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Verification and Validation of Particle Simulation of Turbulent Transport in FRC

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Following the remarkable progress in magnetohydrodynamic (MHD) stability control in the advanced beam driven field-reversed configuration (FRC) at TAE Technologies, Inc., turbulent transport has become one of the foremost obstacles on the path towards an FRC-based fusion reactor. Significant efforts have been made to kinetic simulation capabilities in FRC magnetic geometry. The Gyrokinetic Toroidal Code (GTC) [1] has been upgraded to simulate driftwave instability in the realistic FRC magnetic geometry using Boozer coordinates [2]. GTC local simulations of the C-2 FRC find that electrostatic driftwaves are locally stable in the core. Later, global simulations model[3,4] has been used to investigate the linear drift instabilities and nonlinear turbulence spreading. In this work, we further extend the simulation model, including the zonal flow effect, the radial gyroaveraging, the collision effect and the radial electric field.

The presence of zonal flow reduces the saturation level of non-zonal modes, and the random shear induced by zonal flow reduces the radial eddy size. As a result, the turbulent heat diffusivity is suppressed by zonal flow, as shown in Figure 1.

There is no collisionless damping or neo-classical collisional damping of zonal flow in FRC, the new collision operator considers pitch-angle and gyro-angle scatterings and induce ion guiding center random walk. The zonal flow is shown to be damped by this classical collision effect. The collision effect distorts the phase space structure and makes the nonlinear saturation stationary stage longer. The collision itself does not have significant effect on the turbulence level. However, because the classical collisional damping is the most important damping mechanism, the turbulent transport has an obvious dependence on the effective collision frequency, which can be seen in Figure 2.

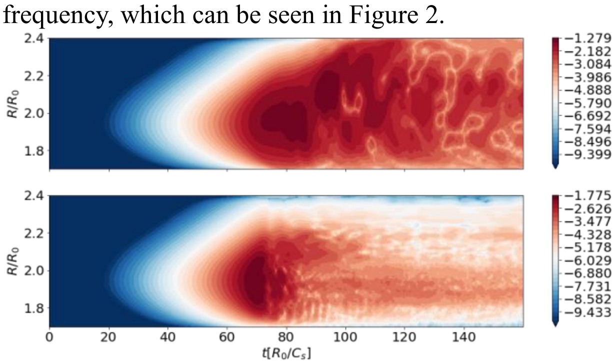

Fig. 1. Radial heat conductivity in SOL of FRC without and with zonal flow.

The electrode biasing control in SOL of FRC is shown to enhance the plasma confinement [5]. Hence the Er shear effect on turbulence is investigated using GTC-X. Figure 3 shows that by increasing the shearing rate of the equilibrium electric field, the linear growth rate of ITG can be effectively reduced. When the shearing rate becomes comparable to the growth rate, the saturated mode and its heat transport are well suppressed during the saturation.

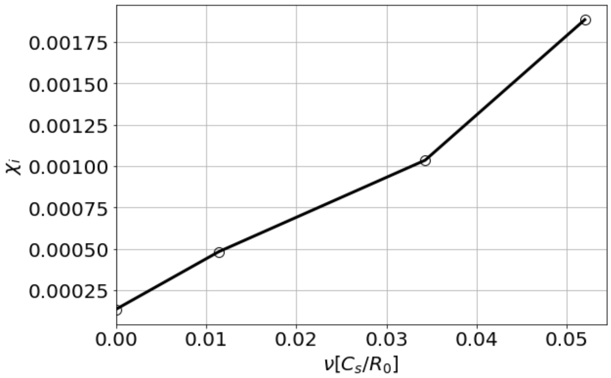

Fig. 2. Dependence of averaged heat conductivity on the collision frequency.

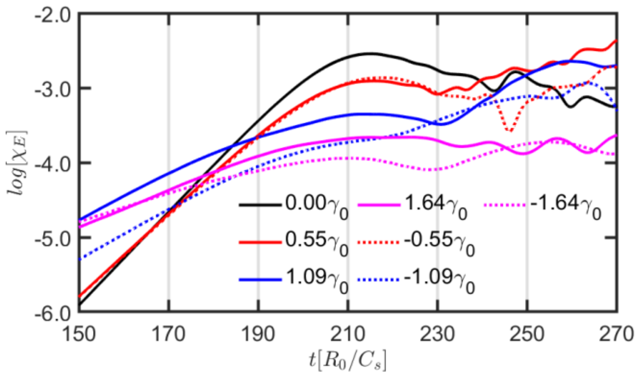

Fig. 3. Er shear effect on linear growth rate and the saturated averaged heat conductivity.

References

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