Spheromak Formation by Steady Inductive Helicity Injection in 3D MHD Simulations

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Abstract

The HIT-SI spheromak, which began operation in 2003, is formed and sustained by a novel means known as Steady Inductive Helicity Injection (SIHI). The device geometry consists of the bow-tie spheromak confinement region and two half toroids which serve as the injectors. Each injector is operated by two coils producing a 5kHz oscillating flux and loop voltage. While the initial stage of the experiment has focused on studies of the injector operation, 3D numerical simulations with the NIMROD code have produced initial results concerning spheromak formation in the confinement region. In the simulations, the injectors are replaced with non-symmetric boundary conditions on the confinement region. Each simulation begins with no magnetic field in the volume, and the SIHI drive ramps up over one cycle (0.2ms), then holds a constant amplitude for two cycles and finally ramps down over one cycle, after which the remaining equilibrium is allowed to briefly further evolve. Computational resources limit the pulse length, which is tens of cycles in the experiment. Because of the predominantly n=1 symmetry of the SIHI injector fields, they are easily distinguishable from the equilibrium fields in magnetic energy spectra of the computational results. At a small Lundquist number, comparable to the initial operating phase of the experiment, the n=0 (equilibrium) magnetic energy remains considerably smaller than the n=1 (injector) energy during the sustained phase. As the injectors ramp down, the injector fields are forced to reconnect in the volume, causing a rise in the equilibrium amplitude at the end of the pulse. The equilibrium then decays once the drive has ceased completely. When the plasma resistivity is lowered to produce a moderate Lundquist number, the n=0 magnetic energy grows much larger than the n=1 energy during the sustained phase, supporting the expectation of observable spheromak formation on the HIT-SI device when hotter plasmas are created in the next experimental phase.