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Simulation of the internal kink mode in visco-resistive regimes

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The (m=1, n=1) internal kink instability plays an important role in the dynamics of a tokamak discharge and is responsible for the occurrence of sawtooth oscillations. Many experimental observations show that plasma rotation can strongly influence the stability properties of sawtooth oscillations. Past theoretical flow studies to understand such stabilization have been done in the low viscosity regimes. Viscosity can be high in tokamaks due to enhancements from turbulent effects. We investigate the stability of the (1,1) mode in the presence of sheared flows over a range of viscosity regimes using the CUTIE code for both RMHD and two-fluid models. Initially, we use the RMHD version of CUTIE and systematically examine the effects of several kinds of sheared flows on the (1,1) mode, namely axial, poloidal and combinations of both types of flows in the linear and the nonlinear regimes. In the absence of flow and for low Prandtl numbers we observe that the growth rate scalings with resistivity and viscosity agree with past theoretical results. However, as we increase the viscosity further, the growth rate scaling changes significantly. It shows that high viscosity can strongly influence the linear growth rate of the modes. We find that in the presence of an axial flow, the stabilizing influence of viscosity is enhanced and can lead to a complete stabilization of the m = 1 visco-resistive mode at high Prandtl numbers. In the nonlinear regime, for axial flows, the saturation level of the mode decreases at a higher viscosity compared to the case of no flow but slightly increases at lower viscosity. Similar results are found for the poloidal flow case. In the case of helical flows at high viscosity, there is a significant change in the nonlinear saturation level depending on the flow helicity. We have continued the above studies into the two-fluid regime and found diamagnetic drift stabilization of the (1,1) mode i.e. the growth rate of the (1,1) mode reduces with an increase in the density gradient. The nonlinear evolution of the mode in the presence of imposed shear flows also shows distinct differences from the RMHD results due to the presence of two-fluid effects.

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Author: Dr CHANDRA, Debasis (Institute For Plasma Research, INDIA)

Co-authors: Prof. SEN, Abhijit (Institute for Plasma Research); Dr THYAGARAJA, Anantanarayanan (Astrophysics Group, University of Bristol, Bristol, BS8 1TL, UK); Mr MENDONCA, Jervis (Institute for Plasma Research Gandhinagar INDIA)

Presenter: Mr MENDONCA, Jervis (Institute for Plasma Research Gandhinagar INDIA)

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