Importance of non-ideal effects for peeling-ballooning stability thresholds in spherical tokamaks*

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We show that non-ideal physics, particularly resistivity, can significantly alter peeling-ballooning (PB) stability thresholds in spherical torus (ST) configurations, such as NSTX and MAST. Edge-localized modes (ELMs) are typically associated with macroscopic PB modes in the edge pedestal due to strong pressure and current density gradients. PB stability thresholds calculated using ideal-MHD agree well with experiments in conventional aspect ratio devices. A long-standing problem has been the reliable modeling of such stability boundaries in STs, where ideal-MHD models often predict stability for ELMing discharges. A more accurate model is needed not only to understand pedestal physics, but also to obtain a predictive pedestal structure model for STs. Employing the state of the art extended-MHD code M3D-C1, we investigate macroscopic edge-stability in ELMing and ELM-free discharges in NSTX and MAST. In ELMing cases we find robust resistive peeling-ballooning modes well before the ideal stability threshold is met. While resistivity has a crucial impact on stability, other non-ideal effects such as finite Larmor radius effects affect the stability limits in a weaker way. With these extended-MHD models the domain of PB instability consistently expands past the experimental point in ELMing discharges. In contrast, it is found that in DIII-D ideal and resistive thresholds are similar, suggesting that resistive effects are important for STs but not for conventional aspect ratio tokamaks. We also consider ELM-free discharges in NSTX, where resistivity appears to be less destabilizing than in the ELMing H-mode cases. In this context two-fluid effects can be important. The results present a valuable basis for the development of a predictive model for ELMs in low-aspect ratio tokamaks. This is an important step towards a compact fusion power plant.

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