§8. Basic Design of Liquid Blanket with Three-Surface and Multi-Layer Coating

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Reduction of MHD pressure drop is one of the important R&D issues in implementing Li/V (liquid lithium-vanadium alloy channel) blanket system. The three-surface and multi-layer coated channel was proposed as a solution by our research group.[1)] The channel is made by inserting a thin plate of vanadium alloy coated with insulated layer onto inner surface of a vanadium alloy rectangular channel. In this study, a capability of the channel to reduce MHD pressure drop is evaluated by an experiment with a large magnetic field. Then applicability of the channel to the blanket system of a fusion reactor will be discussed based on the result. This year, the reduction characteristics of MHD pressure drop are evaluated experimentally and numerically by using simulated three-surface and multi-layer coated channel.

The strong magnetic field up to 5 T generated by a superconducting magnet is applied to transversely to a torus channel with rectangular cross section shown in Fig. 1. The fluid level and the inside and outside diameters of the channel are 30 mm, 80 mm and 156 mm, respectively. The working fluid is Bi-Sn eutectic alloy of 150 °C, whose melting point is 138 °C. Driving force along the channel is generated by the axial magnetic field and radial current passing through the fluid from the inside electrode wall to the outside one. By employing an open channel system, the boundary condition at the free surface is the free slip condition which is equivalent to the symmetry condition and therefore it simulates half region of a rectangular channel. The experimental parameters are the magnetic field intensity (~5 T), the flow velocity (~0.6 m/s) and the thickness of the bottom stainless steel layer (0.02, 0.1 or 0.3 mm). Numerical simulation is also conducted to analyze the experimental results by comparing them with numerical results. The governing equations in this simulation are a 2D steady Navier-Stokes equation in terms of the circumferential component and a poison equation in terms of the electrostatic potential. They are solved alternatively by a finite volume method.

Fig. 2 shows changes in the pressure drop in the simulated channel. The experimentally determined pressure drops tend to be greater than those determined numerically for the smaller magnetic field and thinner stainless steel layer. The difference is attributed to the development of a friction force between an oxide layer (thought to form at the free surface) and the pure liquid metal. On the other hand, the pressure drops for the 0.1 or 0.3 mm thick walls are lower than those obtained by simulation. This is thought to be as a result of the contact resistance between the liquid metal and the wall. To investigate the effect of the contact resistance on the MHD pressure drop, the resistance value was measured. Based on the simple theoretical model in which the contact resistance is treated as a series resistance, the MHD pressure drop is reduced as shown in Fig. 3. Here, friction force regarded as increasing is subtracted from obtained pressure drop. The friction force is estimated by using the pressure drop obtained in the insulated channel. Fig. 3 shows that experimental results correspond with numerical ones by taking account of the effects of contact resistance and oxide layer at the free surface.

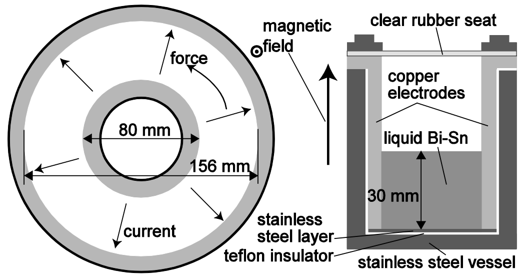

Fig. 1. Test section of experimental set-up.

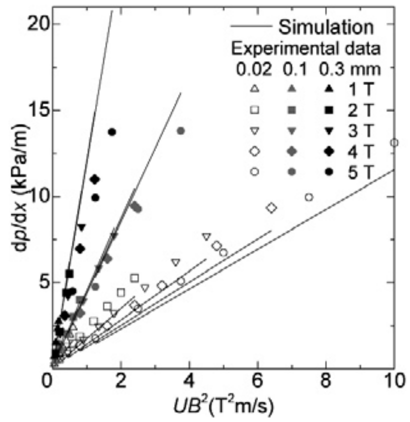

Fig. 2. Experimental (symbols) and simulated (lines) pressure drop

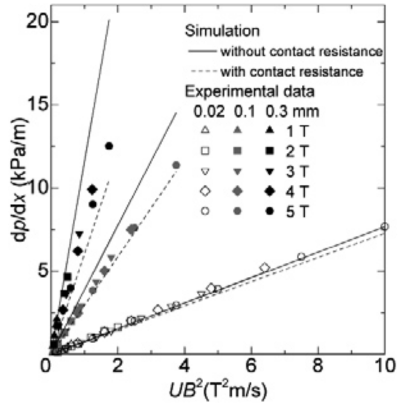

Fig. 3. Experimental (symbols) and simulated (lines) modified pressure drop

1) Hashizume, H.: Fusion Engineering and Design **81** (2006) 1431.