Wave Structures On A Jet Entering The Bulk Liquid

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Project Description

- When a water jet impacts the water surface, the water particles flow away from the equilibrium position due to the interference. Under the effect of the surface tension as the restoring force, the water particles will return to the equilibrium position. Afterwards, the particles continue to move toward the other side under the inertia effect, which forms vibration. As the vibration spreads, the free surface wave comes into being. Such wave is called Capillary Wave.
- The water velocity increases gradually as it falls down. When the water velocity is equal to the wave velocity, we can view the capillary wave with naked eyes.
- In this project, our purpose is to study the relation between the length and velocity of the capillary wave.

Scientific Challenges

While there are theoretical methods to determine surface tension, experimental data is difficult to measure with great accuracy. Smaller measurements especially can add large error to a model.

Potential Applications

Surface tension is currently being used in zoology to communicate with dolphins. A high surface tension allows sound waves to create an imprint on the water.

Anti-Fog agents are also developed by studying surface tension. These chemicals are designed to decrease surface tension so that individual water droplets cannot form on a solid surface.

Function

Laplace's equation

$\nabla^2\phi=0$

$\mathbf{v}=\nabla\phi$

$Z = h(x,y,t)$

$+ V_x \ +V_y \ = V_z$

So $= V_z$ since V_x and $V_y=0$

$h(x,y,t) = e^{ikx-iwt}$

$\phi = -iwh(x,y,t)\, f(z)$

Plug-in $= V_z$

So $-iwh = -iwhf'(z=h)$

So $f'(z=h) = 1$

So slove for the Laplace's equation

$f = e^{k(z-h)}=$ … Equation 1

Bernoulli Equation

$P_1 = P- \rho(+v^2+gh)$

We will ignore gravity, so $gh = 0$

Young's Equation

$P-P_1= \sigma (+)$

So $= (+)$

So $(-iw)(-iwh) = (-k^2h)$

So $-w^2h = (-k^2h)$

So $f(z=h) =$ ………equation 2

According equation 1 and 2

$1/k=\sigma/\rho \, . \, k\uparrow 2 \ /w\uparrow 2$

So $w^2=\sigma/\rho \, k^3$

ω is angular frequency

σ is surface tension number

ρ is density of the water

K is wavenumber and it is equal $2\pi/\lambda$

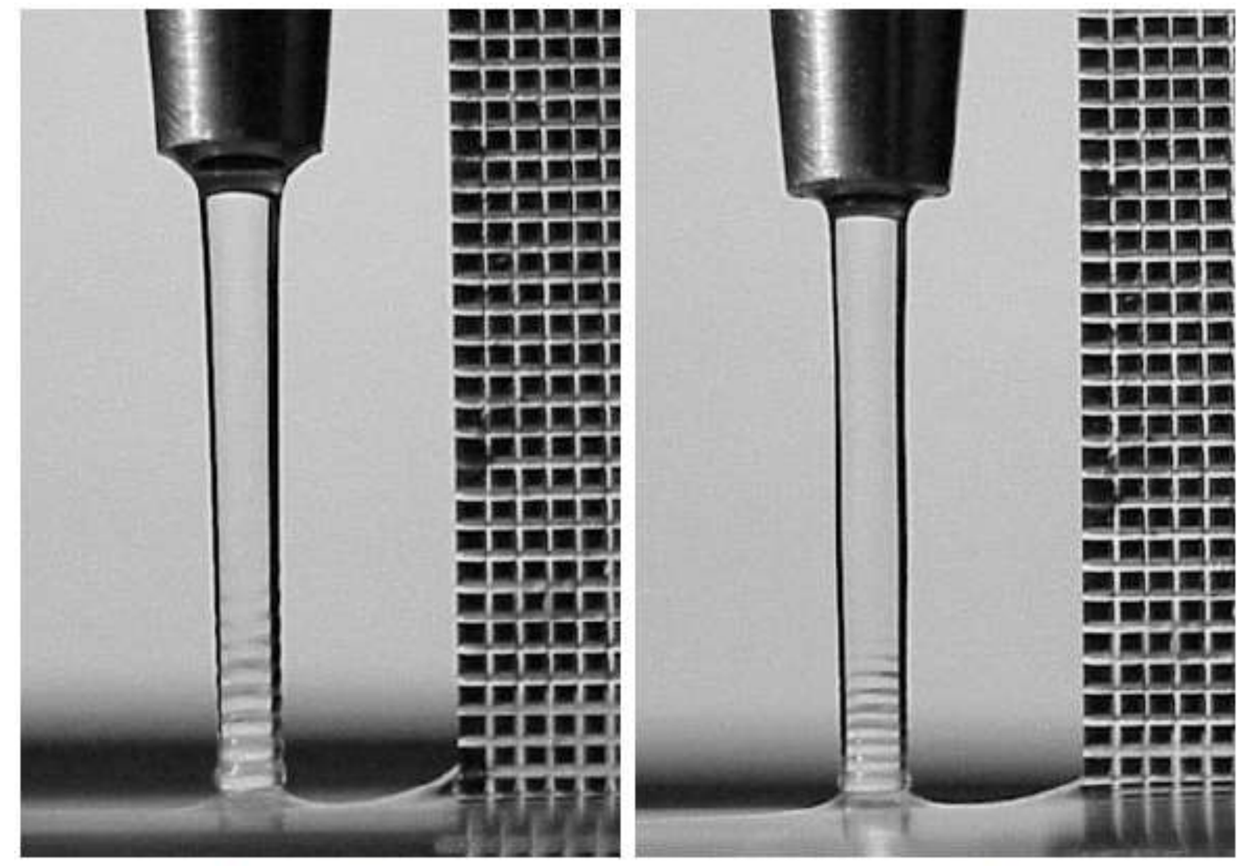

FIGURE 1. Water jets impinging on a pure water reservoir when (a) $Q = 3.2\,cm^3\,s^{-1}$, (b) $Q = 4.6\,cm^3\,s^{-1}$. The grid on the right is millimetric.

Methodology

1. Search materials and websites to find the correct surface tension.
2. Use reference material to understand the theory behind surface tension of a liquid. This theory should allow us to obtain a theoretical equation that can be applied to our model.
3. Perform the experiment to measure the data associated with a jet entering bulk liquid. This will include the jet velocity, wavelength, and jet size.
4. Collect the final data and create a graph, relating the wavelength and jet velocity. This relation will allow us to find surface tension.
5. Check out the graph and calculate the error bar function, then compare our experimental results and theory results.
6. Make a conclusion for our experiment and find out why did we have error.

References

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2. http://en.m.wikipedia.org/wiki.Capillary_wave
3. Laplace's equation; Bernoulli Equation; Young's Equation;
4. MATTHEW J. HANCOCK AND JOHN W. M BUSH, Fluid pipes, J.Fluid Mech.(2002), vol. 466, pp. 285-304, 2002 Cambridge University Press DOI: 10.1017/S0022112002001258;
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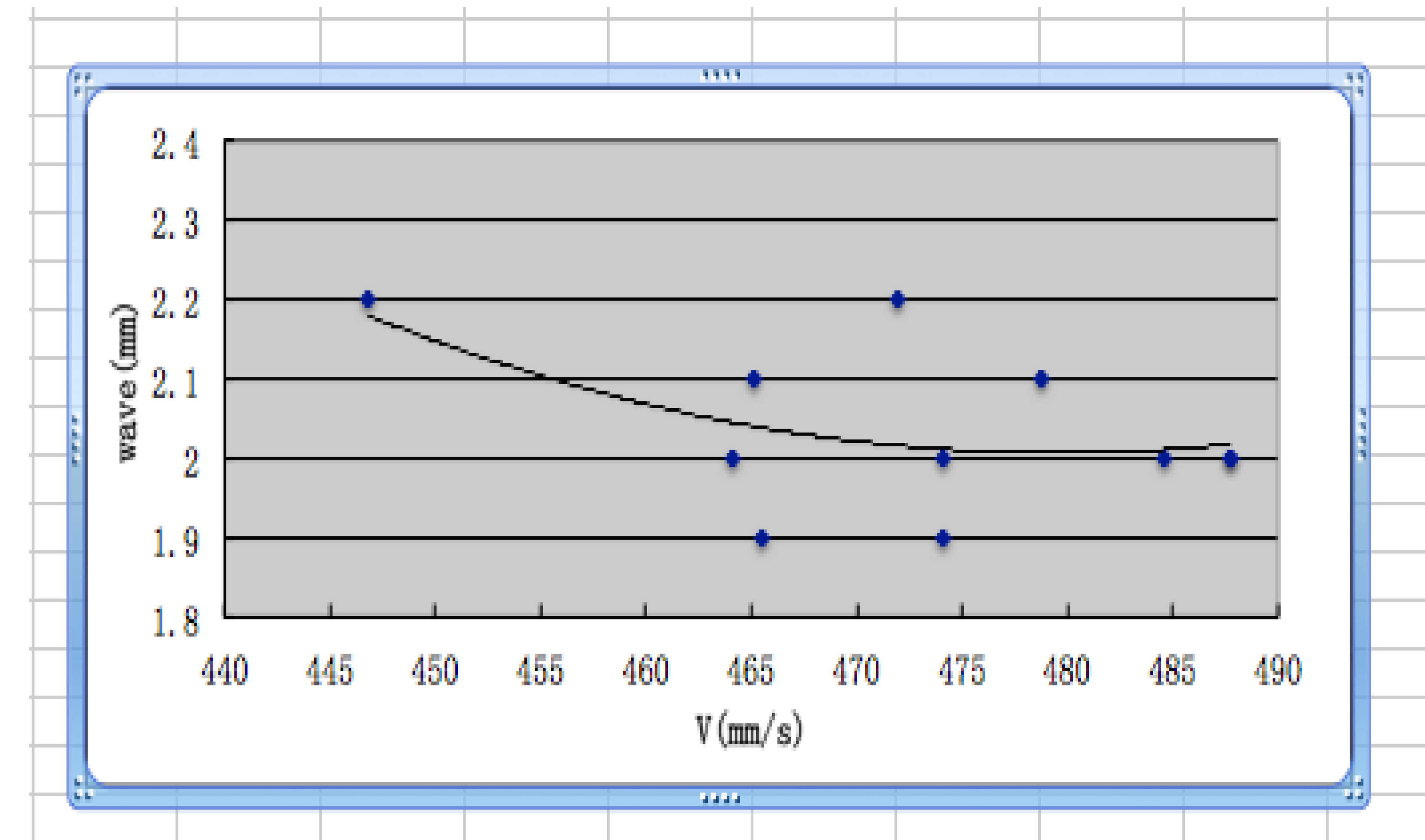
Results

Graph 1: Jet Wavelength vs Jet Velocity

Table 1: Experimental Data

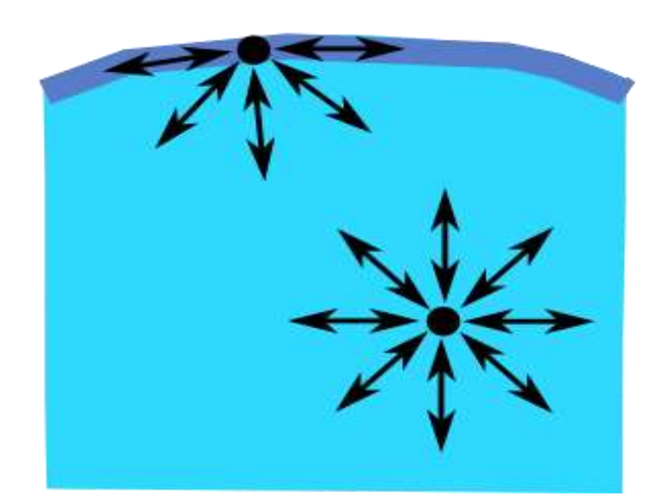


time(s)	flow(mm^3	r(mm)	v(mm/s)	wave(mm)	surfance
105.4	4677.419	1.6	465.5075	1.9	6.55*10^(-2)
110.4	4465.58	1.5	474.053	1.9	6.79*10^(-2)
99.5	4954.774	1.7	464.104	2	6.86*10^(-2)
109.3	4510.522	1.5	478.8239	2.1	7.64*10^(-2)
105.5	4672.986	1.6	465.0663	2.1	7.23*10^(-2)
110.4	4465.58	1.5	474.053	2	7.16*10^(-2)
110.9	4445.446	1.5	471.9157	2.2	7.78*10^(-2)
107.3	4594.595	1.5	487.7489	2	7.56*10^(-2)
108	4564.815	1.5	484.5876	2	7.47*10^(-2)
107.3	4594.595	1.5	487.7489	2	7.94*10^(-2)
109.8	4489.982	1.6	446.8533	2.2	7.29*10^(-2)

Glossary of Technical Terms

Surface Tension:

Surface tension is due to the imbalance of the molecular attraction on the surface layer.



Acknowledgments

This project was mentored by Ildar Gabitov, whose help is acknowledged with great appreciation.

Support from a University of Arizona TRIF(Technology Research Initiative Fund) grant to J.Lega is also gratefully acknowledged.