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Optimization of Biogas Steam Reforming Toward Low Carbon Hydrogen Production Using Integrated Artificial Neural Network and Genetic Algorithm

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ABSTRACT

Hydrogen has been identified as a versatile energy carrier, offering a viable route to decarbonize and meet escalating global energy demands. Biogas produced from the anaerobic digestion of organic matter can potentially serve as a feedstock for hydrogen production using steam reforming process. This research investigates the optimization of a steam reforming process utilizing biogas feedstock for low-carbon hydrogen production using Artificial Neural Network (ANN) integrated with Genetic Algorithm (GA). An equilibrium based steady-state simulation of the process was developed using Aspen HYSYS to generate data for neural network training, validation and testing. Key process parameters considered for optimization include: biogas flow rate, steam flow rate, reformer temperature and reformer pressure with hydrogen mole fraction at reformer outlet as the response variable. A two-layer feedforward neural network with 4-12-1 architecture was trained on simulation data, achieving a correlation coefficient (R-value) of 0.99. This ANN model was integrated within the fitness function of GA to iteratively optimize process parameters subject to a steam-to-carbon ratio constraint ≥ 2.5 to maximize hydrogen mole fraction while reducing the risk of catalyst deactivation via coking. The optimal parameters identified were 63 kg/h biogas flow rate, 62.04 kg/h steam flow rate, 1000°C reformer temperature, and 12.34 bar reformer pressure corresponding to a maximum hydrogen mole fraction of 0.5536 at the reformer outlet as predicted by the ANN model. Validation of these optimal parameters against the Aspen HYSYS model showed a relative error of 2.67% and 98.53% hydrogen yield at the reformer outlet. The proposed hybrid ANN-GA framework provides a robust, systematic approach for determining optimal operating conditions that enhance yield while maintaining operational reliability and efficiency.