Gyrokinetic simulation of momentum transport with residual stress from diamagnetic level velocity shears

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Abstract

Residual stress refers to the remaining toroidal angular momentum (TAM) flux (divided by major radius) when the shear in the equilibrium fluid toroidal velocity (and the velocity itself) vanishes. Previously [R.E. Waltz, G.M. Staebler, J. Candy, and F.L. Hinton, Phys. Plasmas **14**, 122507 (2007); errata **16**, 079902 (2009)], we demonstrated with GYRO [J. Candy and R.E. Waltz, J. Comp. Phys. **186,** 545 (2003)] gyrokinetic simulations that TAM pinching from (ion pressure gradient supported or diamagnetic level) equilibrium $E \times B$ velocity shear could provide some of the residual stress needed to support spontaneous toroidal rotation against normal diffusive loss. Here we show that diamagnetic level shear in the intrinsic drift wave velocities (or "profile shear" in the ion and electron density and temperature gradients) provides a comparable residual stress. The individual signed contributions of these small (rho-star level) $E \times B$ and profile velocity shear rates to the turbulence level and (rho-star squared) ion energy transport stabilization are additive if the rates are of the same sign. However because of the additive stabilization effect, the contributions to the small (rho-star cubed) residual stress is not always simply additive. If the rates differ in sign, the residual stress from one can buck out that from the other (and in some cases reduce the stabilization.) The residual stress from these diamagnetic velocity shear rates is quantified by the ratio of TAM flow to ion energy (power) flow (M/P) in a global GYRO core simulation of a "null" toroidal rotation DIII-D [M.A. Mahdavi and J.L. Luxon, Fusion Sci. Technol. **48**, 2 (2005)] discharge by matching M/P profiles within experimental uncertainty. Comparison of global GYRO (ion and electron energy as well as particle) transport flow balance simulations of TAM transport flow in a high-rotation DIII-D L-mode quantify and isolate the $E \times B$ shear and parallel velocity (Coriolis force) pinching components from the larger "diffusive" parallel velocity shear driven component and the much smaller "profile shear" residual stress component.

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