5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

First principles modelling of the edge and diveror physics of Edge Localized Modes suppression by Resonant Magnetic Perturbations in ITER.

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In the era of International Thermonuclear Experimental Reactor (ITER) construction fusion plasma theory and modelling provide not only deep understanding of a specific phenomenon but play a crucial role in solving urgent issues and taking modelling-based design decisions for active plasma control which is mandatory in ITER. The intensive experimental and theoretical study of the Edge Localized Modes (ELMs) and methods of their control has a great importance for ITER. The applications of small external Resonant Magnetic Perturbations (RMPs) generated by specific coils demonstrated to be efficient in ELMs suppression/mitigation in present day tokamaks [1]. RMPs are foreseen as one of the promising methods of ELMs control in ITER [2]. However, a significant progress in understanding of physics of the interaction of ELMs with RMPs still should to be done to make reliable predictions for next step machines such as ITER and DEMO. The overview of the recent first-principle non-linear Magneto Hydro Dynamics (MHD) modelling results of RMPs and ELMs suppression and mitigation physics in ITER will be presented after the validation of the present models in the existing machines. In particular, the non-linear, multi-harmonics approach, realistic tokamak geometry with the X-point and the Scrape-Off-Layer (SOL), realistic spectrum of RMP coils, toroidal rotation, the bi-fluid diamagnetic effects taken into account in JOREK code [3], represent a minimum model which permitted to reproduce ELM suppression by RMPs in AUG [4], KSTAR[5]. Here we give the predictions of ELM suppression for ITER scenarios using optimized RMP coils spectra. It was demonstrated that RMPs non-linearly generate a continuous MHD turbulent transport stabilizing ELMs in all ITER scenarios starting from a certain RMP current threshold [6]. The importance of external kink plasma response in ELM suppression was pointed out in linear MHD modelling by MARS-F code in many existing experiments [7]. With this respect the RMP coils spectra was optimized to reach maximum kink response, meaning the maximum perpendicular magnetic surface displacement near X-point in all ITER scenarios. One important consequence of RMP application is the complex 3D magnetic topology and splitting of the separatrix into a set of manifolds that while crossing the divertor plates create splitting of the heat and particle fluxes ("footprints") which potentially can represent an issue for ITER, leading to local "hot spots" and hence material erosion. The divertor footprints in different ITER scenarios will be described showing that 3D heat fluxes with RMPs mainly remains within the divertor target/baffle area and within the design limits for development of the modelling of 3D boundary with divertor and wall however with small margins. Further MHD codes would be self-consistent more accurate kinetic description of the divertor physics like neutrals, recycling, ionization, radiation etc. Note that the recent results obtained EMC3-EIRENE code [8] taking into account magnetic topology with plasma response calculated by MARS-F code showed that divertor detachment state is difficult to keep with RMPs which produces high temperature peaks far from the initial strike points. These divertor issues and possible solutions while keeping ELM suppression state will be discussed in the talk

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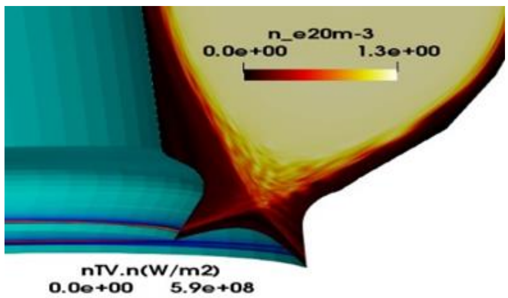

Fig.1. Density and divertor heat flux during natural 4MJ ELM crash in ITER 15MA/5.3T scenario.

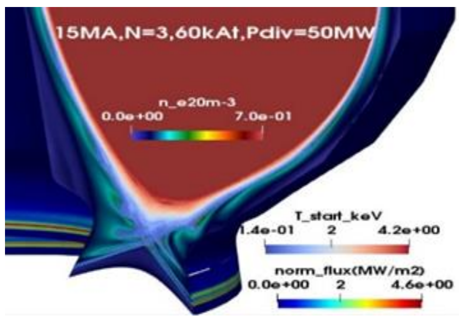

Fig.2. Density, Poincare plot and divertor heat flux in ELM suppressed stage by RMPs N=3, 60kAt in ITER.