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JT-60SAにおける高ベータ定常運転シナリオの統合モデリング

Integrated modeling of JT-60SA high-beta steady-state scenario

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The JT-60SA [1] 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. Especially, JT-60SA explores the high-beta and steady-state operation regime to complement ITER. For the purpose, JT-60SA is equipped with flexibly applicable actuators of NB and EC. The scenario will use lower plasma current than the maximum one (5.5 MA), the plasma density needs to be lower and thus the reduction of divertor heat load is a critical issue. Impurity seeding to the divertor region can reduce the heat load below a preferable level of 10 MW/m^2, however, the accumulation of seeded impurity in the core may reduce the core confinement by enhancing the radiation and dilution.

In this paper, we predict the JT-60SA plasma by integrated modeling code TOPICS [2] which includes a divertor integrated code SONIC and a core impurity transport code IMPACT. For the prediction, we validate typical anomalous heat transport models, which are the major uncertainty in the prediction, for JT-60U and JET experiments with internal transport barriers in the Japan-EU collaborative activity. In the models, CDBM agrees with the experiments better than the other models, or underestimates temperatures. Thus, we consider that CDBM can be used for the conservative prediction. TOPICS with CDBM is used for the prediction without impurity seeding. A stationary state is obtained at the flat top phase of plasma current of I_p=2.3 MA with B_t=1.7 T. Various states with high-β_N (>3.5) and nearly full CD condition can be obtained by using various sets of actuators. By using the total power of 24 MW, a plasma with β_N=3.9 and nearly full CD condition is obtained. The scenario requires the low electron density at the separatrix ($n_{e,sep}$ < 1.7 × 10^{19} m^{-3}), leading to the high heat load on divertor plates. SONIC simulations are carried out to find a solution satisfying the conditions by Ar seeding. With the Ar puff amount of 0.17 Pa m^3/s, a solution with $n_{e,sep}$ = 1.6 × 10^{19} m^{-3} and $q_{div,out}$ = 9.7 MW/m^2 is obtained. TOPICS with IMPACT can clarify the accumulation of seeded Ar in the core and its effect on the plasma performance. Figure shows profiles of Ar densities, neoclassical convective velocities, electron temperature and radiation power density, where Ar densities at the edge evaluated by SONIC is used as boundary conditions in IMPACT to obtain the maximum accumulation. Considering the maximum accumulation, impurity anomalous diffusivities are set to the minimum level of neoclassical ones. The inward neoclassical pinch due to the bulk density gradient exists in the core and the outward convection due to the temperature gradient in the pedestal. This neoclassical convection results in the accumulation of Ar$^{16\text{-}18+}$ in the core. The Ar radiation power increases by 3.8 MW and thus the temperature decreases in the core. The Ar accumulation reduces β_N to 3.6 so that the full CD condition is no longer satisfied. However, it can be recovered by adding the NB power to supplement the radiation increase.

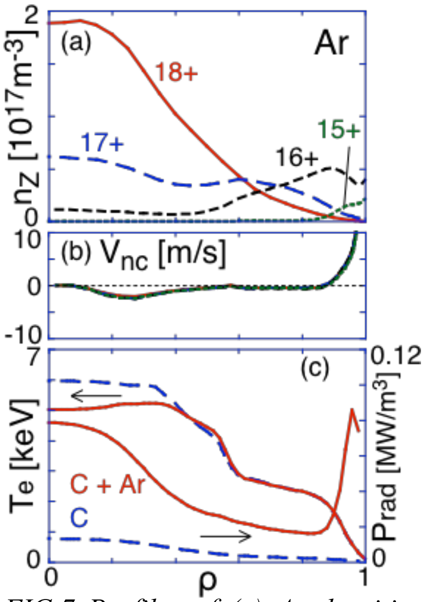

FIG.7 Profiles of (a) Ar densities with charge states from 15+ to 18+, (b) neoclassical convective velocities, (c) electron temperature and radiation power density in a case only with Carbon radiation (broken lines) and a case with seeded Ar (solid lines).

[1] JT-60SA Research Plan - Research Objectives and Strategy Version 3.3 2016, March, http://www.jt60sa.org/pdfs/JT-60SA_Res_Plan.pdf
[2] Hayashi N. *et al* 2010 *Phys. Plasmas* **17** 056112