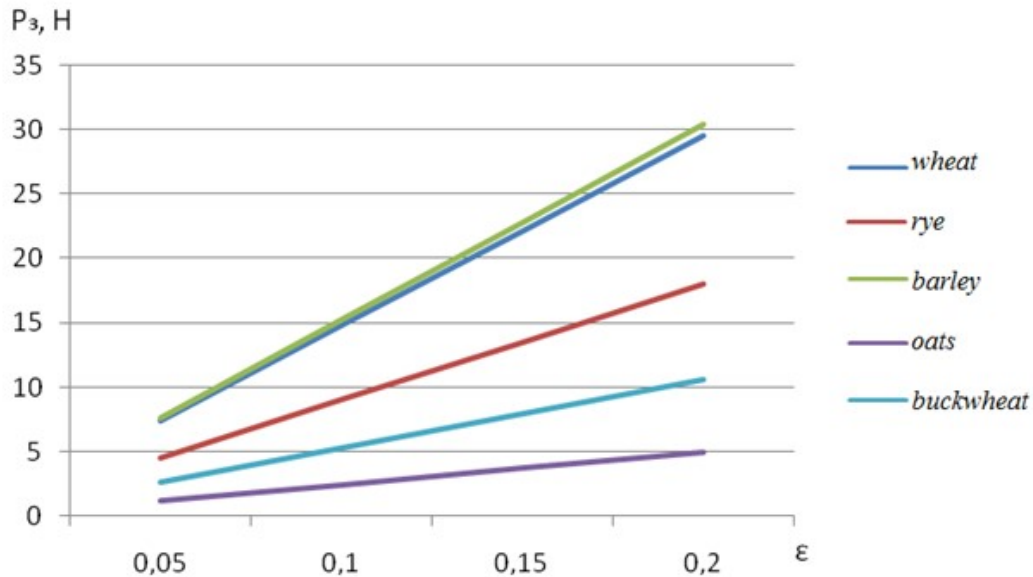
FIGURE 3. Graphs of the dependence of the change in the force to be applied to the grain wedged in the sieve on the relative deformation of the grain.

From the graph data (fig.3) we can see that the jamming of the grains from the pushing force F_n, determined by the expression (6) (fig.1), can occur only if the force R_z is overcome, which is possible only with large values of the inertia forces R_i and minimum values of the relative deformation of the grain.

CONCLUSION

Thus, the presented analysis allows us to draw the following conclusions:

- An increase in the frequency of vibrations leads to an increase in the force pushing the grain through the sieve cell, thereby increasing the depth of penetration of the grain and its deformation;
- In most grain crops, when the grain is deformed in the cell by more than 5 %, the grain extraction force exceeds 2.5 N, with a value of more than 10%, the force can reach 15 N;
- Taking into account the kinematic characteristics of modern grain cleaning machines, the stuck grain in the sieve cell can practically not be extracted without the use of additional devices;
- Thus, for cleaning sieves, in order to increase their specific productivity, it is advisable to use devices with a combination of ejector and impact types of elements.

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