Ideal MHD spectrum calculations for the ARIES-CS configuration

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Abstract

Ideal MHD stability calculations for the ARIES compact stellarator reactor design [Najmabadi, F. *et al* 2008 *Fusion Sci. Tech.* **54** 655] show a spectrum of instabilities. The ARIES design studied is a three period stellarator with engineering coil constraints optimized for magnetic well and alpha particle confinement. The reference design has high $\beta \sim 5\%$. The ideal stability of the reference and the sensitivity with respect to variations in β and rotational transform, ι, were studied. At $\beta = 4\%$, with a conformal wall at twice the minor plasma radius, the equilibrium is slightly unstable to a periodicity-preserving, predominantly $m/n = 9/6$ mode peaked at the edge, and a periodicity-breaking global $m/n = 3/2$ mode. At $\beta \sim 5\%$, these modes, as well as an additional edge-localized $m/n = 3/2$ mode, are destabilized but the growth rates are still moderate. At higher β, above the design value, several modes become unstable. Stabilization by a close fitting conducting wall is ineffective at $\beta = 5\%$ and below but becomes more effective at stabilizing external modes for higher β. The equilibrium at $\beta \sim 6\%$ can be stabilized by a conformal wall at 1.1 times the minor plasma radius, although very weakly unstable internal modes remain at $\beta > 6\%$ with a wall on the plasma boundary. The sensitivity to the presence of the $\iota = 2/3$ surface at the edge of the plasma was also investigated. Generally, either the $m/n = 3/2$ mode is further destabilized or other modes are introduced. Although the reference design with $\beta \sim 5\%$ is above the strict ideal β limit, common experience in tokamaks indicates that weakly unstable internal modes result in relatively benign MHD activity, and edge-localized modes result in ELM-like events. This is consistent with observations in large stellarator experiments that indicate some level of instability is tolerated in stellarators. Alternatively, strict stability can be established by a 5% to 10% increase in major radius, which would lower β to $\sim 4\%$ with only a small penalty in fusion performance.

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