# Experimental Research on Heat Transfer Enhancement for High Prandtl-Number Fluid

S. Chiba[1], M. Omae[2], K. Yuki[1], H. Hashizume[1], S. Toda[3], A. Sagara[4]

[1]*Grad School of Eng., Tohoku Univ., Sendai, Miyagi, JAPAN, schiba@karma.qse.tohoku.ac.jp*
[2]*DENSO corp., Kariya, Aichi, JAPAN*
[3]*Tohoku Radiological Science Center, Sendai, Miyagi, JAPAN*
[4]*National Institute for Fusion Science, Toki, Gifu, JAPAN*

A molten salt Flibe is one candidate material for fusion blanket coolant/breeder since Flibe can play a role in breeding tritium and cooling. The Flibe has many advantages for blanket material. However, the Flibe has also several disadvantages, especially high Prandtl number due to its large viscosity. Generally, a thermal boundary layer of a high Prandtl-number fluid is thin in comparison with a velocity boundary layer. This thin thermal boundary layer causes a low heat-transfer coefficient. Therefore, using the Flibe as a coolant for high surface heat flux conditions, we have to develop a new method of heat-transfer enhancement in a Flibe channel flow to stir the thin thermal boundary layer by some active promoters since turbulent heat-transfer enhancement wouldn't work for high Prandtl-number fluid.

The experimental research on heat-transfer enhancement has been performed with a large molten salt circulating experimental loop that is called "TNT loop" (Tohoku-NIFS Thermofluid loop). Although the TNT loop was designed and constructed in order to employ the Flibe as a working fluid, Heat Transfer Salt (HTS) has been used as a simulant of the Flibe since the melting point of Flibe is so high and its vapor contains beryllium. The compositions of HTS are $NaNO_3$, $NaNO_2$ and $KNO_3$. With the HTS, we can achieve the same Prandtl number as that of Flibe under lower temperature.

We have employed packed-bed tube as the enhancer for molten salt since packed bed can stir the thin thermal boundary layer and fluid flow and so on. Stainless-steel bed and copper bed are chosen as the enhancer to evaluate the effect of material of bed. Especially, in case of the stainless-steel bed, several diameters of metallic spheres are changed as parameter; 1/2 and 1/4 of diameter of circular tube. In the copper bed, the diameter of spheres is fixed to be 1/4 of the tube diameter.

Through the experiments, it is clarified that the enhancement of packed-bed tube is superior to that of turbulent heat transfer from the viewpoint of the same flow rate. Also, the 1/4-diameter bed is superior to the 1/2-diameter one at the same flow rate. Furthermore, at low flow rate, small differences of heat transfer performance can be seen between the stainless-steel and copper beds. At high flow rate, however, the heat-transfer coefficient ratio strongly depends on the flow rate in the case of the 1/4-diameter copper bed which can't be observed in the case of the 1/4-diameter stainless-steel bed. As a result, it is considered that the thermal energy is expanded from a heated wall deeply through the packed beds at low flow rate, so that the difference of thermal conductivity of metallic sphere has little effect for the total heat-transfer enhancement. On the contrary, it is also considered that the convective heat transfer in the vicinity of a heated wall is strong at high flow rate, so that the difference of the conductivity is effective.

The evaluation from the viewpoint of the pressure drop shows that the turbulent heat transfer is superior to packed-bed tube. However, the heat transfer of packed-bed tube is not proportional to the pressure drop at low flow rate. This means that the most optimum thermofluid flow exists where the enhancement of packed-bed tube is better than that by the turbulent flow.