Linear global stability computations of magnetohydrodynamic duct flows

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Abstract

The interaction of the moving liquid-metal fluid with a magnetic field gives rise to a rich variety of phenomena. On the one hand, under a strong magnetic field the mean flow profile may create inflexion points (Kakutani 1964), shear layers (Lehnert 1952) and jets (Hunt 1965), producing instability of free shear flow type. On the other hand, strong magnetic field tends to damp three-dimensional perturbations by suppressing the variation in the magnetic field direction; the action of strong magnetic field would suppress the production of turbulence and make the transition from laminar flow to turbulence occur at much higher Reynolds number (Shatrov & Gerbeth 2010). For the liquid-metal duct flows under such a strong uniform magnetic field, the two combined effects can make the turbulence transition begin with linear instability, which has been conformed by the direct numerical simulations of Kinet, Knaepen & Molokov (2009) for Hunt flows. Furthermore, linear global instability analysis of Hunt flows by Priede et al. (2010) also shows that the critical Reynolds number for large Hartmann number is small about $Re_c \approx 112$ which is scaled by bulk average velocity. According to the presented theoretical results, and from the view point of the theoretical value and engineering practice, it is important to precisely determine the linear stability boundary of the magnetohydrodynamic (MHD) duct flows. In this paper, various numerical techniques for the linear global instability computation of the liquid-metal MHD duct flows (under a strong uniform magnetic field) are presented, especially comparative advantages and disadvantages between them are given. These numerical techniques have laid a good foundation not only for the linear global stability study on the liquid-metal MHD duct flows, but also for the in-depth research on the MHD turbulent transition mechanism.

Keywords: conducting metal fluid, linear global stability, magnetohydrodynamic (MHD) duct flows, Hunt flows

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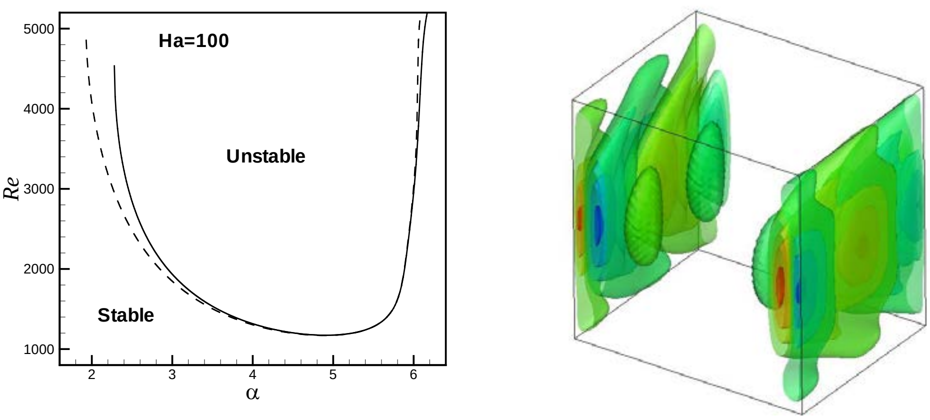

Figure 1. Linear global stability of MHD Hunt flows for $Ha = 100$. Left: neutral boundary curve; Right: spatial structure of streamwise velocity eigenfunction with $\mathrm{Re} = 2500$, $\alpha = 4.0$.