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L. Bühler

Institut für Kern- und Energietechnik
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Abstract

The prediction of three-dimensional MHD flows for applications in fusion engineering, where magnetic fields confining the plasma are very high, is still a challenging task since, up to the present day, numerical simulations for such conditions are beyond the capabilities of modern CFD tools. Also experimentally, on laboratory scales, these values of parameters are hard to reach. Asymptotic analyses instead are able to cover such regimes in which inertia and viscous forces play only a minor role in comparison with the strong electromagnetic forces. However, especially for geometries with sudden changes of cross section, inertia effects may still be present in thin viscous parallel layers, where relatively high values of velocity can occur. For such cases only numerical simulations and/or experiments can give the proper insight into the physics involved. Those methods are therefore applied to determine the relevant scaling laws for strong fields, which allow a physically meaningful extrapolation of data to the desired parameters for engineering applications.

As an example the 3D MHD flow through a sudden expansion of rectangular ducts is considered; results have been obtained by asymptotic theory for strong magnetic fields, by numerical simulations up to moderate magnetic fields and they are compared with experimental data. It is possible to derive the relevant scaling laws for pressure drop, as a function of the Hartmann number Ha and the interaction parameter N. Results obtained by asymptotic analysis and numerical simulations show quite good agreement with experiments for the investigated parameters. Moreover, the numerical simulations allow analyzing the interesting 3D transitions and changes in the flow topology, occurring in the parameter range between the hydrodynamic case with $Ha = 0$ and the strong field case where $Ha \gg 1$, $N \gg 1$.