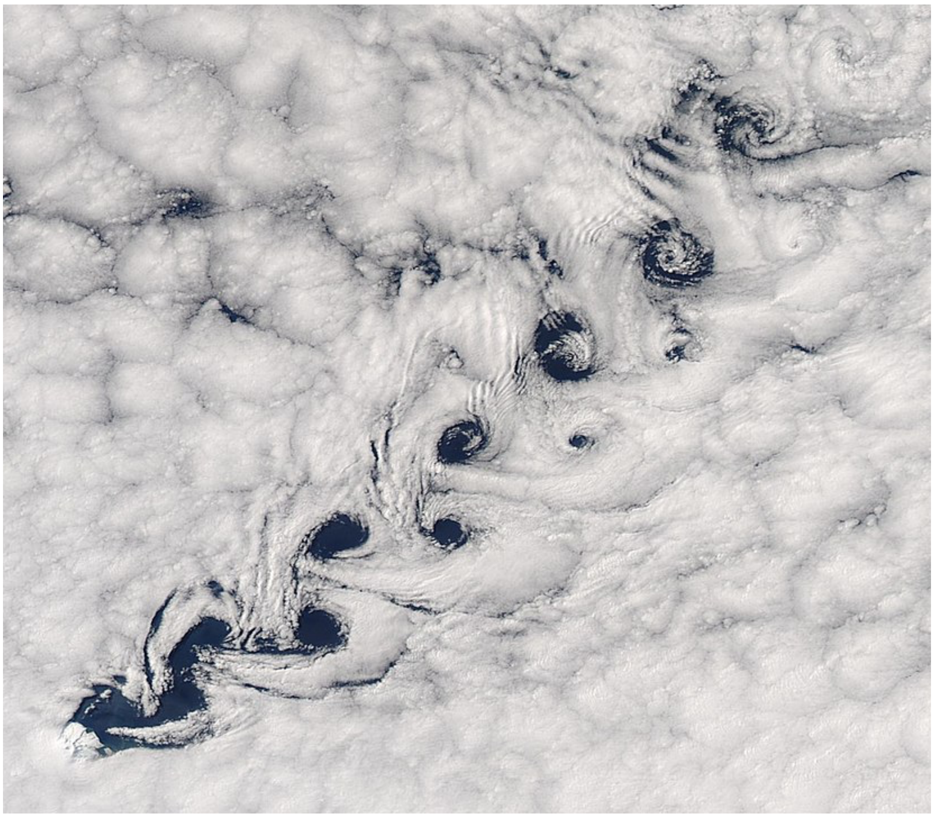
AM5820
Wind Tunnel and Numerical Experiments

Department of Applied Mechanics
Indian Institute of Technology Madras
Chennai – 600036

Visualization of vortex shredding



Submitted by:

Nitin Yadav

AM20M004

Objective

To observe the vortex shedding phenomena in flow behind a cylinder at moderate Reynolds numbers and study the dependence of the non-dimensional frequency of vortex shedding on Reynolds number.

Introduction

Have you ever wondered, why Geese birds fly in V pattern when they fly to far places? It is because of the phenomena of vortex shredding.

Vortex shedding is a fluid dynamics phenomenon in which fluid flows around a bluff body. This interference causes low-pressure vortices to shed from either side of the body and a low-pressure zone to form in the wake behind the body, giving rise to a fluctuating force perpendicular to the direction of the flow. At high velocities, the opposing forces can cause the body to vibrate at a low frequency.

The character of the vortex shedding forces depends on the shape of the body. The frequency of vortex shedding can be determined by Strouhal number (St). The St number is dependent on the cross section of the body which flow passes over and is also dependent on the velocity of the flow, or the Reynolds number.

Practical Applications

Vortex shredding is the cause for overhead power line wires humming in the wind, and for the fluttering of automobile whip radio antennas at some speeds. Tall chimneys constructed of thin-walled steel tubes can be sufficiently flexible that, in air flow with a speed in the critical range, vortex shedding can drive the chimney into violent oscillations. Vortex shedding was one of the causes proposed for the failure of the original Tacoma Narrows Bridge in 1940. A thrill ride, "VertiGo" at Cedar Point in Sandusky, Ohio suffered vortex shedding during the winter of 2001, causing one of the three towers to collapse. In northeastern Iran, the Hashemi-Nejad natural gas refinery's flare stacks suffered vortex shedding seven times from 1975 to 2003.

Equipment description

The setup consists of a large tank (2.5m x 1.5m x 150mm) filled with water, which is made black by dissolving a dye. Inside the tank there are two counter rotating aluminum discs, which are connected to a motor, which in turn is connected to variac from which we can control the speed of the motor. By controlling rotation of the discs, we can control the velocity of the stream. Also, inside the tank there are two guide ways which guide the flow to the test section in the middle. Aluminum powder is sprinkled on water for better visualization of the vortices.

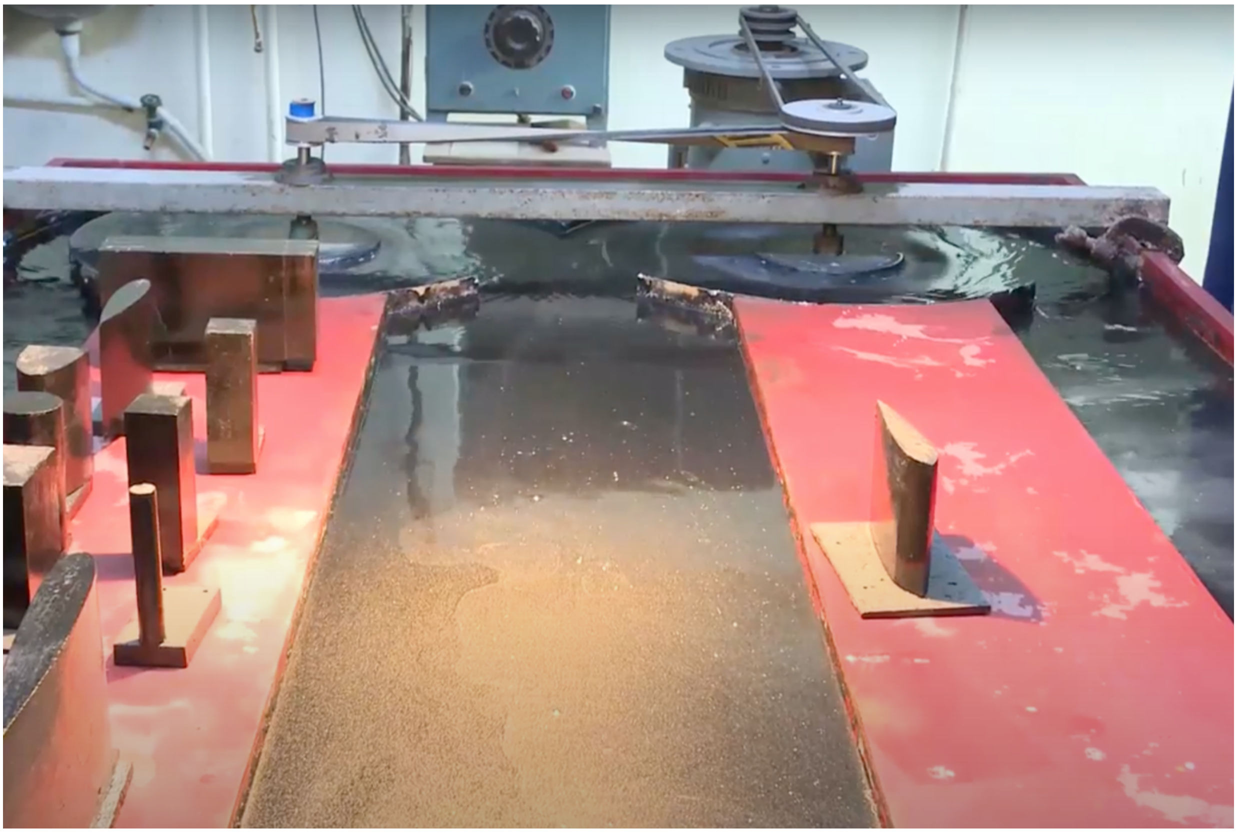


Fig. Schematic of setup in tank

Experimental procedure

Switch on the power to the motor with the variac at its lowest position. Turn the variac clockwise very slowly to start the rotation of the discs. Adjust the variac to obtain steady rotation of the discs.

Now, a small wood particle is dropped in the stream. As, the particle is dropped switch on the stopwatch & observe how much time the wood particle has taken to travel 1m. From this data we can calculate the free stream velocity.

Then for this free stream velocity, we have to place the solid cylinder inside the test section. It can be observed that vortices are formed at the back of the cylinder & breaking off down the line. We have to count the number of vortices formed for a definite interval of time. From this data we can calculate the vortex shredding frequency.

Now, increase the velocity of the aluminum discs by rotating the variac and repeat the process for various free stream velocities.

Raw data & Results

Given,

$$L = Diamter\ of\ cylinder = 0.050m$$

$Water\ with\ following\ properties, is\ assumed\ to\ be\ the\ working\ fluid$

$$\rho = \frac{1000kg}{m^3},\ \ \mu = 8.9 \times 10^{-4} Pa.s$$

Distance travelled by particle (m)	**Time taken (s)**	**Free stream velocity, U_∞(m/s)**	**Number of vortices formed**	**Time for N vortices (s)**	**Vortex shredding frequency, f (s^{-1})**	**Experimental Strouhal Number, St_{exp}**	**Reynolds Number, Re**	**Theoretical Strouhal Number, St_{th}**
0.39	10.76	0.03624535	11	60	0.18333333	0.25290598	2036.2558	0.19608472
0.5	6.32	0.07911392	6	12.12	0.4950495	0.31287129	4444.60247	0.19712253
0.4	4.6	0.08695652	5	12.9	0.3875969	0.22286822	4885.19785	0.19720167
0.39	4.05	0.0962963	27	60	0.45	0.23365385	5409.90429	0.1972791
1	9.833	0.10169836	25	60	0.41666667	0.20485417	5713.39116	0.19731739
1	8.687	0.11511454	28	60	0.46666667	0.20269667	6467.10893	0.19739695
1	6.385	0.15661707	28	60	0.46666667	0.14898333	8798.71187	0.19755675

Note: Data is sorted with respect to Free stream velocity & graph is also plotted from this sorted data itself

Sample Calculation

Strouhal Number (St) is given by,

$$\boxed{St = \frac{f * L}{U_\infty}}$$

where, f = Vortex shredding frequency

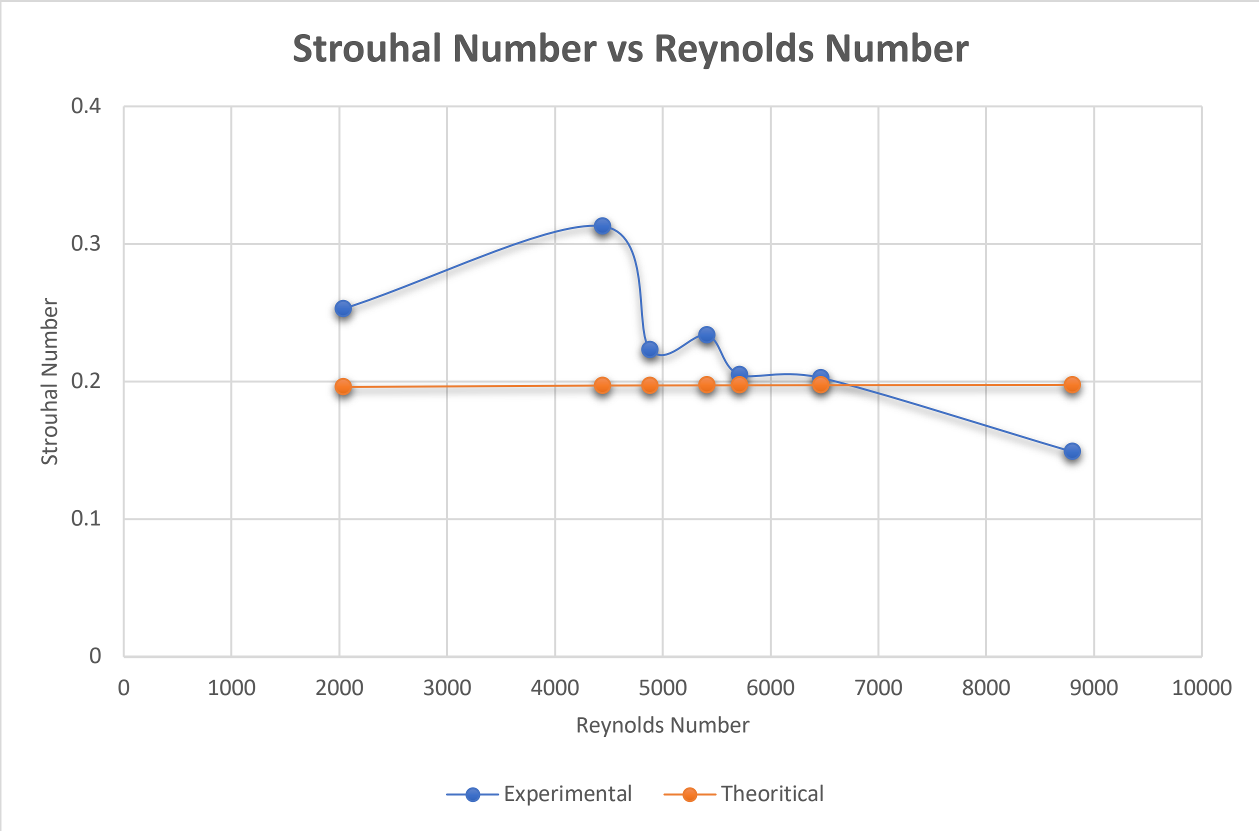
L = Characteristic Length

U_∞ = Free stream velocity

Empirical Relation,

$$\boxed{St = 0.198 - \frac{3.9}{Re}},\quad for\ \ 250 < Re < 2 \times 10^5$$

Plot



Conclusion

It can be concluded from above plot that the experimental Strouhal number deviates from its theoretical value. Theoretical Strouhal number is close to 0.19 & Experimental Strouhal number is close to 0.2. This might be due experimental error while conducting the experiment

Remarks

a) Is vortex shredding good or bad? If it is good, how to increase it and if it is bad, how to reduce it?

Ans: Vortex shredding is a major concern if the vortex shredding frequency coincides with the natural / resonance frequency of the structure. For structures that are tall and uniform in size & shape, the vibrations can be damaging and ultimately lead to fatigue failure.

There are three possible ways to reduce it, namely: -

- Streamlining the body

- Helical spoiler has been found to be successful in breaking the regular vortex pattern in wake of tall cylindrical stack (chimney)
- A plastic ribbon woven into a cable at close intervals could effectively prevent vortex shredding in underwater marine cables

b) What do you mean by Karman vortex street? Explain its formation and its disappearance?

Ans: Flows with steady boundary conditions can have unsteady solutions; flows around bluff bodies at intermediate Re are the common examples. For flow around a cylinder, at low Re the vorticity generated at the surface of the body is diffused (not advected) and there is fore and aft symmetry of flow. When Re is increased above 40, the wake begins to become unstable. With increasing Re, the oscillating wake rolls up into two counter-rotating vortices in two staggered rows. These staggered rows of vortices are known as the Karman vortex street.

The alternation leads to the core of a vortex in one row being opposite the point midway between two vortex cores in the other row, giving rise to the distinctive pattern. Ultimately, the energy of the vortices is consumed by viscosity as they move further downstream, and the regular pattern disappears.

c) What are the sources of error for this experiment?

Ans:

- Number of vortices are counted visually, which might not give accurate counts
- There could be reaction time while pressing the stopwatch, to measure time using stopwatch