Optimizing 3D spectra for rotation control

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A new matrix formulation utilizing the multi-modal plasma response to optimize multi-coil spectra for desired neoclassical toroidal viscosity (NTV) torque profiles has been developed in the Generalized Perturbed Equilibrium Code (GPEC) and applied in experimental optimization on the DIII-D tokamak. The new GPEC formulation [1] solves the single-fluid quasi-neutral anisotropic pressure perturbed equilibrium in the first gyro-radius ordering, representing the nonlinear torque as a function of coil array currents; $\tau(\psi) = I_c \cdot T(\psi) \cdot I_c$. With this representation in hand, the optimal coil configuration for localized torque between any two surfaces ψ_1 and ψ_2 is immediately calculable as the first eigenvector and of $T_b^{-1}[T_1 - T_2]$, where T_b is the boundary matrix. A single perturbed equilibrium calculation thus provides the optimal coil configurations for the maximum, minimum, core localized, and edge localized NTV torque profiles. Experiments have validated this model in nonresonant field space, providing accurate predictions of quiescent (having little impact on density and energy confinement) braking profiles that could be used in rotation control algorithms with little impact on the particle or energy confinement. Large edge resonant magnetic perturbations, however, caused large density pumpout not accounted for in the neoclassical model, significantly distorting the equilibrium from the perturbative model prediction. The impact of the pumpout is quantified here and used to motivate future work using integrated 3D (GPEC) and 2D (TRANSP) transport models for full momentum profile evolution predictions. This experimental application and test of the new GPEC torque matrix predictions represents a significant step in building successful error field correction models towards new practical applications for rotation profile control. The torque profile manipulation with the poloidal 3D field spectrum is a direct application of the multi-mode phenomena [2, 3] for concrete performance enhancements, and validated predictions provide a path towards reduced rotation profile control schemes for the optimization of tokamak stability and performance.

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