§26. Heat Removal Demo-research for Flibe Blanket Development

Hashizume, H., Ebara, S., Ito, S. (Tohoku Univ.),
Kunugi, T. (Kyoto Univ.),
Yuki, K. (Tokyo Univ. Sci., Yamaguchi),
Sagara, A., Muroga, T., Nagasaka, T., Kondo, M.

Flibe blanket is one of the advanced liquid blankets for fusion DEMO reactors and its conceptual design is in progress for LHD-type fusion reactor, FFHR, to date. Although the blanket using molten salt, Flibe, has many strong points, e.g., a simple and compact blanket can be realized because Flibe acts as both a coolant and a tritium breeder, there are still several issues to be solved. From thermal-hydraulic point of view, the following two features can be considered as crucial issues. One is that flowing Flibe has not accomplished high heat load removal assumed at the first wall of the reactor. High heat flux implies a large temperature difference appearing in a coolant which causes large physical property changes such as Pr number in it. Therefore, it is not always true that a heat transfer correlation applicable to low heat flux cases is available for high heat flux ones. The other key issue is heat transfer enhancement in flowing fluid with high Pr number such as Flibe. In order to mitigate a temperature window of the Flibe blanket, it's been proposed that the composition of Flibe is changed, that is, the ratio of BeF_2 is increased to reduce its melting point. This alternative Flibe, however, has an undesirable feature that an already high Pr number up to 30 is made eve higher to about 200.

In this study, two kinds of heat transfer experiments are conducted to obtain meaningful findings relating to the above issues. One is an experiment using Tohoku-NIFS Thermal loop (TNT loop) and molten salt HTS which is a simulant of Flibe to demonstrate the high heat flux removal. As a heat transfer promoter, a sphere-packed pipe (SPP) is used in the test section, and heat flux of about 1.0 MW/m^2 is applied, which is the same value as that assumed for the first wall of FFHR. The other experiment is that using silicon oils as high Pr number fluid to clarify thermofluid characteristics of a sphere-packed annular channel (SPAC) adopted as a heat transfer promoter.

Figure 1 shows the relation between averaged Nusselt number and Reynolds number based on sphere diameter and pore-averaged velocity. All data are obtained for the inlet temperature of 200 deg. C and obtained by using a SPP in which the ration of the inner diameter of a pipe (D) to packed spheres (d) is 2. There is a subtle difference between high and low heat flux cases. Regarding the figure, it is a remarkable accomplishment that the heat flux of 1.0 MW/m^2 can be removed by temperature difference between bulk and wall temperature of about 120 deg. C of a flowing molten salt. Although both of the data obtained by different heat fluxes give close agreement with a heat transfer correlation shown in a curve in the figure which was derived from the previous study, the data of high heat flux becomes higher than that of low heat flux. This difference can be inferred because of change in physical properties caused by temperature change and/or a fin effect caused by packed spheres in the SPP. This must be elucidated in future. For the SPAC experiment, three silicon oils with different Pr numbers (Pr=25, 80, 150) are used. For each oils, several kinds of the SPAC test section as shown in Fig. 2 are tested. As for experimental results, if the heat transfer characteristics are expressed as a similar manner as Fig. 1, each SPAC results do not form a single correlation. It is considered because of a difference between flow rate in the intrados- and extrados-side channel of the annular channel. Large pebble size causes large porosity in the intrados side and therefore causes large flow rate in there. If we consider the two channels separately and take account for the averaged flow velocity in the extrados-side channel (because the heat flux is imposed on the outer wall), the relations for all SPAC between Nusselt number and Reynolds number lie on a single curve, as shown in Fig. 3. As a future plan, the SPAC is to be incorporated in the TNT loop and to be tested for high heat flux cooling.

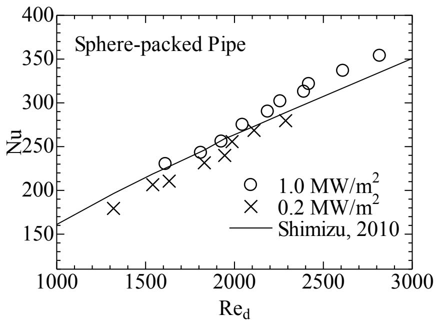

Fig. 1 Averaged Nusselt number varying with Reynolds number at different heat fluxes

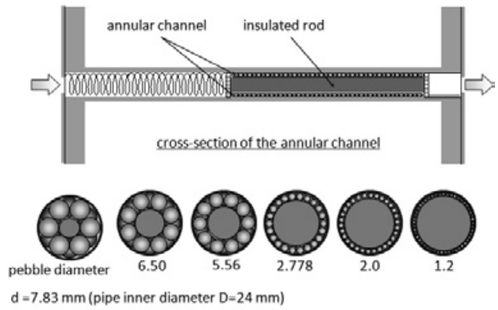

Fig. 2 Schematic view of the SPAC structures

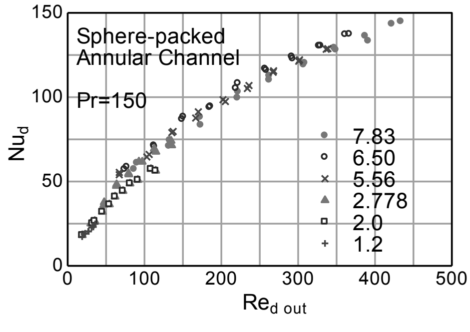

Fig. 3 Averaged Nusselt number varying with Reynolds number based on flow velocity in the extrados channel velocity at Pr=150 in SPAC