§17. 3-D Rayleigh-Taylor Instability in Spherically Stagnating Systems

Sakagami, H.
Okamoto, T. (Sanyo Electric Co. Ltd.)
Horikoshi, M., Nishihara, K. (Institute of Laser Engineering, Osaka University)

In inertial confinement fusion, the Rayleigh-Taylor instability is unavoidable during the implosion and can destroy spherical symmetry of a fusion target. It is, therefore, one of important research topics in this field to investigate this instability. At the Rayleigh-Taylor instability in 3-D systems, dynamics of vertical vortex pairs that are associated with mode coupling plays an important role unlike 2-D systems.[1] On the other hand, the Rayleigh-Taylor instability in spherical geometry is quite different from that in planar geometry, because acceleration and wavelength vary in space and time. Thus we have been investigating nonlinear features of the fully 3-D Rayleigh-Taylor instability in spherically stagnating systems through numerical simulations.

As a Rayleigh-Taylor unstable interface is shrunk during the implosion and a radius of the interface is minimized at the maximum compression, we must set up the simulation system to capture the minimized interface with enough number of meshes. Recently advanced laser systems can be highly aligned and irradiate fusion targets more uniformly than ever, and the highly evolved fabrication technology can produce more precise spherical targets. So inspecting experimental results requires more precise simulations that calculate not only lower mode but also higher mode phenomena. Thus large-scale simulations are essential to analyze those experimental results with enough precision, and they will be accomplished only with parallel supercomputers. We have parallelized a three-dimensional fluid code, IMPACT-3D with High Performance Fortran on the Earth Simulator.[2]

We have introduced a self-similar analysis to describe the stagnation dynamics, which includes the effects of spherical geometry, acceleration and wavelength varying in space and time.[3] At the start of each simulation, a small perturbation was applied to the density profile of the self-similar solution at the contact surface. We have performed large-scale simulations with initial perturbations, which are given by superimposing of two spherical harmonics function modes (6,3) and (12,6). The nonlinear structure is shown in Fig.1 (a). Actually an initial perturbation mainly comes from the fact that fusion targets are irradiated with a finite number of laser beams. This laser irradiation system induces the perturbation with the shape of not the spherical harmonics function but geometrical pattern related to the irradiation symmetry. We have also been investigating the Rayleigh-Taylor instability for initial perturbations based on an icosahedron, which was associated with GEKKO XII at ILE, Osaka University. Small perturbations with various amplitudes were applied to density profile at each vortex and face's incenter of icosahedron, including randomly arranged bubbles/spikes with 32 levels of initial amplitudes, randomly arranged only bubbles with 16 levels, randomly arranged only spikes with 16 levels, a specific bubble surrounded by bubbles or spikes with different levels, and a specific spike surrounded by bubbles or spikes with different levels. The nonlinear structure for randomly arranged bubbles/spikes with 32 levels is shown in Fig.1 (b). From all simulation results, we plotted nonlinear growth rates of the Rayleigh-Taylor instability near the maximum compression as a function of initial perturbation amplitudes in Fig. 2. We found that all data were fallen onto a universal curve. Namely, the nonlinear growth rate is depended only on the initial perturbation amplitude regardless of many other conditions, and this characteristic is similar to that of the Richtmyer-Meshkov instability.

It is noted that the Earth Simulator Center claims more than 95% of vectorization ratio and more than 50% of parallelization efficiency to run the simulation code on the Earth Simulator, and we have cleared these severe criteria on using 1024x1024x1024 meshes and 128 nodes (1024 processors). Jobs can be easily submitted to the Earth Simulator through commonly used NQS-II system and typical runs can be done within 3 hours on 128 nodes of the Earth Simulator.

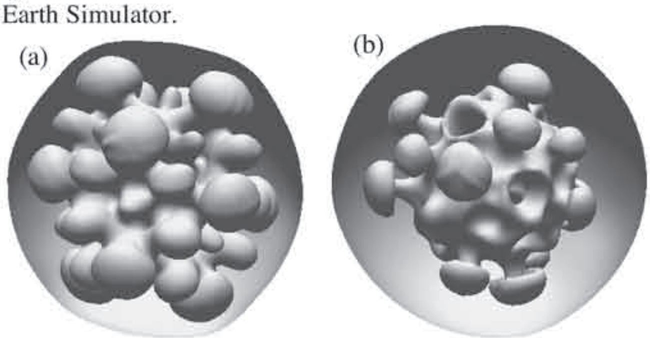

Fig.1. Three-dimensional structures for (a) double modes of spherical harmonics function and (b) randomly arranged bubbles/spikes with 32 levels.

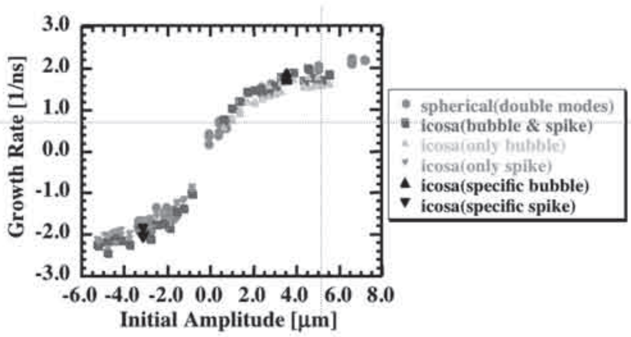

Fig.2. Nonlinear growth rates as a function of the initial perturbation amplitude for various conditions.

References
1) Horikoshi, M., et al., Phys. Plasma **9**, (2002) 3536.
2) Sakagami, H., et al., Proc. IEEE/ACM SC2002, (2002) pap147. (Gordon Bell Awards)
3) Hattori, F., el al., Phys. Fluids **29**, (1986)1719.