§1. Life Time of Plasma States Near Transition Boundary

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A stochastic equation for the amplitude of the neoclassical tearing mode (NTM) has been derived, and the life time of a state free of the onset of NTM is obtained. The model and basis are explained in refs.1 and 2. One has an explicit form of the life time as [3]

$$ t_{\text{life}} = \frac{2\pi}{\eta_{\text{ms}}} \exp \left( S(A_m) \right), $$

(1)

where the time rates $\Lambda_{m,0}$ are given as

$$ \Lambda_m = 2A | \partial A/\partial A | \text{ at } A = A_m \quad \text{and} \quad \Lambda_0 = A(A_0), $$

and the nonlinear dissipation function was given as

$$ S(A) = \Gamma_0 \frac{r_p^2}{\rho_b^2} \left( -\frac{4}{3} \Lambda_0 A^{3/2} + h A^2 \right) $$

$$ + \frac{r_p^2}{\rho_b^2} \frac{L_q}{L_p} \beta_p \left[ 1 + \frac{r_p^2 A^2}{\rho_b^2} \right] $$

$$ - \Gamma_0 \frac{r_p^2}{\rho_b^2} \left( A - \frac{w^2}{w_{\text{cut}}^2} \ln \left( 1 + \frac{r_p^2 A}{w_{\text{cut}}^2} \right) \right) $$

(2)

with $\beta_{\text{pn}} = (L_p/2a_b)e^{1/2} L_q$ and

$$ \Gamma_0 = \frac{2}{R_{\text{M}}^4 k^4 C^2 A^{4} \alpha_{\text{ac}}^4 r_s^2} \beta_p^2. $$

(3)

An explicit value of the transition rate was examined by specifying a micro mode for typical experimental parameters. For the L-mode plasmas, when one employs the current-diffusive ballooning mode (CDBM) as the micro mode, one has $\Gamma_0$ as

$$ \Gamma_0 = \frac{2 \times 10^{-4} \delta}{k^3 \left( -\alpha^{1/2}(1 + \alpha) + \omega_{\text{pe}}^2 B_m / m_e \right) s^4 R_{\text{M}}} $$

$$ \times \frac{r_p^2}{\delta^4} \alpha^{-11/2} $$

(7)

where $\delta$ is the collisionless skin depth and $\alpha = (r_p^2 B_m / L_p)$ is the normalized pressure gradient.

For a set of typical parameters, $r_p/\delta = 10$, $r_p/\delta = 10^2$, $R_{\text{M}} = 10^5$, $B_m / m_e^2 - 10$, $kr_s = 3$, $s = 1$, $\alpha - \beta_{\text{p}} \beta_{\text{pn}}$, one has $\Gamma_0 - 3 \left( \beta_p / \beta_{\text{pn}} \right)^{11/2}$. The life time of the state $A = 0$ (i.e., free from the NTM) is shown in Fig.1. The unit of the life time is $2\pi h \sqrt{\Lambda_0 / \Lambda_m}$, which is of the order of Rutherford growth time. The dependence on plasma beta is shown. (Other parameters are fixed, $\Lambda_0 = 0$ and $h \beta_p^2 = 1/40$.) The life time strongly decreases as the plasma beta increases. And if it exceeds the effective phase limit $\beta_p$, the life time becomes of the order of the magnetic diffusion time. The contour of life time is shown in Fig.2.

**Fig.1 Mean life time before the onset of the NTM as a function of the plasma beta value. (\(\Delta_0 = 0\)) Other parameters are $h \beta_p^2 = 1/40$, $w_{\text{cut}} = \rho_b$ and $L_q / L_p = 2$.

**Fig.2 Contour of life time on the \(\{\Delta_0, \beta_p\}\) plane. Cusp for the multiple solution is also shown by the dotted line. Above the dotted line, multiple solutions are allowed and stochastic transition takes place. (Other parameters are $h \beta_p^2 = 1/40$, $w_{\text{cut}} = \rho_b$ and $L_q / L_p = 2$.)

Reference