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# Influences of Non-uniform Laser Irradiation on Implosion of Cone-Guided Targets
# コーン付爆縮におけるレーザー不均一照射の影響

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The non-uniform laser irradiation is an inevitable problem for implosion of cone-guided targets. The problem is investigated with simulations by use of a fluid code in which the Immersed Boundary (IB) method is installed to treat the boundary of the cone in Cartesian coordinates. This paper shows the IB method and simulation results of non-uniform implosion for the cone-guided target based on laser alignment of GEKKO XII at the Institute of Laser Engineering, Osaka University.

## 1. Introduction

In laser fusion, a fuel target is compressed by implosion using lasers, and both temperature and density of the fuel increase high enough to spontaneously initiate fusion reactions. Since the beginning of laser fusion researches, many schemes have been proposed and developed. Fast ignition (FI) is one of these schemes [1]. There are some approaches in the FI, and especially, in the case of fast ignition with cone-guided targets (FICG), the target is compressed by implosion lasers, and at the maximum compression time, the imploded core is ignited by fast electrons generated by an ultrahigh intense laser.

The implosion laser, GEKKO XII at Osaka University, has twelve laser beams. The conventional spherical target is irradiated by lasers arranged with dodecahedron orientation. The non-uniform implosion is inevitable because the number of beams is limited. Furthermore, the symmetry degrades in the case of FICG because lasers are injected except the cone area. In these implosions, the fluid motion of the target is very complicated and may cross the origin. Cartesian coordinates are preferred to other coordinates for simulating these flows because the Cartesian is suited to calculate such turbulent flows and has no singular points even at the origin. However, the boundary of the cone is not treated adequately in the Cartesian. Therefore, we installed Immersed Boundary (IB) method [2,3] to a three-dimensional Cartesian fluid code IMPACT-3D [4]. The IB method was developed by Peskin (1972) to simulate flows with embedded boundaries on the Cartesian grid, which does not conform to the boundary.

## 2. Immersed Boundary method

In the IB method, each grid point is categorized to solid, fluid or ghost points shown in Fig. 1. The solid point is defined as a point inside the boundary, while the fluid point is defined as a point outside the boundary. The ghost point is determined as the following procedure. If at least one of the four adjacent points of the solid point is outside the boundary, such a solid point is redefined as the ghost point. After determining ghost points, an image point is defined as mirror projection corresponding to the ghost point shown in Fig. 1, which is used for calculating values of flow variables of the ghost point. The values at the image point are interpolated from the adjacent fluid points. Once the values of the image point are calculated, the values at the ghost point are obtained from the image point to satisfy the boundary condition. Time step can be advanced using ghost and fluid points.

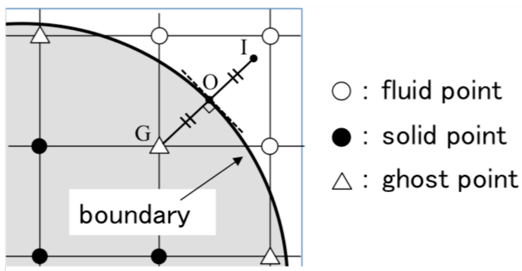


Fig.1. Schematic illustration of the IB method: *G* is the ghost point. *I* is the image point.

## 3. Simulation

3.1 *Initial condition*

The fuel target is assumed to be a shell capsule filled with fuel and the cone is inserted to it. The cone is treated by the IB method. To drive the target inward, a high-pressure region is introduced to a part of the shell as a driven layer. The initial profiles with the spherical implosion are shown in Fig. 2. $P_d$ is the pressure of the driven layer. $\rho_s$ is the density of the shell. $P_f$ and $\rho_f$ are the pressure and density of the fuel, respectively.

To investigate the effect of non-uniform irradiation, a pressure perturbation ($\delta P$) is employed to the driven layer following as,

$$\delta P = \begin{cases} A_i \cdot \dfrac{1}{2}\left[1+\cos\left(\dfrac{\varphi}{\varphi_w}\pi\right)\right] & (\varphi \le \varphi_w) \\ 0 & (\varphi > \varphi_w) \end{cases},$$

$$\varphi = \cos^{-1}(\mathbf{e}_r \cdot \mathbf{e}_i), \qquad (1)$$

and Fig. 3 shows the schematic illustration. $A_i$, $\varphi_w$, $\mathbf{e}_i$, and $\mathbf{e}_r$ represent the perturbation amplitude, the perturbation width in angle, a unit vector with direction pointing from the origin to the center of each side of the dodecahedron, and a unit vector in the direction of the perturbation point, respectively. $i$ is an index of each vertex of the dodecahedron.

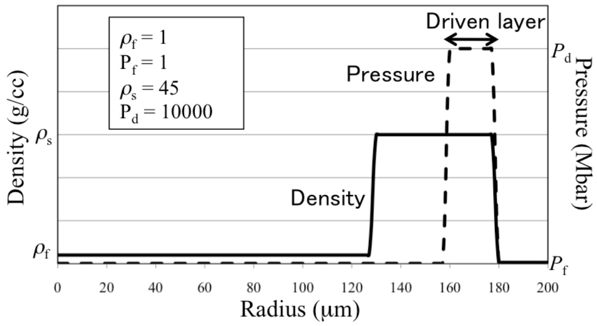


Fig.2. Initial values with the spherical implosion

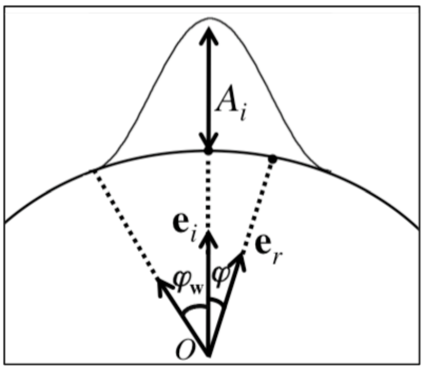


Fig.3. Schematic illustration of pressure perturbation

3.2 *Results*

Figure 4 shows an isosurface of the density at the maximum compression of the cone-guided target with non-uniform laser irradiation. The surface shows the contact surface between the shell and fuel. Figure 5 shows the time evolution of the density averaged over the fuel region. The solid and dot lines indicate the case of the spherical implosion without the cone and of the non-uniform implosion of the cone-guided target, respectively. The density in the case of the non-uniform implosion decreases by 8 percent compared with the spherical implosion.

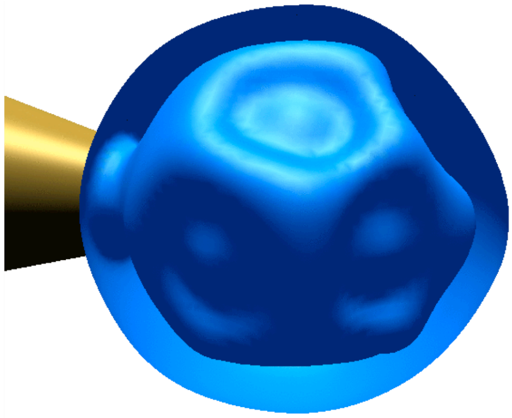

Fig.4. The density isosurface corresponding to the contact surface between the shell and fuel.

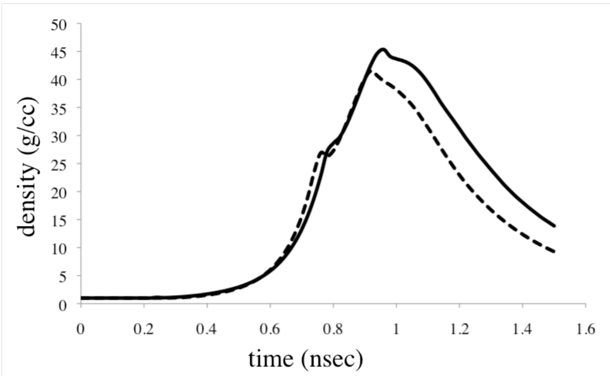


Fig.5. The time evolution of the density

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