§52. Study on Dynamic Smoothing Method of Free Surface for Liquid Metal Mirror of Laser Fusion Reactor

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The lifetime of final optic system is one of the most important problems to develop a laser fusion reactor. A liquid metal mirror can be used to solve this problem. When the liquid metal mirror will be used, the surface wave caused by a plasma generation and/or a thermal shock by the laser shot needs to be dumped before the next shot. Since the requirement of dumping the surface wave caused by the laser shot is less than one-tenth of the laser wavelength, to develop the technologies to measure and analyze the dynamic surface motion when the liquid metal surface is exposed to the laser is necessary. In this study, two subjects will be focused on:

1) To grasp a dynamics of surface wave by experimental approach
2) To analyze the surface wave motion by numerical simulation

In this year, the design of experimental apparatus and some preliminary experiments have been carried out. As for a part of the design work, the 2D numerical simulation on a vortex dipole impingement has been done. The purpose of this simulation is to know how large of the magnitude of the surface wave due to the vortex dipole impingement.
Governing equations are as follows:

Continuity equation: $\nabla \cdot \boldsymbol{u} = 0$ (1)

Momentum equation: $\partial \boldsymbol{u}/\partial \boldsymbol{t} + (\boldsymbol{u} \cdot \boldsymbol{\nabla})\boldsymbol{u} = -(1/\boldsymbol{\rho})\boldsymbol{\nabla} p + (\mu/\rho)\boldsymbol{\nabla}^2\boldsymbol{u} + \delta(\boldsymbol{x} - \boldsymbol{b})\boldsymbol{f}$ (2)

here, $\boldsymbol{u}$ is velocity, t is time, p is pressure, $\boldsymbol{f}$ is boundary body force, $\delta(\boldsymbol{x} - \boldsymbol{b})$ is delta function to attribute $\boldsymbol{f}$ at the desired position, μ is viscosity and ρ is density.

Fluid	Air
Reynolds #	$Re_\Gamma = \Gamma/\nu = 1800$
Domain size	(y, z) = $(4\delta, 2\pi\delta)$
Grid #	(y, z) = (384, 256)
Resolutions	$\Delta y = 0.0065 \sim 0.0231, \quad \Delta z = 0.245$
Time step	$\Delta t = 0.1, 10$
Initial condition	$\omega = \pm \frac{\Gamma}{\pi l^2} \exp\left[-\frac{(y-y_c)^2 + (z \pm z_c)^2}{l^2} \right]$
Boundary condition	Non-slip @ walls Periodic boundaries @ x-directions

Table 1. Computational conditions

The vortex dipole force f is given by the following discretized equation momentum equation includes a source term as follows:

$\boldsymbol{f} = (1/\boldsymbol{\rho})\boldsymbol{\nabla} p - (\mu/\rho)\boldsymbol{\nabla}^2\boldsymbol{u} + (\boldsymbol{U}_{j,k}^{n+1} - \boldsymbol{u}_{j,k}^{n})/\Delta \boldsymbol{t}$

here, $\boldsymbol{U}$ is the specified velocity and $\Delta \boldsymbol{t}$ is time increment. This method is called as “an embedded boundary method,” thus the velocity specified at the desired boundary which is not on the grid line can be determined to interpolate between the velocity at the neighboring grid of the desired boundary and the non-slip wall.

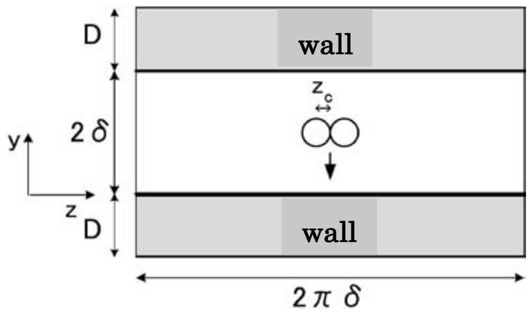

Fig. 1. Computational Domain

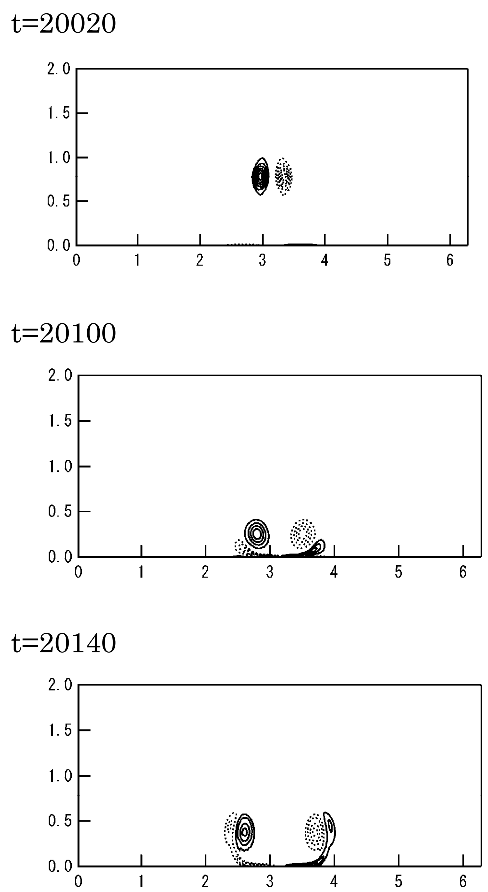

Fig. 2 Transient behavior of vortex dipole impingement

Fig. 1 shows the computational domain and the computational conditions are shown in Table 1. Figure 2 show the transient behavior of vortex dipole impingement. It can be discussed the magnitude of impinging disturbance.