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Tearing mode study with the MARS code: from an analytical approach to a comparison with experiments in FTU tokamak

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A tearing mode is an instability that arises in magnetically confined plasma as a consequence of the plasma finite resistivity [1]. It develops on the rational surfaces of the safety factor and it is driven by the radial gradient of the toroidal current density. This instability is an important issue because it leads to magnetic island creation, that deteriorates the plasma confinement, and eventually to plasma disruption.

The study has been carried out with the MARS code [2]. It's a global, resistive, spectral code for full MHD linear stability analyses, compliant with the WPCD CPOs environment and, recently, ported to the IMAS environment as well. The code uses a two dimensional, axisymmetric general toroidal geometry in flux coordinates with relevant quantities supplied by a high-resolution equilibrium code (e.g. CHEASE [3]).

The study of low-order tearing modes has been initially carried out for a current step profile in the zero pressure, large aspect ratio approximation, where an analytical expression for the stability condition can be derived.

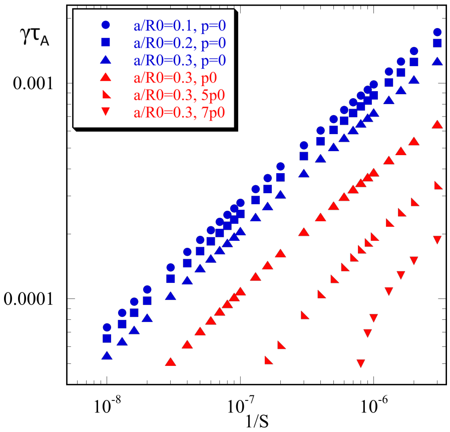

Figure 1. Normalized growth rate of a low order tearing mode (m,n=2,1) versus 1/S is depicted for different inverse aspect ratio a/R_0)values (blue symbols). The effect of finite pressure for a/R_0=0.3 is showed as well (red symbols).

The previous approximations have been successively relaxed to approach the experiment. To this purpose, a parabolic current density profile has been considered as well; firstly, the stabilizing effect of a perfectly conducting wall has been introduced comparing the Δ' parameter, evaluated from the mode growth rate [1], with known results [4]. Next, the growth rate has been systematically evaluated versus the inverse of the Lundquist number S, varying the aspect ratio and introducing the effect of finite pressure (see Figure 1).

As a conclusion, the tearing mode stability analysis has been validated using FTU experimental data. To this aim, the temporal evolution of FTU pulses has been reconstructed with the transport code JETTO and written in CPOs format, suitable to be read by the CHEASE code. A certain number of pulses, in the high-density regime, have been considered to cover a wide range of toroidal plasma current I_p (0.5-0.9 MA) and toroidal magnetic fields B_T (5-8 T). Thus, the evolution of the growth rate versus 1/S has been reproduced, highlighting the stabilizing effect of field line curvature for low values of resistivity (Glasser-Greene-Johnson), as obtained from the previous theoretical analyses (see Figure 2).

Finally, the onset of the tearing mode, established by the MARS code simulations, has been compared with the experimental one and a good agreement can be claimed. It's worth noting that the results obtained have been stated with convergences tests on the mesh size and the number of spectral components.

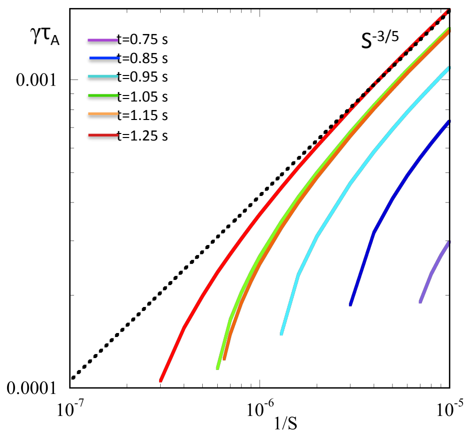

Figure 2. Normalized growth rate of a low order tearing mode (m,n=2,1) versus 1/S obtained with MARS code for different times (equilibria) during the density ramp-up of the FTU pulse #34769 for B_T=8 T and I_p=0.9MA.

References

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