Study on the catalytic hydrogasification reaction of carbonaceous materials into methane-rich stream in a fixed bed reactor

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Abstract

Carbonaceous materials, such as biomass and non-recyclable plastics, are currently an attractive resource to produce energy or green compounds, alternative to fossil fuels, such as syngas, biodiesel, bio-methane and others. Among the different treatments throughout these materials are converted, the catalytic hydrogasification, which involves biomass pyrolysis and char and volatiles hydrogasification, allows to store renewable energy, and obtain an energetic recovery without combustion. In this process hydrogen is used as gasifying agent, which can be produced with an electrified steam reforming or water electrolysis steps, limiting so the environmental impact. The gaseous stream produced is a methane-rich with a high energetic value product (synthetic natural gas), which can be used as a green alternative to natural gas.

High reactivity and conversion efficiency of char can be achieved under high hydrogen pressure and high reaction temperature conditions (850°C and 30 bar). However, owing to the exothermicity of the reaction forming methane the char-hydrogenation equilibrium is limited with reaction temperature rises. The catalytic approach could effectively promote the char reactivity and conversion efficiency under milder conditions as lower temperature and pressure, thus decreasing the hydrogasification costs.

In this work, the use of a suitable catalyst is analysed in order to increase the methane yield of biomass hydrogasification at mild conditions in a fixed bed reactor where the catalytic zone was thermally insulated from the biomass zone to prevent the biomass pyrolysis before the activation of catalyst. A comparison between a commercial pellets catalyst (Ni/alumina) used for the methanation of complex systems and a 40%Ni/CeO_2 powder catalyst, prepared in laboratory, was carried out to identify the best catalytic system in terms of CH_4 and TAR yields. The results showed that the commercial catalyst can achieve a maximum of 50 vol% of methane yield at 500°C using a catalyst:biomass ratio of 2/3 and 160 Ncm^3/min (95 vol%H_2 – 5 vol%Ar). In particular, the optimization of heating system has allowed simultaneously to reduce the content of organic compound in the liquid residue and to minimize the carbonaceous solid residue. Preliminary tests on the catalyst coke resistance have showed very promising results, in particular for the 40%Ni/CeO_2 sample, even if further studies focused on the catalyst formulation optimization in terms of activity and stability will be done evaluating the addition of promoter compounds such as calcium-based ones.