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Comparison of Critical Flow Models' Evaluations for SBLOCA Tests

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1. Introduction

A comparison of critical flow models between the Trapp-Ransom and Henry-Fauske models for all SBLOCA (small break loss of coolant accident) scenarios of the ATLAS (Advanced thermal-hydraulic test loop for accident simulation) facility was performed using the MARS-KS code. For the comparison of the two critical models, the accumulated break mass was selected as the main parameter for the comparison between the analyses and tests. Four cases showed the same respective discharge coefficients between the two critical models, e.g., 6″ CL (cold leg) break and 25%, 50%, and 100% DVI (direct vessel injection) breaks. In the case of the 4″ CL break, no reasonable results were obtained with any possible *Cd* values. In addition, typical system behaviors, e.g., PZR (pressurizer) pressure and collapsed core water level, were also compared between the two critical models. From the comparison between the two critical models for CL breaks, the Trapp-Ransom model predicted quite well with respect to the other model for the smallest and larger breaks, e.g., 2″, 6″, and 8.5″ CL breaks. In addition, from the comparison between the two critical models for DVI breaks, the Trapp-Ransom model predicted quite well with respect to the other model for the smallest and larger breaks, e.g., 5%, 50%, and 100% DVI breaks. In the case of 50% and 100% breaks, the two critical models predicted the test data quite well.

2. Methods and Results

2.1 Test Scenarios for MARS-KS[1] Analyses

Four CL pipe SBLOCA scenarios were selected, i.e., 2.0″, 4.0″, 6.0″, and 8.5″. CL pipe breaks and four DVI line SBLOCA scenarios, 5%, 25%, 50%, and 100%, as shown in Table 1. The break nozzle of a test was modeled by a valve component in MARS analyses. A time-dependent volume was used for the simulation of the containment back pressure in the both SBLOCA analyses. In the post-test analysis, the measured containment pressures with respect to time were used as the boundary condition of the time-dependent volume.

Table 1. Summary of CL pipe and DVI line SBLOCA tests

Test ID	Break Nozzle		Remark
	Size (in.)	*D* (mm)	
SB-CL-07	2.0	3.56	
SB-CL-05	4.0	7.12	
SB-CL-09	6.0	10.68	DSP-02
SB-CL-04	8.5	15.13	
SB-DVI-06	1.9(5%)	3.41	
SB-DVI-05	4.3(25%)	7.63	
SB-DVI-09	6.0(50%)	10.8	ISP-50
SB-DVI-08	8.5(100%)	15.13	DSP-01

2.2 Analyses results

Discharge coefficients of the Henry-Fauske critical model for SBLOCA tests were cited from authors' previous two works, e.g., Kim et al.[2] and Kim and Choi[3] for CL pipe break and DVI line SBLOCAs, respectively. For simulations of SBLOCA scenarios using the Trapp-Ransom critical model, two discharge coefficients were considered, e.g., the subcooled and two-phase discharge coefficients, because there were no superheated conditions at the break location in all SBLOCA tests. Users can input different values for the subcooled and two-phase discharge coefficients, but authors found that no effective results were obtained from the sample calculations. Thus, the same discharge coefficients were used for each SBLOCA scenarios in this study. To obtain the best fitted *Cd* of the Trapp-Ransom critical model for each test, the accumulated break mass was selected as the main parameter for comparison between the calculations and tests. The obtained best fitted *Cd* data of the Trapp-Ransom model for all SBLOCA scenarios of the ATLAS facility were summarized in Table 2 including those of the Henry-Fauske model and typical break conditions. As can be seen in the table, four cases showed the same respective discharge coefficients between the two critical models, e.g., 6" CL break and 25%, 50%, and 100% DVI breaks. The other four cases showed different discharge coefficients to obtain a reasonable fitted result between the calculations and test data, e.g., 2″, 4″, and 8.5″ CL breaks and 5% DVI break. In the case 4" CL break, the discharge coefficients for the best fitted calculation could not be obtained. In the Trapp-Ransom model, all discharge coefficients are allowed in the range of greater than 0.0 and less than 2.0. Although the authors used a maximum *Cd* value, e.g., 1.99, for the scenario, no reasonable results were obtained.

Table 2. Summary of calculated *Cd* data of critical flow models for SBLOCA tests

Break Location	Break Size[a]	D(mm)[b]	Henry-Fauske Model		Trapp-Ransom Model		
			Cd[c]	*TNC*	Cd_{sub}	$Cd_{2\text{-}\phi}$	Cd_{sup}
CL-1A	2″	3.56	0.55	0.14	0.65	0.65	NA[d]
	4″	7.12	0.82	Ditto	1.99	1.99	Ditto
	6″	10.68	0.77	Ditto	0.77	0.77	Ditto
	8.5″	15.13	0.71	Ditto	0.55	0.55	Ditto
DVI-4	5%(1.9″)	3.41	0.55	Ditto	0.50	0.50	Ditto
	25%(4.3″)	7.63	0.79	Ditto	0.79	0.79	Ditto
	50%(6.0″)	10.8	0.77	Ditto	0.77	0.77	Ditto
	100%(8.5″)	15.13	0.71	Ditto	0.71	0.71	Ditto

Note, a: Equivalent diameters of CL SBLOCA or percentages of DVI SBLOCA in APR1400.
b: Diameters of break nozzles in ATLAS tests.
c: *Cd* values were cited from Kim et al.[2] and Kim& Choi[3] for CL pipe break and DVI line SBLOCAs, respectively.
d: The break flows of all CL and DVI SBLOCAs are not applicable to a superheated condition.

The accumulated break mass for each scenario of the CL breaks were compared between the two critical flow models including the test data, as shown in Fig. 1. (Here, MARS-HF means the MARS' result of the Henry-Fauske critical model; and MARS-TR, that of the Trapp-Ransom critical model.) As can be seen in the figure, three scenarios showed good agreements between the two models, e.g., 2", 6", and 8.5" CL breaks. However, for the case of 4" CL break, no reasonable results were obtained despite using a maximum discharge coefficient. Especially in this case, two options for an area change model were compared, e.g., a smooth area change model (a0) and full abrupt area change model (a1). As shown in Fig. 1 (b), the calculation result using the smooth area change model shifted to the test data until 630 s, but the deviation of the total break mass at 3000 s became larger than that of the abrupt area change model. The authors could not obtain a reasonable result for the case of 4" CL break using the Trapp-Ransom critical flow model. (It should be noted that all simulations in this study used the abrupt area change option (a1) as a default model for the area change option of break valve.)

The accumulated break mass for each scenario of DVI breaks was compared between the two critical flow models including the test data, as shown in Fig. 2. As can be seen in the figure, all scenarios showed good agreements between the two models. For the 100% DVI break, the deviation between the two models seemed to be the largest, but there was less than 5% deviation between them. In the overall aspect, the two critical flow models showed reasonable results for the DVI break SBLOCA scenarios.

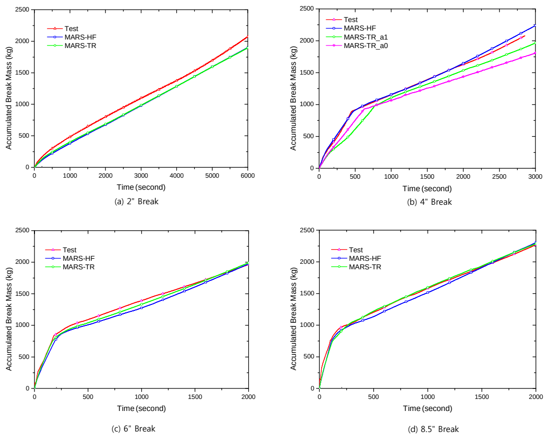

Fig. 1 Comparison of accumulated break mass between the two critical models for CL breaks

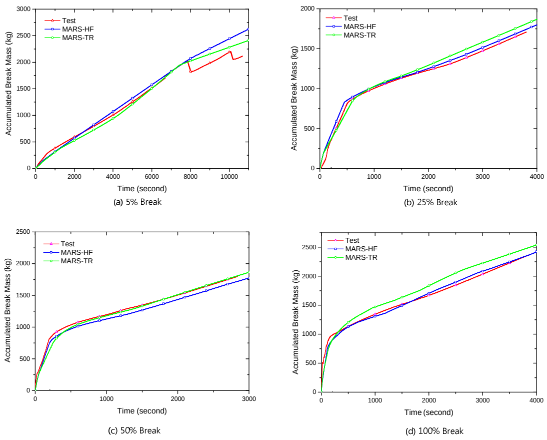

Fig. 2 Comparison of accumulated break mass between the two critical models for DVI breaks

3. Summary and Conclusions

A comparison of the critical flow models between the Trapp-Ransom and Henry-Fauske models for all SBLOCA scenarios was performed using the MARS-KS code. For the comparison of the two critical models, the accumulated break mass was selected as the main parameter for the comparison between the analyses and tests. Four cases showed the same respective discharge coefficients between the two critical models, e.g., 6″ CL break and 25%, 50%, and 100% DVI breaks. In the case of the 4” CL break, no reasonable results were obtained with any possible *Cd* values.

In addition, typical system behaviors, e.g., PZR pressure and collapsed core water level, were also compared between the two critical models. From the comparison between the two critical models for the CL breaks, the Trapp-Ransom model predicted quite well with respect to the other model for the smallest and larger breaks, e.g., 2″, 6″, and 8.5″ CL breaks. In addition, from the comparison between the two critical models for the DVI breaks, the Trapp-Ransom model predicted quite well with respect to the other model for the smallest and larger breaks, e.g., 5%, 50%, and 100% DVI breaks. In the case of the 50% and 100% breaks, the two critical models predicted the test data quite well.

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