전남대학교 일반대학원 기계공학과

2022년 2월 졸업예정자
기계공학과 박사 학위청구논문 공개발표

- 일시: 2021년 11월 19일 PM 2:00
- 장소: 공과대학 1A-218호

Design and Analysis of a Hybrid Sulfur Thermochemical Water-Splitting Cycle for Hydrogen Production

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Abstract

This doctoral dissertation presents a novel design and thermodynamic analysis of a hybrid sulfur (HyS) thermochemical water-splitting (TWS) cycle integrated with a hybrid power system of solid oxide fuel cell (SOFC) and gas turbine (GT) for cogeneration 1 kmol s−1 of hydrogen gas and electric power. Firstly, a fundamental study of heterogeneous catalytic reactions is presented to elucidate the intricacy of the physicochemical phenomena. Therefore, general dynamic modeling was developed regarding a microkinetics reaction mechanism occurring on a washcoat catalyst of monolith reactors, which is incorporated in heat- and mass-transfer submodels based on the quasi-2D analysis of both gas- and solid-phases. Secondly, it is evaluated the feasibility of the integration of a set of bayonet-type sulfuric acid decomposers for sulfur-based thermochemical hydrogen production with a 1 MW tubular-type SOFC stack through thermodynamic modeling. It includes the assessment of the efficiency of the combined system in a low-pressure range through the use of polarization and efficiency curves and the pinch analysis, as well as the selection of a suitable catalyst to meet the SO_2 production requirements as closely as possible of the equilibrium reaction. Thirdly, based on the previous study, the HyS flowsheet is developed in combination with the hybrid system SOFC/GT to meet the high-temperature heat and electric power requirements of the HyS cycle, as well as to produce hydrogen and electric power in excess. Therefore, descriptions of all sections of the combined system, energy requirement determination, and overall thermal efficiency calculation are presented. As a result, the net electric efficiency of the hybrid power system SOFC/GT is 38.83% based on LHV. On the other hand, the consumption of high-temperature heat of 338.48 kJ $molH_2^{-1}$ at 1143 K and 1.25 bar, 148.77 kJ $molH_2^{-1}$ at 1 bar and a low-temperature range, and 134.35 kJ $molH_2^{-1}$ of electric power resulted in an LHV efficiency of the HyS cycle of 29.04%.

[사용언어: 영어]