# §17. Development of Efficient Heat Removal Technology Using Functional Porous Media for FFHR Divertor Cooling

Yuki, K. (Tokyo Univ. of Science, Yamaguchi),
Sagara, A.

In a divertor region, a heat flux of approximately 10MW/m$^2$ is steadily loaded. In general, water cooling under high pressure, high-speed, and highly subcooled conditions or liquid metal cooling has been proposed as the divertor heat removal techniques. However, the development of heat removal technology with much lower pumping power becomes essential from the viewpoint of achieving low cost of electricity of the fusion power reactor. In this study, in order to evaluate the heat removal characteristics, *i.e.* a boiling curve, of the high heat flux removal device using functional metal porous media [1], high heat flux removal equipment which enables a heat transfer experiment on 20MW/m$^2$ class was set up in the last fiscal year.

Using the high heat flux removal equipment, the heat transfer experiments were carried out in this fiscal year. The allowable temperature of a cartridge heater used is 950 $^{o}$C, and the maximum heat input is 30kW. Fig. 1 shows the heating test section. By decreasing the cross section of the copper heat transfer block as shown Fig. 1, it is possible to finally achieve a high heat flux of over 20MW/m$^2$ at the heating surface of 30 mm in diameter. On this heating surface, a copper-particles-sintered porous medium is mechanically attached. The particle diameter is 500 μm and average pore size is 100 μm, and the porosity is approximately 30 %. Cooling water that is distilled one flows into the test section with a pump, and the copper heat transfer block is cooled by passing water through the porous medium. The porous medium has four channels called sub-channel for discharging generated vapor outside the porous medium. The generated vapor is condensed in a spiral tube of heat exchanger, and then flows into the test section again. Inlet temperatures of cooling water in this experiment are 30 $^{o}$C and 70 $^{o}$C, and flow rates are 2.5 L/min and 1.0 L/min.

Figure 2 shows the heat transfer performance of the copper-particles porous medium, which is called a boiling curve. The flow rate is 2.5 L/min (21.2 kg/m$^2$/s) and the inlet temperature is 30 $^{o}$C. It can be confirmed that the heat flux rapidly rises from around 130 $^{o}$C of the wall temperature, which indicates enhancement of the phase change of the cooling water in the porous medium. Judging from the present experiments and the past experiments, the wall temperature is possible to exceed 200 $^{o}$C, so that the heat flux also achieves 10MW/m$^2$ also in this cooling condition. In the meantime, in the case of 1.0 L/min (9.7 kg/m$^2$/s), the increase in heat flux becomes gentle from around 170 $^{o}$C of the wall temperature. At that time, the wall temperature rapidly increases. It seems that the cooling water doesn't reach the heating surface because the flow rate is quite small. In this case, all the cooling water directly flows into the sub-channels. In addition, there is a possibility that the vapor phase excessively develops in the porous medium and works as a thermal resistance layer. At the inlet temperature of 70 $^{o}$C (though I don't show here), it could be confirmed that the data of the boiling curve shifts to higher wall-temperature side a little. However, a heat flux of 10MW/m$^2$ was also sufficiently achievable even in flow rate case of 2.5 L/min.

In this study, the boiling curve which shows heat transfer performance of metal porous medium was evaluated. It was proved that the heat removal of a heat flux of 10MW/m$^2$ was sufficiently possible even under low wall superheat and low flow rate conditions by using the porous heat removal device.

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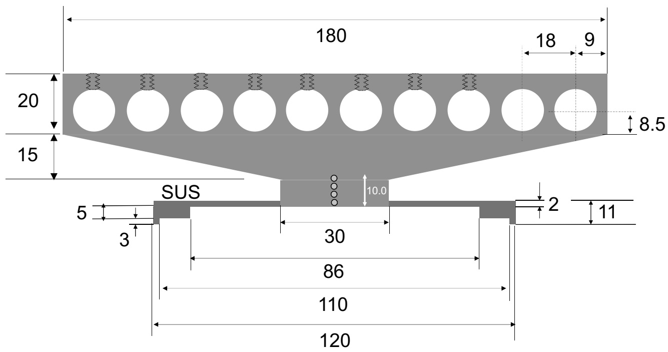


Fig. 1 Detail design of heat transfer block

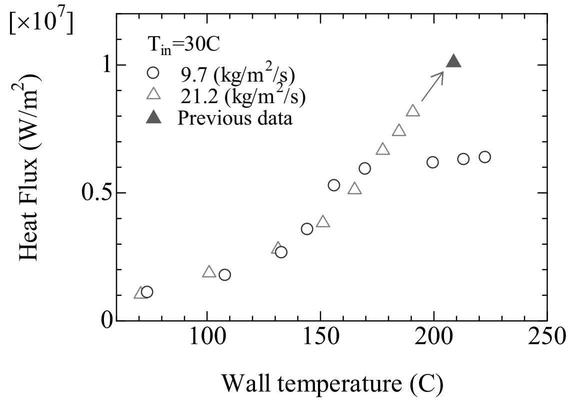


Fig. 2 Heat transfer performance of porous media

[1] K. Yuki, et al., Sub-channels-inserted Porous Evaporator for Efficient Divertor Cooling, Fusion Science and Technology, vol. 60, pp. 238-242 (2011).