ANNOTATION

Of the dissertations for the degree of PhD in the specialty
6D072400 Technological machines and equipment

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Development of equipment for active venting and cleaning of grain from light impurities

The aim of the thesis research: creating resource-saving and highly efficient technological equipment for in-line cleaning of grain from light impurities in the reception as well as transfer points and drying of grain by means of active ventilation in the capacities of grain storages.

Research objectives:

- justification of the relevance of improving the technological processes of cleaning grain from light impurities in the flow and drying by active venting in the capacities of granaries;
- development of scientific and practical approaches to enhance the efficiency of technological processes of cleaning grain from light impurities and drying by active venting and reducing the specific costs with the analytical description of the laws of heat transfer;
- selection of an effective method of in-line cleaning of grain from light impurities and drying by active venting method, development of a rational design of technological equipment for the relevant purpose;
- experimental study and determination of dependency of the coefficient of purification of grain from light impurities depending on the air speed, initial grain layer thickness and height of the working zone of the pneumatic chamber;
- experimental investigation and determination of dependences of final grain moisture content and specific energy consumption for the process of drying grain by active ventilation on temperature, air velocity and height of the grain layer
- testing prototypes of equipment under production conditions and establishing the technological mode of operation.

Research methods: statistical methods of processing experimental results, modern methods of physical and mathematical modeling for determining the main parameters of the installation of active ventilation and purification of grain from light impurities. Analytical methods for solving differential equations, similarity theory, applied software packages for processing and generalization of experimental results.

Main provisions (proven scientific hypotheses and other conclusions that are new knowledge), defended:

Effective way of cleaning grain from light impurities using physical and mechanical properties of the original grain and rational design of pneumatic chamber for cleaning grain from light impurities;

Effective way of active ventilating (drying) grain in granary tanks and a rational design of the installation for drying grain with active ventilation;

Analytical description of the process of cleaning grain from light impurities at free-fall with natural loosening and physical model, describing dependence of efficiency of grain cleaning from light impurities on the accepted factors;

System of criterial equation of heat-and-mass transfer processes of the heat-carrier (warmed air) moving through a layer of grain at drying by active ventilation, allowing one to determine the energy consumption and physical model describing the dependence of specific energy consumption in drying of grain by active ventilation on the factors taken into account.

Description of the main results of the research.

The laws of grain layer movement contributing to the efficiency of the process have been determined on the basis of the law of energy transformation during the free-fall of solids. The system of equations allowing determining the air speed in the intergranular space, in the louvers for air flow inlet and outlet of the aero-mixture, pressure losses in the louvers and in the intergranular space have been derived.

The expediency of using the physical and mechanical properties of the initial grain (density, flowability) as the driving force for providing the natural loosening of the mass and eliminating the need for energy-intensive fluidization has been proved.

The system of criterial equations describing the processes of heat and mass transfer at movement of heat carrier through the layer of grain at drying by active ventilation has been developed, it enables to determine the coefficients of mass and heat transfer and reveals the main factors influencing the specific energy consumption.

As a result of the experimental study the regression equation derived and on the basis of regression analysis the dependence of the coefficient of purification of grain from light impurities on the thickness of the initial layer of grain, air speed and height of the working area of the pneumatic chamber were obtained.

Effective way of grain drying in the tank by active venting method that ensures uniform distribution of the working agent (coolant - heated air) in the horizontal direction with continuous removal of the spent coolant and evaporated moisture has been developed. As a result of the experimental investigation the regression equation is derived and on the basis of regression analysis the dependences of specific energy consumption on the coolant temperature with regard for the height of the blown layer, the coolant (heated air) speed are obtained.

The method of engineering calculation of pneumatic chamber and installation for active ventilation of grain is developed.

Justification of novelty and importance of the obtained results.

The novelty of the established laws of grain layer movement is the use of physical and mechanical properties of the original grain as a moving force.

Development of a system of equations, which is an analytical description of the process of purification of grain from light impurities:

$$\begin{cases} MgH \cdot (1 - f \cdot ctg\alpha) = \frac{M(v_1^2 - v_0^2)}{2} \\ v = \sqrt{\frac{2gH}{1 - f \cdot ctg\alpha}} \\ dV_c = \frac{k_{\text{п}} \cdot \Delta p_{\text{мзп}}^2}{2\mu \cdot p_0 \cdot \delta_2} \cdot dF_{\text{п}} \\ \Delta p_{\text{реш}} = \frac{\rho \cdot v_1 (v_1 - v_2) \cdot cos\gamma}{2} + \frac{\rho \cdot v_1^2}{2} \\ V_{\text{мзп}} = \frac{k_{\text{п}} \cdot \delta_2 \cdot \Delta p_{\text{мзп}}}{\mu} \\ v_{\text{кр}} = \sqrt{\frac{g}{K_{\text{п}}}} \\ \frac{2\, k_{\text{п}} \mu P_0 v_1}{\rho_b \delta_2 F_{\text{п}}} = k_{\text{мзп}}^2 \frac{\rho_b^2}{4} v_{\text{мзп}}^4 \end{cases} \quad (1)$$

The proposed system of equations (1) describes the process of cleaning grain from light impurities in the flow under the adopted pneumatic chamber design. This system of equations describes:

- nature of movement of initial grain flow from the receiving hopper to the working zone of the pneumatic chamber at free fall;
- velocity of free fall of grains from the receiving hopper into the chamber;
- differential equation describing change in mass flow rate of air flow into intergranular space based on the porous medium equation;
- louvered grate losses;
- air velocity in the inter-grain space;
- the critical falling grain velocity.

The equations (2) derived on the basis of the second similarity theorem have the criteria equations in explicit form, which is a mathematical model of the process of drying of a fixed bulk of grain with a description of heat and mass transfer under conditions of forced convection, as well as the movement of the heat transfer medium (heated air):

$$\begin{cases} Nu_{\text{Д}} = A \cdot Re^m \cdot Pr_{\text{Д}}^n \\ Nu_{\text{Д}} = B \cdot Re^x \cdot Pr^y \\ Eu = K \cdot Re^a \end{cases} \quad (2)$$

The values of powers *m*, *n* and coefficient *A* for $Nu_{Д}$ and *x*, *y* for *Nu*, and *a* and *K* for *Eu* are obtained as a result of mathematical processing of experimental data and engineering calculations.

Equations (1) and (2) are the basis for the development of engineering calculations and allow calculating technological parameters of the device for cleaning grain from light impurities and the installation for drying grain by active venting.

In order to determine rational parameters of the pneumatic chamber experimental research was conducted and on the basis of the obtained experimental data we received regression equations with coded values of factors: x_1 - initial grain

layer thickness (mm); x_2 - air speed (m/s) and x_3 - height of the pneumoseparating chamber (mm):

$$\hat{y}_и = 0{,}84 - 0{,}03x_1 + 0{,}076x_2 + 0{,}024x_3 + 0{,}0025x_1x_2 + 0{,}0025x_1x_3 - 0{,}0025x_2x_3 - 0{,}03x_1^2 - 0{,}02x_2^2 - 0{,}01x_3^2. \quad (3)$$

It was made analysis on the choice of effective value of coefficient of purification of grain from light impurities at certain parameters, taking into account the main factors. The mathematical model has been obtained by renaming the coded values of factors not named in equation (3) and plots of dependence of efficiency coefficient of purification of grain from light impurities K (%) on initial thickness of grain layer h (mm), air speed ϑ (m/s); and height of working zone of pneumatic chamber H (mm) have been built.

The novelty of the regression equation describing the cleaning factor of grain from light impurities is that it takes into account the thickness of the initial layer of grain, air velocity and height of the working zone of the pneumatic chamber .

To determine the rational parameters of the installation for drying of grain by means of active venting experimental research was conducted. Experimental data have been processed by using software package STATISTICA 10, which enabled us to obtain regression equations for calculation of energy consumption and final moisture content of grain depending on technological parameters of the process (height of blown layer of grain, temperature and speed of heat carrier - warm air). As a result of optimizing the process of drying the rational values of height of blown layer of grain, air speed and temperature that provide minimal specific energy consumption have been determined. According to the results of the experimental data the generalized function and the desirability graph D were constructed.

High values of reliability coefficients for regression equations on determination of specific energy consumption (92,53 %) and final moisture content Wk (71,75 %) testify to adequacy of the obtained equations.

Based on experimental data, a generalized desirability function D was constructed. It has a minimum value in experiment 8 and amounts to 0.011. For this case the optimum height of the blown zone should be considered to be 1 m, with an air velocity of 1.2 m/s. In turn, in order for the specific energy consumption to be minimal, the air temperature should be about 80˚C.

The novelty of the developed method of engineering calculation of pneumatic chamber is to derive the equation for determining productivity and power, pressure loss in the pneumatic chamber.

The novelty of the methodology of engineering calculation of the installation for the active ventilation of grain is to determine the hydraulic resistance of the gas distribution pipe for the supply of coolant and spiral pipe to remove the exhaust air, to identify the hydrodynamic parameters in the area blower - drying chamber, to determine the coefficient of mass transfer and duration of the drying process.

Compliance with the directions of science development or state programmes. The work corresponds to the priority direction of science development "Energy and Engineering" approved by the Higher Scientific-Technical Commission

in 2021, as well as to the individual plan of the doctoral student.

Description of the doctoral student's contribution to each publication. There were 10 articles published on the topic of the thesis. The total contribution of the doctoral candidate is 60-65%. Contributions to the articles are represented by such components as conducting experimental research, processing the results in the form of tabular values and graphical dependencies, obtaining computational equations.