Simulation of a Station Blackout Accident for the SMART with a Core Flow Blockage using the CINEMA Code

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1. Introduction

An integrated severe accident analysis code, named as CINEMA (Code for INtegrated severe accidEnt Management and Analysis) [1] is used to calculate the severe accident sequence caused by a station blackout (SBO) accident in the SMART reactor [2]. As the validation process for application of the CINEMA code to the SMART is under way, we investigated one of the interesting effects, a core flow blockage which accounts for increase of flow resistance in severely degraded geometries that will arise during a SBO accident.

The present calculation is based on the preliminary design of DL3 (Design Level 3) and restricted to the "in-vessel phase" just before a vessel failure.

2. Analysis and Results

2.1 Assumptions for SBO scenario

The CINEMA calculation has been performed assuming a SBO scenario (loss of the offsite power concurrent with a turbine trip and unavailability of the emergency AC power system), leading to unavailability of all safety injection systems.

The flow path between upper guide section and core support barrel is closed when the void fraction goes up to 99% in the lower plenum for simulating flow blockage by a degraded core geometry.

2.2 Accident sequence

As the SBO transient starts at problem time of 0.0 second, the reactor trip occurs followed by RCP trip, an isolation of feed water, and a turbine trip. The main events during this sequence are shown in Table I. The entry of Severe Accident (SA) is started when the core outlet gas temperature reaches 923 K.

Table I: Time Table of the Main Events for SBO

Main event	Time (sec)
Reactor trip	0
Main feed water isolation	0
RCP trip	0
PZR safety valve opening	1,150
Core uncovery	10,920
Fuel rod dry-out	15,650
SA entry (Core outlet gas temp. 923.K)	19,580
ADS opening (30 min. after SA entry)	21,380
Relocation	25,230
RV rupture	43,230

After 30 minutes of SA entry ADS valves are opened. The failure criteria of reactor vessel is melting conditions of a component material (carbon steel).

2.3 Sensitivity of flow blockage

As shown in Figure 1, the RCS pressure remains high (17.27 MPa, which is the pressurizer (PZR) safety valve (PSV) opening pressure) due to the opening/closing of the PSV until the time of ADS valve opening (21,380 seconds for reference case with flow blockage). Comparing with the case with flow blockage, the consequence of the case without flow blockage is more delayed, where the ADS valve opening occurs at 22,250 seconds.

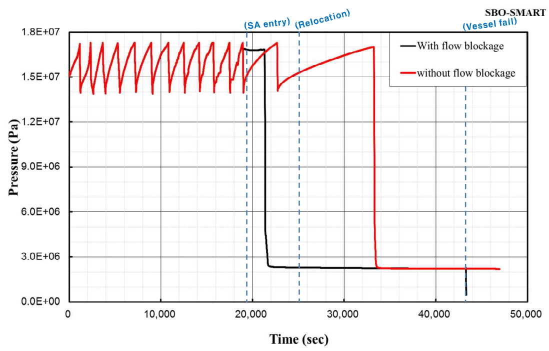

Fig. 1. Comparison of the primary pressures between the models with (base case) and without flow blockage.

The flow blockage in the degraded core limits the natural circulation flow[3] available to carry away decay heat. This limitation of cooling by natural circulation enhances the core heat-up as shown in Figure 2.

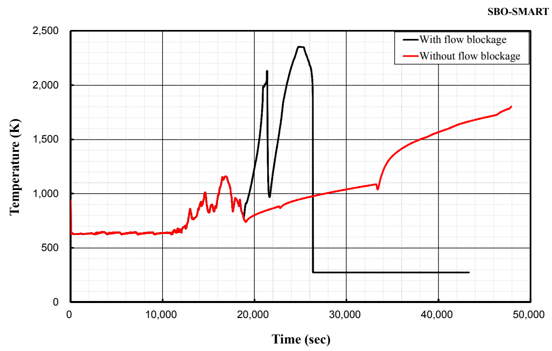

Fig. 2. Comparison of fuel temperatures (centering at 4/5 elevation) between the models with (reference) and without flow blockage.

2.4 Trend of main safety parameters

In this section the results of main safety parameters for SBO calculation with the case of flow blockage are described.

The RCS level (Figure 3) is a factor that shows the key information from an accident sequence perspective, such as core uncovery and fuel rod dry out. The water level decreases with sequentially from the upper plenum, to active core, and to lower plenum. Core uncovery starts at 10,920 seconds when the level reaches top of active core.

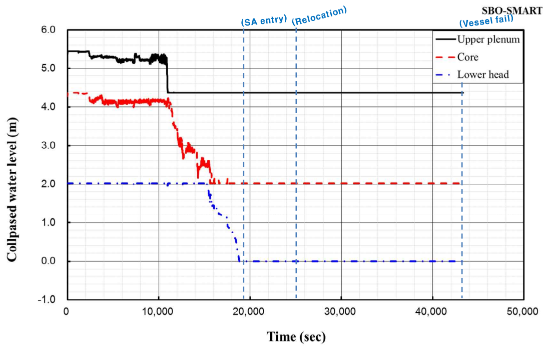

Fig. 3. Water level in the vessel.

Followed by SA entry (19,580 seconds) hydrogen generation starts in the vessel at 19,600 seconds as shown in Figure 4. Maximum generation rate is 0.27 kg/sec. A total mass of hydrogen is calculated as 62 kg.

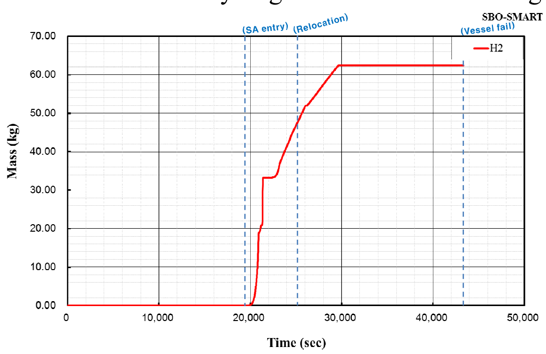

Fig. 4. Hydrogen generation.

Wall temperature increases after relocation of corium.

The vessel failure occurs after reaching a melting temperature of 1,673 K at 43,230 seconds.

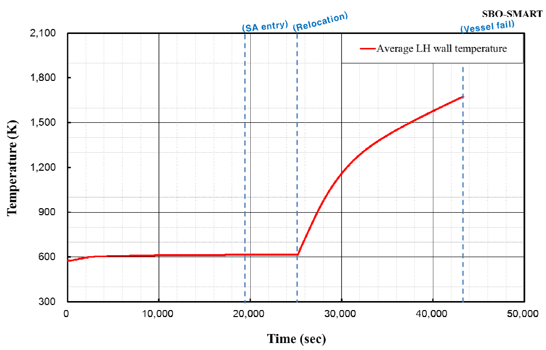

Fig. 5. Wall temperature of lower head.

Metal corium (7.8 ton) and oxide corium (11.9 ton) are generated as shown in Figure 6. Metal corium made of zircaloy, stainless steel, and inconel is relocated earlier (25,230 sec) than oxide corium (25,530 sec) with a relatively higher melting temperature.

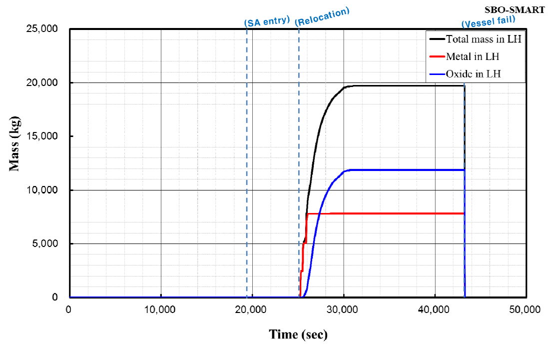

Fig. 6. Corium mass.

3. Conclusions

From the present simulation of the SBO accident for the SMART, inclusion of flow blockage effects in the CINEMA code has been found to improve code predictions accounting for limitation of natural circulation and enhancing the core heat-up. The flow blockage in the degraded core limits the natural circulation flow available to carry away decay heat and to provide steam for core oxidation.

For the future work the final design (DL2) will be applied to the CINEMA input model and its calculation results will be compared with MELCOR [4] results. This study will contribute to the validation of the CINEMA code for severe accident analysis of the SMART.

ACKNOWLEDGMENTS

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