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ラグランジューモンテカルロ法を用いたSOL/ダイバータプラズマ流体コードの開発状況とシース境界条件についての考察

Development of a SOL/Divertor fluid code using a Lagrange-Monte-Carlo Scheme: Consideration of Sheath Boundary Conditions

巽 瞭子[1]、ルノフ アレクセイ[2]、シュナイダー ラルフ[3]、星野一生[1]、畑山 明聖[1]

Ryoko Tatsumi[1], Alexei Runov[2], Ralf Schneider[3], Kazuo Hoshino[1], Akiyoshi Hatayama[1]

[1]慶應義塾大学大学院理工学研究科，[2]マックスプランク・プラズマ物理学研究所(グライフスヴァルト),
[3]エルンスト・モリッツ・アルント大学グライフスヴァルト

[1] Graduate School of Science and Technology, Keio University, [2] Max-Planck-Institute of Plasma Physics, Greifswald,
[3] Institute of Physics, Ernst Moritz Arndt University of Greifswald

To understand requirements for stable operation under detached conditions, several numerical codes have been developed like SOLPS[1], SONIC[2], and EMC3-EIRENE[3]. Especially for a three-dimensional (3D) plasma fluid code, however, it remains a great issue to reproduce the detachment state.

For this reason, we are developing a 3D plasma fluid code with the Lagrange-Monte-Carlo scheme (LG-MC) which uses pseudo-particles and integrates two schemes, the Lagrange scheme for the convective part and the Monte-Carlo scheme for the diffusive part. Though the scheme has been validated with some simple cases so far, one issue is to set the sheath boundary condition, which often causes various numerical difficulties for any scheme.

The following 1D plasma fluid equations for plasma density n, parallel flow velocity V, and ion/electron temperature $T_{i/e}$ are set for the present model ;

$$\frac{\partial n}{\partial t}+\frac{\partial}{\partial x}(nV)=S_n \quad (1)$$

$$\frac{d}{dt}(mnV)=-mnV\frac{\partial V}{\partial x}-\frac{\partial}{\partial x}\left(p-\frac{4}{3}\eta\frac{\partial V}{\partial x}\right)+S_M \quad (2)$$

$$\frac{d}{dt}\left(\frac{3}{2}nT_{i/e}\right)=-\frac{5}{2}nT_{i/e}\frac{\partial V}{\partial x}-\frac{\partial}{\partial x}\left(-\kappa_{i/e}\frac{\partial T_{i/e}}{\partial x}\right)+S_{T_{i/e}} \quad (3)$$

where m, $p\left(=n\left(T_e+T_i\right)\right)$, and $\kappa_{i/e}(=\kappa_{i0/e0}T_{i/e}{}^{5/2})$ are the ion mass, the total pressure, and the parallel ions/electrons thermal conductivity, respectively. The source/sink terms, S_n, S_M, $S_{T_{i/e}}$, take into account ionization and charge-exchange with neutral atoms at present. The neutral density is calculated by a simple continuity equation.

As the sheath boundary conditions, the flow velocity V_{se} and the heat flux q_{se} at the sheath entrances are;

$$V_{se}\ge\sqrt{\frac{k_B\left(T_{ise}+T_{ese}\right)}{m}},\ q_{ese}=\left(\frac{5}{2}nVT_e-\kappa_e\frac{\partial T_e}{\partial x}\right)_{se}=\gamma_e nVT_e \quad (4)$$

In LG-MC, the convective component of the heat flux should be set with the Lagrange scheme, while the rest of it is set with the Monte-Carlo scheme.

Figure 1 shows a result of LG-MC calculated in a 1D symmetric geometry, compared with those calculated by a Finite Volume scheme. In this case, treating the boundary heat flux as the sum of convection and conduction, both numerical results showed good agreement.

However, this does not treat the heat flux at the sheath entrance as “free-streaming” heat-flux. In the conference, results of some cases with different boundary treatments, which consider that point, will be shown and discussed.

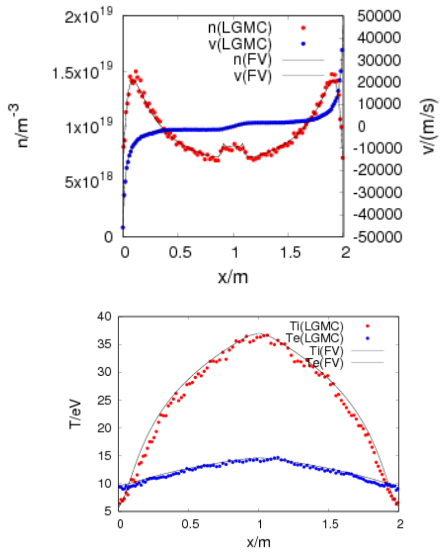

Fig. 1 Results of the Lagrange-Monte-Carlo scheme.

References

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