Hybrid Kinetic-MHD Simulations in General Geometry

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Abstract

The dynamics of fusion plasmas lead to instabilities that can spontaneously erupt and degrade confinement and sometimes lead to catastrophic disruptions of the entire plasma itself. These instabilities occur in a broad range of spatial and temporal scales, spanning many orders of magnitude, often resulting from nonlinear interactions. Computational simulations are crucial to understanding these phenomena.

NIMROD (Non-Ideal MHD with Rotation - Open Discussion)[1] is a massively parallel three dimensional magnetohydrodynamic simulation utilizing finite elements (**FE**) to represent the poloidal plane and a Fourier decomposition in the toroidal direction. The use of finite elements allows flexibility in the representation poloidal domain. This flexibility of cross sectional domain allows **NIMROD** to model realistic axisymmetic plasma device accounting consistently accounting for the geometry.

To expand the physics capabilities of **NIMROD**, kinetic effects have been added through a δf PIC (Particle-in-Cell) module[2]. This kinetic contribution enters through the MHD momentum equation as an addition kinetic pressure[3]. The addition of kinetic particle effects captures wave-particle interactions that are essential in the accurate modeling of internal kink modes, sawtooth, fish bone instabilities, and toroidal Alfven eigenmodes.

This poster will detail the δf PIC implementation in **NIMROD**, paying particular attention to the parallel scaling and performance. Recent recoding has produced a $\sim 20\%$ improvement in performance and some gains in parallel scaling. We will present several validation test to show the accuracy of particle trajectories and their deposition onto the FE grid. We demonstrate the hybrid kinetic-MHD capabilities through several benchmark cases including Landau damping of compressional Alfven waves and stabilization of the internal kink mode and excitation of the fish bone mode. We then present some preliminary hybrid resistive internal kink studies.

[1]C.R. Sovinec, et.al. "Nonlinear magnetohydrodynamics simulation using high-order finite elements," JCP., in press

[2]C.C. Kim, et.al.," Hybrid Kinetic-MHD Simulations in General Geometry", CPC, pending publication

[3]C.Z. Cheng, JGR 96, (1991)