§53. Fundamental Study of Wave Propagation on Liquid Surface Related IFE Mirror

Kunugi, T., Moriyama, Y., Yokomine, T., Kawara, Z. (Kyoto Univ.),
Norimatsu, T. (ILE, Osaka Univ.),
Sakagami, H.

A conceptual design of the laser fusion reactor KOYO-F based on the fast ignition scheme was reported including the target design, the laser system and the design for chamber[1] The final optical system of KOYO-F experiences the direct exposure to the target emission including neutrons, x-rays, high-energy ions and the debris. The solid metal mirrors in the final optical system may receive a severe damage from the neutrons[2]. In particular, the neutron irradiation mirror will produce the hydrogen gas inside the liquid metal film and cause the swelling deformation. This is fatal to optical mirror usage. If the surface were composed of a thin liquid metal film, (Grazing Incidence Liquid Metal Mirror, GILMM), the surface imperfections would heal due to the surface tension, and the hydrogen gas would easily remove from the mirror. According to the conceptual design of the fast ignition laser fusion power plant,1 the amplitude of the induced surface wave is required to damp to less than 1/10 of the wavelength during 250 ms for the optical mirror usage. In this paper, the experiments using the water instead of the mercury were carried out to grasp the liquid-surface wave formation and its propagation due to the impact of a projectile. In order to investigate the liquid surface behavior, we used a projectile impact to simulate the 1 ms duration pulsed laser irradiation, and we used tap water as a surrogate fluid because it is easily handled comparing with the liquid metal and has same order of waver number which is a dimensionless number that represents stability of surface wave (Water has 2.07 times larger Weber number than mercury). Since the liquid itself cannot be moved drastically in such a short duration, there is no influence of the liquid species, and moreover the sound speeds of water and mercury are almost the same: ~1500 m/s. Therefore, the use of a projectile impact and water reasonably represent the design conditions which are the duration of the laser pulse of 1 ms and the pressure of ~10 kPa. Figure 1 shows the schematic view of the experimental apparatus.

The thin water film was prepared on an acrylic resin vat of 300 mm x 300 mm. A rod as a projectile was dropped to this water film. This rod was a 100 mm long thin acrylic stick with 20 mm of radius thin acrylic circular-plate on its terminal. This rod was dropped vertically through the guide tube coupled with the stick, and impacted on the water film surface with the circular plate. The displacement of water surface caused with the impact of the rod was measured by a laser confocal displacement meter. The displacement meter was placed vertically upward, and its laser focused on the observation point (i.e., water surface) from the bottom of vat. The observation point was located at 30 mm from the center of the impact rod. The experiments were performed for the water film thicknesses of 1, 2, 3, 5 and 7 mm as shown in Fig. 2 (as an example). The spatial resolution of the displacement meter was 1 μm and the time resolution was 1 ms. In this experiment, we focus on the propagation of wave on liquid film and not intent to simulate laser impact on liquid metal mirror strictly.

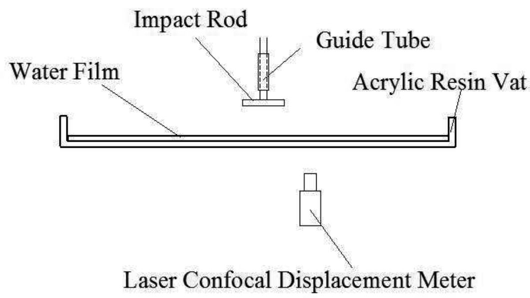

Fig. 1 Schematic diagram of the measurement system

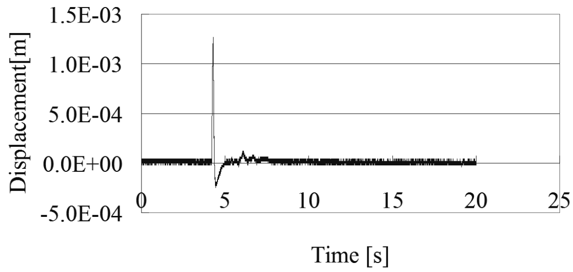

Fig. 2. Time Series of Water Surface Displacement (1 mm Thickness of Water Film)

To clarify the relationship between thickness of liquid film and surface wave propagation, the experiments using water as a surrogate liquid and the computation with the MARS[3] were performed. The experimental results showed the relationship between the wave damping and the thickness of water film: The wave amplitude was suppressed with decrease of the thickness of the water film. Especially, the wave rapidly damps in case of less than 3 mm of the water film. This suggests that the usage of the thinner liquid mirror can be used as an effective manner for surface wave suppression. In addition, the preliminary wave propagation simulations were performed by using the MARS. The difference of wave propagation and its mechanism are discussed based on the computational results. It was shown that the waveform obtained by the computation met the feature of waveform obtained by the experiment.

1) Kozaki, Y., et al.: J. Plasma Fusion Res., (2006) 82, 817
2) Tillack, S. et. al.: Fusion Sci. Technol., (2009) 56, 446
3) Kunugi, T.: Comput. Fluid Dynamics J., (2001) 9, 563