Estimation of the In-Depth Debris Status of Fukushima Unit-2 and Unit-3 with Multi-Physics Modeling
(14) MPS Analyses of Debris-pedestal Structure Interactions of Unit-3

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The debris-structure thermal status during the re-heating period (i.e., March 16th-19th, 2011) of Fukushima Daiichi (1F) Unit-3 pedestal is evaluated with Moving Particle Semi-implicit (MPS) method. For the assumed range of the environment conditions, melting of the structure / re-melting of the debris is unlikely after the relocation of the debris to the pedestal.

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

1. Introduction

For 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 debris interacted with the pedestal structures at low superheat and mobility. The meshless, Lagrangian Moving Particle Semi-implicit (MPS) method developed for simulation of multi-component liquid/solid interactions with phase changes has been applied to simulate such scenarios. The previous study [1] has shown that only limited melting of structures occurred over 75-minute relocation phase (ca. 5:20 to 6:35 on March 14th, 2011) if the environment temperature in the pedestal did not exceed 1000 K. This study will examine the debris-structure thermal status during the re-heating period (i.e., March 16th-19th, 2011) in which cooling could be limited with different representative debris distributions obtained in the previous study.

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.

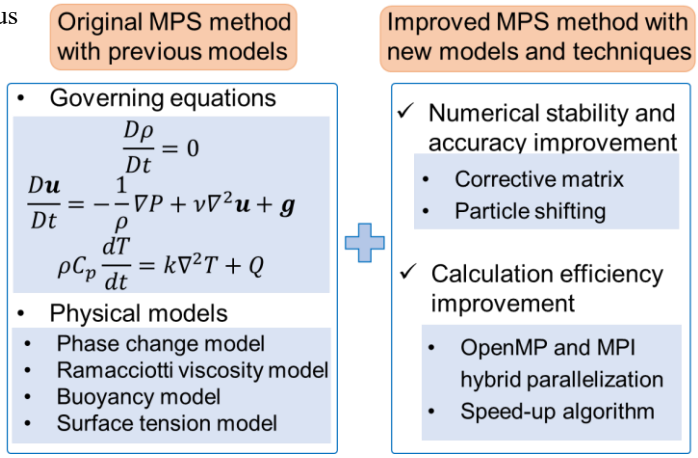

Fig. 1 MPS method and improved models

3. Simulation of debris re-heating phase in the 1F Unit-3 pedestal region

The representative debris distributions in a 1/10 scaled geometry obtained in the previous study were used for the current study. Radiative heat transfer and convective vapor cooling boundaries are applied on the free surfaces of debris and structures. Sensitivity analysis cases with different environment/background temperatures show that 1) thermal equilibrium can be reached for each case in 6-7 hours without significant melting of pedestal structures and 2) assuming emissivity of 0.5 for debris and structure, if the pedestal background temperature is around 1300 K or less, structure melting is not expected even if the debris/structure to vapor heat transfer coefficient is low (below 10 W/m^2/K or less).

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References

[1] Li, X., et al., 2021. Estimation of debris relocation and structure interaction in the pedestal of Fukushima Daiichi Nuclear Power Plant Unit-3 with Moving Particle Semi-implicit (MPS) method. *Annals of Nuclear Energy*, p.108923.