DESIGN AND TECHNO-ECONOMIC ANALYSIS OF LIGHT INTEGRATED GASIFICATION FUEL CELL

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論　文　内　容　の　要　旨

Coal is one of the world's major primary energy resources and its use is associated with a large amount of carbon dioxide emission, causing the global warming. Therefore, it is important to efficiently use coal, and much research and development efforts are devoted for coal gasification power plant technologies targeting high electrical conversion efficiencies. As an ultimately high efficiency system, integrated gasification fuel cell (IGFC) systems are targeted. Because the major components of syngas produced from coal gasification include hydrogen and carbon monoxide, solid oxide fuel cells (SOFCs) that can directly use them as fuel are considered for the use in IGFC systems. Typical configurations adopted for IGFC will require pressurized and high temperature operations of SOFC for better efficiency of bottoming gas turbine and the subsequent steam turbine cycles. Such configuration poses the issues of system complexity and the SOFC durability under severe operation conditions.

In this study, research is conducted with the objective of designing IGFC system with simpler configuration and SOFC operating under moderate conditions. A plant consisting of coal gasifier, dry gas cleanup, and SOFC on the top of a steam turbine, called light IGFC (L-IGFC), is proposed. The system is investigated by using Aspen Plus™ software to evaluate the thermodynamic efficiency. Also, the economic efficiency of the system is evaluated on the basis of levelized cost of electricity (LCOE).

This thesis consists of five chapters, which can be summarized as follows.

In chapter 1, the clean coal technology development status was introduced firstly followed by describing the importance of SOFCs as power generation and their possibility to be integrated with coal gasification power plant technology. Furthermore, the status and the recent progresses on IGFC found in literature was holistically summarized in order to clarify the motivations of the present study. Finally, the objectives of this study are described.

In chapter 2, the proposed power plant integrating a coal gasifier with SOFC and the balance of plants were introduced. The general theory and modeling techniques for the proposed system were described by introducing the Aspen Plus™ simulation at the beginning, followed by the modeling processes for each component of the plant.

In chapter 3, the verification of the simulation results for coal gasifier and SOFC against those in published research was first conducted to find good agreements between them. The atmospheric L-IGFC Plant with wet gas cleanup (WGC) was analyzed as a first step to design highly-efficient L-IGFC. The system efficiency achieved by adopting WGC is 39% LHV. Such efficiency was affected by high energy consumption during WGC operation and significant waste of thermal energy due to working condition requirement of WGC unit. Alternative design for L-IGFC was proposed on the basis of the increased operation temperature of gas cleanup process adopting dry gas cleanup (DGC) method. The system configuration leads to 6.8% improvement in system efficiency by avoiding the low temperature operation necessary for WGC process. Another option to increase the efficiency of the plant is to increase the working pressure of SOFC, which was fond to lead to the maximum system efficiency of 50% LHV achieved when SOFC operates at 4 atm. Furthermore, the system efficiency was increased up to 60% LHV when equipped with a unit of coal dryer into L-IGFC plant by the use of separated nitrogen and exhaust heat.

In chapter 4, the economic analysis was carried out in terms of LCOE. L-IGFC plant is compared with other coal thermal power generation systems such as supercritical pulverized coal, integrated gasification combined cycle, and other types of IGFC in literature. The LCOE of L-IGFC was comparable to that of SCPC and smaller than those of IGCC and IGFC plants.

In chapter 5, the conclusions and future perspective are presented.