DPP05-2005-001507

Abstract for an Invited Paper
for the DPP05 Meeting of
the American Physical Society

Advances in the Numerical Modeling of Field Reversed Configurations[1]

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The field-reversed configuration (FRC) is a compact toroid with little or no toroidal field. It offers a unique fusion reactor potential because of its compact and simple geometry, translation properties, and high plasma beta. Theoretical understanding of the observed FRC equilibrium and stability properties presents significant challenges due to high plasma beta, flows, large ion gyroradius and stochasticity of the particle orbits. Advanced numerical simulations are generally required to describe and understand the behavior of FRC plasmas. Results of such simulations are presented in this paper. It is shown that 3D nonlinear hybrid simulations using the HYM code reproduce all major experimentally observed stability properties of elongated (theta-pinch-formed) FRCs. Namely, the scaling of the growth rate of the $n = 1$ tilt mode with S^*/E parameter (S^* is the FRC kinetic parameter, E is elongation, and n is toroidal mode number), the nonlinear saturation of the tilt mode, ion toroidal spin-up and the growth of the $n = 2$ rotational mode have been demonstrated. The HYM code has also been used to study FRC formation by counter-helicity spheromak merging, and stability properties of FRCs formed by this method have been investigated. A new stability regime has been found for FRCs with $E \sim 1$ and $S^* \sim 20$, which requires a close-fitting conducting shell and energetic beam ion stabilization. It is shown that the $n = 1$ and $n = 2$ MHD modes can be effectively stabilized by combination of conducting shell and beam ion effects, and residual weakly unstable $n > 2$ modes saturate nonlinearly at low amplitudes. The resulting configuration remains stable with respect to all global MHD modes, as long as the FRC current is sustained.

[1] Supported by DE-AC02-76CH03073

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