NUMERICAL MODELING OF FIELD REVERSED CONFIGURATIONS

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The field-reversed configuration (FRC) is a compact toroid with little or no toroidal field, in which plasma is confined by a poloidal magnetic field associated with toroidal diamagnetic current carried by the plasma. It offers a unique fusion reactor potential because of its compact and simple geometry, translation properties, and high plasma beta. Although many MHD modes are predicted to be unstable, FRCs have been produced successfully by several formation techniques and show surprising macroscopic resiliency. Early attempts to explain the apparent gross stability within the MHD framework were unsuccessful, and kinetic effects associated with large thermal ion orbits have been considered as a possible stabilizing factor. 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. A nonlinear 3D delta-f hybrid code HYM has been developed to study the role of kinetic effects on the FRC stability properties. 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 FRC kinetic parameter, the nonlinear saturation of the tilt mode, ion toroidal spin-up and the growth of the $n = 2$ rotational mode have been demonstrated (where n is toroidal mode number). The HYM code has also been used to study FRC formation by counter-helicity spheromak merging, and stability properties of oblate FRCs formed by this method have been investigated in support of the PPPL magnetic reconnection experiment (MRX-FRC). A new stability regime has been found for oblate FRCs, 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.