§ 8. Numerical Analysis on He II Heat Transport in the Long Channel with Abrupt Change of Cross-sectional Area

Hamaguchi, S.

Pressurized He II has been used for a coolant of superconducting magnets and its heat transport capability within the cooling channels has significant effects on the cryogenic stability of magnets. Since cooling channels of existent superconducting magnets are mostly so narrow, long and complicated, it is not easy to clarify the heat transport mechanism of those channels, especially the flow velocity of the internal convection. Therefore, it is important to investigate He II heat transport in the channels by numerical analysis as well as sample experiments.

The helical coils for Large Helical Device will be cooled down by pressurized He II in future. The heat generation in the helical coil windings should be removed through the cooling channels formed by superconductors and FRP spacers. However, the cross-sectional areas of the cooling channels are limited by maintaining the mechanical strength of magnets. The cooling channels have abrupt change of the cross-sectional areas with the ratio of approximately 0.05. In the present study, He II heat transport in a rectangular channel with abrupt contraction and enlargement has been analyzed by using a two-dimensional numerical code developed by Tatsumoto et al. 1). The code is based on the two-fluid model equations and has been able to solve problems of two-dimensional heat transport in He II channels. The flow velocity vectors of He II in this channel are calculated with a heat input. The effects on heat transport mechanism, caused by He II flows in the channel with abrupt change of cross-sectional area, will be clarified by the analysis.

Maekawa et al. had carried out experiments on the heat transport of the channels simulating the cooling channels of the superconducting magnets for the helical coils 2). The present numerical model imitates the experimented channel. A schematic of the channel for the analysis is shown in Fig.1. The channel is 990m long and is located vertically in the He II bath at atmospheric pressure. A heater is placed at the bottom, while the top end is open to the He II bath. The channel has a 400 mm long contraction and the cross-sectional area ratio of the contraction to the channel is 0.05. In the present analysis, a set of the two fluid model equations of He II is used as basic equations. The stepwise heat is inputted uniformly to the heater surface.

Fig. 2 represents details of the flow vectors at the part of the abrupt change of the cross-sectional area. In the narrow part, both superfluid and normal fluid components flow straight like one-dimensional flows in the axial direction. However, the streamlines of both components are complicated near both ends of the contraction. The well-known counter flow mechanism is locally collapsed owing to the abrupt change of the cross-sectional area. Therefore, it will be implied that the net flow of He II becomes unstable near both ends of the contraction and then the excellent heat transport capability of He II deteriorates.

Fig.1 A schematic of the channel.

Fig.2 Flow velocity vectors in the channel.

Reference