The effect of rotation on resonant frequency of interfacial oscillation of a droplet using electrostatic levitator

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Introduction

Under gravity condition

Liquid body is in contact with container.
It is difficult to treat high-temperature molten materials.

Under microgravity condition

It is possible to treat molten materials without container, and measure physical properties of liquid metal which is higher than 3000 [K].

http://www/jaxa.jp/

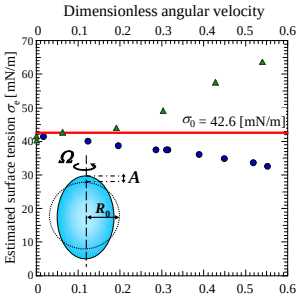
In recent years, it has become possible to use non-contact measurement by levitator under gravity(1).

【 Oscillation drop method for surface tension measurement(2) 】

$$\sigma = \frac{\rho R_0^{\,3} f^{\,2}}{8}$$

σ : Surface tension [N/m]
f : Resonant frequency [Hz]
ρ : Droplet density [kg/m³]
R : Droplet radius [m]

Oscillation & rotation would change the resonant frequency(3).



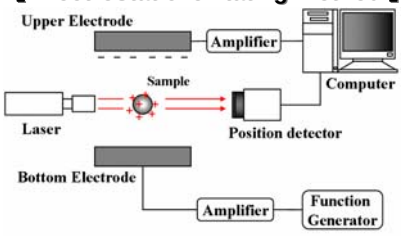
Surface tension measurement

Objectives

- To investigate the effects of oscillation and rotation on resonant frequency shift of levitated droplet in experiment.
- To discuss the factor of frequency shift.

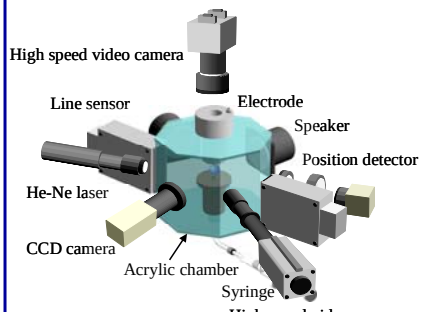
Experimental apparatus

【 Electrostatic levitating method 】



Coulomb force levitates a liquid droplet.

【 Schematic diagram 】

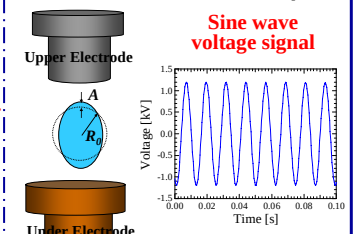


【 Test fluid 】

Propylene carbonate

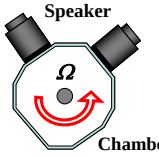
Droplet diameter *D* [mm]	Density ρ [kg/m³]	Surface tension σ [mN/m]	viscosity μ [mPa·s]
1.6 ~ 2.6	1205.7	42.6	2.77

【 Method to oscillate droplet 】



Dimensionless amplitude A / R_0

【 Method to rotate droplet 】



Dimensionless angular velocity Ω / ω_0 $(\omega_0 = 2\pi f_0)$

Observation results

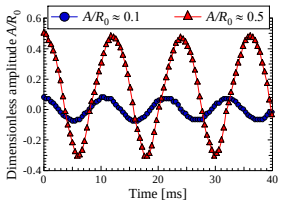
Small amplitude oscillation ($A / R_0 \approx 0.1$)

Large amplitude oscillation ($A / R_0 \approx 0.5$)

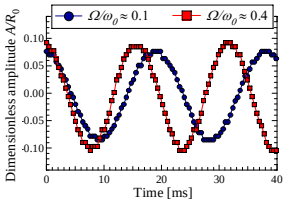
Oscillation with rotation ($A / R_0 \approx 0.1$, $\Omega / \omega_0 \approx 0.4$)

Effects of oscillation and rotation

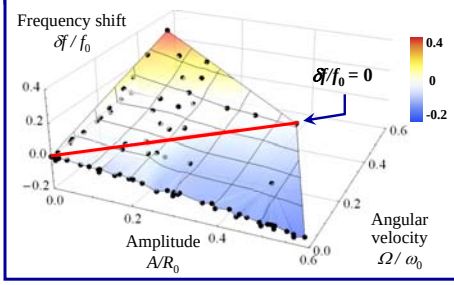
【 Resonant frequency of a droplet 】



Effect of oscillation

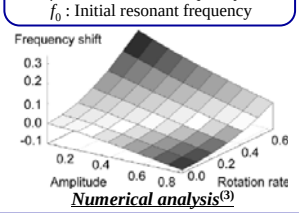


Effect of rotation



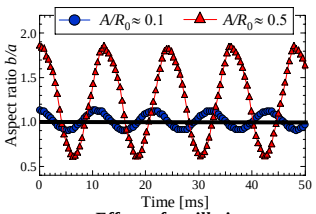
Frequency shift $\delta f/f_0$: $\dfrac{\delta f}{f_0} = \dfrac{f - f_0}{f_0}$

f : New resonant frequency
f_0 : Initial resonant frequency

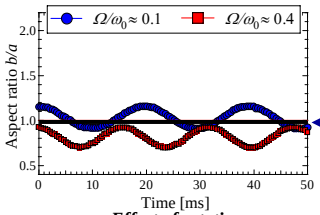


Numerical analysis(3)

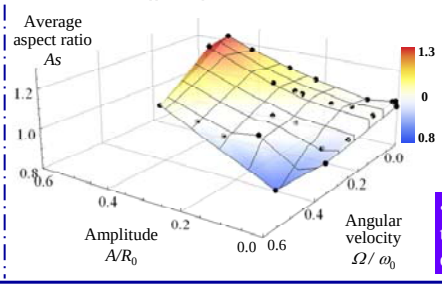
【 Droplet shape 】

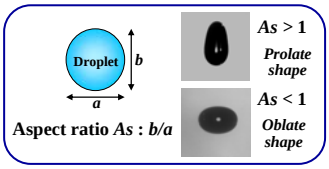


Effect of oscillation



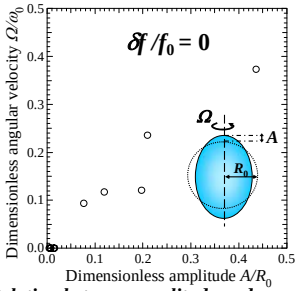
Effect of rotation



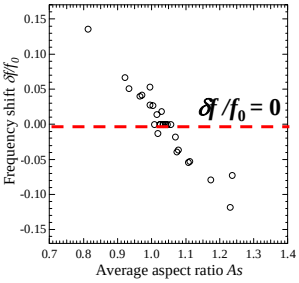


- Average aspect ratio increased due to increase of amplitude, decreased due to increase of angular velocity.

Discussion



Relation between amplitude and angular velocity making frequency shift about 0



Relation between average aspect ratio and frequency shift

- Combination of oscillation and rotation made frequency shift about 0.
- Average aspect ratio correlated with frequency shift.

Conclusion

We observed behaviour of a levitated droplet by using electrostatic levitator. As a result, following discussions are acquired:

- The resonant frequency of a levitated droplet was measured. It is confirmed that the resonant frequency decreases due to increase of amplitude, and increases due to increase of angular velocity.
- It is suggested appropriate combination of oscillation and rotation makes frequency shift 0 in experiment.
- It is suggested that average aspect ratio correlates with frequency shift in experiment.

References

(1) Ishikawa T, Okada J T, Paradis P F and Watanabe Y 2010 Int. J. Thermophysics 31 388
(2) Rayleigh L, 1882 Phil. Mag.14184
(3) Watanabe T, 2009 Physics Letters A

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