Taylor States in the HIT-SI Experiment

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Abstract

The Helicity Injected Torus (HIT) experiment at the University of Washington has been reconfigured into a high beta spheromak with steady state AC current drive [1]. Helicity is injected by two half torus Reversed Field Pinches (RFP's) connected to the ends of the cylindrically symmetric flux conserver, rotated by 90 degrees from each other. The RFP's are driven with sinusoidally varying voltage and flux. Each side has its voltage and flux in phase, but is 90 degrees out of phase from the other side. The helicity injection rate, which is proportional to the voltage times the flux, goes like $\sin(\omega t)^2$ on one side and $\cos(\omega t)^2$ on the other, making the total injection rate constant in time.

The complex multiply connected 3-dimensional geometry of this device make it difficult to compute anything with existing codes that typically use a structured mesh. This poster will describe a new 3-D Taylor State code that uses an unstructured finite element mesh. The mesh is generated by the code T3D [2], which uses an advancing front method to create a tetrahedral mesh for an arbitrarily shaped 3-dimensional volume from a CAD-like description of a collection of simple surface pieces.

Homogeneous Taylor states are computed by iterating the equation $-\mathrm{del}^2\ \mathbf{A}^{n+1} = \mathrm{curl}\ \mathbf{A}^n$, with under-relaxation. The tangential components of **A** are required to vanish on the boundary. When the fastest growing mode eventually dominates, the amplification factor will be the reciprocal of the Taylor eigenvalue. Inhomogeneous Taylor states are computed by iterating the numerical equation $-\mathrm{del}^2\ \mathbf{A}^{n+1} = \lambda\ (\mathrm{curl}\ \mathbf{A}^n + \mathrm{grad}\ \phi)$, where ϕ is a potential for the externally generated magnetic flux, found by solving Laplace's equation with appropriate jump conditions in the handles. This will converge when λ is below the first homogeneous eigenvalue. For higher values of λ, the homogeneous solution must be projected out during the iteration and then added back in at the end.

Both homogeneous and inhomogeneous Taylor states will be presented for the HIT-SI geometry. Inhomogeneous solutions will be shown for different combinations of fluxes and currents in the two injectors. Field line tracing puncture plots will show the quality of the flux surfaces in each solution presented.

[1] T. R. Jarboe, Fusion Technology **36**, p. 85, 1999

[2] http://power2.fsv.cvut.cz/~dr/t3d.html