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Effects of anisotropic energetic particle distributions on the residual zonal flow

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In tokamak plasmas, the interaction among the microturbulence, the zonal flow (ZF) and the energetic particles (EPs) can affect the turbulence saturation level and the consequent confinement quality and thus, is important for future burning plasmas. The zonal flow residual for isotropic particles has been studied [1, 2, 3]. For tokamak plasmas, anisotropic EPs can be produced by NBI or ICRF and their effects on zonal flow residual and the consequent effects on turbulence are not so well understood. In this work, the effects of anisotropic EPs on the ZF residual level are studied. By choosing the EP distribution function as $f = C_p exp - \bar{E}((\lambda - \lambda_0)/\Delta\lambda)^2$, where $\lambda = v_\perp^2 B_0/(v^2 B)$, $E \equiv (mv^2)/2T$, it is shown that EPs have more significant effect on long wavelength ($k_r\rho_t < 0.1$) ZFs than on short wavelength ($k_r\rho_t > 1$) ZFs where $\rho_t = \sqrt{2T_i m_i}/eB$. In the long wavelength range, small to moderate $\delta\lambda$ leads to more significant ZF residual level change compared with pure thermal ions. In addition, barely passing, barely trapped and deeply trapped EPs can enhance the ZF residual level, while well passing and intermediate trapped EPs suppress the ZF residual level. Along with these theoretical analyses in our previous work [4], the EP distributions from ASDEX Upgrade experiments are used and the anisotropic EP effects on ZF residual is analyzed. Two cases with well-passing EPs or barely trapped EPs at the specific radial location are compared and mitigation or enhancement of ZF residual is obtained respectively from the calculation. The possibility of applying ICRF or NBI for ZF enhancement is discussed.

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