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Influence of Perturbations of Fuel Inner Surface of Cryogenic Target on its Burning

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The central question for laser ICF problem is symmetrical compression of the target. Today the active discussions and experimental studies on laser facilities are concentrated on two type of laser targets – so called direct and indirect drive targets [1-4]. Now new more powerful laser facilities as NIF [5], LMJ [6] and ISKRA-6 [7] are being under construction. It is supposed that the power of this facilities is sufficient to achieve burning of the thermonuclear fuel in ICF experiments. The choice of optimal target design is very complicated and multi parametric problem. There are many factors that can have effect on design.

The desire for achievement maximum thermonuclear energy at minimum laser energy applies rigid requirements on laser pulse profile and its agreement with target parameters (mass, diameter, thickness etc.). It depends on the type of compression scheme. But for both type of compression the hydrodynamic flow is unstable. So initial perturbations will be grow during two stage when the target shell will be accelerated by rare targets corona and then during deceleration by fuel. Initial perturbation spectra are formed both due to irradiation non uniformities and due to shell non uniformities which originates during target fabrication.

We performed the analysis of one mode spherical harmonic perturbation growth. The perturbations are setting on the inner surface of DT ice in cryogenic ICF target. To our mind this type of perturbations is more dangerous because the inner surface of cryogenic target could not be controlled during fabrication. When shock wave goes to the inner surface of DT-ice with initial perturbations Richtmayer-Meshkov instability develops and they are carried out to the ablation front by rarefaction wave. The ablation front is unstable due to Raighley-Taylor instability. During this instability the mass flow in DT-ice appears and this mass uniformity can destroy the fuel burning [8]. To simplify the problem we studied the growth of mono mode perturbations. This is true because from the whole spectrum of perturbations only perturbation with maximum increment can play significant role. Using well known criteria for burning [9-11]

$$?R > \frac{3b}{B}\frac{T_h^{3/2}}{\langle sv\rangle} \quad (1)$$

one can obtained that for non uniform fuel density distribution burning criteria is changed to:

$$?R > \frac{3bT_h^{3/2}}{B\langle sv\rangle}\left(1+\frac{3}{8}\left(\frac{d?}{?_0}\right)^2\right). \quad (2)$$

These additional losses induced by perturbation don't depend on the perturbation mode number. So the main characteristic of perturbation which is responsible for burning breakdown is mass flow in the bubble:

$$\mu(t)=\left(\frac{m_0}{m_b(t)}-1\right), \quad (3)$$

where m_0 is unperturbed mass of unit solid angle of the shell, $m_b(t)$ is a current value of mass of unit solid angle near the bubble. Then using generalization of Ott [12] theory analogous as it was made in [8] one can find for bubble mass evolution the following equation:

$$\frac{1}{m_b}\frac{dm_b}{dt}=\frac{D}{\Delta_0}(Ak)_0-\frac{\eta}{k_0\Delta_0}\cdot\frac{(ak)\frac{df_-}{dt}}{(1+(ak)f_-(t))}. \quad (4)$$

Here *A* is initial perturbation amplitude on inner surface of DT ice, $f_-(t)=\sinh\left(\int_{t_0}^{t}\gamma dt\right)-\sin\left(\int_{t_0}^{t}\gamma dt\right)$, γ is the Rahgley-Teylor instability increment *a* perturbation amplitude on ablation front, ? 0 is a shell thickness, *D* is shock wave velocity,

Using target design for NIF [13] we calculated the degree of energy losses caused by perturbation growth for different initial amplitudes and mode numbers using 2D MIMOZA-ND code [14]. The summary of these simulations is shown on figure 1. Analyzed the bubble mass loss in simulation for different modes we found that critical mass loss while the target is burning for NIF target was μ=0.3 (see figure 2). On Figure 3 we compared model predictions using formula (4) and results of 2D calculations of perturbation growth given at inner surface of DT ice as a spherical mode with number *n*. So we found that for mode number less then 50 there is a rather good agreement between the model and computations.

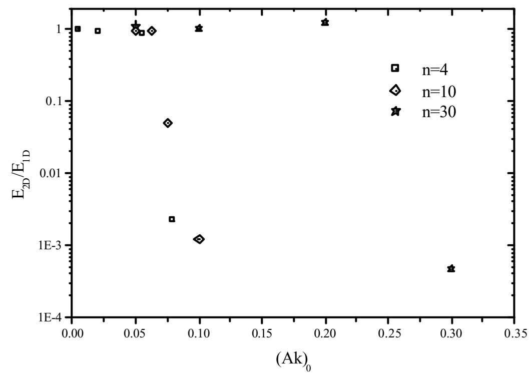

Figure 1. Decrease of thermonuclear energy in 2D simulations relative symmetrical case as a function of initial perturbation amplitude for different perturbation modes n.

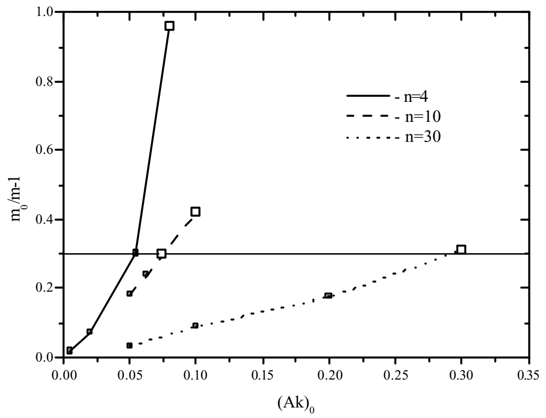

Figure 2. The loss of bubble mass versus initial perturbation amplitude for different modes numbers. Closed squares are the case where targets were burning, opened squares are the case when burning was broken.

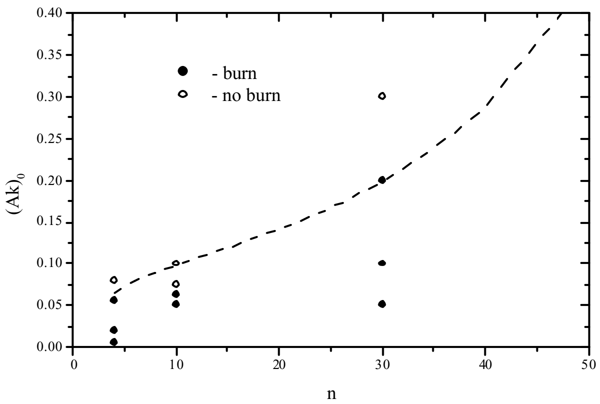

Figure 3. The theory dependence of initial critical perturbation amplitude $(Ak)_0^{crit}$ (the amplitude where loss of bubble mass achieved value 0.3) versus mode number (dashed curve). Circles are the results of MIMOZA-ND simulations.

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