Over View Report 1 MEXT's Nuclear Joint Research Collaboration

Collaborative research between ICL and UT on severe accident phenomena simulation and experiment

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1. Introduction

Boron carbide (B4C) and stainless steel (SS) are the main control-rod materials used in boiling water reactors. The melting temperature of the mixed eutectic material between B4C and SS is lower than the original melting point: approximately 1473 K, which is the lowest one among those of the reactor components. Therefore, they were expected to be the first materials to melt among the reactor components that affected the subsequent severe accident progression and the final state of fuel debris in the Fukushima accident. In this collaborative research, the relocation phenomena during severe accident had been numerically and experimentally investigated under collaboration between Imperial College London (ICL) and The University of Tokyo (UT).

2. Results

2-1. Visualization Experiment

For the validation data of eutectic phenomena, relocation visualization experiment had been carried out by UT. Stainless tube with around 4 to 6 mm had been heated up by tungsten heater from outside. Inside of the tube, B4C powder had been filled with 30% of void fraction. Temperature of the tube were monitored by Thermocouple and kept around 1470K. With heating up the test tube, the eutectic phenomena between SUS and B4C caused the liquefaction of the metal. In some cases, the relocation of the liquefied metal was observed. With analyzing the images, the Verification database had been constructed. The detail of the experimental results was reported in several papers [1][2].

2-2. Numerical Simulation

MPS (Moving Particle Semi-Implicit) technique had been applied to simulate the large deformation during the relocation. To simulate the heating by radiation heat transfer, heat flux boundary condition model had been developed and verified by theoretical heat input condition[3]. Then, the code had been applied to visualize the eutectic phenomena and following relocation phenomena. MPS development were mainly carried out by UT. While, Adaptive refinement FEM technique had been developed by ICL. Using the ARFEM, UT’s relocation visualization experiment had been simulated. The qualitative relocation phenomena agreed with the experiment. However, more modeling and code development were needed for the quantitative validation.

2-3. Human Resource Development

Under the collaboration between ICL and UT, UT students got many awards including international conference awards. Students published several papers related to this collaboration project.

3. Conclusion

The collaboration project between ICL and UT was very successful. We had progress on the severe accident phenomena, especially Eutectic and Relocation. Also, the advanced Numerical simulation codes were developed. The collaboration between ICL and UT will continue to understand the severe accident phenomena, and to improve nuclear system’s safety.

Acknowledgement

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List of publication

[1] S. Ueda, H. Madokoro, B. Jo, M.Kondo, N. Erkan and K. Okamoto, “Time-resolved visualization technique for eutectic reaction between boron carbide and stainless steel at high temperatures,” *Mechanical Engineering Letters*, **2**, 15-00056, (2016)

[2] S. Ueda, H. Madokoro, B. Jo, M. Kondo, N. Erkan, K. Okamoto, “Dynamic visualization of eutectic reaction between boron carbide and stainless steel,” *J. Nuclear Sci. Technol.*, **54**, 81-88 (2017)

[3] K. Takabatake, X. Sun, M. Sakai, D. Pavlidis, J. Xiang, C.C. Pain, “Numerical study on a heat transfer model in a Lagrangian fluid dynamics simulation,” *Int. J. Heat Mass Transf.*, **103**, 635-645 (2016)

List of student awards

- S. Ueda, Fellow Award, *Atomic Energy Society of Japan* (2017)
- K. Takabatake, Best Presentation Award, *AESJ Simulation Engrg. Div.* (2017)
- S. Ueda, Best Presentation Award, *AESJ Thermal-hydraulic Div.* (2016)
- S. Ueda, Encouragement Award, *Conf. for R&D Initiative on Nuclear Decommissioning Technology by the Next Generation (NDEC-1)*, Sendai （2016)
- S. Ueda, Best Paper Award, *8th XJTU-UT-SJTU symposium on Nuclear Technology* (2015)
- K. Takabatake, Special Student Award, *Chemical Engineering Society, Gumma Workshop* (2015)
- K. Takabatake, Best Student Presentation Award, *3rd Japan-China Academic Symp. on Nuclear Fuel Cycle* (2015)