§18. DNS/LES of Magnetized Plasmas by an Extended MHD Model

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Micro-scale effects on short-wave instability are studied numerically for the sake of understanding growth and saturation of pressure-driven instability of the Large Helical Device (LHD). The micro-scale effects such as the Finite-Larmor-Radius (FLR) effect and two-fluid effects can influence short-wave instabilities by enhancing/ suppressing instability, causing diamagnetic drift, and so on. .

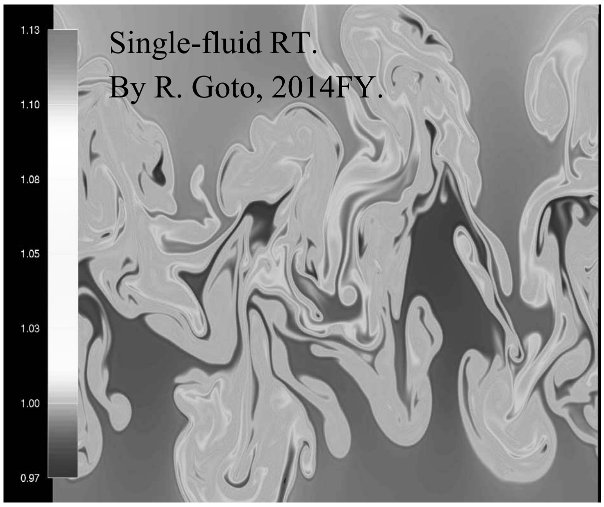
We investigate carrying out Large Eddy Simulations (LES) of a short-wave instability based on an extended MHD system. For the sake of developing a sub-grid-scale model of nonlinear terms in the extended MHD equations, we need to know how the nonlinear terms are related with the short-wave components of the magnetic fields and the velocity fields.

For this purpose, we have carried out numerical simulations of the Rayleigh-Taylor (RT) instability in a 2D geometry for some combinations of the beat value, the two-fluid (or Hall) coefficient, and the gyro-viscous coefficient. The extended MHD equations are solved numerically by the fourth-order central finite difference scheme and the fourth order Runge-Kutta-Gill scheme, starting from an initial equilibrium under the gravity working to the vertical direction. In order to contribute to studies of instabilities in LHD, we set beta values as low as a few percent, being comparable to that in a typical experimental value in LHD.

The numerical simulations of the 2D RT have shown that the growth rate of the RT instability is suppressed strongly at relatively high wave number region only when both the two-fluid and the gyro-viscous coefficients are set finite. When neither the two-fluid term nor the gyro-viscosity is introduced in the system (that is, the single-fluid MHD system), the Rayleigh-Taylor instability causes a strong mixing through its transition to turbulence. (See upper panel of Fig.1.) On the other hand, when both the two-fluid and the gyro-viscous terms are introduced, the absence of the short-wave RT modes leads to growth of the secondary Kelvin-Helmholtz (KH) instability at the high wave-number region. (See the lower panel of Fig.1.) The growth of the secondary KH instability is attributed to the generation of the shear layer due to the large-scale RT modes, and the thinning the shear layer due to the gyro-viscous force. It has been observed that the growth of the KH modes can affect the growth of the mushroom structure of the RT modes.

. It has been also observed in the work that the introduction of both the two-fluid and the gyro-viscous term causes raise of high wave number Fourier coefficients in the nonlinear stage of the time evolution. The raise of the Fourier coefficients should also be closely related with the thinning of the shear layer by the gyro-viscous force. Thus, although the gyro-viscous force can suppress the linear high odes through the combination with the two-fluid term, it brings about a demand of a very high resolution in the nonlinear simulations. Based on these numerical results, it is considered that a very fine resolution should be also required in instability simulations of a torus plasma by extended MHD model. This result has been published in Physics of Plasmas.[1)]

1) Goto. R et al.: Physics of Plasmas **22**, 032115 (2015).



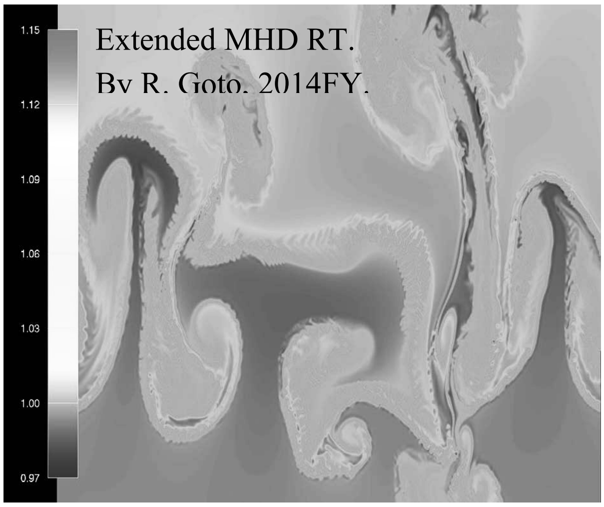


Fig. 1. Contours of the density in RT simulations. Upper panel is for a single-fluid MHD simulation and the Lower panel is for a simulation with both the two-fluid coefficient and the gyro-viscous coefficient.