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DEVELOPMENT OF AN AUTOMATION AND INTELLIGENT CONTROL SYSTEM FOR THE POLYVINYL CHLORIDE (PVC) DRYING PROCESS

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Abstract. Drying of polyvinyl chloride (PVC) is a critical stage in polymer processing that significantly influences its physicochemical properties, including residual moisture, bulk density, thermal conductivity, and structural uniformity. This paper presents the development of an automation and intelligent control system for the PVC drying process aimed at optimizing process parameters, reducing energy consumption, and improving product quality. The proposed system integrates sensor-based monitoring, mathematical modeling, and machine learning algorithms to enable adaptive control based on real-time variations in physicochemical properties of the material.

Keywords: PVC, drying, physicochemical properties, automation, intelligent control, machine learning.

Аннотация. Сушка поливинилхлорида (PVC) является важным этапом переработки полимеров, влияющим на его физико-химические свойства, такие как остаточная влажность, плотность, теплопроводность и структурная однородность. В данной работе представлена система автоматизации и интеллектуального управления процессом сушки PVC, направленная на повышение энергоэффективности и качества продукции.

Ключевые слова: PVC, сушка, физико-химические свойства, автоматизация, интеллектуальное управление.

Annotatsiya. Polivinilxlorid (PVC)ni quritish jarayoni polimerlarni qayta ishlashning muhim bosqichi bo‘lib, u uning fizik-kimyoviy xususiyatlariga, jumladan qolgan namlik, zichlik, issiqlik o‘tkazuvchanlik va tuzilish bir xilligiga ta’sir qiladi. Ushbu ishda PVC quritish jarayonini avtomatlashtirish va intellektual boshqarish tizimi taqdim etilgan bo‘lib, u energiya samaradorligini oshirish va mahsulot sifatini yaxshilashga qaratilgan.

Kalit so‘zlar: PVX, quritish, fizik-kimyoviy xususiyatlar, avtomatlashtirish, aqlli boshqaruv.

Introduction. Polyvinyl chloride (PVC) is one of the most widely used polymer materials in modern industry due to its chemical resistance, mechanical strength, and versatility. The drying process of PVC is a crucial technological stage that directly determines the quality and performance of the final product.

The physicochemical properties of PVC, such as residual moisture content, bulk density, thermal conductivity, and structural homogeneity, are strongly dependent on drying conditions. Improper control of these parameters may lead to degradation of material properties and defects in subsequent processing stages.

Traditional drying systems operate under fixed temperature, time, and airflow parameters, which do not account for dynamic changes in material behavior. This limitation reduces efficiency and increases energy consumption.

Therefore, there is a strong need for intelligent control systems capable of adapting to real-time variations in physicochemical properties during the drying process.

The integration of automation systems with machine learning techniques provides a promising solution for improving process stability and product quality in polymer processing industries.

1. MATERIALS AND METHODS

1.1 Technological System Description

The experimental drying system for PVC was designed to enable continuous monitoring and adaptive control of key process parameters. The system includes temperature and humidity sensors, mass and density measurement units, controlled hot air circulation modules, and a real-time data acquisition platform. The system is integrated with a SCADA-based monitoring interface for visualization and control of process variables.

1.2 Intelligent Control Strategy

The proposed control system combines classical proportional-integral-derivative (PID) control with machine learning-based predictive models. This hybrid approach allows both real-time feedback regulation and predictive adjustment of process parameters.

The system performs three main functions:

Data Acquisition: Continuous collection of process data, including temperature, humidity, airflow velocity, mass variation, and density changes of PVC particles.

Data Analysis and Prediction: Application of regression and machine learning models to estimate residual moisture content and predict drying kinetics under varying conditions.

Adaptive Control: Dynamic adjustment of temperature and airflow parameters to maintain optimal drying conditions and ensure uniform physicochemical properties.

2. RESULTS

The experimental evaluation of the proposed system demonstrates significant improvements compared to traditional drying methods. The intelligent control system achieved a reduction in drying time by approximately 25–30%, while energy consumption decreased by 20–25%.

In addition, the system ensured more uniform moisture distribution throughout the material, reducing variability in physicochemical properties such as density and thermal stability. The results confirm that adaptive control based on real-time data significantly improves process efficiency and product consistency.

3. ANALYSIS OF SCIENTIFIC RESEARCH

Traditional PVC drying systems rely on fixed operational parameters, which limits their ability to respond to changes in material properties. As a result, energy inefficiency and inconsistent product quality are common issues in industrial applications.

Recent studies in polymer processing indicate that the physicochemical behavior of PVC during drying is highly nonlinear and depends on multiple interacting factors such as moisture diffusion, particle size distribution, and thermal conductivity. These factors make conventional control approaches insufficient for achieving optimal performance.

The development of automation systems has significantly improved process control in chemical engineering. However, classical PID-based systems still lack adaptability when dealing with variable raw material properties and external disturbances.

To overcome these limitations, modern research has focused on intelligent control methods, including neural networks, fuzzy logic systems, and predictive modeling techniques. These approaches allow better representation of complex drying kinetics and improve decision-making in real time.

Another important direction in scientific research is the integration of Industrial Internet of Things (IIoT) technologies. By using distributed sensor networks, it becomes possible to continuously monitor physicochemical parameters and implement data-driven control strategies.

Studies also show that combining SCADA systems with machine learning algorithms significantly enhances process transparency and enables predictive maintenance, reducing downtime and operational costs in industrial drying systems.

Despite these advancements, challenges remain in developing universal models capable of accurately describing all stages of PVC drying under varying industrial conditions. Therefore, further research is required to improve model generalization and robustness.

CONCLUSION. The developed automation and intelligent control system for the PVC drying process demonstrates high efficiency in optimizing process parameters and improving the physicochemical quality of the material. By integrating machine learning-based predictive models with real-time sensor data, the system ensures adaptive and stable control of the drying process.

The results show significant improvements in energy efficiency, reduction of drying time, and enhancement of product uniformity. The proposed approach provides a reliable framework for modernizing industrial PVC processing systems.

Future research should focus on improving model accuracy, expanding real industrial testing, and integrating the system into fully digitalized Industry 4.0 environments.

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