§6. Analysis of Kinetic Internal Kink Modes in Reversed Magnetic Shear Tokamak

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Tokamak operation with the reversed shear has attracted much interests in related to the enhanced confinements. It is possible that, in the reversed shear configuration, the internal kink mode or the double kink-tearing mode would be dominated by the kinetic effects as in the case of the normal shear configuration. For example, in the JT-60 tokamak, the high performance discharge with the reversed shear configuration is often suspended by the fast disruption at the beta lower than the critical one predicted by the ideal MHD theory [1]. It is clear that the phenomena cannot be explained only by the collisional MHD theory.

We have studied the linear stability of the $n = 1$ (n is a toroidal mode number) and $m = 1, 2, 3$ (m is a poloidal mode number) kinetic internal kink modes (double tearing modes) by using the gyro-reduced-MHD code in the cylindrical geometry, GRM3F-CY [2-4], which is a three field model of the electrostatic potential, the component of the vector potential in the direction of the longitudinal magnetic field, and the electron density. The gyro-reduced-MHD model is derived by the moment equations of the gyrokintetic Vlasov-Maxwell system and includes the kinetic effects of electron inertia, the diamagnetism of electrons, and the electron pressure gradient along the magnetic field. Multiply accumulated meshes at the rational surface are used to resolve the fine mode structure of the characteristic lengths of the collisionless electron skin depth d_e and the ion gyro-radius estimated by the electron temperature ρ_s.

We selected the parameters close to the present day large tokamaks: $a = 1$ [m] (minor radius), $R = 3$ [m] (major radius), $n_{e0} = 10^{20}$ [m^{-3}] (average electron density), $B = 5$ [Tesla] (toroidal magnetic field), and $T_e = 10$ [kev] (electron temperature). For such a tokamak with deuterium discharge, $d_e/a = 5.315 \times 10^{-4}$ and $\rho_s/a = 2.891 \times 10^{-3}$.

The growth rates and the eigenmode profiles are obtained by numerically solving the temporal evolution of the field quantities. The example of a q profile used in the calculation is depicted in Fig.1. Figure 2 shows the minimum safety factor q_{min} dependence of the growth rate of the kinetic double kink-tearing mode for the cases of ($n = 1, m = 1$), ($n = 1, m = 2$), and ($n = 1, m = 3$). The mode pattern is localized between two rational surfaces for $m \geq 2$. For all cases growth rates which are much greater than those of the normal magnetic shear are obtained. For example, the characteristic time of a few hundreds micro seconds is observed for the case of the $m = 2$ kinetic double kink-tearing modes. So the fast internal collapse observed in the experiment may be explained by the kinetic double kink-tearing mode of $m = 2$.

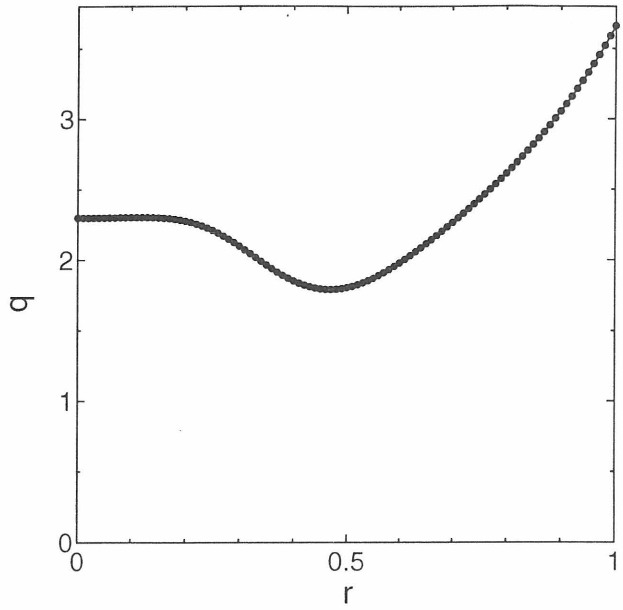

Fig.1 q profile.

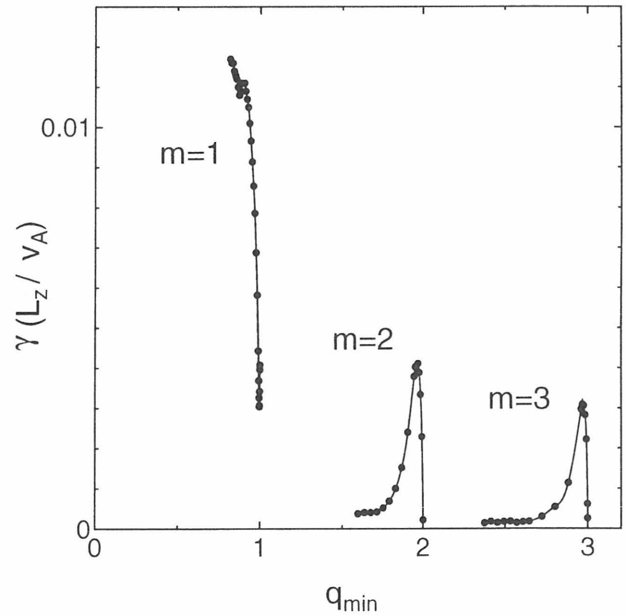

Fig.2 γ depending on q_{min}.

Reference

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