3D nonlinear modeling of Resonant Magnetic Perturbation on EAST

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The Edge-Localized Mode (ELM) control in the H-mode operation is a key issue in the future tokamak fusion reactor research like ITER, and one of the most effective proposals of type-I ELM control is the Resonant Magnetic Perturbation (RMP). Recently, a nonlinear transition from mitigation to suppression of the ELM by scanning of the phase difference between upper and lower RMP coils $\delta\phi_{UL}$ with n = 1 RMP on EAST is observed [1]. In the EAST shot #55272, the ELM frequency behaves significant differently phase at different $\delta\phi_{UL}$. For ELM suppression or strong mitigation phase, the RMP field could penetrate deeply. While the weak mitigation case is in a discrepancy with vacuum modelling result, or the RMP field is shielded by plasma response. To investigate the RMP mechanism in different ELM phases, the plasma parameter profile in the pedestal region and the edge magnetic topological change are the key points. In this work, the 3D nonlinear equilibrium and its associated magnetic topology are investigated by HINT code [2] on EAST to understand the mechanism of how RMP mitigates or suppresses the ELM. In comparation with no RMP case (0.1 second before RMP switched on), the pressure profile in the plasma core region is almost identical while the pressure gradient decreases significantly in the pedestal region in the strong ELM mitigation case or suppression case. It can be inferred that the bootstrap current density will decrease with the pressure gradient degradation, resulting in ELM suppression or strong mitigation concerning peeling-ballooning mode. Here, the evidence of plasma pressure gradient degradation with RMP penetration is presented on EAST for the first time from the point of view of 3D nonlinear equilibrium. On the other hand, the RMP penetration is a nonlinear process essentially. The nonlinear interaction between the RMP and plasma rotation is also the key point for the final 3D equilibrium. The RMP field could be shielded by plasma response, resulting in a weak ELM mitigation case. Based on the HINT model, the plasma response effect is simulated by introducing plasma flow in the evolution of magnetic field calculation. Since HINT employs a resistive model, the initial surface plasma flow cutting the RMP field can generate the electric field when RMP superposed, leading to the screening current by Ohm's law to shield the RMP field. In the meanwhile, the flow velocity is also changed by the momentum equation to keep its self-consistency. Or the nonlinear interaction between the RMP field and plasma rotation is treated as a nonlinear process of equilibrium with plasma flow in the modeling. Recently, the parallel flow concerning the initial 2D magnetic field line by EFIT is included in our modeling, and the magnetic island in the corresponding rational surface could be healed by the flow effects in the modeling of EAST shot #55272 weak ELM mitigation phase, which could give the interpretation of the RMP mechanism in RMP shielding case.

[1] Y. Sun *et al* 2016 *Phys. Rev. Lett.* **117** 115001

[2] Y. Suzuki 2017 Plasma Phys. Controlled Fusion **59** 054008