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JT-60SA実験に向けたプラズマと運転シナリオの統合予測モデリング
Predictive integrated modelling of plasmas and their operation scenarios towards exploitation of JT-60SA experiment

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Modelling strategy towards exploitation of JT-60SA experiment

JT-60SA is a large superconducting tokamak and will start plasma operations in 2020 well in advance of ITER operation. The JT-60SA mission is to contribute to early realization of fusion energy by supporting the exploitation of ITER and by complementing ITER in resolving key issues for DEMO reactors. For the mission, JT-60SA is equipped with flexibly applicable actuators, i.e., negative- and positive-ion-based neutral beams (NBs) and electron cyclotron waves, to control heating, current and torque profiles (total input power P_{in}=41 MW). With the actuators, JT-60SA explores inductive, advanced inductive and steady-state high-beta plasma operation scenarios [1]. Integrated modelling and prediction of plasmas and their operation scenarios plays a key role to plan experiments and prepare the model validation through the prediction confirmation in real experiments. For the purpose, not only JT-60SA modelling itself but also the validation of models for JT-60U and JET experiments to develop the best modelling framework to predict, and the model verification between integrated codes to improve the prediction reliability have been carried out in the close collaboration between Japan and EU [1,2]. These modelling activities are carried out intensely towards the start of JT-60SA experiments and the following results were obtained.

Prediction results

The integrated code TOPICS with the CDBM anomalous heat transport model validated by JT-60U/JET experiments [2] is used for the plasma prediction of high-beta steady-state scenario, which is the most challenging scenario due to simultaneous achievement of full current drive, low divertor heat load and so on, with their strong interactions. The previous prediction [2] used a simple NB model without a finite-orbit effect of fast ions, however, the prediction depends on the accuracy of NB models in the verification between integrated codes. The prediction is improved using the Orbit-Following Monte-Carlo code OFMC, which is also verified by the ASCOT code. Pedestal profiles are determined on the basis of EPED1 model. Temperature profiles are solved, while the electron density profile is prescribed. By the power control with P_{in}~26 MW, a steady-state plasma (β_N=4.3, H_H=1.6) is obtained with an internal transport barrier (ITB) as shown in Fig.1(a). Even with small power perturbations (+/− 0.2 MW) to the above reference case, ITB continuously moves outward/inward, β_N increases/decreases (Fig.1(b)) and the current becomes over/inductively driven. Although the plasma is unstable against the perturbations, the long time scale of deviations is about the current diffusion time in the ITB region (order of 10 s in Fig.1(b)) and enables to sustain the ITB position and target performance by enhancing/reducing powers every several to ten seconds without their runaways.

Other integrated modelling for inductive scenarios reveals that the rotation with the neoclassical toroidal viscosity (NTV) due to the toroidal magnetic field ripple degrades the pedestal height, but it is high enough to achieve target parameters, and error field correction coils in JT-60SA have the potential to control the rotation by changing NTV. The obtained predictions clarify the JT-60SA capability to explore the plasma scenarios indispensable to ITER and DEMO.

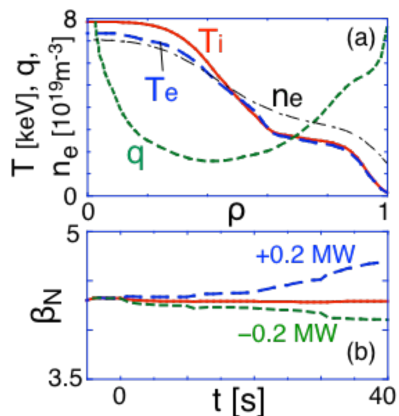

Fig.1 (a) Profiles of ion/electron temperatures, safety factor and prescribed electron density in a JT-60SA steady-state plasma with β_N=4.3. (b) Time evolution of β_N in a reference case (solid line, profiles are shown in (a), input power is adjusted at t=0 s and kept constant to 40 s) and two cases with ±0.2 MW perturbations from t=0 s.

[1] G. Giruzzi et al., Nucl. Fusion **57**(2017)085001
[2] N. Hayashi et al., Nucl. Fusion **57**(2017)126037