

Experiment- 1

Shibayan Biswas, AE21B109
Department of Aerospace Engineering
IIT Madras

Instructor:
Professor Dr. Manikandan Mathur

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1. Aim:

To investigate the validity of the Bernoulli's equation when it is applied to a steady flow of air through Subsonic Wind Tunnel.

2. Introduction:

Energy presents in the form of pressure, velocity, and elevation in fluids with no energy exchange due to viscous dissipation, heat transfer, or shaft work (pump or some other device). The relationship among these three forms of energy was first stated by Daniel Bernoulli (1700-1782), based upon the conservation of energy principle. Bernoulli's theorem pertaining to a flow streamline is based on three assumptions: steady flow, in-compressible fluid, and no losses from the fluid friction. The validity of Bernoulli's equation will be examined in this experiment.

3. Practical Application:

Bernoulli's theorem provides a mathematical means to understanding the mechanics of fluids. It has many real-world applications, ranging from understanding the aerodynamics of an airplane; calculating wind load on buildings; designing water supply and sewer networks; measuring flow using devices such as weirs, Parshall flumes, and venturimeters; and estimating seepage through soil, etc. Although the expression for Bernoulli's theorem is simple, the principle involved in the equation plays vital roles in the technological advancements designed to improve the quality of human life.

4. Objective:

The objective of this experiment is to investigate the validity of the Bernoulli equation when it is applied to a steady flow of water through a tapered duct.

5. Equipment:

The following equipment is required to complete the demonstration of the Bernoulli equation experiment:

- Subsonic Wind Tunnel(Should have a honey comb structure to ensure steady flow and a blower to suck the air from the tunnel)
- Pitot Tube
- Computer(Software installed for passing values as input and getting the corresponding values as output)



Figure 1: MP 315D Subsonic Wind Tunnel

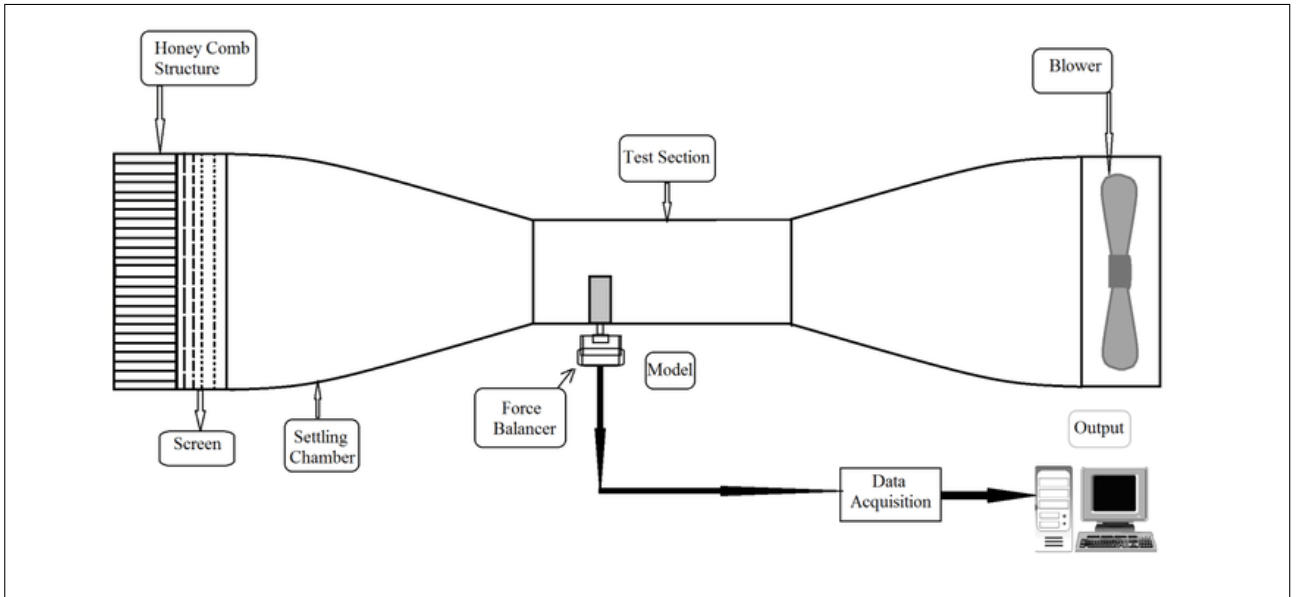


Figure 2: Complete Experimental Setup

6. Theory:

Bernoulli's theorem, in fluid dynamics, is relation among the pressure, velocity, and elevation in a moving fluid (liquid or gas), the compressibility and viscosity (internal friction) of which are negligible and the flow of which is steady, or laminar. First derived (1738) by the Swiss mathematician Daniel Bernoulli, the theorem states, in effect, that the total mechanical energy of the flowing fluid, comprising the energy associated with fluid pressure, the gravitational potential energy of elevation, and the kinetic energy of fluid motion, remains constant. Bernoulli's theorem is the principle of energy conservation for ideal fluids in steady, or streamline, flow and is the basis for many engineering applications.

In most flows of liquids, and of gases at low Mach number, the density of a fluid parcel can be considered to be constant, regardless of pressure variations in the flow. These flows are called in-compressible flows. Bernoulli performed his experiments on liquids, so his equation in its original form is valid only for in-compressible flow. A common form of Bernoulli's equation is:

$$\frac{p}{\rho} + \frac{v^2}{2} + gz = \text{constant} \quad (1)$$

P: pressure
z: height of the fluid
 ρ : density of liquid
v: fluid velocity
g: acceleration
due to gravity

In Bernoulli's hypothesis the stream is friction-less, consistent, and in-compressible. These presumptions are additionally founded on the laws of conservation of mass and energy. Subsequently, the initial mass and energy for a given control volume are equivalent to the final mass and energy:

$$Q_{in} = Q_{out} \quad (2)$$

$$E_{in} = E_{out} \quad (3)$$

In this experiment, the duct is horizontal, so the difference in height can be neglected, it implies $z_1 = z_2$.

The hydrostatic pressure (P) along the flow is measured, and the pressure head (h), is:

$$h = \frac{p}{\rho g} \quad (4)$$

Therefore, Bernoulli's equation for the test section can be written as:

$$h_1 + \frac{v_1^2}{2g} = h_2 + \frac{v_2^2}{2g} \quad (5)$$

in which $\frac{v^2}{2g}$ is called the velocity head (h_d)

The total head might be estimated by the crossing hypodermic test. This test is embedded into the channel with its end-opening confronting the stream so the stream becomes stale locally at this end; thus: The total head might be estimated by the crossing hypodermic test. This test is embedded into the channel with its end-opening confronting the stream so the stream becomes stale locally at this end; thus:

$$h_t = h + \frac{v^2}{2g} \quad (6)$$

The conservation of energy can be expressed as:

$$h_{t1} = h_{t2} \quad (7)$$

The flow velocity is measured by dividing volume of the fluid (V) that passes over a time period (t). The flow rate is measured as:

$$Q = \frac{V}{t} \quad (8)$$

The velocity of flow at any section of the duct with a cross-sectional area is:

$$v = \frac{Q}{A} \quad (9)$$

For an in-compressible fluid, conservation of mass (Equation 2) can be applied across the test section since mass is not accumulating, that implies:

$$A_1 v_1 = A_2 v_2 \quad (10)$$

7. Procedure:

In this experiment, the validity of Bernoulli's equation is determined with the help of a subsonic wind tunnel which measure the pressure head and total head at certain points along the flow.

- Setting up the wind tunnel.
- Turning on the fan of wind tunnel.
- Setting the speed of the fan to certain value, which gives us corresponding wind velocity.

- Note down the pressure readings of the 11 ports which are displayed on computer.
- Now changing the fan speed and repeat the experiment until you get 3 such readings.
- We can note the static pressure as shown on the screen, and use Bernoulli's equation to figure out pressure at every one of those 11 ports and later check results between theoretical and experimental values.

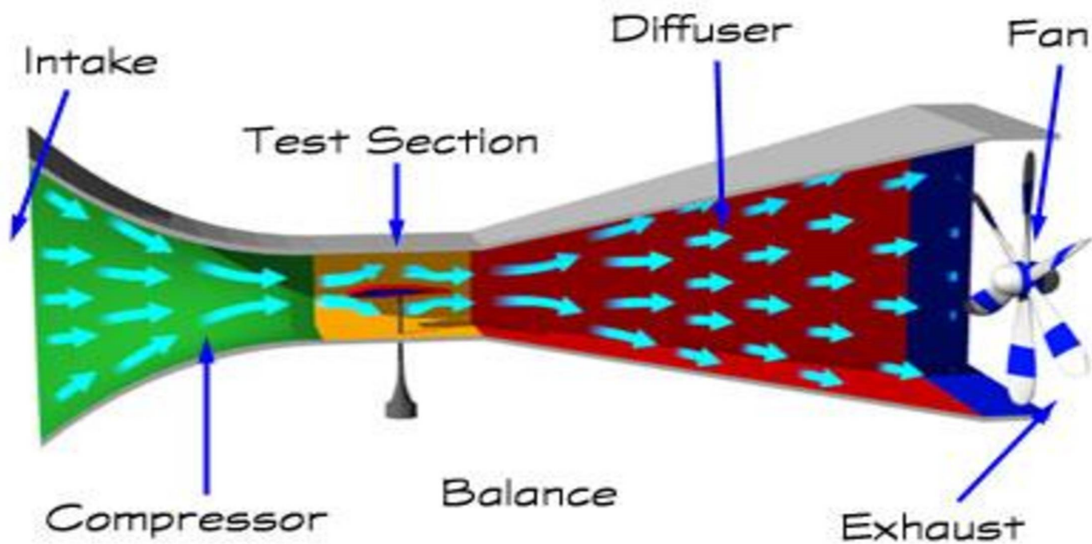


Figure 3: Working of a Subsonic Wind Tunnel

8. Results:

The tables representing the experimental and the theoretical values along with the plots showing the variation of the respective values for the following experiment is provided in this section:

- For velocity of wind $v = 12.4 \text{ m/s}$ at pressure $P = 9.0 \text{ mm of water}$, the following is the pressure and velocity distribution at distribution cross sections of the test section.

Static Pressure(Pa)	Area(mm^2)	Velocity(m/s)	$\frac{1}{2}\rho v^2$	$P + \frac{1}{2}\rho v^2$
88.29	22350	12.4	94.18	182.47
105.95	19860	13.95	119.19	225.14
143.23	17370	15.96	156.02	299.25
109.97	15000	18.48	209.18	319.05
186.39	15000	18.48	209.18	395.57
128.51	15000	18.48	209.18	337.67
169.71	16395	16.90	174.94	344.65
133.42	17902.5	15.48	146.77	280.19
132.44	19410	14.28	124.9	257.34
119.68	20910	13.25	107.53	227.21
112.82	22410	12.37	93.72	206.54

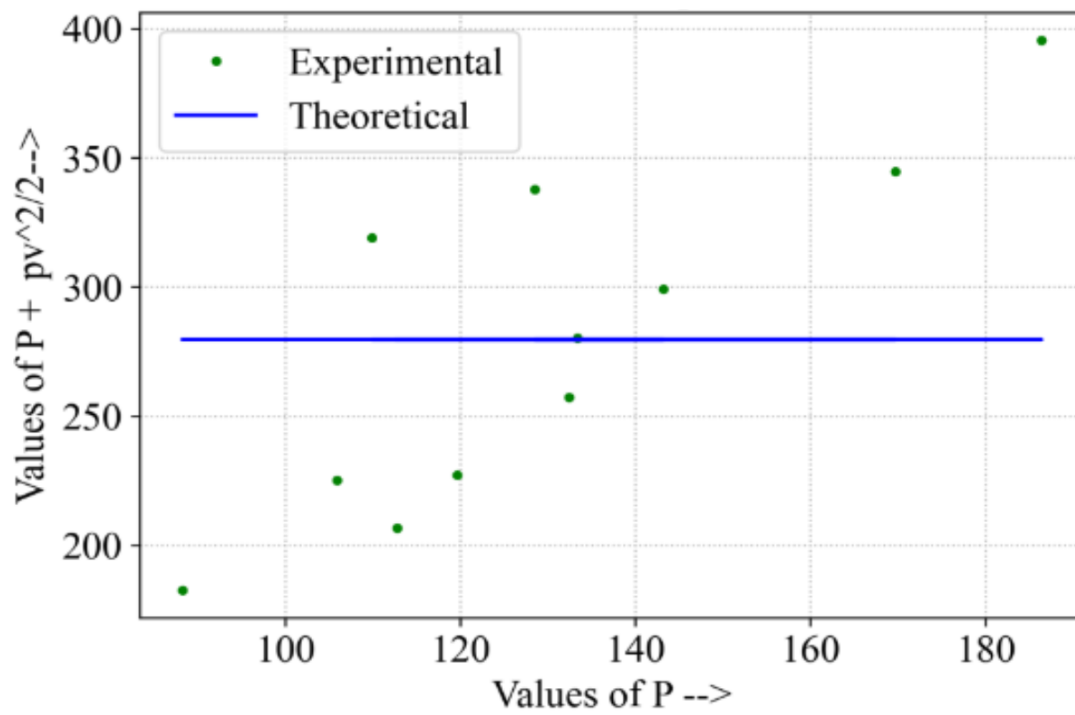


Figure 4: $P + \frac{1}{2}\rho v^2$ v/s P

- For velocity of wind $v = 17.5$ m/s at pressure $P = 17.9$ mm of water, the following is the pressure and velocity distribution at distribution cross sections of the test section.

Static Pressure(Pa)	Area(mm^2)	Velocity(m/s)	$\frac{1}{2}\rho v^2$	$P + \frac{1}{2}\rho v^2$
175.6	22350	17.5	187.58	363.18
206.99	19860	19.69	237.46	444.45
236.42	17370	22.52	310.63	547.05
217.78	15000	26.08	416.6	634.38
368.87	15000	26.08	416.6	785.47
255.06	15000	26.08	416.6	671.66
333.54	16395	23.86	348.70	682.24
272.72	17902.5	21.85	292.42	565.14
268.79	19410	20.15	248.69	517.48
235.44	20910	18.71	214.41	449.85
218.76	22410	17.45	186.51	405.27

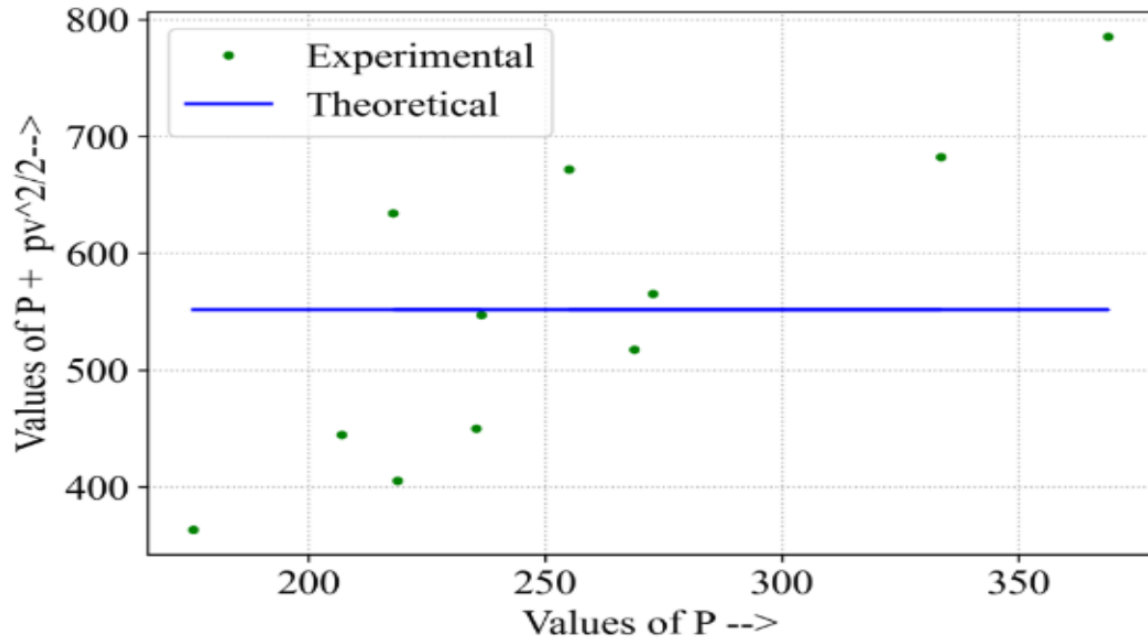


Figure 5: $P + \frac{1}{2}\rho v^2$ v/s P

- For velocity of wind $v = 22.2$ m/s at pressure $P = 28.6$ mm of water, the following is the pressure and velocity distribution at distribution cross sections of the test section.

Static Pressure(Pa)	Area(mm^2)	Velocity(m/s)	$\frac{1}{2}\rho v^2$	$P + \frac{1}{2}\rho v^2$
280.57	22350	22.2	301.86	582.43
335.5	19860	24.98	382.2	717.7
363.95	17370	28.56	499.6	863.55
355.12	15000	33.08	670.25	1025.37
594.49	15000	33.08	670.25	1264.74
413	15000	33.08	670.25	1083.25
534.65	16395	30.26	560.85	1095.5
438.51	17902.5	27.72	470.64	909.15
428.7	19410	25.56	400.15	828.85
377.69	20910	23.73	344.91	722.6
352.18	22410	22.14	300.24	652.42

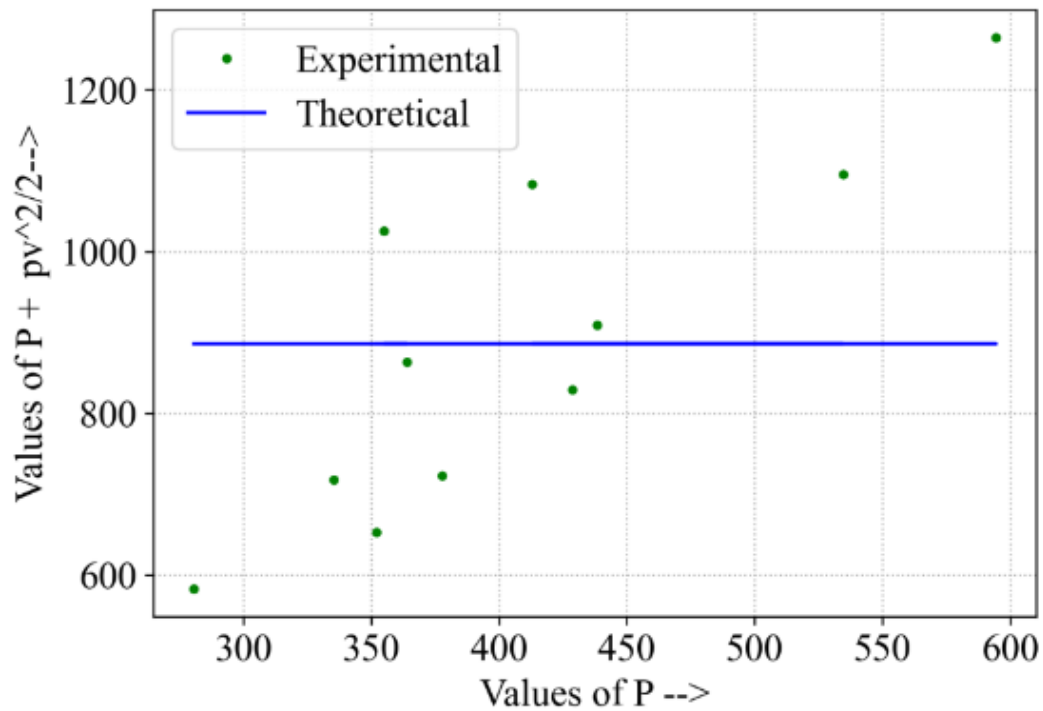


Figure 6: $P + \frac{1}{2}\rho v^2$ v/s P

9. Interpretation:

The graphs of experimental and theoretical pressure variations have a lot of differences because the conditions we assumed are not ideally present, and there are many errors such as equipmental errors, variation of temperature, variation of atmospheric pressure, variation in the flow of wind i.e. not perfectly stream line etc... But the overall idea of the graphs are the same i.e. the graph decreases until a certain value and then increases. So we can conclude that Bernoulli's equation is valid.

10. Sources of Error:

While playing out the experiments, there are some mistakes noticed.. may be it's little relying upon the precision with which we are playing out the analysis however there's mistake certainly. Given beneath are a few potential causes of blunder while playing out this experiments:

- Error in Instruments- Equipment used in the experiments are man made and bound to have certain errors.
- Improper conditions- The conditions at the time of experiment might be off without our notice which ultimately lead to errors.
- Human error- Everything humans do isn't perfects and often challenged to have some mistakes.
- Parallax error- The apparent shift in an object's position as it is viewed from different angles is one of the errors we face.

11. Conclusion:

Even though barring minor mistakes committed due to certain errors, the stream follows Bernoulli's condition (Constant flow), and the wind flow approximately follows Bernoulli's equation and thus we verify Bernoulli's equation using this experiment.

12. Methods of Safety:

- Must make sure that every thing is properly connected before powering on the wind tunnel.
- Must ensure nothing is obstructing the flow of wind current within the wind tunnel.
- Must ensure every pressure port of wind tunnel is properly functioning.