MAE 451 - Experimental Aerodynamics III
Lab 2 – Vortex Shedding Analysis Using CTA
Final report due date: 09/30/2019

Objective: Using the Constant Temperature Anemometry (CTA) system:

- Compare the Strouhal vs. Reynolds number curve for a cylinder operating in the laminar and turbulent flow regimes with existing experimental data trends.

Theory: At very low Reynolds numbers ($Re < 1$), the streamlines close behind the cylinder (no separation occurs). No wake is formed as the flow fore and aft of the cylinder is symmetrical (Figure 1A). At higher Reynolds numbers ($Re \geq 1$) the streamlines no longer close and a wake is formed behind the moving body. The velocity in the wake is smaller than the uniform free stream velocity. This velocity deficit is associated with the drag acting on the body. By measuring the velocity distribution in the wake we can estimate the drag on the moving body.

In the range of Reynolds numbers between 3 and 6 a pair of stationary vortices, called Foppl vortices, are formed behind the cylinder (Figure 1B).

At still higher Reynolds numbers the vorticity behind the cylinder increases as the pair of vortices moves downstream and elongates (Figure 1C and 1D). Finally, at Reynolds numbers greater than 40, the vortices are periodically shed behind the cylinder, thus forming the well-known von Karman vortex street consisting of two rows of vortices equally spaced and arranged with each vortex located at the center of the two vortices of the opposite row (Figures 1E). The shedding of the vortices is due to an instability which develops in the flow.

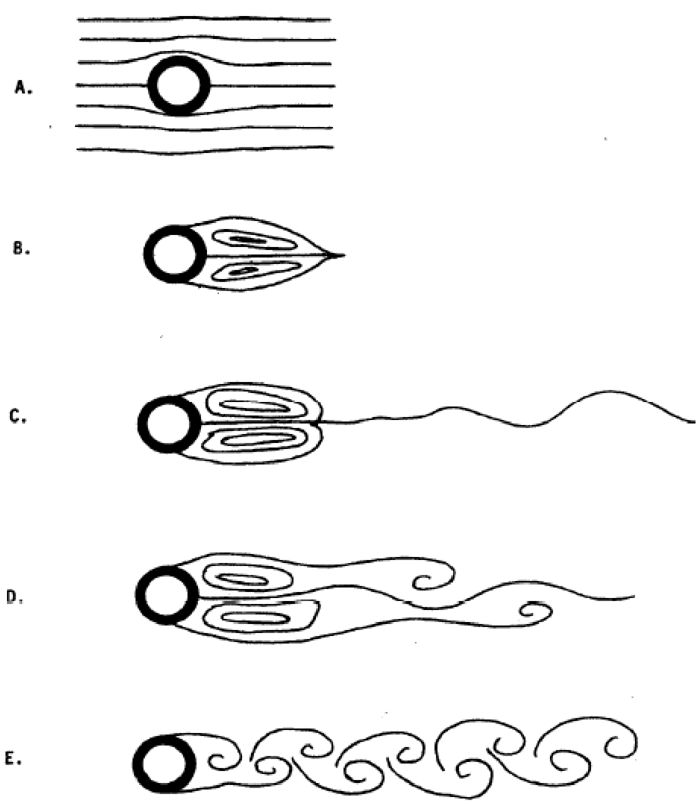

Figure 1: Cylinder wake flow patterns.

When describing oscillating flows, the Reynolds number alone is not sufficient to characterize the flow, since it contains no information about the oscillations. To fully describe the oscillating flows at higher Reynolds numbers, we introduce a non-dimensional number called the Strouhal number. The Strouhal number, S, is defined as:

$$S = \frac{fd}{V_\infty}$$

where f is the shedding frequency of the vortices, from one side of the cylinder, d is the diameter of the cylinder, and V_∞ is the freestream velocity. The change of the Strouhal number as a function of the Reynolds number in the critical Reynolds number regime is shown in Figure 2.

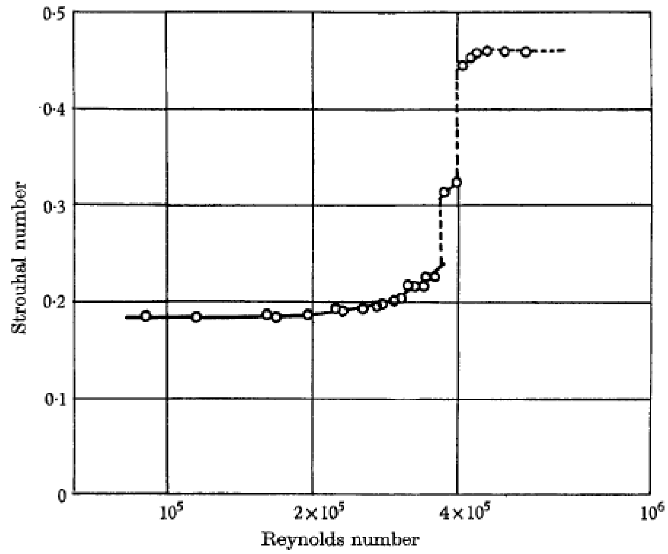

Figure 2: Strouhal number vs. Reynolds number variation for circular cylinders.

Experiment: The MiniCTA system, analyzed in Lab 1, will be used to study the vortex shedding of a circular cylinder in the laminar and turbulent flow regimes with the objective of comparing the trends in data collected in the NCSU subsonic wind tunnel to Figure 2. You will have to perform a Fast Fourier Transform (FFT) on the voltage time history data at various dynamic pressures to calculate the shedding frequency, f, and calculate the variation in Strouhal number with Reynolds number for laminar and turbulent flow.

The following constants can be used to help with your analysis:

1. Freestream density: 1.14 kg/m^3
2. Dynamic viscosity: 1.962×10^{-5} kg/ms
3. Cylinder diameter (d): 0.1016 m
4. Sampling frequency: Number of samples collected in 1 second.
5. Length of the signal: Total number of sample data points collected.
6. The freestream velocity (V_∞) can be calculated from the dynamic pressure obtained from the transducer.
7. You will only need to consider data from 3Hz to 500Hz.

In the final report:

- Compare and discuss your Strouhal vs. Reynolds number curves for laminar and turbulent flows.
- Co-plot your data against the reference curve and discuss.
- Discuss what you will need to change in the set-up to achieve a Reynolds number range from 1×10^5 to 1×10^6 while keeping the dynamic pressure between 1 to 9 psf. Present details of your analysis.

References: Bearman, P. W.,"On vortex shedding from a circular cylinder in the critical Reynolds number regime," Journal of Fluid Mechanics, Vol. 37, Part 3, 1969, pp. 577-585.