§27. Study on MHD Wall Shear Turbulent Flow on High Reynolds Number via Paralleled Direct Numerical Simulation

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1. Objectives

Turbulent simulation is possible to apply to the large Reynolds number via developing large scale computer, and the computation is close to the realized engineering facilities. In the high Reynolds number computation, the large scale structures must be understood by not local structures but that of whole region in computational domain. Therefore, we need large memory for not only main computer but also visualization computer. On the other hand, the large scale computation under a magnetic field have not been carried out, the previous studies is limited for low magnetic number and low Reynolds number computations. In this study, the objective is to calculate the large scale turbulent structures with the large Reynolds and Hartmann number by SX-7 at NIFS. In this study, it is important to understand the turbulence suppression the turbulent channel flow in a transverse magnetic field and to reveal the mechanism of disappearance of large scale turbulence structures.

2. Numerical method for direct numerical simulations

Our DNS code is hybrid spectral finite difference methods (Satake and Kunugi (2003) and Satake et al.(2003)). The number of grid points, the Reynolds number and grid resolutions summarized in Table 1. 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 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 y-axis lies along the axis of the streamwise direction in Fig.1. The Neumann condition for the electrical potential is adopted at the wall: Insulation wall assumption. The Hartmann numbers ($Ha = \boldsymbol{B}_0 2\delta(\sigma/\rho\nu)^{1/2}$) based on the magnetic field $\boldsymbol{B}_0$, the kinematic viscosity ν, the electrical conductivity σ and the channel width 2δ are set to 65.

Table 1

Re_τ	Ha	Region	Grid number	Δx^+	Δy^+	Δz^+
1100	0	$5\pi\delta$x2δx$2\pi\delta$	1024x1024x768	16.8	0.16-4.18	8.9
1194	65	$5\pi\delta$x2δx$2\pi\delta$	1024x1024x768	18.2	0.17-4.54	9.6

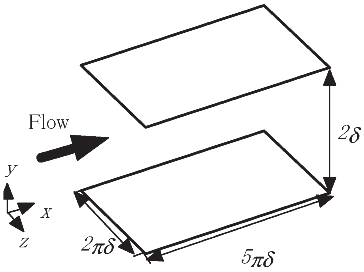

Figure 1 Computational domain.

3. Results

Mean velocity profiles are shown in Fig. 2. Satake & Kunugi (2003) and Satake et al. (2003) found that the logarithmic profile exits and elongated to the channel center. The logarithmic profile at Ha=65 shifted to the channel center, and wake region disappears clearly. The profile is good agreement with the experimental profile by Brouillette & Lykoudis (1967). To investigate this phenomenon for the change of the dominant scales, the streaky structures are visualized in Fig. 3. It is normalized by ν and $u\tau$. The volume visualized obtained as full volume (L_x^+=17278 L_y^+=2200, L_z^+=6911). The many small streaky structures exist in large streaky structures. The width of the large streaky structures are larger than 1000, located at away from the wall. Without MHD case, a few merged large streaks elongated to the channel center away from the wall. A characteristic size of the large streaky structures to the streamwise direction is even larger than the half of the channel width. Almost large structures located in y^+>200, correspond to the wake region in the mean velocity profile. On the other hand, the large scale motion at the channel center disappeared in Fig. 3. It is evident as the reason that the turbulent intensities are decrease at the channel center owing to the applied magnetic field. Moreover, the streaky structures are elongated to the streamwise direction.

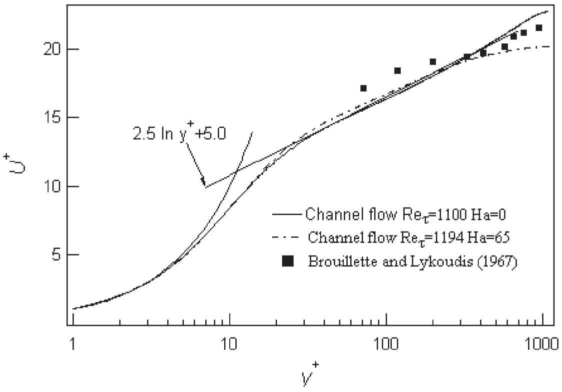

Figure 2 Mean velocity profiles

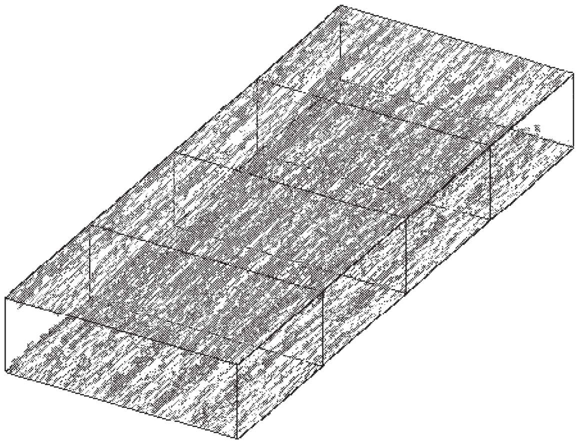

Figure 3 The contour of streaky structure; u^+<-3