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Validation of Theoretical Models of Intrinsic Torque in DIII-D and Projection to ITER by Dimensionless Scaling

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Experiments in DIII-D have validated advanced models of main-ion intrinsic rotation and used dimensionless parameter scans to predict a significant amount of intrinsic torque in ITER. Recent measurements of deuterium toroidal rotation using main ion spectroscopy in DIII-D have validated predictions of Reynolds stress induced toroidal flow in the plasma core and rotation induced by ion orbit losses in the plasma edge. In the core of dominantly electron heated plasmas with Te=Ti, the main-ion intrinsic toroidal rotation undergoes a reversal. Above a critical ECH heating power the core rotation reversal correlates with the critical gradient for ITG turbulence. Residual stress from zonal-flow E×B shear and turbulence intensity gradient are the dominant symmetry breaking mechanisms producing residual stress intrinsic torque, balanced by momentum diffusion, creating the hollow profile. Quantitative agreement is obtained for the first time between the measured main-ion toroidal rotation and the profile predicted by nonlinear GTS gyrokinetic simulations. In dimensionless scaling experiments that vary only ρ*the intrinsic torque in the plasma is found to scale in a favorable way to ITER, projecting to increased intrinsic torque at lower ρ*. The intrinsic torque projected for the high current H-mode phase of ITER is approximately 85 Nm, exceeding the neutral beam torque of 35 Nm. This intrinsic torque is expected to drive an average intrinsic rotation of approximately 60 km/s. The total angular momentum scales with the boundary condition near the separatrix, and in the edge of plasmas with high and low collisionality and either sign of plasma current main-ion intrinsic rotation measurements are consistent with an orbit-loss model. Edge plasma rotation increases as collisionality decreases, projecting favorably to ITER. First-principles based prediction of the ITER rotation profile requires validated models of both turbulent transport that determine the core profile shape, as well as the neoclassical kinetic processes that determine the boundary condition. Experiments at DIII-D are combining the validation of turbulent momentum transport in the plasma core with the intrinsic rotation at the boundary and made significant advancements in our predictive capability for ITER. Work supported by U.S. DOE under DE-AC02-09CH11466, DE-FC02-04ER54698, and DE-FG02-07ER54917

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