



Contribution ID: 338

Type: Poster

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

Tuesday, 18 October 2016 08:30 (4 hours)

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 (β_p and I_i), (2) the plasma shape (ϵ and δ), (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 $\kappa(\epsilon, \beta_p, I_i, b/a, \gamma\tau)$ and $\delta(\epsilon, \beta_p, I_i, b/a, \gamma\tau)$. These theoretically obtained scaling relations should be useful for determining optimum plasma shape in current experiments and future tokamak designs.*

Paper Number

TH/P1-22

Country or International Organization

USA

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Session Classification: Poster 1

Track Classification: THS - Magnetic Confinement Theory and Modelling: Stability