Nonlinear dynamics of the tearing mode for any current gradient

N. Arcis[1], D.F. Escande[2] and M. Ottaviani[1]

[1] *Association Euratom-CEA, CEA/DSM/DRFC, Cadarache*
13108 St-Paul-lez-Durance, France
[2] *UMR 6633 CNRS-Université de Provence, case 321*
Centre de Saint-Jérome, F-13397 Marseille cedex 20

Within the traditional framework of reduced MHD, a new systematic perturbative approach is used to derive the equation ruling the nonlinear growth and saturation of the tearing mode for any current gradient. The perturbation parameter is the magnetic island width w. The standard method of matched asymptotic expansions allows the treatment of both the outer (ideal) and inner (resistive) domains and eventually provides the following evolution equation for the island width:

$$\eta_0^{-1}\partial_t w \sim 1.22\Delta' + \frac{1}{2}\left(\frac{J'_{eq}(0)}{J_{eq}(0)}\right)^2 w \ln\frac{w}{w_0} + \frac{J''_{eq}(0)}{2J_{eq}(0)}w \tag{1}$$

where we have introduced the nonlinear scale length $w_0 = \exp(4.8 - J_{eq}(0)\Sigma'/2J'_{eq}(0))$. Δ', the usual tearing stability index, and Σ' are respectively related to the difference and the (convergent) sum of the logarithmic derivatives of the outer flux function at the resonant surface. The second term on the right hand side of eq. (1) depends explicitly on w_0, not present in previous work [2], which is essential to preserve invariance with respect to a change of length unit. The first term was derived in [1] and the last one in [3, 4].

The technique is applicable to the simple case of an external forcing. The solution provides evolution equations for both the phase shift and the island width that have three different fixed points: one in phase with the external perturbation (stable) and two in phase quadrature (unstable). The former exhibits three different regimes as far as saturation is concerned. In these respects, our work complements that of [5].

References

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