§10. Study on Heat Transfer Region for Fluid System in a Liquid Blanket

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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, to evaluate the effect of interaction of wall and fluid in 3D field, fully developed turbulent channel flow is carried out with high conducting wall. The difference for Reynolds shear stress budget near wall region is clearly observed compared with that of insulated wall.

2. Numerical method and boundary condition for turbulent channel flow with conducting walls

Our DNS code is hybrid spectral finite difference method. The periodic boundary conditions are applied to the streamwise (x) and the spanwise (z) directions. As for the wall normal direction (y), non-uniform mesh spacing specified by a hyperbolic tangent function is employed. The mesh number of 128 x (64) +128+ (64) x128 are used for the computational domain of $5\pi\delta$x (δ)+2δ+(δ) x $2\pi\delta$ in the spreamwise, the wall-normal, and spanwise directions. The all velocity components imposed the non-slip condition at the wall. The non-slip condition is used at the wall. A uniform magnetic field $\boldsymbol{B}_0$ defines that the magnetic orientation is parallel to the axis of the streamwise direction in Fig.6. The Neumann condition for the electrical potential is adopted at outside the wall: Conducting wall assumption. The Hartmann numbers ($Ha = \boldsymbol{B}_0\delta\,(\sigma/\rho\nu)^{1/2}$) based on the magnetic field $\boldsymbol{B}_0$, the kinematic viscosity ν, the electrical conductivity σ and the channel width δ are set to 15.0. The σ at fluid is 1.0. The σ at solid wall is 62.27. If these parameters are assumed as actual material, fluid and solid wall are mercury and copper, respectively. The Reynolds number is 4590 based on the bulk velocity. The fluid flows with constant mass flux condition.

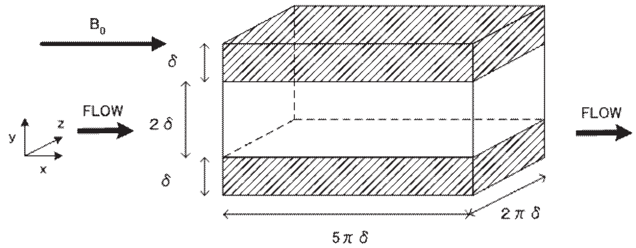
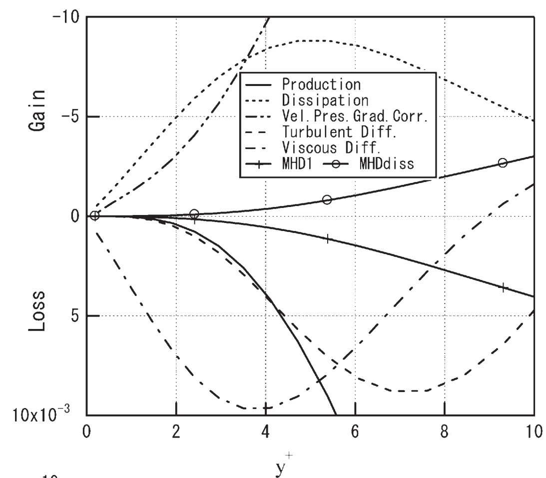


Figure 1 Computational domain.

Table 1

	Cf	Cf/Cf,o
Non MHD	8.5523×10^{-3}	1
Insulated wall, Ha=15	8.2894×10^{-3}	0.969
Conducting wall, Ha=15	8.1848×10^{-3}	0.957

(a)



(b)

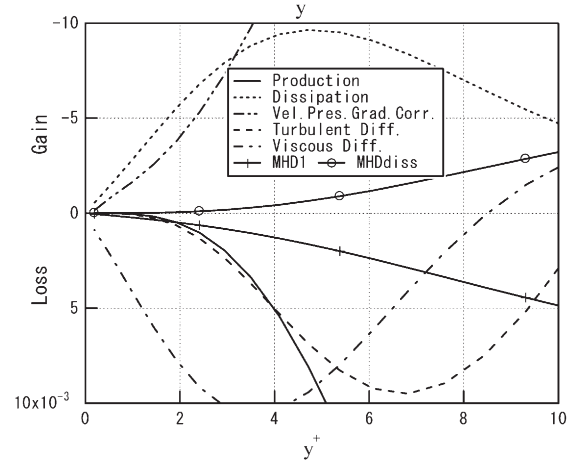


Figure 2 Reynolds shear stress budget: (a) Conducting wall, (b) Insulated wall.

The terms in Reynolds shear stress budget equation for the conducting wall and the insulated wall are shown in Figures 2 (a) and (b). The production terms of the conducting wall decrease at y+<4 compared with those of the insulated wall. The production terms consist of the normal stress and the mean velocity gradient. Although the mean velocity gradient is increased, the normal stress is further decreased. It is evident that the normal stress (not shown here) of the conducting wall is decreased compared with that of the insulated wall.

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