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Effect of helical perturbations on magnetic braking and neoclassical transport in tokamak plasmas

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Magnetic fields in a tokamak can deviate from axisymmetry due to error fields or external coils introduced for controlling MHS instabilities. Such perturbations, even at small magnitudes, can have nontrivial effects on plasma dynamics and transport.[1] The exact mechanisms and effects that arise from perturbations working both singly and in concert are yet to be fully understood.[2]

Previously, toroidally periodic but poloidally symmetric perturbations, which can be used to model error fields from finite toroidal field coils, were investigated using neoclassical transport theory and global gyrokinetic simulations done with the GYSELA simulation code.[3-4] Using the same approach, we extend the analysis to helical perturbations as a general case, specifically for the relationship between magnetic braking (or neoclassical toroidal viscosity) of the plasma with neoclassical transport. The existing theory and transport matrix calculations are further developed to account for helical perturbation modes, which are poloidally as well as toroidally periodic, in contrast to the previous formulation.

Multiple simulations across a range of initial parallel plasma flow velocities generate data from which magnetic braking force is obtained. This is then used to calculate the neoclassical friction coefficient as a function of plasma collisionality. We then compare the obtained values and dependences with predictions from the theoretical model, as well as results from other work on both poloidally symmetric and general helical perturbation modes, to understand how well the model agrees with detailed gyrokinetic simulation results. There is generally better agreement at lower collisionalities and larger perturbation magnitudes, possibly influenced by the various neoclassical transport regimes.

References

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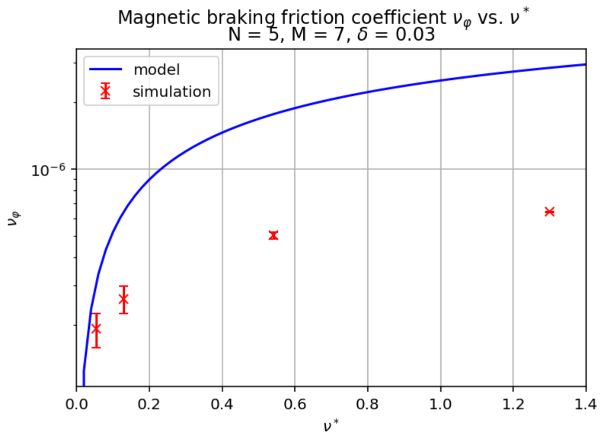

Figure 1: Comparison of magnetic braking friction coefficient from theoretical model and simulation data. There is closer agreement at lower values of collisionality ν^*.