1st Asia-Pacific Conference on Plasma Physics, 18-22, 09.2017, Chengdu, China

Edge magnetic topology effect on ELM control using RMP

Y. Sun[1], Y. Liang[1,2] , Y. Q. Liu[3], M. Jia[1],S. Gu[1],X. Yang[4],Q. Zang[1], L. Wang[1], N. Chu[1], H. H. Wang[1], Y. Li[1], B. Lyu[1], L. Zhang[1], C. Zhou[5], T. Zhang[1], T. Shi[1], W. Guo[1], J. Qian[1], B. Wan[1] and EAST contributors

[1]ASIPP, China, [2]FZJ, Germany, [3]CCFE, UK, [4]DUT, China, [5]USTC, China

To achieve long pulse steady state operation in a tokamak fusion reactor, it is necessary to avoid large transient local heat load on the divertor induced by Edge Localized Mode (ELM)[1]. Resonant Magnetic Perturbation (RMP) is one the most effective methods for ELM control [2] in present tokamaks and it will also be applied in ITER. The underline physics of ELM control by using RMP is not well understood, although significant efforts have been made in many different fusion devices in the last 10 years.

A significant progress has been made in ELM control using RMP on EAST in recent years. A flexible in-vessel RMP coil system has been installed in 2014 for active MHD instabilities control on the EAST tokamak. This coil system can generate a range of spectrum covering most important configurations of the operating coil systems in present tokamaks and the designed one in ITER [3,4]. The RMP spectrum for each toroidal harmonic on EAST can be changed during discharge by adjusting the phasing, $\delta\Phi_{UL}$, i.e. the phase difference between the upper and lower coils. Full suppression of ELM by using n = 1 and 2 RMPs in low rotating plasmas with dominant radio-frequency (RF) wave heating is achieved in the EAST tokamak[5]. Here n is the toroidal mode number. ELM suppression using n = 1 RMP is also extended in fully non-inductive long pulse steady state operation with pure RF heating in EAST.

Plasma responses are important for understanding of the mechanism on ELM suppression. The observations in EAST reveal both linear and nonlinear plasma response effects on ELM suppression. Linear plasma response determines the best RMP spectrum for ELM control [4,6]. A critical level of magnetic topological change taking into account nonlinear plasma response plays a key role to access the final ELM suppression[5].

The observed control effects strongly depend on the RMP spectrum used in EAST. Strongest effect on ELM frequency, density pump out and magnetic braking happens at the spectrum with maximal edge resonances modeled from linear MHD response. A well known criteria for ELM suppression measured by the required vacuum RMP strength has been proposed based on the observations on DIII-D[7]. The used figure of merit for ELM control effect was the width of island overlapping area modeled from vacuum field assumption. However, Plasma response effect can usually shield the external applied RMP and may significantly reduce the magnetic field stochasticity[8]. It is shown in this presentation that this figure of merit can still be used, but it should be evaluated from the modeling taking into account linear plasma response modeled by MARS-F [9].

Nonlinear response in kinetic profiles and magnetic perturbation during the transition between ELM mitigation and suppression has been observed. The nonlinear shift of the phase of the response magnetic perturbation suggests the change of magnetic topology during the transition[5]. Other evidences on topology change like acceleration in the very edge plasma rotation, footprint splitting[9] and pedestal profile change were also observed in EAST. Additional nonlinear change during the transition from strong mitigation to full suppression suggests that a critical level of topology change is necessary for accessing final full ELM suppression.

RMP is also applied for ELM control in fully non-inductive tokamak operation with pure RF heating. It is observed that the suppression effect is decoupled from the density pump out one in this plasmas. By choosing a spectrum with ELM suppression but no strong density pump out effect, ELM suppression without drop of plasma confinement in a fully non-inductive tokamak operation with pure RF heating is achieved in a duration of around 20 seconds, during which clear pump out effect on tungsten is also observed.

References

[1] R. J. Hawryluk *et al*, **Nucl. Fusion 49**, 065012 (2009)
[2] T. Evans *et al* , **Phys. Rev. Lett. 92**, 235003 (2004).
[3] Y. Sun *et al*, **Plasma Phys. Control. Fusion 57**, 045003 (2015)
[4] Y. Sun *et al.*, **Nucl. Fusion 57**, 036007(2017)
[5] Y. Sun *et al.*, **Phys. Rev. Lett. 117**, 115001 (2016)
[6] X. Yang *et al.*, **Plasma Phys. Control. Fusion 58**, 114006 (2016)
[7] M. E. Fenstermacher *et al*, **Phys. Plasmas 15**, 056122 (2008)
[8] M. F. Heyn *et al* , **Nucl. Fusion 46**, S159 (2006)
[9] Y. Liu *et al* , **Phys. Plasmas 17**, 122502 (2010)
[10] M. Jia *et al*, **Plasma Phys. Control. Fusion 58**, 055010 (2016)

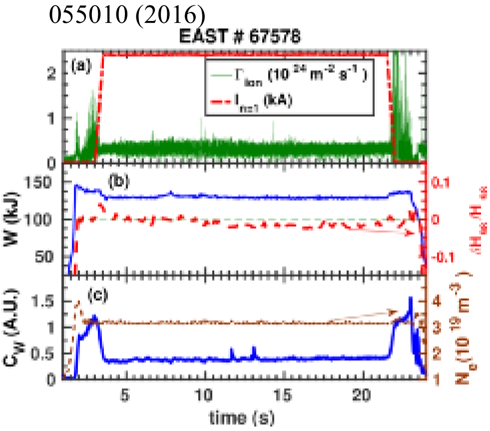

Figure 1. ELM suppression without degradation of confinement for EAST long pulse fully non-inductive shot