§24. Eigenmode Analysis of Rayleigh-Taylor and Kelvin-Helmholtz Instabilities in the Extended MHD Model

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Small scale effects of the Rayleigh-Taylor (RT) and Kelvin-Helmholtz (KH) instabilities in magnetized, finite beta plasmas are investigated based on the linear eigenmode analyses of the extended MHD equations. In these instabilities, small scale effects like two-fluid and ion finite Larmor radius (FLR) effects may not be neglected if the wave number is large or if the scale length of equilibrium profile is small[1)-4)]. In order to compare with nonlinear extended MHD simulations for fusion plasmas, detailed linear stability analyses for more realistic conditions than those assumed in existing theories are needed for the verification. In the extended MHD equations used in this study, the two-fluid effects are introduced into the generalized Ohm's law as the Hall current and electron pressure, and the ion FLR effects appears as the gyroviscosity in the equation of motion. By linearizing the equations, the eigenmode equations are derived.

The eigenmode equations are solved numerically for smooth profiles of flow and density in finite-beta, non-isothermal plasmas with electromagnetic perturbations. We consider sheared flow and density gradient along the gravity perpendicular to an equilibrium magnetic field in a slab. The equilibrium profiles are given from the radial force balance. The two-fluid and ion FLR effects modify the equilibria as well as the stability. The beta value is set to 0.1. For the models with the two-fluid and/or FLR effects, the ion skin-depth normalized by the system size L is set to 0.5. Figure 1 shows the growth rates of RT instability for different models as functions of the wavenumber of perturbation. Short wavelength modes are strongly stabilized when both the two-fluid (TF) and FLR effects are included while the two-fluid effect itself destabilizes and the FLR effect alone only slightly stabilizes. Figure 2 show the growth rates of KH instability for different models. The two panels are for the opposite signs of flow shear, which show asymmetry of the two-fluid and FLR effects on the sign of shear flow. The two-fluid effect stabilizes larger wavenumber modes while the FLR effect destabilizes them. In contrast to the RT instability, the combination of these two effects does not necessarily change drastically the small scale behavior. These results are qualitatively consistent with our simulation results.

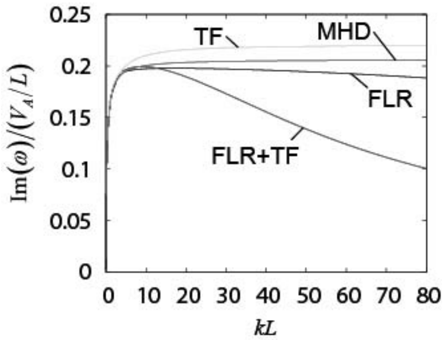

Fig. 1. Dependence of the growth rates of RT mode on the wavenumber for different fluid models.

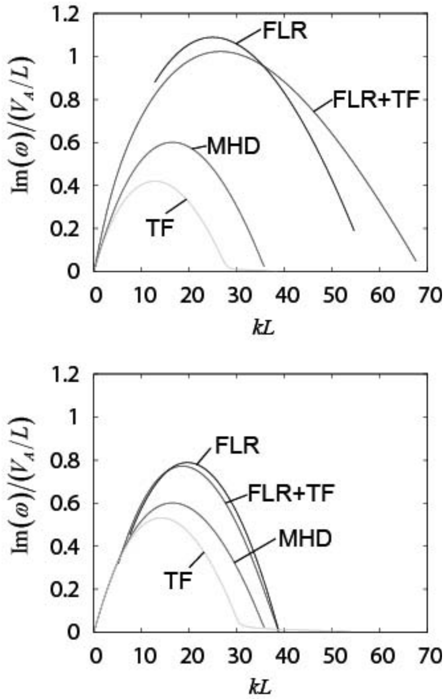

Fig.2. Dependence of the growth rates of KH mode on the wavenumber for different fluid models.

1) K. V. Roberts and J. B. Taylor, Phys. Rev. Lett. **8** (1962) 197.
2) P. Zhu et al., Phys. Rev. Lett. **101** (2008) 085005.
3) J. D. Huba, Phys. Rev. Lett. **72** (1994) 2033.
4) J. D. Huba, Geophys. Res. Lett. **23** (1996) 2907.