ANNOTATION

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Improving the Granulation Process of Biofuel from Secondary Wood Resources and Plant Waste

The relevance of the work is driven by the need for efficient utilization of secondary and waste materials to address the challenges of modern industry and environmental safety. Granulation processes allow for the conversion of dispersed waste into a standardized product – fuel pellets (biofuel). Existing industrial granulation methods, primarily using ring- or flat-die granulators, are often inefficient when processing multicomponent polydisperse mixtures (MPM) derived from wood and plant waste. Key shortcomings include the production of pellets with a significant fraction of non-compacted particles and a lack of consideration for the rheological and structural-deformational characteristics of both the raw materials and the finished granules. Furthermore, data on the thermophysical properties of such composite solid fuels are scarce.

This dissertation aims to address these gaps through comprehensive theoretical and experimental research into the granulation process of fuel compositions. The primary objective is to develop a granulation technology using a rotary flat-die granulator for fuel compositions based on wood, plant, and industrial waste, taking into account their rheological and structural-deformational characteristics.

The research methodology is based on a combined analytical and experimental approach and the principles of mechanics of solid dispersed media, employing methods of multifactorial experimental design. Experimental methods included: determination of the rheological properties of MPM (plastic strength, flowability, lateral pressure ratio) using specialized equipment; determination of structural and deformation characteristics (density and strength of briquettes and granules produced in a closed-die mold and on a through-the-die extrusion press with thermal heating) with measurement of the lateral pressure coefficient using a strain gauge system; investigation of thermophysical properties (calorific value, ash content) and combustion characteristics using a calorimeter; pilot-scale testing of a MasCorp 230 granulator with evaluation of its productivity and energy consumption.

The work yielded significant scientific and practical results constituting its novelty. Based on the study of the roller's movement over the molded mass on the die surface, a mathematical description of the granulation process for multicomponent fuel systems (MFS) in a variable cross-section channel was proposed, and pressure distribution profiles along the channel length were obtained. A description of the granulation process of the molded mass during its forced injection by the roller into the channels of a perforated die was provided, accounting for the gap size between the roller and the die, as well as the rheological properties of the mixtures. Using methods of multifactorial experimental design, equations and nomograms were obtained for determining the density and strength of MFS briquettes as a function of moisture content and specific compaction pressure. The relationships describing the change in the rheological characteristics of MFS depending on moisture content and specific compaction pressure were established. For the first time, the thermophysical properties of MFS fuel pellets were determined; graphical relationships of the changes in calorific value and ash content of the fuel pellets versus the component ratios were obtained, and their combustion stages were described. A refined engineering methodology for calculating the main parameters of MFS granulation and energy consumption in a rotary granulator with a rotating flat die was proposed, taking into account the rheological properties of the mixtures, the ratio of the dimensions of the variable cross-section channels, and the thickness of the rolled layer.

The practical significance of the work is as follows: the complex technology for producing fuel pellets from MPM on a pilot-scale rotary granulator has been improved, suitable for use in low-power boilers, such as those on farms; data were obtained and graphical dependencies were plotted on a pilot-scale rotary granulator to determine its productivity and power consumption at varying contents of the mixture's main component; fuel pellets with increased thermal power were obtained by adding husks, brewers' spent grain, peat, pyrocarbon, and ammonium nitrate (as a combustion initiator) to sawdust; the improved pellet production technology was transferred for implementation to VIVA LLC (Kostroma region) for granulating crushed Jerusalem artichoke stalks; the developed calculation methodology is used in the educational process for master's students at Moscow Polytechnic University.

In conclusion, the dissertation provides a comprehensive solution to the problem of efficient granulation of secondary wood and plant resources into high-quality biofuel. The work makes a significant contribution to the field of chemical technology: it enhances the fundamental understanding of the stress state and mechanics of the granulation process in flat-die presses; provides critically needed data on the properties of composite biomass fuels; offers practical, scientifically grounded tools and methodologies for the design and optimization of industrial granulation processes, leading to increased efficiency, reduced energy consumption, and improved product quality. The research findings are supported by a substantial volume of experimental data, the use of certified measurement equipment, and the convergence of calculated results from the developed models with experimental data. The main findings have been presented at numerous national and international conferences and published in 13 works, including 6 papers in journals indexed by Scopus, Web of Science, and the Higher Attestation Commission (VAK) list.