§22. Thermo-fluid Engineering Design of a Three-surface-multi-layered Channel

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Reduction of MHD pressure drop is one of the most 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] In this study, a capability of the channel to reduce MHD pressure drop is evaluated by an experiment with a large magnetic field and by a numerical simulation. A small open annular channel having free surface was used to evaluate MHD pressure drop[2] until last year in this collaborative research. In this year, we fabricated the three-surface and multi-layer coated channel, whose structure is the same as practical one. Then we experimentally demonstrated the effect of reduction of MHD pressure drop with the channel.

Fig. 1 shows a procedure to fabricate the channel and photo of a prototype of the channel for the experiment. The channel's wall and the thin metal layer, which are made of 316 grade of austenite stainless steel (SS 316) and insulated with silica, are jointed by TIG welding. The MHD flow experiment with the channel having length of 800 mm is conducted using an MHD experimental loop at UCLA.[3), 4)] The loop system consists of a melting tank, an electromagnetic (EM) pump, an EM flow meter, a test channel and circular pipes with outer diameter of 25.4 mm to connect the foregoing components. The working fluid is the PbLi eutectic alloy. A uniform magnetic field up to 1.8 T is applied transversely against the flow for 1 m in the streamwise direction. A sub loop sketched at Fig. 2 is connected to the test channel in order to measure the pressure differences. The experimental parameters are the magnetic field intensity (0~1.8 T), the flow velocity (0.1~2.0 m/s) and the operating temperature (270 ~ 350 °C).

Fig. 3 shows pressure drop in the downstream region (C-D) obtained by the experiment and the calculations in the case of temperature of 300 °C and velocity of 0.5 m/s. Although the experimental data is much smaller than the calculation ones for the conducting channel without insulating coating indicated by thick lines, the experimental data is slightly larger than the numerical ones for the three-surface-multi-layered channel indicated by thin lines. In the case of the magnetic field larger than 1 T, the differences change almost linearly against the magnetic field. This means that the difference between the experimental results and calculated ones is possibly caused by the friction force which changes linearly against the magnetic field. If the Lorentz force affected the difference, the difference should have changed nonlinearly. Therefore there is no more Lorentz force in the experiment than those in the calculation. It means that the insulating coating works well and the three-surface and multi-layer coated channel can reduce the MHD pressure drop under fusion reactor environment having strong magnetic field.

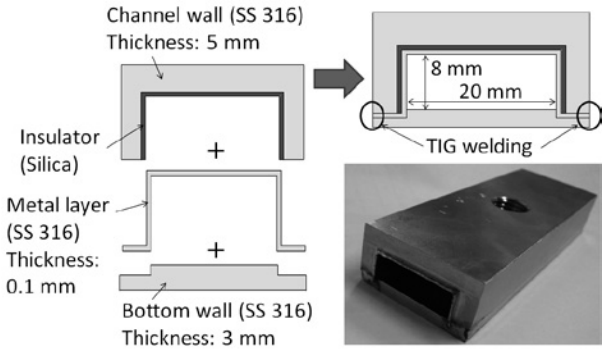

Fig. 1. Fabrication of the three-surface and multi-layer coated channel for the experiment

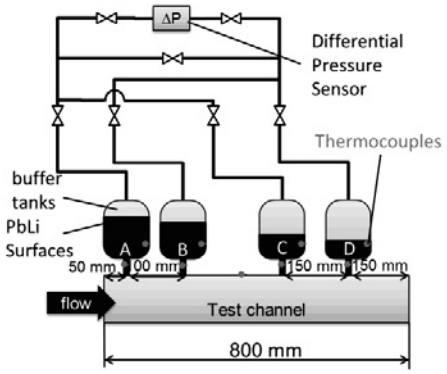

Fig. 2. Schematic view of the sub loop for differential pressure measurement

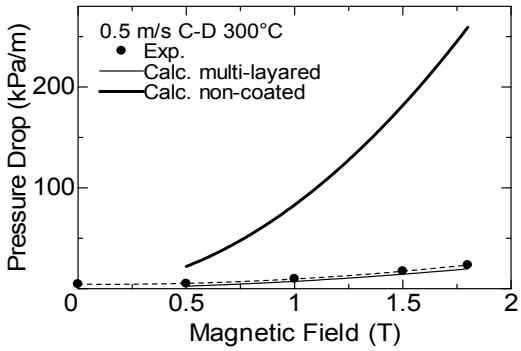

Fig. 3. Relationship between applied magnetic field and pressure drop in the region C-D with a velocity of 0.5 m/s and temperature of 300 °C

1) Hashizume, H.: Fusion Engineering and Design **81** (2006) 1431.
2) Aoyagi, M. et al.: Fusion Engineering and Design, **85** (2010) 1181.
3) Smolentsev, S. et al.: Fusion Engineering and Design **87** (2012) 777.
4) Smolentsev, S et al.: Fusion Engineering and Design **88** (2013) 317.