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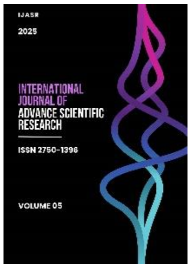

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Research Article

Selection Of Rational Values Based On Systematic Analysis And Design Of Dryer Construction For Primary Drying Process

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Abstract

This article discusses the issues of designing a dryer structure for the primary drying process of grain products based on systematic analysis. The study comprehensively evaluated the relationship between technological and aerodynamic parameters of the drying process, heat and mass transfer indicators, air flow directions, and hydrodynamic resistance in the grain layer. During the design process, rational values for the optimal geometric shape of the dryer, drying agent temperature, moisture removal intensity, and energy consumption were determined using systematic analysis methods. The theoretical and practical results obtained will serve to increase the efficiency of the grain drying process, effectively use thermal energy, and create new generation designs of dryers.

Keywords

Primary drying, systematic analysis, dryer design, grain drying technology, heat-mass transfer, aerodynamics, energy efficiency, rational parameters, drying agent, hydrodynamic resistance.

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Introduction

During the initial processing of grain products after harvesting, reducing their moisture content to the limit values is one of the most important technological stages. Grain with high moisture content is characterized by overheating, microbiological deterioration and a decrease in quality in a short time. Therefore, the scientific organization of the primary drying process, the determination of rational modes of drying technology and the improvement of the dryer design are of great importance in increasing the efficiency of storing agricultural products.

The designs of existing drying devices were considered optimal in terms of drying efficiency. At the same time, the specific features of each device were recognized.However, such devices are not optimal in terms of energy consumption and productivity. Therefore, a systematic analysis was conducted to design and study the right device for the object under study. Systems analysis is a scientific method of predicting a process, expressing the relationship between the sequence of actions and the variable or constant elements of the system under study in order to establish structural relationships and recommending specific parameters. Systems analysis allows solving scientific, experimental, statistical and analytical problems using mathematical methods. Systems analysis appeared during the development of computer technology. Its success lies in its application in solving complex problems. The error rate of the analysis does not exceed 4%. Systems analysis recommends constructions or methods that can be applied to the process using modern capabilities of information technology.

Methods

In order to select the optimal primary drying method and device for the process, a systematic analysis was conducted based on the MatLab program. During the systematic analysis, the most promising primary drying devices recommended by the authors and considered the most modern today (a recirculation grain drying device using the pneumatic tract method, a shaft dryer for drying dispersible materials, a rotating disk grain dryer, a rotating fluvial disc grain dryer and a fluvial cascade grain dryer) were selected.

The scheme for determining rational values in the form of a five-stage systematic analysis is given in Figure 1.1, and the general design of the systematic analysis based on the MatLab program and calculation codes are given in Appendix C. When conducting a systematic analysis, the main parameters selected were the aerodynamic resistance of the dryers - $\Delta P_{а.қ.}$, Pa, the amount of heat required for drying - $Q_{миқ}$, кЖ/кг·К, the actual energy consumption through the electric heater - $N_{қув}$, кВт, the heat balance - $Q_{бал}$, кЖ/кг·К, the efficiency - $\eta_{қ.с.}$, %, and the determination of the ideal working bodies of the devices.

Results and Discussion

The data presented in Figure 1.1 allow us to find the types of primary drying devices that can be used in the process, their operating parameters, and optimal modes. In this case, each column of the five-stage steps is important. Based on the above task, based on the numerous analyses conducted, a four-factor systematic analysis method was used to fully compare the press design parameters and reduce the error of the results and select the optimal design, as well as analyze the binders that can be used in the pressing process. When conducting systematic analyses, coal briquettes obtained from the Fergana coal depots were selected as the pressing material. The systematic analysis was carried out in the following sequence:

In the first initial stage, the aerodynamic resistances of the selected primary drying devices and the factors that cause them were studied. In this case, the parameters of the inlet and outlet of the heat agent to the device were taken as an important factor. For example, in the devices proposed by the authors of patent No. 456964 (Zelepuga Anatoly Sergeevich, Sirotkin Gari Lvovich, Kazakevich Valery Sergeevich, Lyuboshits Alexander Isakovich), the aerodynamic resistance is relatively high, which is explained by the complex design of the devices. This, in turn, negatively affects the efficiency of the dryer. In the device proposed by the author of patent № SU817434A1, the flow of the heat agent is ideal, which ensures maximum contact between the material being dried and the agent. However, due to the high aerodynamic resistance, changes in the physical properties of the material being dried were observed. In patent SU 1126787 A, the authors (П.С. Кутс, А.И. Любошитс, А.И. Зҳидович, В.П. Кочубеев, В.Л. Мелтсер анд М.Г. Дунаевскй) proposed a rotating disk grain dryer in which aerodynamic resistance is reduced due to the artificial ventilation effect and the presence of a cylindrical body and guide vanes in it.

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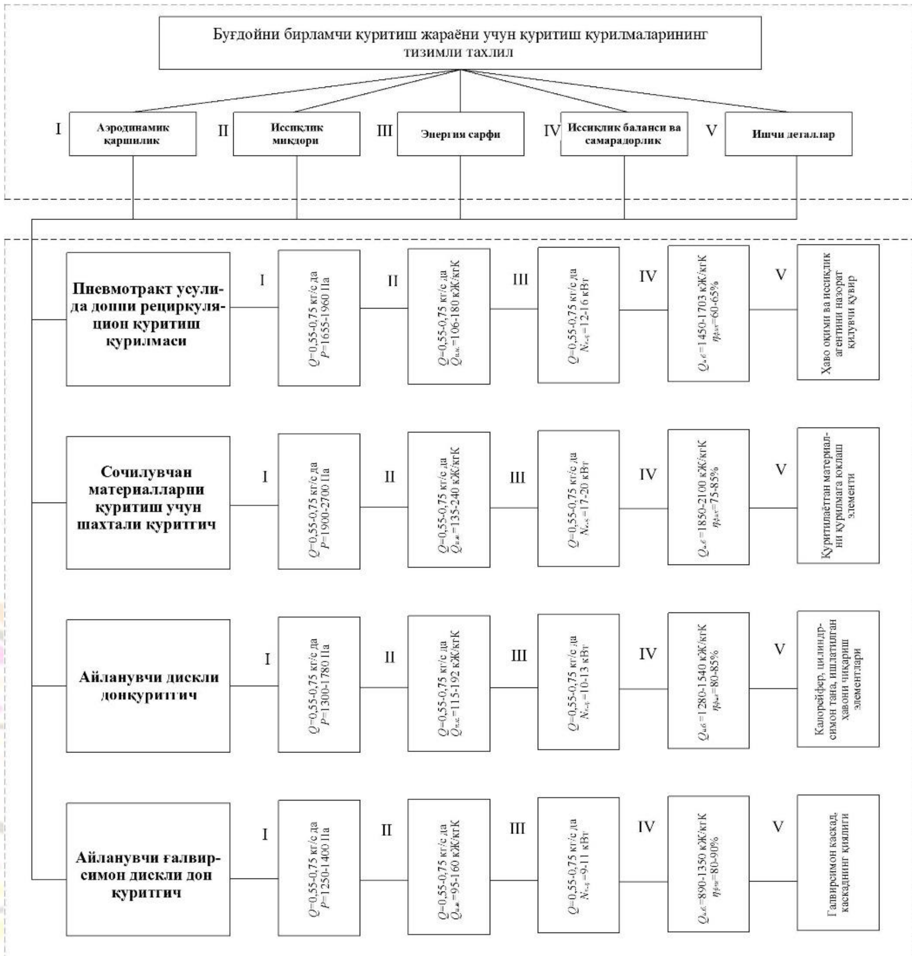

Figure 1.1. Optimization scheme in the form of a systematic analysis in five stages.

Due to this, the heat exchange between the grain and the agent is ideally realized. From the devices analyzed above, it was found that the most optimal option for the object under test with minimal aerodynamic resistance and maximum heat exchange is the rotating disc grain dryer.

In the second stage, the amount of heat consumed in the devices for drying 1 kg of grain was analyzed. In this case, the elements of product transfer, elements of introducing the heat agent into the device and elements of removing the product from the device were considered. The input and output parameters of each auxiliary system were determined. According to the determined parameters, it was determined that the grain throughput loaded into the device is 0.06 kg/s at low load and 0.07 kg/s at high load, and the amount of heat is within the specified requirements when the range of the heat agent speed is 5÷20 m/s.

For example, in the devices proposed by the author В. П. Волкова in patent SU27342A1, the design of the elements for entering and exiting the heat agent and the product into the device was made somewhat more complex. This, in turn, increased the efficiency of using the flow of the heat agent. However, due to the increase in aerodynamic resistance, a reverse process of heat occurred, which in turn led to an increase in the amount of heat spent on drying 1 kg of material.

In the US 11,047,623 B2 (United States Patent Int. Cl. F26B) patent, the author Jun Zheng proposed a cascade grain dryer device in which the heating agent, product inlet and outlet elements are in an ideal state, thereby ensuring drying intensity with minimal consumption of the amount of heat supplied to the material being dried. Therefore, for the object under investigation, it was found that the product transfer elements, the elements for introducing the heating agent into the device and the elements for removing the product from the device are optimal.

In the third stage, the amount of energy consumed for grain drying was systematically analyzed. The input and output parameters of each working element of the device, the overall dynamics, and the drives were determined.

The results of the analysis showed that the minimum average energy consumption for grain drying is 9÷15 kW, which is considered optimal for the studied process.

In the fourth step, the heat balance and drying efficiency of the primary drying process were analyzed. The input and output parameters of all devices for the studied process were determined.

It was found that the optimal parameters for standard drying were the heat balance $Q_{и.б.}$=1500-2000 кЖ/кгК and the drying efficiency $\eta_{фик}$=75-90 %

In the fifth stage, based on the parameters determined in the above four stages, the ideal working details of the devices were selected and their compliance with the determined parameters was checked. Also, the ideal working elements of the studied devices for the improved device were selected. In the pneumatic tract method, the air flow and heat agent control pipe in the grain recirculation drying device, the element for loading the material being dried into the device in the shaft dryer for drying dispersible materials, the calorifer, cylindrical body, elements for exhausting used air in the rotating disc grain dryer, and the corrugated cascade and the cascade slope in the rotating corrugated disc grain dryer and corrugated cascade grain dryer were selected as the most optimal working elements. In this case, the number of cascades was determined to be 4÷8 units according to the parameters determined above.

The dryer scheme developed on the basis of these working bodies is not considered a very suitable design for rational use of the energy consumed in the process, the time of the material's stay in the dryer, and the amount of heat. Therefore, the time of the material's stay in the dryer was considered as the main parameter for the primary drying process, and on this basis, a structural scheme of a cascade dryer device for the primary drying process of wheat grain was developed. Figure 1.2 shows an improved scheme of a cascade dryer.

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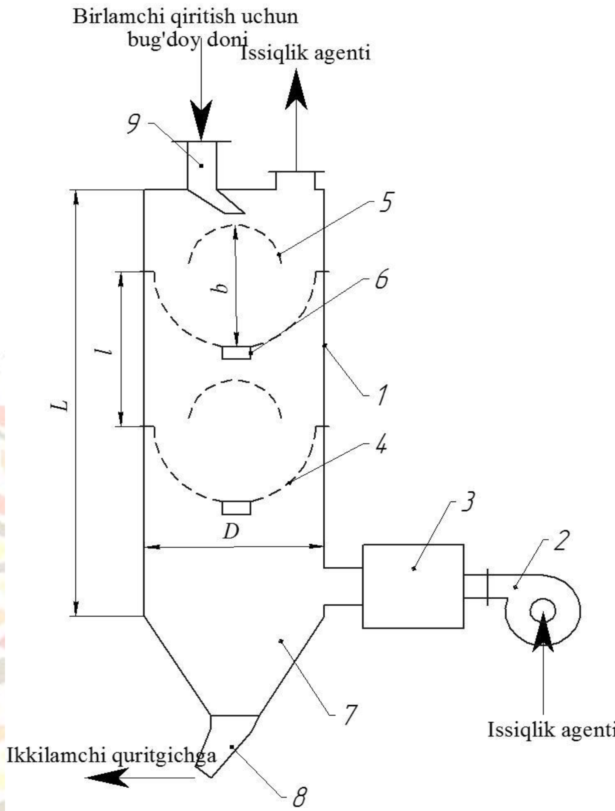

Figure 1.2. Structural diagram of an improved cascade dryer.

The wheat grain being dried in the device is fed through pipe 2 and transferred to cascade 7. The elliptical cascade 7 evenly distributes the product, the perforated holes in the cascade reduce hydraulic resistance and form a so-called boiling layer. The product spread in cascade 7 is transferred to cascade 6 below it. Cascade 7, which is elliptical in shape and has a hole in the middle and collects the material spilled from cascade 6 in the middle. The heat agent introduced through pipe 4 is evenly distributed through elliptical cascades, which reduces the exposure of the heat agent to the Coanda effect. It forms a so-called boiling layer with the product falling from above. The same process continues in each pair of cascades. Then the heat agent exits through pipe 3. The product that has passed the drying stage leaves the device through pipe 5 below the device.

CONCLUSION

The advantage of this device over existing devices is that the cascades, which are elliptically shaped from top to bottom and perforated with holes, are installed one above the other, and the presence of a hole in the middle of the upward cascade for the product to fall (equal to 15% of the cascade), firstly, it assumes the formation of a so-called boiling layer in the cascades. Secondly, it provides heat exchange surfaces between the heat agent and the material. As a result, the drying intensity of the material is ensured.

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