Experimental Measurement of Vibration of Liquid Droplets

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Abstract. Droplet vibration finds numerous applications in inkjet printing, combustion sprays, drop atomization and so on. In several of these processes, the primary interest is to know the resonant frequencies and mode shapes of the drops. The variation ofexperimentally determined resonant frequencies with Bond Number is explored and found to be in good agreement with a 1D capillarygravity wave model.

• INTRODUCTION

Droplet can be slipped due to a pressure difference caused by the hysteretic movement of the liquid on the super-hydrophobic stripes forces the liquid to move away from the super-hydrophobic area to the hydrophilic area.

There are different technique to study the behaviour of the droplets.

the two major technique are using

1. using piezometer (pressure)
2. Using speaker (resonance)

In both technique the mat lab programme is generated using this programme the sinusoidal wave are generated and is passed into the different device.

Using piezometer where the pressure is created under the transducer which vibrates the liquid droplets which has dropped on the surface placed on transducer.

Using speaker where the resonance is created in the speaker which a small platform is placed on speaker the resonance which created from speaker creates a sound waves

While first contact angle is measured by using VCA systems where image is captured from 600mm distance by using micro-lens from high resolution camera.

For measuring the contact angle we need to download a software called imagej software with drop analysis plugin.droplet image is converted into grayscale and contact angle is measured in drop analysis.

Using this contact angle and the radius of the droplet where natural frequency of the liquid by Lamb developed an expression for the natural frequency of these spherical drops neglecting the effect of gravity interms drop volume (V), surface tension (σ) and density (ρ)

$$\omega = \sqrt{\frac{n(n-1)(n+2)\sigma}{\rho r^3}}$$

an experimental analysis of resonant frequency of droplets in first resonant mode was carried out by using electromagnetic speaker.The amplitude of vibrations was large enough to observe resonance using a high speed camera.

The effect of substrates on the free vibration of drops was studied later by partially supporting liquid drops , the results of which conformed to the relation between the drop radius and frequency as given by Lamb.the vibrations of these drops are not completed until it taken further till theoretically.A loudspeaker with a signal generator and power amplifier was used for excitation and images were captured using a digital camera (60fps). It was noted that for contact angles from $0^o to 60^0$ the frequency parameter increased, attained a maximum value between contact angles from $60^o to 80^o$, and then decreased for contact angles greater than 80^o . However, for the drop volumes considered, the theoretical model, failed to predict the frequencies for the cases when contact angle was less than 30_ because the curvature of the drops was found to be more the than the capillary length $(l_c = \sqrt{\sigma / \rho g})$ of the liquid causing the gravity effects to be dominant. Vertical vibration of sessile drops on a hydrophobic surface was experimentally carried out using loudspeaker as excitation source and a high speed camera for capturing the mode shapes.

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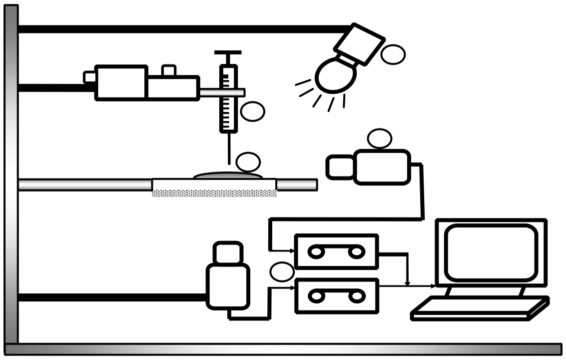
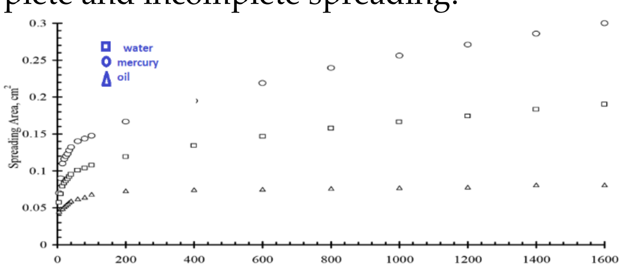
Experimental setup and measurements



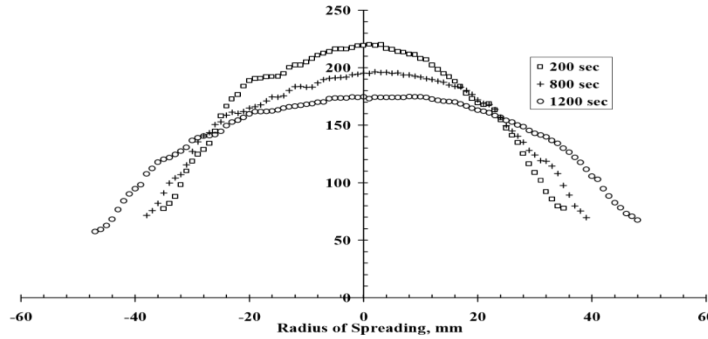
Electronic speaker with different has been used to characterize the droplet vibrations. Fundamental principle being that the path length of light passing through the drop would change due to change in surface geometry at resonance. To the best of our knowledge, this technique has been used in this work for the first time for such application. The technique enables characterization of extremely small size droplets. A customized setup, consisting of a leveller substrate vibrated using a standard loudspeaker, is built to interface with Micro map. The surfaces are cleaned with acetone and distilled water before each measurement. Experiments are conducted in an isolated environment to eliminate the effect of noise and air currents. The drops are repeatedly changed to reduce the effect of evaporation. Resonance is accounted by the sharpness and an increase in the number of fringes observed at a particular frequency. The amplitude of oscillation is kept very low so as to get discernible difference in the number of fringes near the resonant frequency of the drop. To ensure repeat-ability and the accurate determination of the resonant frequency, the oscillation amplitude is varied to control the number of fringes obtained at and around the specific frequency.

- **Experimental results and graphs .**

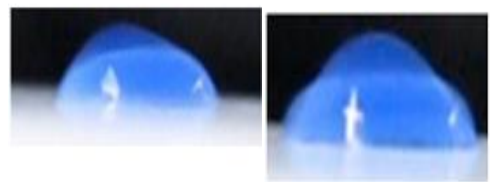
  Two stages of spreading showing complete and incomplete spreading.



Time sequence height profiles of water drop spreading.



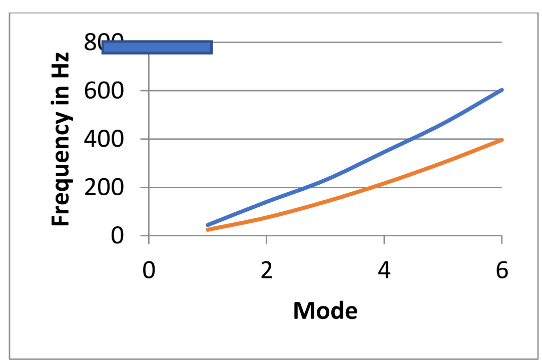
RESULT



Mode 1 Mode 2

Mode	Frequency in Hz (Theory)	Frequency in Hz (Experiment)
1	10	11.5
2	21	23.5

- **Drop oscillations.**



- # Conclusion

The frequency response for vertical vibrations of water drops of different volumes on hydrophilic and hydrophobic substrates are observed using a novel experimental technique, Electronic Speckle Pattern Interferometry(Fringe patternsfor first three axisymmetric and non-axisymmetric modes are correlatedwith the theoretical and experimentally observed drop shapes. A 1D capillary gravity wave model is used to compare the frequencies, the results for which are quite consistent. A dimensionless frequency parameter is used to compare the behavior of resonant frequency on the PS and PDMS substrates with Bond number. The frequencies are found to be higher for the PS substrate, which agrees with the contact angle dependence given in previous findings.

- **REFERENCES**

[1]Cengel, Y. A. and Cimbala, J. M., “Fluid mechanics: fundamentals and applications,” Boston: McGraw-Hill HigherEducation, 2010.

[1] Lord, K., Mathematical and Physical Papers, Vol-IV, Cambridge University Press,Cambridge, 1882.

[2] Rayleigh, L., The theory of sound, Macmillan and Co, London, 1877.

[3] Lamb, H., Hydrodynamics, Cambridge University Press,Cambridge, 1945.

[4] Perez, M., Brechet, Y., Salvo, L., Papoular, M., and Suery, M., “Oscillation of liquid drops under gravity: Influence ofshape on the resonance frequency,” Europhysics Letters, Vol. 47, No. 2, 1999, pp. 189-195.

[5] Strani, M. and Sabetta, F., “Free vibrations of a drop in partial contact with a solid support,”Journal of Fluid Mechanics,Vol. 141, 1984, pp. 233-247.

[6] Wilkes, E. D. and Basaran, O. A., “Forced oscillations of pendant (sessile) drops,”Physics of Fluids, Vol. 9, No. 6, 1997,pp. 1512-1528.

[7] Celestini, F. and Kofman, R., “Vibration of submillimeter size supported droplets,”Physical Review E - Statistical,Nonlinear, and Soft Matter Physics, Vol. 73, No. 4, 2006.

[8] Sharp, J. S., Farmer, D. J., and Kelly, J., “Contact angle dependence of the resonant frequency of sessile water droplets,”Langmuir, Vol. 27, No. 15, 2011, pp. 9367-9371.

[9] Noblin, X., Buguin, A., and Brochard-Wyart, F., “Vibrations of sessile drops,”European Physical Journal: SpecialTopics, Vol. 166, No. 1, 2009, pp. 7-10.

[10] Foote, G. B., “A numerical method for studying liquid drop behavior: simple oscillation,”Journal of ComputationalPhysics, Vol. 11, No. 4, 1973, pp. 507-530.

[11] Lokberg, O. J., “ESPI - The ultimate holographic tool for vibration analysis?”Journal of the Acoustical Society ofAmerica, Vol. 75, No. 6, 1984, pp. 17831791.

[12] Petzing, J. N. and Tyrer, J. R., “Recent developments and applications in electronic speckle pattern interferometry,”Journal of Strain Analysis for Engineering Design, Vol. 33, No. 2, 1998, pp. 153-169.

[13] Sharp, J. S., Farmer, D. J., and Kelly, J., “Contact angle dependence of the resonant frequency of sessile water droplets,”Langmuir, Vol. 27, No. 15, 2011, pp. 9367-9371.

[14] Noblin, X., Buguin, A., and Brochar, W., “Vibrated sessile drops: Transition between pinned and mobile contact lineoscillations,”European Physical Journal E, Vol. 14, No. 4, 2004, pp. 395-404.

Brutin, D., Zhu, Z., Rahli, O., Xie, J., Liu, Q., and Tadrist, L., “Sessile drop in microgravity: Creation, contact angleand.