§23. Thermal Design of Water-Cooled Divertor Utilizing Copper Alloy Porous Media

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

In a divertor region, a heat flux of approximately 10MW/m^2 is steadily loaded. The ITER divertor utilizes water cooling under high pressure, high-speed, and highly subcooled conditions. However, 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. To cope with this difficulty, in this study, boiling/evaporation heat removal characteristics of a high heat flux removal device utilizing a uni-directional porous copper alloy are evaluated.

Figure 1 shows a system diagram of the experimental apparatus. The experimental apparatus is composed of the coolant supplying section, the heat transfer test section, the vapor discharge section, and the heat exchanger. Distilled water is used as coolant. The coolant supplied with a circulating pump flows into the test section and two-phase flow discharged from the test section is condensed in a spiral type of heat exchanger, and then returned into the pump again. The inlet subcoolings of the coolant is 30 K and the flow rate is 2.0 L/min in this experiment. High power eight cartridge heaters are utilized as high heat flux source and a pyramid shape of copper heat transfer block is designed in order to achieve the heat flux of over 10 MW/m^2 at the heat transfer surface. The top surface of the copper block is a circular heat transfer surface of 20 mm in diameter and micro groves on it. The porous medium is mechanically attached onto this surface. At the axial locations of 3.0, 5.0, 7.0, 9.0 mm from the heat transfer surface, a K-type of sheathed thermocouple with the diameter of 0.5mm is installed to evaluate the temperature of the heat transfer surface and the heat flux in a steady state. The referential porous medium used in this study (See Fig. 2) is a uni-directional porous non-oxygen copper with the fine hole of 0.5 mm in diameter at the pitch of 1.5 mm. The porosity is 19.7 %, which results in high thermal conductivity of 219 W/(mK). The thickness of the porous copper is 5 mm and the diameter of the liquid supplying area is 20 mm. In addition, the porous copper has four larger holes to discharge vapor outside the porous copper.

Figure 3 shows boiling curve of the uni-directional porous copper. The horizontal axis is the wall superheat that is a temperature difference between the wall temperature and the saturation temperature. The heat transfer performance seems to be much higher than those of the other porous cooling devices that were introduced in our laboratory. It is confirmed that the heat flux exceeds 7.0 MW/m^2 at a wall superheat of 70 K and a flow rate of 2.0 L/min. It should be noted that the maximum heat flux in this cases does not corresponds to the critical heat flux. In that sense, there is a high possibility that the heat flux of over 10 MW/m^2 is sufficiently possible at a quite low flow rate, that is quite low pumping power.

This work was performed with the support and under the auspices of the NIFS Collaborative Research Program NIFS (NIFS15KERF029, 2015)

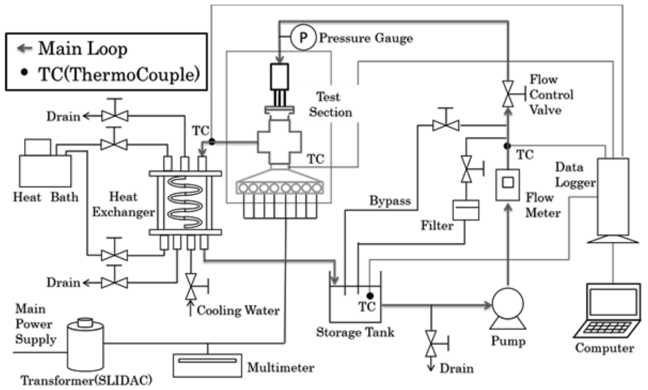

Fig.1 Experimental set up of gas cooling

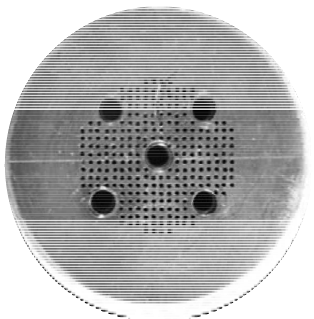

Fig. 2 Uni-directional porous copper

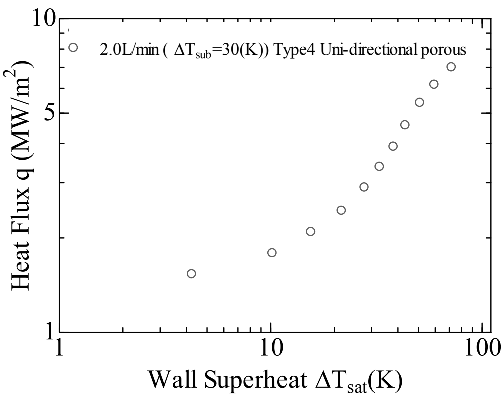

Fig. 3 Experimental result