§17. Applicability of Gas Divertor Using a Porous Medium with High Thermal Conductivity Material

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

In fusion reactors, a heat flux of approximately 10MW/m^2 is steadily loaded to the divertor. In order to remove this heat, in EU and the U.S., utilization of a finger tube with multiple impinging jet has been proposed under high pressure condition of almost 10MPa. However, from the view point of the safety of the cooling line and its maintenance activity, heat removal technology under much lower pressure and lower pumping power conditions should be discussed more. In this study, we focus on the heat removal characteristics of gas cooling with high thermal conductivity metal porous media, and set up a high heat flux removal equipment which enables a heat transfer experiment of 10 MW/m^2.

Figure 1 shows the experimental set up that consists of a gas tank, a pre-heater, a flow meter, a test section, and a heat exchanger. The gas from the gas tank is adjusted its inlet temperature and flow rate, flows into the test section, cooled in the heat exchanger, and then exhausts to the air. In order to evaluate of the heat transfer performance of gas, Nitrogen is used as the simulant of He gas as the first step. The test section is composed of a heat transfer block and a heat transfer area with a metal porous medium. The heat transfer block has eight cartridge heaters at the bottom with an allowable temperature of 950 ^oC and the maximum heat input of 1800 W. The maximum total heat input is 14.4 kW. As shown in Fig. 1, by decreasing the cross section of the copper heat transfer block, it is possible to finally achieve a high heat flux of over 5 MW/m^2 at the heating surface of 50 mm in diameter, while a heat flux of 10MW/m^2 is also possible by changing to the heat transfer surface of 30mm in diameter. On this heating surface, a copper-particles-sintered porous medium is mechanically attached as the reference porous media. The particle diameter is 1000 μm and average pore size is 200 μm, and the porosity is approximately 30 %. The shape of the porous medium is like a circular plate. The diameter is 20 mm and the thickness is 1.5 mm. The porous medium is attached onto the heat transfer surface by pushing a stainless steel rod of 49 mm in diameter that has a jet nozzle at the central axis. The jet from the nozzle outlet flows into the porous medium, impinges to the heat transfer surface through the porous medium, expands in a radial direction, and discharges outside the porous medium. In order to discuss the radial profile of heat flux, wall temperature, and heat transfer coefficient, the temperature field inside the heat transfer block is simulated by solving an equation of heat conduction in the cylindrical heat transfer block. The Inlet temperature of N_2 gas is 17 ^oC.

The experimental results proved that the heat transfer performance of the porous cooling was much higher than that of the impinging jet flow. For instance, at flow rates of 90 L/min and 110 L/min, the heat transfer coefficients of the porous cooling are almost 7.3 and 8.0 times higher than those of the common impinging jet flow. Furthermore, in this experiment, the maximum heat transfer coefficient was almost 6,200 W/m^2/K in the pressure range of 0.1 MPa to 0.8 MPa. In that sense, this figure also proves that the fin effect should be highly improved more by introducing porous media with much higher effective thermal-conductivity and that the pressure of gas should be increased more. Also focusing on the heat transfer coefficient against the pumping power (Pressure loss Δp[Pa] x Flow rate[m^3/s]) as shown in Fig. 2, the heat transfer performance of the porous cooling is more than 4 times higher than that of the common impinging jet.

This study evaluated heat transfer performance of N_2 gas impinging jet flow with particles-sintered porous medium in order to evaluate the feasibility of utilizing the high thermal conductivity porous media and to find out the key issues to further enhance the heat transfer performance. The experiments proved that the heat transfer coefficient of N_2 gas impinging jet flow with the porous medium was much higher than that of common impinging jet flow without the porous medium from the view point of not only flow velocity but also pumping power.

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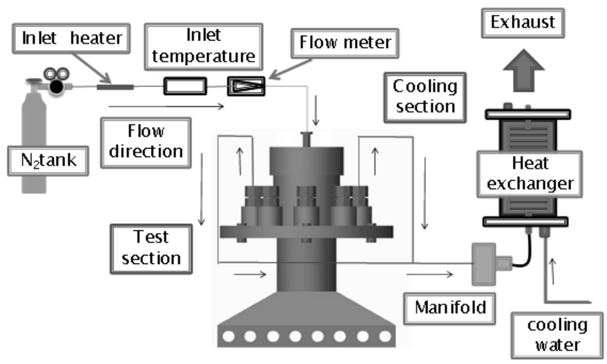

Fig.1 Experimental set up of gas cooling

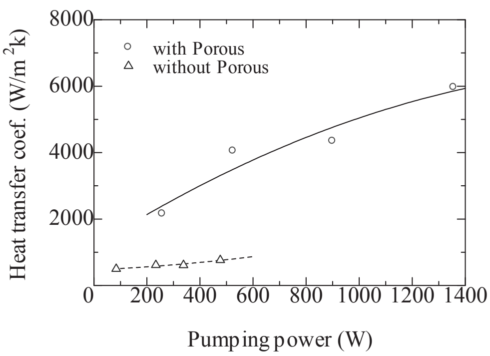

Fig. 2 Heat transfer performance for pumping power