§24. Numerical Studies on Heat Transport Characteristics of He II in a Channel with a Porous Spacer

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Since the cooling channels of superconducting magnets are narrow and complicated, it is important to investigate the heat transport characteristics of He II in the channels. To use the pressurized He II for the coolant of LHD's helical coils, R&D are being conducted for heat transport characteristics of He II channels at the National Institute for Fusion Science.

In the present research, a numerical code, which is named SUPER-2D, developed by Tatsumoto et al. was used 1-2). The code is based on the two fluid model and can solve problems of two-dimensional heat transport in He II channels. So far, most analysis using this code had been carried out on static He II. In the present studies, dynamic heat transport problems will be analyzed in a channel tested by Okamura et al 3). The channel was separated into two regions by a porous spacer. According to their experiments, the use of a porous spacer in the middle of a He II channel could reduce the temperature increase in the heated region. It implied that He II flows were induced through a porous medium by the thermo-mechanical effect.

A schematic of the channel for the analysis is shown in Fig.1. The channel is 170 mm long and 7 mm wide. A spacer 5 mm thick is used to separate two rectangular regions of the same shape. Each region is 3 mm high. A porous medium 150 mm long is installed at the center of the spacer. The porosity is 22%. A heater, 170 mm long, is attached at bottom the channels. Both ends of the channel are kept open to a He II bath at atmospheric pressure. The channels are placed horizontally in the He II bath.

A set of the two fluid model equations of He II is used as basic equations in the analysis. As shown in Fig. 1, the left half of the channel is analyzed because of a symmetric problem. The adiabatic condition is used at the FRP surfaces, where velocities of the total fluid and normal component are zero. The slip condition is applied to velocities of the superfluid component at the surfaces. The heat is applied uniformly to the heater surface and the value of heat flux is kept at 0.1 W/cm2. The temperature of the ends of channels is kept at the He II bath temperature of 1.92 K. It is defined that only the superfluid component can flow in the vertical direction through the porous medium and the non-slip condition is applied to the normal fluid component on surfaces of the porous medium.

Fig. 2 shows the flow velocities of the total fluid, normal fluid component and superfluid component in the channel. Black rectangles in the middle of the channel display the porous spacer. Each vector in the figure expresses both magnitude and direction of flow velocity at each point. In the case of the superfluid component, it entered in the channel from the bath, flowed through the porous spacer and streamed toward the heater at last. On the other hand, the normal fluid component was generated on the heater surface and then went away, spreading over the whole channel.

Concerning the total fluid, He II went into the upper region from the open bath, and passed by the porous spacer, flowed out from the lower region. These flows were induced by temperature differences between two regions. The He II flows promoted the heat transport in the channel.

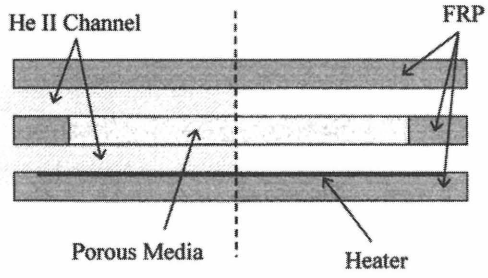

Fig.1 A schematic of the channel.

(a)
(b)
(c)

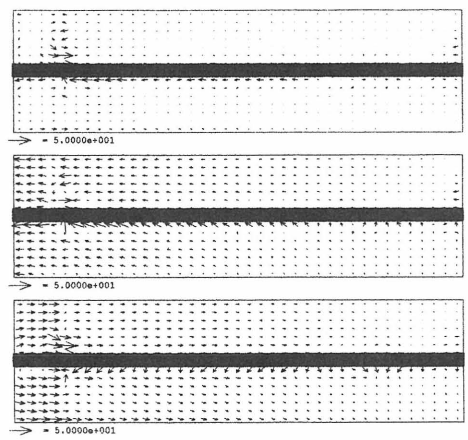

Fig.2 Flow velocity vectors in the channel.
(a) total fluid, (b) normal fluid, (c) superfluid

Reference

1) Tatsumoto, H. et al. : Cryogenics **42**(2002)9.
2) Tatsumoto, H. et al. : Cryogenics **42**(2002)19.
3) Okamura, T. et al. : Cryogenics **38**(1998) 967.