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GEOG 4150 Sedimentary Processes

Laboratory 3

Flow Visualization Using a Smoke Wind Tunnel

BACKGROUND

When a flowing fluid encounters an obstacle, the fluid exerts a force on the body that is proportional to the fluid's velocity, viscosity and density as well as the size and shape of the body. This interaction is frequently described in terms of a drag coefficient (C_D) which is a dimensionless ratio of the drag force (D_f) exerted on the body with a parameter that describes the fluid flow and the size/shape characteristics of the body.

$$C_D = \frac{D_f}{\frac{L}{2}\rho U_\infty^2 A}$$

where
- D_f - drag force
- ρ - fluid density
- U_∞ - free stream velocity
- A - projected frontal area which in this case is D x L where
- D - is the diameter of the cylinder and
- L - length of the cylinder

Every form (sphere, cylinder, cube or irregular shape such as sediment at the bottom of a stream, trees or car bodies) can be described by a drag coefficient that is a function of the objects Reynolds Number. Characteristic curves for various object shapes for a wide range of Reynolds Numbers are available in the literature. Typical Drag curves for spheres and cylinders are given in your handbook (pages 42-43). In sedimentological studies, the drag force exerted on particles at the bed of a stream, for example, will determine whether a particle is entrained (eroded) into the flow and, if entrained, how it will be transported.

AIM

Using a small smoke wind tunnel, we will investigate the flow field around a simple geometric form (cylinders) at different velocities and determine the fluid force on the body.

METHODOLOGY

Three smooth cylinders of differing size will be used in the smoke wind tunnel tests. Dimensions of the cylinders are:

	A	B	C
Diameter (mm)	15.88	21.36	33.38
Length (mm)	101.60	101.60	101.60

1) Carefully place the smallest cylinder in the smoke wind tunnel. Close the door of the wind tunnel and slowly increase the air pressure in the smoke generator with the flow meter to obtain an even flow of smoke

from the tubes (this is really an art rather than a science). If necessary add a **small amount of fluid (1 ml)** into the smoke generator. Align the cylinder so that one of the smoke streams impinges on the centre of the cylinder.

2) Slowly increase the velocity in the tunnel to try and obtain laminar (like) flow. If this is not possible **slowly increase** the velocity in the tunnel until flow separation just occurs in the lee of the cylinder.

3) Record the value of 3 or 4 consecutive readings after the flow has stabilised and take the average. You will need to measure the distance from the point of flow separation on the cylinder to the point of re-attachment in the lee of the cylinder (this of course is somewhat arbitrary in that the flow is not steady) from the photos gathered but describe the nature of the flow around and in the lee of the cylinder just in case the photos do not turn out.

4) Slowly increase the velocity to a level just below the point when the re-attachment can no longer be clearly identified. Record the transducer readings and again measure the distance from flow separation to re-attachment. Describe the nature of the flow around and in the lee of the cylinder.

5) Decrease the velocity until the transducer reading is approximately 70% of the last test and repeat all measurements and observations in step 3. It may be necessary to add a small amount of oil to the smoke generator.

6) Install the largest cylinder (33.38 mm diameter) and repeat steps 3 - 5. If time permits, repeat for the middle size cylinder (21.36 mm diameter).

7) Using the 21.36 mm cylinder slowly increase the velocity until you observe alternating Karman vortices (this may not be quite as clear as described in textbooks and in flow visualization tests that have used very high quality smoke tunnels).

ANALYSIS

1) From the pitot tube transducer measurements compute the free stream velocity from:

$$U = \sqrt{\frac{2g\ mV\ C}{\rho_a}}$$

where
- U - velocity (cm/s)
- mV - mean millivolt reading from voltmeter
- ρ_a - density of air (g/cm^3)
- g - acceleration due to gravity (981 cm/s^2)
- C - constant for transducer equal to 0.3326

2) Compute the particle Reynolds Number for each test using the above velocity (i.e. convert computed velocity to m/s from cm/s), the cylinder diameter and the air density. Briefly compare your observations and Reynolds Numbers to the schematic relationship suggested by Middleton (1984) in the following figure.

3) Calculate the theoretical drag force on the cylinder for each test. Briefly suggest a method by which you might be able to directly measure and confirm these theoretical values.

4) Construct a dimensionless parameter that describes the cylinder characteristics and the size of the flow separation zone. Plot this parameter against particle Reynolds Number for all tests and describe the relationship/comment on what you might expect from theory.

5) Compute the Reynolds Number at which you observed the Karman vortices for the 21.36 mm cylinder. Compare your computed value and observations to that suggested by Middleton (1984) – following figure. Account for any discrepancy.

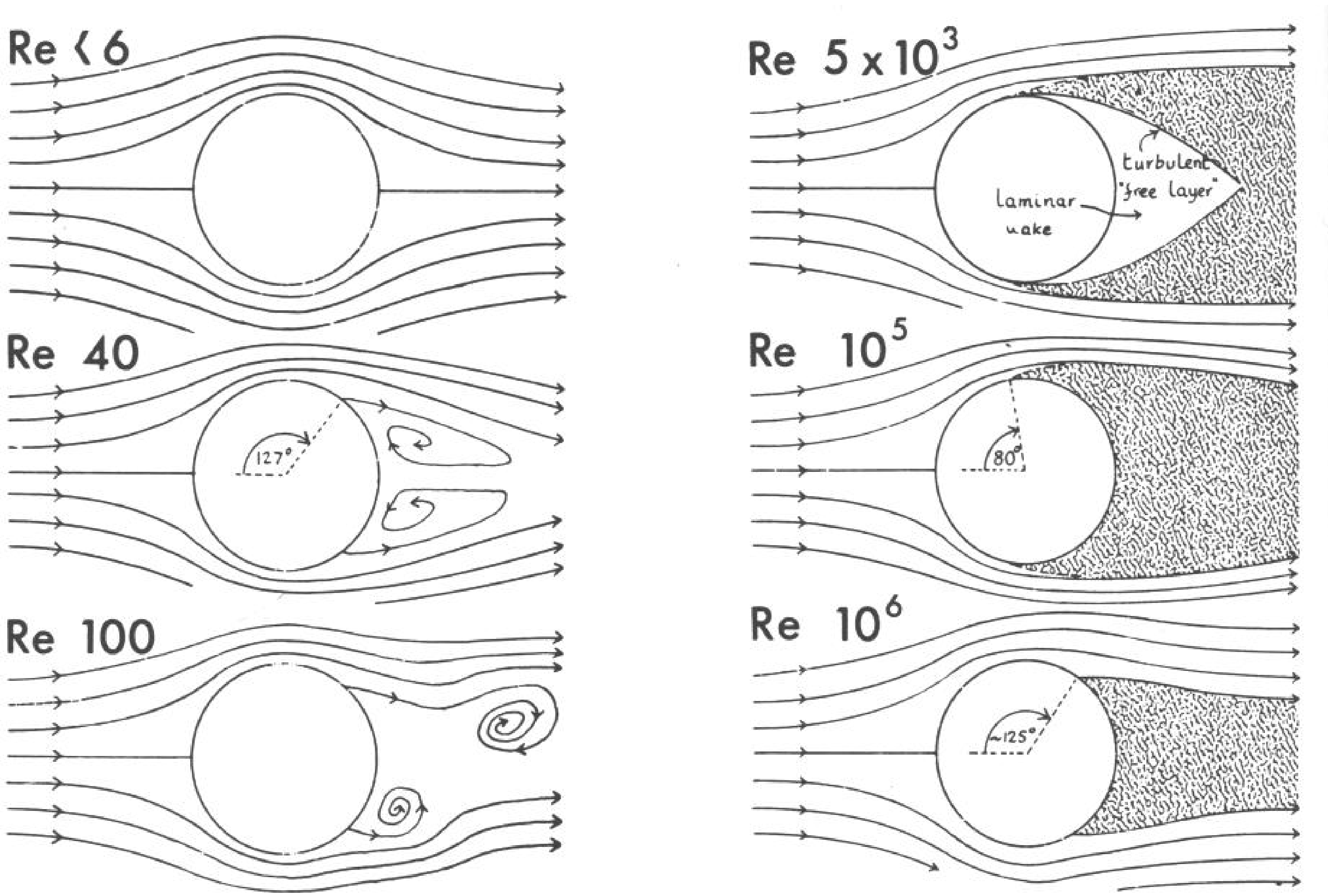

Figure 4.3 Flow patterns around circular cylinders normal to the flow, for Reynolds numbers from less than six to about 10^6.