論 文 の 内 容 の 要 旨

論文題目　Development of Moving Particle Semi-Implicit Method for Simulating Sodium-Water Chemical Reactions in SFR

（高速炉におけるナトリウム―水反応に関する粒子法シミュレーションの開発）

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Liquid sodium as the excellent coolant in the Sodium-cooled faster reactor has the superiority of high thermal conductivity and a large margin to sodium boiling, while it also poses safety issues due to its intense chemical reactivity with water and oxygen. Experimental investigation on the sodium reactivity is limited by the opaque property of liquid sodium. Particle methods are superior to field approaches for investigating sodium-water reaction in terms of its simplicity for modelling chemical reaction without restriction by the flow regime. In the present thesis, a multi-disciplinary, multi-component and multi-phase methodology using the moving particle semi-implicit method (MPS) for simulating sodium-water reactions has been proposed.

The original MPS method was developed for the free-surface flow simulation, whereas it suffers from the limitation of being not applicable to a multiphase and chemical reaction models. To start with, the original MPS is extended with the capability of simulating multi-density flows with high stability, through suppressing the pressure oscillation with modifications on pressure gradient and poison equations. Moreover, a contoured surface tension model with a proposed approach of curvature calculation is applied for depicting the multiphase model. Two reaction models, reactions of water vapor with liquid sodium and gas-phase sodium, are developed by means of discrete methods in this research. The former one, named as surface reaction, is modelled under the assumption of an infinite reaction rate upon water vapour approaches to the interface by convection. At the same time, the latter gas-phase reaction adopting an empirical equation of reaction rate is competitive to the surface reaction. Particles containing multiple

components of reaction products are modelled with the consideration of component diffusion among neighbouring particles.

The present methodology is applied to simulate a configuration with tube bundles where chemical reaction takes place between leaked water vapor and liquid sodium. The distribution of build-up products and temperature are investigated and evaluated. Validation is done by comparing the simulation results from the proposed particle method to that calculated in a mesh-based code, SERAPHIM. Results show the similarity in terms of the temperature distribution of the reaction zone. By implementing the present methodology, the sodium-water chemical reaction is available for further investigation by particle methods.