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反転磁気シアプラズマにおける線形モードと乱流構造に対する磁気シア微分の効果

Effect of magnetic shear derivative on linear mode and turbulence structure in reversed shear plasmas

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Safety factor q is crucial in determining the plasma stability. In many plasmas the safety factor monotonically increases. The reversal of safety factor profile due to the off-axis maximum of the bootstrap current promotes the formation of the internal transport barrier (ITB) which significantly reduces anomalous transport compared to the L-mode. This report focuses on the influence of shear derivative $s_d = \frac{d^2q}{dr^2}\frac{r^2}{2q}$, which quantifies the curvature of safety factor profile at the minimum q surface, on the mode characteristics.

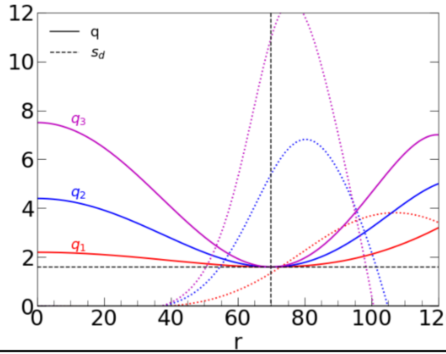

Figure 1. Safety factor and shear derivative profiles for the simulations.

The δf electromagnetic GKNET code with kinetic electrons is applied to solve the gyrokinetic equations [1,2]. The safety factor profiles are set such that the minimum value and location of the minimum are fixed and shear derivatives are modified by changing the centre and edge values. The temperature profiles for ion and electron are set equal and the scale length is much smaller than that of the number density profile. The maximum pressure gradient surface coincides with the minimum q surface such that the modes are induced in the zero-shear region.

According to the linear analyses, the infernal type of mode is induced whose Fourier harmonics are not coupled via ballooning coupling [3]. The linear dispersions are not sensitive to the change in shear derivatives, whereas a negative correlation is observed for the linear mode width. As a result, quasi-linear estimate predicts that transport level is lower in a more strongly reversed plasma.

In nonlinear simulations, linearly stable modes are destabilized via nonlinear couplings. The electric potential shows a clear tendency that the saturation level is lower in a more strongly reversed plasma. The spreading of mode structure due to nonlinear effects continues after the saturation of energy. It is found that the speed of turbulent spreading is faster for a flatter configuration mainly due to the spreading of the outer turbulent front. Also, the saturation locations of the outer turbulent fronts show a split. The overall particle flux is negative so the number density profile is steepened. Both the particle flux and heat flux are larger for a weakly reversed configuration. Periodic bursts are observed for strongly reversed cases but the intermittent burst is seen for the flattest case.

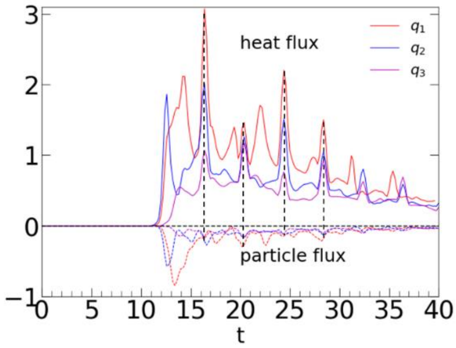

Figure 2. Time evolutions of fluxes.

[1] A. Ishizawa, et al., PoP 26, 082301(2019).

[2] K. Imadera, et al., in IAEA-FEC(Kyoto, 2016), p. TH/P3-3.

[3] Y. Ishida, et al., PoP 27, 092302 (2020).