Determination of grain material damage during transportation by screw conveyor

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Abstract. *An experimental setup was developed and manufactured to study a conveyor with a blade working body, which will improve the functional and operational characteristics of conveyors. When conducting a multifactorial experiment to determine the damage to grain material by the blade working body of the conveyor, the variable factors were: the diameter of the casing D, the conveyor loading coefficient ψ, and the rotation frequency of the blade working body n. Based on the results of experimental studies, corresponding regression equations and response surfaces were constructed to establish the influence of controlled factors on the damage to grain materials.*
KEYWORDS: *TRANSPORTATION, GRAIN MATERIAL, BLADE WORKING BODY, DAMAGE.*

Introduction

Conveyors with screw working bodies are widely used for transporting grain, seed materials, and granular mineral fertilizers, which are subject to significant damage during transportation. The main causes of grain material damage are particles that fall into the gap between the rotating working body and the stationary inner surface of the guide pipe, which causes damage to the materials. It has been established that the existing designs of screw conveyor working bodies do not fully meet the functional requirements regarding damage to grain materials. Theoretical and experimental studies conducted in the loading and transshipment zone of grain materials for screw conveyors [1-4], as well as the intake of material by active loading pipes [5, 6], made it possible to select rational design, kinematic, and dynamic parameters of working bodies and their operating modes. The works [7-9] are devoted to determining the parameters and modes of operation of transporting materials by vertical and inclined screw conveyors, with the establishment of rational parameters of working bodies. The results of the study of material movement in a screw conveyor with a rotating casing are presented in [10].

Therefore, it is important to develop new designs for conveyor working bodies that will be simple to manufacture and ensure the transportation of grain materials with minimal damage.

Results and discussion

To determine the grain material damage during transportation, an experimental setup for studying a conveyor with a blade working body was developed, the diagram of which is shown in Fig. 1. It consists of a frame 10 on which a conveyor is placed, containing a guide casing 7 in which a blade working body 6 is located. A hopper 5 is installed on the material loading side, and in the unloading area there is a window with an adjustable damper 9 and a screw shaft brake 8. The working body is driven by an electric motor 3 through a safety clutch 4.

A frequency converter 2 (Altivar 71) with Power Suite v.2.5.0 software was used to start the motor and regulate its rotation speed. The Altivar 71 system is connected to the network and to a computer 1.

When the required rotation speed is set using a computer via the Altivar 71 system, a command is transmitted to the electric motor, which then begins to rotate the shaft of the blade working body with the set parameters via a safety clutch. First, the grain is loaded into the hopper and, with a certain rotation frequency of the working body and the set parameters, the material is transported to the unloading zone into a measuring container.

A general view of the experimental setup for studying the conveyor and the developed blade working body is shown in Fig. 2.

It is advisable to manufacture blades for the conveyor working body by cutting sheet material and then welding them to a cylindrical shaft. It has been established that it is advisable to use flat blades with a mirror image relative to the vertical within the range from 0º to 90º (full range 180º), since it is not rational to manufacture blade sectors with an angular pitch of up to 20º, both from the point of view of their manufacture (large quantity) and from the point of view of their assembly [8].

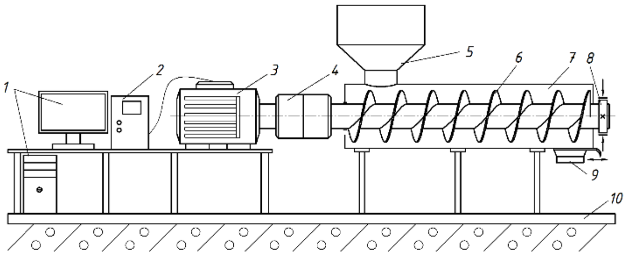
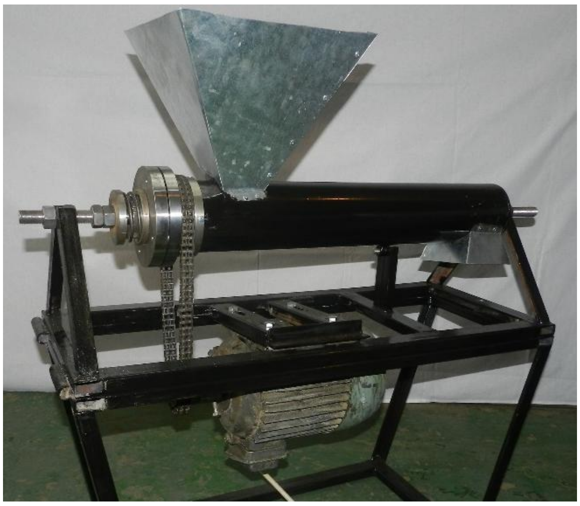


Figure 1. *Schematic diagram of the experimental setup for studying a conveyor with a blade working body:*
1 – computer; 2 – frequency converter (Altivar 71);
3 – electric motor; 4 – safety clutch; 5 – hopper;
6 – blade working body; 7 – guide cover;
8 – screw shaft; 9 – damper ; 10 – frame


a


b

Figure 2. *General view of the experimental setup for studying the conveyor (a) and the developed blade working body (b)*

To determine the extent of damage to corn kernels during transportation, three grain samples were taken before transfer using a specially designed conveyor blade mechanism into a measuring container, which, taking into account the dimensional and geometric parameters of the grain, held about 100 grains. Then, the number of damaged grains was determined and the percentage of damaged grain material before transportation was established. Grains with knocked-out embryos were not taken into account, only crushed grains were considered. The degree of grain material damage was determined by the difference in the number of damaged grains before and after transportation, depending on the variable design and kinematic parameters of the conveyor's blade working body. Reducing damage to grain material during transportation by screw conveyors is one of the main tasks in the design of such structures.

Grains with the following damage were classified as damaged: crushed embryo, damaged embryo, damaged grain shell, damaged endosperm, damaged endosperm shell, broken grain, mechanically compressed grain.

Damaged grains of the studied material are shown in Fig. 3.

***Figure 3.** General view of corn grains with damage*

During the multifactorial experiment to determine the damage to corn kernels caused by the developed blade working body, the variable factors were: the diameter of the casing *D*, the conveyor loading coefficient ψ, and the rotation frequency of the blade working body *n*.

Since, during the experiments, the variable independent factors are heterogeneous and have different units of measurement, and the numbers expressing the values of these factors are of different orders, they were brought to a single calculation system by converting from real values to coded ones.

Research into damage to corn grains has made it possible to determine its dependence on many factors that characterize the transportation process, namely: the inner diameter of the casing *D*, m; the filling coefficient ψ; rotation frequency of the blade working body, *n*, rpm, within the following ranges of input factors: $0.06 \le D \le 0.1$ (m); $0.3 \le \psi \le 0.7$; $100 \le n \le 500$ (rpm).

The study of grain damage by the blade working body was carried out during the transportation of corn with a corresponding bulk density of – 800 kg·m^{-3} and a moisture content W = 12…15 %, which made it possible to construct analytical regression equations.

The processing of the obtained experimental data was carried out using well-known methods and statistical processing techniques, applying well-known methods of correlation and regression analysis to obtain empirical regression equations as the final result [11, 12].

The response function (optimization parameter), i.e., damage $T = f(D, \psi, n)$, determined experimentally, is represented as a mathematical model of a complete quadratic polynomial [11].

General form of the regression equation for corn grain damage during transportation by a conveyor with a blade working body depending on the diameter of the casing *D*, the conveyor loading coefficient ψ, and the blade working body rotation frequency *n*, i.e. $T_{(x_1, x_2, x_3)} = f(D, \psi, n)$ according to the results of the PFE 3^3 in real values after conversion and simplification of expressions for corn transportation, has the following form

$$T_{(D,\psi,n)} = 0.228 + 0.475D - 0.25\psi + 0.00101n - \\ -0.001023Dn - 9D^2 + 0.135\psi^2 - 0.000000297n^2. \quad (1)$$

The obtained regression equation (1) can be used to determine the amount of grain damage T during transportation by a conveyor with a blade working body depending on the diameter of the casing *D*, the conveyor loading factor ψ, and the blade working body rotation frequency *n* when transporting corn within the following ranges of input factors: $0.06 \le D \le 0.1$ (m); $0.3 \le \psi \le 0.7$; $100 \le n \le 500$ (rpm).

Using the application program, we constructed a graphical representation of intermediate general regression models in the form of quadratic response surfaces and their two-dimensional cross-sections of grain damage *T* as a function of two variable factors $x_{i(1,2)}$ at a constant level of the corresponding third factor $x_{i(3)} = const$ (Fig. 4).

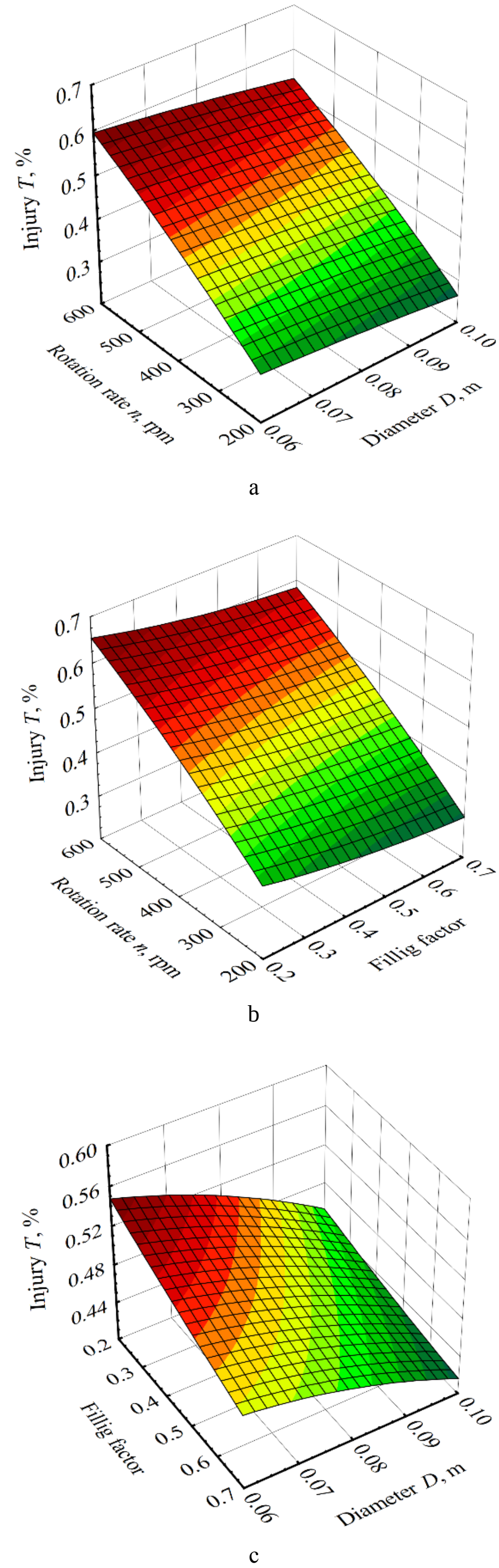


***Figure 4**. The response surface of corn grain injury from: a) T = f(D; n); b) T = f(n; ψ); c) T = f(ψ; n)*

Analysis of the given regression equations shows that the main factor affecting the increase in corn grain damage is factor x_3 (n), the rotation speed of the blade working body. An increase in the values of factors x_1 (D) and x_2 (ψ) leads to a decrease in the amount of grain damage. Therefore, a rational value for the frequency is the rotation speed of the blade working body within the range of $100 \leq n \leq 500$ (rpm).

By changing the diameter of the guide casing D within the range of 0.06...0.1 m, damage to corn grain is reduced by 12...15%; by changing the rotation speed of the blade working body within the range of 200...600 rpm, damage to grain increases by 48...50%; and when the conveyor load factor ψ is changed within the range of 0.3 to 0.7, damage is reduced by 10%.

Conclusions

A methodology for conducting experimental studies of damage to grain material during its transportation by a conveyor blade working body has been developed.

Based on the results of experimental studies, corresponding regression equations and response surfaces were constructed to establish the influence of controlled factors on the damage to grain materials. It was established that the main factor affecting the increase in grain damage is factor $x_3(n)$, the rotation frequency of the blade working body. An increase in the values of factors x_1 (D) and x_2 (ψ) leads to a decrease in the amount of grain damage. Therefore, a rational value for the frequency is the rotation speed of the blade working body within the range $100 \leq n \leq 500$ (rpm).

When changing the diameter of the guide casing D within the range of 0.06...0.1 m, damage to corn grain decreases by 12...15%; when changing the rotation speed of the blade working body n within the range of 200...600 rpm, damage to grain increases by 48...50%; and when the conveyor load factor ψ is changed within the range of 0.3 to 0.7, damage is reduced by 10%.

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