§ 8. 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. (National Institute for Fusion Science)

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 expected: a transition Hartmann number behavior. This behavior also may lead 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 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 potential equation for electrical field under a low magnetism Reynolds number assumption were solved. 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 0.01, 1, and 100. In order to investigate the effect of wall thickness, two cases with different thickness: 1 δ and 1/5 δ were examined.

3. Results

Figure 1 shows the vortex contour that vortex pair attached at the wall with σ=100 at t^*=4 and the 2-D contour for potential 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 potential distribution inside wall with σ=0.01 is different from the fluid one and the sign of the wall potential distribution shows the inverse for the vortex in fluid. At σ =1, the sign of vortex of secondary vortex and primary vortex are negative. Furthermore, the potential distribution disappears at the low electrical conductivity.

$$q = \int_0^{\frac{2\pi\delta}{2}} \left.\frac{du_z}{dy}\right|_{y=0} dz \qquad (1)$$

The equation 1 shows the gradient of the velocity to the z direction at the wall. The equation is integrated for the half region from the wall owing to the symmetry. The value for the time developing is shown in Fig. 2. Although the distribution is the same and closes to the initial state, the difference is remarkable from the first twin vortex collide at the wall to the second one. In particular, at the large conductivity, the difference in case of thicker wall becomes large. Therefore, the flow state is not affected by the difference of the conductivity. Although the difference appears near wall region, the current becomes large for the thicker wall. 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 twin 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 in the future.

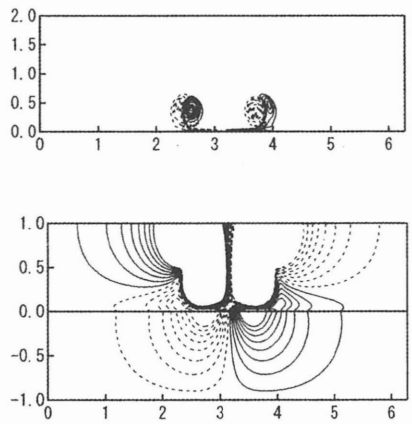

Figure 1 Vortex and potential distributions at t^*=4 and σ= 100: Upper shows the vortex and lower for the potential

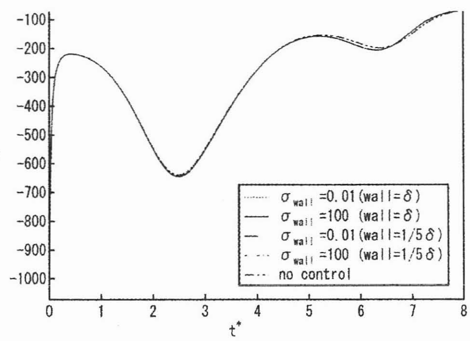

Figure 2 Time developing of the gradient of the velocity to the z direction