§24. Heat Removal Enhancement of Plasma-Facing Components by Using Nano-Particle Porous Layer Method (III)

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In Tohoku University, applicability of NPLS and FP layers with nano-scale structure to heat transfer augmentation of high temperature molten salt flow has been evaluated. To begin with, immersion tests of the NPLS and FP layers were performed to evaluate corrosiveness of nano-scale structure with molten salt HTS (KNO_3:$NaNO_2$:$NaNO_3$=53:40:7) which is Flibe simulant. The NPLS and FP test pieces whose size is 30mm x 30mm are immersed into HTS at 200C for 24 hours. Furthermore, heat transfer experiments of the FP-coated circular pipe flow were performed in a turbulent regime (Re=3,700~12,000) using a molten salt circulation loop named TNT loop (Tohoku-NIFS thermofluid loop). The working fluid is HTS and the inlet temperatures are 200C, 250C, and 300C (The Prandtl numbers are nearly 27, 17, and 13, respectively). In addition, as it is difficult to measure a pressure drop in the TNT loop, a silicon-oil circulation loop is also used to evaluate the heat transfer performance and the pressure drop in a high Reynolds number region (Re=10,000~40,000), simultaneously. The inlet temperature of the silicon-oil is 20C (Pr ~32).

Figure 1 shows averaged Nusselt numbers for the FP-coated circular pipe flow, which was obtained using the TNT loop. For comparison, heat transfer data for a smooth circular pipe flow are also plotted, which proves that the heat transfer characteristics for the smooth circular pipe flow almost correspond to the empirical correlations and that this experiment was carried out with high accuracy under high temperature conditions. Heat transfer performance of the FP-coated pipe is averagely 20% higher than that of the smooth pipe, and besides, increase rate in Nusselt number for each Prandtl number is almost the same. Therefore, heat transfer augmentation using the nano-scale structure could be useful even for high-Prandtl number fluid. This effect doesn't seem to be caused by hydraulically rough surface effect because a viscous sublayer is much thicker than the nano~micro scale of roughness of the FP layer under the present Re number conditions.

Figures 2 and 3 show the Nusselt numbers and friction factors for the FP-coated circular pipe flow, which were obtained in the silicon-oil circulation loop experiment. Here, four kinds of FP pipes are prepared in order to evaluate the effect of the plating time, namely scale effect of the FP structure. The friction factor even for the FP-coated pipe #4 with the largest structure almost agrees with that for the smooth circular pipe. On the other hand, the heat transfer performance of the FP-coated pipes is averagely 16% higher than that of the smooth pipe, and the enhancement rate seems to increase as the structure becomes larger except for #3.

These results mentioned above proves the applicability of nano-scale structure on a heat transfer surface as heat transfer enhancement technique for high temperature and high Pr number molten salt Flibe flow. Optimization of the nano scale structure with strong compatibility in high temperature molten salt Flibe flow has to be discussed in the future study.

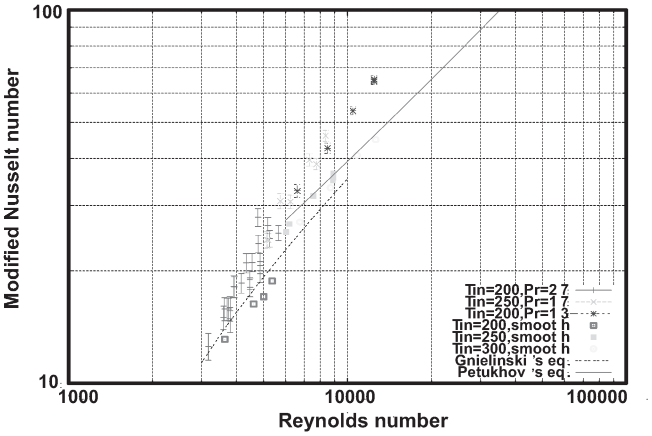

Fig. 1 Heat transfer performance of FP-coated pipe flow

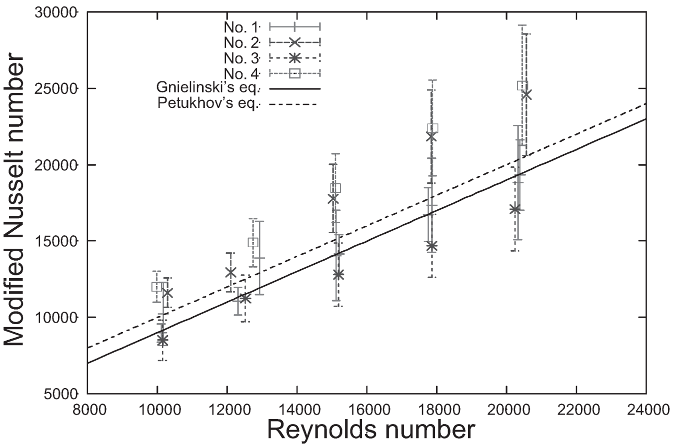

Fig. 2 Effect of plating time on heat transfer performance of FP-coated pipe flow (Working fluid : Silicon oil)

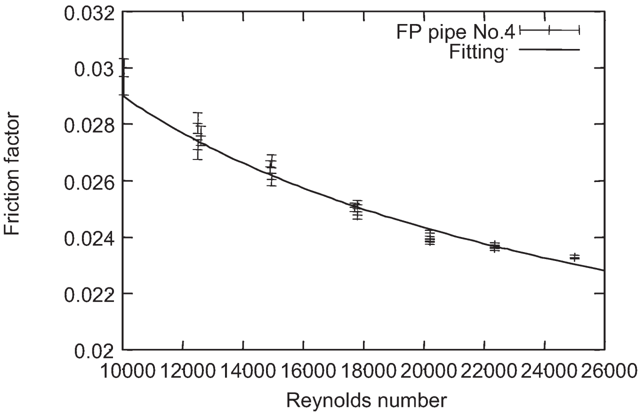

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Fig. 3 Friction factor of FP-coated pipe