Assessment on the Applicable Model in RELAP code to simulate Downcomer Boiling Phenomena

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1. Introduction

The downcomer boiling phenomena at the late reflood period have been issued recently. In late reflood period, the injection water flow-rate is small compared to the that of refill and early reflood period due to the termination of large cooling water source, that is, the Safety Injection Tanks(SITs)[1]. At this situation, the reactor vessel wall is still in a high temperature and injected water is partly vaporized near the reactor vessel wall surface. Some of system codes (e.g. RELAP, TRACE) predict this generated steam prevents the penetration of safety injection water into core and eventually degrades the core cooling capability. In this concern, KAERI performed a separate effect test on the downcomer boiling phenomena in the reactor downcomer during the LBLOCA reflood period. In this paper, we assessed the several models (EPRI, Bestion, and Blasius) in RELAP3.3 code of downcomer boiling phenomena using the experiment by KAERI.

2. Experimental Facility and Results

The test facility models the APR1400 downcomer with rectangle geometry. The facility is designed to meet a full scale of the height and gap of the reactor downcomer. The facility simulates a 1/47.08 azimuthal part of the prototype downcomer section area.[2] Test conditions are summarized in Table 1. The experimental results showed that hydrostatic head drop by downcomer boiling was not large in case of ECC water having 3-5℃ subcooling, and 4-6℃ subcooling was preserved at the bottom of the test section. Also, the following flow characteristics have been observed; bubbly flow accompanied by cap bubble in the bottom, 10% void fraction and its swirling in the middle, and churn turbulent flow with approximately 10~20% void fraction and breakage of void by turbulent in the top.

Table 1. Test Conditions used in the Experiment

Parameter	Case1	Case2	Case3	Case4
T_{ECC}(℃)	110.1	110.2	109.6	109.5
P_{sys}(kPa)	162.8	161.4	166.5	170.8
W_{ECC}(kg/s)	1.22	1.16	1.2	1.2
Q”(w/cm^2)	5.02	6.97	8.21	9.11

3. Base Case Analysis Results

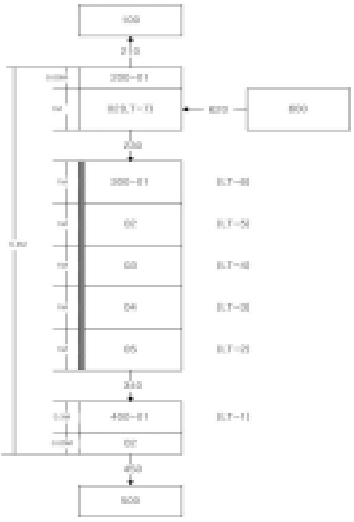

Figure. 1 RELAP Nodalization with Single-channel

In this study, the vertical single-channel model is used to simulate downcomer.(Fig. 1) When water in downcomer is boiled off by heated wall, interaction between void and liquid become important. Interfacial drag model is one of the key factors to handle those phenomena in RELAP. Basically, RELAP adopts Kataoka–Ishii/churn-turbulent correlation for APR1400 and experimental facility geometry (D_H>30cm).[3] The base case analysis results show that water temperature in the bottom of test section slightly below the saturated condition and a numerical oscillation occurred for vapor velocity, flowrate and void fraction (Fig. 2).

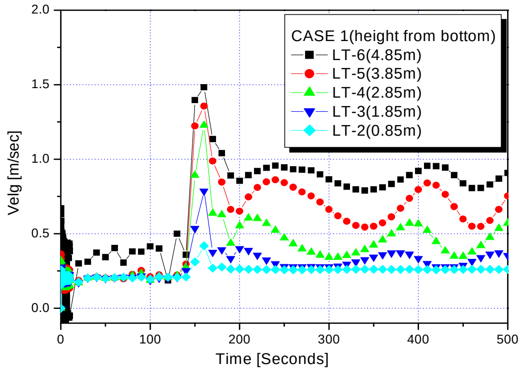

Figure. 2 Behavior of vapor velocity for case 1

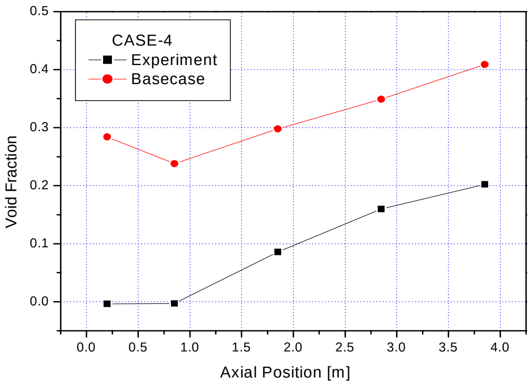

Figure. 3 Void fraction for axial direction

Moreover, void distribution along axial direction is over-predicted(Fig. 3). Because churn-turbulent correlation used as basecase is developed based on the experiments having small diameter in comparison with APR 1400 downcomer, the use of original model shows some limitation on prediction capability.

4. Downcomer Boiling Model and Its Assessment

The interfacial drag coefficient used in RELAP code is originally developed on the circular pipe with small hydraulic diameter. So these correlations might not be applicable to the annulus geometry having large hydraulic diameter and circulation flow. To estimate models having the appropriate drag coefficient range in reactor vessel annulus geometry, some correlations used in the RELAP code are evaluated. EPRI and Bestion correlation is compared to the original Kataoka-Ishii correlation. Also, we performed the comparison by adopting blasius model used in TRACE. In TRACE, Blasius model is a special interfacial drag model which is applied in the downcomer only.

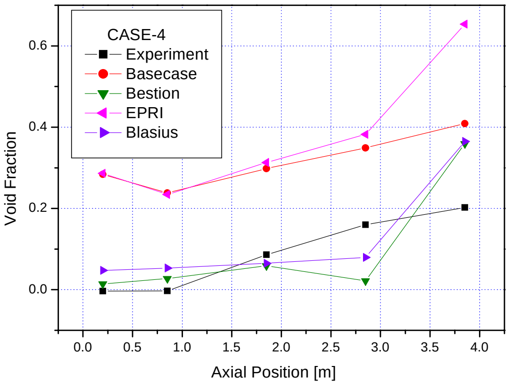

Figure. 4 Void Distribution for Each Model

As shown in void distribution(Fig. 4), All models except the blasius model predict inappropriately. These results show that generated void is not released smoothly. On the other hand, the Blasius model predicts axial vapor velocity fast(Fig. 5), because blasius model reduces Interfacial drag sharply (void fraction>0.05).

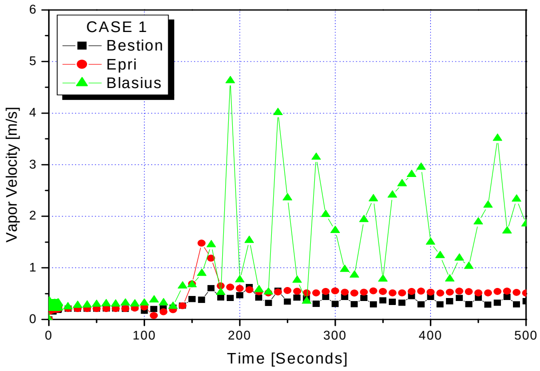

Figure. 5 Vapor velocity in the middle of channel

5. Conclusions

We assessed various models to assess the applicability on downcomer boiling phenomena with RELAP codes using related experiment performed by KAERI. The results show that blasius model shows the closest prediction due to its characteristic. Further evaluation, however, should be made after the local experimental data are produced to finalize applicable model for downcomer boiling..

REFERENCES

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