Critically resolved non-axisymmetric field physics in KSTAR

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The presence of non-axisymmetric magnetic fields ($\delta\mathbf{B}$) in tokamaks poses both challenges and opportunities on magnetically confined plasmas. Since such non-axisymmetry of magnetic fields greatly affects plasma stability, transport and turbulence, we are often attempting to minimize any detrimental effects, while maximizing potential benefits. In that view, KSTAR, whose intrinsic error field and toroidal field ripple are an order of magnitude lower than in other devices respectively [1, 2], appears ideal to address a variety of critical physics premises that could be highly subject to the characteristics and levels of non-axisymmetric fields. In particular, since the 3-row in-vessel control coils (IVCC) in KSTAR is uniquely versatile to rigorously control dominantly resonant and exclusively non-resonant components, we may be in a good position to resolve the associated critical transitions that had not been well understood. Indeed, recent KSTAR experiments have demonstrated several meritorious benefits of low-level of intrinsic non-axisymmetric field on both stability and transport, as well as on turbulence. First of all, we have established robust full ELM-crash-suppression using low-n RMPs, while discovering the importance of shape effects (e.g. triangularity of δ) and electron perpendicular flow of $\omega_{e,\perp} \sim 0$ on pedestal top [3, 4], along with the safety factor of q_{95}, and collisionality of ν^*. Taking advantage of highly reproducible robust low-n RMP-driven, ELM-crash-suppression, a set of intentionally misaligned RMP configurations, similarly configured to the planned ITER RMPs, has been explored to address the 3-D field impact on divertor heat flux profiles [5]. As a result, we have confirmed a broadened divertor heat flux profiles with 3-row RMPs for the first time, while no similar broadening is expected with 2-row RMPs [6]. Unlike resonant components that have affected the power threshold of L-H transition (P_{th}), dominantly non-resonant components were not influencing P_{th} at all [7], which suggests there is no need of non-resonant error field correction in ITER or future reactors. Also, in the vicinity of magnetic islands, the ECE imaging diagnostic has identified the poloidally asymmetric turbulence distribution localized near the X-point [8]. Recent XGC1 and gKPSP simulation results are qualitatively consistent with the experimental observations, predicting a larger electron heat transport near X-point than at O-point [9]. This paper will elaborate such 3-D physics activities in KSTAR, emphasizing the new findings in terms of stability, transport and turbulence.

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