Development of dynamic boundary density models with hydrogenic and impurity densities in *H*-mode scenarios

A. Siriwitpreecha[1], T. Onjun[1], S. Suwanna [1], R. Picha[2] and N. Poolyarat[3]

[1] *School of Manufacturing Systems and Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University, Pathumthani, Thailand*

[2]*Thailand Institute of Nuclear Technology, Bangkok, Thailand*

[3]*Department of Physics, Thammasat University, Pathumthani, Thailand*

Introduction

In the operation of a tokamak, the divertor plates and other plasma facing component (PFC) materials get some interaction with hot plasma by ion backscattering, chemical and physical sputtering processes, which yield impurities into the plasma. In ITER, the critical level of impurity concentration is 4.0% for carbon, 0.1% for ion and 0.008% for tungsten with respect to the electron density [1]. The presence of these impurities can contribute to radiation loses and plasma fuel dilutions, which can decrease the performance of a tokamak. The impurity accumulation occurs when the radial density profile of an impurity evolves a stronger peaking than that of the main plasma ion, which is usually observed in the central part of the plasma, namely inside a normalized radius $r/a < 0.5$ [2]. The impurity transport in the SOL region and the impurity penetration to the core is one of the key issues in the edge plasma physics [3]. In recent work, Leekhaphan P. *et al*.[4] had shown that the impurity accumulation in ITER standard type I ELMy *H*-mode depends sensitively on boundary conditions and the level of impurity transport.

In this work, we investigate boundary conditions for deuterium density and impurity carbon density. Two models are used to simulate the deuterium and carbon density profiles -, like those in [5]. The first is called a *static boundary density model*, where the deuterium and carbon density values at the top of pedestal are kept fixed. The second model is called a *dynamic boundary density model* where the deuterium and carbon density values at the top of pedestal are assumed to vary as a large fraction of their line averaged densities. In this report, we focus our investigation on the dynamical boundary density model. In such the model, the pedestal deuterium and carbon density can be expressed as:

$$n_{D,ped} = C_C \cdot \bar{n}_D \quad (1)$$

$$n_{C,ped} = C_C \cdot \bar{n}_C \quad (2)$$

where C_D and C_C are the deuterium and carbon density constants, while $\bar{n}_D$ and $\bar{n}_C$ are the deuterium and carbon line averaged density, respectively. C_D and C_C - are calibrated against

experimental data obtained from the latest public version of the International Pedestal Database (version 3.2). The dynamic boundary density model is implemented in BALDUR code to provide boundary conditions for simulations of *H*-mode plasmas. In each BALDUR simulation, the core transport is the combination of Mixed Bohm/gyro-Bohm (Mixed B/gB) anomalous transport model and the NCLASS neoclassical transport model. Simulations of *H*-mode plasmas in various plasma conditions are carried out. Statistical technique is used to quantify the agreement between simulations and experimental data.

Development of Dynamic Boundary Density Model

For the deuterium density constant, it can be analyzed from 68 experimental data points from three different tokamaks, namely 36 TFTR discharges, 17 JET discharges and 15 DIII-D discharges. For the carbon density constant, 55 experimental data points from two tokamaks are analyzed, namely 36 TFTR discharges and 19 JET discharges. It is assumed that the deuterium and carbon densities at the top of pedestal are large fraction of their line averaged densities, with the constant of proportionality called the C-value, which can be found from the ratio of the density at the top of pedestal to the line average density. In the current model, theC-value is found by minimizing the RMS between the model and experimental data. Figs. 1a) and 1b) show that the density at the top of pedestal from models compared with the experimental data for deuterium and carbon density, respectively. The root mean square (RMS) deviation is used to quantify the comparison between the predicted and the experiments. It can be found that the RMS deviations for deuterium and carbon density are 22.89% and 19.84%, respectively.

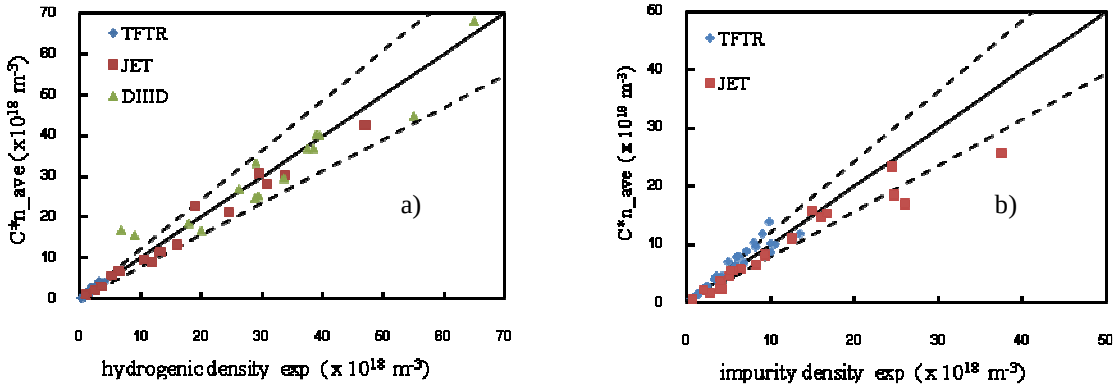

Figure 1 The density at the top of pedestal from model compare with the experimental data for a) deuterium density (68 discharges) b) carbon density (55 discharges).

Next, consider a fraction of discharges which yield constants C_D and C_C above the C-value. Figs. 2a) and 2b) show that the fraction of considered discharges plotted as a function of C-value. Obviously, for low C-value, the fraction is a unity, and C-value

increases, the fraction decreases down to zero. The C-value which corresponds to the fraction value of 0.5 can be thought of as a central representative, much like a mean value. In this, such the value indicates that 50% of considered discharges have C_D and C_C above it, and 50% of discharges have C_D and C_C below it . In this way, the constants C_D and C_C in the model are determined. It is found that the deuterium density constant, C_D, is 0.77 while the carbon density constant, C_C, is 0.74.

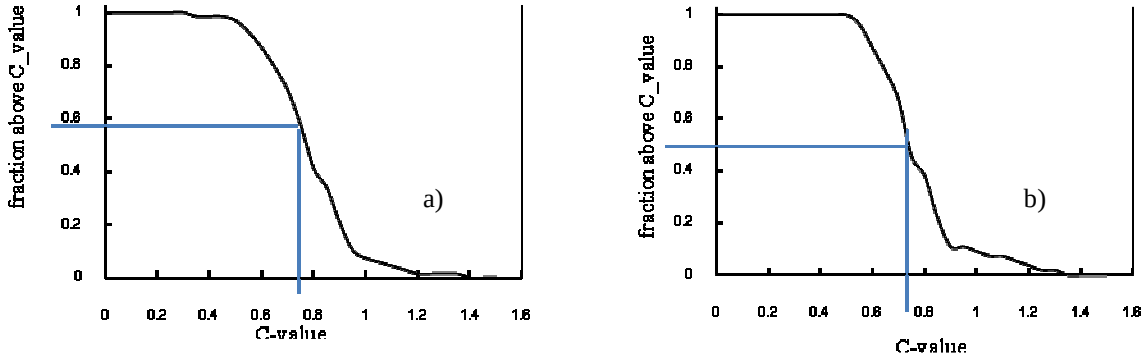

Figure 2 The fraction above C-value plotted against each C-value a) for deuterium density b) for carbon density

Simulations and discussions

Simulations are carried out using 1.5D BALDUR integrated predictive modeling code with the Mixed Bohm/gyro-Bohm (Mixed B/gB) transport model. The deuterium and carbon influxes have strong line-averaged density dependence [6], $i.e.(= c\bar{n}_e I^{\wedge}\beta$ It is assumed here that $\beta = 1$ .From comparing simulations with the experimental data for JET discharge 35156, it was found that c = 32.7 is most suitable. Then, the BALDUR code with the boundary density model provided is used to simulate 5 discharges from JET, and we compare these simulation results in *H*-mode scenarios with the corresponding experimental data. For examples, th simulated density profiles for JET discharge 35156 are shown in Fig. 3. For JET 35156, it can be seen that the electron, deuterium and carbon density somewhat agree with the experimental data. For the other discharges, most of the carbon density tends to be lower than that of experimental data.

A statistical analysis is used to measure an agreement between the simulation and experimental profiles from 5 JET discharges. Figs. 4a) and 4b) show the RMSE and offset values of these simulations, respectively. Fig. 4a) shows that the RMSE of the electron density profiles vary from 12% to 60%, the deuterium density profiles vary from 11% to 22% and the carbon density profiles vary from 12% to 64%. Likewise, Fig. 4b) shows the offset values of the electron and deuterium density profiles, which match equally well with the

experimental data. However, the carbon density profiles tend to be lower than those of from experiments.

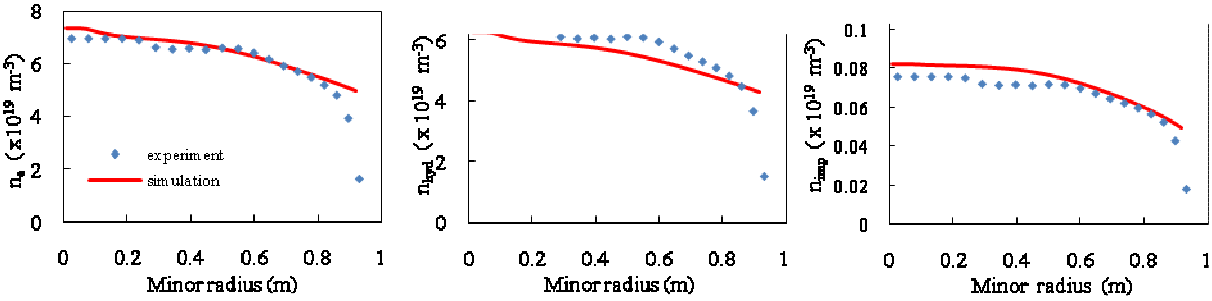

Figure 3 Simulation results of electron, deuterium and carbon densities in JET tokamak compared with the experimental data from discharge 35156.

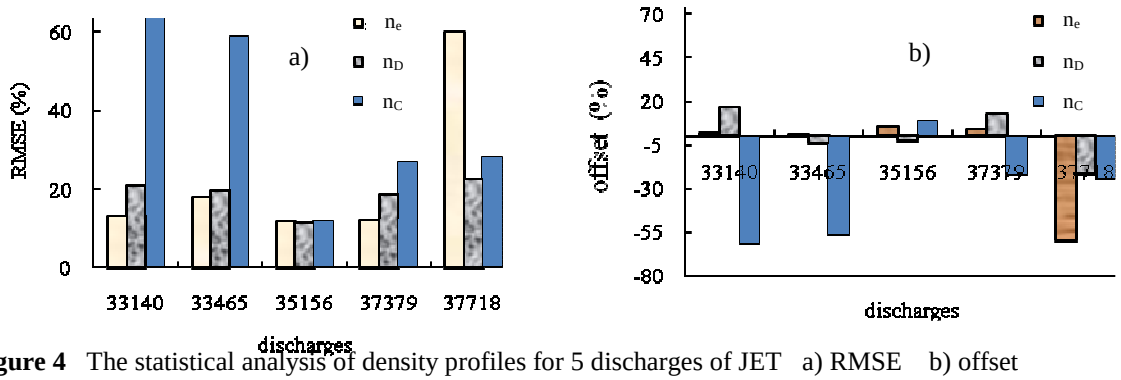

Figure 4 The statistical analysis of density profiles for 5 discharges of JET a) RMSE b) offset

Conclusions

The deuterium and carbon density constants in the dynamic boundary density model for predicting the density at the top of pedestal of deuterium and carbon profiles are 0.77 and 0.74, respectively. The comparison of the simulated results in *H*-mode scenarios with experimental data shows that the dynamical boundary density model can predict the electron and deuterium density at the top of pedestal reasonably, but often under predict the carbon density.

Acknowledgements

This work is supported by the Commission on Higher Education (CHE) and the Thailand Research Fund (TRF) under Contract No RMU5180017.

Reference

[1] Yamada I, *et al. Proceedings of ITC18, 2008*

[2] Dux R, *et al. J. Nucl. Mater*. **313**, 1150 (2003)

[3] Strangeby P, *Plasma Phys. Control. Fusion* **43** 223(2001)

[4] Leekhaphan P, *et al. to be appeared in TIJSAT*

[5] Pianroj Y, *et al. to be appeared in Plasma Phys. Rep.*

[6] Stamp M.F., *et al. Nucl. Mater*. **143**, 236 (1987)