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Preliminary Assessment of the Reflood Heat Transfer Models for the SPACE code

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1. Introduction

The SPACE (Safety and Performance Analysis CodE) code is currently developing as the nuclear safety analysis code, sponsored by Korean government for a licensing purpose of pressurized water reactors in Korea. Several research and industrial organizations such as KAERI, KHNP, KOPEC, KNF and KEPRI have participated in the SPACE development. One of the main features of the SPACE code is that it is based on a multi-dimensional two-fluid, three-field models [1, 2]. KAERI is in charge of developing physical models and correlation packages. Among them are i) a flow regime selection, ii) wall and interfacial frictions, iii) interfacial heat and mass transfers, iv) a wall heat transfer, and so on.

The objective of the present paper is to introduce the reflood heat transfer models implemented in the SPACE code, and particularly the models were assessed against experimental data.

2. Methods and Results

2.1 Reflood model package

In the SPACE code, the wall-to-fluid heat transfer package consists of a heat transfer mode transition map and heat transfer models for each mode [3]. The heat transfer transition map considered in the SPACE code is shown in Fig. 1. As shown in this figure, reflood heat transfer mode (MODE 40) is considered as one of 13 heat transfer modes (a liquid phase natural convection, a liquid phase forced convection, a nucleate boiling, a critical heat flux, a transition boiling, a vapor phase convection, a condensation, and a reflood heat transfer) and selected depending on pressure, noncondensable gas quality, void fraction, bulk temperature, and wall temperature.

In the reflood heat transfer mode, the film boiling are modeled as three different kinds of flow regimes with respect to the void fraction (inverted annular; $\alpha < 0.6$, inverted slug; $0.6 < \alpha < 0.9$, dispersed flow; $\alpha > 0.9$). The heat transfer processes of the inverted annular and dispersed flow regimes are considered as illustrated in Fig. 2 and also the inverted slug flow is regarded as the transition region of the inverted annular and the dispersed flow regimes. More details of the reflood heat transfer models are described in SPACE Models and Correlations Manual [4].

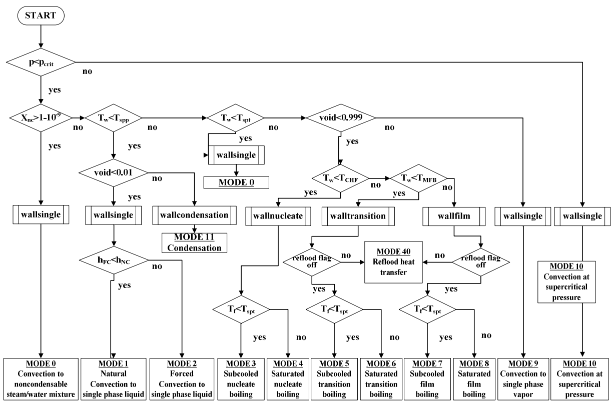
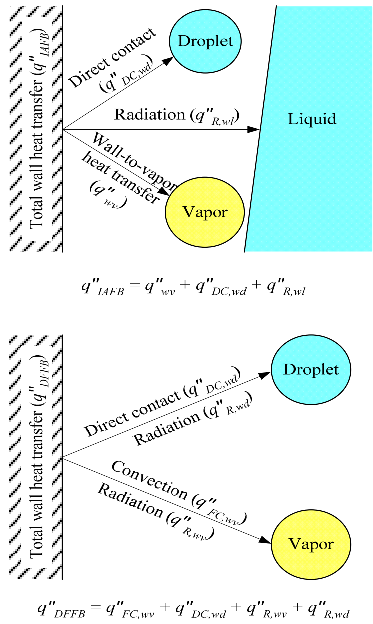


Figure 1. Heat transfer mode transition map.

(a)



(b)

Figure 2. (a) Inverted annular film boiling wall heat transfer; (b) Dispersed flow film boiling wall heat transfer.

2.2 Assessment of reflood model package

The performance of the reflood heat transfer model implemented in SPACE code were assessed against 2×2 rod bundle reflood experiment performed by KAERI [5]. Table 1 shows the test conditions of the selected experiments used in the assessment.

For the present assessment, as shown in Fig. 2, the SPACE code modeled test section consisted of 30 cell vertically oriented pipe with 29 faces, time dependent flow boundary at the inlet, and time dependent pressure boundary at the outlet. The 30 heat structure slabs were simulated for heat generation at the wall.

Table 1. Experimental condition in the assessment

Pressure	Reflood velocity	Reflood temperature	Rod power
0.1 MPa	0.02 m/s	20 °C	1.6 kW

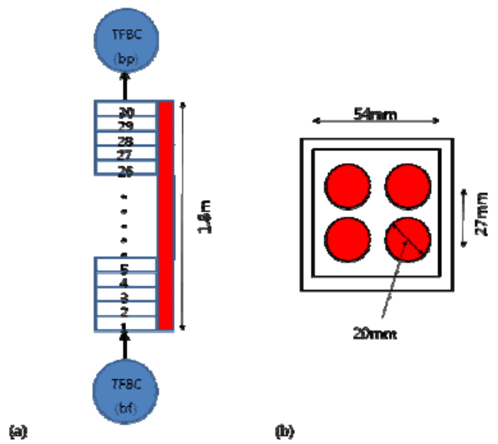


Figure 2. (a) SPACE nodalization and (b) configuration of rod bundle.

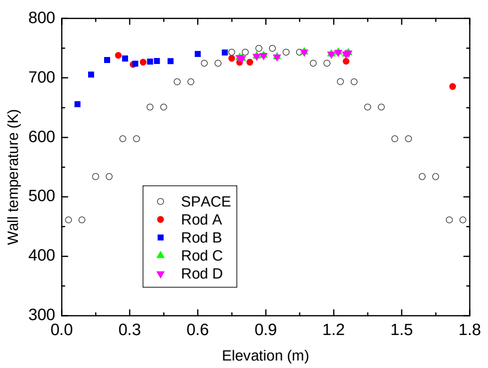


Figure 3. Distribution of wall temperature with respect to elevation at the moment of water injection for reflood.

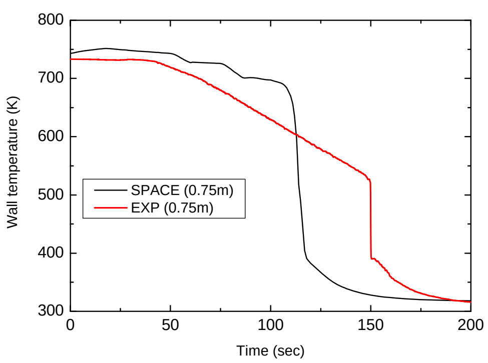


Figure 4. Time variation of the wall temperature at elevation of 0.75m from the bottom.

Figure 3 shows the measured and the predicted wall temperature distributions along with the elevation at the moment of water injection. As shown in Fig. 3, the wall temperature in middle of the rod bundle was reasonably predicted by the SPACE code although those in the lower and upper part of the rod bundle were found to be underpredicted by the SPACE code as compared to the experimental data.

To compare the performance of the reflood models implemented in the SPACE code for the quenching phenomenon, the time variation of the wall temperature at elevation of 0.75 m from the bottom is shown in Fig. 4. Here, the time when the water begins to be injected is set to be *t*=0. The prediction results from the SPACE code and experimental data initially showed a similar value. Right after the water injection for reflood, the SPACE code slightly overpredicted the wall temperature and then showed very rapid decrease of the wall temperature as compared to that from the experiment.

3. Conclusions

The reflood heat transfer model of the SPACE code was introduced and then assessed against the2×2 rod bundle reflood experimental data performed by KAERI. Based on the this assessment, the SPACE code was shown to reasonably predict the spatial and temporal behaviors of the wall temperature in the case of reflood although the further improvement would be required in order for the SPACE code to have better performance for the reflood situation.

ACKNOWLEDGMENTS

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