A second-order accurate semi-implicit δf method for kinetic MHD simulation

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We have developed a second-order accurate semi-implicit δf method for kinetic MHD simulations with Lorentz force ions and fluid electrons. With particle ions treated with the δf method, this model includes full ion kinetic effects. Quasi-neutrality is assumed, which, together with the fluid electrons, makes the model suitable for studying MHD scale physics. This model has been implemented in the GEM code. The field solver is divided into the linear part and the nonlinear part. The two parts are solved separately, with the linear part solved by direct matrix inversion and the nonlinear part solved by iteration. The simulations have been benchmarked on Alfvén waves, ion sound waves and whistler waves against the analytical dispersion relation in a uniform plasma. In particular, by alternating the centering parameter, the first-order and second-order schemes are compared by studying the numerical damping of whistler waves. Furthermore, by adding a resistive term in the generalized Ohm's law, the model is capable of studying the resistive tearing mode using the Harris sheet equilibrium. The linear growth rate and mode structure are compared with the resistive MHD theory. Important nonlinear tearing mode behavior such as the Rutherford regime and saturation are demonstrated. We have also observed saturation behaviors different from previous MHD simulations.