AE-351A: Experiments in Aerospace Engineering

Experiment 5A: Smoke Flow visualization using smoke tunnel

Objective: To study the flow patterns over streamlined and bluff bodies

Apparatus:

- **Smoke tunnel:** Smoke tunnel is an open-circuit type wind tunnel. The tunnel consists of a fan at the inlet and is followed by a big settling chamber. The large size of the settling chamber is to eliminate the disturbances generated by the fan. The settling chamber is then followed by screens and flow straight to make the flow uniform and further reduce its turbulence level. It is followed by a small diffusion section which connects to the test section.

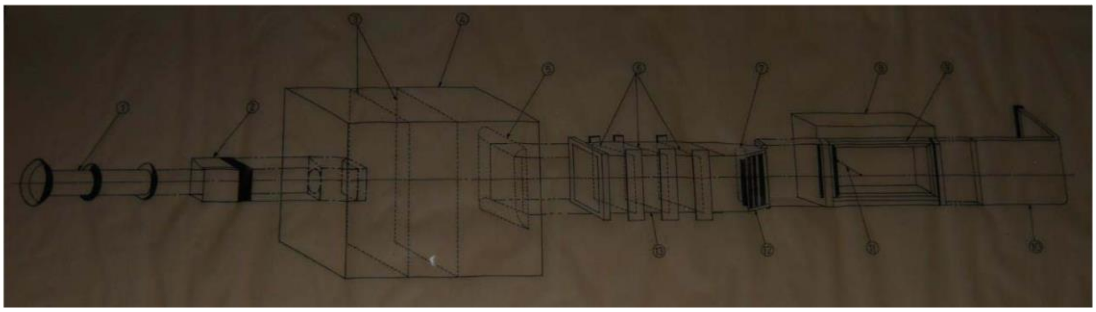

Figure 1: Schematic of smoke tunnel

- **Smoke generator**: Smoke is generated using a Preston-Sweeting mist generator. It consists of a heating facility where kerosene is heated to a high temperature. The kerosene vapour formed is mixed with the relatively cooler air stream to produce the appropriate mist. To introduce smoke in the flow, a rake is used.
- **Angle Change Mechanism**: The mechanism for holding and changing the angle of attack of the models consist of a hollow rod connected to a gear. The gear is driven by a motor connected to it to change the angle of attack.
- **Smoke rake:** the smoke generated is distributed through a rake which allows to form streamlines.
- **Models:**
  Three models are used in the current set of experiments. A circular cylinder, symmetric airfoil and a cambered airfoil.

Figure 2: Smoke generator

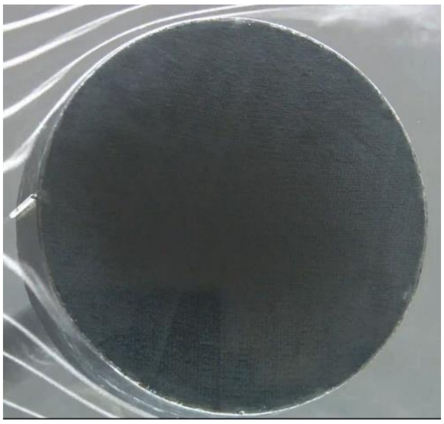

Figure 3: 2D Circular cylinder

Figure 4: 2D Symmetric airfoil

Figure 5: 2D Cambered airfoil

Procedure:

- Mount a model in the test section.
- Start the smoke generator after adequate time.
- Visualize the flow around the airfoil and photograph the flow.
- Change the angle of attack and visualize the change in flow features.
- Visualize the flow patterns for different models

Precautions:

- Always turn off the tunnel before opening the test section for model removal or mounting.
- Keep the room well ventilated while running the smoke-generator.

Observations:

1. Try to recognize, identify and label the followings with respective images from video:
    - Potential flow region
    - Boundary layer region
    - Laminar and turbulent boundary layer
    - Separation bubble
    - Nature and extent of the wake
    - Unsteadiness or vortex shedding in the wake
2. Label the differences between flows over streamlined and bluff bodies with figure.
3. Observe and label the change in flow for airfoil at various angle of attack.
4. Understand the difference between potential and real flows.

References:

1. Merzkich, “Flow Visualization”, Academic Press, 1987.

2. Werle, “Hydrodynamic flow visualization”, Annual review of Fluid Mechanics, vol. 5, 1973.

3. Van Dyke, “An album of fluid motion”, Parabolic Press, Stanford, CA, 1982

Experiment 5B: 2-D Dye Flow visualization using Hele-Shaw Apparatus

Objectives: To study the potential flow patterns over streamlined and bluff bodies.

Apparatus:

- **Hele-Shaw Apparatus:** Hele-Shaw flow is defined as Stokes flow between two parallel flat plates separated by an infinitesimally small gap, named after Henry Selby Hele-Shaw, who studied the problem in 1898. Hele-Shaw apparatus produces streamlines in a laminar, steady flow. The equipment consists of a channel formed between two glass plates. Water flows along the channel at a low Reynolds number. Two separate tanks are available at the top of the apparatus where water and die can be stored separately. Tiny holes at the bottom of the tank allows the dye to flow down through the channel forming streamlines. The fluid can be poured out of the apparatus with the help of the value and pipe connection. The dimensions of this apparatus is dimensions $2mm \times 85mm \times 100mm$.
- **Dye and water**: Potassium permanganate (KMnO4) is used as the dye
- **Beakers**: Beakers are used to fill and collect the fluid from the apparatus
- **Model**: Thin plastic models of various shapes including: 2D Circular cylinder, Symmetric airfoil and Cambered airfoil.

Figure 6: Hele-Shaw Apparatus

Procedure-

- Place the model in test section as required.
- Fill water in the reservoir.
- Once the channel is filled with water with no bubble formation inside channel, pour dye in the reservoir.
- Open the valve at the bottom as required to allow dye to form streamlines.
- Observe the flow around the model.
- Repeat the process with different flow rates and models
- Clean the apparatus after completing the experiments.

Observations:

1. Write and label the differences between flows over streamlined and bluff bodies with figures.
2. Label and explain the change in streamlines for airfoil at various angle of attack
3. Understand the difference between potential and real flows.

Experiment 5C: 3-D Flow visualization over a Delta Wing

Objective: Observe the vortex pair formed on top of the delta wing, and study their breakdown.

Apparatus:

- **Low speed wind tunnel:**

The specifications of the low speed wind tunnel are:

Sl. No.	Property	Measurement
1	Type	Open – Return Suction Type
2	No. Of Screenings in the settling chamber	6
3	Contraction ratio	16:1
4	Test section dimensions	0.6 m X 0.6 m X 3 m
5	Max. Velocity	~ 25 m/s
6	Motor	20 Hp AC

- **Delta wing (model):** When a slender delta wing with a sharp leading edge is at a moderate angle of attack, a vortex pair is generated on top of the delta wing. This happens due to the separation of the flow along the leading edge of the delta wing forming a separated shear layer. This shear layer rolls up to form a counter rotating vortex pair which move past the top surface of the wing. The formation of these vortices delays the stall which happens at relatively high angle.
- **Laser**: For flow illumination a continuous low power green laser is used.

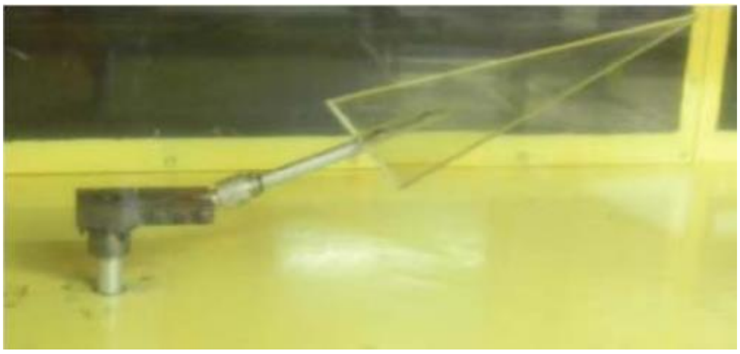

Figure 7: Delta wing model

Figure 8: Laser

- **Smoke Generator**: For flow seeding a kerosene based smoke generator is used

Procedure:

- Mount the delta wing for flow visualization in the test section.
- Start the tunnel, smoke generator and laser for illumination. Observe the vortices formed at different angle of attack.

Precautions:

- Follow the safety instructions while running the laser.
- Do not stand in the laser light path.
- Make sure that the laser light reflected back from the wing surface do not hit any person visualizing the flow.
- Always turn off the tunnel before opening the test section for model removal or mounting.
- Keep the room well ventilated while running the smoke-generator.

Suggested works:

- Study and sketch the low turbulence tunnel. Note special features of the tunnel which gives a low turbulence stream.
- Sketch the delta wing and angle of attack variation system.
- Study the smoke injection and illumination system.
- Observe the vortex structure and its bursting location at incidence using smoke and the laser system.

Observations:

1. Write and label the vortices formed on the delta with figures.
2. Label and explain the change in vortices over delta wing at various angle of attack

Try to answer the following questions for self-assessment:

- What is the effect of the sharp leading edge of delta wing?
- Does the vortex pair always remain symmetric with increasing angle of attack?
- What are the advantages due to the lee side vortices of a delta wing?
- What is vortex breakdown or bursting?
- How does it affect the performance of a delta wing aircraft?

References:

1. Payne, Ng, Nelson, and Schiff, "Visualization and wake surveys of vertical flow over a delta wing", AIAA Journal, Vol. 26, No. 2, 1988, pp. 137--143.

2. Josef Rom, "High angle of attack Aerodynamics", Springer-Verlag.

3. Kuchemann, "The Aerodynamic Design of Aircraft", American Institute of Aeronautics & Astronautics, 2012.