Linear stability analysis of TJ-II stellarator NBI driven Alfvén eigenmodes in ECRH and ECCD experiments

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Alfvén instabilities driven by energetic ions have been observed in several non-axisymmetric devices such as W7-AS [1], W7-X [2], LHD [3], TJ-II [3, 4] and Heliotron-J [3]. On the other hand, a large body of experiments in tokamaks [5] have shown that such types of instabilities may strongly enhance the transport of energetic ions, thus degrading the performance of the neutral beam heating systems − a particularly unwanted effect in high performance steady state scenarios [6] − and precluding the full slowing-down of fusion born alpha particles. As a consequence, Alfvén eigenmodes (AEs) are also considered an issue in burning stellarator plasmas and being able to predict whether or not they will be destabilized in future optimized configurations require numerical tools specifically validated in 3D systems. The rich variety of AEs observed in TJ-II stellarator NBI plasmas, including chirping or bursting modes as well as frequency-locked modes makes the device a perfect testbed for these studies.

We review here some of the experiments on this topic that were carried out in the TJ-II stellarator, in particular those designed to test the impact of ECRH heating on the spectrum of the observed NBI-driven Alfvén perturbations. Besides studying the effect of perpendicular ECRH, these experiments also address the impact that EC driven current has on the Alfvén continuum through the changes produced in the rotational transform of the magnetic configuration. We carry out a comparison of the experimental results with the predictions of FAR3D [7], a gyro-fluid code that solves the reduced linear resistive MHD equations together with the moment equations of the fast particle population. To this end, we obtain the linear growth rates and the radial location of the dominant modes coincident in frequency with the observed fluctuations, and compare the structures and frequencies of the several modes, measured by Mirnov coils, HIBP, and radiation detectors, with the ones predicted by the calculation. Despite the inaccuracies related to the determination of the iota profile or the fast ion pressure profile, FAR3D predictions show reasonable agreement with the experimental results. Further validation studies have been already carried out in LHD [8, 9] using also NBI driven perturbations. The work done in TJ-II [4] contributes to the validation of FAR3D, which, due to the characteristics of the MHD model implemented in the code, specially oriented towards computational efficiency, makes it an appropriate candidate for stellarator design optimization.

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