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ITERにおけるペレット入射によるELM制御の統合シミュレーション
Integrated simulation of ELM control by Pellet Injection in ITER

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The energy loss caused by the edge localized mode (ELM) needs to be reduced for ITER operations with ELMy H-mode plasmas. The pellet injection is considered as one possible method to reduce the ELM energy loss by increasing the ELM frequency (so called ELM pacing). The ELM pacing requires the significant reduction of ELM energy loss, small impact on the plasma performance, and less particle fueling. The reduction of ELM energy loss by the pellet injection for ELM pacing has been studied by an integrated core / scrape-off-layer / divertor transport code TOPICS-IB with an MHD stability code and a pellet model taking account of the *E*x*B* drift of pellet plasma cloud [1]. It was found that the ELM energy loss can be significantly reduced by the low-field-side injection of a pellet with about 1 % of pedestal particle content and a speed fast enough to approach the pedestal top when the pedestal pressure is about 95 % of natural ELM onset [2]. In this paper, we do simulations of JT-60U plasmas with various parameters and ITER plasmas of standard operation scenario, examine the effectiveness of the above suitable conditions for ELM pacing and evaluate the pellet particle content required for ELM pacing.

Figure 1 shows the ELM energy loss ΔW_{ELM} normalized by the pedestal stored energy W_{ped} as a function of pellet position at the ELM onset $\rho_{pel,onset}$ for JT-60U and ITER simulations, where mode locations are also shown. As the same as the previous result, with the suitable conditions, a pellet can significantly reduce the ELM energy loss by penetrating deeply into the pedestal and triggering ELM localized near the pedestal top. Thus, the effectiveness of suitable conditions has been confirmed. Figure 2 shows the relation between the pellet particle content N_p (normalized by the pedestal particle content N_{ped}) required for ELM pacing and the variation of normalized pressure gradient $\Delta\alpha$ (normalized by the critical gradient α_{cr} of ideal ballooning mode (IBM)) required to destabilize IBM. The pellet particle content required for ELM pacing is larger for the pedestal plasma with higher density and farther from the IBM stability boundary near the pedestal top. For ITER, the required pellet particle content is within the range of present empirically-designed value and thus our evaluation gives the physical background to the design.

[1] N. Hayashi et al, Nucl. Fusion **51** (2011) 103030.
[2] N. Hayashi et al, accepted in Nucl. Fusion
[3] A. Loarte et al, 24th IAEA FEC, San Diego, 2012

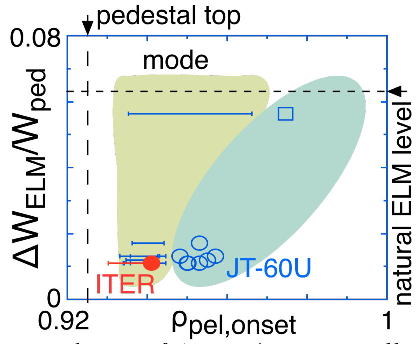

FIG.1. Dependence of $\Delta W_{ELM}/W_{ped}$ on pellet position at ELM onset for JT-60U simulations (blue open) and an ITER simulation (red closed), where horizontal solid lines denote mode locations, circle symbols do results with suitable conditions of pellet injection for ELM pacing, a square symbol does an example without suitable conditions and shaded regions denote other results in JT-60U. Vertical and horizontal dotted lines denote pedestal top position and ΔW_{ELM} of natural ELM level, respectively.

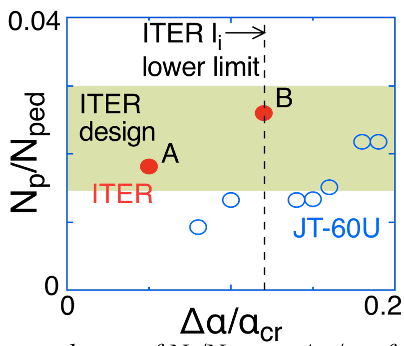

FIG.2. Dependence of N_p/N_{ped} on $\Delta\alpha/\alpha_{cr}$ for JT-60U (blue open) and ITER (red closed) simulations, where shade region denote pacing pellet size of present ITER design [3]. In ITER simulations, normalized internal inductance l_i is varied from a typical value to ITER lower limit (A→B).