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Measurement and Modeling of Large Helical Flows in the HSX Stellarator[1]

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Symmetry in a device's magnetic field strength allows large flows to develop, which may reduce turbulent transport. Although symmetry is an inherent feature of tokamaks and other axisymmetric devices, stellarators typically do not have a direction of symmetry. The quasihelically symmetric HSX stellarator is the only device with a helical direction of approximately constant magnetic field strength. We present here first results that verify the capability for the class of quasisymmetric stellarators to have large intrinsic flows. Flow velocities of up to 20 km/s along the helical direction, with no external momentum injection, have been measured using charge exchange recombination spectroscopy in HSX. Measurements are made using the 529 nm C+5 line at 10 radial locations from two viewing directions allowing the flow direction and magnitude to be determined. These measured flows are compared to the neoclassical values calculated by the PENTA code [1]. A non-momentum conserving collision operator is used when solving the drift kinetic equation for stellarators, which typically have large flow damping in all directions. HSX's parallel flow is under-predicted by an order of magnitude by the non-momentum conserving calculations, but good agreement is seen with parallel flows calculated by PENTA when a momentum conservation correction technique [2] is applied. In addition to verifying a key attribute of quasisymmetric stellarators, these results validate a neoclassical code that can calculate plasma flows in a wide range of toroidal devices from perfectly axisymmetric systems to fully 3D configurations. This allows the effects of symmetry breaking magnetic field components, which can increase flow drive as well as damping, to be studied.

[1] D. Spong, Phys. Plas. 12 (2005) 056114.
[2] H. Sugama, S. Nishimura, Phys. Plas. 9 (2002) 4637.

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