§21. Numerical Analysis on Transient Heat and Mass Flow of He II Through Porous Media

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It is considered that porous media are utilized as electrical insulation on superconducting cables in order to enhance cryogenic stabilities of superconducting magnets cooled with He II. To use the porous media as the electrical insulation of superconducting magnets, it is important to investigate heat and mass transfer of He II through them.[1] In the present study, the heat and mass transfer of He II in micro channels of the porous media has been analyzed using a two-dimensional numerical code. The code, which is based on the two-fluid model equations of He II, can deal with the friction loss of normal component and the tortuosity in porous media.[2] The transient heat and mass transfer of the He II through the porous media was calculated for various widths of the micro channels in the porous media and various helium volumes between the heater and the porous media.

A numerical code has been developed for steady state heat and mass transfer of He II through porous media. The numerical model is based on two fluid model of He II with Gorter-Mellink mutual friction and deals with the friction loss of normal fluid and the tortuosity of the porous media. In the present study, the code was applied to calculations of the transient heat and mass transfer of He II through porous media. Fig. 1 shows a schematic of numerical model. The model consists of a heater, porous media, an adiabatic wall and He II. The height of the porous media is 1.5 mm, the porosity is 62 % and the tortuosity is 1.66. In the present study, the width of micro channels in the porous media is changed from 1 μm to 31 μm and the gap between the heater and porous media is varied from 0 mm to 2.0 mm. The time step is set to be 1 ns and time integration is carried out explicitly. The slip condition is applied to the velocities of the superfluid on the surface of walls, while the non-slip condition is applied to the velocities of the total and normal fluid there. The stepwise heat of 77 kW/m2 is applied uniformly to the surface of the heater. The temperature of He II bath is kept constant at 1.8 K.

Fig. 2(a) shows the helium temperature profiles at the center of the top surface of the porous media as a function of the width of micro channels in the porous media. In this case, the sum of the widths of the micro channels was 310 μm and there was no gap between the heater and the porous media. The time constant up to steady state became longer, as the width of the micro channels in the porous media decreased. That is because the friction between normal fluid and the walls of the micro channels in the porous media influenced the development of flow of normal fluid. The time constant of 1 μm channel was about 10 ms. Fig. 2(b) shows the helium temperature profiles at the center of the top surface of the porous media as a function of the gap between the heater and porous media. In this case, there were 31 micro channels with 10 μm width in the porous media. The time constant became longer, as the gap between the heater and the porous media increased. That is because the heat capacity of He II in the gap between the heater and the porous media affected the temperature rise. In the case of gap of 2.0 mm, the steady state was reached after 25 ms.

From these numerical results, it is found that the geometric parameters such as the channel width in the porous media and the gap between the heater and porous media had a significant effect on the transient heat and mass flow of He II through porous media. On the other hand, helium temperature increase at the steady state hardly changed even if the channel width and the gap were varied.

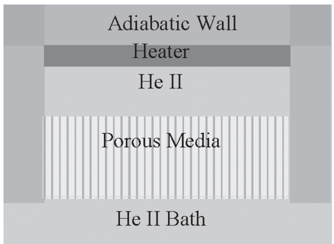

Fig. 1. Schematic of numerical model.

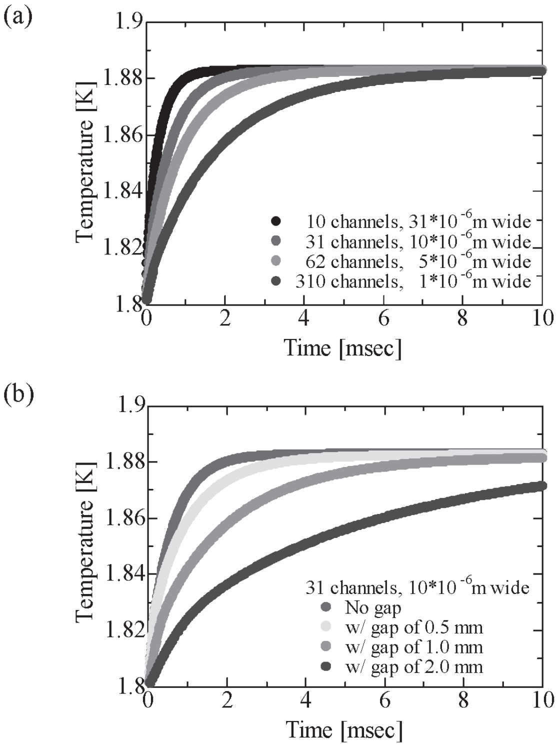

Fig. 2. Temperature profiles as a function of (a) channel width, (b) gap.

Reference

1) Baudouy, B., et al., Adv. in Cryo. Eng. (2006) 51A 409-416.
2) Hamaguchi, S., et al., Adv. in Cryo. Eng. (2006) 51A 105-112.