Dynamic parallel viscous force in the low collisionality regime*

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Some neoclassical effects in toroidal geometries can be illustrated via a simplified 2D bumpy cylinder magnetic field. With this model, we explore the dynamics of parallel flow damping due to the parallel viscous force. A dynamic closure for $\langle \mathbf{B} \cdot \nabla \cdot \Pi \rangle$ is introduced in the parallel momentum equation and the flow evolution is obtained as an integral equation. Long and short times limits are calculated in a large aspect ratio approximation and compared to previous results obtained by other authors [1]. The result is further extended to toroidal geometry and the ambipolarity of cross field fluxes addressed [2].

The closure is obtained as an initial value problem using a Chapman-Enskog-like [3] approach. A Laplace transform to frequency space allows a solution in terms of Cordey eigenfunctions [4] which can be inverted analytically in a small $\sqrt{\epsilon}$ approximation. The expression obtained is time dependent and this allows us to explore the viscous damping at all times. For early stages the evolution is governed by the decay of the initial perturbation as $\partial U/\partial t \sim (\epsilon\nu/t)^{-1/2}$. For longer times, the initial condition is damped and an exponential decay with a decay rate $\nu_p \sim \epsilon\nu$ is obtained. Finally, in steady state the known static result $\nu_p \sim \sqrt{\epsilon}\nu$ is recovered. The poloidal angle dependence of the parallel viscous force in an axisymmetric torus can also be obtained; progress in this direction will be presented. The final expression that we are after, having explicit time and spatial dependences should be useful for numerical codes like NIMROD.

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