24aE03P

トカマクプラズマにおける輸送障壁形成のシミュレーション研究
Simulation study on transport barrier in tokamak plasmas

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Recently, simulation study on L/H transition are performed using two-field model where the effects of the self-consistent neoclassical poloidal rotation damping on the radial electric field dynamics is taken into account [1-2]. It is shown that (1) increasing the input power leads to avalanches, triggering strong stabilizing zonal flows (ZFs), (2) the resulting steepening of the pressure gradient further generates a shear mean flow via the neoclassical friction, (3) the positive feedback loop between pressure gradient and poloidal flow by neoclassical terms gives rise to pedestal formation. This transition scenario may be applicable for internal transport barrier (ITB) formation. Therefore, we shall revisit our previous work to examine the neoclassical flow effect [3].
The model is given by

$$\frac{dW}{dt}+ik_\theta\kappa_n\phi=-A\nabla_{//}v+\varepsilon_a\hat{\omega}_dF-\rho_*^2\mu\nabla_\perp^4F+\rho_*\frac{q}{\varepsilon}\frac{\partial}{\partial r}\left(\mu_{nc}U_p\right),$$

$$\frac{dv}{dt}=-A\nabla_{//}F+4\mu\nabla_\perp^2v-\mu_{nc}U_p-\frac{2\sqrt{\pi}}{5}\frac{A}{\sqrt{\tau}}\left|\nabla_{//}\right|v+\frac{2}{5}\frac{A}{\tau}\nabla_{//}T,$$

$$\frac{3}{2}\left(\frac{dT}{dt}+\kappa_T\frac{1}{r}\frac{\partial\phi}{\partial\theta}\right)-\left(\frac{dn}{dt}+\kappa_n\frac{1}{r}\frac{\partial\phi}{\partial\theta}\right)=\frac{5}{2\tau}\varepsilon_a\hat{\omega}_dT+\chi_\perp\nabla_\perp^2T-\frac{9}{5\sqrt{\pi}}\frac{A}{\sqrt{\tau}}\left|\nabla_{//}\right|T+\frac{2}{5}A\nabla_{//}v,$$

where $W=n-\rho_*^2\nabla_\perp^2F$, $F=\phi+(n+T)/\tau$, $n=\phi-\langle\phi\rangle$. The normalization: $t/t_B\to t$, $r/a\to r$, $e\phi/T_{e0}\to\phi$, $v/c_s\to v$, $T/T_{i0}\to T$ is used for the system where $c_s=(T_{e0}/m_i)^{1/2}$, the sound velocity and $t_B=a^2/\chi_B$, the Bohm time [4]. The neoclassical viscosities are given by [5]

$$\mu_{nc}=\frac{0.66\varepsilon^{1/2}\nu_i}{(1+1.03\nu_{*i}^{1/2}+0.31\nu_{*i})(1+0.66\varepsilon^{3/2}\nu_{*i})},$$

and $\kappa_{nc}=\frac{1}{1+\nu_{*i}^2\varepsilon^3}\left(\frac{1.17-0.35\nu_{*i}^{1/2}}{1+0.7\nu_{*i}^{1/2}}-2.1\nu_{*i}^2\varepsilon^3\right).$

The poloidal fow is written as

$$U_p=v+\rho_*\frac{q}{\varepsilon}\left(\frac{\partial F}{\partial r}-\kappa_{nc}\frac{\partial T}{\partial r}\right).$$

In the previous work, the neoclassical viscosities are fixed in time. However, the dynamical change of these viscosities is important for ITB formation, so that we have updated the code which is now enable to treat quasi-linear modification of neoclassical viscosities. In addition, the effect of κ_{nc} in the poloidal flow was not considered in the previous work, so that we will investigate it. Figure 1(a) shows initial q profile and κ_T. Note that the q minimum is located at $r=0.6$. The saturation is obtained at $t\sim1.0\ t_B$. Figure 1(b) shows the turbulent thermal flux and mean electric field at $t=2.0\ t_B$. The detailed analysis will be shown.

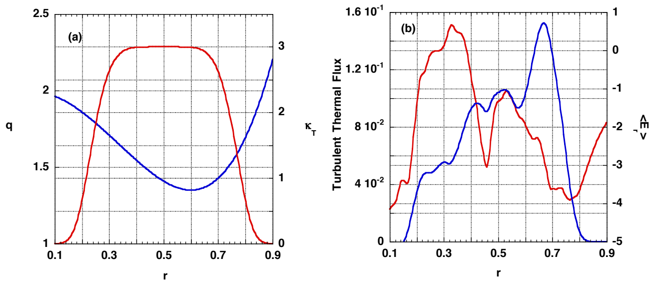

Fig.1 (a)Equilibrium profiles (b)Turbulent thermal flux(blue) and mean electric field(red).

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