§13. Development of Novel Heat Transfer Promoters for First-wall Cooling in a Heliacal Type of Fusion Reactor

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When designing a Flibe cooling system of the first wall of FFHR [1], development of novel heat transfer promoter, which is excellent in reductions of MHD pressure loss, electrolysis, and chemical compatibility as well as achieving high economical efficiency and maintainability, becomes one of pressing needs. In this study, the heat transfer promoter using a sphere-packed pipe (SPP) is investigated in order to not only overcome these complicated requirements but also enable high heat removal of the first wall.

The fundamental heat transfer and flow characteristics have been discussed before [2], so that our task should be sifted to evaluate the net heat transfer performance and construct a heat transfer correlation that can be applicable to the 1st-wall design under real heat flux and Re number conditions of FFHR. Therefore, in this study, they are evaluated by using an oil circulation loop whose working fluid is high Pr number of silicon oil that is also Flibe simulant. Fig. 1 shows the silicon oil circulation loop, and the silicon oil can be used under a room temperature. The inlet temperature is 20C and the Prandtl number is almost 30. Though the specifications of the loop such as a test section and a mixing chamber are referred to those of TNT loop [3], this loop enables much higher *Re* number conditions. The sphere sizes packed into the SPP are $D/3$ and $D/2$ (D: pipe diameter).

Summarizing all the heat transfer data including the TNT and water-test data, the following heat transfer correlation was obtained.

$$Nu_D = C(f_w Re_w)^a (Pr)^b [\arctan\{D/d - 1 + \tan(1)\}]^c$$

Here, f_w is friction coefficient, Re_w is modified particle Reynolds number, Pr is Prandtl number, and D/d is the ratio of the pipe diameter to the particle size. Figure 2 shows that this correlation can predict the heat transfer performance within ±21.6% error. However, the mean value of the errors is quite low 5.74% and in special it is possible to predict that in high Re number region up to Re=32,000 while the existing correlation is available under Re≦3,600.

This correlation was adopted to evaluate the heat transfer performance of 60:40-Flibe, the concrete cooling conditions for obtaining a heat transfer coefficient of 20000W/m^{2}K were discussed. The pipe diameter was set here to be 30mm. The flow velocities necessary for achieving the heat transfer coefficient 20000W/m^{2}K by the SPP, are 0.7m/s and 1.3m/s, in the cases of $D/3$ and $D/2$, respectively, which are quite low velocity. On the other hand, in cases using a smooth tube and a swirl tube, the velocities are 21.0m/s and 14.3m/s, respectively. Furthermore, the pumping powers of the SPPs necessary for the same heat transfer coefficient are nearly equivalent to other heat transfer promoters, which also proves high economical efficiency of the SPP system.

As the next step on developing the novel SPP cooling system, the fin effect should be promoted by improving the contacting state between the heating wall and the sphere, and then spirally packing structure is investigated in order to develop the SPP suitable for one side heating of FFHR. Furthermore, the heat transfer experiment under magnetic field needs to be performed in the next year.

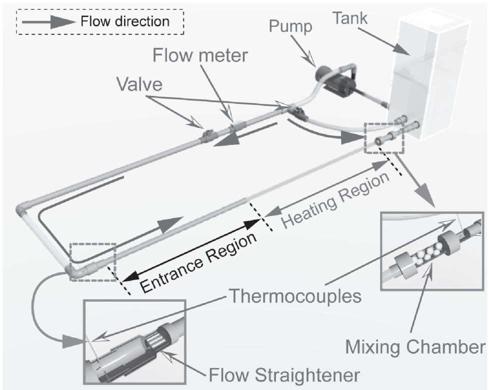

Fig. 1 Silicone oil circulating loop

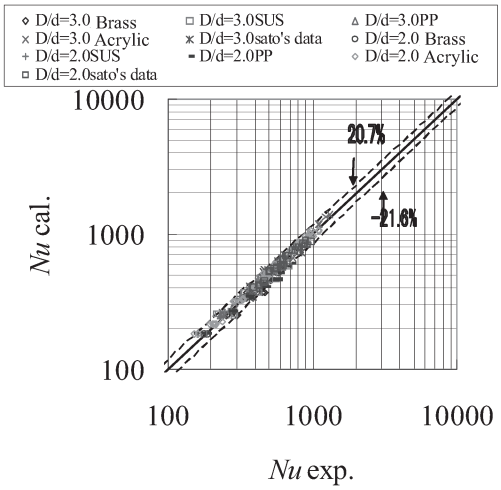

Fig. 2 Prediction of hat transfer performance of SPP

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