# High-temperature structural modeling on the PHE prototype for KAERI's helium gas loop

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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 (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) provide a route of a 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 the various processes such as nuclear steam reforming, nuclear methanol, nuclear steel, nuclear oil refinery, and nuclear steam [1]. PHE of the SO3 decomposer which generates process gas, such as $H_2O$, $O_2$, $SO_2$, and $SO_3$ at very high temperature is a key component in the nuclear hydrogen program in ROK [2, 3].

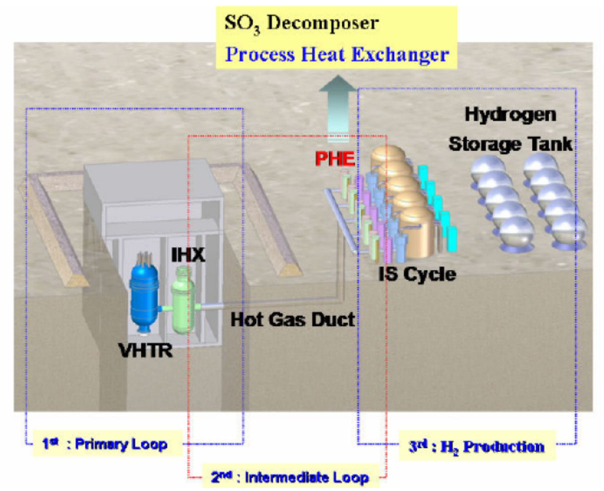


Fig. 1 Nuclear Hydrogen System

Recently, KAERI (Korea Atomic Energy Research Institute) established the helium gas loop for the performance test of VHTR components as shown in Fig. 2 and a PHE prototype by diffusion bonding process was manufactured in order to be tested in the helium gas loop. In this study, in order to investigate the macroscopic structural characteristics and behavior of the PHE prototype under the fixed test condition of the helium gas loop, FE (finite element) modeling, thermal analysis, and structural analysis on the PHE prototype are carried out.

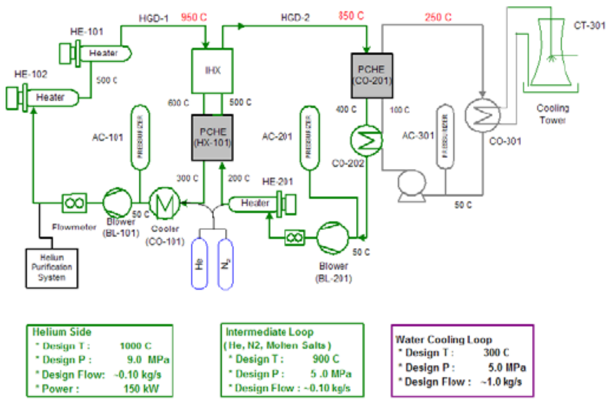


Fig. 2 KAERI's Helium gas loop

## 2. FE modeling

Figure 3 shows each part of the PHE prototype from the 3-D CAD modeling. Based on Fig. 3, FE modeling using I-DEAS/TMG Ver. 6.1 [4] is carried out and analysis such as thermal analysis and thermal expansion/structural analysis are carried out using ABAQUS Ver. 6.8 [5].

## 3. Analysis

*Thermal analysis*

Figure 4 shows the thermal analysis results of the PHE prototype outside under the fixed test condition of the helium gas loop [6]. According to Fig. 4, the temperature distribution is nearly symmetrical along the vertical axis and maximum temperature of the outside represents about 886.9℃.

*High temperature structural analysis*

Figure 5 represents the stress distribution under temperature/pressure condition at the pressure boundary of the PHE prototype. The maximum local stress of 1,069.7 MPa near the connection between the secondary in-flow pipeline and PHE, and maximum stress along the thickness through stress linearization is about 991.9, in that far more exceeds the yield stress of the material (291 MPa at 500℃) [7].

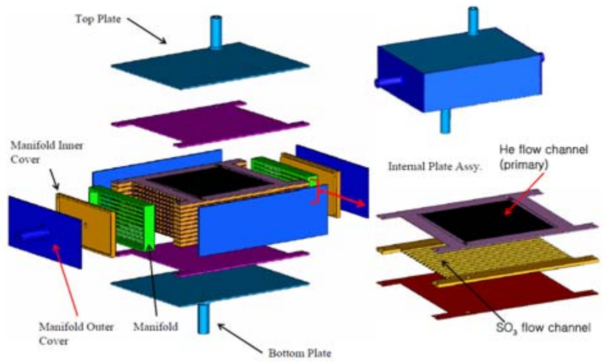


Fig. 3 Parts of a Process Heat Exchanger Prototype

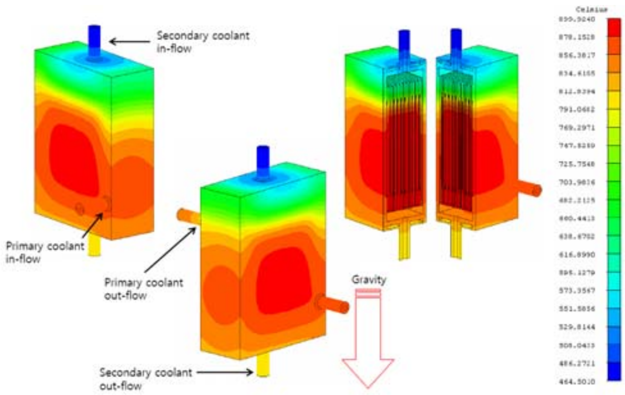


Fig. 4 Temperature distribution of PHE outside

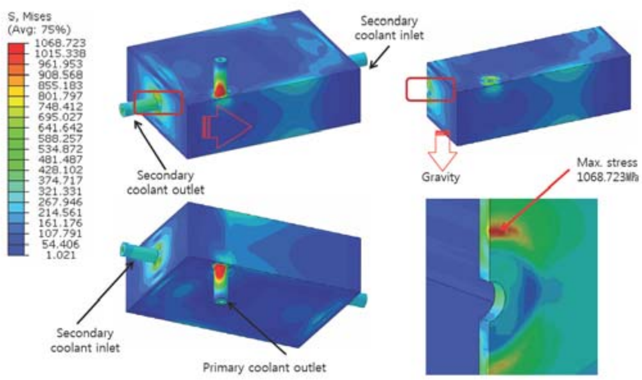


Fig. 5 Structural analysis results under temperature and pressure condition

Figure 6 represents the stress distribution under pressure condition at the pressure boundary of the PHE prototype. The maximum local stress of 9.65MPa near the connection between the secondary in-flow pipeline and PHE, and maximum stress along the thickness through stress linearization is about 0.67MPa, in that sufficiently is below the yield stress of the material (291MPa at 500℃).

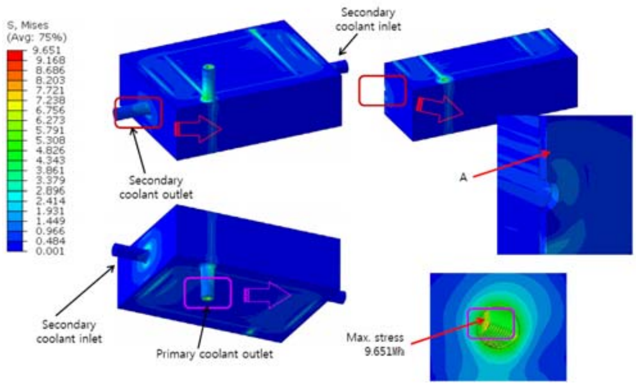


Fig. 6 Structural analysis results under pressure condition

## 4. Conclusion

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

1. Under the temp./pressure condition, the maximum stress at the pressure boundary of the PHE prototype is much higher than the yield stress of Hastelloy-X. 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 PHE prototype than the pressure condition. So, thermal expansion is very important for the structural integrity evaluation of the PHE prototype in the helium gas loop.

## Acknowledgements

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