The Corium Spreading in the Reactor Cavity During Severe Accident in the SMART

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1. Introduction

SMART (**S**ystem integrated **M**odular **A**dvanced **R**eac**T**or), is under development at the Korea Atomic Energy Research Institute (KAERI). The thermal power is 330 MWth. SMART is an integral type pressurized water reactor which contains a pressurizer, 4 reactor coolant pumps (RCPs), and 8 steam generator cassettes(S/Gs) in a single reactor vessel[1]. This reactor has substantially enhanced its safety with an integral layout of its major components, 4 trains of safety injection systems (SISs), and an adoption of 4 trains of passive residual heat removal systems (PRHRS) instead of an active auxiliary feedwater system .

The possibility of severe accident in the SMART is determined very low[2]. Furthermore, SMART has adopted the strategy to hold the corium within the reactor vessel through the external vessel cooling even though the possibility of core damage is very low.

An assessment of the performance of the designs under postulated severe accidents includes the demonstration that the coolability of the core materials can be assured if melt is released from reactor pressure vessel into the below-vessel cavity region, in spite of extremely low probability of reactor vessel failure. A computer code, MELTSPREAD-1[3], which is developed at Argonne National laboratory, is used to predict whether or not the melt will spread to cover the full floor area, to determine the local distribution of spread material depth and the corium layer coolability.

2. SMART Cavity Nodalization

The SMART vessel lower head does not have any penetrations. Consequently, the lower head failure is assumed to result from the creep rupture of the lower head. So a hole diameter of the lower head at the time of creep rupture is assumed to be a relatively large diameter of 0.5m. The reactor cavity is filled with water and the depth is 6.6m. The vessel is located only 1.7m above the floor. So conditions of melt arrival on the floor are not expected to differ significantly from the melt release conditions shown in Table 1. The geometry of the SMART reactor cavity is square and the length of a side is 8 m. A depiction of the nodalization scheme used for the MELTSPREAD-1 code is shown in Fig. 1. Melt is assumed spread symmetrically in a 360^o sector. A total of 8 numerical mesh cells which areas are same, were employed.

Table 1. Conditions for MELTSPREAD-1 Calculations

	Case 1	Case 2
Released Melt Mass, kg	37,160	37,160
Melt Release Time, s	10	10
Melt Composition, kg		
- Zr Metal	2,540	2,540
- ZrO_2	3,320	3,320
- UO_2	16,800	16,800
- Steel	14,500	14,500
Melt Temperature, K	2885	2370
Water Present	yes	yes
Initial Water Subcooling, K	21.6	21.6
Cavity Pressure, MPa	0.3	0.3
Concrete Composition	basalt	basalt

3. Results

The first calculation for SMART is for the case of a UO_2-ZrO_2 oxide freezing range and a superheat of 12 K. Figure 2 shows the calculated distribution of spreading layer elevation, substrate height, and spreading layer temperature at just 1 second after the completion of melt release (11 seconds from initial melt release). Melt arrived to the cavity wall at 6 seconds after the initial melt release. Initial freezing of the spreading layer is predicted to occur at radii near the cavity wall during first 20 seconds following melt release, due to heat transfer to the water and underlying steel-lined concrete. The relocating melt is not quenched (i.e. the temperature remains above the melt solidus temperature) and spreads over the full cavity floor. By 21 seconds, the melt layer depth within the cavity region is approximately uniform as shown Fig. 3.

For Case 2, the melt is assumed to arrive on the floor in the form of the liquid-solid slurry with a solid fraction of 0.5 and a mean melt temperature of 2370 K. The melt is calculated to spread only to the region 5. When the melt release ended, the melt in the region 4 and 5 became solid. The melt is piled up in the ring 1 due to the low temperature of the melt, as shown Fig. 4.

4. Conclusions

The behavior of melt spreading in the cavity was examined using MELTSPREAD-1 code for SMART. The spreading behavior is sensitive to the temperature of melt. When the melt temperature is assumed to be 2885 K, the melt spread uniformly all over the full cavity floor. The height of melt layer is approximately 9 cm. When the melt temperature is assumed to be 2370 K, the melt spread to the region 5 only and the maximum depth of melt layer reached 12 cm. Regardless of the melt temperature, the depth of melt layer is thin and cooled by the overlying water.

REFERENCES

[1] SMART Reactor System Description, KAERI, 2010
[2] SMART SSAR Ch. 19, KAERI, 2010
[3] The MELTSPREAD-1 Computer Code for the Analysis of Transient Spreading and Cooling of High-Temperature Melts, TR-103413, EPRI, 1993

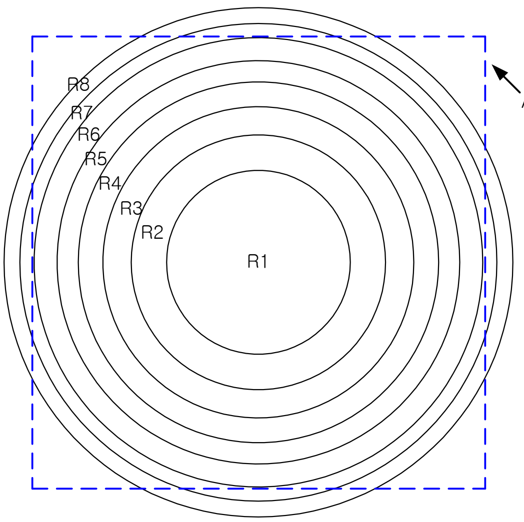

Fig. 1 Depiction of nodalization scheme for the SMART cavity region

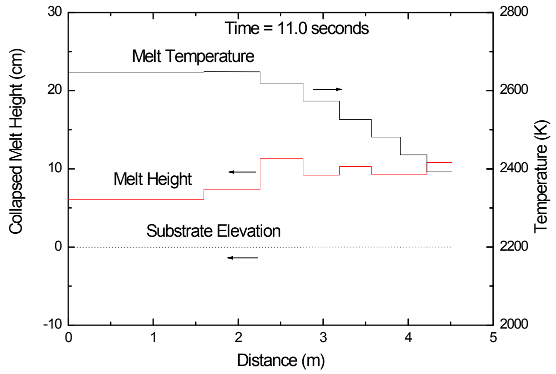

Fig. 2 Predicted melt spreading layer height, substrate elevation, and melt temperature at 1 second after the completion of melt release for SMART (Case-1)

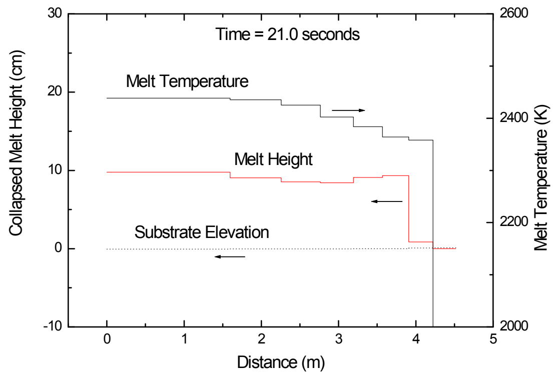

Fig. 3 Predicted melt spreading layer height, substrate elevation, and melt temperature at 11 second after the completion of melt release for SMART (Case-1)

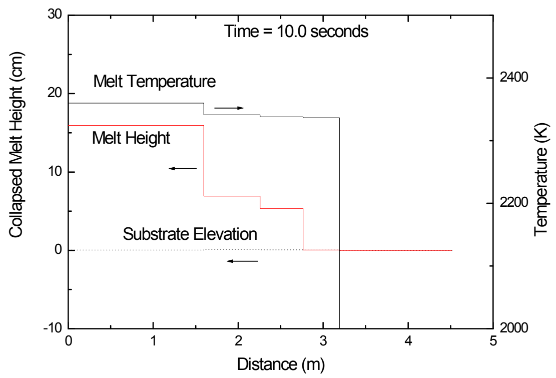

Fig. 4 Predicted melt spreading layer height, substrate elevation, and melt temperature at the completion of melt release for SMART (Case-2)