27E02P

ヘリオトロンJにおけるプラズマ流に対する磁場リップルの影響
Effect of Magnetic Ripple on Plasma Flow in Heliotron J

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The plasma flows have been investigated experimentally and theoretically in magnetically confined plasmas for a variety of reasons; those relate to transport barrier and improved confinement, such as L-H transition with a reduction of edge turbulence in tokamak and stellarator/heliotron devices [1,2].

In Heliotron J [3], which is a helical-axis heliotron device, the effect of magnetic ripple on the viscous damping of parallel flow $v_{\|}$ during Neutral Beam Injection (NBI) has been investigated in the three mirror configurations: high, standard and reversed mirror configurations [4]. The mirror configuration is characterized by the magnetic ripple strength, γ, which is defined as $\gamma = \{<(\partial B/\partial l)^2/B^2>\}^{1/2}$. Here, l is the length along the magnetic field line and <•••> is the flux surface averaged value. The values of magnetic ripple strengths at ρ = 0.07 in the high, standard and reversed mirror configurations are 0.073, 0.03 and 0.029 m^{-1}, respectively. The radial profiles of $v_{\|}$ are measured using a Charge-eXchange Recombination Spectroscopy (CXRS) system for NBI plasmas. The line-averaged electron densities were 0.8-1.0×10^{19} m^{-3} in the three mirror configurations. In the region of ρ < 0.5, $v_{\|}$ in the high mirror configuration is 2-3 times smaller than those in the standard and reversed mirror configurations. The difference of external momentum input by NBI between the three mirror configurations is small [4], thus the cause of difference on $v_{\|}$ is attributed to the difference in viscous damping effects.

To investigate the effect of parallel viscous damping force, we have compared the neoclassical (NC) parallel viscosity with the effective parallel viscosity near the plasma center. Figure 1 shows the ratio of the effective parallel viscosity coefficient $\mu_{\|eff}$ to the NC parallel viscosity coefficient $\mu_{\|NC}$ as a function of γ at ρ = 0.07. The NC parallel viscosity coefficient is given by [2, 5] as follow:

$$\mu_{\|NC} \approx \xi_1 \sqrt{\pi}\gamma^2 \frac{eT_i}{m_i \omega_{ti}}, \tag{1}$$

where m_i is the mass of the ion and ξ_1 is the energy integral coefficient. In the plateau regime, $\xi_1 = 2$ [2, 5]. The transit frequency of ions, ω_{ti}, for a helical device can be expressed as $\omega_{ti} = M/R(2eT_i/m_i)^{1/2}$, where M is the helical pitch number of helical coil. The effective parallel viscosity coefficient is defined as $\mu_{\|eff} \equiv dF_{\|ext}/n_i m_i dv_{\|}$, where $F_{\|ext}$ is the external momentum input by NBI calculated by the FIT code [6]. We assumed that electron density profile is $n_e(\rho) = n_e(0)(1-\rho^2)$, where line-averaged electron density is approximately 1.0×10^{19} m^{-3}, and that effective charge number (Z_{eff}) is 2. The effective parallel viscosity gets close to the NC parallel viscosity as γ increases. However, $\mu_{\|NC}$ is still smaller than $\mu_{\|eff}$ even in the high mirror configuration. This result suggests that $\mu_{\|eff}$ cannot be explained by $\mu_{\|NC}$ alone, and the perpendicular viscosity, such as momentum diffusion, should be taken into account.

In this presentation, the viscous damping of $v_{\|}$, including the perpendicular viscosity, will also be discussed.

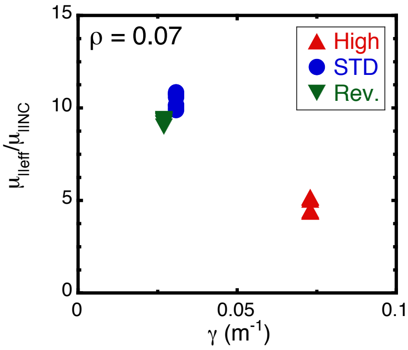

Fig 1. Ratio of $\mu_{\|eff}$ to $\mu_{\|NC}$ as a function of γ at ρ = 0.07.

Reference

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