Ideal MHD Spectrum of the ARIES Compact Stellarator Configuration*

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Ideal MHD stability calculations for variations of a compact stellarator equilibrium show a complex spectrum of ideal instabilities. The ARIES compact stellarator reactor design [1] is a three period stellarator with a major radius of 7.75 m, B0 = 5.7 T, and an aspect ratio of 4.5, optimized with engineering coil constraints for magnetic well and alpha particle confinement. A reference equilibrium is computed from the VMEC code [2] and variations with β and rotational transform, ι, were studied to determine the sensitivity of the stability using the TERPSICHORE code [3]. At β = 4.06%, the equilibrium is slightly unstable with a conformal wall at 2.05 times the minor plasma radius to a "symmetry-preserving" (coupled toroidal mode numbers with n = 3k, k = $\pm$1, $\pm$2, …), predominantly m/n = 9/6 mode peaked at the edge, and a symmetry breaking (n $\neq$ 3k) global 3/2 mode. The growth rates are small indicating proximity to the β limit. At higher β, several modes become unstable and for β = 8.2% there are three external and two internal symmetry breaking modes, and one unstable symmetry-preserving mode. A scan over conformal wall position showed that the symmetry-preserving mode and the first three symmetry-breaking modes are stabilized by a closer wall. The remaining symmetry-breaking 2/1 and 4/2 modes are still unstable with a wall on the plasma but have very low growth rates. The sensitivity to the presence of the ι = 2/3 surface at the edge of the plasma in the reference equilibrium was also investigated. With the 2/3 surface removed at constant β, the equilibrium is marginally unstable to an m/n = 13/5 mode peaked in the core. On increasing ι so that the ι = 2/3 surface moves deeper into the plasma, the 3/2 mode is destabilized. This mode requires a conformal wall within 1.1 times the average plasma minor radius for stability. In summary, while the reference design with β = 6.5% is above the calculated limit, given the resilience of stellarators to weakly unstable modes this seems reasonable; LHD and W7-AS results indicate that this level of internal instability is tolerated in stellarators. Alternatively, an increase in major radius to 8.25 m would lower β to ~4% with only a small penalty.

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