7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Linear and quasi-linear toroidal modelling of resonant magnetic perturbations in preparation for eight ITER H-mode scenarios

L. Li[1], Y. Q. Liu[2], A. Loarte[3], S. D. Pinches[3], A. Polevoi[3], M. Becoulet[4], G. T. A. Huijsmans[4], and F. C. Zhong[1]
[1] College of Science, Donghua University, China, [2] General Atomics, USA, [3] ITER Organization, France,
[4] CEA, France
e-mail (speaker): lili8068@dhu.edu.cn

Large scale (type-I) edge localized modes (ELMs) are of significant concern in future devices such as ITER [1], since large amount of particles and heat fluxes can be released onto the plasma facing components during each ELM bursts. Fortunately, the resonant magnetic perturbation (RMP) has been shown experimentally to be capable of successfully controlling type-I ELMs in many present-day tokamak devices [2-9]. Extensive theoretical and modelling efforts have helped establish that the plasma response plays an important role in understanding the ELM mitigation/suppression physics.

This work aims at a systematic numerical study of both linear and quasi-linear plasma response to RMP fields for eight H-mode scenarios designed for ITER with varying plasma current and magnetic field [10], utilizing the toroidal resistive MHD codes MARS-F [11] and MARS-Q [12].

Based on the MARS-F computed linear response, the surface displacement near the X-point of the divertor plasma is used as a criterion to optimize the RMP configuration for ELM control. The results reveal that the optimal RMP coil current phasing for controlling the type-I ELMs scales roughly linearly with the edge safety factor q_{95}. Certain deviation from this scaling also occurs (for the ITER 7.5 MA/4.5 T and 7.5 MA/5.3 T scenarios) due to variation of the vacuum RMP field spectrum at higher q_{95}-value (but not directly due to the plasma response).

Quasi-linear initial-value simulation of the plasma response has also been carried out, focusing on the *n*=3 RMP coil configuration for ITER. Here, the study aims at minimizing the side effects of RMP on the plasma momentum and particle confinement for the ITER scenarios. For several scenarios (such as the 15 MA baseline scenario), the RMP induced change of the plasma edge flow is found to be un-voidable. Similar effects due to RMP are also found on the plasma density. In general, RMP with the optimal coil phasing (for ELM control) provides the strongest particle transport. For ITER, this side effect can be large and sensitive to choice of the plasma scenario, as well as to the coil current phasing.

The plasma response based on the linear and quasi-linear models provides useful guidance to the choice of the ELM control coil configurations in ITER. It should however be realized that other physics, e.g. fully non-linear MHD, also play important roles in understanding ELM control in particular the ELM suppression.

This work is supported by National Natural Science Foundation of China (NSFC) [grant numbers 12075053] and by National Key R&D Program of China under contract No. 2022YFE03060002.

References

[1] Loarte A et al 2014 Nucl. Fusion 54 033007
[2] Evans T. et al 2004 Phys. Rev. Lett. 92 235003
[3] Liang Y. et al 2007 Phys. Rev. Lett. 98 265004
[4] Hawryluk R.J. et al 2009 Nucl. Fusion 49 065012
[5] Nardon E. et al 2009 Plasma Phys. Control. Fusion 51 124010
[6] Kirk A. et al 2010 Nucl. Fusion 50 034008
[7] Suttrop W. et al 2011 Phys. Rev. Lett. 106 225004
[8] Jeon Y.M. et al 2012 Phys. Rev. Lett. 109 035004
[9] Sun Y. et al 2016 Phys. Rev. Lett. 117 115001
[10] Li L. et al 2022 Nucl. Fusion 62 096008
[11] Liu Y. Q. et al 2000 Phys. Plasmas 7 3681
[12] Liu Y. Q. et al 2013 Phys. Plasmas 20 042503

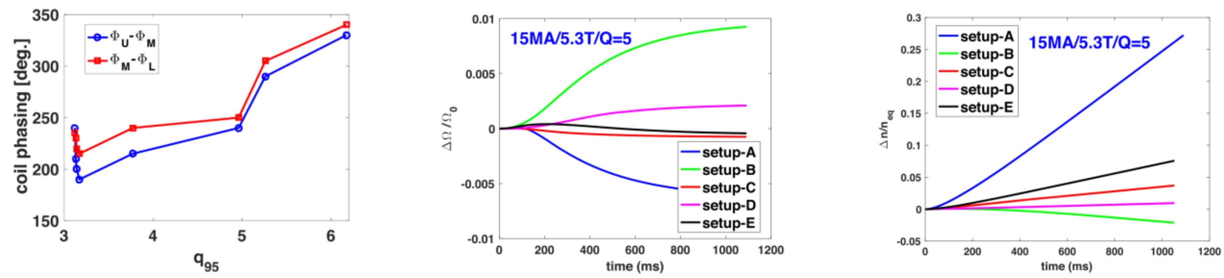

Figure 1. The optimal coil phasing for eight ITER scenarios computed by the linear plasma response (left) for the three-row (U+M+L) ELM control coil configuration. MARS-Q simulated time traces for the net change of the toroidal rotation frequency at the magnetic axis (middle) the plasma density (right) integrated over the plasma volume for the 15 MA/5.3 T/Q=5 ITER scenario at 90 kAt coil current. where, the n=3 RMP coil configuration is assumed.