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MODERN CHALLENGES IN POLYMER MATERIAL PRODUCTION BY EXTRUSION: TECHNOLOGICAL INNOVATIONS

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The production of polymer materials by extrusion is extremely important in the industry, as it enables the manufacturing of a wide range of products – from films and fibers to rigid structural materials. Despite being a well-developed method, modern market trends require its improvement due to the need for increasing production efficiency, reducing energy consumption, and ensuring environmental safety. Moreover, the demand for polymers with enhanced mechanical and physicochemical properties is growing, posing new challenges in the field of extrusion.

One of the key challenges is the uniform mixing of additives, particularly pigments and fillers, in the polymer melt. The presence of pigment agglomerations or the uneven distribution of fillers significantly affects the quality of the final product, causing issues with mechanical properties and appearance. Another serious issue is the viscosity of the polymer melt, which determines the extrusion process speed and the uniformity of material flow through the extrusion head. Improper rheology can lead to surface defects, loss of product strength, or even deformation of the extruder due to excessive pressure [1].

Another significant aspect is equipment wear, which becomes particularly pronounced when processing filled polymer blends or composites. The wear of the screw and the extruder walls leads to material losses, changes in process parameters, and increased maintenance frequency. Additionally, the high energy consumption required to maintain the melt temperature and perform mechanical processing of the material poses a challenge for manufacturers to improve energy

efficiency. All these factors drive the active development of new technological solutions aimed at optimizing the extrusion process.

Modern developments in the field of extrusion aim to overcome these challenges through the integration of advanced materials, physicochemical methods for improving the rheological properties of the melt, as well as the automation and digitalization of processes.

One of the most promising approaches is the use of ultrasonic and vibrational technologies, which improve component mixing, reduce melt viscosity, and enhance process efficiency. Ultrasonic treatment is applied directly during extrusion to improve the wetting of filler and pigment particle surfaces by the polymer melt. This results in better dispersion of components and, consequently, improved mechanical properties of the final product. Vibrational modules installed in the mixing sections of the extruder help reduce particle agglomeration of colorants and ensure their uniform distribution within the polymer matrix [2].

In addition, structural improvements in extruder design are being made. For example, modern equipment models are equipped with combined heating systems that ensure uniform temperature distribution along the entire length of the extrusion channel. This significantly reduces the likelihood of local overheating or incomplete melting of the material, which is a crucial factor in achieving process stability. Moreover, new types of wear-resistant coatings for screws are being developed, allowing for a significant extension of their service life [3].

Automation is another key direction in the development of modern extrusion production. The use of control systems based on artificial intelligence and adaptive algorithms enables real-time monitoring of process parameters, allowing for immediate responses to any deviations. The implementation of sensor-based monitoring systems makes it possible to precisely control temperature, screw rotation speed, pressure, and other parameters, ensuring the stability of the final product's quality.

Moreover, technologies are being developed to enable the automatic adjustment of extrusion parameters in response to changes in raw material composition. This is particularly relevant when using secondary raw materials or recycled polymers, which may have variable physicochemical properties. Such systems help prevent defects and minimize waste in the production process [4].

Modern technological innovations in extrusion manufacturing aim to boost efficiency, cut energy consumption, and enhance product quality. The adoption of ultrasonic and vibrational technologies, intelligent control systems, improved extruder designs, and new materials helps tackle key industry challenges. Further research opens new prospects for developing high-tech, energy-efficient extrusion processes.

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BENCHMARKING AS AN INSTRUMENT FOR ENERGY MONITORING RELIABILITY

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The vast majority of Ukrainian enterprises participate in energy efficiency programmes in order to improve their competitiveness, primarily by expanding production capacity, rather than by improving the energy efficiency of existing equipment by reducing non-productive losses [1]. Therefore, these programmes have little or no impact on the actual decarbonisation and the achievement of enterprises target annual energy consumption reduction [2].

The purpose of the research is to assess the feasibility and required regularity of energy monitoring, as well as to find ways to improve its reliability in order to reduce energy costs and actually reduce greenhouse gas emissions.

To achieve these goals, an energy audit of two supermarkets of similar format (with an area of 9991 m² and 8708 m²) located in Kyiv shopping centres was conducted, a comparative analysis of their power consumption was performed, and their energy efficiency was benchmarked [3]. Based on the results of the on-site surveys, it was found that the energy-consuming equipment in both supermarkets is almost identical and is used in similar regimes.

Taking into account the difference in the area of supermarkets, the comparison of power consumption was made not in absolute, but in specific values (per 1 m² of occupied space). As a result, it was determined that the power consumption of Supermarket 1 exceeds the power consumption of Supermarket 2 by 55%. This discrepancy is extremely large, even taking into account the small difference in equipment and operation patterns.

In order to determine the estimated electricity consumption of each supermarket, all the power equipment was documented, with an indication of its installed capacity, operating hours and usage modes. Thereafter, respective calculations were carried out. In addition, measurements of power consumption were conducted for main distribution panels (power, lighting, ventilation) and for the most energy-intensive consumers (compressors, ovens, stoves, proofing chambers) as well as their groups (fish and meat departments, cookery, bakery). As