Neoclassical Parallel Momentum Balance and Flow Damping in Quasi-Symmetric Stellarators

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Quasi-symmetric stellarators encompassing the three possible forms of quasi-symmetry: quasi-poloidal (QPS), quasi-toroidal (NCSX) and quasi-helical (HSX) are now either operational or in the planning stages. These different symmetries will allow tests of neoclassical transport physics in a range of three-dimensional toroidal systems whose $|B|$ variation within a flux surface varies from nearly tokamak-like [$|B| \approx |B|(\theta)$] to mirror-like [$|B| \approx |B|(\zeta)$]. Recently, a fluid moments approach has been developed that provides a more self-consistent way to evaluate the effects of these differing symmetries on both the parallel and perpendicular transport; this is based on a theory[1] that corrects for momentum-conserving and ion-electron frictional coupling effects. We have developed tools to numerically evaluate the viscosities, flow velocities, self-consistent ambipolar electric field, bootstrap currents, and cross-field fluxes of particles and energy based on this moments method approach. The DKES code[2] is first used to generate the monoenergetic particle/energy diffusion, Ware-pinch and neoclassical resistivity enhancement coefficients over a range of collisionality, electric fields and flux surfaces. Velocity integrations and momentum-conserving corrections are then carried out, resulting in a complete transport matrix that takes into account ion-electron coupling effects and provides both the parallel and perpendicular components of transport. This model has been applied to the above stellarator configurations and has indicated a number of interesting effects. For example, in the quasi-poloidal QPS device, poloidal flow-damping can be suppressed by about a factor of 10 relative to equivalent axisymmetric devices. Other examples of application of this model to three different symmetries will be discussed.

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[2] W. I. van Rij, S. P. Hirshman, Phys. Fluids B, **1** (March, 1989).