Flow regime comparison of MARS-KS to SPACE during LBLOCA

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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 each code. Especially in this study, the flow regime of each code is being investigated. The comparison was made for a LBLOCA (Large Break Loss of Coolant Accident) scenario in a Korean nuclear power plant for two codes. The result will be extended in the follow up study, such as comparing heat transfer coefficient, friction factor, and so on.

MARS-KS and SPACE vertical volume flow regime map are shown in Fig. 1 [2], Fig. 2 [1] and Fig. 3 [1]. Vertical flow map of SPACE is divided into the film boiling regime map and other regime flow regime map which depends on the temperature condition. If temperature of steam is higher than the saturation temperature of water, the flow regime is considered as a film boiling.

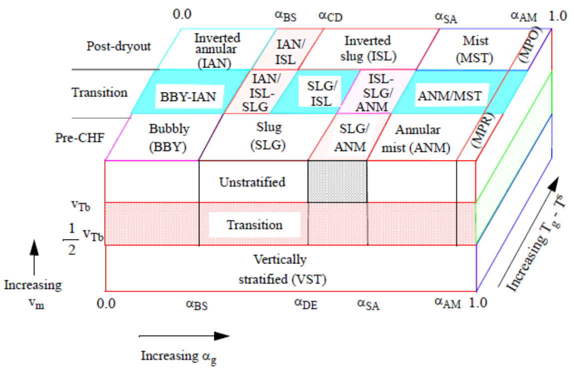

Fig. 1. Vertical Volume Flow Regime Map of MARS-KS

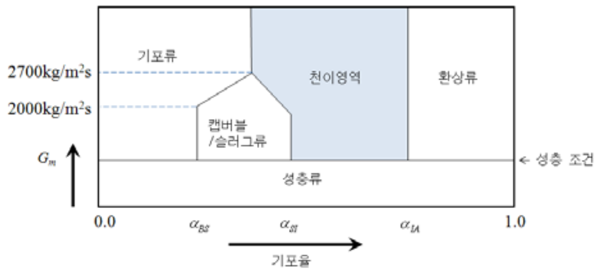

Fig. 2. Vertical Volume Flow Regime Map of SPACE

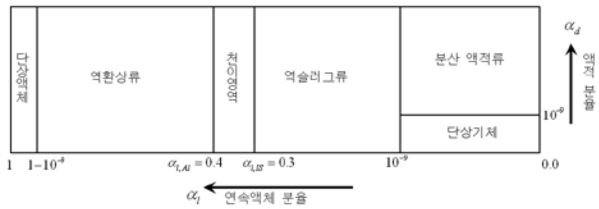

Fig. 3. Film Boiling Flow Regime Map of SPACE

2. Problem Definition

To investigate the difference of each code, KSNP reactor is selected as a reference reactor. MARS-KS nodalization for the reactor input is shown in Fig. 4.

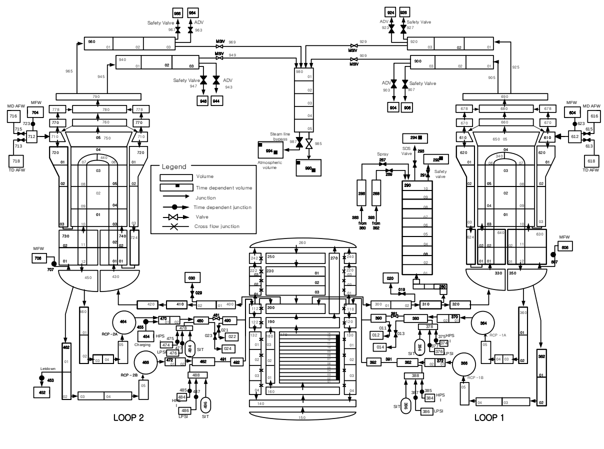

Fig. 4. Nodalization of KSNP

3. Analysis

3.1 Analysis Method

To obtain the flow regime of each time step, different methods are used to each code. In the case of MARS-KS, authors used WIN7 released version to run input. However, since SPACE executable file of the code is not released yet, the authors wrote a simple in-house code to obtain the flow regime by utilizing the MARS-KS output data as an input data to SPACE flow regime determination. The flow regime map of SPACE was referred from the manual of SPACE code [2]. The output data of MARS-KS required for SPACE flow regime calculation were density of steam and water, viscosity and surface tension of water, total pressure, critical pressure of water, temperature and velocity of steam and water, void fraction, hydraulic diameter and angle of the node. The mass flux and superficial velocity are calculated from the obtained density, velocity and fraction of steam and water. Fraction of droplet is assumed to be zero in this analysis.

3.2 Analysis Result

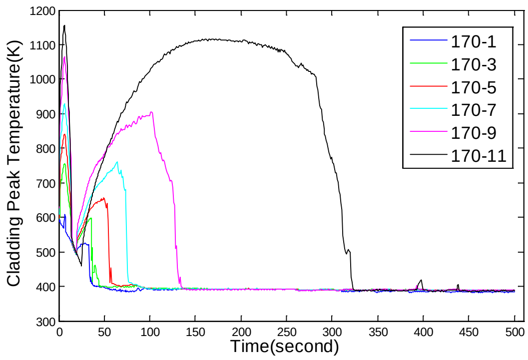

Fig. 5. Peak Cladding Temperature of Core Nodes

During the whole calculation time, node 170-11 shows the highest peak cladding temperature. Therefore the authors chose the node 170-11 as a reference node in this study.

Table II: Flow Regime Difference between MARS-KS and SPACE

MARS-KS Regime	SPACE Regime	Time Step
Mist	Inverted Slug /Annular	~12s
Mist post-CHF	Single Phase Gas	107s
Mist	Inverted Slug	28-200s
Slug	Churn	200-500s

During the transient, MARS-KS indicates that the reference node is in the mist regime, SPACE indicates that the node is in the inverted slug regime. During the large fluctuation region (50s-120s in real time), MARS-KS predicts that the flow regime is in the mist post-CHF regime while SPACE predicts as the inverted slug or single phase gas regime. It is again noted that SPACE flow regime is obtained not from the calculation done by SPACE, but just interpreting the MARS output result with SPACE flow regime logic.

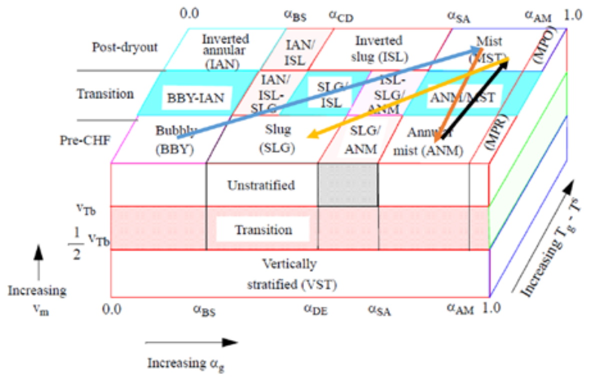

Fig. 6. Flow Regime change during calculation time in MARS-KS

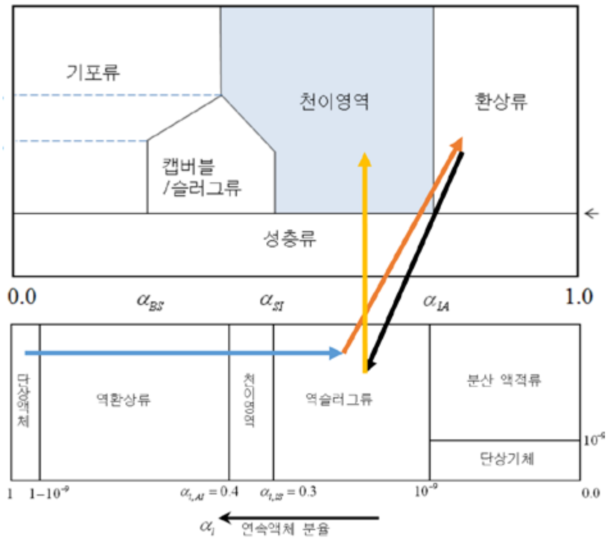

Fig. 7. Flow Regime change during calculation time in SPACE

In Fig. 6 and Fig. 7, flow regime change during the calculation time is visualized. The flow regime changes in the order of blue, orange, black and yellow line.

In Fig. 6, the MARS-KS flow regime changes from bubbly to mist, during 0s to 12s of calculation time. And regime moves to annular mist until 28s, and comes back to mist regime again. It remains until 200s, and the flow regime moves to the slug regime. In Fig. 7, the SPACE flow regime changes from single phase liquid to inverted slug regime until 10s of calculation time. And regime moves to the annular regime up to 28s, and it comes back to the inverted slug regime until 200s. The flow regime moves to churn regime after then.

4. Summaries and Further Works

To compare the flow regime of MARS-KS and SPACE during LBLOCA, KSNP was selected as the model nuclear power plant. The node where the peak cladding temperature occurs was selected by the authors and the node was calculated with MARS-KS code. The output from MARS-KS was used as the input of an in-house code which represents the SPACE two phase flow

regime map. The in-house code is based on SPACE code manual. From the result, the authors found that the two codes are predicting different flow regime under the same thermal hydraulic conditions, and this is expected since the flow regime of two codes are different and the selection criterion of the flow regime is also 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 by similar method used in this study.

Acknowledgement

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