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PSEUDOLIQUEFACTION, TURBULIZATION AND VIBRATION AS FACTORS OF INTENSIFICATION OF THE DRYING PROCESS OF DISPERSED BULK MATERIALS - A REVIEW OF DOMESTIC AND FOREIGN RESEARCH

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ABSTRACT:

The article reviews modern foreign studies devoted to the influence of hydrodynamic flow structures during drying in a fluidized flow. The physical and technical foundations of these methods, their advantages, areas of application and experimental confirmation of their effectiveness are considered. The relevance of introducing such solutions into agricultural production in order to improve energy efficiency and quality of bulk material processing is emphasized.

INTRODUCTION. Fluidization is a process in which the grain mass behaves like a boiling liquid when an ascending gas flow passes through it. This leads to a significant improvement in the uniformity of heating and the intensity of mass transfer. The studies conducted by the author of [1] were aimed at studying the effect of the fluidization mode on the drying time of various bulk materials. As part of the work, the author [1] studied the drying of grain crops and fine powders in a fluidized bed apparatus. Experimental data showed that when organizing fluidization, more intense heat and mass transfer is achieved, which leads to a reduction in the total drying time by 20-30% compared to traditional methods (for example, chamber or convective drying). In his experiments [1], he varied the feed rate of the drying agent, air temperature and bed load, identifying optimal modes that ensure the most efficient process.

In turn, foreign scientists [3] focused on the theoretical and experimental substantiation of the conditions of a stable fluidized bed. In their works, they investigated the critical and minimum gas velocity at which particle fluidization begins. Scientists found that the correct selection of this velocity is critical for maintaining the uniformity of the bed and preventing negative phenomena such as channeling (formation of voids) or bed destruction. Scientists

[3] developed mathematical models to predict the behavior of the bed depending on the characteristics of the material (particle size, density) and the properties of the drying agent (density, viscosity), and also verified their models in practice. Their research emphasized the importance of optimizing the gas velocity to improve energy efficiency and drying quality.

Research results. The results show that the use of fluidization allows to significantly reduce the drying time and increase the uniformity of material processing [1]. The critical gas velocity is a key parameter for ensuring the stability of the process and increasing its energy efficiency [3].

The creation of a turbulent flow of the coolant increases the heat transfer coefficient, destroys the boundary layer of air at the surface of the grain, enhancing heat transfer. Modern research confirms the high efficiency of using fluidization technology to intensify drying processes of various materials.

The author [2] focused on studying the influence of fluidized bed parameters on the efficiency of drying bulk materials. During the experiments, the author investigated the drying processes of various grain fractions in a laboratory setup equipped with an air flow rate and temperature control system. Particular attention was paid to optimizing the fluidization conditions : the ascending flow rate, the initial material moisture content, and the degree of bed loading. As a result, it was found that with the correct selection of operating parameters, the efficiency of the drying process increases by 18–22% compared to traditional convective drying. The efficiency was assessed by reducing specific energy costs and increasing the uniformity of the final material moisture content. The researcher also noted a decrease in the time it takes for the material to reach the specified process parameters, which has a positive effect on the productivity of drying units.

A foreign group of researchers [6] conducted and a comprehensive study of the effect of a fluidized bed on the overall drying time of various biomaterials (in particular, corn grain and agricultural waste). Their work included both experimental studies and numerical modeling of heat and mass transfer processes and methods for stepwise increasing the drying agent speed to achieve optimal fluidization conditions without destroying the bed. As a result of the experiments, a significant reduction in the overall drying time was recorded while maintaining the high quality of the dried material. The researchers focused not only on the drying rate, but also on minimizing energy losses and preserving the physical properties of the original product. In addition, the use of fluidization allows to increase the efficiency of the process by reducing energy costs and increasing the uniformity of drying [2, 6].

One of the promising areas for increasing the efficiency of bulk material drying processes is the use of mechanical vibrations, in particular vibration effects. Vibration helps to intensify the movement of particles in the drying zone, reduce the caking of the material and

provide more uniform heating, which is especially important when working with finely dispersed or agglomeration-prone substances.

The author [7] conducted a series of experiments to study the effect of vibration on the energy efficiency of the drying process in a fluidized bed. In his work, he used a laboratory setup equipped with a vibration platform located under the working chamber. The amplitude and frequency of vibration varied over a wide range, which made it possible to determine the optimal parameters for different types of grain crops. As a result of the studies, a decrease in energy costs of 10-15% was recorded compared to a similar drying process without the use of vibrations. The achieved effect is explained by better particle mobility, improved contact with the drying agent and a reduced likelihood of the formation of "dead zones" in the layer.

Foreign scientists [4] focused their attention on continuous vibration dryers. They developed and tested an industrial model of a drying unit in which the material moved along an inclined vibrating surface, simultaneously being exposed to hot air. The study was conducted using the example of drying agricultural raw materials, including rice and legumes. According to the results, the productivity of the unit with the introduction of vibration effects increased by 25% compared to classic convective dryers. This is explained by a reduction in the time the material spends in the drying zone without loss of quality, as well as a reduction in the risk of forming dense, poorly ventilated areas.

The use of mechanical vibrations helps to intensify heat and mass transfer processes, vibration technologies reduce energy costs and significantly increase productivity, the most promising are combined methods: fluidization with vibration, or continuous vibration drying, especially when working with difficult-to-process or caking materials [4,7,5]. The combination of the described methods (for example, vibration + fluidization) allows achieving a synergistic effect, the process of turbulence and vibration allowed to reduce the drying of wheat by 40%.

Conclusion. The review confirms the high efficiency of fluidization , turbulence and vibration as means of intensifying the grain drying process. Their implementation not only increases productivity, but also improves the quality of the product. An integrated approach taking into account the hydrodynamics of the phases is a promising direction.

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