Severe Accident Analysis of SBLOCA sequences for SMART using MELCOR code

Jaecheol Kim[a*], Gunhyo Jung[a], Hanchul Kim[b]
[a]*FNC Technology Co., Ltd., Seoul National University, GwanakRo 599, GwanakGu, Seoul, Korea, 151-742*
[b]*Korea Institute of Nuclear Safety, 19 Guseong-dong, Yuseong-gu, Daejeon, Korea 305-338*
**Corresponding author: jc1466@fnctech.com*

1. Introduction

SMART (System Integrated Modular Advanced ReacTor) has a unique design concept adopting the integrated reactor system, the passive residual heat removal system, and so on. The severe accident analysis for SMART is needed to prepare the safety review and the licensing. For the safety review of SMART design, identifying the safety issues in the early design stage is necessary because it helps to prevent the unexpected cost increase and the delay of a SMART licensing schedule.

In this paper, MELCOR1.8.6 model [1] for SMART severe accident was developed and the severe accident analysis of SBLOCA (Small Break Loss of Coolant Accident) sequence was performed for 1 and 2 inches break size in diameter at the safety injection system pipe. As major concerns, the reactor vessel failure, RCS pressure, containment pressure, etc. were discussed.

2. Methods and Results

2.1 MELCOR1.8.6 Model for SMART

As shown in Figure. 1 [2], SMART is the small and medium power reactor that the core, RCS (Reactor Coolant System) pumps, SGs (Steam Generators), and the pressurizer are designed in a reactor vessel. To improve the safety performance, SMART is designed to introduce passive safety technologies. The safety system of SMART consists of passive residual heat removal system and safety injection system.

Considering these systems and the characteristics, the MELCOR1.8.6 model for SMART was developed for the severe accident analysis. In Figure 2, SMART primary side consists of the reactor core, RCS pumps, SGs, the pressurizer, flow mixing header assembly, and lower plenum. The volumes of the reactor core and the lower plenum were modeled by the 14 axial levels (10 core cells, 4 lower plenum cells), 8 radial rings. The 4 pumps were simulated as one with respect to the total capacity.

As a heat transfer boundary between the primary side and the secondary side, helical tubes in SG cassette were modeled. However the heat transfer model of MELCOR 1.8.6 cannot support helical tube type. In this paper, the helical tubes were modeled simply as the cylindrical type and the effective heat transfer of helical tube was additionally considered. In the secondary side, SG cassettes, total 4 SG tubes lines were modeled to remove thermal energy from reactor coolant in primary. To maintain the constant flow rate in helical tube, the coolant mass source volume was modeled, and the coolant mass sink volume was modeled as the turbine in SG tube outlet side.

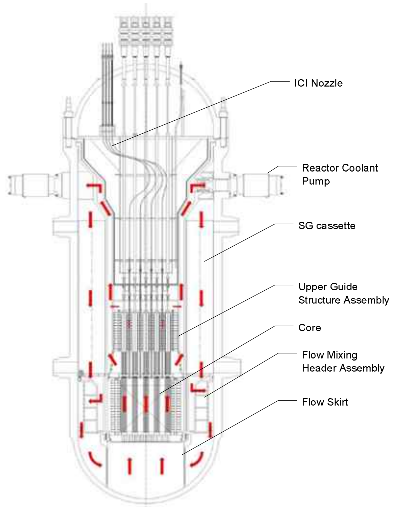

Fig. 1. Flow path of the SMART reactor vessel assembly

2.2 Accident Sequence and Calculations

The LBLOCA is not considered because SMART is the integrated system without large diameter pipe. In this paper, as a representative low pressure sequence, the SBLOCA sequence was selected, that is, in this sequence, all engineered feature systems such as SI, SDS, PRHRS, CFS, CSS, etc. are not available.

On the top of the core support barrel, the 2 inches diameter pipe is connected to SCS, SIS, and CVCS. So, in the SBLOCA sequence analysis, it is assumed that this 2 inches pipe is ruptured.

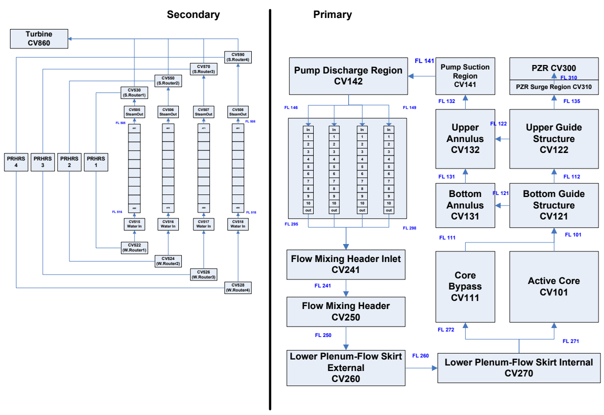

Fig. 2. Nodalization of the SMART MELCOR model

Table I. Major event occurrence time

Event	1 inches case (s)	2 inches case (s)
SBLOCA	0	0
Reactor Trip	152	37
RCP Trip	1,059	317
Cladding Temperature 1477 K	31,965	19,978
Core Uncovery	62,173	54,134
Vessel Creep Rupture	112,440	101,056

The flow path from pump discharge region to the containment was modeled and the calculations were performed for 1 and 2 inches break.

3. Results

Table 1 shows the occurrence times of major events. After SBLOCA initiation, the phenomena of the reactor trip, increase of cladding temperature, core uncovery, molten corium relocation, and vessel creep rupture were occurred successively. The creep rupture times of the reactor vessel for 1/2 inches break were estimated that are 11,440/101,056 seconds, respectively. This creep rupture times can be confirmed using the liquid level in Fig 3 where the liquid level is decreased by coolant vaporization due to the decay heat and then no coolant is in the reactor vessel.

Fig 4 and Fig 5 indicate the calculation results of RCS pressure and containment pressure. In Fig 4, it is estimated that the RCS pressure in case of 1 inch break is gradually decreased while the RCS pressure in case of 2 inches break is rapidly decreased. Also in Fig 5, the containment pressure is increased by pressure loading from RCS due to the ejection of steam with the high pressure and temperature. Fig 6 shows the H_2 mole fraction in containment which is generated by interaction between high temperature steam and cladding material (Zr). In results of comparing the time of H_2 generation in Fig 6 with the arrival time of 1477K cladding temperature in Table 1, it can be confirmed that each value are similar.

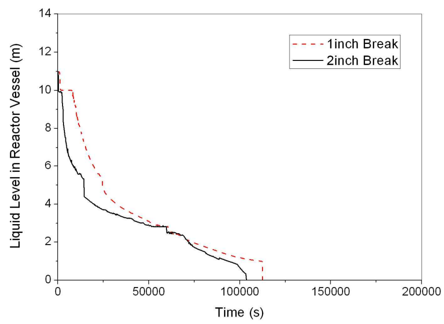

Fig. 3. Liquid level in reactor vessel

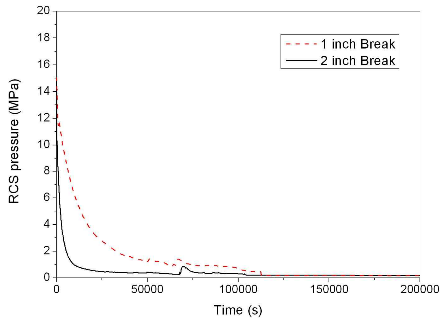

Fig. 4. RCS pressure

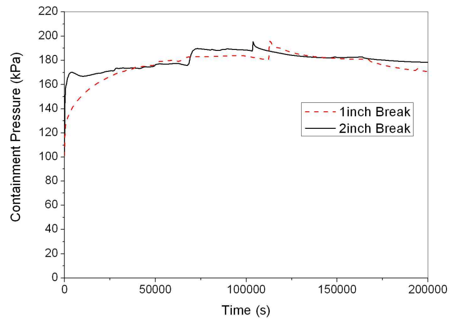

Fig. 5. Containment pressure

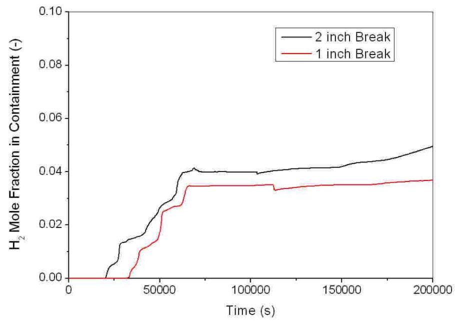

Fig. 6. H_2 mole fraction in containment

4. Conclusions

In this paper, the MELCOR1.8.6 model was developed and the sever accident analysis of SMART were performed for SBLOCA sequence, and the accident sequence of SBLOCA, RCS and containment pressure, and H_2 generation are simply analyzed. To estimate the SMART safety for severe accidents using this MELCOR1.8.6 model, the accident sequences in Level 1 PSA report [3] such as LOFW, SBO, SGTR, GNTR, etc. should be evaluated in detail.

REFERENCES

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