§19. Nonlinear Simulation of Neoclassical Tearing Mode

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Nonlinear simulation with a single helicity m/n=2/1 is performed using the reduced neoclassical MHD equations[1]. The formula in the banana regime is used for the neoclassical viscosity. In addition, the numerical viscosity (or the classical viscosity) with the order of 10^{-5} is introduced for the numerical stability. It is found that the combined effect between the neoclassical viscosity, whose effective collision frequency corresponds to the one in collisional regime in reality (we calculate the value of neoclassical viscosity using the normalized resistivity with $\eta = 10^{-5}$) and the numerical viscosity makes the fictitious modes in the high toroidal mode number regime for weak shear parameter. Figure 1 shows the dependence of the toroidal mode number on the growth rate of tearing mode. Here we use the model q profile as

$$q(r) = q_1(1+(r/r_s)^a)^b + q_2 \qquad (1)$$

with $q_1 = (q_s - q_0)/(2b-1)$, $q_2 = q_0 - q_1$, $q_s = 2$, $a = 3$, $b = 1$, $r_s = 0.6$. Cases with $q_0 = 1.0, 1.1, 1.2$ are plotted. The corresponding shear parameters are $s = 1.50, 1.35, 1.20$.

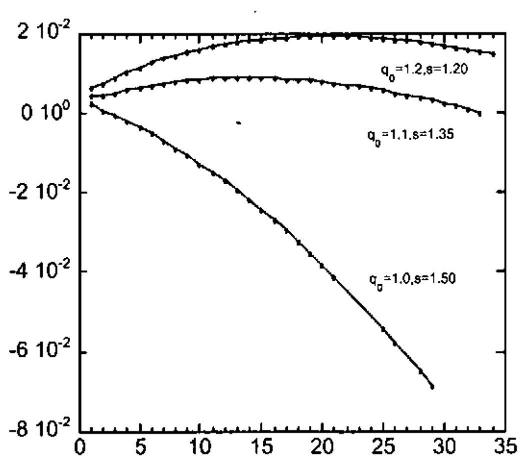

Fig.1 Linear growth rate versus toroidal mode number n.

This situation never happen for the realistic parameter with $\eta = 10^{-8}$. In this case, the growth rate is negative for all toroidal mode numbers (even for the lowest mode with (m,n)=(2,1) as is discussed in detail[1]). However, our simulation might be interpreted as the idealized case with micro-turbulence in the high k regime. Figure 2 shows the time evolution of the electromagnetic energy in cases with various Fourier modes. $q_0 = 1.2$ is used for these simulations. The nonlinear acceleration is observed in the linearly growing phase. On the other hand, the saturation amplitude of the electromagnetic energy is not changed so drastically, which implies the high n modes (in other words, micro-turbulence) weakly affect on the island saturation.

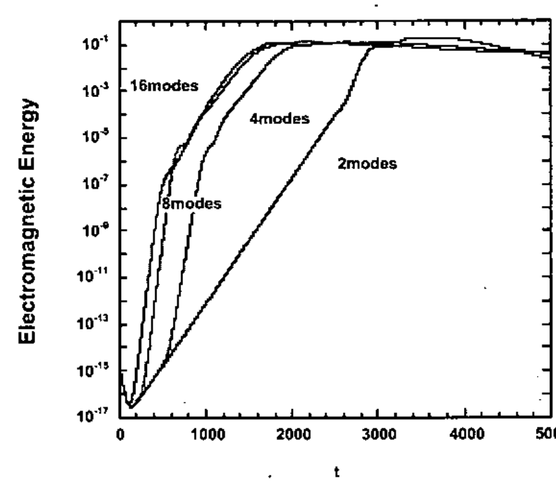

Fig.2 Time evolution of electromagnetic energy.

Figure 3 shows the time evolution of power spectrum of electromagnetic energy in the case with 64 Fourier modes. The inverse cascade is observed in the spectral space and (2,1) magnetic island is formed. This result is clearly different from the case of classical tearing mode.

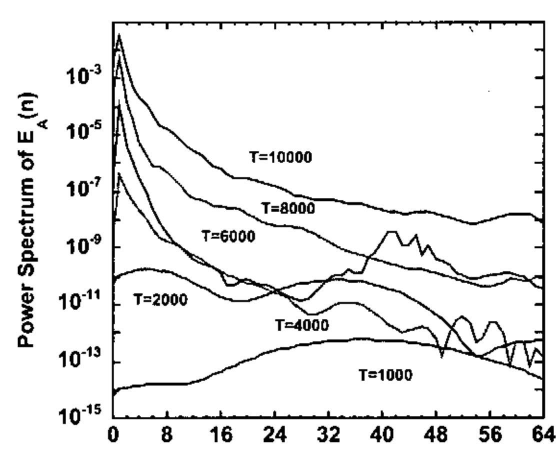

Fig.3 Power spectrum.of electromagnetic energy.

As the future work, we will introduce neoclassical ballooning mode in the system and perform the nonlinear simulation for $\eta = 10^{-8}$ which will give the threshold value of NTM excitation as the function of turbulence amplitude.

Reference

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