Abstract

Low quality coals can be considered a by-product of coal mining. Because the economic attractiveness of such coals is limited, they are commonly dumped in stockpiles, which results in additional costs and the risk of endogenous fires. Flotoconcentrates are one of many waste materials associated with coal production. At the same time, problematic municipal wastes from a wide range of human activities represent an abundant fuel stream. However, the above waste streams can be considered as attractive carbon-containing materials; therefore, environmentally friendly and economically viable options for their utilization should be developed. In this study, selected coals, flotoconcentrates and RDF (Refuse Derived Fuel) alternative fuel were investigated for their reactivity in steam gasification process. The reactivity of low quality coals and flotoconcentrates at 50% carbon conversion R_{50}, varied between $1,46 \cdot 10^{-4}$ and $2,39 \cdot 10^{-4}$ 1/s , while the maximum reactivity, R_{max} changed from $3,28 \cdot 10^{-4}$ to $4,62 \cdot 10^{-4}$ 1/s. Advanced mathematical models were developed to study the similarities and differences between the fuels studied, as well as the relationships between the physicochemical parameters and reactivity of the fuels manageable by steam gasification. On this basis, low-quality coals were selected and then blended with $5\%_{w/w}$, $10\%_{w/w}$ and $20\%_{w/w}$ of the aforementioned RDF alternative fuel and subjected to experimental co-gasification. The study focused on the production of hydrogen-rich gas which is a clean, environmentally friendly energy carrier that can be used in power generation and transportation. The experiment resulted in the production of gas with hydrogen concentration ranging from $59\%_{vol.}$ to $68\%_{vol.}$

The first chapter characterizes the issues addressed in the research work, emphasizes the importance of coal in the process of electricity production in Poland, the importance of electricity generation technologies including carbon dioxide capture technologies and clean coal technologies. The problem of waste of anthropogenic origin was discussed together with the indication of effective fuel processing technologies, such as gasification and co-gasification technologies. The second chapter presents the scientific objective, which is to determine the parameters of the co-gasification process of selected low-energy coals, sludge and flotation concentrates and waste processed into alternative fuels (RDF), aimed at the production of hydrogen-rich gas. The chapter also presents the utilitarian objective, which is to demonstrate the feasibility of utilizing the aforementioned products in a steam co-gasification process. This objective is closely related to the economic aspect of the economic utilization of the products produced in mining companies along with the utilization of by-products accompanying the mining process. In the third chapter, fuels such as hard coal,

alternative fuels (RDF), hydrogen, which are important in the considered co-gasification process, are characterized. The chapter also discusses the issue of clean coal technologies in the whole coal processing process, the economic significance of coal in Poland and characterizes reactor-based gasification and co-gasification technologies. The third chapter includes the characteristics of syngas production technologies using low energy products, starting from the 1930s, when economically important coals were used, obtained without the currently used coal enrichment units in mechanical processing plants, to the current high efficiency gasification technologies of ConocoPhillips (E-Gas), SES technologies and Shell technologies, with particular emphasis on the use of waste. The fourth chapter contains a description of the methodology, the laboratory test bed of the fixed bed reactor and the test procedure used in this study with the characteristics of the test material. The chapter describes the physicochemical parameters of the test samples as well as their reactivity. The chapter presents the results of co-gasification of coals and flotoconcentrates of PGG S.A. in the process of co-gasification with steam with the participation of RDF. The chapter then proceeds to analyze the obtained results using MATLAB and MS Excel. The experimental results obtained are analyzed with the application of the hierarchical clustering method and discussed and the specific parameters of the gasification and steam co-gasification process are identified that allow the process to be directed to maximize hydrogen production with particular attention to the correlation of oxide composition in the production of hydrogen obtained in the synthesis gas. Chapter five presents a summary and conclusions of the research work carried out, with an indication of further research directions, the determination of an appropriate proportion of RDF, taking into account the correlation of oxide composition in the samples studied, in order to obtain the most favourable effect on hydrogen production when co-gasifying with low-quality fuel and flotoconcentrates. The possibility of using low-quality coals and RDF alternative fuels in the process of co-gasification with steam in a fixed bed reactor, aimed at the production of hydrogen-rich gas, has been demonstrated. It was found that the reactivity of low quality coals and flotoconcentrates at 50% coal conversion R_{50}, varied between $1,46 \cdot 10^{-4}$ and $2,39 \cdot 10^{-4}$ 1/s , while the maximum reactivity R_{max} changed from $3,28 \cdot 10^{-4}$ to $4,62 \cdot 10^{-4}$ 1/s. The addition of alternative fuels has been observed to increase hydrogen production, this is likely due to the composition of RDF such as plastics. The individual oxides in the coal fuel and in the alternative fuel exhibit significant catalytic properties, with particular emphasis on K_2O and Al_2O_3, as well as TiO_2 oxide supplied to the gasified fuel mixture in the form of added RDF.. It was observed that the highest hydrogen production yields were obtained with $5\%_{w/w}$ of RDF and at a gasification temperature of

900ºC. An increase in temperature decreases the concentration of carbon dioxide in the product gas. The achieved methane concentrations were very low, irrespective of the temperature in the reactor, which may indicate the disappearance of the hydrogen gasification and methanation reaction as a result of the catalytic effects of K_2O and Al_2O_3 and the TiO_2 supplied in the RDF fuel, contributing to an increase in hydrogen production, through more efficient processing of tar and soot.