SIMULATIONS OF RMP CONFIGURATIONS FOR TUNGSTEN IMPURITY CONTROL IN EAST TOKAMAK

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1. ABSTRACT

The accumulation of high-Z tungsten (W) impurities in EAST poses significant challenges for plasma performance and steady-state operation [1]. This study systematically investigates the optimization of resonant magnetic perturbation (RMP) parameters, including coil current amplitude (I), toroidal mode number (n), and upper/lower coil phase difference ($\Delta\phi$), to mitigate W impurity sputtering and accumulation, leveraging the combined capabilities of EMC3-EIRENE [2] for impurity transport simulations and MARS-F [3] for plasma response field analysis. Key conclusions are structured as follows:

1. Divergent impurity suppression phases between vacuum and plasma response fields. While vacuum RMP fields achieve optimal W suppression at a coil phase difference of $\Delta\phi = 0^\circ$, plasma response fields shift the effective suppression phase due to screening/amplification effects (Fig 1). MARS-F computations demonstrate that plasma shielding modifies the resonant magnetic topology. This mismatch explains operational challenges in impurity control when relying solely on vacuum field predictions.

2. Complete W suppression windows emerge only in plasma response fields. Unlike vacuum fields, plasma response fields generated by n = 1 RMPs exhibit complete suppression zones at $\Delta\phi$ = 0-135˚ (Fig 1). This phenomenon correlates with resonant amplification edge magnetic perturbations, which amplify plasma transport at the boundary. The stronger stochasticity at the plasma edge results in higher density and lower temperature near the target plate, resulting in an incident energy below the sputtering threshold.

3. Overlap of RMP operational windows for ELM and impurity suppression. The phase difference range that suppresses edge-localized modes (ELMs) in EAST aligns with the window for W impurity reduction (Fig 1). This synergy enables the use of established ELM suppression criteria (e.g., total field including plasma response at the last rational surface) [4] as proxies for predicting impurity control efficacy, streamlining RMP parameter optimization.

4. Non-monotonic dependence of W suppression on RMP current. W density initially improves with increasing coil current but declines beyond ~ I = 0.5kA. However, excessive current will increase the risk of H-mode falling to L-mode, so the balance between suppression efficiency and confinement preservation is under investigation.

5. Toroidal mode n = 2 maximizes W suppression in EAST. n = 2 RMPs yield a greater reduction in core W density compared to n = 1 and 3. Plasma response analysis reveals that n = 2 enhances resonance at the plasma edge, amplifying edge stochasticity while minimizing core perturbations, which is a configuration uniquely suited to the magnetic geometry on EAST.

These findings highlight the critical influence of plasma response on RMP effectiveness and provide a quantitative basis for parameter selection. The study advances the understanding of RMP-driven impurity dynamics and offers actionable strategies for optimizing impurity control in EAST, with implications for the design of RMP systems in future fusion reactors such as ITER and CFETR.

2. FIGURES

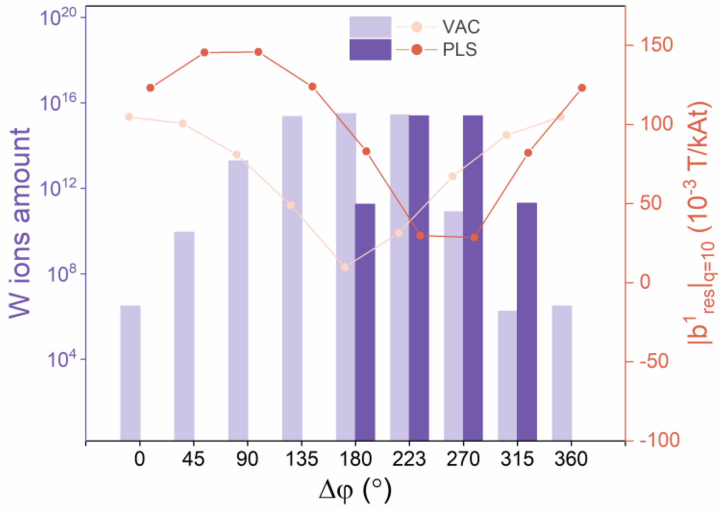

Fig 1. Comparison of integral W ions amount and $|b^1_{res}|$ *at the last rational surface (q=10) for vacuum and plasma response field with varying coil phase difference* $\Delta\phi$ *for toroidal mode number n = 1 and coil amplitude I = 8.8kAt.*

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