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Enhanced understanding of non-axisymmetric intrinsic and controlled field impacts in tokamaks

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An extensive study of intrinsic and controlled non-axisymmetric field impacts in KSTAR has enhanced the understanding about non-axisymmetric field physics and its implications, as well as demonstrating the importance of optimal 3-D configurations in resonant magnetic perturbation (RMP)-driven control on edge localized modes (ELMs) in tokamaks. The $n = 1$ intrinsic non-axisymmetric field was measured to remain as low as $\langle \delta B/B_0 \rangle_{m/n=2/1} \sim 4 \times 10^{-5}$ at high-beta plasmas ($\beta_N \sim 2$), which corresponds to approximately 20% below the targeted ITER tolerance level. A systematic survey of $n = 1$ controlled resonant field has revealed that KSTAR has a lower power threshold for L-H transition (at least 10 %) than DIII-D (configured with $n = 3$ RMP) with similar plasma densities of $n_e = (2 - 2.6) \times 10^{19} m^{-3}$, possibly benefiting from a low level of intrinsic error field and toroidal field ripple. As for the RMP ELM control, a high-quality $n = 1$ RMP ELM suppression (duration of $\sim 40\tau_E$) was achieved using an operationally 'reproducible'approach. Throughout this investigation, we diagnosed edge activities using 3-D ECE imaging diagnostics (ECEI) on both high-field-side (HFS) and low-field-side (LFS) simultaneously for the first time. According to ECEIs, the RMP ELM suppression was full of lively edge activities, which appears quite challenging to a prevailing theory that 'peeling-ballooning' stability boundary is crossed from unstable to stable regimes due to RMP. While exploring the most favorable 3-D configuration ($n = 1$, +90 deg. phasing), we discovered that midplane IVCC coils played a major role in mitigating the ELMs, while two off-midplane IVCCs ($n = 1$ odd-parity) appeared insignificant on ELMy behavior change. In contrast, when the off-midplane IVCCs are configured with n=1 even-parity, strong plasma response was observed, even triggering mode-locking at high RMP currents. Considering that the ITER RMP coils are composed of 3-rows, just like in KSTAR, further 3-D physics study in KSTAR is expected to help us minimize the uncertainties of the ITER RMP coils, as well as establish an optimal 3-D configuration for ITER and beyond.

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