# § 6. Design Research on the Advanced Thermal Structure System in the Nuclear Fusion Reactor

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Introduction

To enable design of a Flibe liquid blanket system in helical type of nuclear fusion reactor FFHR, it is indispensable to enhance Flibe's low heat transfer ability originated from high Pr number fluid. In the present study, in order to contribute the design of advanced thermal system in the fusion reactors, heat transfer experiments by use of high-temperature molten salt HTS, which has the equivalent thermofluid characteristics to Flibe, are performed and the fundamental heat removal performance for the high Pr fluid as well as the handling techniques of high temperature molten salt is evaluated.

Heat transfer experiment with HTS forced-circulation loop

In a molten salt forced-circulation loop TNT(Tohoku-NIFS Thermofluid Loop)[1], it is possible to circulate the high temperature molten salt such as Flibe, HTS etc. at the maximum fluid temperature of 600C and at the maximum flow rate of 20L/min. The TNT mainly consists of the dump tank, the circulating pump, the test section, the upper tank, and the air-cooling tower as shown in Fig. 1 and the high temperature molten salt, which is melted in the dump tank, is filled up into whole the piping systems by pressurizing Ar gas inside the dump tank and then circulated. In order to evaluate the fundamental heat transfer characteristics and develop an advanced heat transfer promoter for the high Pr fluid, several types of packed bed tube are adopted as the test section. With the packed bed tube, the diameter of pebble sphere is D/3(D: inner diameter of pipe) and Cu and SUS spheres are prepared to estimate the effect of thermal conductivity on the heat transfer enhancement. Fig. 2 shows the heat transfer performance of the packed bed tubes. The packed bed tubes indicate much higher heat removal performance compared with a straight smooth tube especially in a laminar flow region and that is useful finding against the heat transfer with high-speed flow that has a problem on erosion. In addition, it is confirmed that the heat transfer of Cu pebble is improved in a higher velocity region and there is a possibility that that results from the synergism of highly improved turbulent heat transport near between the wall and the pebble and the increase of fin effect by high thermal conduction inside the Cu pebble. The heat transfer experiment at the higher flow velocity is desired.

Heat transfer enhancement mechanism in packed bed tube

Numerical simulation of high Pr fluid flow around group of circular cylinder was performed to clarify the heat transfer mechanism in complicated geometry tubes like a packed bed tube etc. and their effectiveness. The Cut-cell method was adopted in order to reproduce the geometrical boundary of circular cylinder with accuracy. Fig. 3 shows the representative flow field near the wall. As a result of making the cylinder's configuration as the parameter on the heat transfer, it was confirmed that rapid flow formed between the cylinder and the wall and wake, which fluctuates behind the cylinder, strongly affected the heat transfer enhancement. The detailed mechanism of heat transfer enhancement for the packed bed tube and the optimum design of bed which take the pressure drop into account will become possible by carrying out 3-dimentional calculation around the pebble sphere.

Conclusion

The effectiveness of packed bed tubes for the heat transfer enhancement of high Pr fluid like Flibe was verified from the heat transfer experiment using high temperature molten salt HTS. In the future, it is necessary to enhance the heat transfer more by developing an advanced packed bed tube. Furthermore, it was clarified that the analogy of heat transfer in a straight smooth tube didn't stand up under the high temperature conditions. It is considered that fluid composition change by thermal decomposition in the vicinity of wall that is a high temperature region seems to be a main cause and that is a very important issue for the future blanket design.

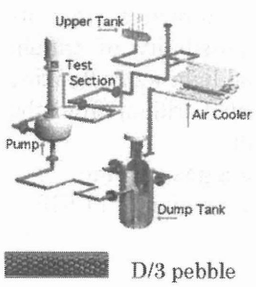


**Fig. 1** TNT loop & pebble

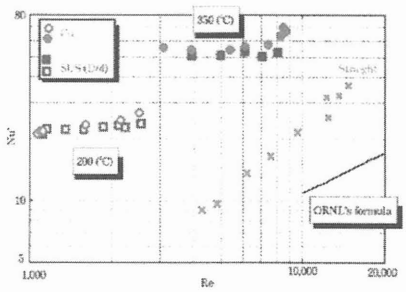


**Fig. 2** Heat transfer enhancement by pebble tubes

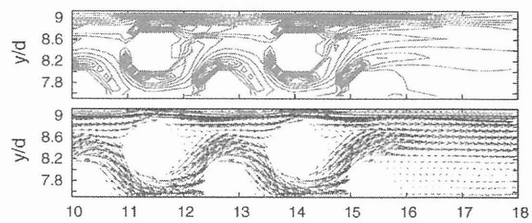


**Fig. 3** Flow structure near wall

[1] S. Toda, S. Chiba, K. Yuki, et al., Experimental research on molten salt thermofluid technology using a high-temperature molten salt loop applied for a fusion reactor Flibe blanket, Fusion engineering and design, 63-64 (2002), 405-409.