

12. Saltwater Oscillator Forcibly Induced by Magnetic Force (Videos: 23–28)

<Explanation>

The saltwater oscillator denotes a non-linear phenomenon that can be observed when vertically neighboring liquids of different densities are periodically exchanged in a small orifice. For a conventional saltwater oscillator, a liquid with a larger density is placed above another liquid with a smaller density. The difference in the head between the two liquids, namely the gravity, functions as a driving force.

In the case of this research, a gadolinium chloride solution with a smaller density is put on saltwater with a larger density so that both liquids can keep contact with each other in an orifice of 0.8 mm in diameter and 1.0 mm in length. Since this condition is stable, no exchange of liquids can occur, and therefore no saltwater oscillation can be observed.

In this state, a downward magnetic force is applied perpendicularly. Since the solution of gadolinium chloride is paramagnetic, it is attracted downwards and enters the saltwater-side domain through the orifice. When the intensity of magnetic force is so adjusted, it is possible to induce a saltwater oscillator forcibly.

In this experiment, the density of gadolinium chloride solution was fixed at a constant level of $1.03 \times 10^3 \text{ kg/m}^3$ and that of saltwater was changed in four ways: to (A) $1.15 \times 10^3 \text{ kg/m}^3$, (B) $1.12 \times 10^3 \text{ kg/m}^3$, (C) $1.09 \times 10^3 \text{ kg/m}^3$, and (D) $1.06 \times 10^3 \text{ kg/m}^3$. The flux density was also changed from 0 T to 4 T. The results of this experiment gave us some interesting knowledge about the behavior of liquid flow and oscillatory frequency.

<Small difference in density between saltwater and gadolinium chloride solution (cases C and D)>

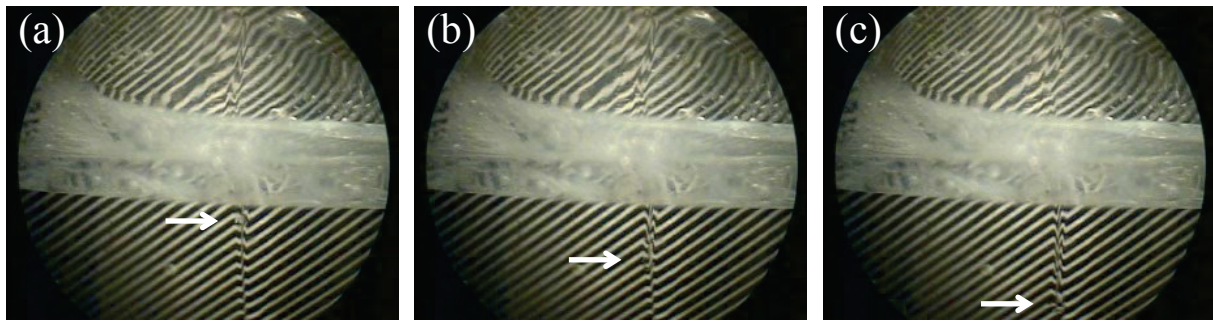
At 2.53 T and above, we observed a conventional saltwater oscillation. Such a flow shall be called the alternating upward and downward flow (AUD flow hereafter). (Video 23)

On the one hand, there is no saltwater oscillation below 2.53 T. A specific type of flow was observed in which an upward flow and downward flow run out of the orifice at the same time. The behavior of such flows resembles a phenomenon called “bifurcation” in the field of saltwater oscillator. Here, we shall call it the simultaneous upward and downward flow (SUD flow hereafter).

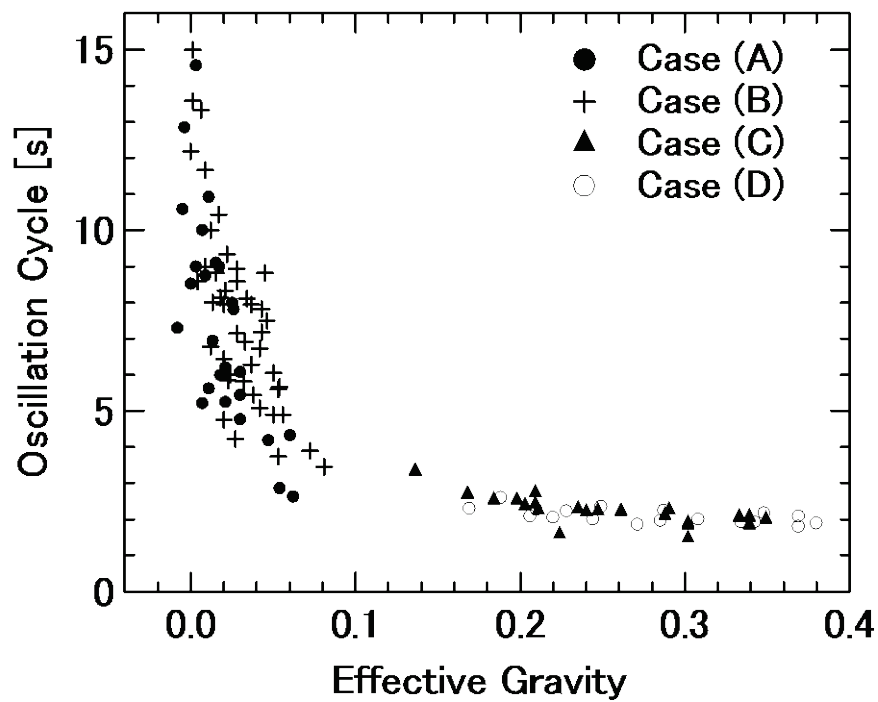
<Large difference in density between saltwater and gadolinium chloride solution (cases A and B)>

When there was a large difference in density between saltwater and the gadolinium chloride solution and the intensity of magnetic force was comparatively small, a swollen portion like a knot periodically appeared in the SUD flow, as shown in the images below (white arrow mark). This flow looked like a new type of flow where both the periodicity in the AUD flow and the characteristic of the SUD flow are combined. This type of flow shall be called the periodically locally thickened flow (PLT flow hereafter). (Videos 24–26)

At 2.60 T and above, the PLT flow turns into a SUD flow. (Videos 27 and 28)



When we use the quantity of effective gravity, where the intensity of magnetic force is converted into gravity, we can recognize a relationship between the intensity of magnetic force and the cycle of PLT flow knot appearance and that of oscillation by the saltwater oscillator, as shown below. Refer to [1] in regard to case (D) and to [2] for cases (A) to (C).



<Place of execution>

Faculty of Pharmacy, Osaka Ohtani University

<Research papers>

[1] S. Maki, C. Udagawa, S. Morimoto, and Y. Tanimoto,
“Induction of rhythmic flow with a vertical magnetic force”,

Journal of the Physical Society of Japan **82**, pp. 033402-1-4, (2013).

[2] S. Maki, C. Udagawa, S. Morimoto, and Y. Tanimoto,

“Periodical oscillation phenomena observed in salt-water oscillator experiments under small gravity conditions”,

Microgravity Science and Technology, in press.