Measuring Surface Tension with Faraday Waves

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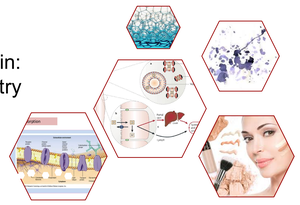
Abstract

Surface tension is a macroscopic property of liquids caused by differences in molecular cohesion forces between the bulk liquid and the interface. Surface tension determines the wettability and absorption of liquids. It has important implications in detergent industry, cosmetics and drug discovery. Here, we use a novel technique to measure surface tension by creating 2D Faraday waves in small, confined cell called a Hele-Shaw cell and speakers. Results from dynamical systems with high-speed photography and image processing are combined to extract the time-dependent shape of the liquid interface and, consequently, the value of the surface tension. Our results show that this approach is effective in determining the surface tension in a variety of liquids provided that the wavelength is experimentally calculated and excitation frequency is known.

Introduction

Surface Tension has uses in:

1) Detergent & Soap industry
2) Ink production
3) Drug Discovery
4) Cosmetics
5) Lipid research



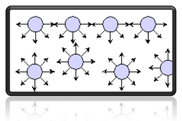


Fig. 1 cohesion and adhesion forces in a liquid (left)

Question

Can we measure surface tension using a variation in wavelength of vibration?

Hypothesis

Wave data from vibrating liquid on speaker can yield necessary properties to calculate wavelength. Surface tension is measured in Force/length or Energy/area needed to break a film or a layer where:

$\omega_0^2 = K*\tanh(K*h) * [g+(T/rho)*K^2]$ simplified for $k*h>>1$

$\omega_0^2 = g*K + (T/rho)* K^3$ where frequency is ω_0, wavenumber is $K = 2\pi/\lambda$, and layer depth is h.

Procedure

1. Record video of liquid with 20-200 Hz excitation frequency
2. Extracting frames
3. Processing: binarizing images, and obtaining edges
4. smoothing waveform

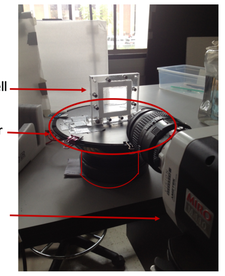


Fig. 3: set up (right)

Results and Analysis

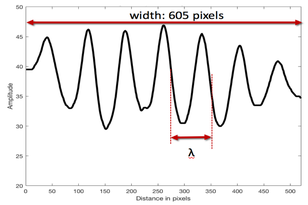


Fig. 4: Extracting a smooth and clean data is from experimental data is im this is also an advantage over a bath of 3D Faraday waves.

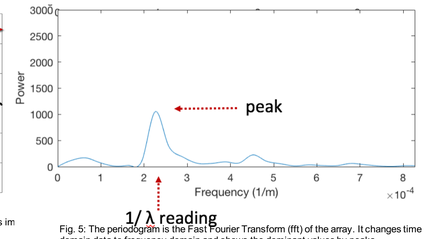


Fig. 5: The periodogram is the Fast Fourier Transform (fft) of the array. It changes time domain data to frequency domain and shows the dominant values by peaks

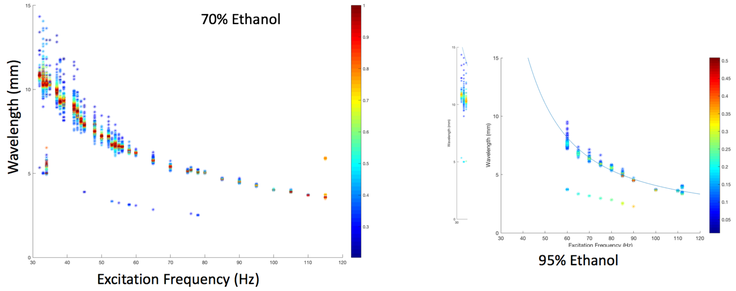
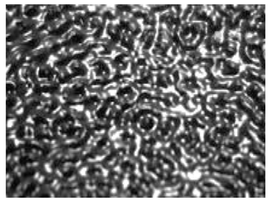
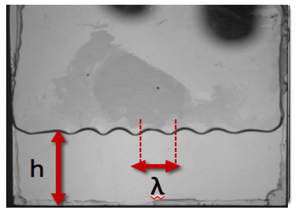


Fig 6: Theoretical line superimposed on experimental results



3D Faraday Waves



2D Faraday Waves

Fig. 1 Controlled dimension in 2D waves gives us a clear interface to work with

Discussion

State-of-the-art techniques in measuring surface tension, such as the Du Noüy ring method, contact angle measurement, or pendant drop method, all require either relatively large amount of fluid, expensive equipment or exposure to the fluid. This may be prohibitive when considering biological fluids, or scarce, toxic, or expensive materials. In particular, we show that this method works even in closed, highly confined geometries, and thus requiring very small amount of fluid and no exposure. These findings will allow the development of low-budget methods for characterizing surface tension properties using only small liquid volumes, signifying implications in industry.

Conclusions

- Measure surface tensions of different liquids and check the accuracy with respect to accepted values
- Design a commercial equipment for low-budget, small and contained surface tension measuring instrument

References

S. Douady: *Experimental study of the Faraday instability*

Acknowledgements

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