Experiment - 4

Calibration of wind tunnel and verification of Bernoulli's equation

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5 March, 2023

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1. Aim :

- Calibration of wind Tunnel.
- Verification of Bernoulli's equaqtion.

2. Apparatus :

Required apparatus for performing this experiment are:

- Manometer
- C15-10 Armfield tunnel
- Pitot-static Probe

Figure 1: C15-10 Armfield

3. Theory :

Bernoulli's Principle is basically the form of energy conservation.Bernoulli's equation has different forms and is used based on type of flow.Generally simplest form of the principle is applicable for both compressible flow and incompressible flow for most of the fluids at low Mach number only and more complicated form used for flows with higher Mach numbers.Bernoulli's equation states that :

$$P_t = P_s + \frac{\rho v^2}{2} \tag{1}$$

P_t = Total Pressure/Stagnation Pressure;
P_s = Static Pressure;
$\Delta P = P_t - P_s = \frac{\rho V^2}{2}$ = Dynamic Pressure

ρ = Density of Air. From eqn(1) :

$$\frac{\rho V^2}{2} = (P_t - P_s) \tag{2}$$

$$V^2 = \frac{2(P_t - P_S)}{\rho}$$

$$V = \sqrt{\frac{2(P_t - P_S)}{\rho}} = \sqrt{\frac{2(\Delta P)}{\rho}}$$

4. Procedure :

1. In wind tunnel test section is set.
2. Pitot-static probe is connected to manometer.
3. Fan speed is fixed.
4. Required readings are taken.

5. Observation :

5.1 Experimental Data :

Ambient Temperature = 30° = 303 K
Ambient Pressure = 1018mBar = 101.8 KPa
Gas const.(R) = 287 J/Kg K

5.2 Comparison of Theoretical Pressure and Experimental Pressure at different tapping point of Tunnel

Table 1: **Pressure variation at different distance of Pipe and corresponding flow velocity**

Tapping Point	Area(mm^2)	Velocity at port(m/s)	Theoretical Pressure(Pa)	Experimental Pressure
P_1	22350	10	60.53	47.09
P_2	19860	11.25	76.08	57.88
P_3	17370	12.87	98.95	73.58
P_4	15000	14.9	131.94	99.08
P_5	15000	14.9	131.94	106.93
P_6	15000	14.9	131.94	110.85
P_7	16395	13.63	110.74	98.1
P_8	17902.5	12.48	93.16	89.27
P_9	19410	11.51	79.54	77.50
P_{10}	20910	10.69	68.89	71.61
P_{11}	22410	9.97	60.18	62.78

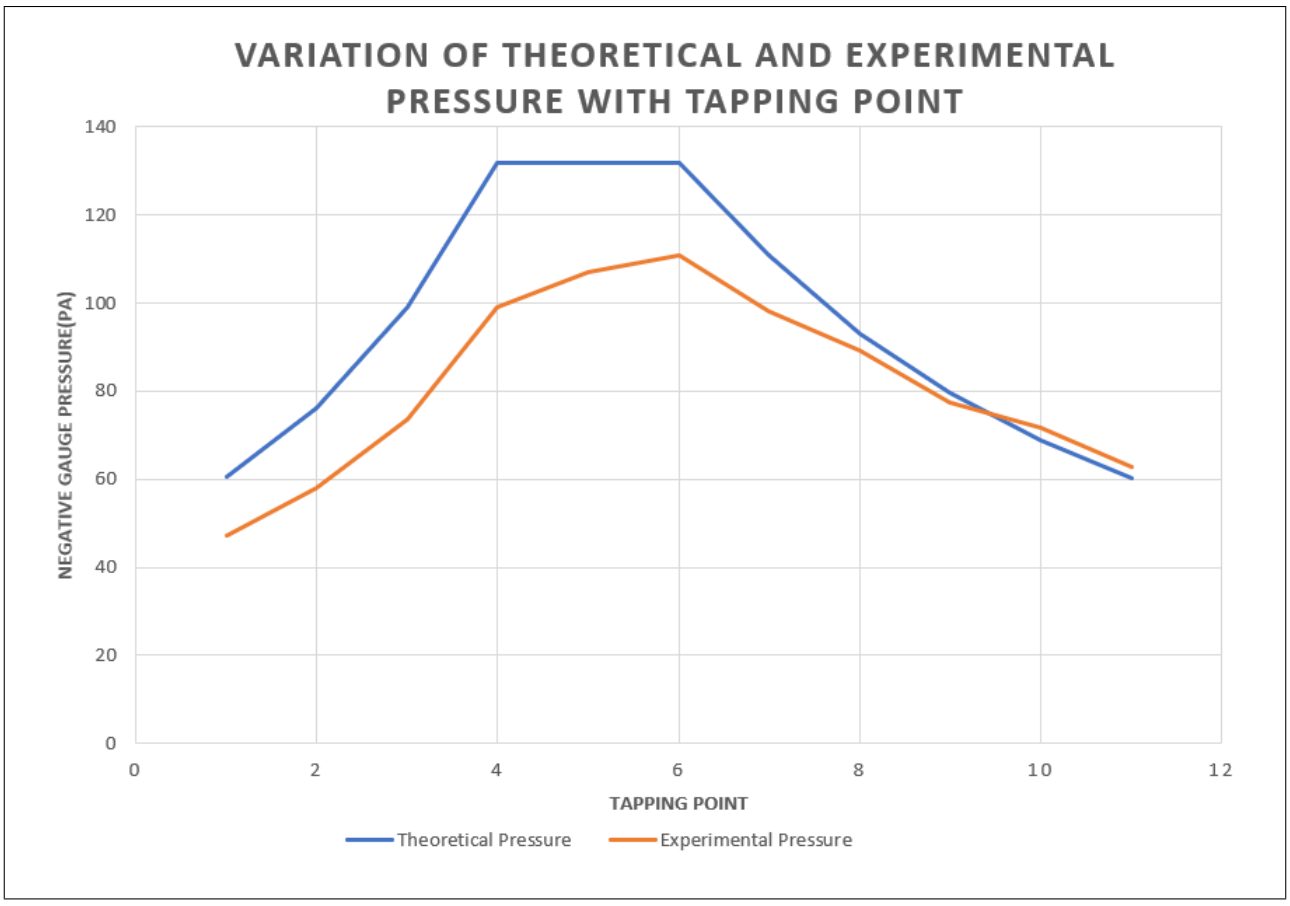

Figure 2: Theoretical and Experimental Pressure variation with tapping point

5.3 Pressure and Velocity at 3 parts of wind tunnel :

- **Central Line :**
  Dynamic Pressure(ΔP) = 116 Pa
  Static Pressure(P_s) = -118 Pa (Gauge Pressure)
  Stagnation Pressure(P_t) =P_t+P_s = -2 Pa (Gauge Pressure)
  Therefore, Velocity of flow = $\sqrt{\frac{2(\Delta P)}{\rho}}$ = 14.08 m/s

- **35 mm Down :**
  Dynamic Pressure(ΔP) = 116 Pa
  Static Pressure(P_s) = -118 Pa (Gauge Pressure)
  Stagnation Pressure(P_t) =P_t+P_s = -2 Pa (Gauge Pressure)
  Therefore, Velocity of flow = $\sqrt{\frac{2(\Delta P)}{\rho}}$ = 14.08 m/s

- **35 mm Above :**
  Dynamic Pressure(ΔP) = 108 Pa
  Static Pressure(P_s) = -110 Pa (Gauge Pressure)
  Stagnation Pressure(P_t) =P_t+P_s = -2 Pa (Gauge Pressure)
  Therefore, Velocity of flow = $\sqrt{\frac{2(\Delta P)}{\rho}}$ = 13.58 m/s

Flow velocity is almost uniform at a particular section of the tunnel.

6. Calculations :

Density of Air flow (ρ) = $\frac{P}{RT}$ = $\frac{101800}{287\times303}$ = 1.1706 Kg/m^3

6.1 Theoretical Pressure Calculation :

From experimental geometry we know area of each tapping point.
Speed of Fan(V_1) = 10 m/s
We know,
A_1 = 22350 mm^2 , V_1 = 10 m/s , A_2 = 19860 mm^2

For tapping point P_2 :
Using mass conservation principle :
$V_2 = \frac{A_1V_1}{A_2} = 11.25m/s$
From Bernoulli's equation :
Dynamic Pressure (ΔP) = $\frac{\rho v^2}{2}$ = 58.53Pa
Stagnation Pressure (P_t) = -2 Pa
Therefore, Static Pressure(P_s) = -60.53 Pa (gauge)

Thus velocity is calculated at each tapping point and hence static pressure is calculated.

6.2 Experimental Pressure Calculation :

For tapping point P_2 :
Pressure at P_2 = -5.9 mm of Water
Static pressure = $-5.9 \times 10^{-3} \times 10^3 \times 9.81 = -57.88Pa$(gauge)

7. Sources of Error:

- Error due to instrumental defect.
- Error may occur in taking readings before flow becomes steady.
- Error due to environmental effect like temperature,pressure change.

8. Conclusion :

- Experimental pressure variation across the tunnel(at different tapping point) is almost same with the tend of Theoretical Pressure variation.
- Uniformity of flow is maintained throughout the wind tunnel.
- Bernoulli's equation is verified.