§31. Study on Nonlocal Transport Based on Transport-MHD Model

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The transient response of heat pulse propagation is investigated based on transport-MHD model. The reduced MHD equations in the cylindrical geometry (r,θ,z) are used in the simulations, which are given by

$$\frac{\partial}{\partial t}U + [\phi, U] = -\nabla_{//}J - [2r\cos\theta, p] + \mu\nabla_\perp^4\phi, \quad (1)$$

$$\frac{\partial}{\partial t}A = -\nabla_{//}(\phi - \delta p) + \eta J, \quad (2)$$

$$\frac{\partial}{\partial t}p + [\phi, p] = \beta[r\cos\theta, \phi - \delta p] - \beta\delta\nabla_{//}J + \chi\nabla_\perp^2 p + S. \quad (3)$$

The system is normalized by using the minor radius a and the poloidal Alfven time $\tau \equiv R/v_A$. Here, $U = \nabla_\perp^2\phi$ is the vorticity, $J = \nabla_\perp^2 A$, the plasma current, ϕ, the electrostatic potential, A, the z component of the vector potential and the Poisson bracket is defined by $[A,B] = \frac{\partial A}{\partial r}\frac{1}{r}\frac{\partial B}{\partial \theta} - \frac{1}{r}\frac{\partial A}{\partial \theta}\frac{\partial B}{\partial r}$. $\delta = c/(a\omega_{pi})$ represents the finite lamor effect of electrons, β is the plasma beta, S, the heat source and μ, η, χ are the viscosity, resistivity and thermal conductivity. The electrostatic energy $E_{\nabla_\perp\phi}$, the electromagnetic energy $E_{\nabla_\perp A}$ and the internal energy E_p are defined by $E_{\nabla_\perp\phi} = \frac{1}{2}\int d^3x|\nabla_\perp\phi|^2$, $E_{\nabla_\perp A} = \frac{1}{2}\int d^3x|\nabla_\perp A|^2$, $E_p = \frac{1}{2\beta}\int d^3x|p|^2$, respectively.

Figure 1 shows the time evolution of fluctuating energies $E_{\nabla_\perp\phi}$(purple), $E_{\nabla_\perp A}$(orange) and E_p (green). Parameters are chosen as $\mu = 10^{-3}$, $\eta = 5\times10^{-3}$, $\chi = 10^{-4}$, $\beta = 10^{-2}$ and $\delta = 10^{-2}$. The toroidal mode number n and poloidal mode number m are given by (n,m)=(0,0),(1,1-11),(2-22). The heat pulse is applied at $t = 200$ in the central region such as $S = 24\varepsilon(r - 0.1)$. It is found that the flow is generated by the heat pulse and plasma starts to rotate gradually due to the $E \times B$ drift.

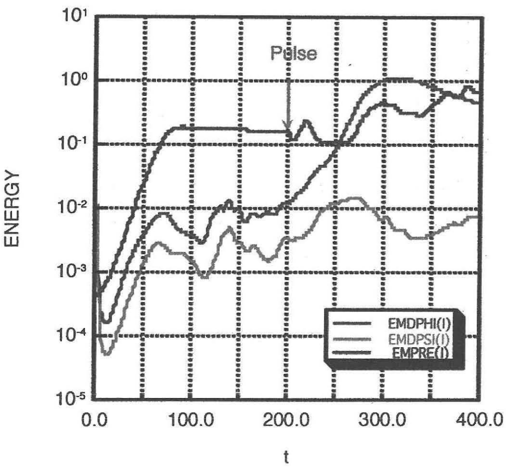

Fig.1 the time evolution of fluctuating energies.

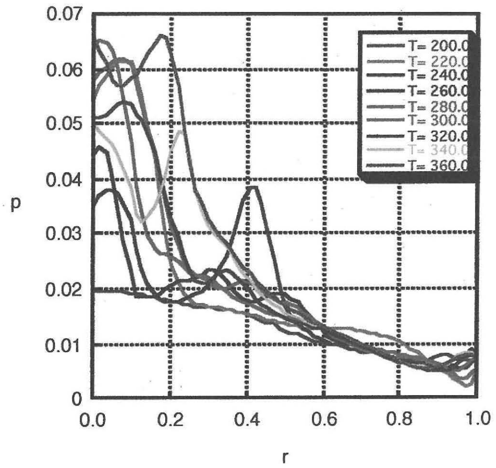

Fig.2 the time evolution of pressure profile.

Figure 2 shows the time evolution of pressure profile at $\theta = 0, z = 0$. If the heat pulse propagation is dominated by the diffusion process only, the profile will develop smoothly, however, this is not the case. For example, the observer at $r = 0.4$ will observe the large pulse abruptly at $t = 240$. The combined effect between $E \times B$ rotation and diffusion process generates the nonlocal transport in this simulation. The pulse propagation might depend on the mode number. It should be investigated in the future work.

Reference

1) M. Yagi, "Study on Nonlocal Transport Based on Transport-MHD Model", US-JAPAN Workshop on Self-organization, Dec. 9(2000) NIFS.