Predicting neoclassical toroidal viscous torque in present and future tokamaks: status and challenges

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This is an overview on the state of predictive modeling of neoclassical toroidal viscous (NTV) torque driven by non-axisymmetric magnetic perturbations in tokamaks [1]. Such perturbations arise from toroidal field ripple, error fields and auxiliary coils for intentional 3D perturbations. NTV torque results from perturbations of the magnetic field strength from both, direct Eulerian perturbation and Lagrangian contribution from distortion of flux surfaces. Since NTV torque scales with the square of the perturbation amplitude, accurate plasma response models are key for quantitative predictions. Currently, linear and nonlinear ideal and resistive magnetohydrodynamic models are available with options to include kinetic effects in perturbed equilibria. At reactor-relevant collisionality in present-day medium sized tokamaks, ion orbital resonances have been shown to add orders of magnitude to NTV torque predictions compared to models that don't account for this effect [4]. Significant influence is seen from electrons in collisional regimes, magnetic shear and finite ion orbit width effects. In addition, non-linear attenuation can modify the result. At fast rotation approaching the ion thermal velocity, usual model assumptions break down. We assess the importance of the listed NTV model details together with the underlying plasma response models for current devices and at reactor scale. The focus is on machines in the current EUROfusion task on tokamak exploitation and future EU-DEMO. Based on this analysis and currently available numerical models, we quantify the uncertainties in NTV torque predictions and identify their drivers. We conclude with a discussion of strategies in modeling and experiment to overcome these challenges.

References

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