§24. Second Stability Boundary of Ion Temperature Gradient Mode and Trapped Electron Mode

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In connection with the H-mode state, which is characterized by the confinement improvement and steep density gradient near the edge, the stability boundary of steep density gradient for the ion temperature gradient mode (ITGM) and the trapped electron mode (TEM) have been investigated by numerically calculating the local dispersion relations in a toroidal system.

For the toroidicity induced ITGM, we assume that the perturbed electron distribution is adiabatic, the ion Larmor radius effect is negligible and the magnetic curvature drift frequency has the simple energy dependence: $\omega_D = \hat{\omega}_D E$, and calculated the local dispersion relation:

$$1 + \frac{1}{\tau} - \frac{2}{\sqrt{\pi}} \int_0^\infty \frac{\omega - \omega^* (1 + \eta_i (E - 3/2))}{\omega - \hat{\omega}_D E} \sqrt{E} e^{-E} dE = 0$$

where $\hat{\omega}_D = 2e_n \omega^*$, $\omega^* = cTk_\theta/eBL_n$, $e_n = L_n/R$, $L_n^{-1} = d\ln N/dr$, $\eta_i = d\ln T/d\ln N$ and other notations are standard.

The discrete eigenvalue obtained by the dispersion relation depends on two parameters e_n and η_i. Since the inhomogeneities of plasma density N and temperature T are the source of the ITGM, it may be stabilized when e_n and η_i are reduced, which may give ordinary stability boundary.

Our purpose here is to find the (second) stability boundary in the opposite steep density gradient regime. To find the second stability boundary, we carefully calculated the discrete complex eigenvalue ω_0 in small e_n region by a contour plotting method. As presented in Fig. 1, for a fixed η_i, the ITGM becomes stable when e_n is smaller than certain critical value or the density gradient is larger than certain critical value.

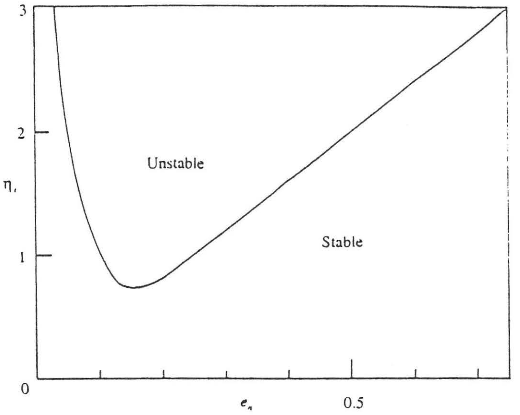


Fig.1.

To find the steep critical density gradient for the trapped electron mode (TEM), we assume a simple model without transit ion and Larmor effect for ions, and use the same local dispersion relation as in a previous report[1]:

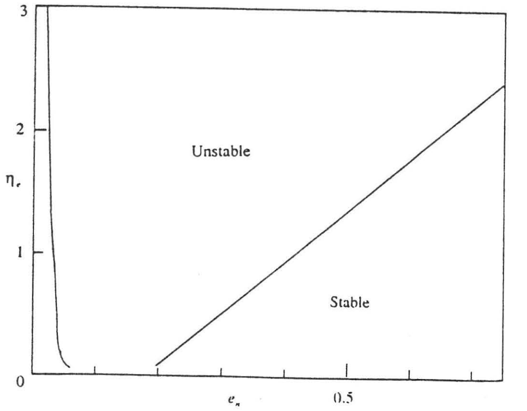
$$1 - \frac{1}{\omega} - \frac{2\sqrt{\varepsilon}}{\sqrt{\pi}} \int_0^\infty \frac{\omega - 1 - \eta_e (E - 3/2))}{\omega - 2e_n E} \sqrt{E} e^{-E} dE = 0$$

where ω has been normalized by the drift frequency ω^*. In this case too, e_n and η_e together with the toroidal effect R are the source of the TEM which may be stabilized when e_n and η_e are reduced. This may give the ordinary first stability boundary. From the dispersion relation with the marginal condition $\mathrm{Im}\,\omega=0$, the first stability boundary has been obtained as $e_n=(1-\varepsilon^{1/2}(1-3\eta_e/2))/3$.[1]

To find the second stability boundary for e_n, we numerically calculated the above dispersion relation by the same method as in the ITGM for small e_n regime. Result is presented in Fig. 2 for the toroidal effect $\varepsilon=0.3$. There is a stable e_n region below a lower critical boundary, i.e., the collisionless TEM becomes stable when the density gradient is steeper than certain critical value.

The existence of the second stability boundary for the ideal ballooning mode (IBM) is well known. The anomalous diffusion induced by these ITGM, TEM and IBM may be eliminated when the density gradient becomes steeper than the critical value determined by these modes, althought anomalous transport due to plasma turbulence may still exist.

Fig.2.



[1]T.Yamagishi, Report NIFS-247 (1993).