§6. Analysis of Helium Bubbles Motion in Liquid Helium for the Evaluation of Cryogenic Stability in Superconducting Magnet

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Analysis of the complex flow of liquid helium is not only challenging but also an important task in order to evaluate the cryogenic stability of a superconducting magnet. For example, the multiphase turbulent flow is difficult to analyze by conventional numerical calculations based on Navier-Stokes equations. Therefore, the development of new calculation methods of complex flow is needed. In a previous paper [1], we investigated the cooling capability and the stability of superconducting magnets by analyzing the convection of liquid helium in the superconducting magnet. However, the bubble formations in liquid helium were not considered and only the sub-cooled regime was studied.

In the present report, we consider the void formation of liquid helium and treat the combined model of bubble formation and convection. In the calculation, we apply the lattice Boltzmann method which is suitable for the analysis of the complex heat transfer problems [2].

The analysis procedures simulating the convection by heat generation are described in the previous paper [1]. We analyzed the separation of liquid and gas of two immiscible components system by using Shen-Chen model [3] for multiphase fluid. Two kinds of particles are considered, particles 1 (helium molecules in the gas phase) and particles 2 (in the liquid phase). And the calculation field was discrete with a 2-dimensional hexagonal lattice with size of unit length 1, and the velocity was also discrete. The effect of gravity was introduced into calculations by adding the particle density of the constant rate. The phase separation was realized by introducing the interaction between particle 1 and particle. Initial numerical densities of particle 1 and particle 2 are set to 0.2 and 0.8 per unity lattice point, respectively, and total density is unity.

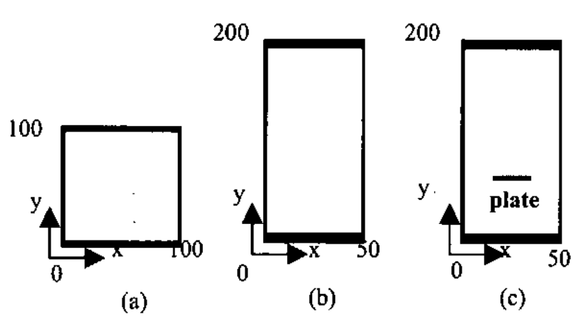

Fig. 1 Calculation system of multiphase model.

Figure 1 shows the geometry of calculation system. The bounce-back boundary condition is introduced into the surrounding walls. The number of lattice points of calculation system (a) is set to 100x100 point grid (18.9x18.9 mm; a length of a point grid corresponds to 0.189 mm), and the effect of gravity is not considered. Thereby, we confirm that the phases of particles 1 and 2 are separated with time. The number of lattice points of the calculation system (b), (c) was set to 50x200 point grid size (9.4x37.8 mm). The effect of gravity was considered in those cases, and the rise of helium bubbles by the effect of the buoyancy was simulated. In the calculation system (c), the plate was inserted in x= 20-30 and y= 50, and we simulated the process of generated helium bubbles captured at the plate.

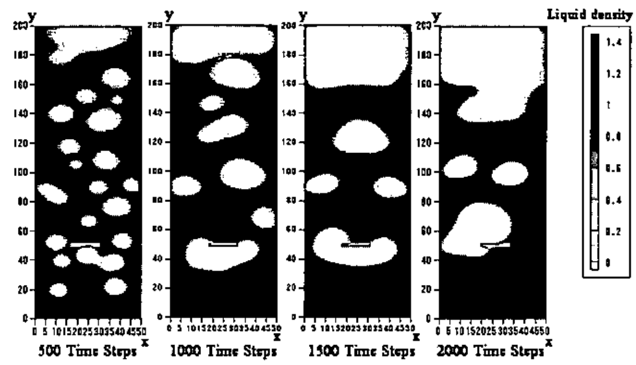

Fig. 2 Density distribution of liquid helium introducing the effect of gravity with a flat plate.

Fig. 2 shows the results of the system inserting a plate at x=20-30 and y=50 as shown in **Fig. 1 (c)**. It was found that the rising of the gas parts was decreased by an insertion of plate and remained on that area. Therefore, by introducing the dynamic change of gas into the convection model, when void appears, the heat propagation can be analyzed, and the various behaviors of liquid helium can be calculated.

In conclusion, we developed new method to analyze the helium bubble formation. The combined calculation, in which both of convection and bubble formation were considered, enabled the analysis of the following maters: heat conduction of wires, convection of liquid helium, and generation of voids. By using this calculation technique, the evaluation of cooling stability of the system, which is close to an actual condition, can be estimated.

References

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