Instabilities of thin current sheets: kinetic effects and nonlinear evolution

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We discuss the transition to fast growth of the tearing instability in thin current sheets starting from the purely resistive case and then describing generalizations to collisionless effects, from the Hall term to the more extreme cases where electron inertia drives the reconnection process. Previously we have shown that in resistive MHD there is a natural maximum aspect ratio (ratio of sheet length and breadth to thickness) which may be reached for current sheets with a macroscopic length L, the limit being provided by the fact that the tearing mode growth time becomes of the same order as the Alfven time calculated on the macroscopic scale.

For current sheets with a smaller aspect ratio than critical the normalized growth rate tends to zero with increasing Lundquist number S, while for current sheets with an aspect ratio greater than critical the growth rate diverges with S. Here we include the Hall effect and then electron inertia. The first process does not in itself lead to a violation of the frozen in theorem, but its presence increases the resistive instability growth rate. Previously found scalings of critical current sheet aspect ratios with the Lundquist number are generalized to include the dependence on the ion inertial length and electron inertial lengths respectively. Finally we discuss two-dimensional nonlinear simulations of a collapsing sheet which display self-similar behavior in a generalized form of the fractal reconnection scenario first proposed by Shibata and Tanuma (2001).