Estimation of the In-Depth Debris Status of Fukushima Unit-2 and Unit-3 with Multi-Physics Modeling
(10) Evaluation of debris relocation and interaction with pedestal structures in Fukushima Daiichi Unit-3 with MPS method

*Xin Li[1], Akifumi Yamaji[1], Ikken Sato[2], Masahiro Furuya[1], Hiroshi Madokoro[2], Yuji Ohishi[3]
[1]Waseda Univ., [2]JAEA, [3]Osaka Univ.

The Moving Particle Semi-implicit (MPS) method is developed to simulate debris relocation and interaction with pedestal structures in Fukushima Daiichi (1F) Unit-3 [1]. Different debris distributions and structure damages are evaluated with different debris relocation amount / intervals and convective vapor cooling from the debris surface.

Keywords: severe accident, decommissioning of Fukushima Daiichi (1F) reactors, numerical simulation, MPS method

1. Introduction

In decommissioning of Fukushima Daiichi (1F) Nuclear Power Plants, knowledge of the in-depth debris status within the pedestal regions of the damaged reactors must be gained. For 1F Unit-3, the 2-3 m sedimentation in the pedestal indicates the possibility that the oxidic debris interacted with the pedestal structures at low superheat and mobility, which hindered some of the debris to reach the pedestal floor. The meshless, Lagrangian MPS method developed for simulation of multi-component liquid/solid interactions with phase changes has been applied to simulate such scenarios.

2. MPS method and developed models

Fig. 1 summarizes the improved MPS method with new models and techniques for improved numerical stability and calculation efficiency.

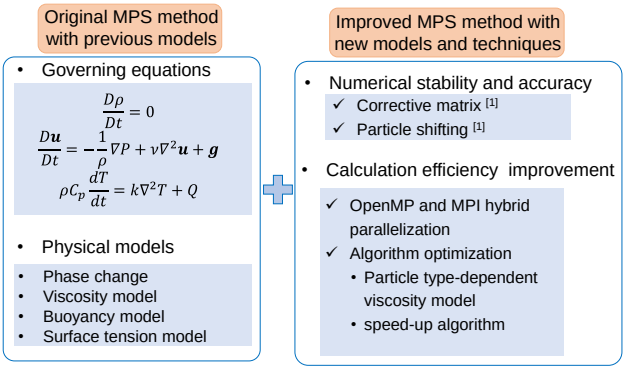

Fig. 1 MPS method and improved models

3. Simulation of debris relocation and distribution in the 1F Unit-3 pedestal region

The debris relocation, distribution, and interaction with structures in the 1F Unit-3 pedestal region are simulated in a 1/10 scaled geometry. 56% of the total fuel debris in Unit-3 was assumed to relocate from the RPV to the pedestal region during the major debris relocation period (i.e. for 75 min from ca. 5:20 to 6:35 on March 14th, 2011). Sensitivity analysis cases with different 1) debris initial temperature and viscosity, 2) relocation amount/intervals, and 3) convective vapor cooling from the debris surface have been performed. The simulation results show that 1) the less the debris injection amount per injection cycle and the stronger the vapor cooling are, the less pedestal structure damage and more debris mass distribution on/above mid-level work platform occur; 2) pedestal structures are more likely to survive if most debris can “bypass” them without direct thermal interactions.

4. Acknowledgement

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References

[1] Li, X., et al., 2021. Estimation of the In-Depth Debris Status of Fukushima Unit-2 and Unit-3 with Multi-Physics Modeling (7) Preliminary evaluation of debris relocation and interaction with pedestal structures in Fukushima Unit-3 with MPS method. AESJ 2021 Annual Meeting, Mar. 17 - 19, online.