First MHD stability analysis of the SMall Aspect Ratio Tokamak (SMART)

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The SMall Aspect Ratio Tokamak (SMART), a new spherical tokamak (ST) under construction in the University of Seville, will explore the viability of negative triangularity (NT) plasmas in STs for a future fusion power plant [1-4]. SMART has been designed to operate at $B_t \leq 1$ T, Ip ≤ 1 MA, major radius $R_{mag} = 0.45$ m, triangularities $-0.6 \leq \delta \leq 0.6$, aspect ratios $1.4 \leq A \leq 3.0$ and elongation $\kappa < 3$.

To estimate the operational windows of SMART, and with the aim of guiding the diagnostic and power supply designs, linear and nonlinear MHD stability analysis has been conducted for SMART tokamak with MARS-F [5] and MEGA [6] codes, respectively, to identify all the possible MHD instabilities that could degrade SMART performance. The target case is an ohmic baseline scenario with $B_t = 0.4$ T and $I_p = 0.2$ MA. At the plasma core, n = 1 internal kink and n = 2, …, 10 infernal modes are found to be stable in advanced scenarios with moderate triangularity ($\delta = 0.3$) up to $\beta_N \approx 2$ in MARS-F simulations. These modes are more unstable in NT plasmas compared to positive triangularity (PT) plasmas. MARS-F simulations including toroidal flows have been performed and reveal a significant stabilizing effect on infernal modes, which is stronger in NT plasmas. Nonlinear MHD MEGA simulations predict that these core MHD instabilities may lead to Internal Reconnection Events (IRE) and, thus, to a significant reduction of the core plasma pressure.

The linear MHD stability boundary of peeling-ballooning (PB) modes at the plasma edge of SMART has been obtained for PT and NT plasmas and for two different aspect ratios, A = 1.98 (the expected aspect ratio of SMART) and A = 3.00 (the typical aspect ratio of conventional tokamaks), as seen in Fig. 1. The stability boundary of PB modes is reduced when we increase the aspect ratio from 1.98 to 3 in both PT and NT plasmas; as expected, ST plasmas have better stability properties compared to conventional tokamak plasmas. In NT plasmas, the stability boundary of these modes is reduced, which indicates that NT plasmas could be a path to avoid the steep pressure gradients of H-mode while keeping a substantial plasma β in SMART.

References

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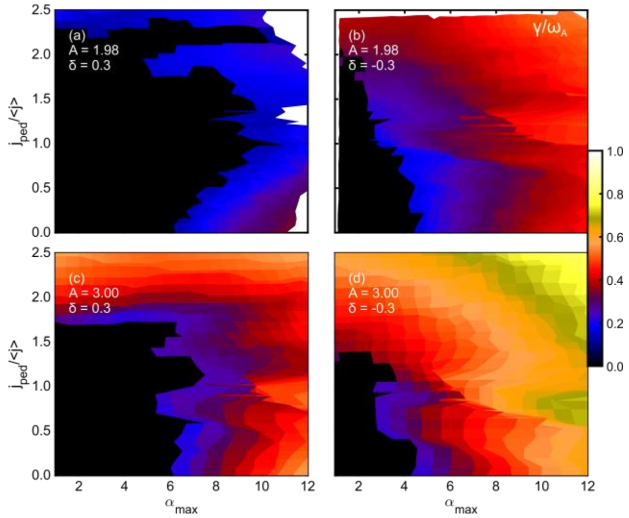

Figure 1: MHD stability diagram for PB modes for aspect ratio A = 1.98 (top row) and A = 3.00 (bottom row), with $\delta = 0.3$ (a), (c) and $\delta = -0.3$ (b), (d). Colour indicates linear growth rate of the most unstable mode at each grid point of the (α_{max}, $j_{ped}/\langle j\rangle$) mesh.