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Title of the PhD dissertation

BIOMASS DERIVED SYNGAS CONDITIONING WITH THE USE OF MICROWAVE PLASMA

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Abstract

In the near future, biomass gasification may become an important technology in many fields considering energy production as well as in chemical and petrochemical industry. This technology has been gaining a great attention for almost 30 years. The reason for that is connected with a proceeding shortage of fossil fuels, biomass renewable character, and its zero-emission considering CO_2, but also due to the wide flexibility of the producer gas (syngas) considering its application. In fact, syngas may be used in power machines but also for the purpose of synthesis and hydrogen production.

Despite these advantages, biomass gasification commercialization is limited by many difficulties. One of the most important factors responsible for this situation is the presence of tars in the producer gas. Tars are unwanted by-products (hydrocarbons) that can be characterized by high viscosity and high condensation temperature. As a result, the presence of tars may cause serious installation failures. Consequently, many methods have developed to provide a reduction of tars concentration. One of the methods, which can result in a high conversion rate of tar compounds, involves plasma application.

Atmospheric microwave plasma seems to be essentially suitable for tars conversion since it provides high temperature and the presence of reactive particles, e.g. electrons and radicals. Both of these factors play a crucial role in the tars conversion process.

The main aim of this work was to determine the microwave plasma efficiency in tar compounds conversion and to investigate the influence of the main syngas compounds, i.e. CO, CO_2, CH_4, H_2O and N_2 on this process. Besides, the other important goals of this work included determination of the interactions between the main syngas compounds, identification of the products obtained due to plasma processing and characterization of the microwave plasma discharge in the presence of these compounds.

The thesis postulate that: "Microwave plasma application will enable achieving high conversion rate of tar compounds, while the crucial role in this process will be attributed to the high temperature of the plasma and the presence of radicals derived from the main syngas compounds".

The scope of the research included a wide range of experiments with the use of nitrogen plasma, plasma obtained in the artificial (simulated) syngas and plasma obtained in the presence of syngas derived from the sewage sludge gasification process. The research involved the determination of the tar compounds conversion rate depending on the gas composition and its flow rate, microwave power and the concentration and nature of converter compounds. A great attention was given to the quantitative and qualitative analyses of the post-process products, mainly, with the use of gas chromatography (GC) technics. Additionally, the scope of the research included diagnostic of the microwave plasma discharge with the use optical emission spectroscopy (OES).

The research carried out in the work proven, that depending on the process parameters, a high conversion rate of 98% can be achieved. Moreover, the tar compounds were converted into valuable products, i.e. light hydrocarbons, CO and H_2. Additionally, it was proven that the presence of O, OH and H radicals enhanced the conversion process. These radicals, derived from CO_2, H_2, and CO_2 included in the syngas, have been produced due to the high temperature of the plasma, but their production might have been additionally intensified by the excited species presented in the plasma. The high temperature of the plasma provided both the high population of radicals and intensification of tar compounds thermolysis and their interaction with radicals. While the addition of H_2O, CO_2, and H_2 resulted in an increase of the tar compounds conversion, the presence of CH_4 (and radicals derived from its decomposition) caused its decrease. Considering these information, the thesis postulate has been proven.

On the basis of obtained results, it can be stated, that the microwave plasma has a high potential in the conditioning of the producer gas. However, conducted research shown that the process is highly energy-consuming. Additionally, some other drawbacks have been indicated, like the production of unwanted nitrogen compounds. To solve these problems, a further research and the process optimization, which were pointed out in the work, are necessary. At the same time, the obtained results suggest, that the most profitable application of microwave plasma in tar conversion should be provided by matching this technology with production of syngas for the purpose of hydrogen production of hydrocarbon fuels synthesis. These processes require syngas with a high content of hydrogen, significantly low tars concentration and heat that is used during the process. All these factors can be provided by microwave plasma conditioning of producer gas and the costs of products obtained in these processes may justify the energy consumption of the plasma reactor.

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