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Sustainable Hydrogen Generation via Gasification of Pig Hair Biowaste with NiO/Al_2O_3 Catalysts

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Abstract : Over one thousand tons of pig hair biowaste (PHB) are produced yearly in Taiwan. The improper disposal of PHB can have a negative impact on the environment, consequently contributing to the spread of diseases. The treatment of PHB has become a major environmental and economic challenge. Innovative treatments must be developed because of the heavy metal and sulfur content of PHB. Like most organic materials, PHB is composed of many organic volatiles that contain large amounts of hydrogen. Hydrogen gas can be effectively produced by the catalytic gasification of PHB using a laboratory-scale fixed-bed gasifier, employing 15 wt% NiO/Al_2O_3 catalyst at 753–913 K. The derived kinetic parameters were obtained and refined using simulation calculations. FE–SEM microphotograph showed that NiO/Al_2O_3 catalyst particles are Spherical or irregularly shaped with diameters of 10–20 nm. HR–TEM represented that the fresh Ni particles were evenly dispersed and uniform in the microstructure of Al_2O_3 support. The sizes of the NiO nanoparticles were vital in determining catalyst activity. As displayed in the pre-edge XANES spectra of the NiO/Al_2O_3 catalysts, it exhibited a non-intensive absorbance nature for the 1s to 3d transition, which is prohibited by the selection rule for an ideal octahedral symmetry. Similarly, the populace of Ni(II) and Ni(0) onto Al_2O_3 supports are proportional to the strength of the 1s to 4pxy transition, respectively. The weak shoulder at 8329–8334 eV and a strong character at 8345–8353 eV were ascribed to the 1s to 4pxy shift, which suggested the presence of NiO types onto Al_2O_3 support in PHB catalytic gasification. As determined by the XANES analyses, Ni(II)→Ni(0) reduction was mostly observed. The oxidation of PHB onto the NiO/Al_2O_3 surface may have resulted in Ni(0) and the formation of tar during the gasification process. The EXAFS spectra revealed that the Ni atoms with Ni–Ni/Ni–O bonds were found. The Ni–O bonding proved that the produced syngas were unable to reduce NiO to Ni(0) completely. The weakness of the Ni–Ni bonds may have been caused by the highly dispersed Ni in the Al_2O_3 support. The central Ni atoms have Ni–O (2.01 Å) and Ni–Ni (2.34 Å) bond distances in the fresh NiO/Al_2O_3 catalyst. The PHB was converted into hydrogen-rich syngas (CO + H_2, >89.8% dry basis). When PHB (250 kg h−1) was catalytically gasified at 753–913 K, syngas was produced at approximately 5.45 × 105 kcal h−1 of heat recovery with 76.5%–83.5% cold gas efficiency. The simulation of the pilot-scale PHB catalytic gasification demonstrated that the system could provide hydrogen (purity > 99.99%) and generate electricity for an internal combustion engine of 100 kW and a proton exchange membrane fuel cell (PEMFC) of 175 kW. A projected payback for a PHB catalytic gasification plant with a capacity of 10- or 20-TPD (ton per day) was around 3.2 or 2.5 years, respectively.

Keywords : pig hair biowaste, catalytic gasification, hydrogen production, PEMFC, resource recovery
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