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An analytic scaling relation for the maximum tokamak elongation against n=0 MHD resistive wall modes

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In this study, the maximum achievable elongation in a tokamak against the n=0 MHD resistive wall mode is investigated theoretically and compared with experimental observations. A highly elongated plasma is desirable to increase plasma pressure and confinement for high fusion power output. However, there is a limit on the maximum achievable elongation which is set by vertical instabilities driven by the n=0 MHD mode. This limit can be increased by optimizing several parameters characterizing the plasma and the wall. The purpose of our study is to explore how and to which extent this can be done. Specifically, we extend many earlier calculations of the n=0 mode to determine maximum elongation as a function of dimensionless parameters describing (1) the plasma profile (beta_p and l_i), (2) the plasma shape (eps and delta), (3) the wall radius (b/a) and (4) most importantly the feedback system capability parameter gamma*tau. We make use of a new formulation of n=0 MHD theory developed in our recent study [Freidberg et. al. 2015; Lee et. al. 2015] that reduces the 2-D stability problem into a 1-D problem. This method includes all the physics of ideal MHD axisymmetric instability but it reduces the computation time significantly so that many parameters can be explored during the optimization process. We have explored a wide range of parameter space, and compared our results with data from tokamak experiments. Perhaps the most useful final result is a simple analytic fit to the simulations which gives the maximum elongation and corresponding optimized triangularity as functions kappa(eps,beta_p,l_i,b/a,gamma*tau) and delta(eps,beta_p,l_i,b/a,gamma*tau). These theoretically obtained scaling relations should be useful for determining optimum plasma shape in current experiments and future tokamak designs.

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