Transport and bootstrap current in a small aspect ratio torus

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Calculations of collisional thermal and particle diffusivities in toroidal magnetic plasma confinement devices order the toroidal gyroradius to be small relative to the poloidal gyro-radius, i.e $\rho_{i_\phi} << \rho_{i_\theta}$ where $\rho_{i_\phi} \equiv m_i v_{th_i}/qB_\phi$ and $\rho_{i_\theta} \equiv m_i v_{th_i}/qB_\theta$. This ordering is central to what is usually referred to as neoclassical transport theory[1]. This ordering is incorrect at low aspect ratio (with aspect ratio $A \equiv R/a$, where R is the major radius of the torus and a is the minor radius), where it can often be the case that $\rho_{i_\phi} > \rho_{i_\theta}$. This means that excursions of a particle from its nominal flux surface are much larger than estimated in neoclassical theory, with a consequent increase in both radial transport and bootstrap current. We calculate the correction to the particle and thermal diffusivities at low aspect ratio by comparing the diffusivities as determined by a full orbit code[2] (which we refer to as omniclassical diffusion) with those from a gyro-averaged orbit code[3] (neoclassical diffusion). In typical low aspect ratio devices such as the National Spherical Torus Experiment [4] [5] the omniclassical diffusion can be up to 2.5 times the calculated neoclassical value, and the bootstrap current also larger than neoclassical values, with the ratio of bootstrap currents approximately equal to the square root of the ratio of the diffusivities. We discuss the implications of this work for low aspect ratio magnetic confinement experiments.

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