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Macroscopic structural behavior on the small-scale PHE prototype under high-temperature test condition

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Abstract

PHE (Process Heat Exchanger) is a key component to transfer the high temperature heat generated from a VHTR (Very High Temperature Reactor) to the chemical reaction for massive production of hydrogen. Korea Atomic Energy Research Institute established a small-scale gas loop for the performance test of VHTR components and manufactured a PHE prototype in order to test in the small-scale gas loop. In this study, in order to investigate the macroscopic structural characteristics and behaviour of the PHE prototype under the test condition of the small-scale gas loop, we carried out high-temperature structural analysis modelling, thermal analysis, and an elastic/elastic-plastic structural analysis for the PHE prototype under the loop test conditions as a precedent study prior to the performance test in the small-scale gas loop. The results obtained in this study will be compared with the performance test results in the near future.

*Keywords:*Process heat exchanger, High-temperature structural analysis, Very high temperature reactor,

1. Introduction

Hydrogen is considered a promising future energy solution because it is clean, abundant and storable and has a high energy density. One of the major challenges in establishing a hydrogen economy is how to produce massive quantities of hydrogen in a clean, safe, and economical way. Among the various hydrogen production methods, hydrogen production using the high temperature heat from nuclear energy has been the focus of recent research [1]. Researches demonstrating the massive production of hydrogen using a VHTR

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(Very High Temperature Reactor) designed for operation up to 950℃ have been actively carried out worldwide, including in the USA, Japan, France, and the Republic of Korea (ROK) [1,2,3].

The nuclear hydrogen program in the ROK is strongly considered to produce hydrogen through Sulfur-Iodine (SI) water-split hydrogen production processes. An intermediate loop that transports the nuclear heat to the hydrogen production process is necessitated for the nuclear hydrogen program as shown in Fig. 1. In the intermediate loop, whereas the HGD (Hot Gas Duct) provides a route of high temperature gas from the nuclear reactor to the IHX (Intermediate Heat Exchanger), the PHE (Process Heat Exchanger) is a component that utilizes the nuclear heat from the nuclear reactor to provide hydrogen. PHE is used in various processes such as nuclear steam reformation, nuclear methanol, nuclear steel, nuclear oil refinery, and nuclear steam [1, 4]. The PHE of the SO_3 decomposer, which generates processed gases, such as H_2O, O_2, SO_2, and SO_3 at very high temperatures is a key component in the nuclear hydrogen program in ROK [5, 6].

Recently, KAERI (Korea Atomic Energy Research Institute) established a small-scale gas loop for the performance test of VHTR components and also manufactured a PHE prototype in order to be tested under the small-scale gas loop conditions. In this study, in order to investigate the macroscopic structural characteristics and behavior of the PHE prototype under the test conditions of the small-scale gas loop, FE (finite element) modeling, thermal analysis, and elastic/elastic-plastic structural analysis on the PHE prototype are carried out.

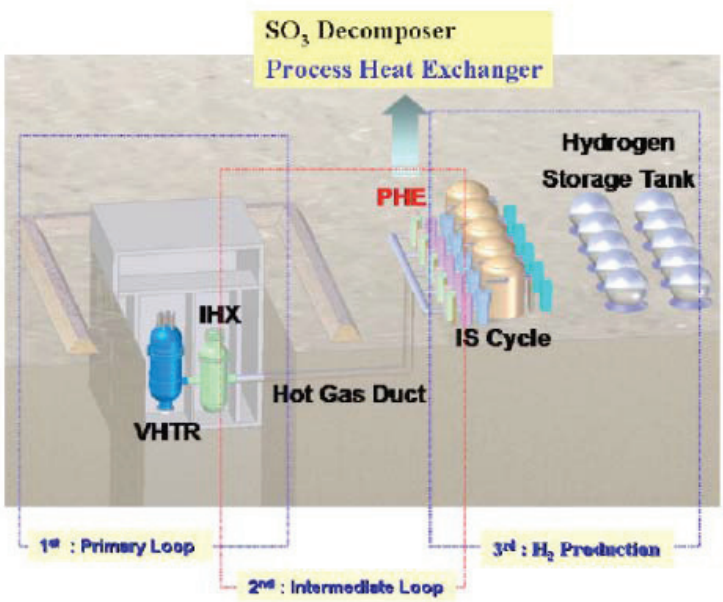

Fig. 1 Nuclear hydrogen system

2. FE modeling

2.1. Structure of a PHE prototype

A schematic view of the inside of the PHE prototype is illustrated in Fig. 2. The PHE prototype is designed as a hybrid concept [7] to meet the design pressure requirements between a nuclear system and hydrogen