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Effect of Dynamo On Electric Field And Current Density In Reversed Field Pinches

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Abstract

In high temperature laboratory experiments with plasma self-organization (reversed field pinches, spheromaks, and field reversed configurations), large scale magnetic and electric fields applied to plasma externally provide the free energy sources to drive tearing instabilities. These instabilities support a mechanism for the relaxation process to equilibrium states close to the Taylor's state of minimum energy. Standard regimes of Madison Symmetric Torus (MST) RFP experiments are characterized by the periodic sawtooth fluctuations in the plasma velocity and magnetic field. The corresponding nonlinear $\mathbf{v} \times \mathbf{B}$ dynamo effect produces mean electric field and current density, all of which are well measured in the MST near the reversal surface. This motivates our interest to: (1) provide an explanation of the experimental results, and (2) calculate the quasilinear contribution of the mean parallel current to analyze its feedback effect on the tearing mode stability. The problem is treated on the basis of parallel (to unperturbed magnetic field) component of flux surface average Ohm's law: $\langle \mathbf{E} \rangle_{\|} + (1/c)\, \langle \mathbf{v}^{(1)} \times \mathbf{B}^{(1)} \rangle_{\|} = \eta \langle \mathbf{j} \rangle_{\|}$, where $\mathbf{v}^{(1)}$ and $\mathbf{B}^{(1)}$ are tearing eigenfunctions for plasma velocity and magnetic field. The above equation does not address the question as to what fraction the contribution from $\langle \mathbf{v}^{(1)} \times \mathbf{B}^{(1)} \rangle_{\|}$ term is shared between the mean electric field $\langle \mathbf{E} \rangle_{\|}$ and the mean current density $\langle \mathbf{j} \rangle_{\|}$. Simple 1D cylindrical temporal model is used to find these functions separately. In highly conductive case, the self-inductance of the tearing layer prevents fast changes in the mean parallel current, thus, providing a "stiffness" with respect to perturbations. This is observed in the MST experiments where the mean electric field is measured to be balanced by the dynamo term during a sawtooth crash.

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