§21. Engineering Feasibility of a Grid Mesh Structure in a Traveling Wave Direct Energy Converter

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Engineering feasibility of grid meshes in TWDEC (Traveling Wave Direct Energy Converter) [1] was studied. The protons from D-^{3}He fusion reaction are guided into TWDEC with a radius of 5 m where power density is as high as 3.5 MW / m^2 [2].

The lifetime of grid meshes due to the sputtering was estimated by use of the empirical formula developed by Yamamura et al.[3]. This gives us the sputtering yield for proton on SS and Cu to be about 7.1×10^{-7} and 1.5×10^{-6}, respectively. For the particle flux of 1.4×10^{18} /m^2 sec with the energy 15 MeV in "ARTEMIS-L"[2], the lifetime of grid mesh with a thickness of 0.5 mm is estimated to be longer than 10^6 years, which is much longer than a reactor lifetime of about 30 years.

Regarding heat removal from grid meshes, a radiative cooling without liquid flow is ineffective because of the high heat flux. Indeed, the temperature of grid mesh determined by the radiative cooling rises up to 2105 K even for largest emissivity, i.e. black body radiation, which is much higher than the melting temperature of SS (~ 2000 K) and Cu (~ 1300 K).

By use of liquid flow to remove the heat, the temperature and pressure of pressurized water in the pipe of grid mesh change according to the heat transport equation and the drop of water pressure along the length. Here the coefficient of friction at the turbulent flow is introduced by using Blasius equation. The temperature of grid pipe at the inner surface is obtained from the heat transmission relation between fluid and inner surface of pipe. The coefficient of heat transmission is determined from the empirical heat transmission equation of a turbulent flow in a cylinder, i.e. Dittus-Boelter equation. The pipe temperature at outer surface is obtained from the heat conductive relation to a radial direction of a grid pipe. The pressure of a grid pipe is limited by a maximum shearing stress, i.e. Tresca yield condition, at the inner surface of grid pipe.

In Fig.1 (a) and (b), the temperatures and the pressures at the outlet (10m) are shown as a function of the flow velocity, where water temperature and pressure at inlet are 20℃ and 15 MPa in a pipe with inner and outer radii of 4.5 mm and 5.0 mm. The slower flow velocity than 2.9 m/sec makes the water temperature higher than the saturation temperature. From these results, by applying a grid pipe of Cu or SS, the pressurized water of 15 MPa with a flow velocity of higher than 10 m/sec is feasible to remove the input heat due to fusion protons.

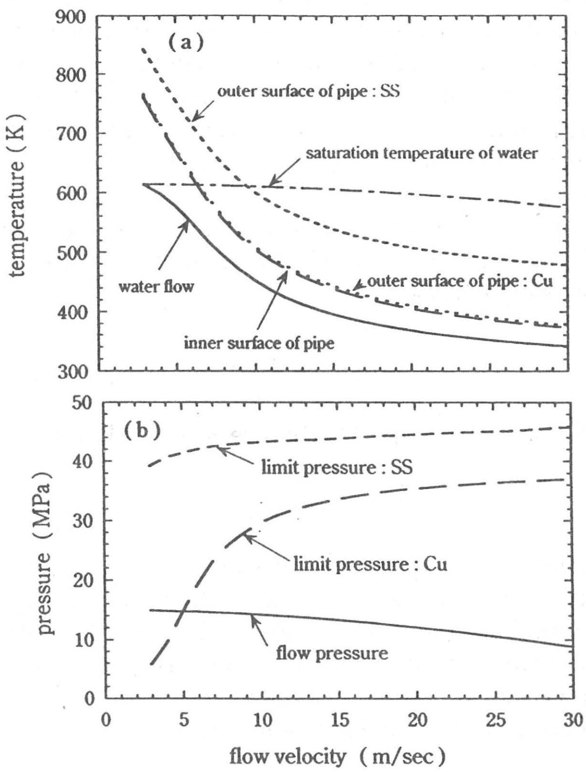

Fig.1. (a) The temperatures and (b) the pressures at outlet of a cooling pipe as a function of flow velocity.

References
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3) Yamamura, Y.,.Matsunami, N., and Itoh, N., Radiat. Eff. 71 (1983) 65.