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Overview of MST Reversed Field Pinch Research in Advancing Fusion Science

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The reversed field pinch (RFP) offers unique capabilities that could be essential to closing gaps to fusion power. The RFP has large plasma current and small toroidal field, with q(r)<1. Two key benefits arise: (1) the possibility for ohmic heating to ignition and (2) minimization of the field strength at the magnets. The material boundary can be made invisible to an inductive electric field, and the first-wall need not accommodate power injection ports or antennas. These features could help achieve a maintainable and reliable fusion power source. This overview summarizes MST results important for the advancement of the RFP as well as for improved understanding of toroidal confinement generally. Evidence for first observations of trapped-electron mode (TEM) turbulence in the RFP is obtained. Short-wavelength density fluctuations exhibit a density-gradient threshold, and GENE modeling predicts unstable TEM's. Core-localized neutral beam injection stimulates bursty modes with both Alfvenic and EPM scaling. One mode agrees with a new analytic theory for the magnetic-island-induced Alfven eigenmode (MIAE), which conspires with an EPM to affect fast ion transport. At high current the RFP transitions to the quasi-single-helicity (QSH) state. A method to control the locked phase of QSH has been developed using resonant magnetic perturbations (RMP). Runaway electrons that appear without RMP are suppressed. An improved model for simultaneous interactions of multiple tearing modes and error fields has been developed. The RFP's tearing-relaxation behavior together with well-developed theory and computation create a ripe opportunity for rigorous validation of MHD models. Integrated data analysis (IDA) complements validation by maximizing the information embedded in multiple diagnostics, which is essential for future fusion development steps having limited diagnostics. Using IDA methods, meta-diagnostics that combine charge-exchange recombination spectroscopy, x-ray tomography, and Thomson scattering yield more robust measurements of Z_eff and T_e, critical parameters for MHD. Nonlinear studies using an extended MHD model including drift and two-fluid physics in NIMROD show features similar to MST observations, including a tendency for the MHD and Hall emf terms to oppose each other in Ohm's law, and opposition of the Maxwell and Reynolds stresses in momentum balance.

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