LINEAR AND QUASI-LINEAR TOROIDAL MODELING OF RESONANT MAGNETIC PERTURBATIONS DURING ELMS MITIGATION IN HL-3

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Controlling large edge localized modes (ELMs) is critical for tokamaks operating in H-mode, due to potentially severe consequences on material damages caused by ELM bursts in future large scale devices such as ITER [1]. Resonant magnetic perturbation (RMP) has been extensively applied to mitigate or suppress ELMs [2]. Active mitigation of ELM with the odd parity of n=1 (n is the toroidal mode number) RMP has been recently achieved for the first time on the HL-3, as shown in figure 1. HL-3 experiments extend the database of ELM control by RMP.

The linear and quasi-linear plasma responses to resonant magnetic perturbation (RMP) fields are numerically investigated during ELMs mitigation in HL-3, by utilizing the MARS-F and MARS-Q [3-5]. The linear response results show that RMP induces a strong edge peeling-tearing response which facilitates ELM mitigation. The 50-degree phase shift for the *n*=1 coil current between the upper and lower rows of the RMP coils presents the optimal coil phasing.

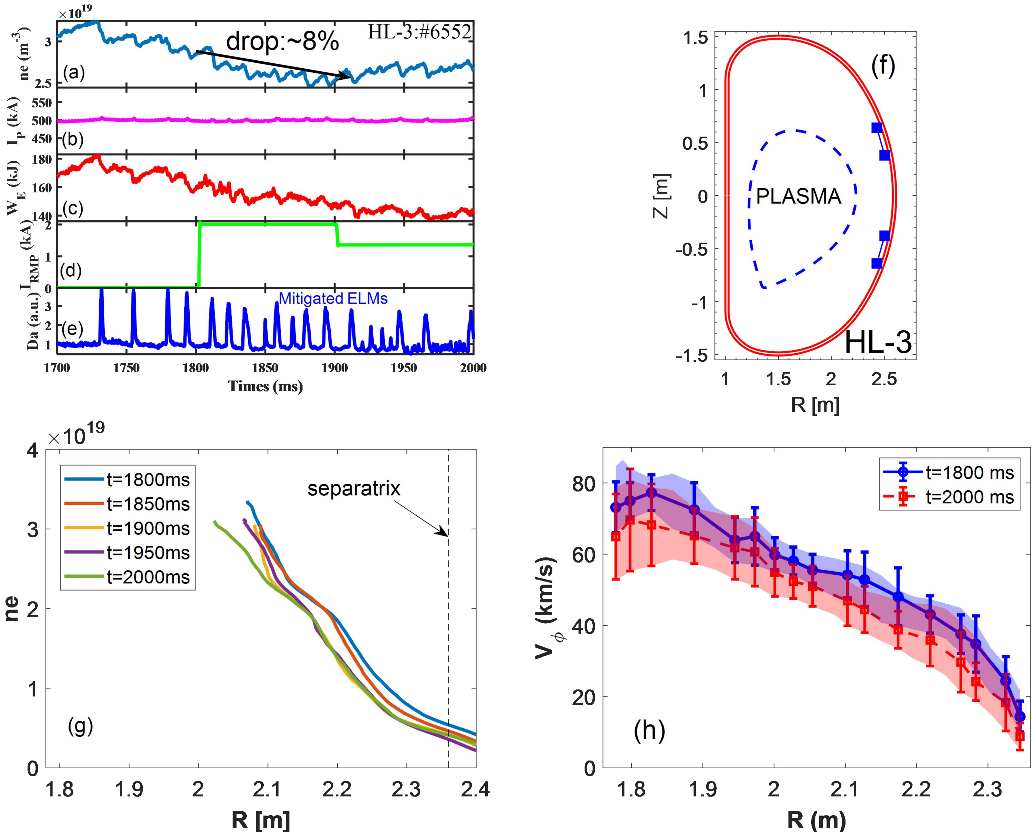

Fig.1 Time traces of the HL-3 discharge 6552 for (a) the line averaged plasma density, (b) the plasma current, (c) the stored energy, (d) the RMP coil current and (e) the Dα signal; (f) The plasma boundary shape and the locations of the RMP coils on the (R, Z)-plane; (g) and (h) are the evolution of the radial profile of electron density and the plasma toroidal rotation frequency, respectively.

The MARS-Q quasi-linear results show that: (i) without involving peeling-tearing instability near the plasma edge, the applied RMP has no side effects on the toroidal momentum confinement nor the radial particle transport in the HL-3 plasma considered; (ii) allowing weak peeling-tearing instability together with RMP produces finite flow damping and density pump-out level that is comparable to experiments; (iii) the modeled flow damping and density pump-out is not very sensitive to the assumed resistivity model (Spitzer vs uniform resistivity). It is also found that (iv) the neoclassical toroidal viscosity (NTV) due to 3D fields plays the key role in modifying the plasma momentum and particle transport in the HL-3 plasma.

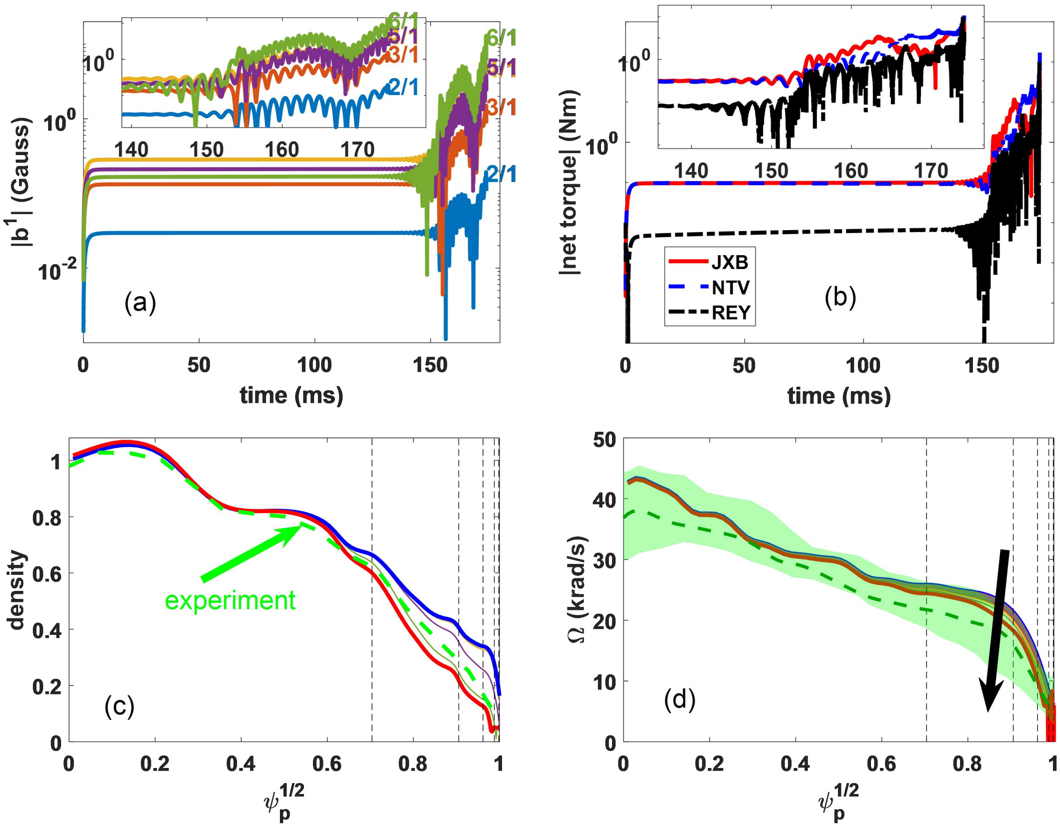

Fig.2 The MARS-Q quasi-linear initial-value simulation of the HL-3 discharge 6552 with the applied n=1 RMP field, based on an equilibrium reconstructed at 1790 ms. Shown are simulated time traces of (a) amplitude of resonant poloidal harmonics (in the straight-field-line coordinates) of the perturbed radial magnetic field at the corresponding rational surfaces, and (b) magnitude of net toroidal torques acting on the plasma including the resonant electromagnetic torque (JXB), the NTV torque and the torque associated with the Reynolds stress. Plotted in (c) and (d) are the time evolution of the radial profile of the plasma toroidal rotation frequency and density.

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REFERENCES

[1] A. Loarte et al. 2014, Nucl. Fusion 54 033007

[2] Evans T.E. et al 2004 Phys. Rev. Lett. 92 235003

[3] Zhang N. *et al* 2020 *Nucl. Fusion* **60**, 096006

[4] Liu Y.Q. *et al* 2013 *Phys. Plasmas* **20** 042503

[5] Liu Y.Q. *et al* 2000 *Phys. Plasmas* **7** 3681