§23. Extended MHD Simulation Study of Instabilities in a 2D Slab

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Effects of two-fluid and Finite-Larmor-Radius (FLR) terms to magnetohydrodynamic (MHD) instabilities are studied numerically. Although there are some earlier works on this subject[1-3], the parameters in the literatures are not necessarily suitable for torus plasma, and discussion there is much more on linear growth than on nonlinear evolutions. Here we carry out numerical simulations of the Rayleigh-Taylor and the Kelvin-Helmholtz instabilities with an intention to cover parameters suitable for heliotron plasma as well as to obtain some perspectives in nonlinear saturations of the instabilities. We restrict ourselves to simulations in a 2D slab, keeping three components of the magnetic field. Braginskii-type extended MHD equations[4] are solved numerically by the use of the 4^{th} order central-finite-difference scheme and the Runge-Kutta-Gill technique.

In simulations of the Rayleigh-Taylor instability, the influences of the gyroviscosity and the Hall terms appear as the decrease/increase of the growth rates of $\beta = 10\%$ plasma. In Fig.1(a), the growth rates under the presence of the gyroviscosity and/or the Hall term are shown. It is easily find that the gyroviscosity reduces the growth rates, while the Hall term increases the growth rates slightly. The density contours in the single-fluid MHD simulation is shown in Fig.1(b). It may be noticeable that the introduction of both the gyroviscosity and the Hall term brings about a larger reduction of the growth rates in comparison to a simulation only with the gyroviscosity. Although the gyroviscosity reduces the growth rates, the time evolution of the mixing width in Fig.1(c) shows that the gyroviscosity does not necessarily brings about a saturation of the growth of the instability with a limited mixing width. This problem is going to be studied further.

In simulations of the Kelvin-Helmholtz instability, the influences of the gyroviscosity and the Hall terms on the growth rates appear just opposite to those in the Rayleigh-Taylor simulations. As is shown in Fig.2, the growth rates decreases as the Hall coefficient becomes larger. On the other hand, the growth rates increases as the gyroviscosity becomes larger. It is also noted that the inclusion of both the gyroviscosity and the Hall term does not necessarily bring about a large reduction of the growth rates.

We are now carrying out full-3D simulations of the Braginskii-type extended MHD equations. Growth and saturation of instabilities in torus plasma, especially at the edge region, will be studied with a help of these 2D studies.

1) Roberts, K.V. and Taylor, J. B.: Physical Review Letters **8** (1962) 197.
2) Huba, J. D.: Physics of Plasmas **3** (1996) 2523.
3) Zhu, P. et al.: Physical Review Letters 101 (2008) 085005.
4) Braginskii, S.I.: Review of Plasma Physics **1** (1965) 205.

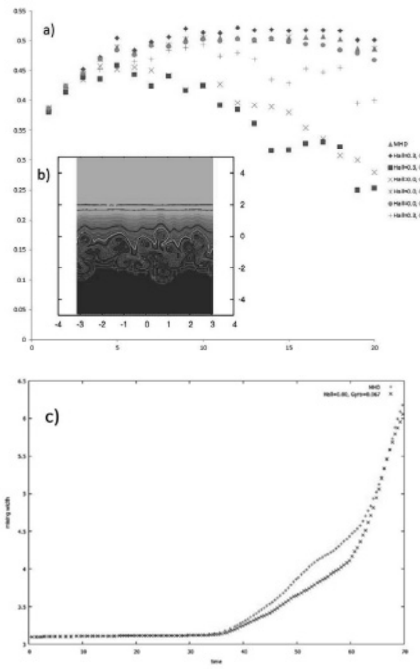

Fig. 1. (a) The growth rates of the Rayleigh-Taylor modes under the influences of the gyroviscosity and/or the Hall terms. The abscissa is the wave number in the horizontal direction. (b) Density contours in a nonlinear stage of the single-fluid MHD simulations. (c) Time evolution of the mixing width in a single-fluid MHD simulation (red) and a simulation with the gyroviscosity (blue).

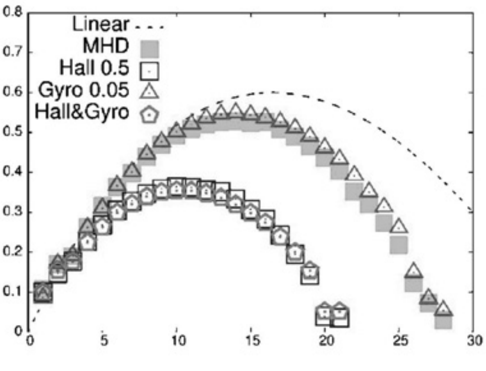

Fig. 2. The growth rates of the Kelvin-Helmholtz modes under the influences of the gyroviscosity and/or the Hall terms.