Peeling-ballooning modes in low aspect ratio - towards a predictive edge pedestal model for spherical tokamaks

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Edge-localized modes (ELMs) are a major concern for tokamak devices and their control is crucial for the operation of future reactor-scale machines. ELMs can be triggered when strong gradients are present in the edge transport barrier (edge pedestal). The width and height of the pedestal is often constrained by the occurrence of ideal-MHD peeling-ballooning modes [1] as well as kinetic ballooning modes (KBMs) in the pedestal region; this model has been successfully applied by the EPED model [2] to predict the pedestal height and width in conventional aspect ratio tokamaks. The predictions of the EPED model however often do not accurately describe observations in machines with low aspect ratio (e.g. spherical tokamaks). For ELMing discharges in NSTX the EPED model predicts stability. The reasons for this discrepancy might be associated with the limitation to ideal-MHD computations or the breakdown of the assumption that local ballooning theory well approximates the stability limit of kinetic ballooning modes in the edge of low aspect ratio plasmas.

With the goal of obtaining a model to predict ELMs in spherical tokamaks and to find the limiting values for pedestal width and height, we model peeling-ballooning modes including non-ideal effects. The extended-MHD code M3D-C1 [3,4] is applied to determine the stability thresholds of peeling-ballooning modes in NSTX discharges. We mainly focus on the influence of plasma resistivity and rotation on edge stability, but also consider two-fluid effects. By varying pedestal parameters such as the pressure gradient and current density for given (ELMing) discharges, we are able to locate these discharges in parameter space relative to the stability boundary. In this context, we also identify the physics mechanisms that are important to describe these macroscopic edge modes in spherical tokamaks.

We find robust resistive peeling-ballooning modes well before the ideal stability threshold is met. These modes thus extend the region of ideal peeling-ballooning instability in the investigated ELMing NSTX discharges. It is found that the actual NSTX plasmas are localized close to, or slightly within, the unstable side of the stability boundary calculated with our model. For large aspect ratio discharges the model is benchmarked with the ELITE code, which is employed in the frame of the EPED model. This study of macroscopic instabilities constitutes a first step towards a model to predict pedestal width and height in H-mode discharges in spherical tokamaks.

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