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High-temperature structural analysis modeling on the small-scale PCHE prototype

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1. Introduction

Recently, a nuclear hydrogen production is gathering worldwide attention since it can produce hydrogen, a promising energy carrier, without an environment burden. The nuclear hydrogen program in Republic of Korea (ROK) is strongly considered to produce hydrogen by Sulfur-Iodine water-split hydrogen production processes [1,2]. 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, the IHX (Intermediate Heat Exchanger) of VHTR (Very High Temperature Reactor) transfers the high heat of 950℃ generated from the VHTR to a hydrogen production plant through a Hot Gas Duct. A PCHE (Printed Circuit Heat Exchanger) is considered as a candidate of the IHX of the nuclear hydrogen system in ROK.

Recently, KAERI (Korea Atomic Energy Research Institute) established the small-scale gas loop for the performance test of VHTR components as shown in Fig. 2 and manufactured a small-scale prototype of PCHE in order to be tested in the gas loop.

In this study, in order to investigate the macroscopic structural characteristics and behavior of the PCHE prototype under the test condition of the gas loop, FE (finite element) modeling, thermal analysis, and structural analysis on the PCHE prototype are conducted.

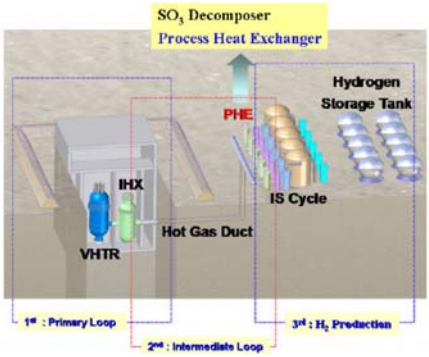

Fig. 1 Nuclear Hydrogen System

2. FE modeling

Figure 3 shows each part of the PCHE prototype from the 3-D CAD modeling. Based on Fig. 3, FE modeling using I-DEAS/TMG Ver. 6.1 [3] is carried out as shown in Fig. 4 and analysis such as thermal analysis and thermal expansion/structural analysis are carried out using ABAQUS Ver. 6.8 [4].

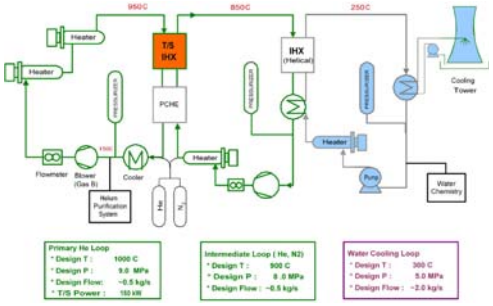

Fig. 2 KAERI's small-scale gas loop

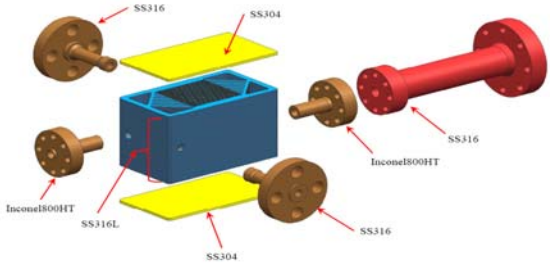

Fig. 3 Parts of a PCHE prototype

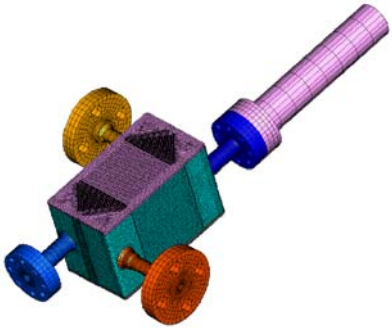
Fig. 4 FE model of small-scale PCHE prototype

3. Analysis

Thermal analysis

Figure 5 shows the thermal analysis results of the PCHE prototype outside under the test condition of the gas loop [5]. According to Fig. 4, the maximum temperature of the outside represents about 620℃.

High temperature structural analysis

Figure 6 represents the overall stress distribution at the pressure boundary of the PCHE prototype and Fig. 7 shows the stress distribution on the top plate under test temperature condition. High stress occurred near the high temperature inlet chamber on the top/bottom plate of the PCHE prototype, and maximum local stress of stress is about 689.7 MPa. Figure 8 represents the overall stress distribution at the pressure boundary of the PCHE prototype under test pressure condition.

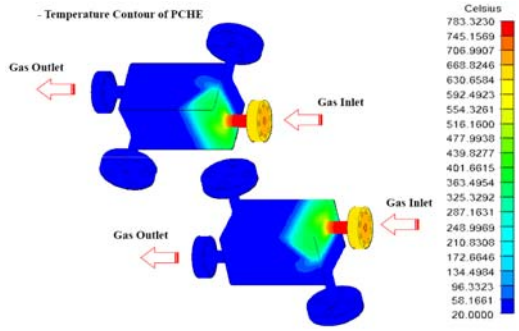

Fig. 5 Temperature contour of PCHE outside

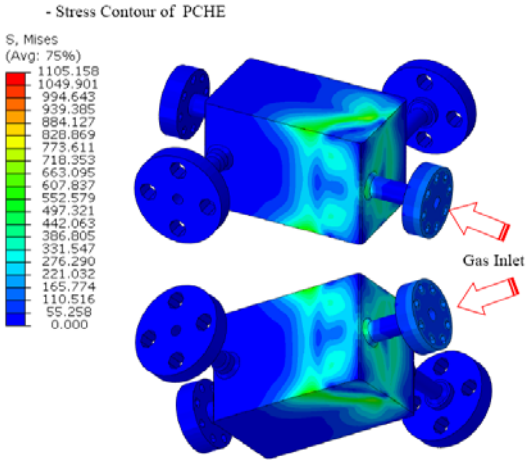

Fig. 6 Stress contour under test temperature condition

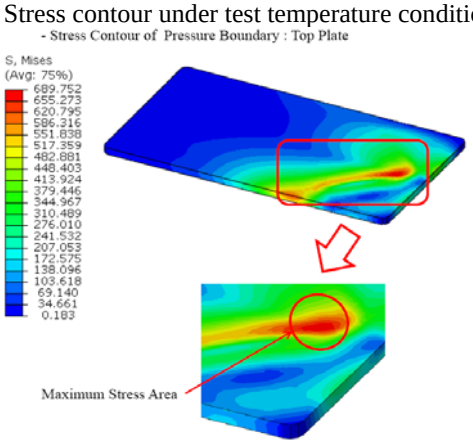

Fig. 7 Stress contour on the top plate

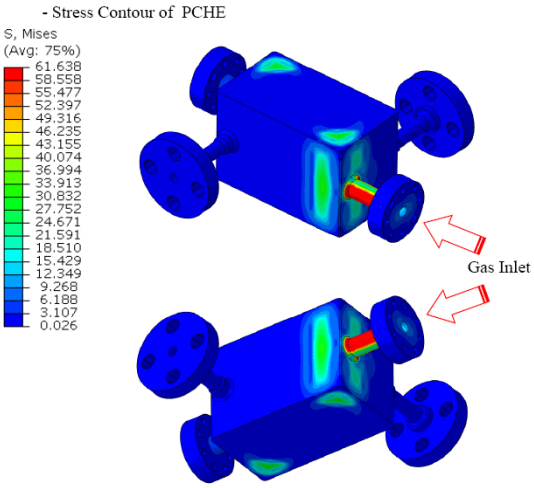

Fig. 7 Stress contour under test pressure condition

4. Conclusion

In the effort to determine the high-temperature structural integrity of the PCHE prototype prior to the actual performance test, FE modeling, thermal/high-temperature structural analysis are carried out on the PCHE prototype under the test condition of the small-scale gas loop established at KAERI. As a result of the analysis, we draw the following conclusions.

1. Under the test temperature condition, the maximum stress at the pressure boundary of the PCHE prototype is about 689.7 MPa. Thus, some measure to strengthen the structural integrity of the PHE prototype should be found out.
2. The temperature condition is a far more effective condition to the structural integrity of the PCHE prototype than the pressure condition. So, thermal expansion is very important for the structural integrity evaluation of the PCHE prototype in the gas loop.

Acknowledgements

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