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3-D Equilibrium Reconstruction in the HSX Stellarator[1]

J.C. SCHMITT, HSX, UW-Madison

Axisymmetric toroidal devices reconstruct the MHD equilibrium properties from measured pressure, magnetic field components, external field coil currents, and other diagnostics, by solving the Grad-Shafranov equation. For modern toroidal systems including advanced stellarators and tokamaks with asymmetric fields, such as those that arise from finite toroidal ripple or ferromagnetic blanket materials, a 3-D equilibrium reconstruction is required to account for non-axisymmetric effects and accurately determine the plasma profiles. The 3-D equilibrium reconstruction of plasma current and pressure profiles in the quasi-helically symmetric stellarator HSX is presented. The equilibrium currents in the HSX stellarator are measured with a set of magnetic diagnostics, which includes Rogowski coils, diamagnetic loops, two poloidal 'belts' that are separated by 1/3 of a field period, and internal coils. Each belt consists of 16 3-axis magnetic pick-up coils to measure the local magnetic field, and 15 internal coils measure the poloidal field. V3FIT [1], a 3-D equilibrium reconstruction code, is used to reconstruct the pressure and current profile from the measured fields and fluxes. Reconstructions based on the external diagnostics confirm that the Pfirsch-Schlüter current is helical due to the lack of toroidal curvature in HSX. The reconstruction of the pressure profile and stored energy based on the internal poloidal array agrees well with that measured by Thomson scattering and the flux loop. Later in time, the measurements are dominated by the bootstrap current which rises on a timescale comparable to the length of the discharge. The reconstruction of the current profile is consistent with the neoclassical bootstrap current when the effects of momentum conservation between plasma species [2] and the 3-D inductive response of the plasma column [3] are considered. The magnitude of the Pfirsch-Schlüter and bootstrap currents are reduced by the high effective transform ($\sim$3), which is characteristic of quasi-helically symmetric systems. The level of uncertainty in the reconstructed pressure and current profiles is largest near the core of the plasma.

[1] J.D. Hanson, et al, Nucl. Fusion 49 (2009) 075031.
[2] D.A. Spong, Phys. Plasmas 12, (2005) 056114.
[3] P.I Strand and W.A. Houlberg, Phys. Plasmas 8 (2001) 2782.

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