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Computational Analysis of MHD Flows in a Conduit with Multiple Channels under a Magnetic Field

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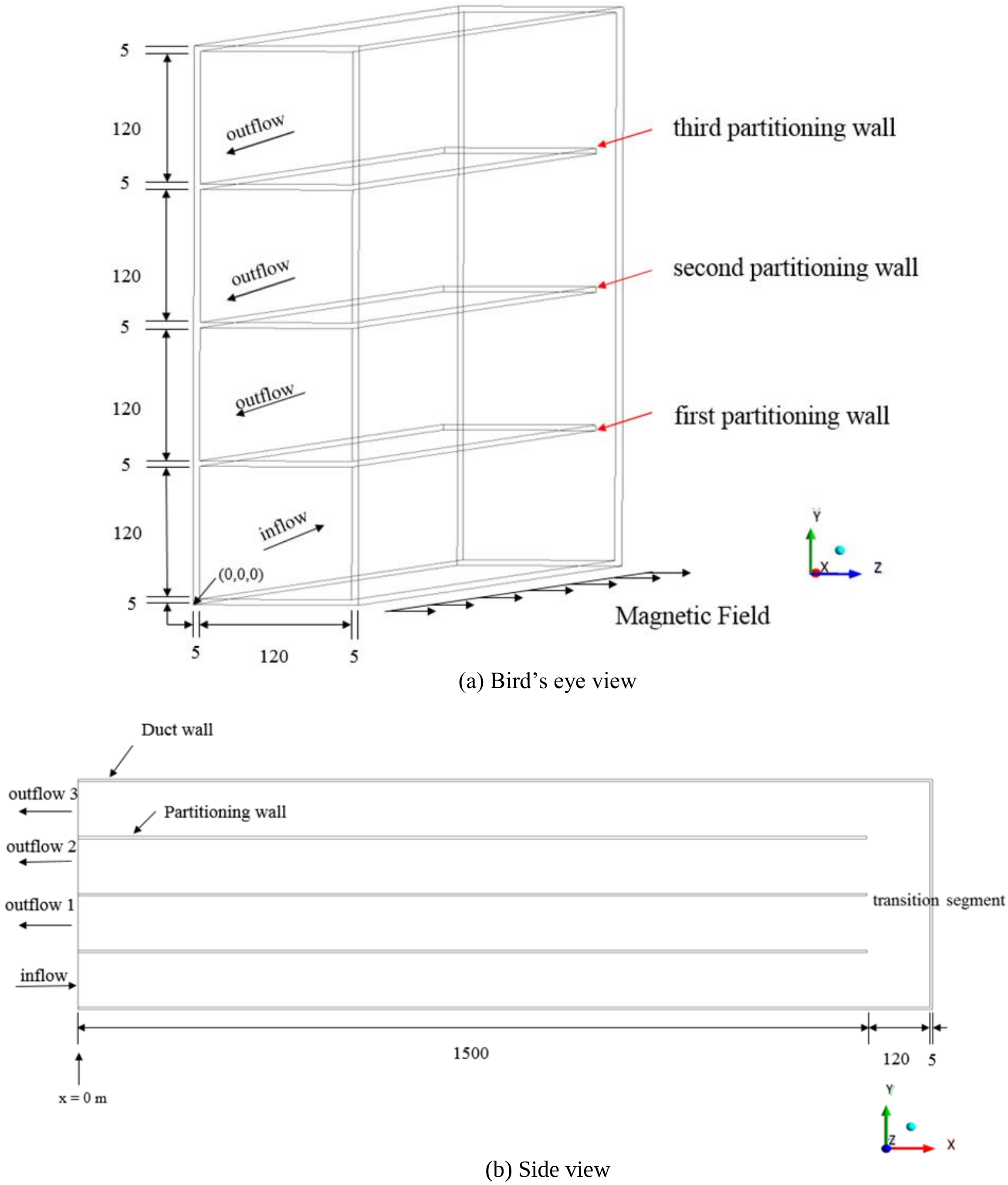
Extended Abstract

This study performs the numerical simulation of a three-dimensional liquid-metal magnetohydrodynamic flows in a conduit with multiple channels under a uniform magnetic field applied perpendicular to the plane of flow. Magnetohydrodynamic (MHD) flow is a field of great interest in engineering applications, especially important in the design of liquid-metal (LM) cooling system of fusion reactor, where a plasma is confined by a strong magnetic field, as previously shown (Mistrangelo, Buhler, 2007). The fluid motion of LM in a strong magnetic field results in serious MHD effects, having dramatic impacts on velocity distribution, pressure drop and the required pumping power for the cooling system, as shown by Zhou et al. (2010). The geometry of the conduit is of a four-parallel-channels system including one inflow channel and three outflow channels, as displayed in Fig. 1. The liquid-metal flows in the inflow channel, then turns 180^o in the transition segment, finally flows into three different outflow channels simultaneously. A uniform magnetic field B = 0.4822 T (correspond to Hartmann number 600) is applied in the z-direction. A structure grid system with 4,203,000 grids is used in the present study. Finer grids are employed in the fluid region near the walls and in the transition segment. Under-relaxation is utilized in the iteration procedure for the coupled governing equations. The second-order upwind scheme is used to discretize the convective terms and the central difference scheme for diffusion terms. The simulation results show that, the highest axial velocity is observed in the side layer near the first partitioning wall, which is located between the inflow channel and the first outflow channel. 'M-shaped' velocity profiles are obtained in the side layers of the inflow and outflow channels. When the fluid is fully developed, the axial velocity near the first partitioning wall is larger than that near the second and third partitioning walls in the outflow channels. Moreover, the axial velocity in the fluid region below the first partitioning wall (in the inflow channel) is larger than that in the fluid region above the first partitioning wall (in the first outflow channel). In the inflow channel, the current flows downward, then returns to the first partitioning wall through the duct walls. In the outflow channels, the current flows upward. However, in the first outflow channel, the current distribution is more complex because the complicated velocity therein. The higher electric potential is formed in the outer walls, while the lower electric potential is induced in the first partitioning wall and in a fluid region near the first partitioning wall-fluid interface. In the transition segment, the highest velocity observed near and above the end of the first partitioning wall. And the separated flow yields velocity recirculation above the end of the first portioning wall. The pressure almost linearly decreases along the main flow direction, except for in the transition segment. The pressure in the inflow channel decreases more rapidly than that in the outflow channels. Moreover the pressure gradient of the first outflow channel is the largest in the three outflow channels.

***Keywords**:* Liquid-metal; Magnetohydrodynamic; Multiple channels



(a) Bird's eye view

(b) Side view

Fig. 1. Duct geometry, coordinate system and an applied magnetic field (unit: mm).

References

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