Steady-State, High-Bootstrap-Fraction Discharges: Prospects for DIII–D

F.W. Perkins
Princeton, DIII–D Colaboration

T.A. Casper
Lawrence Livermore National Laboratory

P.A. Politzer
General Atomics

Given knowledge of the plasma pressure gradient, it is a straightforward procedure to construct solutions of the Grad-Shafranov equation with almost 100% bootstrap current. This has been carried out by Miller [1] for the case of spherical tokamaks and yields near-perfect alignment between the bootstrap current density profile and the actual profile. We report similar solutions for discharges representative of high-bootstrap-fraction, fully noninductive DIII–D discharges [2] in magnetic steady-state. Two models for the steady-state pressure gradient, which drives the bootstrap current, are investigated: (1) The critical gradient model wherein $d(lnp)/dr = -(\text{const.})/R$ and (2) a gyroBohm conductvity model where the steady-state heat conduction equation $h = \chi \nabla P$ determines the pressure gradient. Here h denotes the heat flux through a magnetic surface and χ is a gyroBohm thermal diffusivity $\chi = \chi_o T^{1/2} |\nabla T| M^{1/2} c^2 q^2 / e^2 B^2$. The q^2 factor is needed to replicate the plasma current scaling of confinement. For the gyroBohm model, one finds that $\nabla p \propto q^{-2}$, reversing the usual dependence of bootstrap current on poloidal field. For both models, the density is taken as constant to replicate H–mode confinement. The resulting equilibria are investigated for stability against magnetic and heat diffusion, including auxiliary power and thermonuclear sources for h. To diminish NBI current drive with respect to bootstrap current, DIII–D will be operated at high densities $\sim 5 \cdot 10^{19}$ m^{-3} and low temperature (at fixed β_θ). Moreover, this increases the rate of magnetic diffusion and equilibrium should be attained within the allowable 5–10 s discharge duration. Technical limitations on total injected energy constrain these discharges to $\beta_{\text{tor}} \approx 0.01$. Consequently, β-limit physics will not complicate the study of mutual heat and magnetic diffusion.

This is a report of work supported by U.S. DOE Contracts DE-AC02-76CH07030, W-7405-ENG-36, and DE-AC03-99ER54463.

References

[1] R.A. Miller et al., Phys. Plasmas **4**, 1062 (1997).
[2] P.A. Politzer et al., Phys. Plasmas **1**, 1545 (1994).