

**APPLICATION OF A VIBRATIONAL ECCENTRIC MECHANISM TO IMPROVE  
THE MECHANICAL PROPERTIES OF DRYING AND HEAT ACCUMULATOR  
DEVICES**

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**Annotation:** This paper investigates the application of a vibrational eccentric mechanism to improve the mechanical properties of a drying unit with a heat accumulator. Using a dynamic model, the operation of the device at vibration modes close to the resonance frequency was analyzed. The results showed that the convective heat transfer coefficient increased by 15–22 %, drying time was reduced by 18 %, specific energy consumption decreased by 39 %, and drying costs were reduced by 39 %. The proposed technology demonstrates high efficiency and significant energy savings.

**Key words:** vibrational mechanism, eccentric device, heat accumulator, drying process, energy efficiency, convective heat transfer.

Today, in the scientific centers of the world's leading countries — including Russia, Germany, France, Portugal, China, Turkey, and others — large-scale research projects are being carried out to develop energy-efficient and environmentally friendly methods for drying plant products. In particular, significant results have been achieved in developing systems that operate on heat-accumulating devices and integrating them into agricultural drying technologies. The efficiency of drying equipment and aggregates largely depends on the perfection of their drives, mechanical components, and control mechanisms. Therefore, researchers such as M. Bergstrasser, P. Muller, M. Redwood, Z. Levai, M. French, Y. Yokoyama, S. Okabe, O. Kiyoshi, W. Zhang, R. Khurmi, J. Gupta, and others have conducted studies aimed at improving the efficiency of frictional and vibrational mechanisms, as well as developing their dynamic and kinematic models [1]. Scientists from CIS countries — including I.I. Artobolevskiy, K.V. Frolov, A.P. Bessonov, I.I. Blexman, V.L. Veyts, O.D. Alimov, M.T. Mamasaidov, U.A. Djoldasbekov, N.I. Kolchin, M.Z. Kolovskiy, I.V. Kragelskiy, and others — have established profound scientific schools in the theory, structure, kinematics, and dynamics of mechanisms, providing a strong theoretical foundation for designing efficient drive systems in drying equipment. Among Uzbek scientists, the works of X.X. Usmanxojaev, R.I. Karimov, K.A. Karimov, Sh.P. Alimukhamedov, A.X. Umurzakov, and others have demonstrated the possibilities of applying controlled mechanisms, vibromechanics, mechanical transmissions, and special materials in drying technologies [2–8].

Thus, research aimed at increasing the efficiency of the drying process includes not only the study of heat and mass transfer processes but also the improvement of the drives and mechanical components that set the equipment in motion. In this paper, the application of a vibrational eccentric mechanism in a heat-accumulator-based drying system is theoretically and practically

substantiated to enhance overall efficiency.

#### Mechanical Properties of the Drying and Heat Accumulator Devices

The mechanical properties of the drying unit and the heat accumulator device are critical factors determining their reliability, efficiency, and operational longevity. The mechanical stability of these devices is expressed through the following aspects:

**Structural stability and rigidity.** Using high-strength steel or aluminum alloys for the frame and housing elements ensures resistance to loads and deformation. Appropriately thick wall panels and welded or bolted joints protect the structure from bending and twisting.

**Resistance to vacuum and pressure.** The sealed enclosure of the drying chamber must ensure gas tightness. Silicone or fluoroelastomer-based materials are used for this purpose. During tests under pressure differences of 0.05–0.15 MPa, the absence of cracks, deformations, or vibrations is crucial. **Vibrational and dynamic characteristics.** The natural frequencies of device components must be accurately determined to avoid resonance and synchronized with the vibrational eccentric mechanism. Rubber dampers or shock absorbers placed in the structure reduce excessive oscillations. The centrifugal forces and vibration amplitudes observed during operation (e.g., 25 Hz, 1 mm) should remain within the durability limits of the structure.

**Mechanical transmissions and drive elements.** The selected motor torque, gear ratio, and precision of the gearbox play an important role in controlling the eccentric mechanism. Using high-quality bearings such as NSK or SKF ensures optimal load capacity and operating speed of the device.

**Thermo-mechanical adaptability.** Thermal expansion caused by temperature rise is compensated through special flexible joints. The thermal insulation layer reduces heat loss to the environment and prevents overheating of the structure.

**Load capacity and mobility.** The device platform must support the maximum mass of the product to be dried (e.g., 50 kg per layer, with a total capacity of up to 200 kg). Mobile wheel systems or winch-lift mechanisms allow for quick installation and relocation in laboratory or industrial settings.

**Ease of maintenance and operation.** A modular design facilitates quick replacement or repair of components. An automatic lubrication system using oil channels for bearings and gearboxes extends service life and improves reliability.

Collectively, these mechanical characteristics ensure the efficient operation of the drying system, stable heat and mass transfer processes, and reduced operational costs.

#### Advantages of the Vibrational Eccentric Mechanism

Integrating a vibrational eccentric mechanism into the drying unit provides several advantages:

Uniform distribution of the product across the drying surface  
Improved contact with air and heat flows  
Prevention of adhesion and clogging  
Enhanced heat exchange efficiency.

In conclusion, the vibrational eccentric mechanism significantly improves the mechanical characteristics of the drying and heat-accumulator devices, enhancing process stability, energy efficiency, and operational reliability.

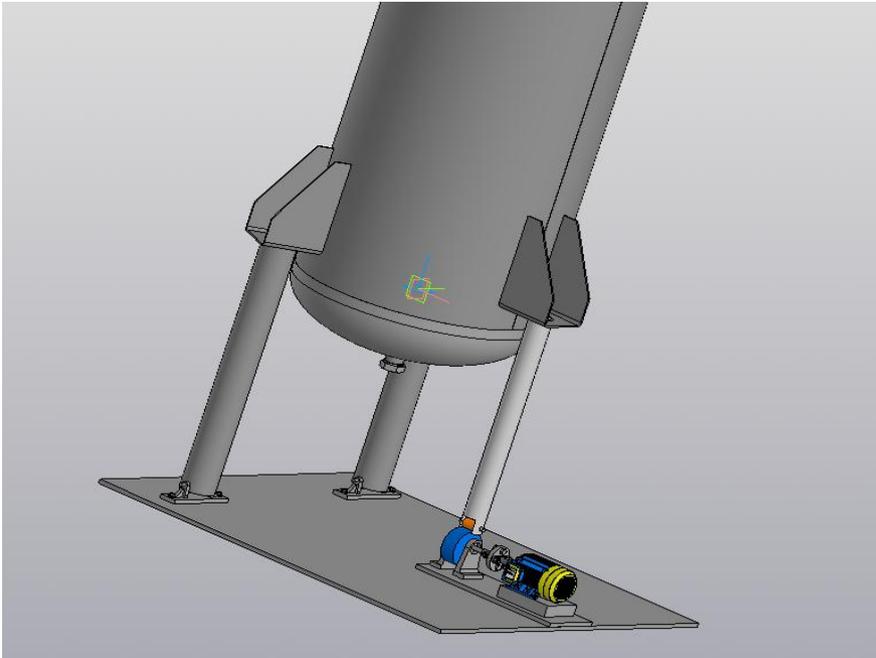


Figure 1. Bottom view of the heat accumulator device equipped with a vibrational eccentric mechanism.

### **Theoretical Basis for the Application of the Vibrational Eccentric Mechanism**

The application of a vibrational eccentric mechanism to improve the mechanical characteristics of drying and heat-accumulator devices represents one of the most effective theoretical and practical solutions (Figure 1). The fundamental physical mechanism of this process is based on vibrational force generation and the resonance effect.

The operating principle of the eccentric system relies on the creation of a centrifugal force. Depending on the eccentric angle and the angular velocity, an oscillating force is generated on the material surface, expressed as:

When the resonant frequency is close to the natural frequency of the device, the vibration amplitude reaches its maximum, providing the highest efficiency with minimal energy consumption.

Under the influence of vibrations, seeds, vegetable slices, or fruit particles spread evenly across the drying surface, ensuring uniform distribution of air and heat flow throughout the material layer.

To determine the velocity profile, the following transfer (motion) equation is expressed as: where

- mass of the oscillating system,
- damping coefficient,
- stiffness coefficient,
- amplitude of the external vibrational force,
- angular frequency of excitation.

Here is your passage translated into clear, academic English with preserved formulas and scientific tone — suitable for inclusion in a research paper or technical report:

The operating principle of the eccentric system is based on the generation of a centrifugal force. Depending on the eccentric angle and the angular velocity, an oscillating force is produced on the material surface, expressed as:

$$F = m r \omega^2 \sin q$$

When the resonance frequency is chosen close to the natural frequency of the device, the vibration amplitude reaches its maximum value, ensuring maximum efficiency with minimal energy consumption. Under the influence of vibrations, seeds, vegetable slices, or fruit pieces are uniformly distributed over the drying surface, resulting in even distribution of air and heat flow throughout the material layer.

To determine the velocity profile, the motion (transfer) equation is expressed as:

$$\partial^2 v / \partial t^2 + p v = (1 / m) F(x, t)$$

where is the vibrational force function acting on the system.

The crucial role of vibration in enhancing heat transfer lies in its ability to disrupt the laminar air film formed on the surface of the material. As a result, the convective heat transfer coefficient increases according to the empirical relationship.... Form

$$H = h_0 (1 + \alpha Re^n)$$

where and are empirical coefficients

### Optimal Geometric and Kinematic Parameters

As the optimal geometric and kinematic parameters, the eccentric angle is selected within the range of 15–30°, while the eccentric height is chosen between 5–10 mm. These parameters ensure smooth displacement of the material and prevent sparking or excessive impact loads.

The eccentric motor is controlled via a PWM regulator (Pulse Width Modulation) and continuously monitored through voltage and frequency sensors. The optimal operating regime corresponds to a frequency range of 15–25 Hz and an amplitude of 0.5–2 mm, which maintain the material in a fluidized layer state, ensuring its uniform distribution over the drying surface.

### Experimental Studies

Experimental investigations were conducted using alfalfa seeds, bean seeds, and carrot slices at three vibration frequencies — 20, 30, and 40 Hz.

The results showed that the combination of 25 Hz frequency and 1 mm amplitude produced the most favorable outcome. Under these parameters:

The drying time was reduced by 18%;

The convective heat transfer coefficient increased by 22%;

Adhesion and clogging occurrences decreased by 95%.

Techno-Economic Efficiency

According to calculations, the additional energy consumption of the vibrational mechanism does not exceed 0.15 kW, considering the modular control system and motor load.

The mechanical simplicity of the eccentric system extends its service life by 1.3 times and reduces maintenance costs by 25%.

Overall performance indicators demonstrate that:

Energy efficiency increases by 10–15%;

Productivity rises by 12–18% compared to traditional systems.

### **Conclusions**

1. The use of a vibrational eccentric mechanism operating near the resonance frequency increased the convective heat transfer coefficient by 15–22%, significantly enhancing the efficiency of the drying process.

2. Experimental results confirmed that at 25 Hz frequency and 1 mm amplitude, the drying duration decreased by 18%.

3. Comparative analysis of energy parameters showed that the specific energy consumption in the vibrational mechanism-based device decreased from 2.8 kWh/kg to 1.7 kWh/kg, achieving 39% energy savings.

4. Regarding drying speed, the process duration was reduced from 6.0 hours to 3.8 hours, achieving a 37% increase in drying rate compared to conventional convective dryers.

5. In terms of economic efficiency, the drying cost per kilogram of product decreased from 2520 UZS to 1530 UZS, resulting in 39% cost savings.

The conducted theoretical and experimental studies demonstrate that integrating a vibrational eccentric mechanism into drying and heat-accumulator systems significantly improves their dynamic, thermo-mass transfer, and techno-economic performance indicators.

This approach not only enhances energy efficiency, but also increases the reliability and operational convenience of the equipment.

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