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Reduced Neoclassical Flow Damping with Quasi-Symmetry: Measurements and Modeling from HSX

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The quasisymmetric stellarator concept may represent a solution to a conundrum in toroidal confinement. We wish to have the good neoclassical transport properties associated with a symmetric system, including the minimal flow damping in the direction of symmetry, as in a tokamak. At the same time, we desire an inherently steady state reactor, as in a stellarator. The Helically Symmetric eXperiment (HSX) was developed to test this concept; the quasi-helically symmetric base configuration can be modified using "trim-coils" to break the quasisymmetry, leading to configurations with the transport qualities of a traditional stellarator. We have constructed system of biased electrodes and Mach probes for flow damping studies, as well as arrays of H-alpha detectors to estimate the flow damping caused by ion-neutral friction. We have demonstrated that the flow damping in the quasisymmetric configuration is reduced compared to the symmetry-broken configuration. Neoclassical modeling has demonstrated that the reduction is in the amount predicted by theory, but that there is additional damping beyond the contribution of neoclassical parallel viscosity. This is similar to the results of large tokamaks, where toroidal flow damping is anomalously large. This research was funded by the U.S. DOE.

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