§20. Study on MHD Wall Shear Turbulent Flow with Free-slip Wall

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1. Objectives

Liquid-metals as coolant material in a fusion reactor have a significant role in the design of advanced reactors. To understand it better, an investigation of interaction between the wall and working fluid under a magnetic field is needed, such as in the case of slip-wall with magnetic effect. In the present study, direct numerical simulations (DNS) for turbulent channel flow with slip-wall have been carried out under a magnetic field. In this simulation the value of slip length was kept as 0.02. Using DNS the parameter such as mean velocity, Reynolds shear stress, and velocity fluctuations were quantified. The Reynolds number for channel flow based on friction velocity, viscosity, and channel half width was set to be constant as Re_τ =1100. A uniform magnetic field was applied in a direction perpendicular to the wall of the channel. Hartmann number Ha was set to be 65. Using the simulation we could see that the turbulent intensities have some value at the wall with increasing the Hartmann number.

2. Numerical method for direct numerical simulations

In our simulation model a uniform magnetic field B_0 defines the y-axis perpendicular to the streamwise direction that defines the x-axis as shown in Fig. 1. Our DNS code is a hybrid of spectral finite difference method. And for the normalization of the temperature equation, a constant positive temperature difference between the bottom and top walls was used. Slip condition gives one wall to assume slip effect. Its Hartmann number was varied as shown in table 1. All variables and parameter in the governing equations were normalized by the channel half-width δ, the friction velocity. The Reynolds number was kept fixed at 1100; the number was based the friction velocity and channel half width. The fluid then flowed with a constant pressure. The Hartmann numbers were set to be 0, 65. The number was based on the values of the magnetic field, the kinematic viscosity, the electrical conductivity and the channel half-width. Table 1 summarizes the values of Prandtl number, Reynolds number, and Hartmann number. Periodic boundary conditions were applied to the streamwise (x) and spanwise (z) directions. For the wall-normal direction (y), a non-uniform mesh spacing was employed that was specified by a hyperbolic tangent function. A non-slip condition at the wall was applied to the velocity components. The Prandtl number was 0.059 as is for Lithium, and this number was selected for the working fluid used for this computation.

Table 1 Computational parameters

Re_τ	Pr	Ha	Ls	Region	Grid number
1100	0.059	0	0.02	$5\pi\delta$x2δx$2\pi\delta$	1024x1024x768
1100	0.059	65	0.02	$5\pi\delta$x2δx$2\pi\delta$	1024x1024x768

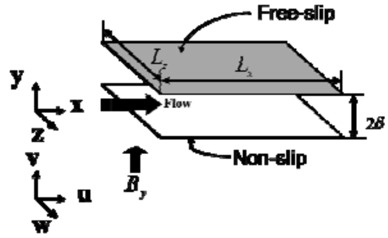
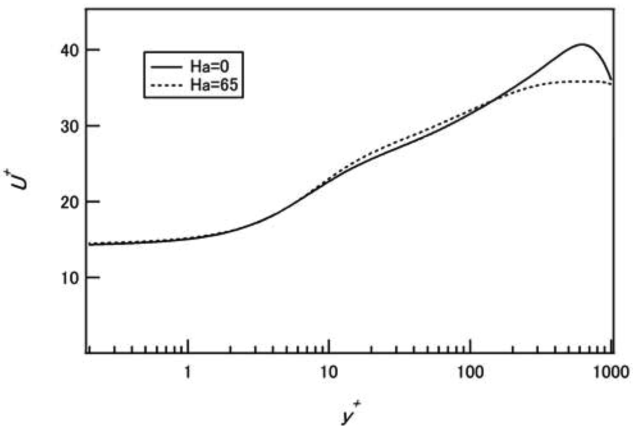


Figure 1 Computational domain.

3. Results

Mean velocity profiles are shown in Fig. 2. With a magnetic effect, the velocity profiles changed in the logarithmic region. At U-slip, the velocity profile shifted upward, the friction velocity becomes small, and the profile in the logarithmic region also flattens. In the case of W-slip, the profiles increased in the logarithmic region.

(a)



(b)

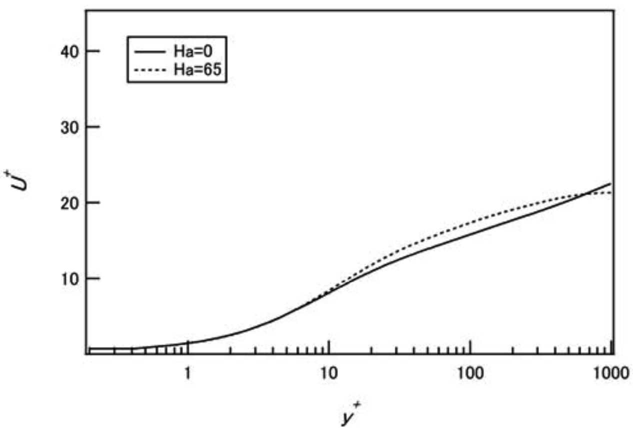


Figure 2 Mean velocity profile with slip: (a) U-slip, (b) W-slip