Performance of a Novel Steam Reforming Catalyst under Real Gasification Conditions for H_2-Rich Syngas Production

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The gasification of biogenic waste is a promising thermochemical route for the sustainable production of renewable energy carriers, including hydrogen, synthetic fuels, and platform chemicals. Its flexibility in feedstock and product composition makes it an attractive option within circular economy strategies. However, the formation of tar in the raw syngas remains a major challenge, severely limiting process efficiency, increasing operational costs, and compromising downstream applications such as fuel synthesis or high-temperature energy conversion systems.

This study investigates a novel nickel-based catalyst for catalytic tar reforming under severe gasification conditions, including the presence of sulfur species and high tar concentrations. This innovative catalyst exhibits remarkable performance in terms of activity, thermal stability, and resistance to sulfur poisoning. Previous experimental results showed complete conversion of model tar compounds (naphthalene and toluene) at temperatures as low as 650 °C, even in the presence of up to 100 ppm_v H_2S. These results significantly outperform those of benchmark commercial catalysts, which typically requiring temperatures above 800 °C to achieve comparable conversion levels. The enhanced catalytic activity is attributed to a 3-4 fold higher BET surface area compared to commercial seam reforming catalyst and improved NiO dispersion, resulting in more accessible active sites. To validate the catalyst under realistic operating conditions, a series of experimental tests were performed using a laboratory-scale bubbling fluidized bed gasifier. A ceramic filter candle was installed in the freeboard of the reactor and filled with the catalyst during testing. This configuration enables simultaneous gas filtration and in-situ catalytic tar reforming. Tests were carried out at three different temperatures and in both empty and catalyst-loaded candle configurations. Long-duration experiments (3–4 hours) were conducted to assess the catalyst's operational stability and resistance to deactivation. A dedicated tar sampling system, based on impingers filled with 2-propanol and followed by HPLC analysis, was used to quantify and characterize the tar content. Syngas composition (H_2, CO, CO_2, CH_4) was monitored in real-time via online gas analysers. This research provides new insights into low-temperature catalytic tar reforming, opening the way for more efficient, sulfur-tolerant, and economically viable gasification systems for waste-to-X applications, including plastic-rich feedstocks and sorption-enhanced gasification processes.

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