AM5820
Wind Tunnel and Numerical Experiments

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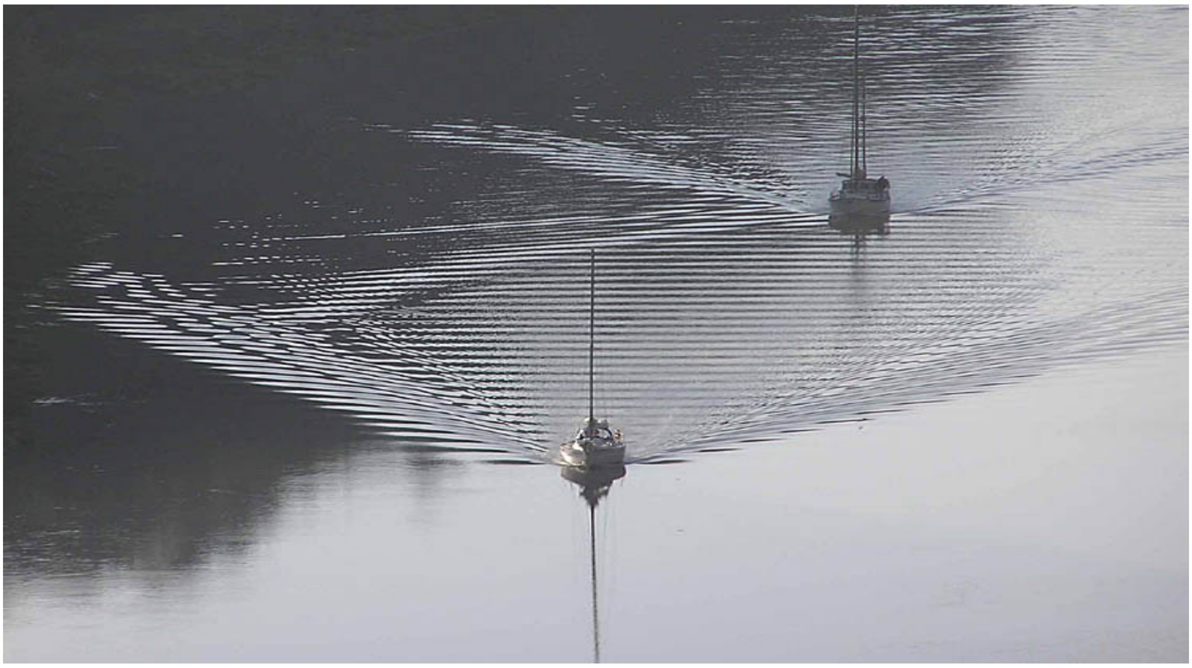
Wake velocity measurement for flow over a circular cylinder



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Objective

To measure flow velocity in the wake region behind the circular cylinder and plot the non-dimensional velocity distribution in a plane behind the cylinder.

Introduction

External flows past objects have been studied extensively because of their many practical applications. Flow past a blunt body, such as a circular cylinder, usually experiences boundary layer separation and very strong flow oscillations in the wake region behind the body. In certain Reynolds number range, a periodic flow motion will develop in the wake as a result of boundary layer vortices being shed alternatively from either side of the cylinder. This regular pattern of vortices in the wake is called a Karman vortex street. It creates an oscillating flow at a discrete frequency that is correlated to the Reynolds number of the flow. The periodic nature of the vortex shedding phenomenon can sometimes lead to unwanted structural vibrations, especially when the shedding frequency matches one of the resonant frequencies of the structure. In this experiment, we are going to investigate the flow past a circular cylinder and measure the velocity of flow field in the wake of the cylinder.

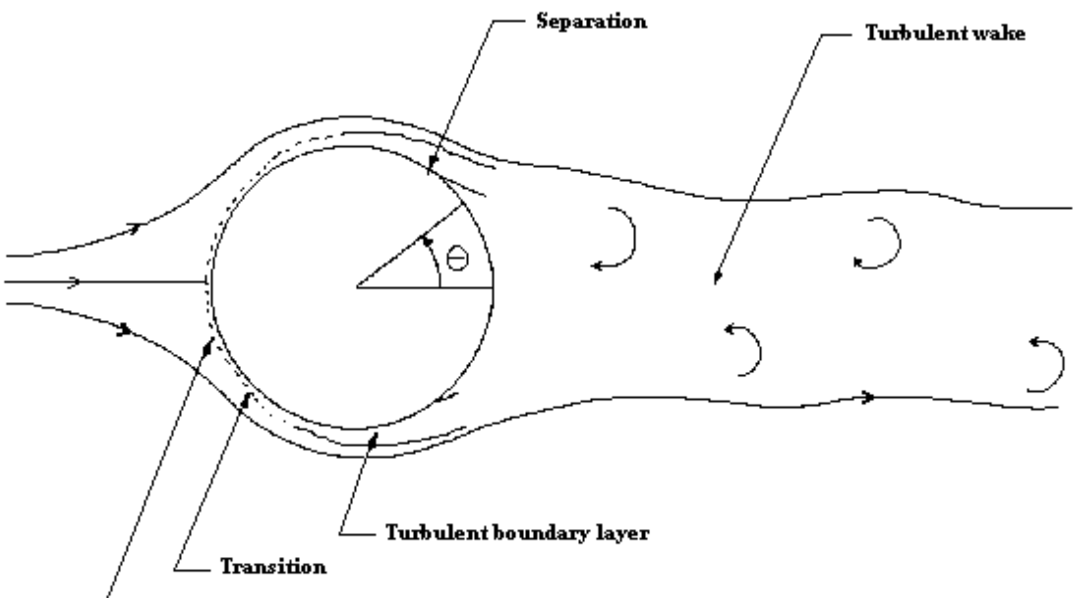


Fig. Wake behind circular cylinder

Practical Applications

For a blunt body in subsonic external flow, for example the Apollo or Orion capsules during descent and landing, the wake is massively separated and behind the body is a reverse flow region where the flow is moving toward the body. This phenomenon is often observed in wind tunnel testing of aircraft, and is especially important when parachute systems are involved, because unless the parachute lines extend the canopy beyond the reverse flow region, the chute can fail to inflate and thus collapse. Parachutes deployed into wakes suffer dynamic pressure deficits which reduce their expected drag forces. Other applications include rocket stage separation and aircraft store separation.

Equipment description

The apparatus consists of a low-speed subsonic open circuit wind tunnel. The test section of the wind tunnel has a uniform cross-section of 0.6 x 0.6 m^2. There is a vertical slot in the test section in which the pitot static tube can be inserted. Wind tunnel has a fan at one end which sucks in air from the other end. The air flow in wind tunnel is from right to left direction. Therefore, the wake will be created on the left side of the cylinder. After starting the fan, we have to wait for few minutes so that the air velocity sets in.

Experimental procedure

Experiment is started by mounting the cylinder in the slot provided in the test section of the wind tunnel perpendicular to flow velocity. In the vertical slot in the test section behind the cylinder the pitot static tube is inserted. To take reading we have to start the digital manometer after connecting it to the pitot tube. The manometer will show the static pressure when knob of selection box is at position one & total pressure when knob of selection box is at position two.

At this point there are two things to note:

- Total pressure shown by manometer is lower than static pressure. But the reading manometer is showing is the gauge pressure. Therefore, while noting down we have put a negative sign in front of both total & static pressure.
- Values in manometer are constantly fluctuating because the wake region is very unsteady. So, to note down the pressure we have to wait for few minutes and

note down the maximum & minimum values of pressure given by manometer and finally take average of the two for static as well as total pressure.

After taking pressure readings at one position of pitot static tube (y = 0), we have to move the pitot static tube up by 2mm using the mechanical arrangement. We will keep on moving the pitot static tube up till the point we have moved out of the wake region (If we see that for few successive positions of the pitot static tube, reading of total & static pressure are not changing than we can say that we are out of the wake region & into the free stream region).

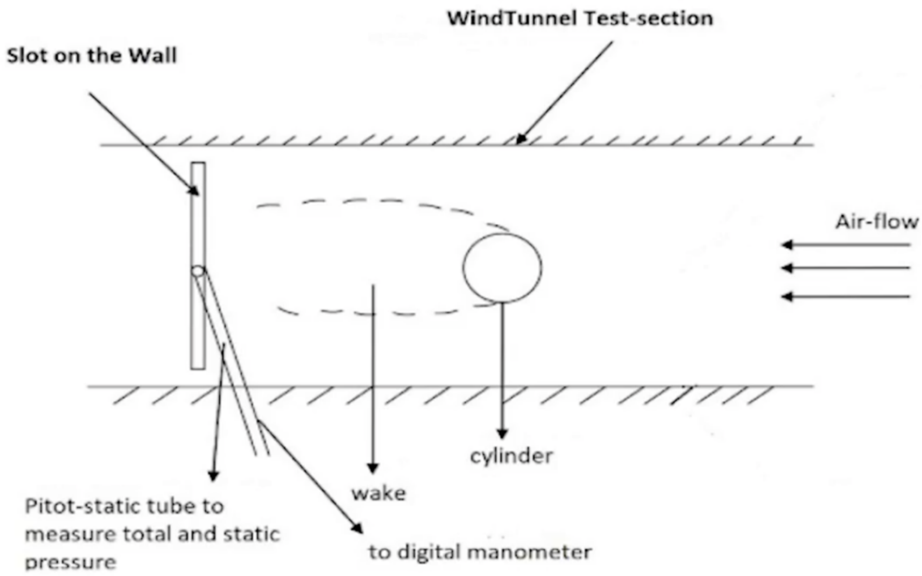


Fig: Schematic diagram of the experimental set-up

Raw data & Results

Given,

$$d = diameter\ of\ cylinder = 25\mathrm{mm}$$

$$\rho_a = Density\ of\ air = 1.1415\ kg/m^3$$

We can see from below table that,

$$U_\infty = Free\ stream\ velocity = 21.4253382\ \mathrm{m/s}$$

y (mm)	Total Pressure, P_T (Pa)	Static Pressure, P_s (Pa)	Flow Velocity, U (m/s)	y/d	U/U_∞
0	-202	-365	16.8993827	0	0.78875687
5	-205	-365	16.7431447	0.2	0.78146466

10	-200	-365	17.0027438	0.4	0.79358112
15	-187	-363	17.5603583	0.6	0.81960705
18	-180	-361	17.8080484	0.72	0.83116767
24	-157	-358	18.766145	0.96	0.87588559
30	-135	-355	19.6330775	1.2	0.91634854
40	-112	-350	20.4204599	1.6	0.9530986
50	-95.5	-345	20.9079915	2	0.97585351
60	-82	-340	21.2611569	2.4	0.99233705
70	-74	-335	21.384411	2.8	0.99808978
80	-68	-330	21.4253382	3.2	1
90	-68	-330	21.4253382	3.6	1

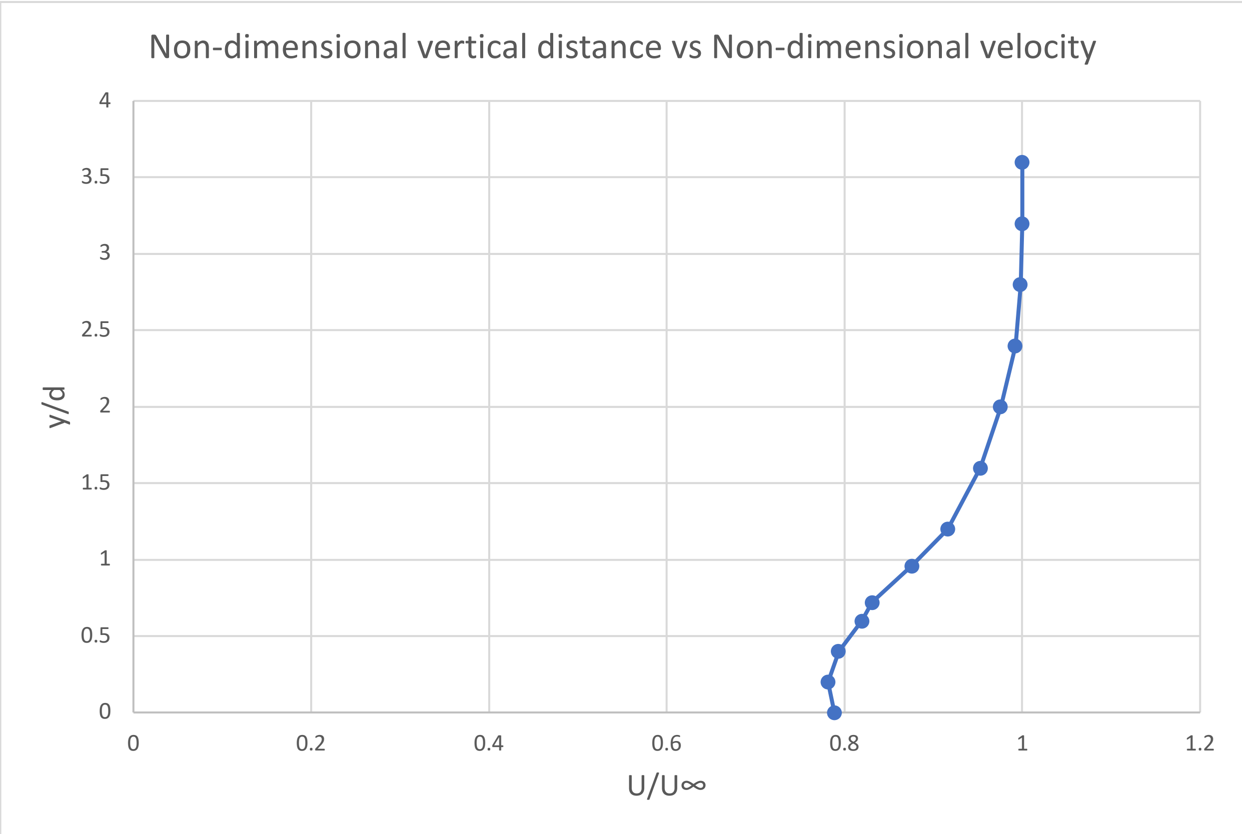
Sample Calculation

$$U_\infty = Free\ stream\ velocity; \qquad U = Local\ velocity\ to\ be\ measured$$

$$Using\ Bernoullis\ Equation, \qquad P_S + \frac{1}{2}\rho_a U^2 = P_T$$

$$\Rightarrow U = \sqrt{\frac{2(P_T - P_S)}{\rho_a}}$$

Plot



Conclusion

It can be seen from above plot that as we move up from the center of the cylinder the velocity of the wake region increases and finally it asymptotically matches the free stream value. This shows that wake region is confined to a finite vertical distance from the cylinder center.

Remarks

a) What are the possible sources of error?

Ans: Possible sources of error are:

- Digital manometer is not 100% accurate. This error is not taken into consideration
- The pitot tube is moved manually, which might involve human error

b) What is the purpose of honeycomb structure in the wind tunnel?

Ans: At the entrance of the wind tunnel a honeycomb structure is present so that the inlet velocity of air is properly aligned & uniform.

c) Is it not feasible to have a constant area test section with a fan at the exit? Why has the present day convergent-constant area- diffuser configuration has evolved?

Ans: The present-day wind tunnel configuration has evolved because it gives following benefits over a constant area test section configuration:

- The contraction serves following purposes:
  - Enable velocity to be low at location of placement of screens
  - Reduces both mean and fluctuating velocity variations to a smaller fraction of the average velocity
  - Reduce spatial variations of velocity in the wind tunnel cross section
- The diffuser serves the purpose of salvaging the kinetic energy of flow in the test section as pressure energy