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Modern Portable Drum Grain Dryer for Farmers and Their Mathematical Model

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ABSTRACT

The article improves the method of increasing energy efficiency and the design of the dryer drum for farmers by accelerating the process of drying the grain of the grain dryer and reducing the time spent on drying the product.

KEYWORDS: *portable dryer, dryer drum, grain, spiral fin, spring.*

The proposed device belongs to the agricultural sector and can be used, in particular, for drying grain products in farmers. A literary analysis of some existing devices was carried out [1, 2].

The main part of the drying process is carried out in a tumble dryer using hot air generated in a heater. One of the disadvantages of this dryer is the complex design and high energy consumption, i.e. the screw transport of the dryer, which operates regularly, is located outside the drum. As a result, during the drying process, the grain passing through the auger is not spontaneously cooled, since the temperature of the auger is much lower than the temperature inside the drum, and at the same time, the consumption of electricity, the time spent on drying increases, and the process of uneven periodic drying also negatively affects the quality grains and others.

The key task of the proposed device is to improve the process of moving and increase the intensity of drying grain by volume and reduce the time spent on drying the product by improving the design of the grain dryer drum and eliminating the screw transport.

In the proposed device, intensive mixing of the grain mass by volume is provided by a spiral-shaped rib fixed (welded) to the drying drum from the inside along the entire length [3]. In this case, the proposed direction of the spiral coincides with the direction of rotation of the drum. The proposed drum provides grain movement not only down the slope due to gravity, but also partially up due to its spiral rib. As a result, the volume and movement of the moved grain increases. The accumulation of grain in the lower part of the drum is reduced, which improves the uniform drying process.

The main part of the grain drying process is drying with hot air generated in the heater. The hot air generated in the heater accelerates the process of forced mixing of the dried grain mass with the help of spiral fins. This ensures that the grain is of the same quality by volume and reduces the time required to dry the product.

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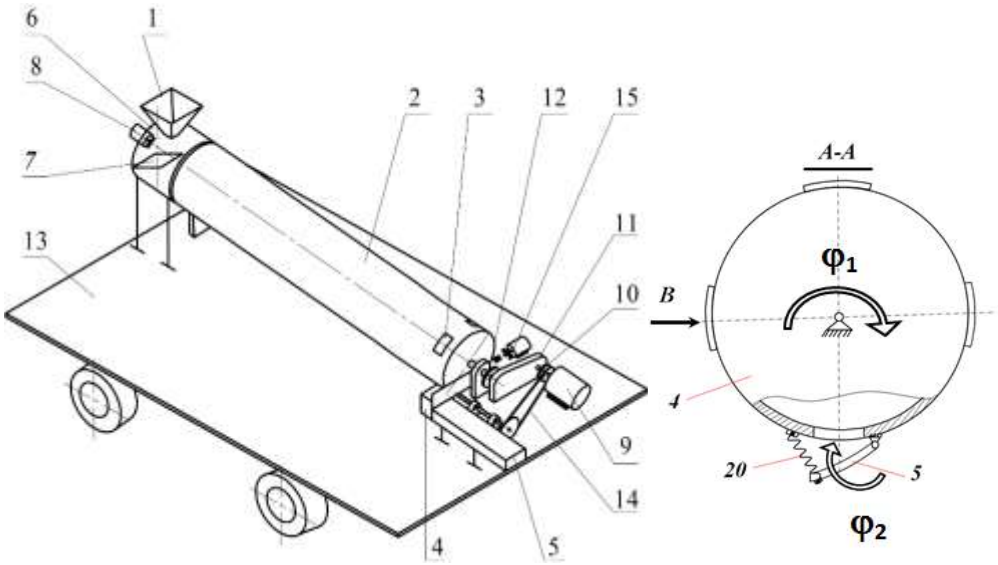

Fig. 1. Structural scheme of a portable grain dryer for farmers:

1 – loading bunker; 2-drying drum; 3 – automatic control valve; 4 and 5 product sorting mechanisms; 6 - fixed section; 7 – heater; 8 – fan; 9 – electric motor; 10 and 12 front clutch and rear clutch; 11 – gearbox; 13 – trailer; 14 - belt drive

The proposed device is illustrated by the following drawings and photocopies: Structural diagram of a portable grain dryer in Fig.1, view of the drying drum (section A-A, section B-B) in Fig.2.

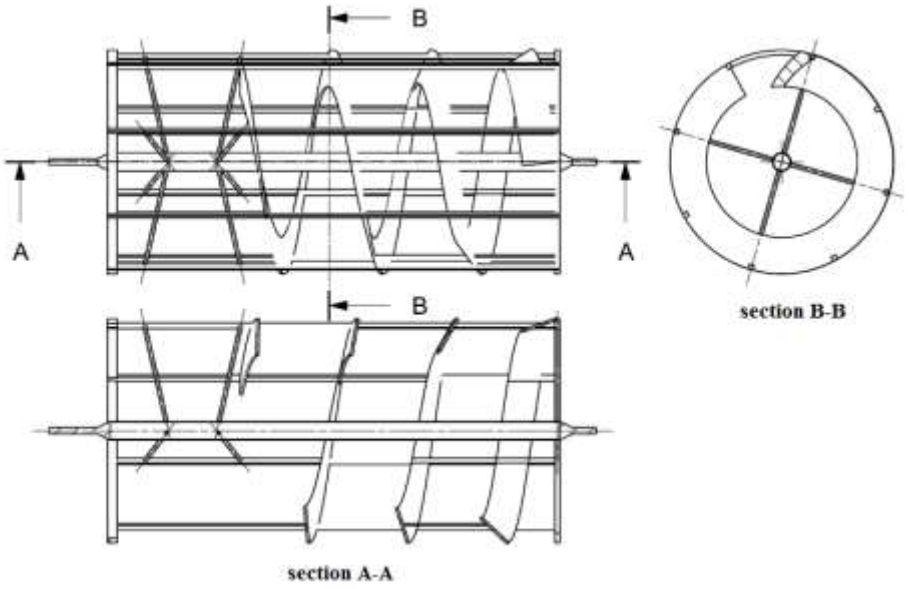

Fig.2. Type of dryer drum

A portable dryer consists of a receiving hopper 1, fixed to a drying drum 2, located at an angle to the horizon (Fig. 2). At the same time, the dryer drum has a mechanism for pouring 3 grains with automatic control. At the bottom of the automatically adjustable mechanism for pouring out the product, there are mechanisms for sorting 4 and 5 of the finished product. A stationary section 6 is coaxially installed at the top of the dryer drum, in which a heater 7 and a fan 8 are provided with belt drive 14 and fan 15.

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The principle of operation of the portable proposed dryer of the proposed grain products is as follows: a certain amount of dried grain is fed through the hopper 1 to the dryer drum 2. After the grain is poured into the dryer drum to a certain volume, the dryer drum starts to rotate and at the same time the heater 7 supplies a stream of hot air to the drum. Drying of grain is gradually carried out by a stream of hot air located in a drum. In the grain dryer, the working drum is located at a certain angle relative to the horizon, most of the volume of the dried grain mass will begin to accumulate at the bottom of the drum. A spiral-shaped rib installed inside the dryer drum (Fig. 2) pushes the accumulated grain mass against the hot air flow created by the heater 7 located in the fixed section 6. the movement of the flow of grain in the lower part of the drum. As a result, the volume of grain to be displaced per revolution of the drum increases, and thus the drying of the grain is accelerated, which leads to a reduction in the time spent on drying the product. The cover of the drum is opened and closed automatically by the spring 20 [4].

The cycle (process) will continue until the grain moisture is reduced on demand level.

The proposed device differs from the closest analogue (prototype) by the following advantages:

1. In the proposed device, the rejection of screw transport and the simplification of the drying device.
2. The process of mixing and drying of grain is accelerated by a spiral-shaped rib fixed inside the drum. As a result, energy consumption is reduced.

To determine the main parameters that affect the regular opening and closing of lids, we will build a dynamic model of a rotating drum and a complex movable lid (Fig. 3). In this case, we consider this mechanical system as a two-mass mechanical system with respect to a stationary engine. We show the vectors of forces acting in a mechanical system and the directions of their moments in a dynamic model. Assume that the direction of the airing dryer is clockwise rotation.

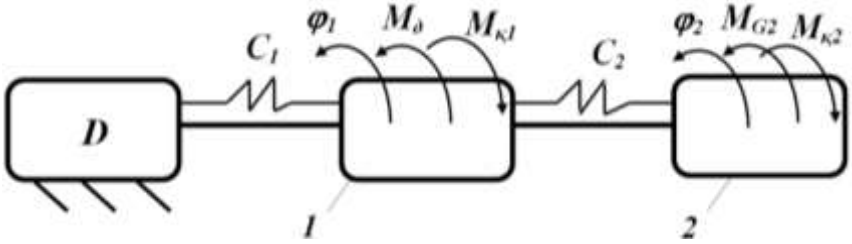

Fig.3. Dynamic model of the mechanism

In the diagram: D - electric motor; 1- dryer drum with grain; 2- cover; φ_1 - angular displacement of the drum, deg; φ_2 - angular displacement of the cover, deg; $M_Д$ - engine torque, N.m.; $M_{к1}$ - torque relative to the axis of rotation of the sum of resistance forces (resistance forces and grain friction forces) to the rotation of the drum, N.m.; M_{G2} - the moment of gravity on the drum (relative to its axis of rotation, i.e. relative to the movable axis), N.m.; $M_{к2}$ - the moment of grain pressure force acting on the lid relative to the drum, N.m.; C_1 - stiffness coefficient of the belt and other gears between the electric motor and the dryer drum, Nm/rad; C_2 - coefficient of stiffness of the spring that opens and closes the lid, N/m.

We obtain the systems of equations of motion of the device mechanism [5]:

$$\mathcal{E}_1 = [\, M_Д * i_{ДБ} \;-\; G_Д * r_Б * \sin\gamma \;-\; (G_1 + G_2 + G_Д) * r_B * f \;-$$
$$-\; C_1 * (\varphi_1 - \varphi_Д * / i_{ДБ})\,] / (J_{оБ} + J_{оК})$$

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$$\mathcal{E}_2 = [\ 0{,}5\ \ l_2 (m_2 * g * \sin(\varphi_1 - \varphi_2) - S * p_Д * \sin\varphi_1) - C_2 * l_2 * \cos\varphi_2] / J_{oK}$$

We accept the initial conditions:

at $t = 0;\ \ \varphi_{01} = \varphi_{02} = 0\ ;\ \omega_1 = \omega_Д\ ;\ \mathcal{E}_1 = \mathcal{E}_2 = 0$

border conditions:

at $t = T\ ;\ \ \varphi_{T1} = 180^0$, those. this corresponds to half a revolution of the drum, which is sufficient to analyze the process of opening and closing the lid during operation.

Using the obtained mathematical model, it is possible to construct the following dependency diagrams, which are necessary for the synthesis of design parameters [6]:

$\varphi_2 = \varphi_1\ (f)$ – dependence diagram of the angular displacements of the drum and cover;

$\varphi_2 = S_2\ (f)$ - diagram of the dependence of the angular displacement of the cover on the coefficient of spring stiffness;

$\varphi_2 = p_D\ (f)$ - diagram of the dependence of the angular displacement of the cover on the pressure of the grain;

$\varphi_2 = G_D\ (f)$ - diagram of the dependence of the angular displacement of the cover on the weight of the grain;

$\varphi_2 = G_Q\ (f)$ - diagram of dependence of the angular displacement of the lid on the weight of the lid;

$\varphi_2 = \omega_Б\ (f)$ - diagram of dependence of the angular displacement of the lid on the angular velocity of the drum;

$\varphi_2 = l_2\ (f)$ - diagram of angular displacement versus cover length.

Conclusions:

1. Thus, designed new device of the portable dryer for farmers and proposed new drum.
2. A system of equations has been obtained that takes into account almost all quantities that affect the movement of a mechanical system, that is, a mathematical model of the first approximation of this mechanical system.
3. Using a mathematical model, it is possible to construct the necessary diagrams not only of the angular accelerations $\mathcal{E}_1$ and $\mathcal{E}_2$ of drums and covers, but also of their angular velocities ω_1, ω_2 and angular displacements φ_1, φ_2. It is possible to carry out the synthesis of parameters based on the given values of the coefficient of elasticity of the lid spring (C_2) and the area of the window for unloading dried rice (S), which is necessary for the proposed drying device.

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