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CIP-Soroban法を用いた重イオン慣性核融合燃料標的爆縮過程の数値シミュレーションの検討

Study on numerical simulation using CIP-Soroban method for implosion process of heavy-ion-beam driven inertial confinement fusion

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Heavy-ion-beam driven inertial confinement fusion (HIF) is a hopeful way to achieve nuclear fusion power plant [1]. In the study of HIF, numerical simulation based on hydrodynamics model is a powerful way to predict and analyze the implosion dynamics of fuel pellet [2,3]. The large gradients of physical values during implosion process are important obstacles of numerical simulation, for example, the density gradient between the dense plasma of heated fuel pellet and near vacuum environment in the chamber, which can be the source of numerical instability and accuracy reduction. The CIP-Soroban method is one of adaptive mesh refinement methods, which has been used for the numerical simulation in hydrodynamics of incompressible fluid [4].

We have developed a 2D CIP-Soroban cylindrical Euler fluid code for the simulation of implosion dynamics in HIF. The advection and non-advection terms of governing equations were calculated by interpolation of CIP method. To get adequate advection accuracy, we used the “Type-C scheme” in advection step [4]. To refine local mesh grids adequately, our mesh refinement method is refining the mesh grids as the gradient values of density, temperature and velocity increase. The Courant-Friedrichs-Lewy (CFL) number was difficult to determine in the CIP-Soroban method due to the reconstruction of calculation grids at each time step. To avoid the error from breaking CFL condition, we used a smaller time interval in the calculation time loop than general time interval obtained by CFL condition.

A test calculation result of explosion problem at the time of 0.2s is shown in Fig. 2, the corresponding initial conditions are shown in Table 1 and the initial density map is shown in Fig. 1. As shown in Fig. 2, the shape of explosion is well simulated with spherical symmetry and the areas with steep gradients of physical values have more fine calculation grids.

We will report the results of the numerical simulation for implosion dynamics in HIF by CIP-Soroban method, and the comparison between it to the results from uniform mesh code.

Table 1: Initial conditions of explosion problem

Radius [m]	Density	Pressure
r < 0.4	1kg/m³	1Pa
others	0.1kg/m³	0.1Pa

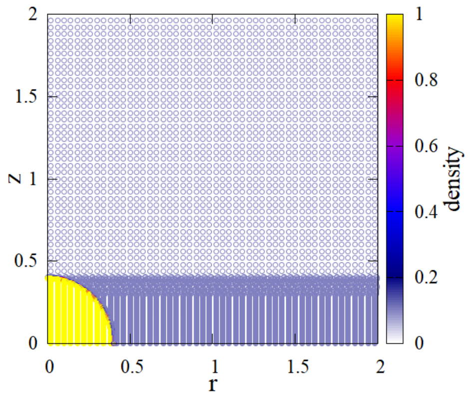

Figure 1. Initial density map of the explosion problem.

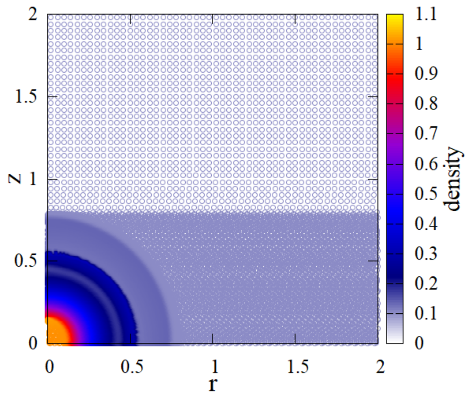

Figure 2. Density map at 0.2s of explosion problem simulated by the 2D CIP-Soroban cylindrical Euler fluid code, dots indicate for the calculation grid points.

Reference

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