Predicting and Optimizing Pedestal Structure

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The pressure and temperature at the top of the edge transport barrier ("pedestal height"), play a strong role in fusion performance, with fusion power density in power plant scale plasmas scaling roughly with the square of the pedestal pressure. The EPED model [1] was developed to predict the structure of the pedestal based on two calculated constraints (1) onset of stiff transport due to nearly-local kinetic ballooning modes (KBM), and (2) global constraint on the pedestal height due to peeling-ballooning (P-B) modes. The KBM constraint in EPED is typically defined in terms of a critical gradient in poloidal beta with respect to normalized poloidal flux, fit to a function which quantitatively captures the behavior of the high-n modes (particularly increase in critical gradient with decreasing magnetic shear), and approximately captures the onset of finite-n modes at low shear. The behavior of the KBM constraint as a function of aspect ratio is quite complex – typically it increases going from high to moderate aspect ratio, but then decreases and becomes less dependent on shear at low aspect ratio. It has also been noted that kinetic effects can play a stronger role in KBM onset at lower aspect ratio [2]. In strongly shaped plasmas, the shape-induced decoupling of peeling and ballooning modes improves peeling-ballooning stability, and can in some cases open access to the Super H-Mode regime above a critical density [3-5]. Experiments exploring access to Super H-Mode have led to high performance, including record (~80 kPa) pedestal pressure on C-Mod, and record DD fusion gain on DIII-D [4,5], and have motivated a modification of DIII-D which is expected to further enable high, Super H pedestals. Here we explore the parametric dependence of the coupled KBM and P-B constraints on aspect ratio, including predicted Super H-Mode access. An analytic formula is derived to approximately capture the behavior of the KBM constraint, and optimal aspect ratio, density, and safety factor ranges are identified for achieving very high pedestals.

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