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CFD Simulation on Single Bubble Behavior Using VOF Model

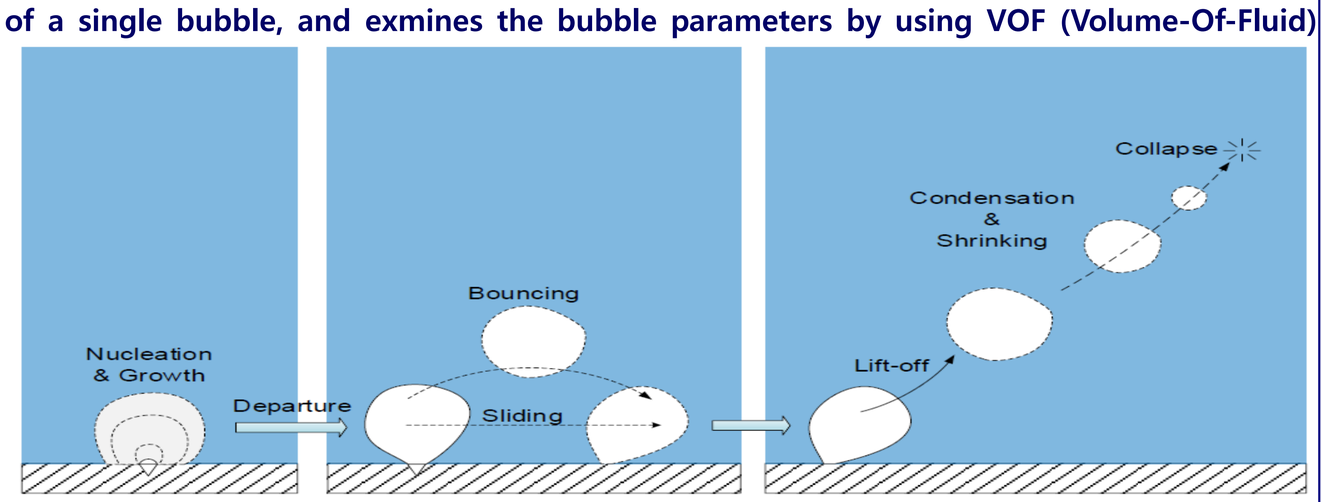
Jae-Ho Bae[a], Seong-Su Jeon[a]*, Min-Seok Ko[a], Sang-Hun Shin[a]

[a] *FNC Tech., Heungdeok IT Valley, Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 446-908, Korea*

**Corresponding author: ssjeon@fnctech.com*

Introduction

- Boiling heat transfer is a powerful heat transfer mode used in many industrial applications such as boilers and nuclear reactor.
- The characteristics of boiling heat transfer are governed by bubble behavior in the system.
- Thus, developing predictive models and correlations for boiling heat transfer requires a sufficient understanding of parameters (bubble shape, contact angle against wall, departure diameter, lift-off diameter, bubble velocity, moving trajectory and etc.) describing bubble behavior.
- There have been many experimental analyses on bubble behavior in various conditions, but it has been impossible to obtain complete information due to very complexity and difficulty to measure.
- Therefore, it is necessary to carry out CFD analysis to simulate the bubble behavior directly as a complement to experiments.
- Although many CFD studies for bubble behavior have been conducted so far, there are few researches on the bubble behavior analysis while simulating the entire bubble life time (bubble generation to collapse).
- In this study, CFD studies are performed to simulate the generation to collapse of a single bubble, and exmines the bubble parameters by using VOF (Volume-Of-Fluid) model in FLUENT 2019.
- This presentation describes the main results of the study so far.



▪ Bubble behavior in subcooled boiling flow

UDF Model of Interface Heat and Mass Transfer

- The bubble behavior was simulated by using the VOF model which could track the complex change of the bubble interface.
- The bubble growth and condensation was simulated by modeling source terms with the developed UDF (User-Defined Function) on Lee model.
- Lee evaporation and condensation model developed to express the heat and mass transfer across bubble interface.
- In this study, γ (mass transfer intensity factor (s^{-1})) is used as 10^3 considering numerical accuracy and calculation speed

(1) Mass transfer:

Evaporation ($T > T_{sat}$)

$$S_M = -r\alpha_L\rho_L\frac{T-T_{sat}}{T_{sat}} \text{ (Liquid)}$$

$$S_M = r\alpha_L\rho_L\frac{T-T_{sat}}{T_{sat}} \text{ (Vapor)}$$

Condensation ($T < T_{sat}$)

$$S_M = r\alpha_V\rho_V\frac{T_{sat}-T}{T_{sat}} \text{ (Liquid)}$$

$$S_M = -r\alpha_V\rho_V\frac{T_{sat}-T}{T_{sat}} \text{ (Vapor)}$$

(2) Energy transfer:

Evaporation ($T > T_{sat}$)

$$S_E = -r\alpha_L\rho_L\frac{T-T_{sat}}{T_{sat}}h_{fg},$$

Condensation ($T < T_{sat}$)

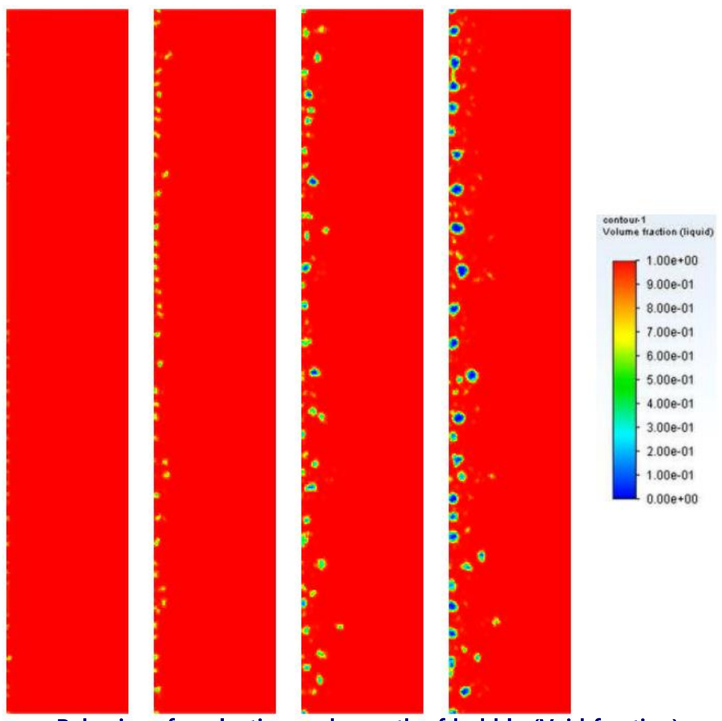
$$S_E = r\alpha_V\rho_V\frac{T_{sat}-T}{T_{sat}}h_{fg},$$

CFD Simulation Procedure

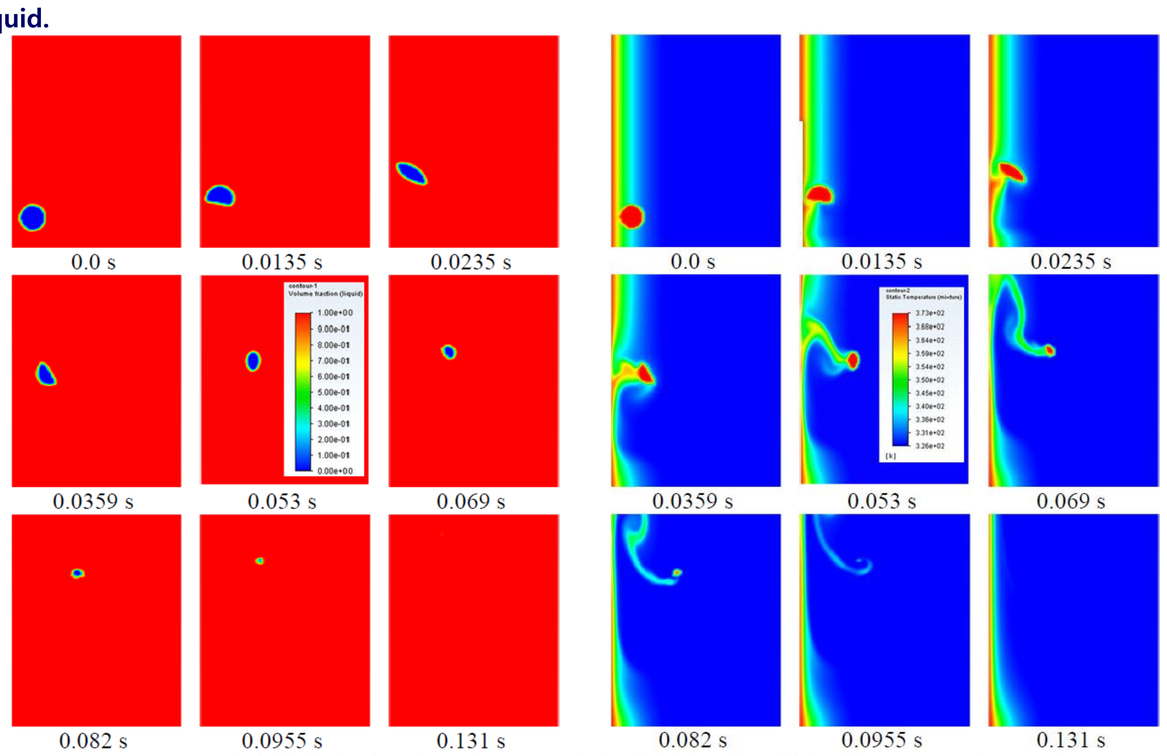
- The flow channel and meshes are generated in a 2D Cartesian coordinate system.
- The dimension of the test channel are 20 mm X 25 mm.
- As the initial condition, the water condition of 1 atm, 373 K is considered and the properties of water/steam derived from the steam table are used.
- The surface tension considered important for bubble formation and behavior is 0.05891 N/m.
- The evaporation/condensation is simulated using developed UDF.
- Time step size is 10^{-5}.
- The inlet and outlet of the channel are modeled as the velocity inlet (0.1 m/s) and pressure outlet (1 atm), respectively.
- One wall is abiabatic wall and the other is heated wall (383 K).

Simulation Results

- Unfortunately, this study could not continuously simulate whole life time of bubble from generation to collapse.
- Instead, the simulation was performed separately on the nucleation and growth of bubble, and behavior after bubble is generated.
- Behavior of nucleation growth of bubble
  - ✓ Small bubbles are generated and rising from the wall.
- Behavior after bubble departure
  - ✓ Bubble generated near wall lifts off, and completely condenses and disappear by sub-cooled liquid.



▪ Behavior of nucleation and growth of bubble (Void fraction)



▪ Bubble behavior after departure (Left: Void fraction, Right: Temperature)

Conclusion and Future Work

- This study shows the nucleation and growth of bubble, and the behavior after departure of bubble.
- Unfortunately, it was not succeed to see the whole life time of bubble.
- But, this study identifies that simulation is possible from the beginning of the bubble`s life time.
- Later, through research, the whole life time of bubble will be simulated with CFD code.