§22. Advanced Design of the Three-surface-multilayered Channel by Optimizing Structure of the Metal Layer

Ito, S., Hashizume, H., Isshiki, D. (Tohoku Univ.), Muroga, T.

Our research group has proposed the three-surface-multi-layered channel to reduce MHD pressure drop[1)] in Li/V (liquid lithium/vanadium alloy channel) blanket system. The MHD pressure drop can be reduced to be acceptable value by using an inner thin metal layer with a thickness of <0.02 mm. However, the thickness is too small to insure its structural integrity. To solve this problem, we proposed a new design of the channel,[2)] in which the inner metal layer is partially reinforced by attaching reinforcing structure as shown in Fig. 1. The purpose of this collaborative study is designing the three-surface-multi-layered channel with reinforced inner metal layer achieving low MHD pressure drop, high mechanical strength and high heat transfer performance. In this year, we numerically evaluated flexural rigidity of a reinforced inner metal layer and MHD pressure drop with the metal layer. The results are also compared to those in the case of an unreinforced inner metal layer.

Fig. 2 shows geometry of a reinforced layer proposed in this study. We assumed that the thickness of original inner metal layer before the reinforcement is 0.02 mm and that is made of the vanadium alloy (V-4Cr-4Ti). We set reinforcing structure made of the vanadium alloy only on Hartmann wall because the pressure drop changes a little even if a side wall is reinforced completely. First, this study evaluates flexural rigidity of the reinforce layer as functions of w, h, θ, then also evaluates pressure drop at a magnetic field of 1.0 T and an average velocity of 0.10 m/s depending on w, h, θ. Governing equations are the equilibrium equation (eq.(1)) for structural analysis to evaluate the flexural rigidity, and Navier-Stokes equation of steady laminar flow (eq.(2)) and charge conservation (eq.(2)) for MHD analysis,

$$\nabla \cdot \sigma = 0 \tag{1}$$

$$\rho(\boldsymbol{U} \cdot \nabla)\boldsymbol{U} = \mu\nabla^2\boldsymbol{U} - \nabla p + \boldsymbol{J} \times \boldsymbol{B} \tag{2}$$

$$\nabla \cdot \boldsymbol{J} = 0 \tag{3}$$

where σ, ρ, $\boldsymbol{U}$, μ, p, $\boldsymbol{J}$, and $\boldsymbol{B}$ are stress tensor, fluid density, velocity, viscosity, pressure, current density and magnetic field, respectively. We used commercial FEM software, COMSOL Multiphysics 4.4 for the analyses.

We successfully fabricated a three-surface-multi-layered channel by using the inner metal layer with a thickness of 0.10 mm in a previous study.[3)] This fact indicates that we can fabricate the channel if a reinforced inner layer have the same level of stiffness property. At conditions of w = 10.0 mm, h = 0.08 mm, θ = 0 degree, which corresponds to inner metal layer with a thickness of 0.10 mm, the flexural rigidity and the pressure drop are estimated to be 125 times and 2.38 times larger than those in the case of inner metal layer with a thickness of 0.02 mm. Fig. 3 shows flexural rigidity for rotations about the axes of x and z as a function of θ at the conditions of w = 2.0 mm, h = 0.14 mm, where the is normalized by that of the layer with a thickness of 0.02 mm. There is a cross point where anisotropy disappears at the about θ = 34 degree. In this point, the flexural rigidity and the pressure drop are respectively 128 times and 1.16 times larger than those in the case of the inner metal layer with a thickness of 0.02 mm. Therefore, we can secure the intensity of the inner metal layer sufficiently and reduce the pressure drop by 50% from the case of the layer with a thickness of 0.10 mm.

As a next step, we plan to fabricate the reinforced inner metal layer, then, demonstrate the the three-surface-multi-layered channel with the reinforced layer by flow experiments.

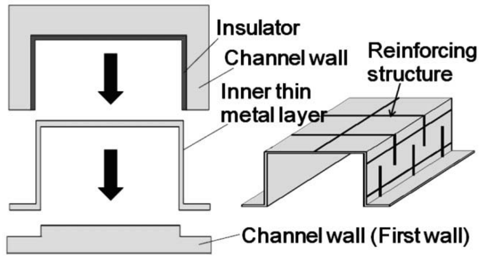

Fig. 1. Reinforcement of inner thin metal layer in the three-surface-multi-layered channel

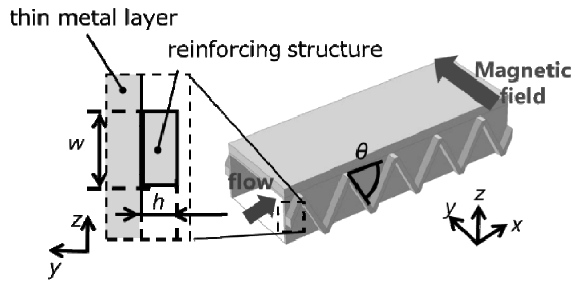

Fig. 2. Geometry of inner metal layer structure for the numerical analysis

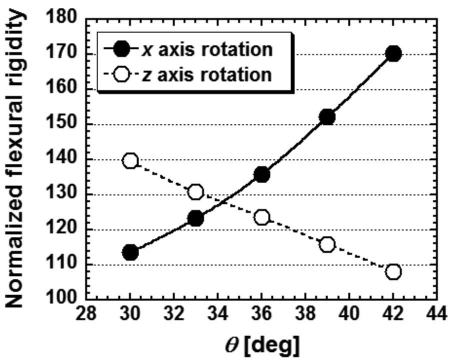

Fig. 3. Result of numerical analysis about flexural rigidity of inner metal layer

1) Hashizume, H.: Fusion Eng. Des., **81** (2006) 1431.
2) Inage, Y. et al.: Proc. NTHAS8. (2013).
3) Aoyagi, M. et al.: Proc. NTHAS8. (2013).