The Mechanisms of Interaction of Vortices, Turbulence and Collision between The Bluff Body and Flow Field

Kai-Chi Chang; Yi-Hsiang Chang

Advisor: Chia-Lung Chin, Pao-Cheng Sheng

Taipei Municipal Lishan High School

Taipei, Taiwan

Motivation

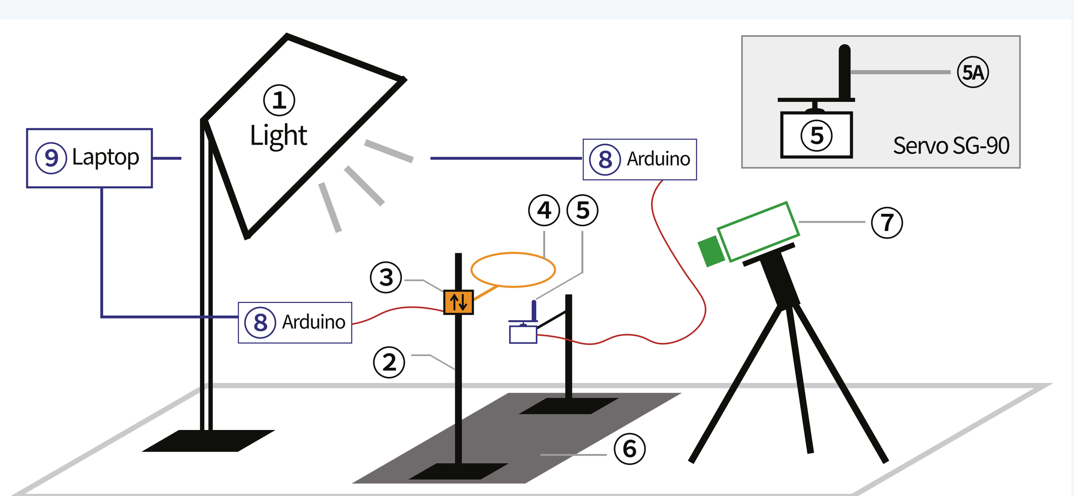
The way wind flows has considerable relevance to the devices of human transportation systems, such as shipbuilding and aircraft manufacturing. If we understand the characteristics of "fluid" and "turbulent flow" enough, it would help us manufacture, improve, and design these transportation systems more safely, and even predict atmospheric phenomena to ensure human safety.

Purpose on This Study

This study would like to analyze the vortex in different stability of the flow field. Then, we want to observe, integrate and summarize the changes in the speed and area of the vortex when the bluff body hits the flow and the eddy current falls off in the stable and unstable flow field.

In the previous literature experiments, the bluff body was always fixed, so we let the fluid flowed through. However, to planes and ships, **an object (equivalent to a bluff body) always moves and collides with a stable flow fields** (such as air, ocean), which is the opposite of what we have seen in the refernece and previous reaseach. Therefore, our experimental design will be carried out with the latter model.

Material and Equipment



1. Light
2. Metal Stand
3. Automatic Lifting System
4. Bubble Frame
5. Servo
5A. Wooden Stick
6. Black Fabric
7. Camera
8. Arduino
9. Laptop

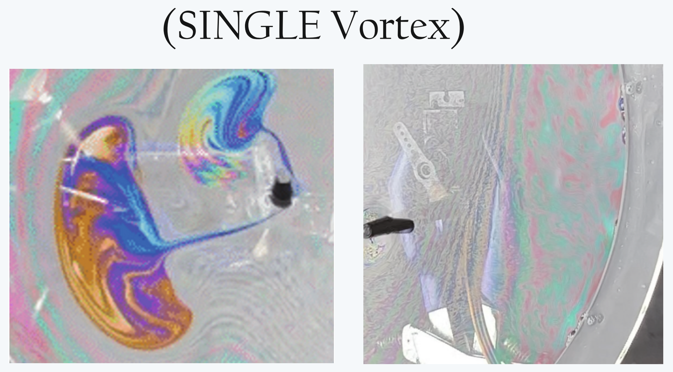
1. We used a soap bubble film with a viscosity similar to that of air to simulate the flow field. We connected a wooden sitck to a servo and rotate.
2. Due to thin film interference, the color of the bubble film can be observed easily due to the interenfence happening on the bubble film, which is convenient for us to record and observe the invisible fluid and analyze.

Result and Discussion

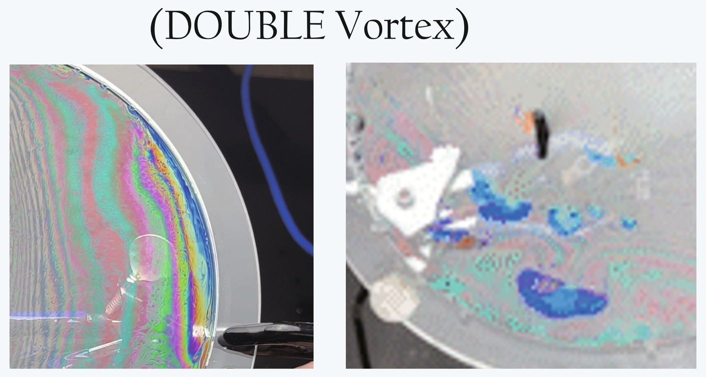
I. About Vortices

The servo runs in a constant speed (0.7 Rad/s), and the wooden stick stirs the bubble film for a circle from the bottom.
We records the changing field with a camera.

Steady Flow Field (SINGLE Vortex)



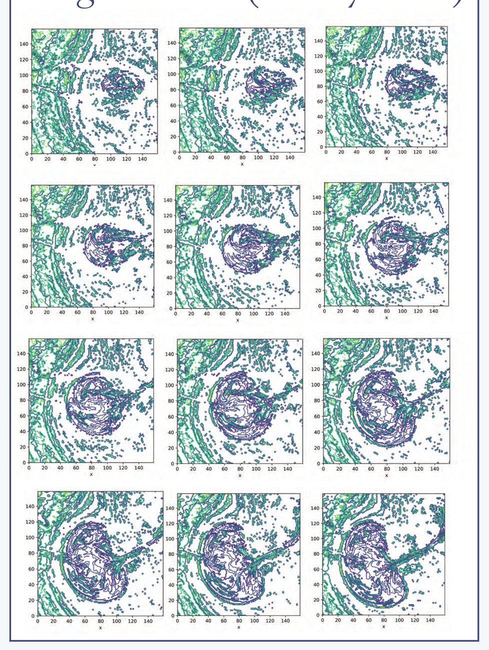
Unsteady Flow Field (DOUBLE Vortex)



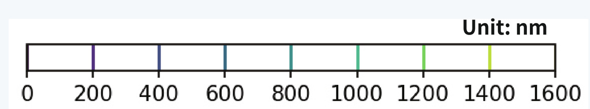
Due to the unstable low pressure and high pressure areas formed in the flow field when the bluff body is disturbed, the turbulent flow hits the obstacle, so the vortex separates. (Picture Right)

II. Velocity on the flow field

Single Vortex (Steady Flow)

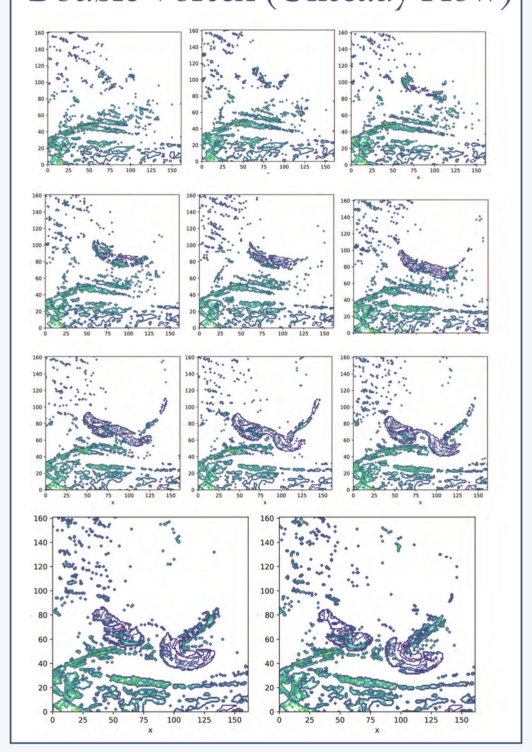


1. Convert the film thickness and color table into data by ImageJ Software.
2. Draw isothickness line graphs, as shown on the left and right, by Python. (The corresponding table of thickness line colors and thicknesses is shown below.)



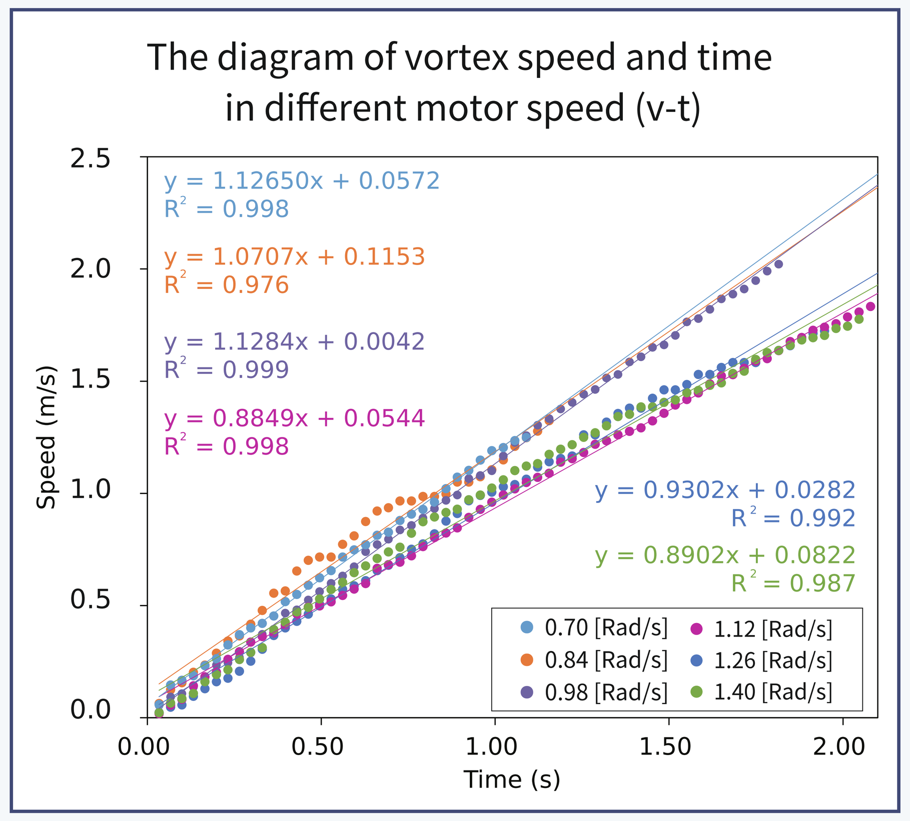
It can be confirmed from the **"Iso-thickness Diagram"** that it is the same shape as the vortex we see with the naked eye (photographed by a camera), and the shape of the vortex can be determined.

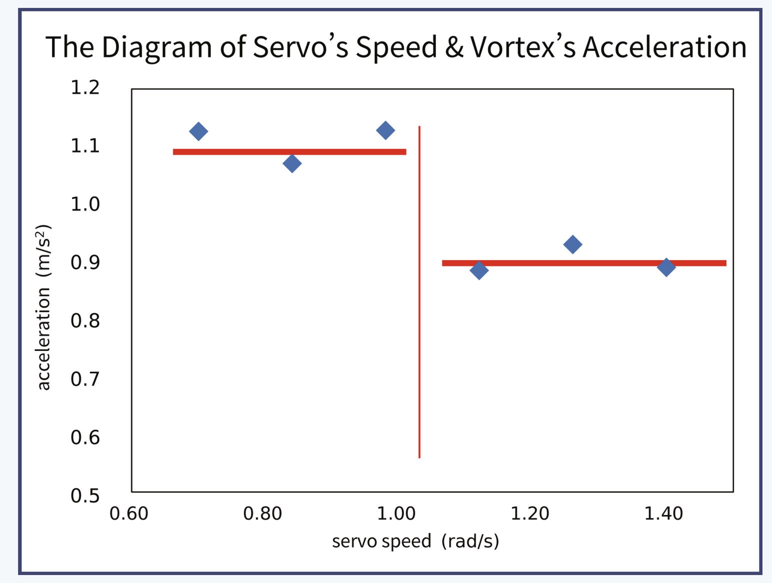
Double Vortex (Unteady Flow)



III. Velocity of Vortices Motion

Observing the velocity of the vortices by time by changing the servo rotation speed. Tracker is used to analyze the data.

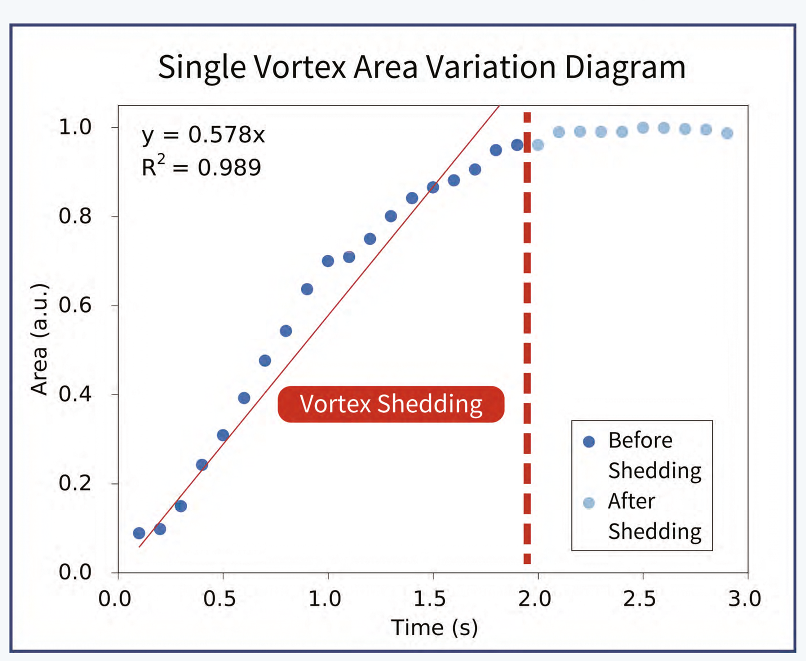




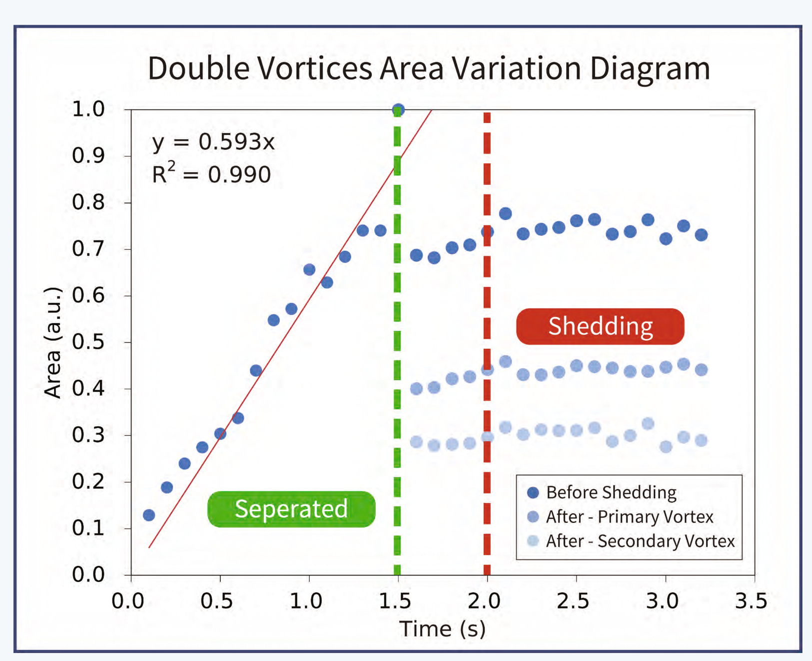
- The diagram on the left shows that the rate of vortex motion is linearly related to time. motion of the vortex is a uniform accelerated motion.
- We found it a fault when the motor speed is 1.00 Rad/s, which seperated into two different speed zones.

IV. Area of Vortices

Experiment 1 measures the area change of the single and double vortex from generation to shedding under the constant speed stirring of the blunt



★ In the early stage, the area continued to expand, because the energy has not yet fully diffused;
★ The late area hardly changes anymore, as the shedding of the second vortex compresses into the space where the first main vortex that is being analyzed expands

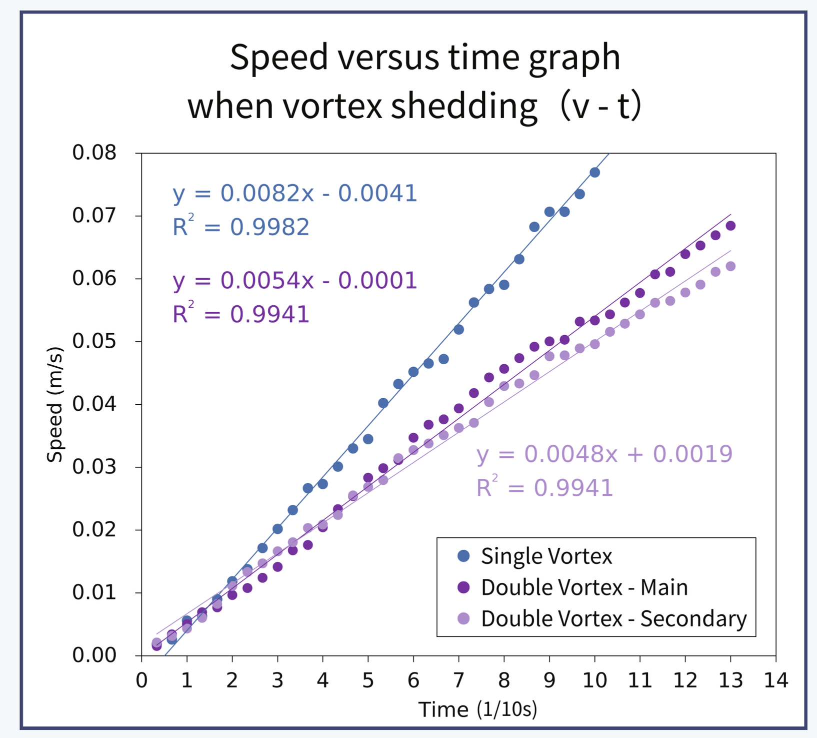


★ Before falling off, the area increases as a quadratic function graph over time. However, the area of the vortex does not change after shedding.
★ It is inferred that the time from formation to shedding is longer than that of a single vortex, and the energy has almost completely dissipated thereafter.

V. Velocity of Single Vortex and Double Vortex

At a fixed servo (stirring) speed, this experiment observe the speed change the single vortex and the double vortex by time.

1. Import the image of the vortex movement into Tracker
2. Divide the path length data by the time distance to obtain the velocity value, and plot it against time (v - t graph), and obtain the acceleration value from the slope of the trend line



acceleration [m/s²]	0.0082	0.0054

1. The single vortex acceleration value is larger than that of the double vortex acceleration

2. Comparing the single vortex and double vortex-main vortex acceleration values, the difference is about 1.5 times, which is close to $\sqrt{2}$

$$v_S : v_D = \sqrt{2} : 1$$

$$\Rightarrow E_{K_S} : E_{K_D} = 2 : 1$$

Conclusion

1. **Stability would affect the number of the numbers of the vortex.**
   The single vortex will forms in the steady flow field, while the double vortex forms in the unsteady flow.
2. **The area and the speed increase linearly over time in both steady and unsteady flow field.**
3. **The faster bluff bodies stirs, the lower accelation the vortex has,** and it has a fault when the servo speed is approximately at **1.0 rad/s.**
4. **The velocity of the flow field increase from inside to outside of the vortices.**

Future

- **Change different shapes blunt body, for instance, triangular blunt body**
  1. The quality of the eddy current signal is improved
  2. Reduce pressure loss
  3. Change the shape of the blunt body to make the research more close to the actual project

  Turbulence Analysis of Rotor Wake
- The rotor wake on a helicopter is easily disturbed by the wake field of the previous blade, which results in nonlinear turbulence that cannot be accurately predicted

  Rotation of wooden sticks to simulate the pattern of rotor wake
- Analyze the disturbance model under rotation, find out the periodic coefficient, and make the unstable flow field controllable.

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