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非接触プラズマを対象とした運動論的なプラズマ-中性粒子相互作用モデリング

Kinetic modeling of plasma and neutral interaction in detached plasma

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Plasma detachment is thought to be one of the most effective methods to reduce the plasma heat flux to the divertor. Atomic and molecular processes such as three-body recombination and molecular activated recombination(MAR) play an essential role in detached plasmas[1]. On the other hand, plasmas of high temperature and density due to the heat pulse by the edge localized mode(ELM) can cause a collapse of steady-state detachment state. In the ELMs, the energy distribution of plasma deviates from thermodynamic equilibrium. Therefore, a kinetic model is needed to analyze the ELM. In the present study, we developed the kinetic model of the interaction between plasmas and neutrals including the charge-exchange, electron-ion recombination and MAR. We developed the model of the collision between neutrals and plasmas using the Null Collision Method(NCM) and Collisional Radiative(CR) model. For the validation of this model, we compared the results from this model with the results from 0-Dimensional(0D) model assuming the simulation region without boundary. In the 0D model, time variation of the particle density is calculated from the rate equations :

$$\frac{dn_s}{dt} = \sum_{j,k} R_{\text{gain}} n_j n_k - \sum_{l,m} R_{\text{loss}} n_j n_m \tag{1}$$

where indices s, j, k, l and m are particle species($\mathrm{H}, \mathrm{H}_2, \mathrm{H}^-, \mathrm{H}_2^+$), n_s is the number density of particle s, R_{gain} is the production rate coefficient and R_{loss} is the loss rate coefficient. The distribution function $f(E)$ is assumed to be Maxwellian. This model takes into account radiative/three-body recombination, MAR, excitation/deexcitation/spontaneous radiation/ionization of H, dissociation of H_2^+, and loss of H^-. Excited states p of hydrogen atoms and vibrationally excited states v of hydrogen molecules are distinguished($p = 1 \sim 35, v = 0 \sim 14$).

The time evolution of H(p)(p:excited state) (see Fig. 1) and H_2(v)(v:vibrationally excited state)(see Fig. 2) is calculated from the 0D model and NCM. Each result from the NCM shows good agreement with 0D model. Based on this model, the coupling of neutral model and Particle-In-Cell(PIC) model is now undergoing.

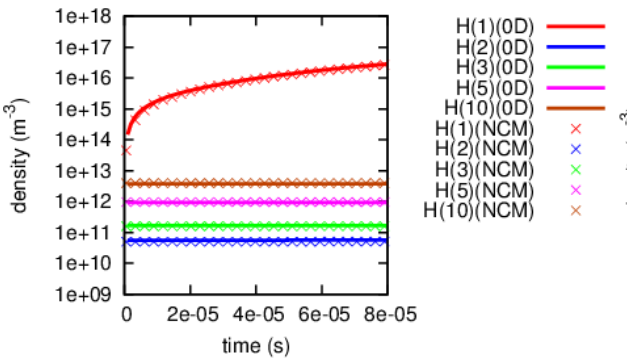

Fig.1 Time evolution of density of H(p)

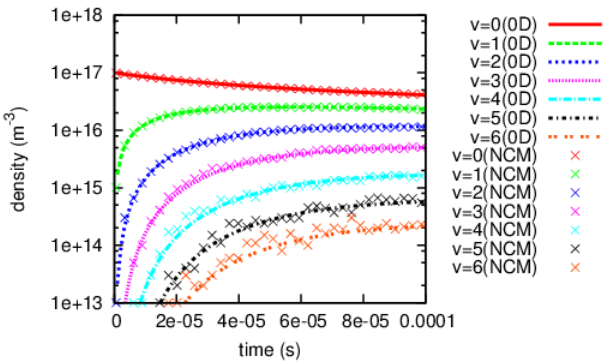

Fig.2 Time evolution of density of H_2(v)

[1] A.Yu. Pigarov, S.I. Krasheninnikov, D.J. Sigmar, Phys. Lett. A **214**(1996).