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A Fully-Relaxed Helicity Balance Model for the HIT-SI Spheromak

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A fully relaxed Taylor-state model is shown to agree with HIT-SI surface and internal magnetic profile measurements. Helicity balance predicts the peak magnitude of toroidal spheromak current and the threshold for spheromak formation. The model also accurately predicts the division of the applied injector loop voltage between the injector and spheromak regions. The Taylor state for HIT-SI can be thought of as a linear superposition of three Taylor states: One for each injector with the injector flux as a boundary condition, and one for the spheromak equilibrium itself. [T.R. Jarboe, W.T. Hamp, G.J. Marklin, B.A. Nelson, R.G. O'Neill, A.J. Redd, P.E. Sieck, R.J. Smith, and J.S. Wrobel, *Phys. Rev. Lett.*, v 97, p 115003, (2006)] The Taylor states are calculated directly from the machine geometry, and the magnitudes of the injector states are determined by the measured injector currents. Both the surface fields and internal field profile agree to within 10% of the fields measured in the experiment, using only the spheromak current as the fitting parameter. By assuming helicity is injected at a rate $2V\Psi$, and only decays through resistivity the equilibrium is predicted with no fitting parameters, demonstrating helicity balance in a sustained spheromak for the first time without the large uncertainty of sheath drops. Spitzer resistivity (using Z=2) is assumed with the electron temperature measured by Langmuir probe. Although the experimental results suggest a higher effective resistivity by a factor of 1.5 compared to the Spitzer value the prediction is still within the uncertainties in the measured parameters. The voltage division between injector and spheromak regions is measured with internal electrostatic probes and agrees with the model to within 20%. HIT-SI produces 1 m diameter spheromaks with toroidal currents of up to 30 kA. FIR density data will also be presented.