§22. Direct Numerical Simulation of Thermofluid for Gas Cooling

Satake, S. (Tokyo Univ. of Science),
Kunugi, T. (Kyoto Univ.)

1. Objectives

Gas cooling 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 have been carried out. 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 =2200. Our DNS code parallelized by MPI+OpenMP was carried out at a new supercomputer system.

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. 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 2200; the number was based the friction velocity and channel half width. The fluid then flowed with a constant pressure. 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 0.71 as is for air, and this number was selected for the working fluid used for this computation.

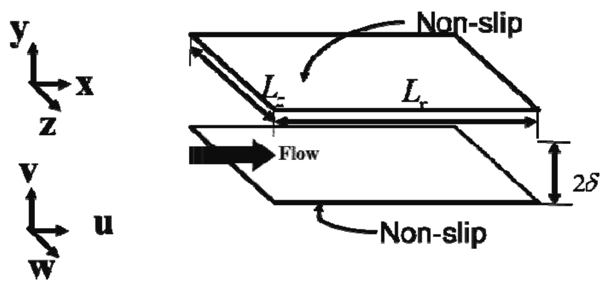
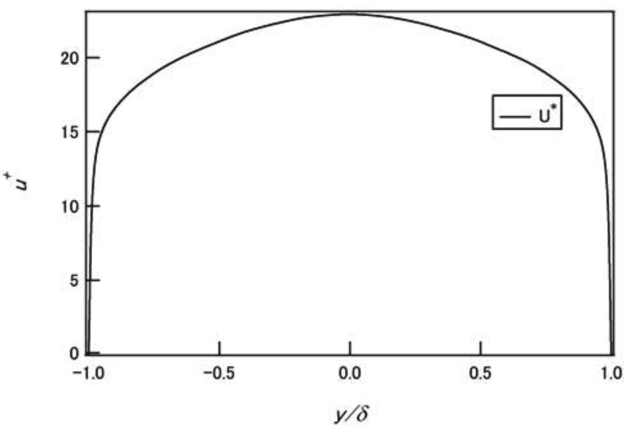


Figure 1 Computational domain.

3. Results

Mean velocity profiles are shown in Fig. 2 (a). The velocity profiles is symmetric. Velocity fluctuations profiles shows in Fig. 2 (b). The each component of velocity fluctuation is also symmetric. The flow state is a fully developed flow. Moreover, our DNS program in the case was rewritten in MPI+OpenMP, those results show that even use of a small number of nodes can have them achieved a calculation performance equal to the one achievable by using a large number of nodes.

(a)



(b)

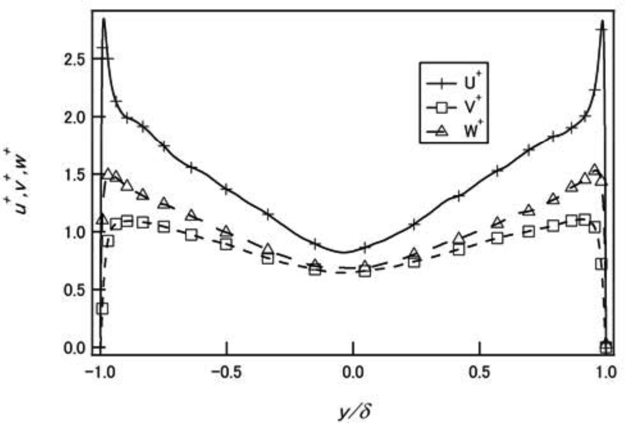


Figure 2 Turbulent statistics: (a) Mean velocity profile, (b) Turbulent intensities