Exploring the Effect of Oscillating Boundary on Two-Dimensional Fluid Flow Using Soap Film

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Abstract

Fluid dynamics is a field shown to attract a great deal of attention for its alluring nature. Once a body is in path of a fluid, vortices will shed as a result. The phenomenon of vortex shedding is prevalent when there is a low Reynolds number because of low flow rates. Soap films have been shown to effectively provide a physical approximation of two-dimensional fluid behavior. In this study, the length and width of the film is significantly larger than the thickness that this can be considered two-dimensional. This particular film is on a vertical setup made up of a pulling mechanism with fishing wire. A Schlieren setup is utilized to visualize the disturbance in the film and demonstrate the effects of external factors, such as acoustics. The film will react to external factors by varying the thickness as a result of deformations within it. Sinusoidal oscillations on the soap film boundary with different frequencies and amplitudes are applied to study the effect on the flow. The soap fluid flow method has shown to demonstrate how two-dimensional fluids should perform by analyzing the thickness variation in the film. Studies of fluid flow can be applied at both a macro and micro level that impact a variety of natural and engineering systems such as the human circulatory system and the design of hydraulic structures.

Introduction

A soap fluid film has shown to be the closest physical approximation to demonstrate 2-dimensional fluid flow. The irradiances illuminated by a light source within the soap film will create new swirls, splits, and merges when a body propagates through it and allows us to study the body affects the film.

Properties of soap

- Soap is a thin layer of water protected by a hydrophilic polar head and hydrophobic hydrocarbon tail which encourages hydrophobic tail to move to the surface and away from the water *(as shown in Figure 1).*
- The changing surface tension of the film allows for more stability and elasticity.
- A thin film allows for higher viscosity, which in turn generates a lower Reynolds number and flow produced.

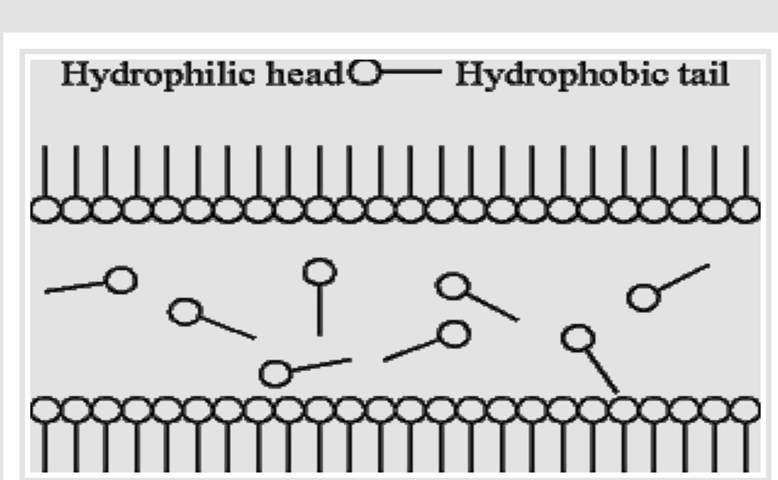


Figure 1: *Molecular structure of soap film*

Schlieren Visualization

- A series of convex lenses and concave mirrors placed to bend light rays, allowing for flow to be visualized *(as shown in Figure 2).*
- Light source passes through the lenses then a slit and bent with two mirrors
- Blade following last mirror is used to control contrast of the flow being recorded.

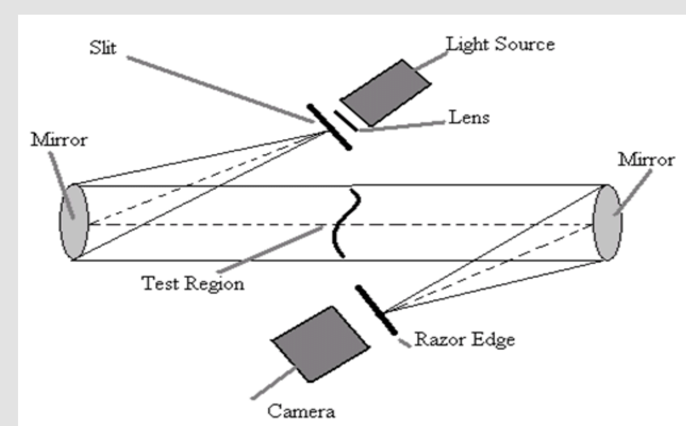


Figure 2: Display of Schlieren setup

Reynolds Number

- Ratio of inertial to viscous forces that helps predict whether flow will be laminar or turbulent (straight vs. irregular flow).
- Laminar flow is characterized as Re < 2000 ; Turbulent flow is characterized as Re > 4000.
- Transitional flow is a mixture of both, with turbulent flow at the center and laminar at the edges where 2000 < Re > 4000.

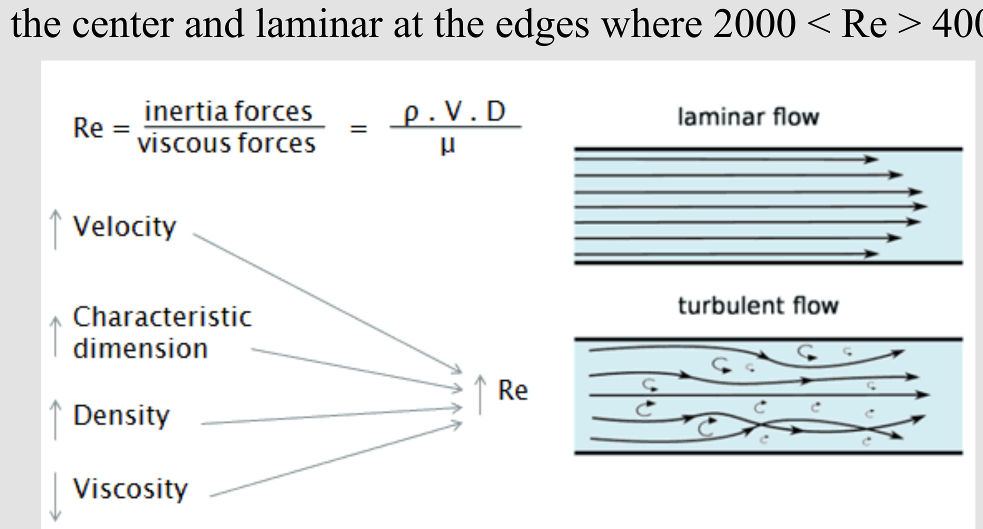


Figure 3: Explanation of Reynolds number

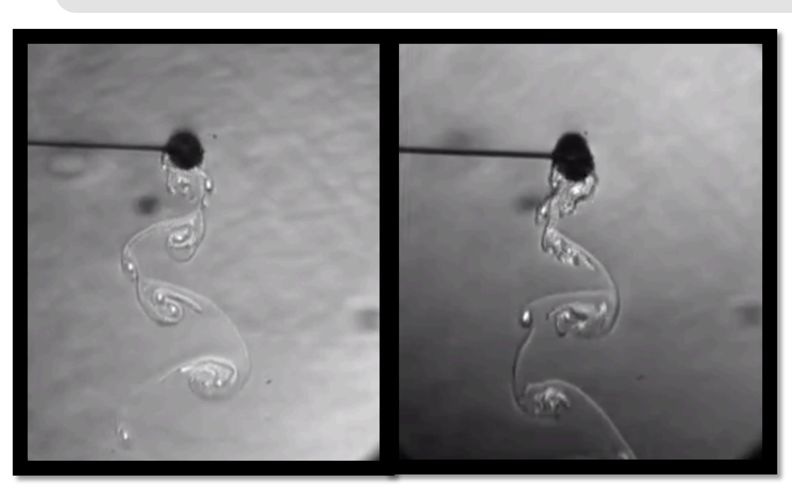
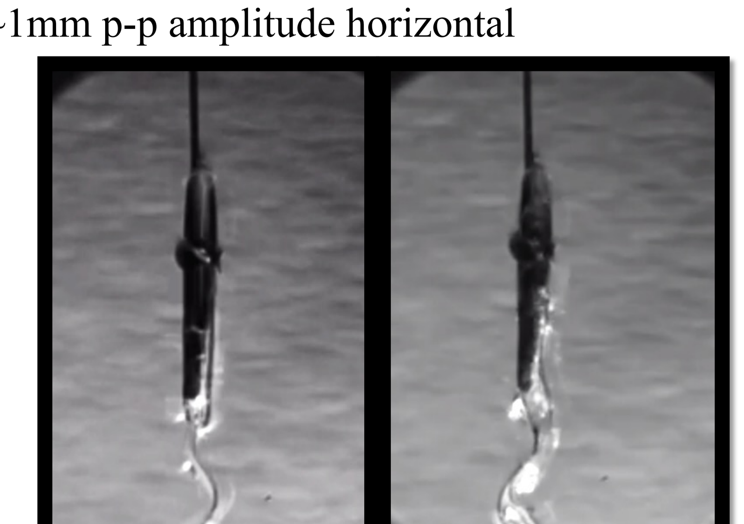


Figure 4: Image capture of vortices being formed with cylindrical body

Stationary *vs.* 200 Hz ~1mm p-p amplitude horizontal

Figure 5: Image capture of vortices being formed with aerofoil



Stationary *vs.* 75 Hz ~0.5mm p-p amplitude vertical

Case Study

Design

- Soap film is formed vertically with a pulling mechanism of fishing wire and a soap mixture being dispensed from above *(as shown in Figure 6).*
- In this study, a body is attached to a speaker that will project a certain frequency with a certain volume percentage through the film.
- Film in this study consists of 2% dishwashing soap with 98% water ratio.
- Body is placed into middle of film, to allow uniform velocity flow around it.
- Gravity allows mixture to flow and keep film intact.

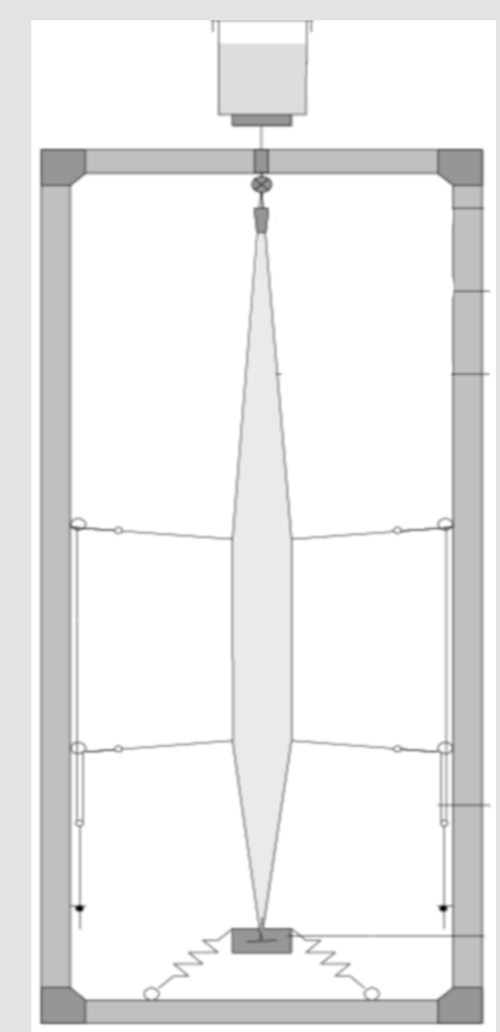
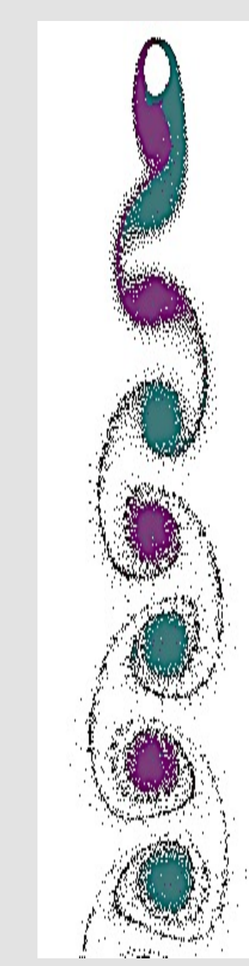


Figure 6: Design setup for soap film

Figure 7: Demonstration of vortex shedding



Method

- A high-speed camera captures a video of the acoustic effects on the film.
- Video is filmed at 3000 frames per second (fps) and acoustics range was tested from 250 – 70 Hz at different amplitudes.
- Light source comes from a DC power supply and illuminates the film through Schliren visualization.
- Stationary body in flow will cause vortices to form *(as shown in Figure 7).*
- With acoustics being played, cylindrical body vibrates transversally to the flow, changing the formation of vortices *(as shown in figure 4).*
- With acoustics being played, aerofoil vibrates along the flow, changing the formation of the vortices *(as shown in Figure 5).*

Scan here to watch vortex shedding videos

Scan me

Results & Conclusion

- Soap film is an effective method for exploring the concept of true two-dimensional fluid flow phenomena.
- Flow visualization allows us to better understand how vortices are formed and how they might behave in or affect the flow.
- Two-dimensional fluid flow is capable of generating and sustaining vortical structures because dynamics of vortices is constrained to a two-coordinate system.
- Using this setup, major changes in vortices formation was observed when forced oscillations were applied to the bodies in the flow.
- Since it is two-dimensional flow future analysis and simulations can be applied to study the phenomena relatively easier than three-dimensional flow.

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