EXTENDED FLUID MODELS AND THEIR IMPLICATIONS FOR SIMULATION ALGORITHMS

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Any attempt to model correctly the dynamical behavior of modern laboratory plasmas must include extensions that capture the effects of separate ion and electron fluids and finite ion Larmor radius to the usual resistive MHD model. This is true for alternative concepts (in particular the FRC and the RFP) as well as for tokamaks. These extensions include the Hall and electron pressure gradient terms in Ohm's law and the gyro-viscous stress in the momentum equation. For tokamaks, models for the neo-classical contributions to the ion and electron stress tensors should also be included. In this paper we present a systematic study of the proper form of these equations in different parameter regimes. Only a few dimensionless parameters appear in the coefficients of the two-fluid equations if they are suitably normalized.. Fluid models valid in different parameter regimes emerge by ordering these parameters as large or small compared to the normalized ion Larmor radius. In addition to the usual ideal and resistive MHD models, these include Hall MHD, which incorporates the Hall term but not the ion gyro-viscous stress, and drift MHD, which incorporates the gyro-viscous stress and neo-classical stresses, but only the parallel electron pressure gradient survives in Ohms law. The modifications to Ohm's law in both the Hall and drift MHD models introduce dispersive normal modes (the whistler wave for the case of Hall MHD, and the kinetic Alfvén wave for drift models) that do not appear in ideal or resistive MHD. In addition, the Braginskii form of the gyro-viscosity introduces independent dispersive modes that come from the ion dynamics. While these dispersion relations can be derived by taking the proper limits of the underlying kinetic theory, they are not often discussed within the context of fluid models. Each of these dispersive modes can lead to severe time step restrictions that may impede the ability of numerical algorithms to model long time scale plasma dynamics. We describe several semi-implicit approaches for removing these severe simulation constraints, and report progress in their implementation.