1-D PCSG Model Development for Preliminary Safety Analysis of SMART Plus

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1. Introduction

- There is strong interest in small modular reactors (SMRs) in many countries and institutes.
- Korea Atomic Energy Research Institute (KAERI) develops the SMART Plus, the next generation design of SMART.
- The Printed Circuit Heat Exchanger (PCHE) is adopted as the steam generator for SMART Plus.
- The preliminary safety analysis of SMART Plus will be performed using the TASS/SMR-S code.
- The PCSG model is developed to simulate the heat transfer of the steam generator adopted the PCHE in the TASS/SMR-S code.

2. TASS/SMR-S

- The TASS/SMR-S is a computer code that simulates the thermal-hydraulic behavior of nuclear steam supply system using conservation equations on liquid mass, mixture momentum, gas energy, and mixture energy for non-equilibrium two-phase flow.

3. PCSG Model

3.1. 1-D Conduction Model

- The complex multiple flow paths of the PCSG are simplified to a rectangular heat structure and two paths (Figure 1).

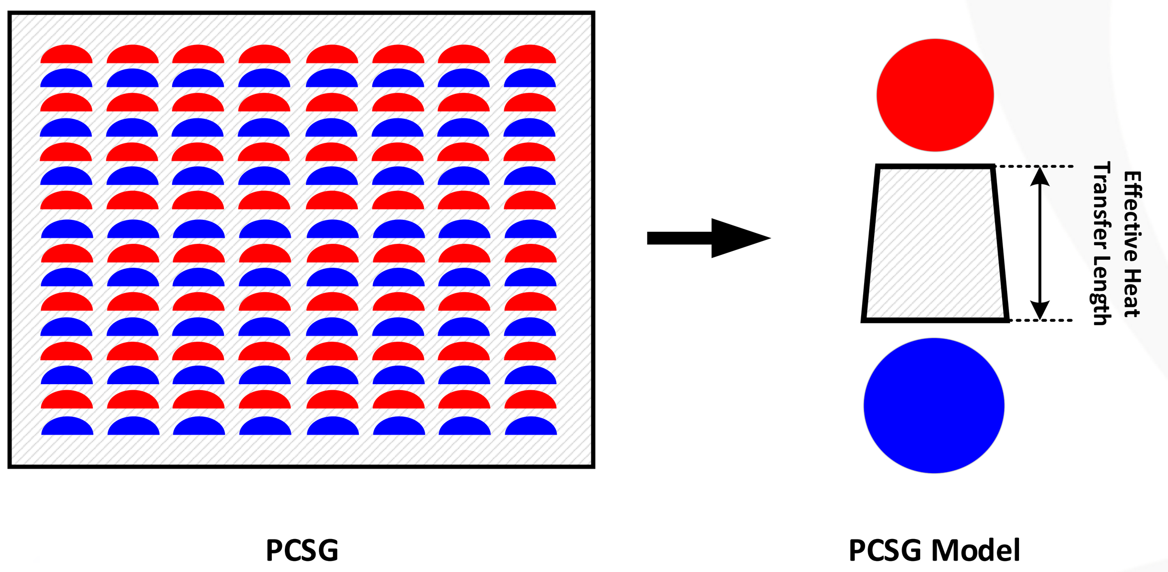

Figure 1. Schematic drawing of the PCSG model

- The effective heat transfer length is calculated from the 3-d computational fluid dynamics (CFD) code.
- The generated heat is conducted in one direction from the hot channel to the cold channel. Thus, the effective heat transfer length that is calculated from the 3-d CFD code is twice that of the PCSG model

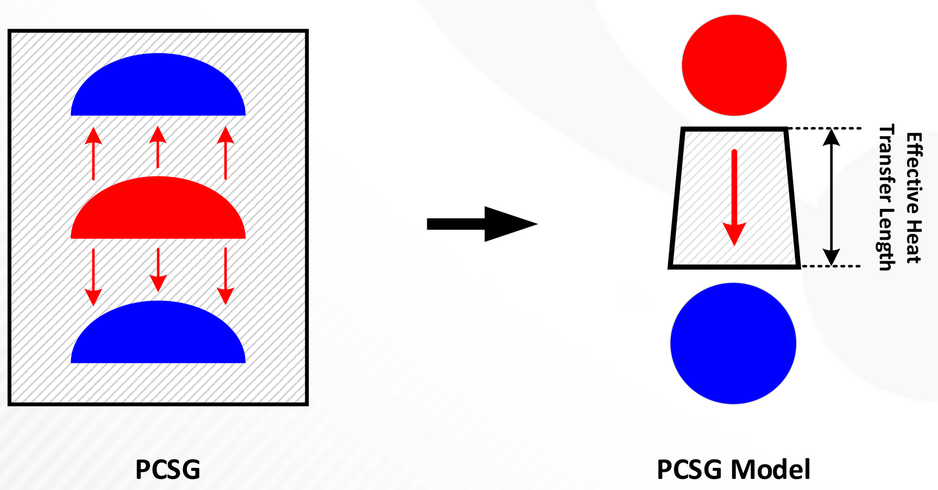

Figure 2. Schematic drawing of the effective heat transfer length for the PCSG model

3.2. Convection Model

- The heat transfer correlations of the general pipe are inaccurate in the PCSG model as the channels are micro size.
- The single-phase heat transfer correlation uses the correlation obtained from 3-d CFD calculations.
- The Chen heat transfer correlation [1] is used for the boiling condition.

4. PCSG Model Verification

- The developed PCSG model is confirmed for preliminary safety analysis of SMART Plus.
- The boundary conditions are inlet conditions of the primary and secondary channels and Figure 3 shows the PCSG nodalization.

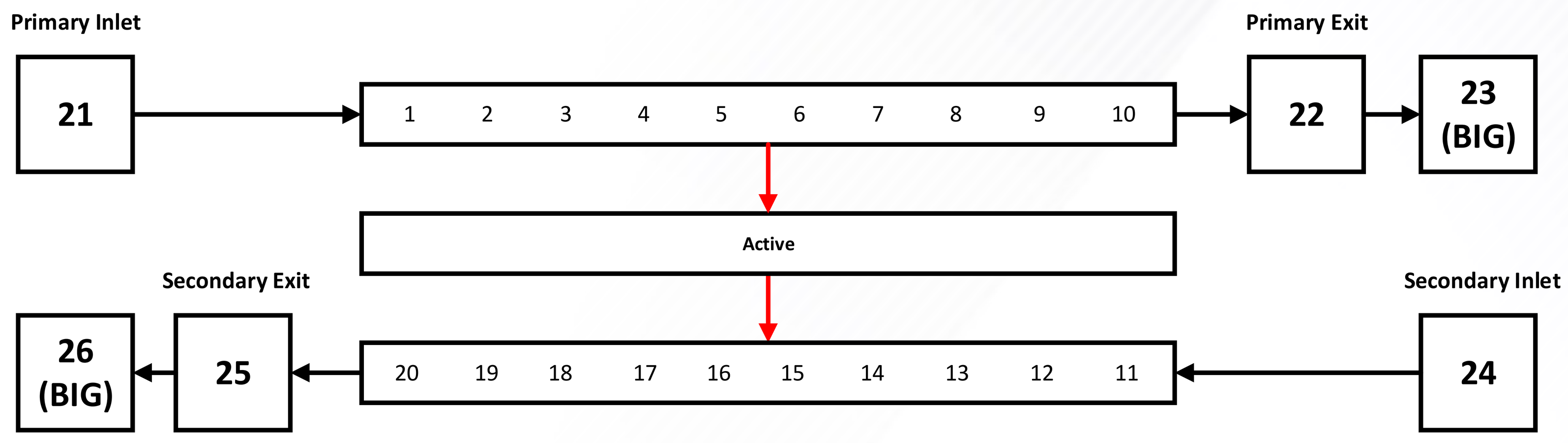

Figure 3. PCSG Nodalization for Verification

- Two cases are simulated to evaluate the effect of the heat transfer length.
- The heat transfer length of the Case 2 that is calculated from the 3-d CFD code is twice that of the Case 1.
- The PCSG area factor is heat transfer area of the PCSG model divided by the designed PCSG heat transfer area.
- After 40 seconds, the PCSG area factor is changed to match the primary outlet temperature to the design value.
- In the Case 2, The PCSG area factor increases due to the increased heat resistance of the PCSG structure (Figure 4).
- The PCSG primary and secondary exit temperatures reach the design values (Figure 5).

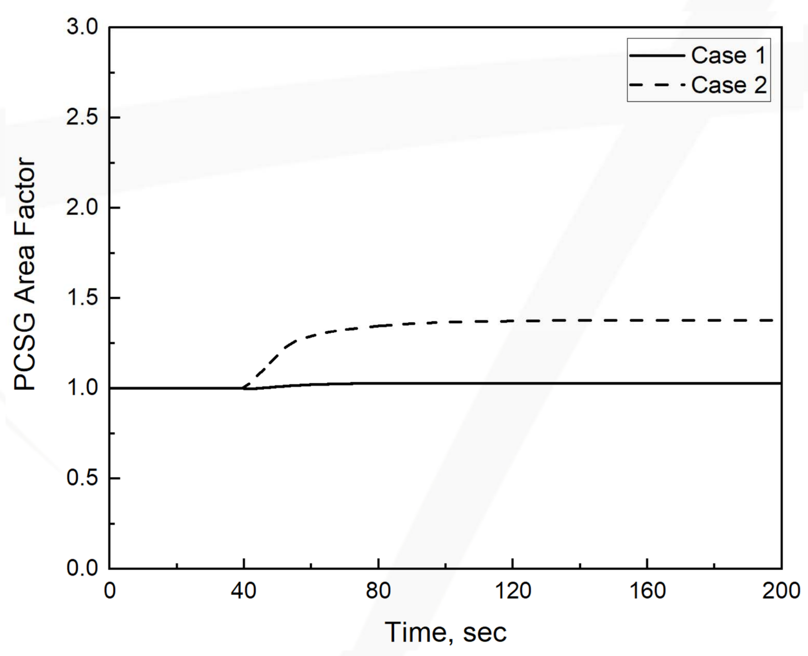

Figure 4. PCSG Area Factor

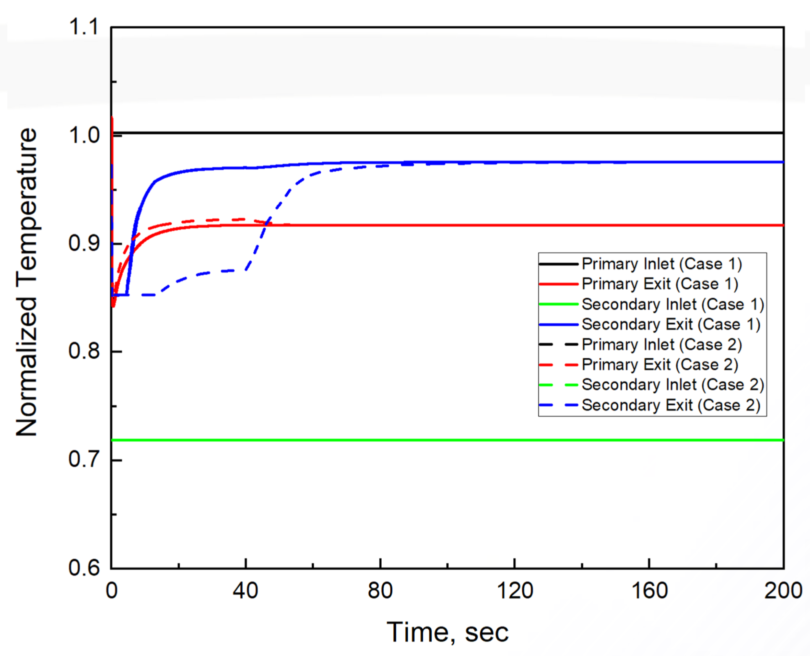

Figure 5. PCSG Normalized Temperature

Conclusion

- The effective heat transfer length and the heat transfer correlation are adjusted in the PCSG model to simulate the heat transfer of the micro channels.
- In the further studies, the PCSG model will be validated by comparing with the experimental results.

Reference

[1] J. C. Chen, Correlation for Boiling Heat Transfer to Saturated Fluids in Co nvective Flow, I & EC Process Design and Development, Vol.5, No.3, pp.322-329, 1966

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