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Preliminary Calculation on the Conceptual design of PCSG system for the i-SMART plant using MELCOR1.8.6

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1. Introduction

The objectives of this study is to evaluate the possibility and capability for simulating the PCSG (Printed Circuit Steam Generator) system in i-SMART plant, which is developing by KAERI, using MELCOR. The MELCOR code, which was developed by SNL, has been applied successfully to simulate the severe accident for the PWR, BWR and GCR. Also It has been applied to simulate the severe accident related experiments.

The i-SMART plant, which is under development by KAERI, has an option to use the special steam generator, so called, PCSG system. In the PCSG system, flow paths for the primary and the secondary were formed by etching over the surface of aluminum base plates. The each plate for the primary and the secondary become to consist of one pair in total. The PCSG system has 32 blocks. The one block includes around 105 pairs. The hot coolant water coming from the core region flows through the etched circuit over the primary base plate.

Also the cold coolant water coming from the feed water pump flows through the circuit over the secondary base plate simultaneously. A massive heat transfer occurs through the base plates from the primary to the secondary. Finally, hot steam discharges at the exit of the secondary channel. All these produced steam discharge through one channel and exit to the turbine.

The main interest is not to see the detail behaviors within the PCSG system but is in predict the thermal hydraulic parameters such as the amount of heat removal, flow rates, the degree of pressure drop and the amount of steaming through the PCSG system with a lumped manner.

2. Methods and Results

2.1 Modeling of i-SMART plant for MELCOR

Two problems exist in applying the MELCOR code to simulate the PCSG system. The first problem is that there are no available input data in MELCOR to simulate the type of geometry as like a PCSG system. For example, the only geometrical types that can be simulated by MELCOR are a slab, a cylindrical pipe or a hemisphere [1]. The geometrical form of the PCSG system does not belong to any one above mentioned available geometrical types in MELCOR. The second problems is that the heat transfer coefficients (boiling curve data) for simulating the thermal-hydraulic behaviors through the micro channels under the various flow conditions does not available in MELCOR.

In spite of these difficulties, the main reason for simulating the PCSG system using MELCOR is because the estimation on the severe accident sequences for the i-SMART plant should be evaluated under the condition of connecting all the systems in the i-SMART plant including the PCSG. Therefore, for the time being, the current embedded MELCOR models as default concerning the geometries and the heat transfers will be used to simulate the thermal-hydraulic behaviors of the PCSG system without any modifications. But to simulate the PCSG system, it needs some assumptions to make the PCSG system be properly simulated by MELCOR. These assumptions are as follows.

It is assumed that the base plate is a cylindrical wall form and this cylindrical wall is a mixed wall of these base plate for the primary and the secondary. The inside space of this mixed wall is assumed as a secondary channel and the outside space of this mixed wall is assumed as a primary channel, respectively. Also, it is assumed that the outer-most boundary of the primary channel was insulated. Figure 1 shows the conceptual input modeling for simulating the PCSG system with MELCOR.

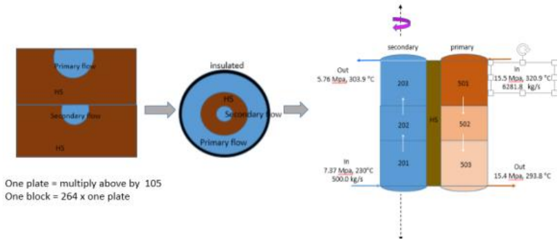

Fig 1. Conceptual Modeling of PCSG system in i-SMART plant

2.2 Calculation Results on important parameters for the PCSG system in i-SMART plant

- Primary fluid temperature

For the primary fluid temperature, Figure 2 shows that the fluid temperature goes down along the channel as the heat of primary side transfers to the secondary side through the mixed wall. The entrance temperature of the primary side was predicted as 319 ºC, which was similar to the design value of 320.9 ºC. The degree of the temperature decrease was predicted only as 8 ºC, which was much under-predicted value compared to the preliminary design data of 27.1 ºC. It seems that this under-prediction occurs due to the modeling based on the assumption that the both primary and secondary base plate are mixed together.

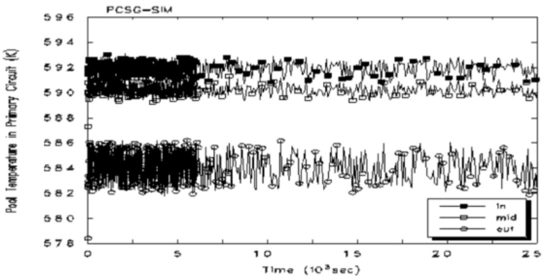

Fig 2. Primary fluid temperature

- Secondary Pressure

According to the preliminary design data, it is predicted that the secondary pressure may have a value between 57.6 bar at the inlet and 73.7 bar at the outlet of the secondary channel. This calculation shows that the predicted secondary pressure oscillates from 57.5 bar in minimum up to 66 bar in maximum. This oscillation means that the modeling based on the assumption of mixed wall could not simulate the heat transfer between primary and the secondary through the mixed wall.

- Secondary fluid temperature

From the preliminary design data, the entering fluid temperature at the inlet of the secondary side keeps constant as 230 ºC and the complete phase change occurs at the outlet. The discharging steam at outlet was designed to keep constant temperature of 303.9 ºC.

But the calculation results from Figure 3 shows that the fluid temperature at the secondary side oscillates the state between the subcooled and the super-heat. It was predicted that the inside surface temperature of mixed wall, which are in contact with the secondary channel, was more higher than the saturation temperature of the secondary channel

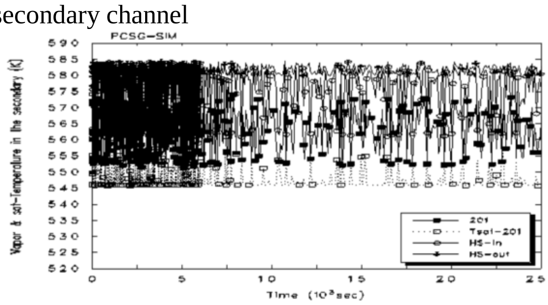

Fig 3. Secondary fluid temperature

- Heat Fluxes at both side of the base plate

There are no data for the heat flux values from the base plates under the normal operation. Figure 4 shows the heat flux values from the both sides of mixed wall. The line with the green color indicates the inlet heat flux from the primary to the mixed wall. The red line indicates the outlet heat flux from the mixed wall to the fluid in the secondary channel. The inlet heat flux value for the mixed wall from the primary channel was calculated to be 0.1 Mw/m^2 and for the predicted heat flux value from the mixed wall to the secondary channel was calculated to be 1 Mw/m^2, respectively.

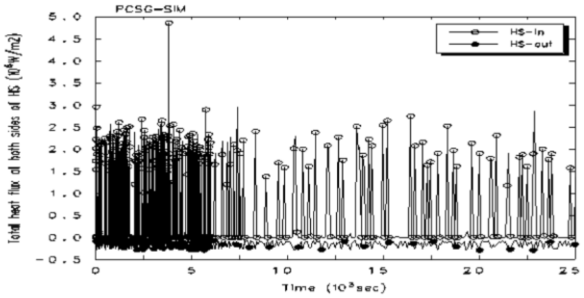

Fig 4. Calculated heat fluxes from the base plate

3. Conclusions

In this study, the preliminary calculations to simulate the PCSG system was performed using MELCOR code. To simulate the PCSG system, the actual plate type of PCSG was assumed to be modified into cylindrical type and also, two base plates for the primary and the secondary were mixed together. The current preliminary calculation results from these assumptions show that the amount of steam production at the exit of the secondary channel was largely under-predicted.

It is estimated that this may be caused from the under-predictions of the heat transfer through the mixed wall. These under prediction may also be caused from the assumption on the geometry for the base plates and from the assumption, which modified the two separate base plate into the single mixed structure.

If a more recent design data on PCSG system such as the heat transfer coefficients through the micro channels, the size of pressure drop, the material properties are provided, then it will be possible to develop the method for simulating the PCSG system using MELCOR. This works can contribute to estimate the overall thermal behaviors for the i-smart plant with connecting PCSG system using MELCOR.

REFERENCES

[1] R.O. Gauntt et al., "MELCOR Computer Code Manuals vol.2: Reference Manuals Version1.8.5, COR-RM 103-106, "SNL, Albuquerque, NM 87185-0739, NUREG/CR-6119 (2000).