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Impacts of plasma rotation and ion diamagnetic drift on MHD stability in DIII-D QH-mode plasmas

N. Aiba, X. Chen*, T. H. Osborne*, S. R. Haskey**, K. H. Burrell*, P. B. Snyder*

QST, *)GA, **)PPPL

In H-mode regime in tokamaks, edge localized modes (ELMs) often appear and induce large heat load to divertors. Since the heat load is unacceptable for future large reactors like ITER and DEMO, it is necessary to suppress and/or mitigate the ELMs. Quiescent H-mode (QH-mode) is one of promising candidates realizing ELM suppression and high confinement performance with ITER and DEMO relevant plasma parameters [1]. One of the important characteristics of the QH-mode is that edge harmonics oscillations (EHOs) are observed, though ELMs disappear. Since QH-mode can be obtained when bootstrap current and rotation shear near plasma surface are large, the EHOs have been recognized as a rotation shear destabilized current-driven MHD (peeling) mode. Hence it is important to conduct a quantitative numerical study to identify the threshold rotation shear triggering the peeling mode. In addition, the ion diamagnetic drift frequency, $\omega_{*\mathrm{i}}$, in DIII-D QH-mode plasmas is large near the edge region, hence, its stabilizing effect can have an impact on peeling mode stability. In this study, we analyze numerically the MHD stability in DIII-D QH-mode plasmas by taking into account plasma rotation and $\omega_{*\mathrm{i}}$ effects simultaneously with the linear extended MHD stability code MINERVA-DI [2]. Figure 1 shows the profiles of (a) density n and temperature T, and (b) vxB rotation frequency $\omega_{\mathrm{vxB,C}}=\omega_{\phi,\mathrm{C}}+\omega_{\theta,\mathrm{C}}$ and $\omega_{*\mathrm{i}}=-\boldsymbol{k}\cdot(\boldsymbol{B}\times\nabla(p_{\mathrm{D}}+p_{\mathrm{C}}))/e(n_{\mathrm{D}}+6n_{\mathrm{C}})B^2$ of the analyzed DIII-D plasma (#153440), where subscripts D, e, C show deuterium, electron, and carbon. Here $\omega_{\phi,\mathrm{C}}$ is the toroidal rotation frequency, $\omega_{\theta,\mathrm{C}}=-V_\theta B_\phi/RB_\theta$, $\boldsymbol{k}$ is wave number vector, $\boldsymbol{B}$ is magnetic field, p is pressure and e is elementary charge. Note that n_{D} and p_{D} are evaluated by assuming charge neutrality and $T_{\mathrm{D}}=T_{\mathrm{C}}$, because n_{C} and T_{C} are measured. In this plasma, the EHO was observed with the large n=2 component in magnetic fluctuation, where n is the toroidal mode number.

Figure 2 (a) shows the stability diagram of edge MHD modes on the (j_{ped},α) plane without the $\omega_{*\mathrm{i}}$ effect, where j_{ped} is the pedestal current density and α is the pedestal normalized pressure gradient. As shown in this figure, the stability boundary of peeling modes slightly moves downward by rotation, because the mode is destabilized. However, by taking into account both rotation and the $\omega_{*\mathrm{i}}$ effects, the peeling mode is stabilized, and the boundary moves upward, the trend which is opposite to that observed when analyzing ideal MHD stability. The detail physics stabilizing the peeling mode and destabilizing the peeling-ballooning mode will be discussed in the presentation.

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[1] K. H. Burrell et al., PRL 102, 155003 (2009).
[2] N. Aiba, PPCF 58, 045020 (2016).

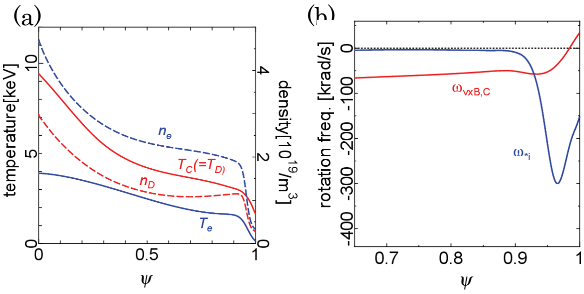

Fig.1: Profiles of (a) n_{i}, n_{e}, T_{i}, T_{e}, and (b) $\omega_{\mathrm{vxB,C}}$ and $\omega_{*\mathrm{i}}$, respectively.

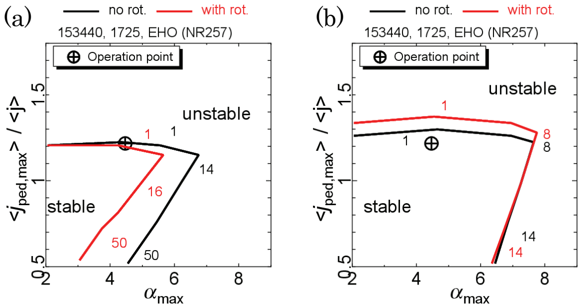

Fig.1: Stability diagram of MHD modes on (j_{ped}, α) diagram; (a) w/o $\omega_{*\mathrm{i}}$. and (b) w/ $\omega_{*\mathrm{i}}$. Red and black lines show the stability boundary with and without rotation, respectively. The number indicates the n number of the most untable mode.