§5. Extended Modeling for MHD Equilibrium and Stability of Toroidal Plasmas

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In this study we construct extended models for magnetohydrodynamic (MHD) equilibrium and stability of toroidal plasmas to include plasma flow and small scale effects on the conventional MHD theory. Based on extended MHD models, we have studied kinetic effects on equilibria with flow, two-fluid and finite Larmor radius (FLR) effects on the Rayleigh-Taylor instability in finite beta plasmas and two-fluid tearing modes.

Equilibria of toroidal plasmas with flow and kinetic effects have been studied. A new model of toroidal equilibria with flow to include the effect of particle motion along the magnetic field is being developed based on the so-called kinetic MHD.

The parameter dependence of two-fluid and finite FLR effects on the Rayleigh-Taylor (RT) instability in finite beta plasmas has been examined. Local and eigenmode analyses for the linear RT instability are done for Four MHD models, the MHD model, two-fluid MHD model, MHD model with FLR and two-fluid MHD model with FLR. The absence of complete stabilization of large wavenumber modes due to FLR effect occurs for low beta when the pressure gradient is small. The combination of two-fluid and FLR effects can also cause the absence of complete stabilization and the two-fluid MHD model with FLR is not always most stable among the other models, depending on beta. For the case of MHD with FLR, for large wavenumber modes, the growth rate of the eigenmode is larger than that of the local analysis at the center. The eigenfunction has two humps in the regions that are still unstable while the RT mode is completely stabilized at the center in the local analysis.

For low collisionality plasmas, the terms with parallel heat flux to the magnetic field included in the gyroviscosity derived from the fluid moment of the kinetic equation[1,2] cannot be neglected. We examine the effects of parallel heat flux in the ion gyroviscosity on tearing instability based on extended MHD models. To study linear stability of tearing modes, the linearized extended MHD equations including parallel heat flux in gyroviscosity are simplified by taking only the first-order terms in the MHD ordering. We solve the resulting linear eigenmode equations for the tearing mode numerically. We first examine the two-fluid tearing instability[3] in order to in a wide range of parameters as a benchmark. By changing both plasma beta value and ion skin depth, three regimes with different algebraic scaling law, weak-Hall, strong-Hall with high beta and strong-Hall with low beta regimes, have been reproduced. Figure 1 shows the transitions (1) from weak-Hall to strong-Hall with high beta regimes (2) from strong-Hall with high beta to MHD regimes and (3) from weak-Hall to strong-Hall with high beta regimes and (4) weak dependence of low beta regime on the two-fluid effect for three different values of magnetic Reynolds number S=10^4, 10^5 and 10^6 by changing the ion skin depth d_i and the beta value. Based on the results for the parameter dependence of two-fluid tearing instability, we will examine the effects of gyroviscosity with parallel heat flux.

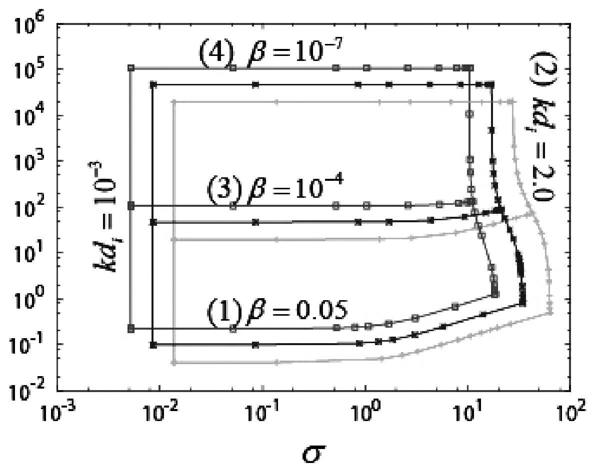

Fig. 1. Parameter space of the two-fluid effect and the beta value for tearing instability.

1) J. J. Ramos, Phys. Plasmas 12, 052102 (2005).
2) J. J. Ramos, Phys. Plasmas 12, 112301 (2005).
3) E. Ahedo and J. J. Ramos, Plasma Phys. Control. Fusion **51**, 055018 (2009).