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Comparative investigation of ELM control based on toroidal modelling of plasma response to RMP fields[1]

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The type-I edge localized mode (ELM), bursting at low frequency and with large amplitude, can channel a substantial amount of the plasma thermal energy into the surrounding plasma-facing components in tokamak devices operating at the high-confinement mode, potentially causing severe material damages. Learning effective ways of controlling this instability is thus an urgent issue in fusion research, in particular in view of the next generation large devices such as ITER and DEMO. Among other means, externally applied, three-dimensional resonant magnetic perturbation (RMP) fields have been experimentally demonstrated to be successful in mitigating or suppressing the type-I ELM, in multiple existing devices. In this work, we shall report results of a comparative study of ELM control using RMPs. Comparison is made between the modelled plasma response to the 3D external fields and the observed change of the ELM behaviour on multiple devices, including MAST, ASDEX Upgrade, EAST, DIII-D, JET, and KSTAR. We show that toroidal modelling of the plasma response, based on linear and quasi-linear magnetohydrodynamic (MHD) models, provides essential insights that are useful in interpreting and guiding the ELM control experiments. In particular, linear toroidal modelling results, using the MARS-F code, reveal the crucial role of the edge localized peeling-tearing mode response during ELM mitigation/suppression on all these devices. Such response often leads to strong peaking of the plasma surface displacement near the region of weak equilibrium poloidal field (e.g. the X-point), and this provides an alternative practical criterion for ELM control, as opposed to the vacuum field based Chirikov criteria. Quasi-linear modelling using MARS-Q provides quantitative interpretation of the side effects due to the ELM control coils, on the plasma toroidal momentum and particle confinements. The particular role of the momentum and particle fluxes, associated with the neoclassical toroidal viscosity, will also be reported. Finally, predictive simulations are carried out for ITER and DEMO plasmas, for the purpose of the RMP configuration optimization, in terms of both the coil geometry and the coil currents.

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