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Title: Bi-fluid and Neoclassical Physics in Non linear MHD simulations of tokamak plasmas

P. Maget

Contributors: X. Garbet, H. Lütjens[1], J.-F. Luciani[1], N. Mellet, D. Meshcheriakov, T. Nicolas, and Tore Supra Team

CEA, IRFM, F-13108 Saint Paul-lez-Durance, France.

[1]Centre de Physique Théorique, Ecole Polytechnique, CNRS, France.

Summary

Magneto-Hydro Dynamic (MHD) instabilities that develop in the core of tokamak plasmas raise a deep interest in both experimental and modelling research. Below the hard operating limit of ideal MHD, a range of modes taking their energy from magnetic reconnection often appear that can grow up to a size where they can severely alter the energy confinement or even lead to a disruption. The dynamics of these reconnecting (or tearing) modes is strongly sensitive to the fact that ions and electrons have a different diamagnetic rotation velocity (we refer to this as a bi-fluid effect). Also, the poloidal variation of the equilibrium magnetic field in tokamaks generates a friction force, different for each species, which not only affects the linear stability of tearing modes, but also give rise to a metastable branch. The physics associated to this force is called neoclassical, and the metastable branch is known as the Neoclassical Tearing Mode (NTM) instability. In experiments where the confined kinetic pressure is large, as will be the case in ITER, this NTM instability is a major concern.

We will report on physics studies relative to bi-fluid and neoclassical physics, and their application to the interpretation of tokamak experiments, using the non linear MHD code XTOR-2F [1]. First, bi-fluid physics proved to strongly impact the dynamics of the tearing instability in Tore Supra experiments with a large non inductive current fraction. The mode can be completely stabilized [2], and its saturated width greatly reduced [3], by diamagnetic rotation. The cyclic behaviour of the sawtooth instability also results from bi-fluid effects [4], and the analysis of the particle redistribution at the sawtooth crash compares well with experimental observations, with the surprising result that about one third of the particle content is not expelled by the crash [5]. Second, neoclassical physics was investigated, and the friction on the ion species proved to reduce significantly the stabilizing influence of the magnetic field curvature [6]. This result is illustrated in the analysis of a Tore Supra experiment with hollow current profile. While diamagnetic rotation is found to reduce the saturation of the double-tearing mode, neoclassical friction increases it at a level consistent with experimental observations [7]. Finally, non linear simulations of Neoclassical Tearing Modes have been performed on a test equilibrium, showing the feasibility of consistent bi-fluid simulations of neoclassical island dynamics [8, 9].

References

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