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Coupling of Steam Gasification of Biomass and Catalytic Plasma Tar Reforming Over Low-cost Catalyst for H2 Production

[1]Cui Quan, [1]Ningbo Gao, [2]Hakan Cay, [2]Gozde Duman, [3]Xin Tu and [2]Jale Yanik

[1]*International Joint Research Center for Solid Waste Recycling and Utilization, Energy and Power Engineering, Xi'an Jiaotong University, Xi'an, Shaanxi, 710049, China*
[2]*Department of Chemistry, Ege University, 35100, Izmir, Turkey*
[3]*Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3GJ, United Kingdom*

Abstract

Biomass gasification is considered as a viable pathway for syngas and hydrogen production which can be further transformed into chemical intermediates, industrial products and energy. The formation of tar in biomass gasification is one of the major challenges which limits development and commercialization of biomass gasification technology (Tao, M.et al., 2018). Formation of tar not only lead to serious maintenance failures, but also reduces gasification efficiency since tar consists of significant amounts of energy in the form of mixture of aromatic hydrocarbons. Various techniques for tar removal/decomposition have been attempted in the literature, including hot gas filtration, water scrubbing and catalytic cracking etc (Chai, Y. et al., 2020). Plasma assisted tar reforming is a novel approach to reduce tar content in gas products by converting tar into gaseous products (Liu, L. et al.,2019; Xu, R. et al., 2021). In this work, steam gasification of olive tree pruning was carried out by a hybrid two-stage reaction system to produce hydrogen. Thermal steam gasification of biomass took place at 850 ℃ by introduction steam (flow rate of 5 ml/h) from top of reactor. Tar containing gas products evolved at the first stage were subsequently passed through dielectric barrier discharge reactor (plasma power of 15 W) at two different temperatures (200 and 500 ℃) in the second-stage plasma reforming process. To enhance the tar reforming, red mud (RM), dolomite (CD) and their nickel doped forms (Ni-RM and Ni-CD, respectively) were used as low-cost catalysts in the plasma-catalytic reforming process. The results revealed that the highest H2 production (51.36 mmol/g) and selectivity (70.64%) was obtained with 7.5Ni-CD at reforming temperature of 500 ℃. It may be attributed to the catalytic activity of Ni and CO_2 adsorption of CD, which can also be confirmed from the lower CO_2 yield when using CD-based catalyst. In case of Ni-CD, increase the plasma reforming temperature from 200 to 500 ℃ enhanced the gasification efficiency, probably due to high catalytic activity of Ni at high temperatures. On contrast, reforming temperature has an adverse

effect in case of CD, resulting in slight decrease of H_2 yield (from 26.98 mmol/g to 22.53 mmol/g), implying that higher temperature may be detriment to the positive effect of plasma reforming. Although RM was used as an iron catalyst, less amount of gas products was obtained from gasification in presence of both RM and Ni-RM catalyst at a reforming temperature of 500 ℃. It was concluded that some minerals in the RM melt in the high temperature plasma environment, blocking the active sites of the catalyst and causing weak gasification activity. On the other hand, Ni addition into RM had almost no effect on both overall gas yield and H_2 production at a reforming temperature of 200 ℃. Moreover, the catalytic effect of RM and Ni-RM was considerably lower than CD based catalysts.

Keywords: Hydrogen; Catalytic steam gasification; Plasma

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