Preliminary Simulation for Slug Flow Boiling on Downward Heated Surface

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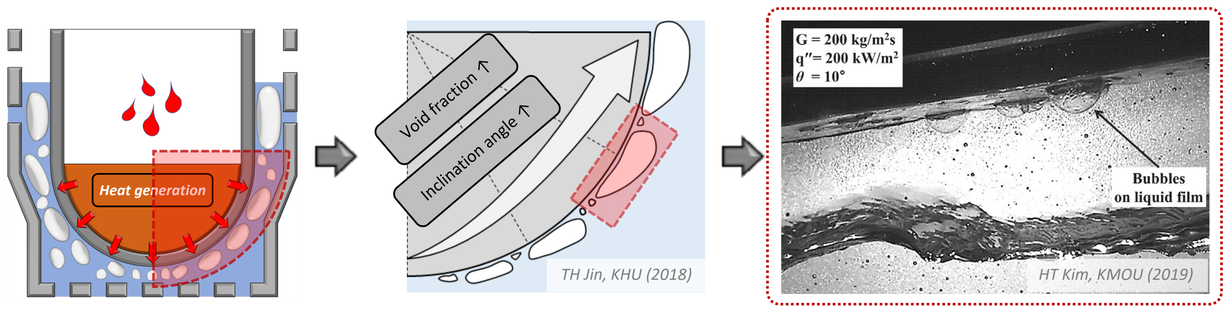
Motivation and Objective



- ❑ IVR-ERVC has been presented in an effective way to maintain the integrity of reactor vessel during severe accident.
- ❑ The **liquid film** is formed beneath the **slug bubbles** and the heat conduction with high heat flux occurs due to this thin layer.
- ❑ However, the **conventional wall boiling model** of Kurul and Podowski does not properly simulate the heat transfer mechanism associated with liquid film of slug bubbles.
- ❑ To perform **physics-based** simulation of slug flow boiling, these two things are necessary.
  - (1) To track the position of slug bubbles
  - (2) To apply the wall boiling model considering the heat transfer through the liquid film

❑ Objective: Development of a hybrid simulation methodology for flow boiling with dispersed and slug bubbles and conducting a preliminary simulation.

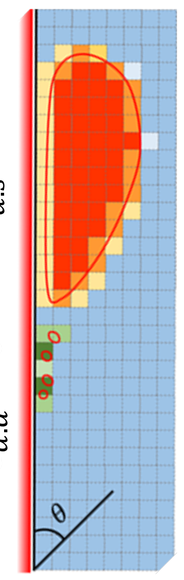
Simulation methods

❑ Interface capturing method

- To track the position of slug bubbles, the **hybrid multiphase solver** was used which can apply the interface capturing method selectively between discrete and slug bubbles.

$$\frac{\partial \alpha_k}{\partial t} + \vec{u}_k \cdot \nabla \alpha_k + \boldsymbol{\nabla} \cdot \left(\boldsymbol{C_{\alpha.phase}} |\vec{\boldsymbol{u}}| \frac{\boldsymbol{\nabla \alpha_k}}{|\boldsymbol{\nabla \alpha_k}|} (\mathbf{1} - \boldsymbol{\alpha_k}) \right) = \frac{\Gamma_{ki} - \Gamma_{ik}}{\rho_k}$$

- $C_{\alpha.slug} = 1$ - Interface capturing **on**
- $C_{\alpha,dispersed} = 0$ - Interface capturing **off**



❑ Hybrid Wall Heat Flux Partitioning(WHFP) model

- To track the position of s

$$q''_w = [1 - H(\alpha_{slug})] q''_{RPI} + H(\alpha_{slug}) q''_{slug}$$

- Blending function for WHFP model

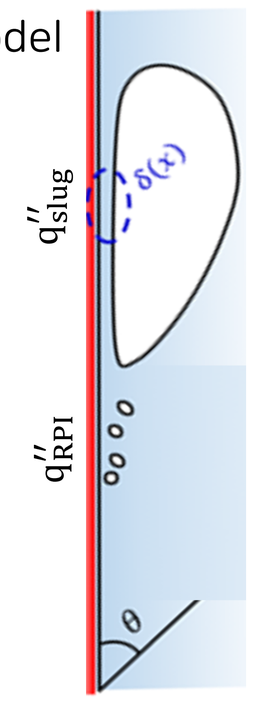
$$H(\alpha_{slug}) = \max\left(0, min\left(1, \frac{\alpha_2^f - \alpha_{slug}}{\alpha_2^f - \alpha_1^f}\right)\right)$$

- WHFP model for continuous phase bubbles

$$q''_{slug} = \frac{k_l}{\delta_{film}} (T_w - T_{sat})$$

- WHFP model for dispersed phase bubbles

$$q''_{RPI} = q''_c + q''_q + q''_e \begin{cases} q''_c = h_c A_{1\phi} (T_w - T_l) \\ q''_q = h_q A_{2\phi} (T_w - T_l) \\ q''_e = N_a \left(\frac{\pi}{6} D_{dep}^3\right) f \rho_g h_{fg} \end{cases}$$



Simulation results

❑ Comparison with conventional CFD method

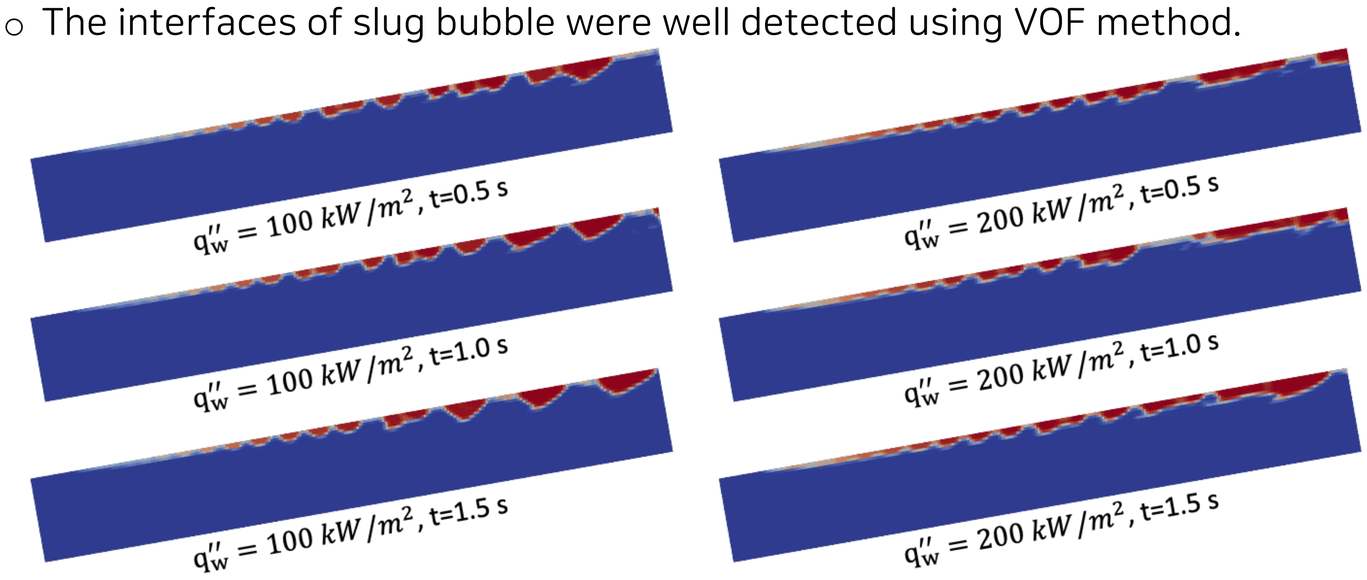
- The result of conventional CFD method was similar to the film behavior.
- Hybrid method simulated the distribution of bubbles more properly.

Conventional CFD(Euler-Euler)

Hybrid method (Euler-VOF)

❑ Preliminary simulation for slug flow boiling on downward heated surface

- The dispersed bubbles grew and the slug bubbles formed as merged.
- The interfaces of slug bubble were well detected using VOF method.



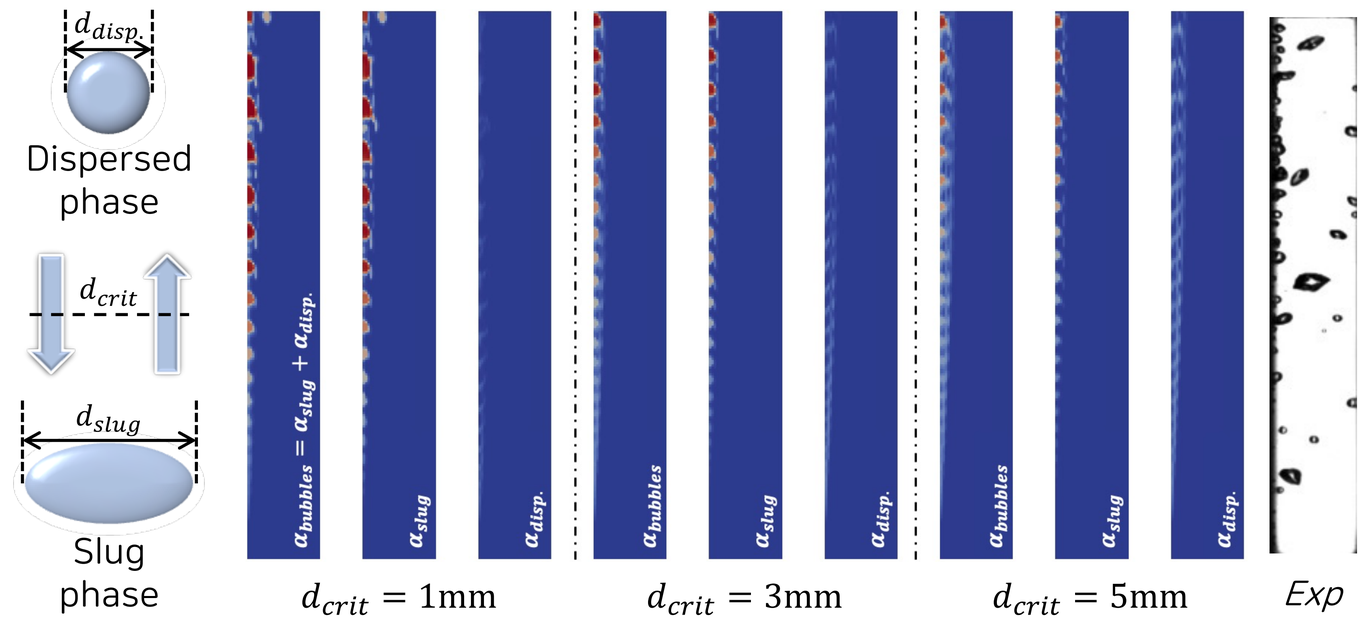
Conclusion & Future works

[Conclusion]

- ❑ The hybrid multiphase modelling which can tracking the position of slug bubble was developed.
- ❑ The wall boiling model was modified to consider heat transfer through the liquid film.
- ❑ The preliminary simulation of slug flow boiling on downward heated surfaces was conducted.

[Future works]

- ❑ The sensitivity test will be conducted to define the critical diameter for phase transfer
- ❑ The qualitative evaluation of WHFP model will be conducted using experimental data



[The effect of critical diameter on phase transfer]

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