Magnetohydrodynamic Turbulent Channel Flow with Transverse Square Cylinders

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Turbulent flows of electrically conducting fluids are of most importance in the various engineering aspects of the future fusion power plant. Some of these flows are expected to interact directly with immersed solid bodies. Although a significant number of direct numerical simulations (DNS) have been reported for magneto-hydrodynamic (MHD) turbulent flow in channels, only few investigations taking into account such bodies have been considered so far.

Direct Numerical Simulations of MHD turbulence in channel flow with transverse square cylinders placed at selected positions normal to the channel wall are presented. The magnetic field is assumed to be parallel to the stream-wise direction of the flow. This external magnetic field configuration was selected because it minimizes the Hartmann effect on the non-conducting walls of the channel, although a strong Hartmann effect is encountered at the cylinder walls. The induced magnetic field is assumed to be negligible and, thus, the low magnetic Reynolds number approximation has been used, instead of the full magnetic induction equations. The numerical method used to solve the low-Rm equations is based on a semi-implicit fractional step method; the diffusion term is advanced in time with the Crank-Nicolson method, while the non-linear and Lorentz force terms are advanced with a third-order Runge-Kutta (RK3) method. An efficient immersed-boundary method is adopted for the square cylinders.

The parameters studied in the present work are the magnetic interaction parameter (Stuart number), which is the ratio of the electromagnetic force to the inertial force, and the size and position of the transverse square cylinders. The Reynolds number is fixed at the relatively low value of 3000. The results show that the usual MHD turbulent channel flow is characterized by more organized and elongated structures than that in the channel flow without a magnetic field. The streaky structures are substantially weakened and the streak spacing appears to be larger. The influence of the simultaneous presence of the transverse square cylinders with the magnetic field is investigated. Results show a strong connection of the Stuart number with the Hartmann effect due to the presence of the square cylinders.