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

Ito, S., Hashizume, H., Aoyagi, M. (Tohoku Univ.), Muroga, T.

Reduction of MHD pressure drop is one of the important R&D issues in implementing Li/V 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 experiments with a magnetic field up to 5 T and by a numerical simulation. Then applicability of the channel to the blanket system of a fusion reactor is discussed based on the result. This year, we clarified the relationship between contact resistance and MHD pressure drop since the contact resistance between wall of the channel and the liquid metal might affect the MHD pressure drop. A thermo-fluid simulation was also conducted to investigate the design window of the first wall cooling channel in the self-cooled Li/V blanket with the three-surface-multi-layered channel.

At first, we evaluated relationship between the contact resistance and pressure drop by using simulated three-surface and multi-layer coated channel used in this corroborative research.[2] The contact resistance on the surface of the base stainless steel wall was evaluated by measuring the potential difference between the base wall and the side electrodes when current flows from the side electrodes to the base plate. The pressure drop is measured by the same method as the previous collaborative research.[2] Fig. 1 illustrates the pressure drop obtained both experimentally and analytically for various contact resistance values. The calculated data is based on the simple theoretical model in which the contact resistance is treated as a series resistance. Fig. 1 shows that there is a correlation between the MHD pressure drop and contact resistance. In the case of small contact resistance, varied pressure drop values are measured against the almost constant contact resistance on the base wall surface due to the large contact resistance on the side wall. These result shows that the contact resistance caused the disagreement between the experimental and numerical result in the previous collaborative research.

The simulation model is illustrated in Fig. 2. A thermo-fluid simulation is conducted by taking the channel dimensions of width, height and the thickness of first wall as parameters. Parameter range in the channel width ($2w$), height (h) and the first wall thickness (t) were 20 - 60 mm, 4 - 20 mm, and 3 - 5 mm, respectively. The working fluid is liquid lithium and the structural material is vanadium alloy. The MHD flow was computed supposing 2D-fully-developed laminar flow while the heat-transfer simulation was three dimensional with using the flow velocity obtained by the flow simulation. On the first wall surface, uniform heat flux was given as the boundary condition. In order to obtain the minimum flow velocity required for keeping the first wall temperature lower than the upper operating temperature limit of 700 ˚C, iterative calculations were conducted where the flow velocity was increased step-by-step until the maximum temperature appearing on the first wall surface became less than or equal to 700 ˚C. Fig. 3 shows the maximum mechanical stress. The stress of 200 MPa indicated by the broken line corresponds to the yield strength of V-4Cr-4Ti alloy. Mechanical stress became larger than the allowable stress in the cases of h = 20 mm or $2w$ = 60 mm. Therefore relatively smaller dimension channels were likely to be acceptable as the design window.

It was clarified that there is a correlation between the MHD pressure drop and the contact resistance on the base wall surface through the experiment and numerical analysis. In addition, the thermo-fluid simulation showed the design window of the first wall cooled by the liquid metal flowing in the three-surface-multi-layered channel.

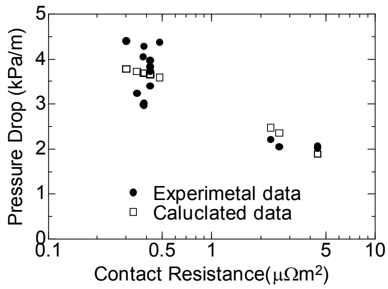

Fig. 1. Relationship between the pressure drop and contact resistance

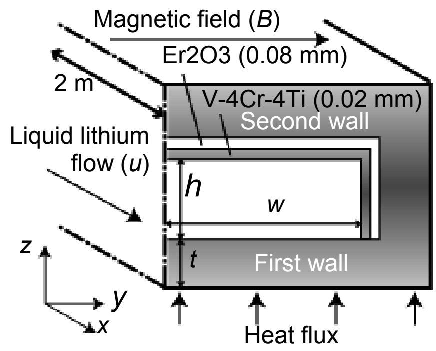

Fig. 2. Schematic view of the simulation model of the three-surface-multi-layered channel

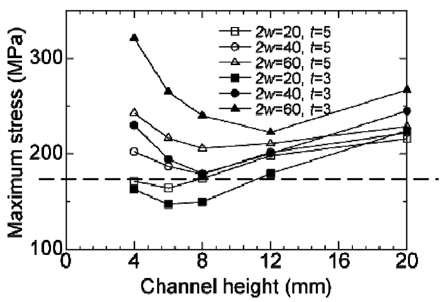

Fig. 3. Maximum mechanical stress

1) Hashizume, H.: Fusion Engineering and Design **81** (2006) 1431.
2) Aoyagi, M.: Fusion Engineering and Design **85** (2010) 1181.