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Validation test of computational code for corium pool behavior in the lower plenum of the reactor pressure vessel against LIVE experiments

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1. Introduction

Thermo hydraulic behavior of molten core materials in the severe accident of nuclear power plant is one of important research subjects in nuclear safety field. So far, severe accident analysis codes (MAAP, MELCOR, ASTEC, etc.) were validated against various experiments (PHEBUS, LIVE, LHF, etc.) or real plant accidents (TMI-2, Fukushima). Nowadays, Korean severe accident analysis code COMPASS (COre Meltdown Progression Accident Simulation Software) is being verified and validated against various experiments and numerical simulations [1, 2].

The corium pool behavior in the lower plenum of the reactor pressure vessel was validated against LIVE experiments, performed by KIT in Germany. For instance, LIVE L1 and L3 tests were validated with their new version of MAAP5 [3]. Therefore, the objective of present study is to validate COMPASS against the LIVE experiments performed by KIT.

2. Numerical methods

As a part of COMPASS, SIMPLE (Severe In-vessel Melt Progression in Lower plenum Environment) calculates the lower plenum thermal hydraulics as well as the molten pool behavior after the melts relocated into the lower plenum from the core support plate during severe accidents [4]. The scope and range of SIMPLE calculation eventually covers to the lower head vessel failure.

2.1 Lower plenum model of COMPASS

SIMPLE calculates the thermal hydraulic behavior of the relocated molten material in the lower plenum based on the following steps [4].

- Read inputs for the geometry and thermal dynamic variables
- Initialize the geometry and state variables
- Read inputs for the core melt relocation history into the lower plenum
- Coolant evaporation from the melt jet
- Debris formation, heat-up and melting
- Molten pool formation and separation
- Metallic pool formation and mass/heat transfer
- Oxidic pool behavior and mass/heat transfer
- Lower plenum water level
- Output File for Plot variables

2.2 Initial and boundary conditions

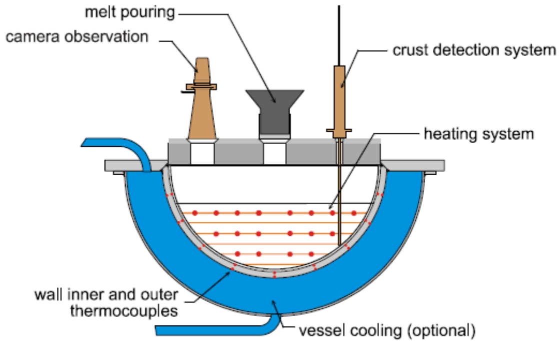

Figure 1 Schematic of the LIVE test vessel with some instrumentation.

LIVE L3A and L6 were simulated with SIMPLE code. L3A is similar to the L3 and L6 is a representative two-layer experiment. Figure 1 shows the schematic of the LIVE test facility. Corium pool (mixture of 20% $NaNO_3$ and 80% KNO_3) is heated by the heating wires, to mimic the decay heat of the corium. In the case of L3A, total mass of the pool is 224.4 kg, with the pouring rate of 6 kg/s and the pool temperature is 623K. The heating power is 10 kW until 90237 second and decreases 7kW after then. Detailed experimental conditions are available in the literature [5]. For the case of L6, literature shows the experimental and calculation results of LIVE [6, 7].

3. Results

3.1 LIVE L3A test

Figure 2 shows the temperature of the corium pool in the case of LIVE L3A. Present simulations show good agreement with the result of LIVE. Although SIMPLE does not calculate the temperature gradient inside of the corium pool, the average temperature ranges between the measured values.

Figure 3 shows the heat fluxes measured at different locations of the corium pool. In general, the heat flux is higher at the top location of the pool. Present calculation shows a good agreement with respect to the experiment.

Figure 4 is the crust thicknesses at the different angles on the RPV wall. Crust grows thicker when the angle decreases. At center, the angle is 0. SIMPLE overestimated the crust thickness than the experiments; it is because of underestimated wall temperatures.

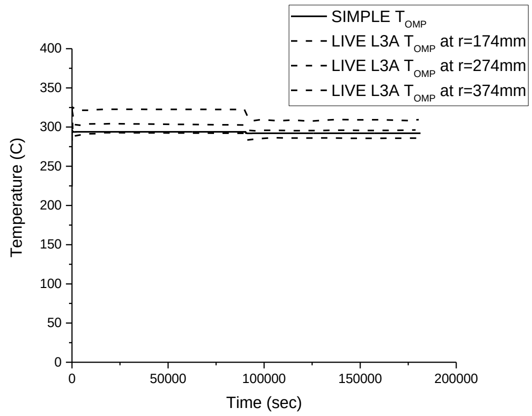

Figure 2 Temperatures of the corium pool (LIVE L3A).

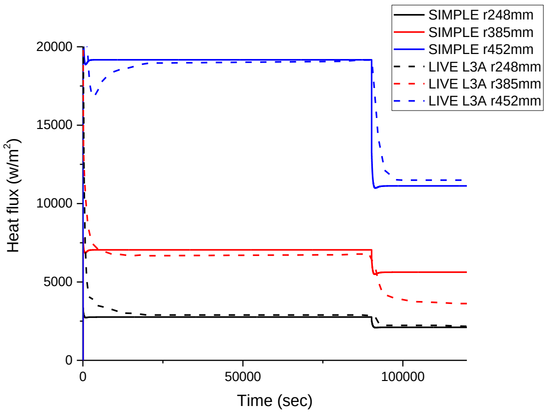

Figure 3 Heat flux behavior of the pool at several locations (LIVE L3A).

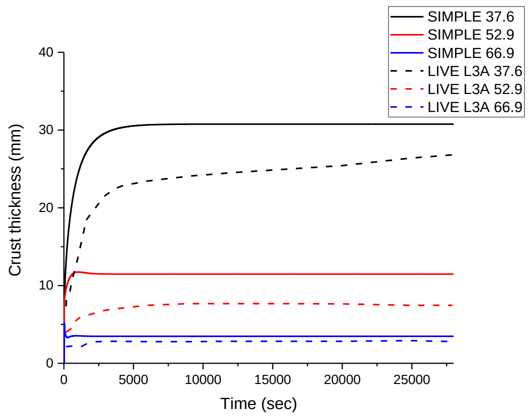

Figure 4 Crust thicknesses at various locations (LIVE L3A).

3.2 LIVE L6

LIVE L6 is a two separated pool experiment, with time varying heating power to the corium pool. Figure 5 shows the heat fluxes at different locations. As shown, the heating power is changed in 3 different values. At the higher location of the corium pool, heat flux to the RPV wall increases.

Figure 6 is corresponding crust thickness at different locations. As opposed to the heat flux, crust thickness increases when the heating power decreases. At the bottom position of the pool, the crust thickness is maximized. As compare to the result of LIVE L6, present result shows reasonable similarity.

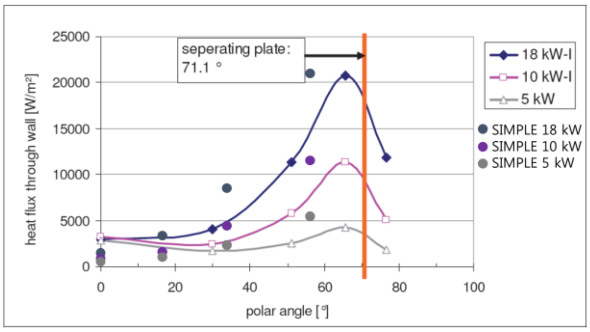

Figure 5 Comparison of the heat fluxes at the different locations of the RPV wall with SIMPLE and LIVE L6

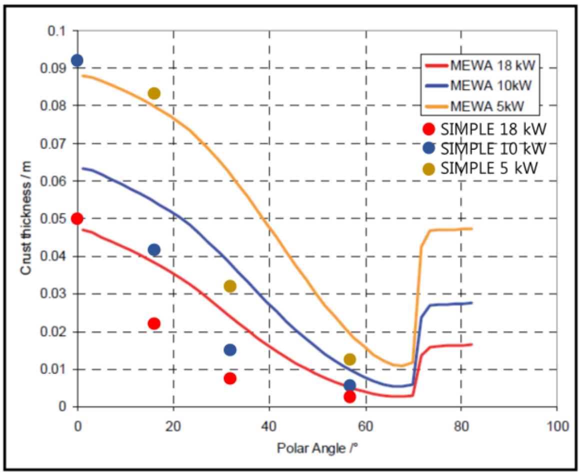

Figure 6 Comparison of the crust thicknesses at different locations of the corium pool with SIMPLE and LIVE L6

3. Conclusions

A validation test of the corium pool experiments LIVE L3A and L6 was performed by the Korean severe accident analysis code SIMPLE. Representative single pool (L3A) and two separate pool (L6) experiments were simulated, and the results showed reasonable similarity of SIMPLE and LIVE experiment. Further verification and validation works will be performed in the next phase.

ACKNOWLEDGMENTS

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