§6. Study on Thermo-Fluid Behavior of Turbulent MHD Flows in a Liquid Blanket

Satake, S. (Tokyo University of Science), Hashizume, H. (Tohoku University), Takahashi, M. (Tokyo Institute of Technology),
Sagara, A.

1. Objectives

In the region of transition Reynolds numbers, the increase or decrease of friction coefficients of the coolant like a Molten Salt having a low magnetic conductivity is obtained: a transition Hartmann number behavior. This behavior also leads the deterioration of heat transfer. Therefore, the thermo-fluid design of blanket under the magnetic filed fluctuation is very important. Since the magnetic field is strongly influenced by mean velocity when the magnetic field applies perpendicular to the flow direction, it is necessary to investigate the turbulent MHD flow behaviors for each direction of the applied magnetic field normal to the main flow one. Furthermore, in case of considering the wall with various electrical conductivities, the flow characteristics of the coolant could be different from the usual turbulent non-MHD flows. In this sense, the numerical simulation is very convenient to evaluate the flow changes due to the change of physical properties of the wall materials or the direction of applied magnetic field. In the present study, the numerical analysis with conduction equation of the well-known "Vortex Dipole" problem under a magnetic field is performed in order to evaluate the influence of an electrical conductivity of the first wall.

2. Numerical method and boundary condition for Vortex Dipole problem

The two-dimensional continuity and momentum equations for fluid motion and the magnetic flux equation for electrical field under a magnetic field were solved.

$$\nabla \cdot \mathbf{u} = 0 \tag{1}$$

$$\nabla \cdot \mathbf{B} = 0 \tag{2}$$

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\frac{1}{\rho} \nabla p + \nu \nabla^2 \mathbf{u} + \frac{\sigma}{\rho} (\mathbf{j} \times \mathbf{B}) \tag{3}$$

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\mathbf{u} \times \mathbf{B}) + \frac{1}{\mu_0 \sigma} \nabla^2 \mathbf{B} \tag{4}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{j} \tag{5}$$

Where $\mathbf{u}$, p, $\mathbf{j}$, $\mathbf{B}$ are velocity vector, pressure, current, and magnetic flux, respectively. ν, σ, ρ, μ_0 are dynamic viscosity, electrical conductivity, density, and magnetic permeability ($= 4\pi \times 10^{-7}\ H/m$), respectively.

The MHD fluid is in a channel with electrical conductive walls. One pair of vortex with a positive or negative circulation located at the center of the channel is introduced at first and then the vortex motion is traced by numerical simulation. The Reynolds number based on the circulation and the viscosity is 1800. The electrical conductivities of the wall are set to $1.036 \times 10^6 [1/\Omega m]$ for mercury, $6.452 \times 10^7 [1/\Omega m]$ for copper, $4.545 \times 10^6 [1/\Omega m]$ for lead. In order to investigate the effect of magnetic strength, two cases with different Hartman numbers: 100 ($0.003842 [Wb/m^2]$) and 200 ($0.007648 [Wb/m^2]$) were examined.

3. Results

Figure 1 shows the vortex contour that vortex pair attached at the wall for copper at t=1.5[s]and the 2-D contour for ***B*** distribution inside the wall at the same time. The distributions of vortex for all cases with different wall electrical conductivities are almost the same. However, the ***B*** distribution inside wall for copper is different from the fluid one and the sign of the wall ***B*** distribution shows the inverse for the vortex in fluid. Figure 2 shows ***B*** distribution for lead. The ***B*** distribution disappears at the low electrical conductivity.

Although the difference appears near wall region, the current becomes large for large electrical conductivity. That is, the reduction of wall shear at the wall is necessary to design for the reactor with conduction wall. As for turbulent flows, many turbulent vortexes must be existed near the wall. The effect of the wall conductivity must not be negligible. Therefore, we will perform the 3D turbulent MHD flow calculation with conduction wall in the future.

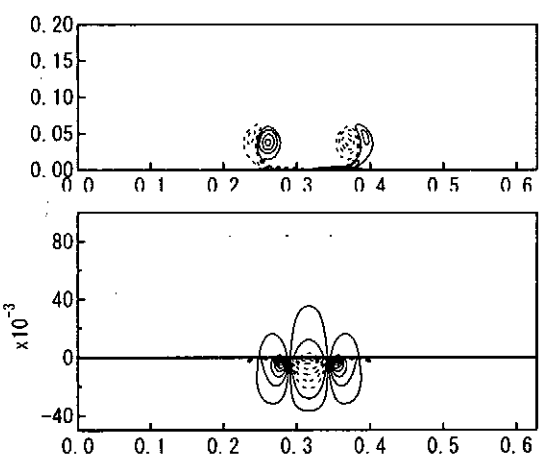

Figure 1 The vortex and ***B*** distribution at t =1.0 [s]: Upper is vortex, lower is ***B*** for capper.

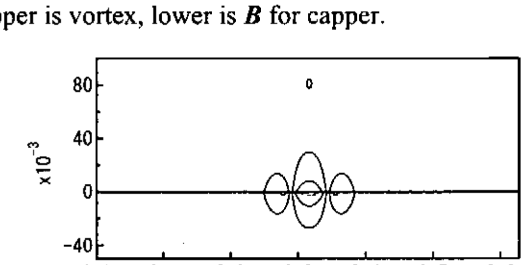

Figure 2 The ***B*** distribution for lead.