§19. A Novel Turbulence Trigger for Neoclassical Tearing Modes in Tokamaks

Yagi, M., Yoshida, S., Itoh, S.-I. (RIAM, Kyushu Univ.)
Naitou, H., Nagahara, H. (Yamaguchi Univ.)
Leboeuf, J.-N. (UCLA),
Matsumoto, T., Tokuda, S., Azumi, M. (JAERI)
Itoh, K.

The nonlinear evolution of neoclassical tearing mode (NTM) in the presence of drift wave turbulence is investigated using the four-field neoclassical MHD equations, where the fluctuating ion parallel flow and ion neoclassical viscosity are taken into account[1,2]. The model equations are written as

$$\frac{d}{dt}\nabla_\perp^2 F = -\nabla_{/\!/}\nabla_\perp^2 A + \mu_i^c \nabla_\perp^4 F - \frac{q_s}{\varepsilon_s}\mu_i^{nc}\frac{\partial U_{pi}}{\partial r} - \frac{q_s}{\varepsilon_s}\frac{m_e}{m_i}\mu_e^{nc}\frac{\partial U_{pe}}{\partial r}$$

$$\frac{\partial}{\partial t}\left(A - \alpha^2\frac{m_e}{m_i}\nabla_\perp^2 A\right) = -\nabla_{/\!/}(\phi - \alpha_e p) + \alpha^2\frac{m_e}{m_i}[\phi, \nabla_\perp^2 A] + \eta_{/\!/}^c \nabla_\perp^2 A$$
$$-4\mu_e^c \alpha^2 \frac{m_e}{m_i}\nabla_\perp^4 A + \alpha\frac{m_e}{m_i}\mu_e^{nc} U_{pe}$$

$$\frac{dv}{dt} = -\nabla_{/\!/} p + 4\mu_i^c \nabla v - \mu_i^{nc} U_{pi} - \frac{m_e}{m_i}\mu_e^{nc} U_{pe}$$

$$\frac{dp}{dt} = -\hat{\beta}\nabla_{/\!/}\left(v + \alpha\nabla_\perp^2 A\right) + \eta\hat{\beta}_\perp^c \nabla_\perp^2 p - \alpha\hat{\beta}\frac{m_e}{m_i}\frac{q_s}{\varepsilon_s}\mu_e^{nc}\frac{\partial U_{pe}}{\partial r}$$

where $d/dt = \partial/\partial t + [\phi,]$, $\nabla_{/\!/} = \partial/\partial z - [A,]$ and $[,]$ is the Poisson bracket. The normalization: $v_A t/R \rightarrow t$, $r/a \rightarrow r$ is adapted. Other parameters are explained in [1,2]. The subscript 's' indicates the value evaluated at the resonance surface. The energy balance in the system is given by

$$H = \frac{1}{2}\int dV\left(|\nabla_\perp F|^2 + |\nabla_\perp A|^2 + |v|^2 + \hat{\beta}^{-1}|p|^2 + \alpha^2\frac{m_i}{m_e}|\nabla_\perp^2 A|^2\right)$$

$$\frac{dH}{dt} = -\int dV(\mu_i^c|\nabla_\perp^2 F|^2 + \eta_{/\!/}^c|\nabla_\perp^2 F|^2 + 4\mu_i^c|\nabla_\perp v|^2 + \eta_\perp^c|\nabla_\perp p|^2$$

The nonlinear simulation with single helicity modes is performed using spectral code. The boundary condition is given by $f_{m,n}(0) = f_{m,n}(1) = 0$ and $f'_{0,0}(0) = 0$, $f_{0,0}(1) = 0$ [3]. Figure 1 shows the time evolution of electromagnetic energy in the cases with different Fourier mode in the spectral space. For 2 Fourier modes case, the linear growth and quasi-linear saturation are obtained. It is newly found that the nonlinear acceleration occurs in the early growing phase as the number of Fourier modes increase; However, saturation amplitude is weakly affected by high n modes. Figure 2 shows the time evolution of power spectrum of electromagnetic energy. The case with 64 Fourier modes is plotted. It is seen that high-n modes saturate at lower level and (2,1) mode dominates the electromagnetic energy in the final phase. The acceleration of the growth of the tearing mode by the background microscopic turbulence is clearly demonstrated.

The effects of fluctuating bootstrap current and of the collisional drift wave turbulence on the development of magnetic island for linearly unstable TM were investigated. The changes in radial structure and temporal growth rate, which are caused by turbulence, were demonstrated. The saturation was attained by the quasi-linear effect. We found that the structure of fluctuating bootstrap current inside the island, which is not taken into account in the conventional theory of NTM. This study demonstrated the importance of the turbulent pump on the rapid growth of the tearing mode.

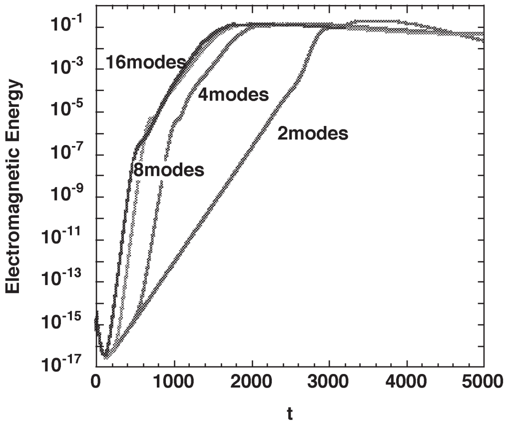

Fig.1 Time evolution of electromagnetic energy with various Fourier modes.

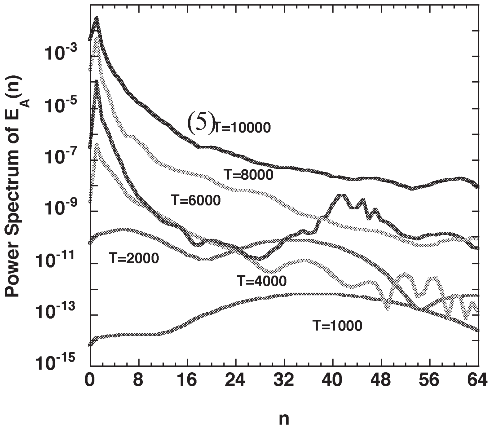

Fig.2 Time evolution of power spectrum of electromagnetic energy.

Reference

[1] M. Yagi et al., Proc. of 19th Fusion Energy Conf. 2002, TH-1-4.
[2] A. Furuya, M. Yagi and S.-I. Itoh, J. Phys. Soc. Jpn. **72** (2003) 313.
[3] M. Yagi et al., Proc. of 20th Fusion Energy Conf. 2004, TH/P5-17.