Two-Fluid Simulations of 2D Magnetic Reconnection

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Recent experimental and theoretical results have led to two lines of thought regarding the physical processes underlying fast magnetic reconnection. One is based on the traditional Sweet-Parker model but replaces the Spitzer resistivity with an enhanced resistivity caused by electron scattering by ion acoustic turbulence. The other includes the finite gyroradius effects that enter Ohm's law through the Hall and electron pressure gradient terms. Numerical simulation aimed at distinguishing the predictions of these two models using full two-fluid MHD in the context of merging flux tubes faces the challenge of resolving a dramatically varying range of spatial and time scales: from the system size down (at least) to the ion skin depth; and from Alfvén times down to the transit times of the fastest whistler waves. A new, parallel algorithm that has met some success in solving this problem in two dimensions involves the use of a fixed, non-uniform rectangular mesh and an alternating-direction implicit (ADI) method with high-order artificial dissipation. The results of simulations using this algorithm are presented, demonstrating that the behavior of the plasma under each of the above two sets of assumptions is quite distinct. The enhanced resistivity model yields resistivity-dependent reconnection with a thick, moderate-aspect-ratio current sheet. For current sheets thinner than or on the order of an ion skin depth, the Hall effect predominates, producing true fast reconnection with a microscopic current sheet of unit aspect ratio and a distorted out-of-plane magnetic field.