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C2Po1D-06: Design and Optimization of Efficient Catalyst-filled Spiral Wound Heat Exchangers for Large-Scale Hydrogen Liquefaction Systems

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It seems to have become a consensus that spiral wound heat exchangers are more suitable for large-scale cryogenic liquefaction processes than plate-fin heat exchangers, based on the mature experience of LNG industry. In the hydrogen liquefaction systems, the most advanced continuous catalytic technology integrates the exothermic conversion process of orthohydrogen to parahydrogen within the heat exchanger unit. It is necessary to explore the design criteria of spiral wound heat exchangers for hydrogen liquefaction considering this distinct characteristic. This study establishes a comprehensive model, which couples the first-order reaction kinetics for ortho-para hydrogen conversion and the energy balance model for the flow and heat transfer of hydrogen in the spiral wound two-fluid heat exchanger. The performance of the component is evaluated from the fields of catalysis, flow, heat transfer, and economics. The variations in effectiveness with the design parameters of the heat exchanger in different temperature ranges, including 80-65 K, 65-50 K, 50-40 K, and 40-30 K, are determined. Furthermore, a Genetic algorithm is used for optimization, and the effects of optimization indicators such as minimum weight, pressure drop constraints, and cost on the design are analyzed. This paper aims to provide theoretical data and model references for the design of efficient spiral wound heat exchangers for hydrogen liquefaction, and to lay the foundation for the progressive large-scale development of hydrogen liquefaction plants.

Keywords: Hydrogen liquefaction; Spiral wound heat exchanger; First-order reaction kinetics; Energy and economic analysis; Genetic algorithm

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