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# ISS 軌道実験で得られた密閉容器内スロッシング現象での周波数応答に関する検証

# Verification of on-orbit experiments aboard the ISS on frequency response in sloshing phenomenon

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For future space explorations such as the ARTEMIS program[1)] and the "Moon to Mars" program[2)], the elucidation of gas-liquid two-phase flow is essential and indispensable. The lunar rover being developed for lunar surface operations and the Space Launch System (SLS) rocket, for instance, are equipped with liquid tanks: Extreme liquid motion in the tanks must be controlled because it would lead to vigorous momentum variation as well as leakage of liquid from the tanks, resulting in horrible accidents that must be avoided. The Japan Aerospace Exploration Agency (JAXA) conducted a series of experiments on behaviors of liquid partially filled in different types of closed vessels on the International Space Station (ISS) in 2022. One of these experiments is on the sloshing phenomenon within a small rectangular container[3)] (**Fig. 1** (a) and (b)). In the on-ground experiments with the Engineering Model[3)] as well as the on-orbit experiments, a peculiar frequency response of the liquid was identified (**Fig. 1** (c)). This study focuses on the response of liquid partially filled in a rectangular closed vessel in swinging motion.

Target geometry of the present study is rectangular vessel: **Figure 1** illustrates the front views of small

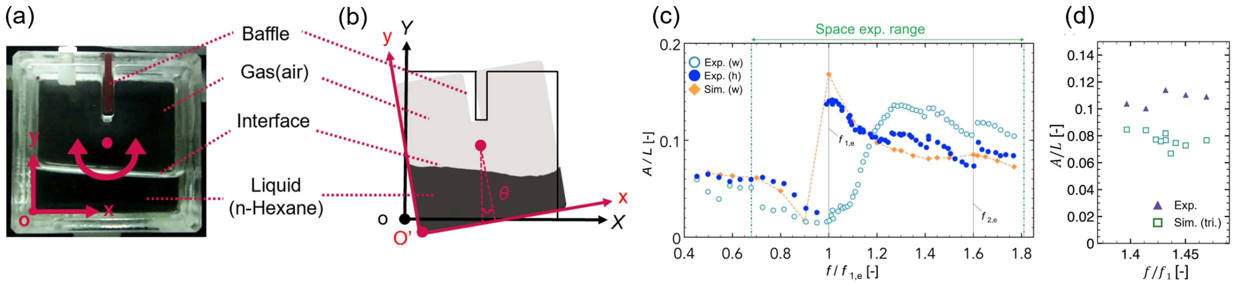


**Figure 1**. Small rectangular container used in (a) ground experiment and (b) numerical simulation, and frequency responses of liquid motion under initial liquid level $h_0$ = 9.33 mm by (c) on-ground experiments[3)] with water (as denoted as (w)) and n-Hexane (as denoted as (h)) and by (d) present numerical simulation by applying triangle wave with n-Hexane.

rectangular container used in (a) the on-ground experiments and (b) the numerical simulations. The container is reciprocally swung around a rotating axis (as shown in the circle) normal to the front and rear panels. In the experiments, the vessel is oscillated by the stepping motor. The oscillation is realized by varying the angle via triangle wave with the designated period corresponding the inverse of excitation frequency. The motion of gas-liquid interface is observed with a digital camera from the front of the vessel. The detail of apparatus is introduced in Ref[3]. The test liquid and gas in the vessel are n-Hexane and the air, respectively. In the numerical simulation, the behaviors of test fluids are reproduced by the equations of continuity and Navier-Stokes equation by applying the Continuum Surface Force (CSF) method. These governing equations are solved by the InterFoam solver of OpenFOAM (ver. 9).

To elucidate peculiar frequency response of induced motion (*e.g.*, at $f/f_{1,e}$ ~ 1.4 in **Fig. 1** (c)), a series of numerical simulation with oscillating the vessel by applying not only the sinusoidal function[3] but also the triangle function. **Figure 1** (d) shows a typical example of the correlation between the amplitude of gas-liquid interface oscillation and excitation frequency with the initial liquid level $h_0$ = 9.33 mm by applying the triangle wave. The on-ground experimental results are also plotted. The excitation frequency of triangle function is defined as the inverse of fundamental period $\tau^{(tri)}$, $f^{(tri)}$: $=1/\tau^{(tri)}$. Slight bump of the amplitude is successfully reproduced at around $f/f_1$ ~ 1.43 (or $f^{(tri)}$ = 6.33 Hz) by numerical simulation. In the poster presentation, we will discuss the effect of temporal variation of swinging angle on sloshing phenomenon.

## References


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