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境界層プラズマにおける流体方程式の解法の比較
Basic Comparison of the Numerical Method to Solve Fluid Equations for SOL/divertor Plasma

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Understanding plasma transport in the SOL/divertor region is one of the most important issues to reduce heat and particle loads to the divertor plate in future fusion reactors. For this purpose, several numerical codes based on the fluid plasma equations have been developed so far. Among them, there are mainly two types of method, finite difference method like B2-EIRENE(SOLPS)[1], and Monte Carlo method like EMC3[2] and E3D[3]. The former seems to be harder for three dimensional large scale simulations, while the latter seems to have difficulty on setting boundary conditions. Therefore, the objective of our study is to solve the benchmark problem with both methods and compare them.

The plasma transports can be described as the following convection-diffusion equation[4]:

$$\nabla \cdot \left[V_{fp} F - D_{fp} \nabla F \right] = S \,, \tag{1}$$

where F is plasma quantity (e.g. density), V_{fp} is convection vector, D_{fp} is diffusion tensor, and S is a source, respectively. As the first step, we have developed a one dimensional fluid simulation model using the Monte Carlo method. In order to check the program, test calculations were conducted. The plasma density, momentum, and energy equations were separately solved with each appropriate boundary conditions (e.g. energy flux at the sheath). The each result shows good agreement with the analytic solution (see Fig. 1).

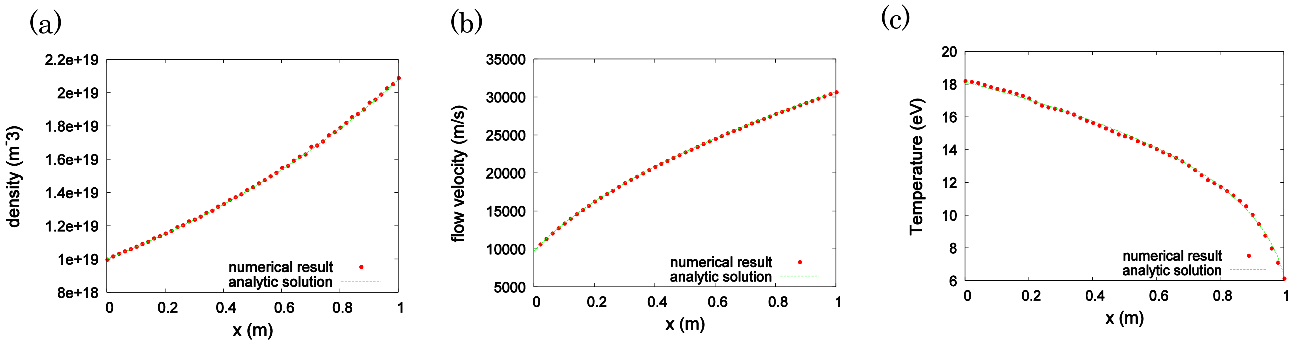

Fig. 1. The numerical results and the analytic solution. (a) Plasma density ($D_{fp} = 0$). The ionization source term S is assumed such as $S = nn_n \langle \sigma v \rangle$, where n is plasma density, n_n is neutral density, and $\langle \sigma v \rangle$ is ionization cross section, respectively. (b) Ion velocity with the source term $S = -\partial p / \partial x$, where p is the plasma pressure determined as $p = nT$ ($D_{fp} = 0$). (c) Plasma temperature with no source term ($V_{fp} = 0$).

For the next step, we are adding other convection/diffusion and source terms. The coupling results and comparison with a finite difference method will be presented at the conference.

Reference
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