§9. Reduction of Turbulent Transport and Zonal Flow Generation in Helical Systems

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In order to investigate effects of helical magnetic configurations on the ion temperature gradient (ITG) turbulence and zonal flows, we have performed gyrokinetic Vlasov simulations [1, 2] by utilizing the Earth Simulator at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and the Plasma Simulator at NIFS. The GKV simulation code is extended so as to incorporate magnetic configuration models relevant to the Large Helical Device (LHD) experiments.

In our recent work [3] for experimentally relevant conditions, we confirmed that an initially given zonal flow kept a higher level for a longer time in the inward-shifted configuration than that in the standard one. This is consistent with our analytical theory of zonal flows [4, 5]. It should be emphasized that the inward-shifted case is optimized for reducing the neoclassical transport but with more unfavorable stability property than the standard configuration.

In the present study, the nonlinear GKV simulation implemented with the specified magnetic field parameters for the inward-shifted and standard plasma positions successfully confirms generation of large zonal flows enough to reduce the ion heat transport in the former case [6]. Contours of the electrostatic potential in the steady ITG turbulence are shown in Fig. 1. For the inward-shifted configuration shown in Fig. 1 (upper), we clearly see radial structures of poloidal $\mathbf{E}\times\mathbf{B}$ zonal flows in the turbulent flow patterns on the poloidal cross section, while more isotropic $\mathbf{E}\times\mathbf{B}$ vortices are observed in the standard case [Fig. 1 (lower)]. The larger zonal-flow generation in the inward-shifted case agrees with the linear analysis of the zonal-flow response [3-5] which predicts a larger zonal-flow response to a given source in neoclassically optimized helical configurations such as the inward-shifted one.

The obtained results agree with our theoretical prediction, and are consistent with observation of better confinement in the inward-shifted LHD plasma [7].

* This work is carried out using Earth Simulator under the support by JAMSTEC.

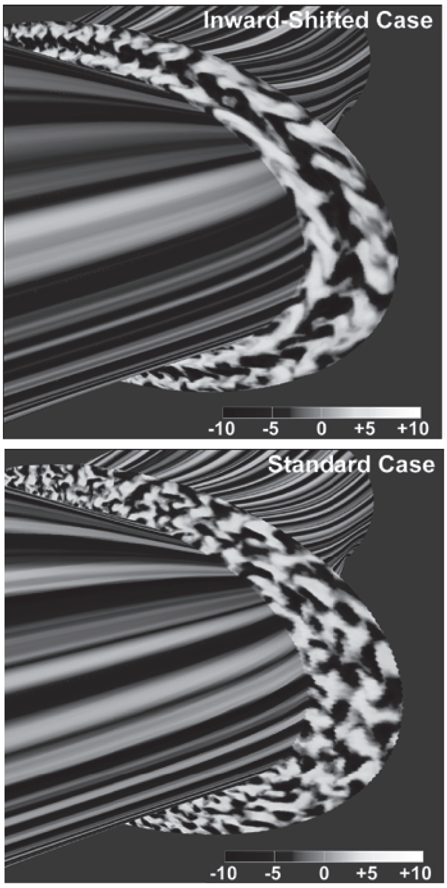

Fig.1: Contours of the electrostatic potential ϕ of the zonal flow and the ion temperature gradient (ITG) turbulence obtained by the GKV simulation for inward-shifted (upper) and standard (lower) model configurations of the Large Helical Device (LHD). Normalization is chosen as $e\phi L_n/T_e\rho_i$.

1) T.-H. Watanabe and H. Sugama: Nuclear Fusion 46 (2006) 24.
2) T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet: Nuclear Fusion 47 (2007) 1383.
3) S. Ferrando-Margalet, H. Sugama, and T.-H. Watanabe, Physics of Plasmas 14 (2007) 122505.
4) H. Sugama and T.-H. Watanabe, Phys. Rev. Lett. 94 (2005) 115001.
5) H. Sugama and T.-H. Watanabe: Phys. Plasmas 13 (2006) 012501.
6) T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet: Phys. Rev. Lett. 100 (2008) 195002.
7) H. Yamada, et al., Nuclear Fusion 41 (2001) 901.