Fachbereich 4
Produktionstechnik
Maschinenbau &
Verfahrenstechnik

CENTER OF
APPLIED SPACE TECHNOLOGY
AND MICROGRAVITY
ZARM

Fluids and Space Engineering Seminar

Date: Wednesday, June 12, 2019 at 13:00
Location: ZARM, Room 1730

Sloshing experiments: from linear to nonlinear dynamics

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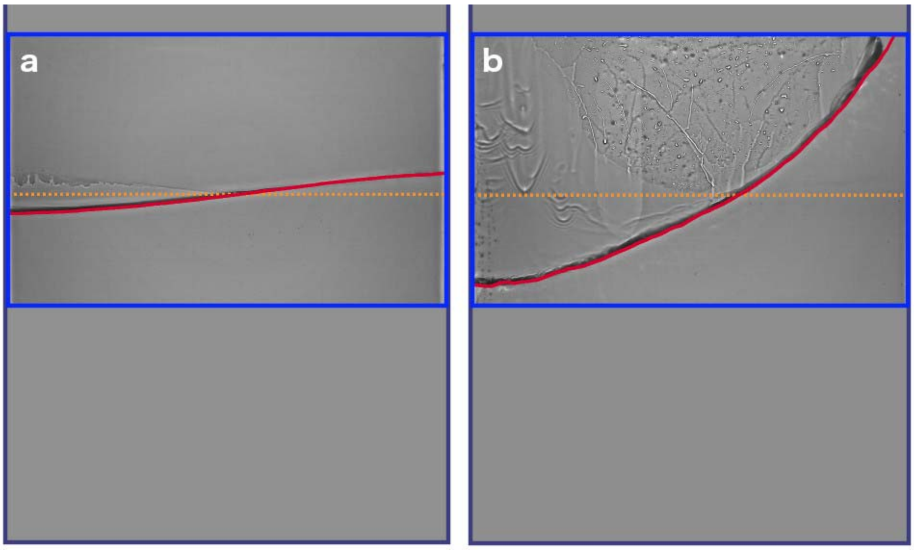

Fig.1 Identical driving parameters lead to different sloshing modes depending on the initial condition (hysteresis). The red lines mark the free surface detected by image processing, whereas dashed orange indicates the quiescent surface. The blue boxes display the field of view of the camera.

Sloshing motion of fluids occurs in partly filled containers subjected to vibrations, oscillations or more generally under non-uniform accelerations. The resulting shift of mass and impact on the container walls are the phenomena most relevant for engineering. In spacecraft tanks, sloshing can pose a threat, whereas in skyscrapers it has been exploited to damp energy following an earthquake. Hence, many studies have focused on the details of the occurrence of sloshing in complex or shallow tank geometries and on developing nonlinear models for simulations.

In this talk, we take a different approach and revisit experimentally the fundamentals of deep water sloshing in a rectangular container under harmonic oscillation. Besides the well-known linear response, we observe nonlinear effects like hysteresis, shifts of the resonance frequency and period-three motion. Surprisingly, all these effects are quantitatively captured by the Duffing equation. Even though this equation was developed already 100 years ago to describe nonlinear oscillations, a quantitative agreement with experiments has so far only been observed for simple one-dimensional systems such as the pendulum. We believe that our experiments bridge the gap between theoretical studies of the Duffing equation and the extremely complex sloshing phenomena in engineering.

In the second part of the talk, we correlate the shape of the sloshing waves to the flow field in the bulk. We reveal large-scale circulations filling the entire container in the vicinity of the resonance frequency. These vortices can only be observed by subtracting the purely periodic motion and have therefore not been noticed before. Their characterization paves the way for quantifying and predicting fluid mixing in sloshing tanks.