Effects of kinetic ions on internal kink modes with XTOR-K

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The effects of kinetic ions on the dynamics of macroscopic extended MHD modes is known to be important, both from experimental measurements and previous theoretical / numerical works. To extend the understanding of the mechanisms in play, the XTOR-K code was developed at CPhT, Ecole Polytechnique. XTOR-K is a full 3D hybrid code, solving part of the plasma dynamics by a bi-fluid model and selected populations of ions by a PIC method, integrating their trajectories along the gyromotions: the method is 6D full-f for the kinetic ions, and based on the implicit code XTOR-2F [1] on the fluid side.

Two test problems were used to validate the code. The first one is the so-called Hinton Rosenbluth test [2], where an initial m=n=0 velocity perturbation is Landau damped by a thermal kinetic deuterium population. In this example, the electrons are handled as a fluid and the ions are 100% kinetic. We found an excellent agreement between the theoretical and the numerical damping rates. The second test case is the so-called fusion alpha fishbone branch [3]. Coppi et al. demonstrated that increasing kinetic alpha pressure firstly stabilizes the internal kink and secondly destabilizes the fishbone branch. We have reproduced this result with an excellent agreement with XTOR-K.

XTOR-K is then used to study the impact of a 100% kinetic thermal ion bulk on the dynamics of internal kinks, thus including trapped ion and all ion FLR effects. Linear theory predicts a stabilization of the kink [4]. However, the picture from existing numerical results [5] and first simulations with XTOR-K seems more complicated. For instance, the kink stabilization predicted by theory seems much weaker with first XTOR-K simulations. These issues will be clarified by a parameter study.

The last issues addressed in the present work are first nonlinear simulations of the internal kink with kinetic ions. In particular the behavior of kinetic thermal ions and alphas during the kink saturation will be investigated.

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