Comparison of SPACE to MARS-KS under SUBO experimental conditions

Min-Gil Kim [a], Wonwoong Lee [a], Young Seok Bang [b], Jeong Ik Lee [a*]
[a]*Department of Nuclear and Quantum engineering, Korea Advanced Institute of Science and Technology (KAIST)*
291 Daehak-ro, (373-1, Guseong-dong), Yuseong-gu, Daejeon 305-701, Republic of KOREA
[b]*Safety Evaluation Department, Korea Institute of Nuclear Safety (KINS)*
62 Gwahak-ro, Yuseong-gu, Daejeon 305-338. Republic of KOREA
[*]*Corresponding author: jeongiklee@kaist.ac.kr*

1. Introduction

To evaluate safety of a Korean Nuclear Power Plant (NPP) MARS-KS code is being used by the Korean regulator. The governing equations of MARS-KS are based on two-phase and two-fluid model. Recently, SPACE (Safety and Performance Analysis CodE for nuclear power plants) was developed by a consortium led by Korea Hydro & Nuclear Power Co., Ltd. (KHNP), which the code is aimed for evaluating the safety of the designed nuclear power plant. The governing equations of SPACE are based on two-phase (liquid and gas phase) three-fluid (continuous liquid, gas and droplet) model.

However, MARS-KS and SPACE have different governing equations, as well as model and correlations implemented in two codes. Due to this reason, the authors are studying the difference in the analysis result of SET (Separate Effect Test) of each code.

2. Problem Definition

To investigate the difference of each code, comparison was made for a SUBO (SUbcooled Boiling flow) experiment done by KAERI [1]. Test section of the SUBO facility is shown in Fig. 1[1]. SUBO Test facility consists of water pipes and rod shape heater. Subcooled water flows from the bottom to the top with constant mass flow rate, and it is heated by the rod shape heater. Tables I to IV show the boundary and analysis conditions.

Table I: Boundary Condition of SUBO experiment

Heat Flux(kW/m^2)	472.92
Mass Flux(kg/m^2s)	1115.89
Inlet Pressure(kPa)	192.55
Outlet Pressure(kPa)	160.47
Inlet Temperature(K)	374.63
Heat(kW)	45.77
Mass Flow Rate(kg/s)	1.017

Table II: Hydraulic Components Geometry

Hydraulic Components		
Area		$9.1126E-4m^2$
Length (Component)	Lower	0.229m
	Heated	3.087m
	Upper	0.384m
Hydraulic Diameter		0.02552m
Roughness		4.6E-5m
Pressure	Inlet	192.55kPa
	Outlet	160.47kPa
Temperature		374.63K

Table III: Time Step of Analysis

Time	
Minimum Time Step(s)	1.0E-7
Maximum Time Step(s)	0.01
Final Time Step(s)	50.0

Table IV: Heat Structure Geometry

Heat Structure	
# of Meshes	3
Area	$0.15435m^2$
Heated Length	0.15435m
Heated Diameter	0.02552m

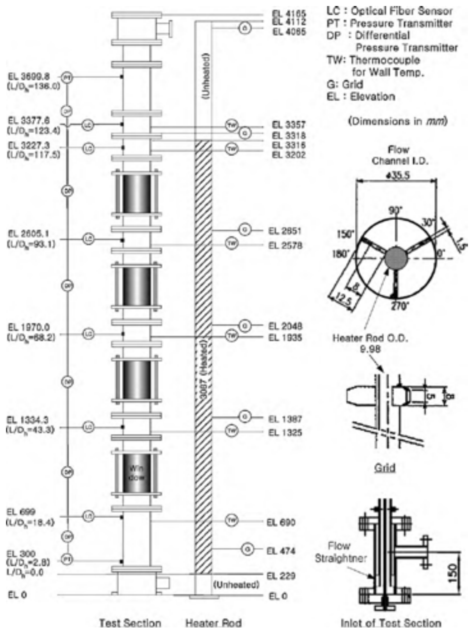

Fig. 1. Test section of the SUBO facility [1]

3. Analysis

3.1 Input Nodalization

To obtain the analysis result, the authors prepared input decks for MARS-KS and SPACE code with respect to SUBO experiment facility. Nodalizations of each code are shown in Fig. 2.

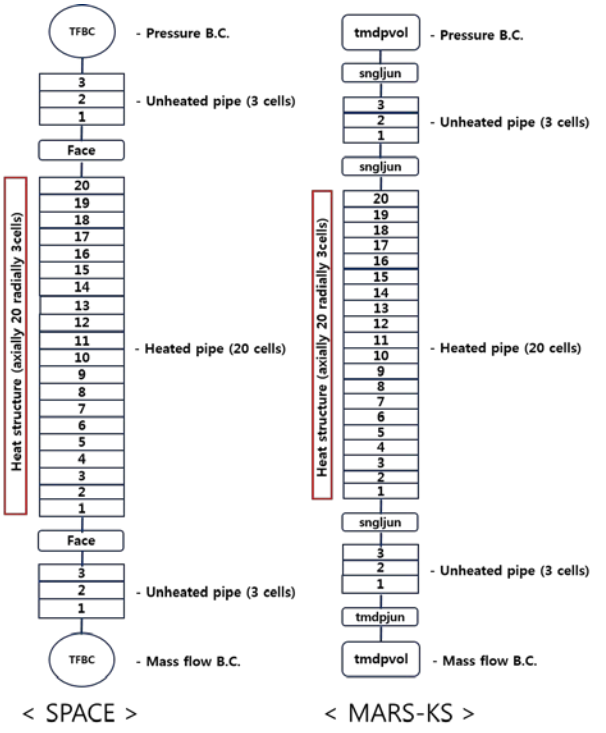

Fig. 2. SUBO Nodalization for MARS-KS and SPACE

3.2 Analysis Result

From the inputs of each code, calculation results are obtained, respectively. MARS-KS 003 and SPACE 2.15 was used to retrieve results. Firstly, the authors compared the code results that can be compared with experimental data. Figs. 3 to 6 show the void fraction, temperature of liquid, velocity of liquid and vapor along vertical direction. Each value was measured in the experiment. Values of temperature and void fraction are chosen from the result at junction (face), while velocities are obtained from volume (cell).

For the liquid temperature, calculation results from both codes predict experimental data well. The vapor velocity from both calculation results are higher than the experimental data while the liquid velocity is the opposite. Calculation results of the void fraction from MARS-KS is higher than the experimental data, but it is lower in SPACE calculation. Since the information on the uncertainties of experimental data is not provided to the authors yet, it is early to draw any definitive conclusions at this stage.

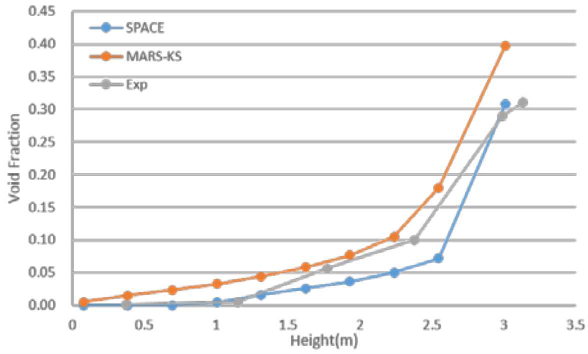

Fig. 3. Void fraction along vertical direction

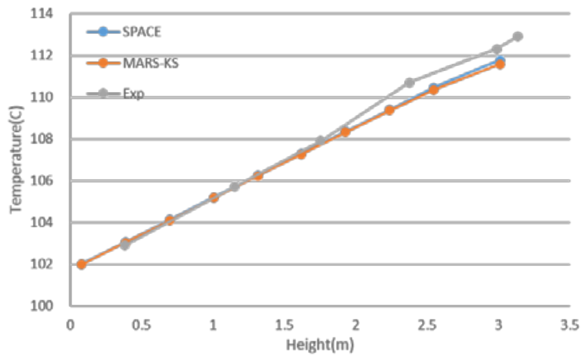

Fig. 4. Liquid Temperature along vertical direction

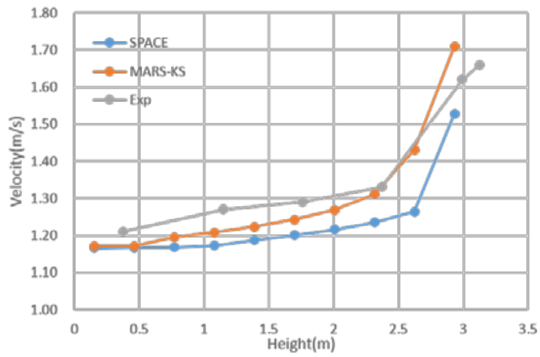

Fig. 5. Liquid velocity along vertical direction

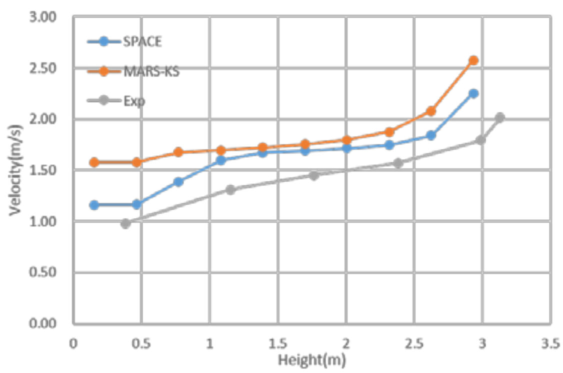

Fig. 6. Vapor velocity along vertical direction

To check heat balance along the heated length, the authors performed simple calculation to reconfirm the calculation results. From the experimental condition, the first added heat is calculated. In the heated pipe, 1st and 20nd nodes are selected as reference nodes. Then added heat is 95% of total added heat, since the measurement points are located at the middle of the node. Mixing cup enthalpy at each node are calculated from the vapor and liquid enthalpy, density, void fraction, fluid mass in each node. Calculation results are shown in Table V.

Table V: Analysis Result for Heat Balance

	SPACE	MARS -KS
Mass flow rate (kg/s)	1.017	1.017
Enthalpy at 1st node (kJ/kg)	42.75	42.75
Enthalpy at 20nd node (kJ/kg)	46.98	46.95
$\dot{m}\Delta h$ (kW)	42.96	42.66
$\dot{Q}$ (kW)	43.48	43.48
Error (%)	-1.19	-1.89

And, mass flow rate is checked. Values are got from junction (face).

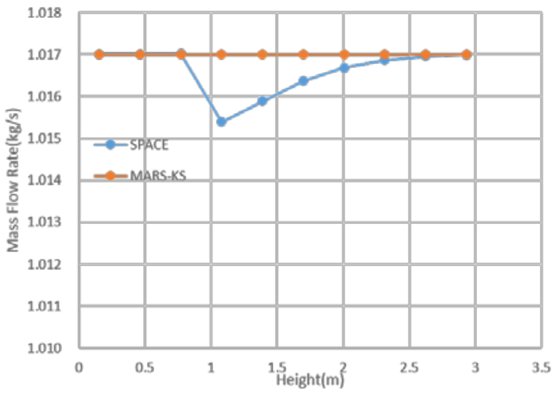

Fig. 7. Mass flow rate along vertical direction

Next, the authors compared flow regime at each node. Since flow regime affects heat transfer coefficients and friction coefficients, it is important information to discuss the difference between the results. Table VI shows the flow regime along the vertical direction in the heated section, especially at volume (cell).

Table VI: Flow Regime along the vertical direction

Height(m)	SPACE	MARS-KS
0.077	Liquid	Slug
0.386	Liquid	Slug
0.695	Bubbly	Slug
1.003	Bubbly	Slug
1.312	Bubbly	Slug
1.621	Bubbly	Slug
1.929	Bubbly	Slug
2.23	Bubbly	Slug
2.547	Bubbly	Slug
3.010	Slug	Slug

The authors used a simple in-house code described in [2] to obtain the flow regime from the data of MARS-KS and SPACE, respectively. Physical quantities are retrieved from the volume (cell). Fig. 8. shows the flow regime change along the vertical direction.

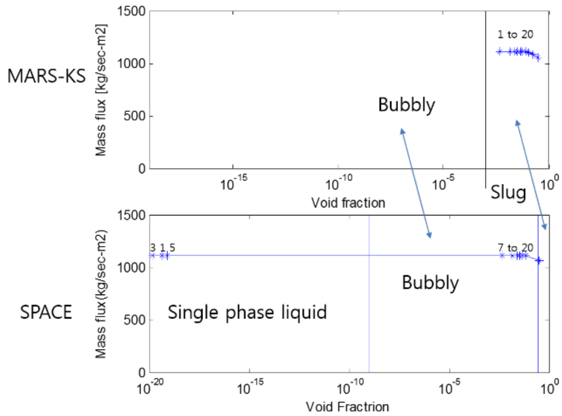

Fig. 8. Flow regime change along the vertical direction

4. Summary and Further Works

To compare the SPACE and MARS-KS performances, the authors chose SUBO experiment as the first reference case. Input deck of each code was prepared. The results from the two codes were compared to the experimental data, but due to the lack of information on the uncertainties it is too early to conclude the code performance. However, from the obtained analysis results, some differences between MARS-KS and SPACE are observed. Especially, flow regimes at heated region are considerably different. More detailed analysis of the flow regime and its effect in MARS-KS and SPACE analysis results will be followed in the near future. The heat transfer coefficient and friction factor at the interface and at the wall will be compared with similar method used in this study.

Acknowledgement

This work was supported by the project “Feasibility assessment by SET and independent review of the SPACE code” funded by Korea Institute of Nuclear Safety (KINS).

REFERENCES

[1] B. J. Yun, B. U. Bae, D. J. Euh, G. C. Park and C. –H. Song, Characteristics of the local bubble parameters of a subcooled boiling flow in an annulus, Nuclear Engineering and Design, Vol.240, p. 2295, 2010.
[2] M. –G. Kim, Y. Lee and J. I. Lee, Flow regime comparison of MARS-KS and SPACE during LBLOCA, Transactions of

the Korean Nuclear Society Autumn Meeting, Pyeongchang, Korea, Oct 30-31, 2014