Politechnika Częstochowska

WYDZIAŁ INŻYNIERII PRODUKCJI I TECHNOLOGII MATERIAŁÓW
KATERDA ZARZĄDZANIA PRODUKCJĄ
POLITECHNIKA CZĘSTOCHOWSKA

Analiza możliwości zagospodarowania uciążliwych dla środowiska produktów termicznego przetwarzania odpadów kalorycznych do opalania hutniczych pieców grzewczych

Rozprawa doktorska

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Abstract of the doctoral thesis

The process of waste pyrolysis is a promising method of thermal conversion, which can be used in the steel industry to reduce the operating costs of the plant. In this doctoral dissertation, entitled "*Analysis of the possibilities of utilizing environmentally harmful products of thermal conversion of calorific waste for firing metallurgical heating furnaces*", the possibility of thermal conversion of various types of waste is examined, using its products for co-combustion with natural gas, in a metallurgical heating furnace. The work focuses on the analysis of the physicochemical properties of selected waste and on the selection of appropriate parameters of the pyrolysis process, so that the gas fraction yield is as high as possible. In my work, I focus on selecting the appropriate waste, which, when subjected to the pyrolysis process, will demonstrate the best technical properties (appropriate calorific value) and will be an alternative, possible to be used on a large scale, to reduce the dependence of the metallurgical industry on fossil fuels, the reserves of which will one day run out. The first part of the doctoral dissertation presents the motivation for the undertaken topic, the thesis and the utilitarian goal of the work, explaining why diversification of energy sources in the steel industry will contribute to the decarbonization of the steel industry and bring energy-intensive industries closer to the transition from a linear economy to a circular economy. Then I focus on the current methods of using pyrolysis gas. In the next part, I describe the directions of energy use from waste on the example of Poland and the possibilities of waste management and thermal conversion products in the steel industry, taking into account the need to decarbonize the steel industry.

The chapter on methodology describes in detail the applied research techniques and computer simulations, clearly showing what tests and simulations were performed at each stage of the research.

The main part of the work analyzes a number of wastes, namely: pine waste, alder waste, medical waste - protective mask, rubber waste - granulate from passenger car tires, furniture industry waste - MDF boards and RDF waste. Comparing the results of simulations and calculations of the calorific value of pyrolysis gases produced from the above-mentioned materials, RDF waste was selected for further research due to its high calorific value (20.5 MJ/m^3) of the obtained gas (below 35 MJ/m^3 – technological conditions of burners) and high availability throughout the country. In the further part of the work, pyrolysis gas from RDF was considered from the perspective of its co-combustion with natural gas in a metallurgical heating furnace. The

research on the waste was extended to a detailed technical analysis and analysis of the ash composition. In the next step, a pyrolysis experiment was carried out in the laboratory of the Faculty of Materials Engineering and Industrial Computer Science (Department of Thermal Technology and Environmental Protection) of the AGH University of Science and Technology in Krakow. Then, all products obtained during the pyrolysis process (solid, liquid and gaseous fractions) were collected and analyzed. The best results in gas fraction yield and the highest calorific value were obtained for the pyrolysis temperature of 800°C and the sample residence time of 3 min. The gas fraction yield reached over 46%, and the calorific value of the obtained gas was 22.5 MJ/m^3. The tested condensates were also characterized by a high calorific value of over 30 MJ/kg. Fourier transform infrared spectroscopy (FTIR) analysis of the obtained chars showed a lack of clear absorption band ranges in the solid fraction from pyrolysis at 800ºC, which indicates the degradation of most bonds during pyrolysis. The next part of the paper describes the concept of incorporating a pyrolysis reactor into the existing technological sequence of the pusher furnace in the thick plate department of one of the Polish steelworks. The description provides technical parameters of the installation. It was assumed that the pyrolysis reactor with a capacity of 1000 kg/h would produce over 50% of the input mass of natural gas together with the uncondensed liquid fraction (process temperature 900°C), which would be directed directly to the pusher furnace burners. The estimated value of the investment is EUR 5,300,000 of capital expenditure (CAPEX).

Then, using the Ansys Chemkin PRO (v. 2021 R1) computer program, computer simulations were performed, predicting the composition of exhaust gases generated after co-combustion of natural gas with pyrolysis gas. The analysis showed a similarity in the composition of exhaust gases. Co-combustion of both gases did not increase the share of undesirable compounds in the exhaust gases from co-combustion, compared to the exhaust gases from the combustion of pure natural gas.

For the above solution, an economic analysis was carried out using the net present value (NPV) method, which showed the profitability of the investment. The monthly savings that the steelworks will experience due to the reduced consumption of natural gas will amount to PLN 200 by 450 thousand euros per month, depending on the efficiency of the furnace. The analysis showed a return on investment within 3-4 years of its operation.

The dissertation ends with a summary of the most important conclusions and an indication of the potential economic and environmental benefits resulting from the implementation of the solution presented above.