Experiment 3 : Wind Tunnel Velocity Characterization

AS2510 Low Speed Lab

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Aim

To determine the velocity of a fluid flowing through a varying diameter cross-section

Apparatus

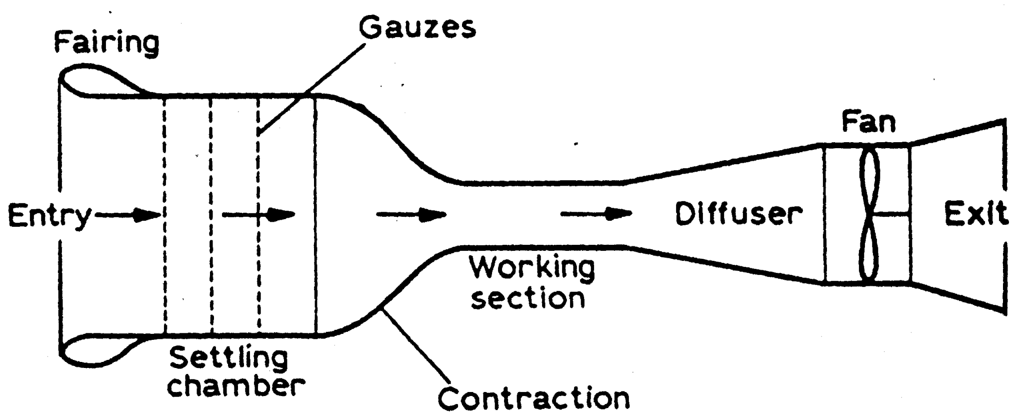

Figure 1: Schematic of open return wind tunnel used in experiment

The apparatus is a wind tunnel similar to the one depicted above. The cross-sectional area of the test section changes with the addition of slabs in it. The test section now initially converges, remains constant, and finally diverges. The location of the probes from the entry test section is mentioned below, with the value of the distance from the start of the test section and test section measurements given in mm.

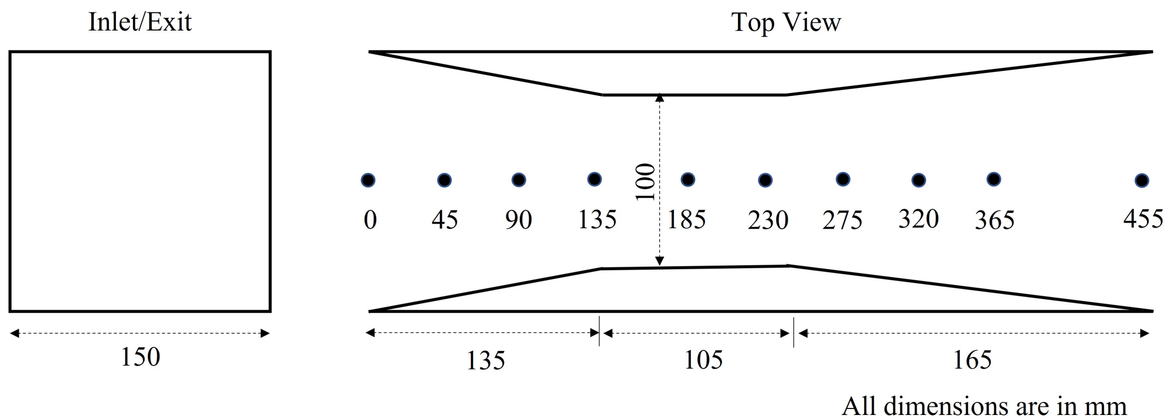

Figure 2: Plot showing the variation of width along the apparatus

In our experimental set up, there are 10 ports located at the following places :

- Port 1-4 : converging section
- Port 5-6 : constant area section
- Port 7-10 : diverging section

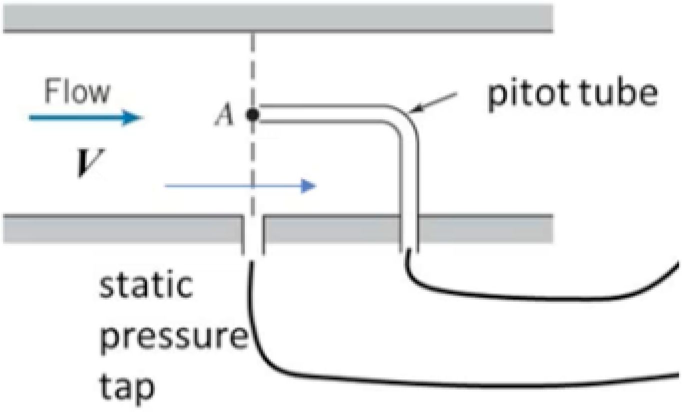

Figure 3: Static and Total pressure measurement set-up

We use a static pressure tap to measure the static pressure at different points in the flow. We also use a pitot tube to measure and verify the stagnation pressure. These are recorded with the help of a flow meter.

Since the source of the flow is the atmosphere, we know the stagnation pressure to be equal to the atmospheric pressure. The head loss in the low-speed flow is negligible as compared to the initial stagnation pressure and hence we use the atmospheric pressure as the stagnation pressure.

Principle

Fluid pressure is the measure of force per unit area exerted by a fluid. Pressure can be divided into two different types : static pressure and Dynamic pressure.

The stagnation pressure p_0 is the sum of static and dynamic pressures. It corresponds to the pressure attained if the fluid is brought to rest.

Using Bernoulli's Equations

$$p_0 = p + 0.5\rho u^2$$

Thus the free-stream velocity u can be measured by measuring the static and stagnation pressures if the density of the fluid is known.

Procedure

1. Set-up the apparatus with a steady flow
2. Measure the pressure at different location using the pressure probes on the apparatus
3. With the pressure measurements, stagnation pressure calculate the free-stream velocity of the flow.

4. Plot the variation of free-stream velocity along the flow.

Results

Calculations & Results

Atmospheric Pressure : 101325 Pa
Density of Air : 1.275 kg/m^3

Pitot Pressure Measured : 101321 Pa (4 Pa below atmospheric pressure)

% change in Stagnation pressure = (4 Pa / 101325 Pa) $\times$ 100 $\approx$ 0.004%

Thus, we can use the atmospheric pressure as the stagnation pressure.

To obtain the free-stream velocity from the experimental readings, we use the following :

$$static\ pressure = absolute\ pressure = atmospheric\ pressure + gauge\ pressure$$

$$gauge\ pressure = measurement \times conversion\ factor$$

$$1mmH_2O = 9.80665 pascals(Pa)$$

$$dynamic\ pressure = stagnation\ pressure - static\ pressure$$

$$velocity = \sqrt{2 \times dynamic\ pressure \times \rho}$$

	gauge pressure (mm H_2O)	static pressure (Pa)	dynamic pressure (Pa)	free-stream velocity (m/s)
Port 1	-22.1	101,108.27	216.73	23.51
Port 2	-24.6	101,083.76	241.24	24.81
Port 3	-31.3	101,018.05	306.95	27.98
Port 4	-39.2	100,940.58	384.42	31.31
Port 5	-43.7	100,896.45	428.55	33.06
Port 6	-42.9	100,904.29	420.70	32.76
Port 7	-39.7	100,935.68	389.32	31.51
Port 8	-34.9	100,982.75	342.25	29.55
Port 9	-31.3	101,018.05	306.95	27.98
Port 10	-24.4	101,085.72	23928	24.70

Table 1: Experiment Readings

Velocity variation along the flow

The plot below shows the variation in free-stream velocity along the apparatus.

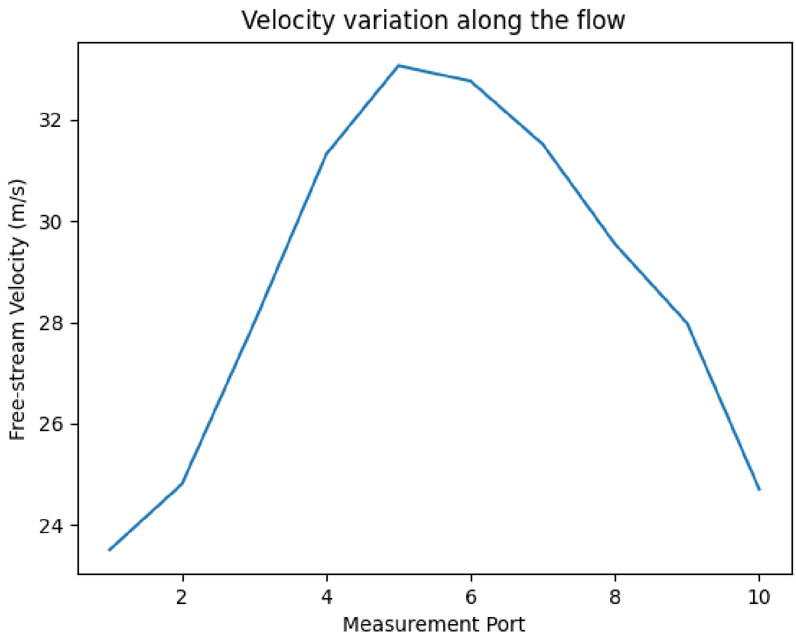

Figure 4: Plot showing the variation of velocity along the flow

Inference

We can see that the velocity increases in the converging section, remains nearly same in the constant area section and decreases in the diverging section. Such a behaviour is expected for a sub-sonic flow. The experimental findings thus align with the theoretically expected outcome.