Modelling for ELMs and H-mode pedestal: MHD, gyrokinetic modelling

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High-confinement mode (H-mode) plasma has been robustly observed in many tokamak experiments in the world. The confinement improvement of the H-mode is obtained as the result of the formation of edge transport barrier (ETB), called H-mode pedestal, and the mechanism required for the formation has been qualitatively understood as the suppression of plasma turbulence. The H-mode is an attractive regime for fusion reactor, but the pedestal can cause a major issue in tokamaks, called edge localized modes (ELMs). ELMs can give periodically large transient energy loss of the confined plasma and heat flux to plasma facing components (PFCs), and they seriously damage the lifetime of the PFCs in case the heat flux exceeds the threshold value depending on the PFCs' material. Hence, for large tokamak reactors like ITER, suppression or mitigation of such large ELMs is indispensable. To find a solution solving the issue, we should understand quantitatively the confinement physics at H-mode pedestal and ELM dynamics theoretically and/or numerically.

In this talk, progresses on modelling activities in the field of the H-mode physics will be presented, including the latest results from the participants of this workshop. The contents will be as follows. First, past achievements of modeling/numerical studies for explaining the results in experiments and remaining issues for ITER/DEMO will be introduced briefly, then the recent updates in a wide range of topics regarding the issues will be presented. For example, nonlinear MHD codes have been improved and realize simulations for not only multiple cycles of large/small ELMs but also magnetic fluctuations in ELM-free H-modes and ELM control with magnetic perturbations (MPs) or pellet pacing [1,2]. Gyrokinetic simulation codes also have been advanced significantly and one of the latest result shows that electromagnetic micro-turbulent homoclinic tangles have potential to regulate pedestal pressure gradient stable to ELMs and to broaden the divertor heat-exhaust footprint simultaneously [3]. Such the topics challenging to solve the issues on edge pedestal will be main topics. In addition, integrated modeling studies realizing the prediction of pedestal profiles in future reactors is also important and will be addressed in this talk, e.g., one of the recent results successfully reproduces and predicts pedestal profiles in present experiments and future reactors [4].

[1] M. Hoelzl et al., 2021 Nucl. Fusion 61 065001
[2] N. Li et al., 2022 Nucl. Fusion 62 096030.
[3] C. S. Chang et al., 2024 Nucl. Fusion 64 056041.
[4] S. Saarelma et al., 2023 Nucl. Fusion 63 052002.