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DIII-D/JT-60UのQH-modeにおけるMHD安定性に影響を与える回転種に関する数値解析

Numerical Analysis identifying the kind of rotation changing MHD stability in DIII-D/JT-60U QH-mode plasmas

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In H-mode regime in tokamaks, edge localized modes (ELMs) often appear and induce large heat load to divertors, but the heat load is unacceptable for future large reactors like ITER and DEMO. Quiescent H-mode (QH-mode) is one of promising candidates realizing ELM suppression with ITER and DEMO relevant plasma parameters [1]. One of the characteristics of the QH-mode is that edge harmonics oscillations (EHOs) are observed, though ELMs disappear. Since QH-mode can be obtained with large bootstrap current and large rotation shear at edge pedestal, the EHOs have been recognized as current-driven MHD modes (K/PMs, kink/peeling modes) affected by rotation. In addition, the ion diamagnetic drift frequency, ω_{*i}, in DIII-D QH-mode plasmas is also large at edge pedestal, its stabilizing effect can change the stability. From these viewpoints, we analyzed the K/PM stability by considering rotation and ω_{*i} effects in a DIII-D QH-mode plasma and clarified that the rotation stabilizes K/PM in case considering the ω_{*i} effect [2]. In that work, we assumed bulk plasma (deuterium) rotation is same as that of carbon measured in experiment, but the deuterium rotation can be different in low collisionality conditions [3].

In this study, we analyze numerically the MHD stability including rotation and ω_{*i} in several QH-mode plasmas in DIII-D and JT-60U with two kinds of rotation; one is the measured carbon rotation, $\Omega_{v\times B,C}$ as in the previous study, and the other is a one-fluid rotation, $\Omega_{v\times B,CD}$, evaluated by averaging the profiles of deuterium and carbon, where

$$\Omega_{v\times B,CD} = \frac{\rho_C \Omega_{v\times B,C} + \rho_D \Omega_{v\times B,D}}{\rho_C + \rho_D},$$

$\Omega_{v\times B,D} = \Omega_{E\times B} - \omega_{*i,D}$, $\Omega_{E\times B} = \Omega_{v\times B,C} + \omega_{*i,C}$, ρ is the mass density, and subscript C (D) expresses carbon (deuterium). Note that $\Omega_{v\times B,C}$, $\omega_{*i,C}$ and $\omega_{*i,D}$ are obtained with measured data.

Figure 2 (a) shows the stability diagram of MHD modes on the (j_{ped},α) plane in DIII-D QH-mode plasmas, where j_{ped} is the pedestal current density and α is the pedestal normalized pressure gradient. The figure clearly shows that both $\Omega_{v\times B,C}$ and $\Omega_{v\times B,CD}$, have stabilizing effect on K/PM, and $\Omega_{v\times B,CD}$ can effectively stabilize it in both plasmas. In addition, the toroidal mode number of the MHD mode marginally unstable on the K/PM stability boundary is consistent with that of the dominant harmonic of EHOs experimentally measured in both discharges. It should be noted that the plasma profiles used in the analysis are obtained in a stead state as a QH-mode with EHOs, hence the plasma analyzed here is thought to be stable to MHD modes. From this viewpoint, only $\Omega_{v\times B,CD}$ stabilizes K/PM enough to put the operational point in the stable region in the discharge #157102. The result implies that some sort of evaluation of rotation rather than simple carbon rotation is needed to better explain the data/numerical results of QH-mode. Other results including JT-60U will be shown in the presentation.

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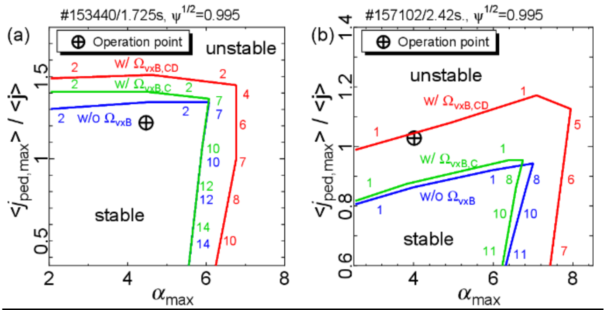

Fig.1: Stability diagram of MHD modes on (j_{ped}, α) plane in DIII-D QH-mode plasmas; (a) #153440 and (b) #157102. Red, green and blue lines show the stability boundary with $\Omega_{v\times B,CD}$, $\Omega_{v\times B,C}$and without rotation, respectively. Numbers indicate the toroidal mode number of the untable mode.