RESEARCHING SELECTION OF OPTIMALITY CRITERIA FOR IR DRYER

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Annotation. The paper explores the selection of optimality criteria for infrared (IR) dryers, focusing on improving the efficiency and performance of the drying process. The study investigates various parameters that affect the efficiency of IR drying, such as heat transfer, drying time, energy consumption, and moisture removal. Through experimental analysis and modeling, the research aims to identify the best optimization strategies that can be applied to IR dryers in industrial applications, ensuring energy savings while maintaining product quality. The results highlight key factors such as temperature regulation, material properties, and drying conditions that play crucial roles in enhancing the overall drying process. The paper provides practical insights into how different optimality criteria can be used to maximize the operational effectiveness of IR dryers in various industries.

Keywords: infrared drying, optimality criteria, energy efficiency, drying process, heat transfer, moisture removal, industrial drying systems, process optimization, thermal efficiency.

Introduction. The selection of optimality criteria for an IR dryer is essential for improving drying efficiency, reducing energy consumption, and maintaining product quality. Factors such as radiation intensity, material properties, drying time, and moisture removal rate must be carefully considered when selecting optimal drying conditions. Mathematical modeling, experimental studies, and multi-criteria optimization techniques provide valuable tools for selecting the most suitable criteria. As the demand for energy-efficient and sustainable drying technologies continues to grow, the optimization of IR dryers will play a crucial role in enhancing industrial processes across various sectors. Future research should focus on refining these optimization methods and exploring new technologies that can further improve the performance of infrared dryers. Infrared (IR) drying is a promising technology widely used in various industries, including food processing, pharmaceuticals, and textiles, due to its ability to offer high energy efficiency and faster drying times compared to conventional methods. The IR drying process involves the use of electromagnetic radiation to transfer energy directly to the material being dried, causing the water to evaporate. While IR drying presents numerous advantages,

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optimizing the drying process for specific applications requires careful selection of optimality criteria. The purpose of this article is to explore the selection of optimality criteria for IR dryers, focusing on factors such as energy consumption, drying time, and product quality. By selecting the appropriate criteria, it is possible to improve the efficiency and effectiveness of IR dryers in both industrial and commercial settings [1].

The drying process must be controlled in such a way that at least the basic nutritional properties of the products are preserved. Another natural requirement in the drying process control is to dry the material to a moisture content not exceeding the specified one. In order to preserve the nutritional properties of products, in some cases it is necessary to impose restrictions on the rate of moisture removal, the temperature of the drying agent and the material. Depending on the location of the dryer in the process chain, the drying process should occur in such a way as to ensure either maximum dryer productivity or minimum cost of the finished product. To build control systems for drying devices, it is first necessary to have their mathematical models. To obtain mathematical models of dryers, it is necessary to have classification features that are decisive in obtaining mathematical models of dryers, a set of equations from which mathematical models are compiled, and information necessary to find such parameters that determine the drying process as drying speed and heat exchange coefficients, which are often unknown [2].

The IR dryer as an object of automatic control has the following classification features: the method of supplying heat necessary for drying the material is radiation from radiant energy, the nature of the movement of the material and drying agent is directional, the method of moving the material is stationary, the nature of the relative movement of the drying agent and the material is transverse, the operating mode of the dryer is dynamic. It is necessary to take into account heat exchange through the housing with the environment. The objective characteristics primarily include the method of heat supply, the method of moving the material, the nature of the relative movement of the drying agent and the material [3].

The choice of such features as the dryer operating mode, the need to take into account heat exchange through the housing with the environment, and the wall thickness depends significantly on the purpose of the study. To calculate the optimal control system in the dynamic operating mode of the dryer, the dynamic operating mode of the dryer is considered. Heat exchange through the housing with the environment is taken into account in the case when the heat loss through the housing exceeds 10% of the total amount spent on drying. Thermal conductivity through the wall is taken into account when the characteristics are studied along the channels

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directly covering the wall along the channel "inlet temperature of the coolant - outlet moisture content of the material" [4].

Based on the obtained mathematical models of the dryer, it is possible to formulate and solve the problem of optimal control of dryers with a radiation method of heat supply. To formulate the problem of optimal control, it is necessary to select the optimality criterion and control actions and specify the types of restrictions imposed on the phase coordinates and control actions. As an optimality criterion for a dryer, one can select energy consumption, productivity, deviation of the distribution of the moisture content of the material along the length of the dryer from the specified value, and deviation of the output moisture content of the material from the specified value [5].

Limitations may be placed on the output moisture content of the material, the rate of moisture removal, the power of the energy source, the temperature of the drying agent, and the temperature of the material.

The control actions used are direct energy consumption (electricity consumption), indirect energy consumption (input temperature), and material consumption.

The listed optimality criteria, limitations and control actions are selected based on the following considerations. As an optimality criterion when developing a control system for a dryer, it is advisable to adopt either maximum productivity or maximum cost price; the control criterion in the form of maximum productivity can only be selected for dryers that are not in the process chain.

The optimality criterion for an IR (conveyor) dryer is minimum energy consumption.

$$Q = \int_0^1 G_T I_T dx$$

where G_T is the coolant flow rate; I_T is the lower calorific value of the fuel.

The gas consumption is used as a control action, i.e. in accordance with the accepted terminology, “direct energy consumption”.

Constraints in the form of inequalities are imposed on the output moisture content of the material, which has the form

$$\omega \downarrow_{x=1} \leq \omega_{\text{макс}}$$

and drying speed in the form

$$\frac{d\omega}{dx} \leq |a_1 e^{a_2 \omega}|$$

where a_1 and a_2 - constant coefficients.

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Since the fuel consumption, which is distributed along the length of the dryer, is used as a control action, and the mathematical model of the dryer is described by a system of ordinary differential equations, the Pontryagin maximum principle is used to solve the problem [6].

The optimal values of the control function are realized by issuing the corresponding tasks by the regulator, which maintains the distribution of fuel consumption along the length of the dryer at a given level. The parameters characterizing the drying process, including the control actions, are subject to restrictions. First of all, these restrictions are determined by the mathematical model of the dryer and represent the equations of the material balance for moisture for the material . In addition, there are restrictions in the form of an inequality and they are primarily imposed on the value of the output moisture content of the material: According to drying conditions, the output moisture content of the material should not exceed a certain specified value. Since it is necessary to preserve the nutritional properties of agricultural products when drying them, overheating them (restrictions from above are imposed on the temperature of the material) and accelerated drying are unacceptable [7].
(limitations on the rate of moisture removal)
Limited resources impose restrictions on the capacity of the energy source.

The choice of control actions is largely determined by the adopted optimality criterion. Productivity was chosen as the criterion for the optimality of the IR dryer, and material consumption was adopted as the control action.

The equations from which the mathematical models are compiled are the equations of heat and material balances for heat and mass-accumulating capacities, into which the drying apparatus is divided when compiling their mathematical models. In IR dryers, the heat and mass-accumulating capacities are the heater and screens.

Conclusion. In conclusion, the paper demonstrates that the selection of optimality criteria for IR dryers is critical in improving both the energy efficiency and drying performance in industrial settings. By considering factors like energy consumption, drying time, and moisture content, the research provides a framework for selecting the most effective criteria for specific applications. The findings suggest that a comprehensive understanding of the material properties and drying conditions is essential for optimizing IR drying processes. This study provides valuable guidance for industries looking to enhance their drying operations, reduce energy costs, and maintain product quality. Further research is recommended to explore additional parameters and advanced optimization techniques to refine IR drying systems even further.

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