Contribution ID: **336** Type: **ORAL**

Experiment and Numerical Simulations on SFR Core-catcher Safety Analysis after Relocation of Corium

Friday, 22 April 2022 11:54 (12 minutes)

An In-vessel core catcher located in European type SFR is a safety design feature to guarantee the integrity of the SFR during a core-melting accident. The core catcher collects and distributes the relocated melt from the core region via discharging tubes to avoid firstly a significant molten pool in the core, and secondly the local thermal attack on bottom part of the vessel. The heat transfer and ablation behavior of core-catcher material under the thermal load of the core melt at high-temperature and with high decay heat will be studied experimentally with a new facility in Karlsruhe Institute of Technology and numerically in CEA within the ESFR-SMART European project.

The new facility, named ESFR-LIVE, is a 3-dimensional model of Core-catcher in a length scale of 1:6. The lower part of the tray-type core-catcher is a truncated cone and the upper part is a cylinder with 1 m diameter. The cooling of liquid Na at all boundaries is simulated by a water cooling channel enclosing the test vessel, and a cooling lid at the upper surface of the simulate. Four planes of individually controllable heater in the vessel enable the variation of the height of the core melt, and the shapes of the melt pool. The distribution of bulk temperature, boundary temperature, wall temperatures and heat flux can be measured or determined. The simulant of core-melt is the eutectic NaNO3-KNO3 mixture, which is representative for the character of the general liquid oxide melt. Similarity comparisons on geometry, material properties and heat transfer features are presented in this paper. With the similar pool height, the EFSR-LIVE facility can well capture the dimensionless heat transfer features, e.g. Ra and Nu.

Computational Fluid Dynamics (CFD) pre-calculations of the LIVE-ESFR experiments will be performed on the basis of the ESFR-LIVE test conditions. These simulations will be performed with the TrioCFD code using High Performance Computing on ten million of mesh nodes. A parametric study according to the heating power distributions will be presented.

Regarding the turbulent flows with large Rayleigh numbers, these simulations require to use Large Eddy Simulation (LES) models. This study is supplemented by a mesh resolution analysis and a validation of TrioCFD on natural convection turbulent flows using past molten-pool experiments (BALI) and academic results.

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Session Classification: 2.4 Severe Accidents

Track Classification: Track 2. Fast Reactor Safety