Contribution ID: **217** Type: **Poster**

Steady states for nonaxisymmetric rotating toroidal plasmas

Tuesday, October 23, 2018 8:30 AM (20 minutes)

Small applied nonaxisymmetric magnetic fields have been demonstrated to have strong and complex effects on otherwise axisymmetric toroidal fusion plasmas. Their importance raises the question of the best "steady state" plasma configuration to use for their analysis. A steady state that is valid on fast time scales of a few Alfvén times is needed to invert and interpret experimental measurements and as an initial state to study slower-developing plasma instabilities and plasma processes. It should possess a magnetic flux function Psi with B dot grad(Psi)=0 and a well-confined boundary surface that confines the magnetic field lines. It contains free functions and parameters that must be taken from observations or outside models. The simplest choice is ideal MHD. Axisymmetric and helical MHD plasmas with zero plasma flow possess a good flux function, the plasma pressure, which in axisymmetry is equivalent to the poloidal magnetic flux psi. Axisymmetric states with plasma rotation have two functions, psi and the centrifugally shifted plasma mass density, which represent electron and ion surfaces, respectively. The shifted density modifies the mapping of experimental density to magnetic flux surfaces and allows larger density gradients at the large-R boundary of the torus. Magnetic nonaxisymmetry due to external fields couples the two functions. In single-fluid MHD, the coupling can be shown to impose strong and probably unrealistic constraints on the allowable variation of
the rotation and density relative to the magnetic field. Two-fluid models decouple the electron and ion motions and allow greater freedom that removes the restrictions. They also have other properties that reflect experimental observations. The proposed solutions will be studied for experimental cases with rotation and nonaxisymmetry, by numerical simulation with the nonlinear extended MHD code M3D [1], using the real nonaxisymmetric fields. The results will also be compared to the nonlinear evolution.

*Work partially supported by U.S. DOE OFES contract DE-SC0007883.

[1] Park, W. et al. 1999, Phys. Plasmas 6, 1796; Sugiyama, L.E., and Park, W. 2000, Phys. Plasmas 7, 4644.

Country or International Organization

United States of America

Paper Number

TH/P1-4

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Session Classification: P1 Posters