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Linear and quasi-linear toroidal modeling of resonant magnetic perturbations during ELM mitigation in HL-3 tokamak

N. Zhang[1], Y.Q. Liu[2], G.Z. Hao[1], T.F. Sun[1], G.Q. Dong[1], S. Wang[1]
[1] Southwestern Institute of Physics
[2] General Atomics
e-mail (speaker): zhangn@swip.ac.cn

Resonant magnetic perturbation (RMP) coils have been installed in many present-day magnetic confinement fusion devices, for the main purpose of actively controlling the edge localized mode (ELM) in H-mode plasmas. On the other hand, the toroidal asymmetry produced by three dimensional (3D) RMP fields can cause substantial side effects on the plasma transport, such as reductions of the plasma density and/or the toroidal flow speed, which in turn impacts the plasma energy confinement and stability. Understanding physics mechanisms of the plasma density pump-out and rotation damping due to RMPs is therefore essential for the success of ELM control in future tokamak devices.[1, 2]

Active mitigation of ELMs with the n=1 (n is the toroidal mode number) RMP has been recently achieved for the first time on the HL-3 tokamak. 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 ELM mitigation in HL-3, by utilizing the MARS-F and MARS-Q codes. 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. 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. [3, 4]

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References

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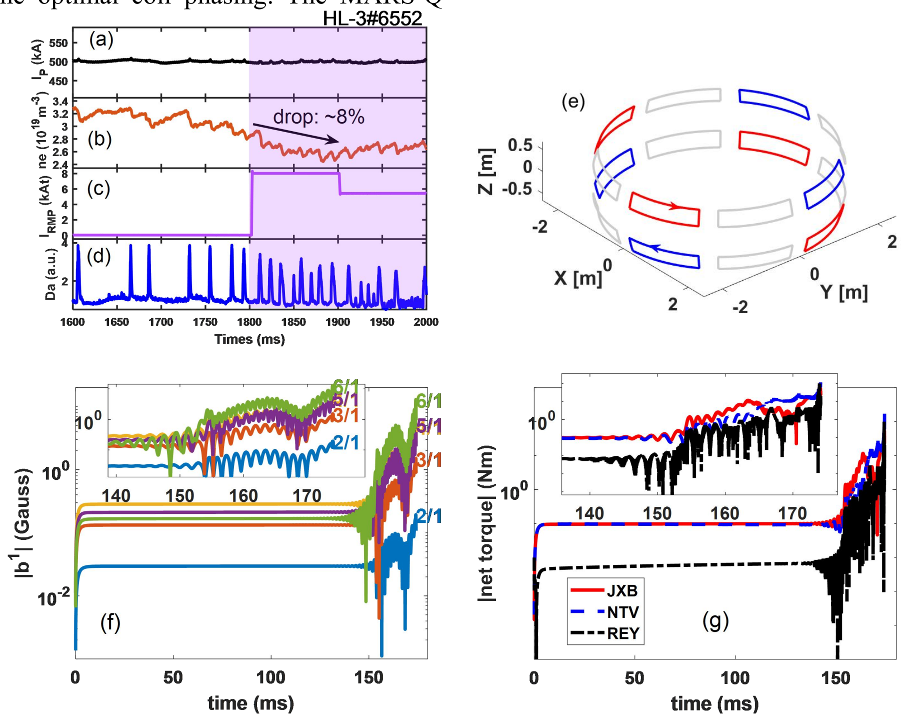

Figure 1. Time traces of the HL-3 discharge 6552: (a) the plasma current, (b) the electron density, (c) the current of RMP, (d) the Da signal, (e) the location of RMP coils, (f) and (g) are the MARS-Q computed the time evolution of b^1 and toroidal torques, respectively.