Transient Vortex Bursts Behind Magnetic Obstacles

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ABSTRACT

The present paper reports on numerical investigations of vortical structures in transient flow regimes generated by the local action of the Lorentz force on an electrically conductive fluid. The locally imposed non-uniform magnetic field generates similar effects as observed for flows over submerged solid obstacles. It is demonstrated that complex flow patterns can be generated by imposing magnetic fields of different strengths and configurations.

The initial validation of the electromagnetically extended Navier-Stokes solver on unstructured numerical grids is performed in the low-Reynolds number range $100 \leq Re \leq 400$ for different values of the magnetic interaction paramete, ($0 \leq N \leq 11.25$). A generally good agreement is obtained in comparison with similar numerical studies of Votyakov *et al.* [1], [2] for the low-Reynolds number cases.

Then, a series of simulations are performed in transitional flow regimes ($Re = 1000, 1500$) for different values of the interaction parameter ($N = 0, ..., 50$). In addition to a single magnetic obstacle configuration, multi-magnet configurations with different geometric constrainment parameter (a ratio between the magnetically affected area and the total cross-section area) were analysed too.

Simulations demonstrated the appearance of vortex-shedding phenomena similar to the flows behind solid obstacles. In contrast to the solid obstacles, the magnetic obstacles also generated the vortical flow patterns inside the magnetically affected regions. The passive scalar distributions (temperature) are also simulated. Despite the laminar inflow conditions, turbulent bursts are observed in the magnetic wake region, which in turn generated significant mixing enhancement of a passive scalar (temperature). We have visualised the temporal dynamics of the vortical structures in the magnetic obstacle wake. The velocity and temperature spectra at characteristic locations are analysed. Surprisingly, the characteristic vortex-shedding frequency was very weakly affected by changing the magnetic interactive parameter (N). The analysis of the long-term averaged second-moments, demonstrated that a strongly anisotropic turbulence was locally sustained in the proximity of the magnetic wake edge.

References

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