§ 34. Study on Neoclassical Tearing Mode

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The linear neoclassical tearing mode is investigated using the four-field reduced neoclassical MHD equations. We consider a high temperature plasma of major and minor radii R_0 and a with a toroidal magnetic field B_0 in the cylindrical coordinates (r,θ,z). The model consists of vorticity equation, Ohm's law, ion parallel flow and electron density equation. If we take the collisional limit $\omega < \mu_i$, where μ_i is the neoclassical ion viscosity, then this model is reduced to the three-field model. The detail explanation of the model equation is given by reference[1].

Figure 1 shows the collisionality dependence of the growth rate. The solid line indicates the result from four-field model. The result from the three-field model is also shown by the dashed line. In the case of the three-field model, the growth rate is positive in an entire collisionality regime. As the results, the stability of the NTM is determined by the sign of Δ'. In the case of the four-field model, the NTM is stabilized in the banana-plateau regime in spite of $\Delta' > 0$. This stabilization is caused by the compound effect of the parallel compressibility, diamagnetic drift and ion neoclassical viscosity. The ion neoclassical viscous force caused by the ion parallel flow has the stabilizing effect on the NTM and this effect is stronger in the low-collisionality regime, where eigenmode is more strongly localized at the rational surface and the relative amplitude of fluctuating ion parallel velocity has the larger value than that in the collisional règime.

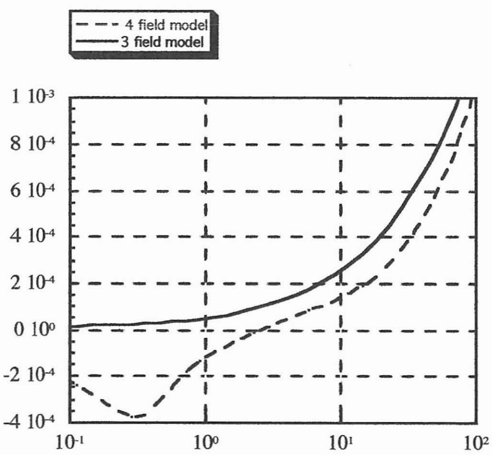

Fig.1. The collisionality dependence of the growth rate. The solid curve indicates the result of three-field model including only electron neoclassical viscosity and dashed curve indicates the result of four-field model.

Next, we investigate the diamagnetic drift effect on the stability. Essentially, two terms contribute it. The one is the ion finite Larmor radius (FLR) effect which appears in the vorticity equation and the other is electron diamagnetic effect in the Ohm's law. Figure 2 shows the diamagnetic drift effect on the growth rate for the four-field model. Here the diamagnetic drift parameter is related with normalized ion skin depth $\delta = c / a\omega_{pi}$. In cases with $\delta = 0, 0.005, 0.01, 0.02$ are plotted. It is found that NTM is stabilized in the banana-plateau regime for large δ values. In the large size tokamak plasma, δ is about $0.01 \sim 0.1$, therefore, the NTM might be easily stabilized in the banana-plateau regime, even if $\Delta' > 0$. We also check the diamagnetic drift effect in the case with three-field model and conclude that the stabilization effect is smaller than that of four-field model and complete stabilization never happen for three-field model. The combined effect of diamagnetic effect with ion neoclassical viscosity and parallel compressibility plays a crucial role for the stability.

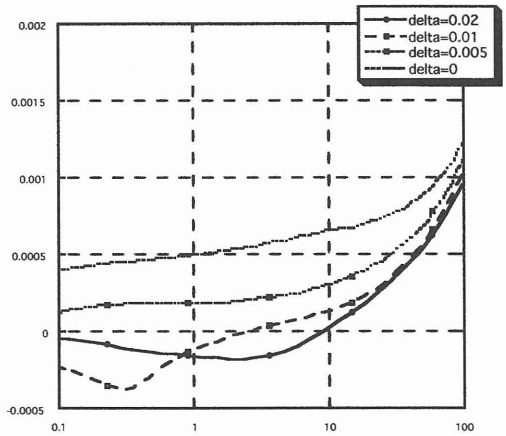

Fig.2. The collisionality dependence of the growth rate for the cases of $\delta = 0, 0.005, 0.01, 0.02$. The solid curve indicates the result for $\delta = 0.02$ and the dashed curve for $\delta = 0.01$.

Finally, the q profile effect on the NTM is analyzed. This affect on the NTM through the magnetic shear and the change of the free energy source. It is found that the weak shear limit, the NTM coupled with parallel ion flow via neoclassical viscosity is excited. These modes could be excited in the reversed-shear configuration, however, the drift tearing mode or the other internal mode might have the larger growth rates in this limit. The comparison study is left for the future work.

To clarify the onset condition or its excitation mechanism of the NTM, the nonlinear simulation with multi-helicity is necessary including the ballooning coupling terms and/or sawtooth oscillation. It is now going on and will be reported somewhere.

References

1) A. Furuya, M. Yagi and S.-I. Itoh, J. Phys. Soc. Jpn 72 (2003) 313.