Sensitivity Study for Active Single Failure in the Intermediate Break LOCA

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1. Introduction

The emergency core cooling system (ECCS) is designed to cool the reactor core in design basis accidents such as loss of coolant accident (LOCA). The ability of ECCS is demonstrated to withstand the single active failure, such as the failure of a pump [1].

The draft rule for ECCS performance has been proposed, which is integrated with recent research findings such as cladding embrittlement mechanism [2]. In response to this new rulemaking, it is necessary to reconsider the ECCS performance evaluation methodology. LOCA has been classified as large and small break LOCA according to the break size and thermal-hydraulic phenomena, and only these accidents were analyzed.

This paper focuses on accident analysis of intermediate break LOCA (IBLOCA). In this study, peak cladding temperature (PCT) sensitivity study was performed according to the line location in which a single failure of high pressure safety injection (HPSI) system occurred during the IBLOCA.

2. Method

2.1. IBLOCA SPACE Model

The accident is simulated using the SPACE 3.3 version [3]. The Westinghouse 3-loop plant is selected as the reference plant. Table I shows the major hydraulic parameters compared with design values and SPACE steady state values, which the difference value is less than 4%. It is confirmed that SPACE model simulates the actual nuclear power plant normal operation state well. It is assumed that IBLOCA occurs at the cold leg located in the loop without pressurizer (PZR).

Table I: Comparison for Design Value and SPACE Steady-state Value

Parameter	Unit	FSAR	SPACE	Diff.
Core Power	MW	2830.5	2830.5	0.0%
Core Inlet Temp.	K	558.6	558.0	0.1%
Core Outlet Temp.	K	600.3	600.0	0.0%
PZR Pressure	MPa	15.5	15.9	-2.2%
RCS Flow Rate	kg/s	4293.2	4288.8	0.1%
2nd Pressure	MPa	5.8	5.5	3.8%
2nd Steam Flow Rate	kg/s	504.2	513.6	-1.9%

2.2. Sensitivity Cases

The sensitivity cases are classified to single failure of HPSI occurring at the broken-loop or intact-loop without PZR. The break size is expressed as % unit compared to the cold leg cross-sectional area and two break sizes are selected: 10% and 25% [4].

3. Result

The reactor coolant system pressure depressurizes as IBLOCA occurs at 0 second and low PZR pressure signal is generated. The reactor trip, main feed water pump and turbine trip signals are actuated subsequently. The safety injection signal is actuated with low-low PZR pressure signal, and HPSI pumps are started. The pressure on the primary side is lower than the accumulator (ACC) set pressure, and a large amount of coolant is supplied from the ACC to the primary system. After the coolant supply from the ACC is finished, HPSI system mainly cool down the core.

Figure 1 shows the maximum cladding temperature data and Figure 2 shows the collapsed water level of the core. In the case of 10%, the cladding temperature gradually decreases. In the cases of 25%, the PCT occurred at beginning of the accident and the minimum core water level, and the maximum PCT value is evaluated about 684 K at first peak in both cases. As coolant is supplied from the ACC, the core water level recovers and core temperature decreases.

Figure 3 shows the accumulated coolant mass of core inlet and break side, and Figure 4 shows the liquid volume fraction of core top cell in 25% cases. In the case Intact-loop, a smaller amount of coolant is supplied to the core than case Broken-loop, and a larger amount of coolant leaked out to the containment as shown in Figure 3. Although the difference is in the amount of coolant in the primary system depending on the location of the HPSI system single failure, the coolant is supplied to the top of the core in both cases due to the ACC operation. The PCT behavior shows very small difference by single failure location of the HPSI system.

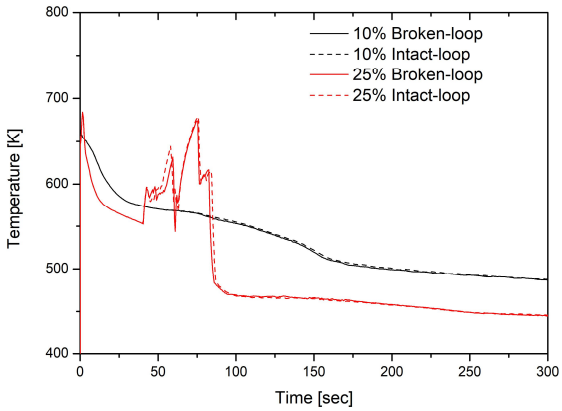

Fig. 1. Maximum Cladding Temperature

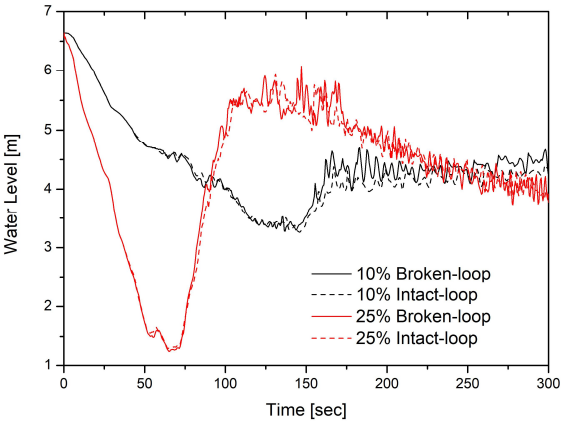

Fig. 2. Collapsed Water Level of the Core

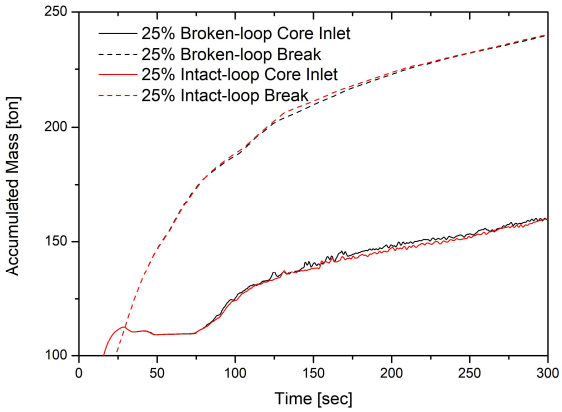

Fig. 3. Accumulated Coolant Mass of Core Inlet and Break Side

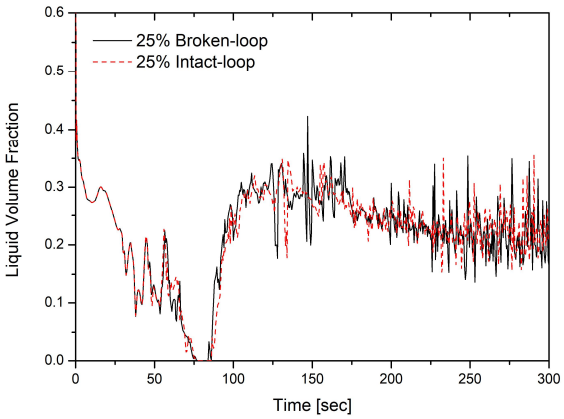

Fig. 4. Liquid Volume Fraction of Core Top Cell

4. Conclusion

In this study, PCT sensitivity study for location of HPSI system single failure during IBLOCA is performed. The PCT is evaluated about 684 K at beginning of the accident in both cases, which are case Intact-loop and Broken-loop. It seems that the PCT is affected very little by the location where the active single failure occurred and has sufficient safety margin.

ACKNOWLEDGMENTS

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