Study of pedestal parameters in \( n = 1 \) RMP ELM-crash control experiments on KSTAR

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For reliable edge-localized mode (ELM)-crash control by resonant magnetic perturbation (RMP) application, it is critical to understand access conditions to ELM-crash suppression. Based on the high reproducibility of the ELM-crash suppression in KSTAR, reliable edge profile diagnostics, such as Thomson scattering\(^1\) (for \( n_e \) and \( T_e \)) and charge exchange spectroscopy\(^2\) (for \( T_i \) and \( V_{\text{tor}} \) of carbon impurity), makes it possible to analyze pedestal conditions for ELM-crash suppression rigorously.

Figure 1. (a) \( \nu_{e,\text{ped}}^* \) vs. \( n_e \) (b) \( I_{\text{RMP}} \) vs. \( \nu_{e,\text{ped}}^* \) (c) \( V_{\text{tor}} \) vs. \( I_{\text{RMP}} \) space. Square: ELMy phase before RMP, circle: ELM-crash mitigation, pentagram: suppression phase.

A discharge database for the pedestal parameter study consists of 28 discharges having the same RMP coil configuration (\( n = 1 \), 90-degree phasing\(^3\)). Discharge conditions in the database are as follows: \( B_T(R_0) = 1.8 \) T constant, \( q_{95} \sim 4.9-5.5 \), \( I_p \sim 500-560 \) kA, \( \delta \sim 0.58 \pm 0.08 \), and \( \kappa \sim 1.74 \pm 0.03 \). In this study, we focus on the normalized electron collisionality (\( \nu_e^* \)) and toroidal rotation velocity (\( V_{\text{tor}} \)) on the pedestal top as key parameters for ELM-crash suppression onset. The pedestal profiles are quantified by the modified hyperbolic tangent curve to obtain \( \nu_{e,\text{ped}}^* \) and \( V_{\text{tor,\text{ped}}} \).

The ELM-crash suppression data points are distributed in range of \( 0.2 < \nu_{e,\text{ped}}^* < 1.1 \) (with \( Z_{\text{eff}} = 2 \) assumption) and \( V_{\text{tor,\text{ped}}} > 40 \) km/s, experimentally confirmed parameter space of suppression so far in KSTAR. Some notable points are inferred from the distribution of suppression data points. I) Most suppression points are below \( n_{e,\text{ped}}/n_{GW} \sim 0.2 \), where \( n_{GW} \) is the Greenwald density limit (figure 1(a)). II) The range of \( \nu_{e,\text{ped}}^* \), obtained the suppression, gets wide as \( I_{\text{RMP}} \) increases (figure 1(b)). III) \( I_{\text{RMP}} \) threshold for ELM-crash suppression is lower in high \( V_{\text{tor,\text{ped}}} \) compared to low \( V_{\text{tor,\text{ped}}} \) plasmas (figure 1(c)). However, for the verification of the above remarks, high-density experiments and rigorous investigation for the relationship between \( I_{\text{RMP}} \) and \( V_{\text{tor,\text{ped}}} \) are necessary.

The pedestal parameter database described here provides a new feasibility database that contributes to the study of ELM-crash control in ITER. We plan to conduct additional experiments in ITER-relevant conditions, unexplored parameter space in the current datasets, which make it possible to address the boundary or limit of suppression window.

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References