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

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Flibe blanket is one of the advanced liquid blankets for fusion DEMO reactor and its conceptual design is in progress to date. Although the blanket using molten salt, Flibe, has many strong points such that a simple and compact blanket can be realized because Flibe acts as both coolant and tritium breeder, there are still several issues to be solved. One of the key issues is heat transfer enhancement in flowing fluid with high Pr number such as Flibe. Previous design activity indicated that conventional Flibe composed of 66 % of LiF and 34 % of BeF_2 has too high melting point of 459 deg. C to design the blanket because of small temperature window between allowable temperature of structural material (about 550 deg. C for the case of reduced activation ferritic steel) and the melting point, and it is necessary for extensional design to reduce the melting point of Flibe by changing its composition, i.e., increasing the ratio of BeF_2. This operation, however, increases Pr number of the resultant Flibe, and makes the already low heat transfer performance lower. Sphere-packed pipe (SPP) has been proposed as a measure to enhance the heat transfer performance and as a cooling channel of the first wall of the Flibe blanket. There are many parameters such as the channel width, diameter of the packed sphere and so on, and they have to be optimized for realization of the blanket.

In this study, heat transfer experiment using silicon oils as high Pr number fluid was conducted to clarify thermofluid characteristics of the SPP for the silicon oils with Pr number up to 100. Besides, in preparation for high heat load removal experiment using Tohoku-NIFS Thermal loop (TNT loop) with Filbe simulant as coolant, the loop was improved. Bypass operation of a heat exchanger piping and maintenance and repair of a pumping system were done in order to increase coolant flow rate.

Parameters of the heat transfer experiment were Pr number (Pr=25 or 100), ratio of diameter of spheres to that of a circular pipe (D/d=2 or 3), material of the spheres (brass, SUS or polypropylene) and Re number (Re_D=200-8,000). Fig. 1 shows a test section. Heat deposition of 45-140 kW/m2 was given between two electrodes by applying direct current. Because wall temperature of the pipe depended on location of the pipe, a total of 60 thermocouples were installed to estimate more accurate averaged wall temperature. Averaged heat transfer rate was calculated by using averaged inner wall temperature estimated from temperature of the thermocouples and bulk temperature of flowing coolant. Figs. 2 and 3 shows averaged Nusselt number for the case of Pr=100, D/d=2 and Pr=100, D/d=3, respectively. In these figures, solid lines correspond to a correlation data obtained from previous studies by using experimental data of 5.1<Pr<31, $820<Re_D<33500$, and dashed lines are extrapolated from this correlation. It is found from these figures that Nusselt number obtained from the experiment is quite different from the correlation. The previously obtained correlation has a relation of $Nu \propto Pr^{0.391}$, but for high Pr number fluid, this relation is considered not to be applicable. To derive the brand-new heat transfer correlation for high Pr number fluid, additional heat transfer experiment should be necessary and that using silicon oil with Pr=200 is scheduled.

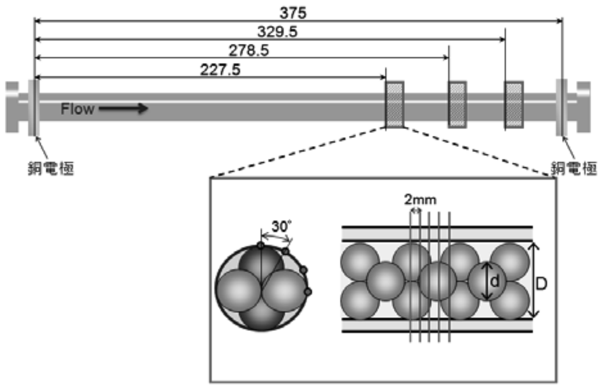

Fig. 1. Test section of experimental setup and location of thermocouples

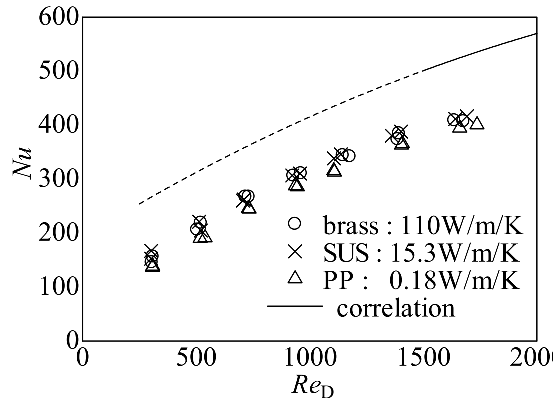

Fig. 2. Averaged Nusselt number for the case of Pr=100, D/d=2

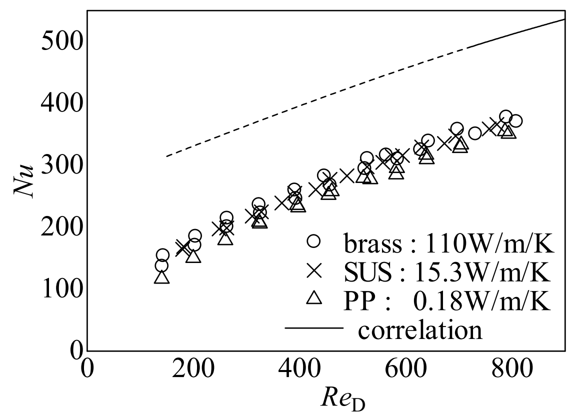

Fig. 3. Averaged Nusselt number for the case of Pr=100, D/d=3