Magnetic instability in a rotating layer at highly eccentric positions of the critical level

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Abstract: This study follows the numerical results presented in Marsenić and Ševčík, (2010) that explored the influence of the critical level position on stability of a system. The model was a horizontal fluid layer between $z = \pm 0.5d$ rotating with an angular velocity $\mathbf{\Omega} = \Omega_0 \hat{\mathbf{z}}$ about the vertical axis $\mathbf{z}$. The fluid was considered to be inviscid, finitely electrically conducting and incompressible and was permeated by a horizontal magnetic field $\mathbf{B_0} = \mathcal{B}_I B_0(z)\hat{\mathbf{y}}$, where $\mathcal{B}_I$ was the magnitude of the field and the function $B_0(z) = \tanh[\gamma(z - z_0)]$. When γ is large, the field gradient is concentrated near $z = z_0$, the critical level, the field being almost homogeneous elsewhere. In this way it controls the width of the magnetic shear layer associated with the current sheet. It was found that at conditions when the magnetic field gradient was large enough ($\gamma = O(10)$) and the critical level was placed close enough to the (bottom) perfectly conducting boundary ($z_0 < -0.388d$ for $\gamma = 80$), magnetically driven convection appeared localized to a close neighbourhood of the critical level - the so called critical layer. Based on the circumstances of its rise and its properties it was identified with the resistive tearing-mode instability.

This paper presents an analytical treatment of the problem assuming $\gamma >> 1$. The approach consists in separation of the computational domain into an outer region where the diffusionless limit (Elsasser number $\Lambda \to \infty$) applies and an inner region (the critical layer) of finite conductivity. According to the tearing-mode theory in classical systems, the solution in the inner region is sought as long-wavelength with respect to the width of the critical

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layer. The obtained solution shows features similar to the one obtained numerically and confirmed relevance of the simplifying physical assumptions made in each region and is presented in Marsenić and Ševčík, (2011).

Key words: Magnetohydrodynamics, Resistive instabilities, Tearing mode

References

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