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JT-60Uにおける慣性力と密度の変化を通じたトロイダル回転の熱輸送に対する影響の解析と予測研究

Analysis and prediction of effects of toroidal rotation on heat transport via changes in inertial forces and densities in JT-60U

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Toroidal rotation is one of the keys to improve the energy confinement in tokamak plasmas. Many previous studies have shown that toroidal rotation affects various transport channels via the radial electric field E_r. Also for conventional H-mode discharges in JT-60U, in the pedestal region, the toroidal rotation direction has been found to affect heat transport via the E_r shear. But in the core region, where the moderate E_r shear is formed, the clear correlation between the rotation direction and heat transport has not been observed. On the other hand, in the JT-60U discharge with an internal transport barrier (ITB), when the rotation direction changes with almost constant heating power, it has been found that the electron temperature T_e gradient is steeper for the case with co rotation with respect to the plasma current than that with counter rotation. In both the H-mode discharge and the ITB discharge, the impurity (carbon) density n_C is also found to vary together with the profile of the toroidal rotation velocity V_ϕ. In this study, focusing on the V_ϕ profile and n_C, we delve into the effect of the toroidal rotation on heat transport in the discharges using the flux-tube gyrokinetic code GKW.

First, in the GKW calculations, the V_ϕ profile influences heat transport through the inertial force [1]. The dependence of heat transport on the rotation direction changes, according the V_ϕ gradient. By paying attention to the relationship between the rotation direction and the V_ϕ gradient, it is found that heat transport is suppressed with co rotation only in the ITB discharge. Next, an increase in n_C stabilizes the ion temperature gradient mode, but can destabilize the trapped electron mode (TEM). The calculations show that in the ITB discharge, which is more TEM dominant than the H-mode one, the increase in n_C with counter rotation leads to the enhancement of heat transport due to the TEM. Both results for the V_ϕ profile and n_C agree with the experiments. Counting these effects simultaneously, the nonlinear electron heat flux $V'Q_\mathrm{e}$ is calculated for the ITB discharge, as shown in Fig. 1. In the calculations, the parameters other than the V_ϕ profile, n_C and the T_e gradient $1/L_{T_\mathrm{e}}$ are fixed. Since the co and counter cases were heated by the similar heating power in the experiment, it is inferred that $V'Q_\mathrm{e}$ is almost equivalent to each other. The scan of $1/L_{T_\mathrm{e}}$ with the V_ϕ profile and n_C taken from the counter case (blue squares) shows $1/L_{T_\mathrm{e}} \sim 2.9$ makes $V'Q_\mathrm{e}$ equivalent to that for the co case with the nominal value $1/L_{T_\mathrm{e,co}}$ (red triangle), as observed in the experiment. $1/L_{T_\mathrm{e}} \sim 2.9$ is actually higher than the nominal value for the counter case, $1/L_{T_\mathrm{e,counter}}$, but if the effects of the V_ϕ profile and n_C on heat transport were not counted, identical $V'Q_\mathrm{e}$ could not be predicted with different $1/L_{T_\mathrm{e}}$ shown by the arrow [2]. In this study, a modelling of the rotation effects based on the linear gyrokinetics is also discussed.

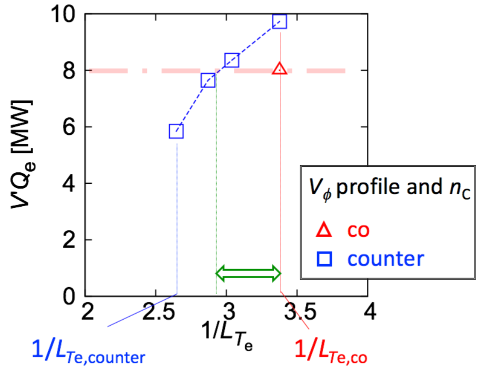

Fig. 1: Nonlinear $V'Q_\mathrm{e}$ as a function of $1/L_{T_\mathrm{e}}$ with the V_ϕ profile and n_C taken from the co and counter cases.

[1] Y. Camenen *et al.*, Phys. Plasmas **23**, 022507 (2016).
[2] E. Narita *et al.,* submitted to Plasma Phys. Controlled Fusion.