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SUMMARY OF THE DOCTORAL DISSERTATION

The research carried out for the purposes of this study focuses on the development of a method for predicting the composition of the producer gas. The work deals with the problems of the constant increase in the prices of traditional fuels and the shortage of natural gas, which is the main source of energy for heat generation in the municipal energy sector.

The first chapter discusses biomass as an important energy resource that can replace a large number of traditional fuels used in municipal heating and energy systems. Poland has a sufficiently large dry combustible biomass potential to replace approximately 80% of the burnt natural gas for municipal heat supply. After analyzing the physico-chemical properties of biomass and various methods of using biomass energy, it was found that among all the methods of using its energy for the purposes of supplying municipal heat, gasification is the most optimal and universal. Then, an analysis of the varieties of gas generators was carried out and found that the gas generator with solid layer and downflow gas flow was the most optimal. It was also found that the actual gasification process can be as close as possible to the thermodynamic equilibrium state, which is taken into account in the Gibbs free energy minimization method, in order to meet certain gasification conditions. It was also indicated that the existing methods of studying the state of thermodynamic equilibrium have a large number of simplifications, significantly reducing the accuracy of modeling and requiring improvement.

The second chapter considers and analyzes various methods of mathematical modeling of the gasification process. As a result of the analysis, it was found that most of these methods do not allow for an accurate prediction of the composition of the producer gas under various conditions of biomass gasification. The model that takes into account the state of thermodynamic equilibrium was selected as the basis. The proposed changes to the thermodynamic model, increasing its accuracy, expand the possibilities of its application. The limiting conditions under which the model is considered are described. Comprehensive analysis of the modeling process made it possible to significantly reduce the list of limiting conditions by eliminating a number of constraints that significantly influenced the accuracy of the modeling process. The model was completed with empirical dependencies and mass and energy balance equations, which allow for the analysis of the efficiency of the gasification process under various gasification conditions, in order to increase the modeling accuracy. The Lagrange multipliers method is used for mathematical modeling of the thermodynamic equilibrium state in the gasification process, and an algorithm for solving the obtained system of equations was developed. The improved model of the gasification process made it possible to obtain, with high reliability, the main characteristics of the process and the composition of the producer gas, depending on a wide range of operating parameters of the installation and factors influencing the efficiency of the process.

The third chapter describes an experimental study of the biomass gasification process carried out in accordance with the methodology and using equipment that allows the assessment of individual effects of various gasification parameters on the process, and, consequently, the assessment of the gas composition and efficiency of the installation. The works were carried out in Stockholm. The biomass humidity (Wp), the process air excess coefficient (αbio) and the temperature in the reactor (Treact) were selected as influencing factors. The knowledge of the elemental composition of the raw material (pine sawdust) on which the research was carried out made it possible to conduct modelling and then experimentally verify the results of the experiment. During the research, the basic indicators of the gasifier's operation were measured, in particular biomass moisture, process temperature, mass and composition of the producer gas, weight and composition of tar, fuel and electricity consumption for the maintenance of the process. Processing the obtained data made it possible to create a mass and energy balance equation and to determine the influence of gasification parameters on the efficiency of the process. The study of the tar mass in the gasification process showed that it largely depends on the parameters of the process. The study of tar composition made it possible to determine the critical temperature of the producer gas at which the basic tar components condense. Using the experiment planning method and the gasification process model described in Chapter 2, a mathematical experiment and an analysis of the influence of the main gasification parameters on its efficiency were carried out. Based on the obtained data, a regression equation was developed to determine the efficiency of the gasification process depending on the biomass moisture, excess air ratio and process temperature.

The fourth chapter describes the research work on the experimental research installation, thanks to which further research on the gasification process was carried out. After conducting experimental tests in the pyrolysis laboratory of the Kielce University of Technology, the verifiability of the mathematical model was confirmed. After conducting experimental tests in the pyrolysis laboratory of the Kielce University of Technology, the verifiability of the mathematical model was confirmed. After analyzing the results of the research carried out in Stockholm and Kielce, it was found that carrying out the process at a higher temperature allows for higher yields of methane and hydrogen, and the low excess air coefficient reduces the amount of carbon dioxide obtained in favor of other, valuable gases, with the simultaneous verifiability of the mathematical model.

Chapter five summarizes the research and gathers conclusions from the thesis, it is stated that the collected data paves the way for further research on the methods of forecasting the composition of the producer gas and shows the energy potential in waste biomass without the need to process it in the oxidation process. Limiting the oxidation process is related to limiting the production of carbon dioxide, which is now a priority of the policy of European countries. Due to political and economic reasons, Poland faces particular challenges in terms of reducing CO2 emissions.

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