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Reduced Model for Gyrokinetic Turbulent Transport in Helical Plasmas

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A reduced model for turbulent transport driven by micro-instabilities such as ion temperature gradient (ITG) modes is constructed based on nonlinear and linear gyrokinetic plasma turbulence simulations performed under a wide range of conditions for the local plasma parameters and different field configurations of helical systems. It is shown that the ion heat diffusivity has a functional dependence on the amplitudes of turbulent fluctuations and zonal flows in the nonlinear simulations.
On the other hand, the amplitudes of turbulent fluctuations and zonal flows obtained from the nonlinear simulations are well correlated with linear gyrokinetic simulation results on the ITG instability and zonal flows. Based on these properties, the reduced model for the ion heat transport in helical plasmas is constructed by combination of the linear growth rates of the instability, the linear response functions of the zonal flow potentials, and elaborate nonlinear gyrokinetic simulations. The model involves a similarity with the conventional mixing length ansatz but with explicit introduction of the zonal flow contribution. It is confirmed that the model is in good agreement with nonlinear gyrokinetic simulation results including the cases of the high ion temperature plasmas in the Large Helical Device experiment.
Since the present model is represented in terms of only linear calculation results, the computational cost of the model, i.e. the elapsed time, is extremely smaller than that of the nonlinear turbulence simulations (the ratio is less than 5 %). Therefore, the model can be applied to an integrated transport code or survey of the transport levels in a wide range of multiple parameters corresponding to various experimental conditions. The basic idea of the model is also applied to tokamak configurations including the both species of ions and electrons, although detailed values of the coefficients in the model function may be altered.

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