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Integrated Simulation of Core, SOL/Divertor and Plasma-Wall Interaction
コアプラズマ・ダイバータ・炉壁統合シミュレーション

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Development of an integrated model including SOL/divertor plasma transport, neutral transport, impurity transport, core transport and plasma-surface interaction, is important issue for prediction of the burning-plasma behavior. An integrated divertor code SONIC has been developed and well reproduced the time evolution of the X-point MARFE in the JT-60U experiment. The impurity Monte-Carlo simulation by the IMPMC code coupled with the erosion/deposition code EDDY showed that the hydrocarbons sputtered from the dome contribute to the enhanced radiation near the X-point. The integration of the SONIC and a 1.5D core code TOPICS-IB allows dynamic simulations, such as the evolution of the divertor plasma through the L-H transition.

1. Introduction

In order to understand behavior of the burning plasma (D/T/He) in fusion machines, understanding of many physics in the SOL/divertor region and its synthetic analysis are necessary. For example, the tritium flux to the wall depends on the SOL/divertor transport, recycling, effects of impurity species, exhaust characteristics, the outflux from the core region etc. In addition, these phenomena have strong interaction with each other. Therefore, development of an integrated model including SOL/divertor plasma transport, neutral transport, impurity transport, core plasma transport and plasma-surface interaction, is important issue.

As shown in Fig. 1, a suite of integrated divertor codes SONIC has been developed, and has been extended by integration with an erosion/deposition code EDDY and 1D core transport code TOPICS-IB, in JAEA [1, 2]. In Keio University, integration of the divertor code SOLPS and the high-Z impurity code IMPGYRO have been undertaken [3]. In this paper, the development of the integrated model in JAEA is briefly summarized.

2. Integration of Plasma and Impurity Transport

For analysis of the impurity transport in the SOL/divertor region, two dimensional multi fluid divertor codes are often used. However, it is difficult for fluid codes to take into account the kinetic effect, complicated atom/molecular processes, such as dissociation process of hydrocarbons. The Monte-Carlo (MC) approach is suitable for including such effects, but has disadvantages, such as long computational time, large MC noise, and assumption of steady state. Recently, we have overcome these disadvantages and an integrated divertor code SONIC, which consists of the plasma fluid code SOLDOR, the neutral MC code NEUT2D and the impurity MC code IMPMC, has been developed [1].

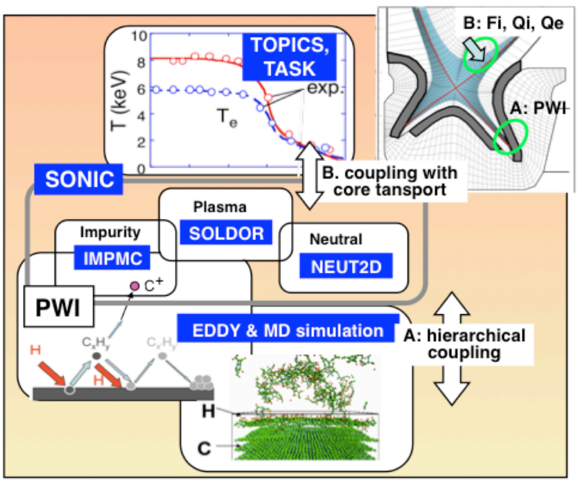

Fig.1 Integrated modeling of core, SOL/divertor and plasma-surface interaction.

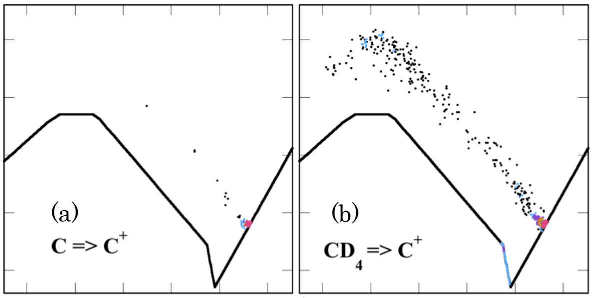

Fig. 2 The birth point of C^+ ionized by the simplified carbon ionization model (a) and dissociated from methane (b). The carbon atom or the methane is emitted from the outer strike point.

The SONIC code applied to the analysis of the dynamic evolution of X-point MARFE in JT-60U. In the attached case, the impurity radiation is localized near the target. With increasing in the gas puff rate, the recycling becomes enhanced and the electron temperature at the strike point becomes low. The radiation region moves toward the X-point from the target and the X-point MARFE occurs finally. The process toward the X-point MARFE agrees well with the JT-60U experimental results.

3. Integration with Plasma-Surface Interaction

In the above simulation, the complex dissociation processes of CD_4 are simplified down to an ionization process of C with a low energy (∼1 eV), as widely used in other divertor codes. For appropriate treatment of the dissociation process of CD_4, the IMPMC code has been coupled with the EDDY code [1]. The EDDY code is a 3D MC impurity code for analysis of erosion/deposition processes, and takes into account of ionization and complex dissociation processes of hydrocarbons. The IMPMC/EDDY simulation indicated that the hydrocarbons sputtered from the dome contribute to the enhanced radiation near the X-point and that the dissociation process cannot be simplified down to the ionization process of carbon with low energy, as shown in Fig. 2.

4. Integration with Core Transport

Usually, simulations by 2D divertor codes are performed by giving the boundary condition of particle and heat fluxes at a certain magnetic surface in the core plasma near the separatrix. Since the core confinement and the SOL/divertor characteristics are significantly affected each other, above core boundary condition could not simply be given as input parameters. In order to study the divertor characteristics including interactions between the core and the SOL/divertor plasma, SONIC has been consistently coupled to a tokamak transport code TOPICS-IB [2].

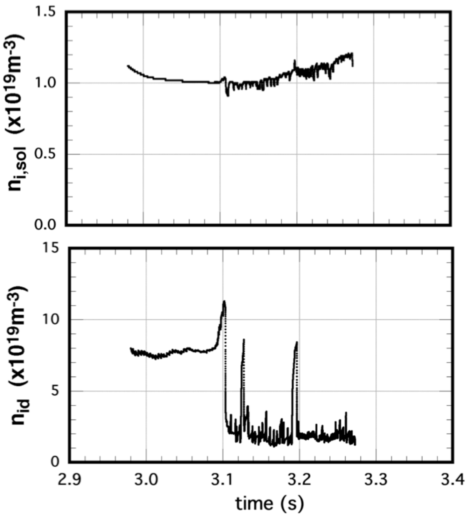

Fig. 3 Time evolution of ion density (n_{ed}) at inner divertor strike point and (n_{esol}) at outer mid- plane through the L/H transition.

The dynamic simulation of the L-H transition in the JT-60SA has been carried out by SONIC/ TOPICS-IB with a CDBM transport model [4]. In the simulation, the L/H transition and the resultant change in the transport coefficient are described by the CDBM model. Figure 3 shows the time evolution of ion density (n_{id}) at outer strike point and ($n_{i,SOL}$) at the outer mid-plane through the L/H transition. The SONIC/TOPICS-IB successfully simulates dynamic evolution of the divertor plasma from the high recycling phase to the low recycling phase by the L/H transition.

5. Summary

The SOL/divertor transport model, the plasma-surface interaction model, and the core transport model have been self-consistently integrated. In order to predict the behavior of the burning plasma, the improvement to treat D/T/He is in progress.

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References

[1] K. Shimizu *et al.*: Nucl. Fusion **49** (2009) 065028.
[2] K. Shimizu *et al.*: 23rd Fusion Energy Conference (Daejeon, Korea, 2010), Contributed Papers, THD/5-2Ra (IAEA, Vienna).
[3] M. Toma *et al.*: 13th International Workshop on Plasma Edge Theory in Fusion Devices (South Lake Tahoe, USA, 2011)
[4] M. Yagi et al.: ibid.