Numerical Analysis of Break Flow According to Ambient Control Volume Size

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1. Introduction

Steam generator feed water line break accident is regarded as one of the important limiting events in PWR safety analysis. For numerical analysis of this event, appropriate modeling of feed water line break is important because it directly affects the amount of heat removal in primary system by the feedwater line break. To properly simulate the physical phenomena including flashing flow, it is important to define the appropriate modeling parameters such as numerical schemes, definition of modeling domain, initial conditions and so forth. Among them, the dependency on the control volume size of ambient size will be assessed in this study with CFX version 19.2.

If the diameter of ambient control volume is too small, the flashing flow to the free volume might be inaccurately modeled because the flow will be limited by the ambient control volume boundary. On the other hand, if the diameter of ambient control volume is too large, the flashing flow might be exactly modeled but the large computational resources are required. Thus, the appropriate ambient control volume size should be determined in terms of accuracy and computational time. For this, four cases with different ambient control volume sizes are simulated under the identical flashing flow conditions in this work.

2. Methods and Results

2.1 Methods

Table I summarizes geometries of four different ambient control volumes. Ambient control volume is modeled in the form of a cylinder, and the break is considered as circle shape at the center of one circular plane of the cylinder volume. Break size is assumed to be 2 inches. Calculations are conducted for ambient control volume with diameters of 1.7, 3.4, 9, and 27 times of break size.

Table I: Test Matrix

	Ambient Volume Diameter (m)	Ratio to Break Diameter (-)
Case1	0.087	1.7
Case2	0.173	3.4
Case3	0.462	9
Case4	1.385	27

Mesh type including hex elements require a lot of man-hours in mesh generation step, but have excellent convergence and high result accuracy despite having a small number of elements [1]. A rapid flow occurs in a short time near the break and large pressure changes occur, so meshes are generated using a hex element to increase convergence. Fig. 1. shows the generated meshes of the case 2 as an example. The meshes are generated by using the hex dominant and multizone methods, and other cases is also meshed in the same way.

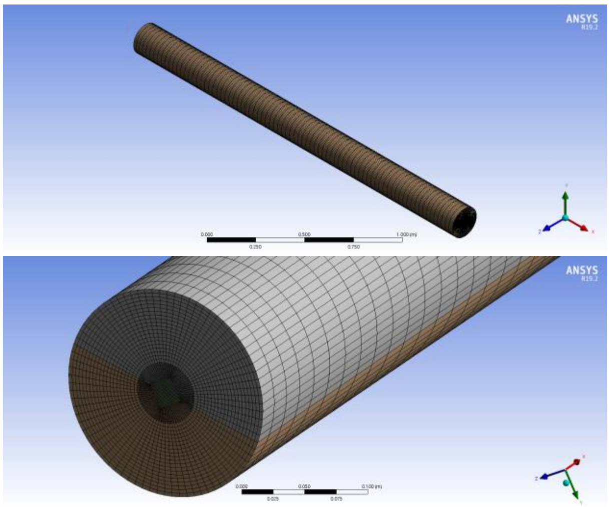


Fig. 1. Generated Meshes in case 2

At the start of calculation, water is injected from the break of 7 MPa to the ambient control volume having an initial condition of 0.1 MPa and 25 °C. The boundary of the break is fixed at 7 MPa, and the circular plane of the ambient control volume in the opposite direction to the break is set to 0.1 MPa steam. The calculation is performed for 15 msec through adaptive time steps limiting Courant number under 1. The turbulence model used the SST model. [2]

2.2 Results

Figs. 2-9 show the steam Mach number of break flow in the ambient control volume at 5, 10, 15 msec and void fraction at 15 msec in the case 1-4, respectively. Fig. 10 shows the mass flow from break to ambient control volume.

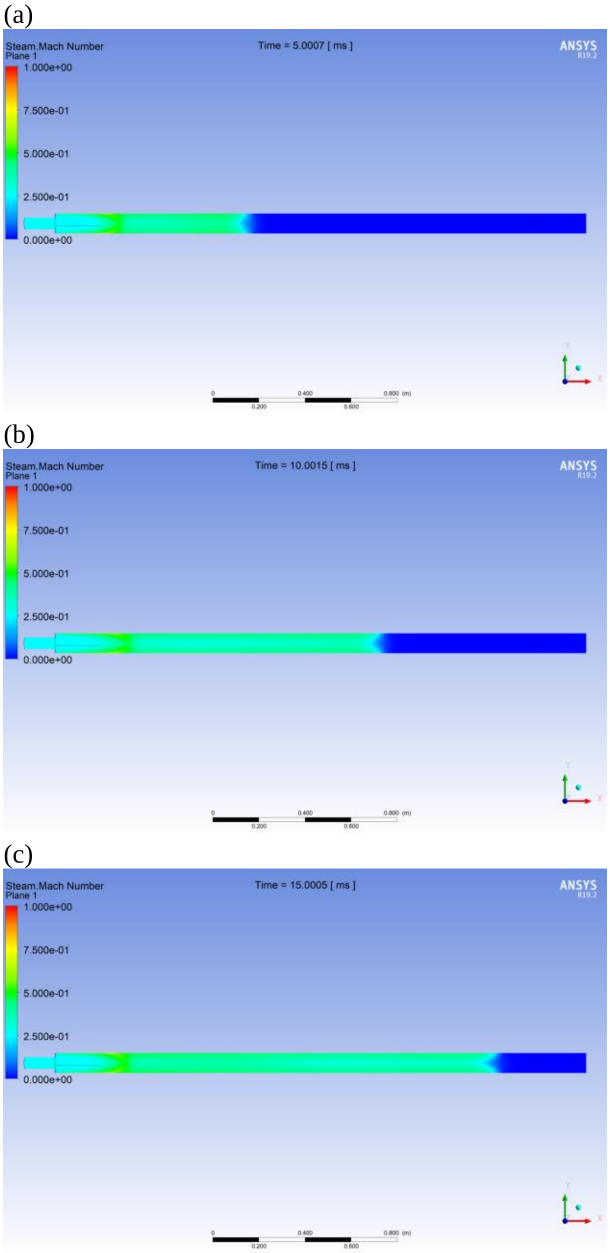


Fig. 2. Velocity profile in the ambient volume of case 1 at (a) 5 msec (b) 10 msec (c) 15 msec

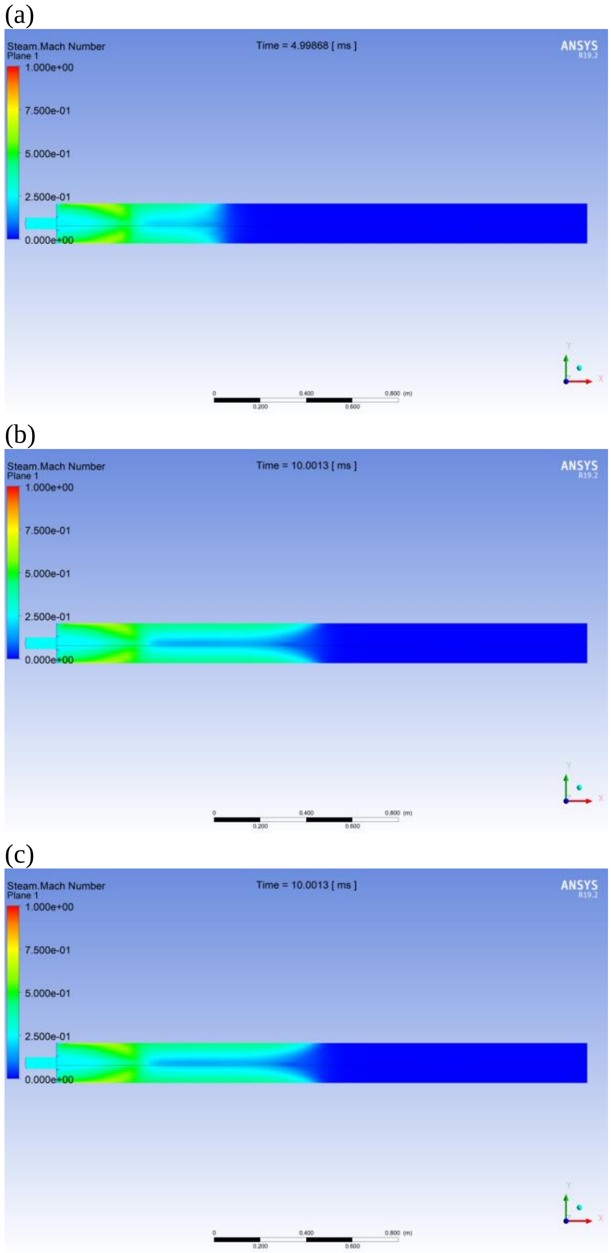


Fig. 4. Velocity profile in the ambient volume of case 2 at (a) 5 msec (b) 10 msec (c) 15 msec

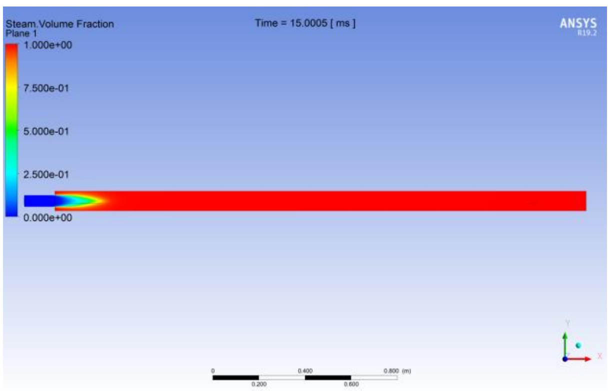


Fig. 3. Void fraction of case 1 at 15 msec

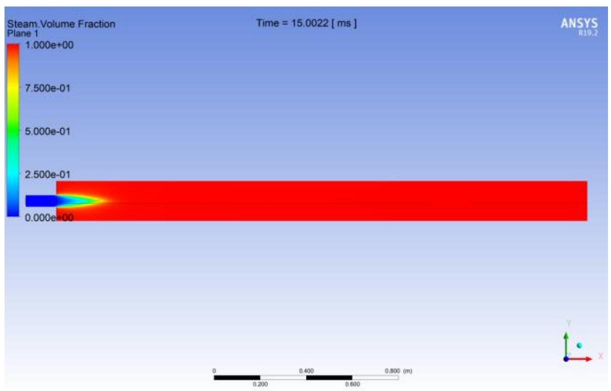
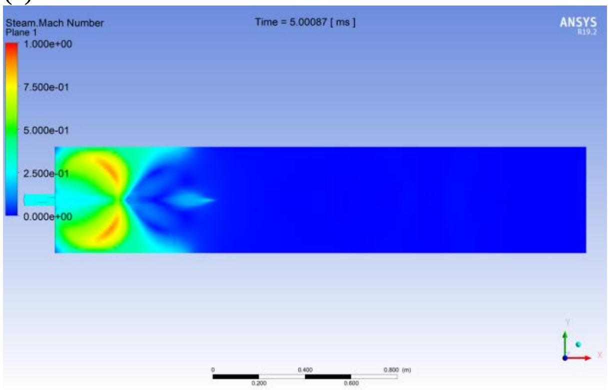
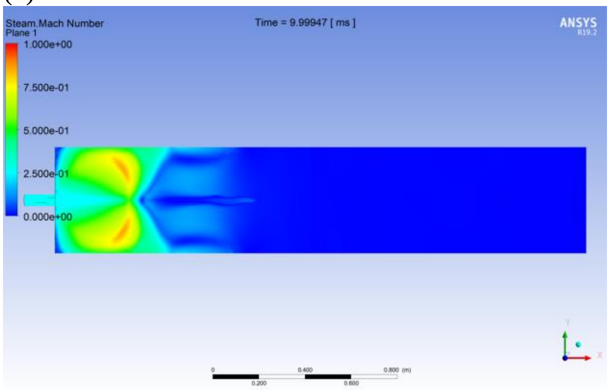


Fig. 5. Void fraction of case 2 at 15 msec

(a)



(b)



(c)

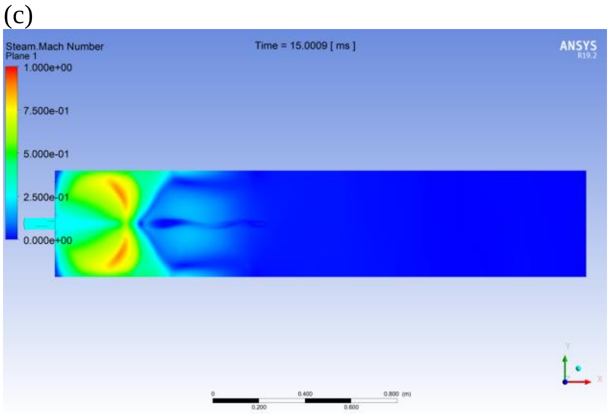


Fig. 6. Velocity profile in the ambient volume of case 3 at (a) 5 msec (b) 10 msec (c) 15 msec

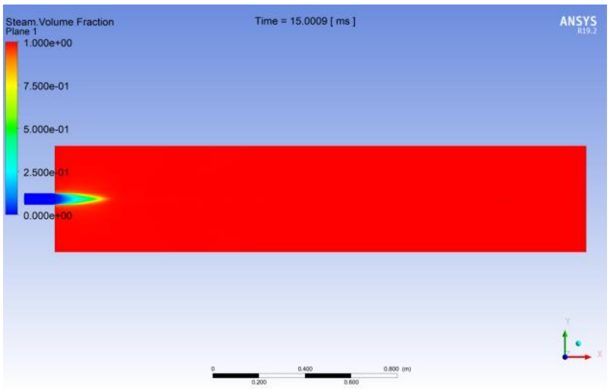
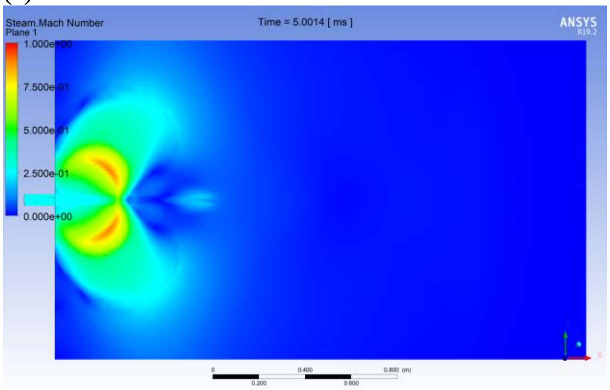
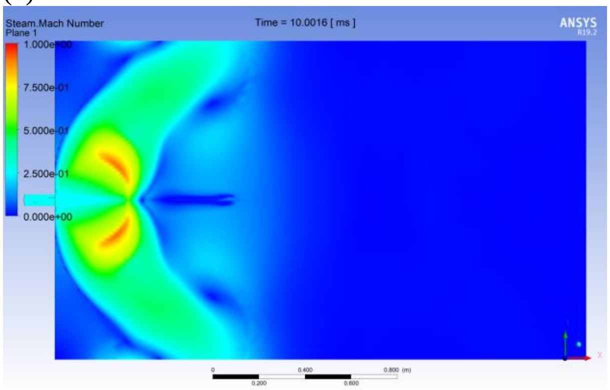


Fig. 7. Void fraction of case 3 at 15 msec

(a)



(b)



(c)

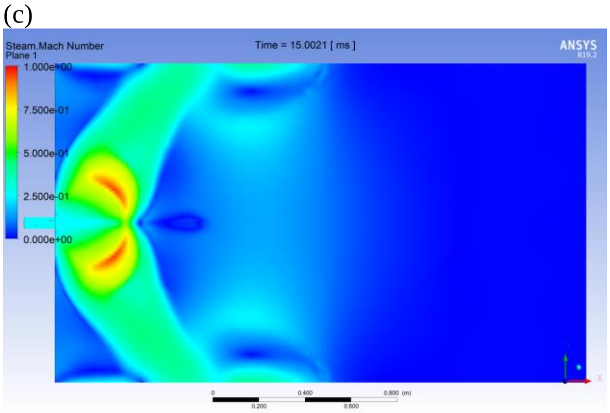


Fig. 8. Velocity profile in the ambient volume of case 4 at (a) 5 msec (b) 10 msec (c) 15 msec

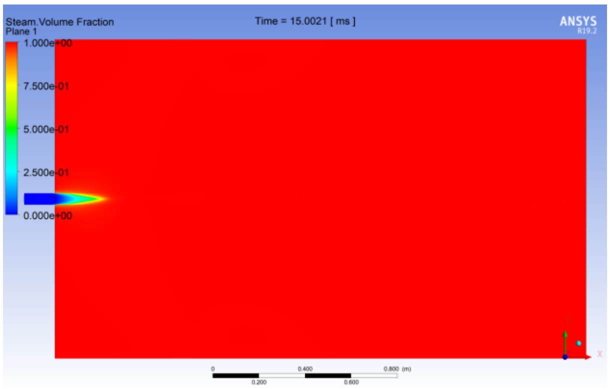


Fig. 9. Void fraction of case 4 at 15 msec

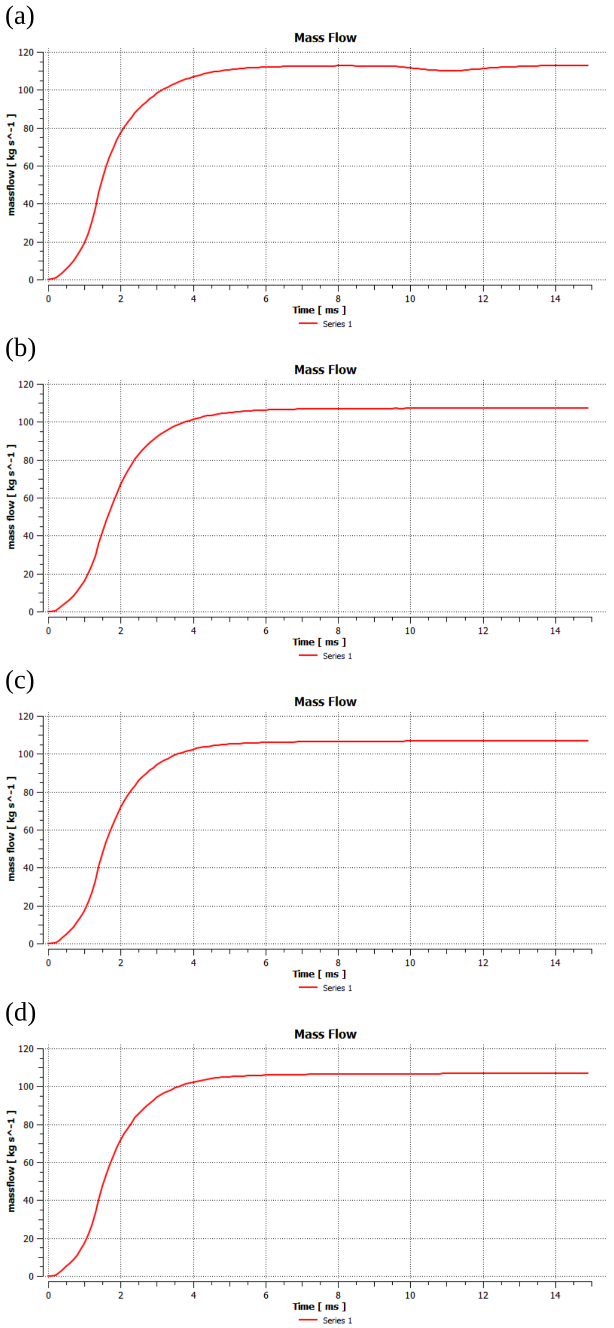


Fig. 10. Mass flow trend from break to ambient volume of (a) case 1 (b) case 2 (c) case 3 (d) case 4

In Figs. 3, 5, 7, and 9, it can be seen that all four geometries predict the water jet well. However, it can be checked from Figs. 2, 4, 6, and 8 that the phase change occurs around the water jet and the occurrence of the maximum Mach number in the vicinity of the phase change is observable only in cases 3 and 4. In cases 3 and 4, the maximum Mach number was about 0.97, but in cases 1 and 2, only about 0.75 was observed. On the other hand, in the case of mass flow in Fig. 10, it can be seen that cases 2, 3, and 4 predicted almost the same mass flow trends, whereas case 1 had an unstable values between about 10-12 msec.

3. Conclusion

Prior to the steam generator feedwater break accident analysis, the analysis according to the control volume size is performed using CFX 19.2 to simulate the free volume. Ambient control volume size is sufficient from a diameter of about 9 times the break diameter.

REFERENCES

[1] CFX-Solver, A. N. S. Y. S. "Modeling guide.". 2006.
[2] Kim, Jae-Hyung, Sun-Hun Woo, and Heuy-Dong Kim. "A CFD prediction of a micro critical nozzle flow." Proceedings of the KSME Conference. The Korean Society of Mechanical Engineers, 2001.