Experiment 2 : Flow through a Bend

AS2510 Low Speed Lab

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Aim

To verify the theoretical results obtained for pressure gradient for a flow through a 90° bend

Apparatus

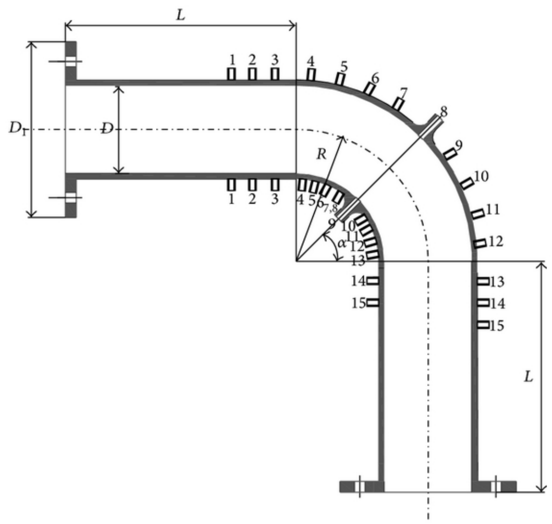

Figure 1: Apparatus to measure pressure in a bend

The apparatus is similar to the one depicted above. The diameter of the flow tube is constant, and the location of the probes from the entry cross-section is mentioned in degrees.

In our experimental setup, there are 6 ports located at the following places :

- Port 1 : inner wall at 0°
- Port 2 : outer wall at 0°
- Port 3 : inner wall at 45°
- Port 4 : outer wall at 45°
- Port 5 : inner wall at 90°
- Port 6 : outer wall at 90°

To get measurements from this apparatus we use a flow meter.

Principle

Euler's equation, when expressed in streamline coordinates, provides useful and physically insightful relationships between the various terms in relation to the streamlines. For the radius of curvature being R, the below depicts the streamline.

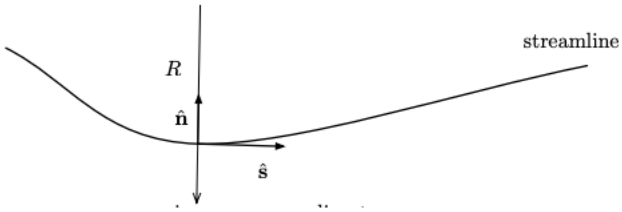

Figure 2: Coordinate System along a streamline

For s, n and l be respectively the coordinates along a streamline, normal to a streamline along the radius of curvature, and in the bi-normal direction, we get the following equations be collecting the terms of respective components along :

$$\vec{s} : \frac{\partial}{\partial s}\frac{u^2}{2} + \frac{1}{\rho}\frac{\partial p}{\partial s} = 0$$

$$\vec{n} : -\frac{u^2}{R} + \frac{1}{\rho}\frac{\partial p}{\partial(-n)} = 0$$

Thus the pressure varies according to

$$\frac{\partial p}{\partial(-n)} = \rho\frac{u^2}{R}$$

The negative sign is due to the direction of $\vec{n}$, since the direction of normal taken in towards the center and the pressure gradient is expected to be positive along the outward normal. Taking the normal to be pointing outward, the pressure variation is described as :

$$\frac{\partial p}{\partial n} = \rho\frac{u^2}{R}$$

This is obtained from and is coherent with the derivation from the below schematic.

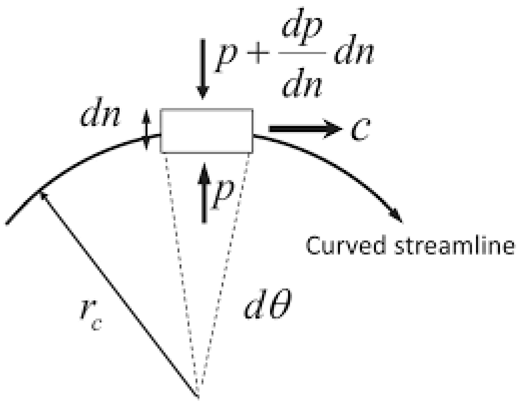

Figure 3: Pressure gradients in a curved streamline

Procedure

1. Set-up the apparatus with a flow of pre-defined velocity
2. Measure the pressure at different location using the pressure probes on the apparatus
3. With the pressure measurements, plot pressure and pressure difference as a function of the angle along the curve
4. Repeat the experiment with different velocity flows

Results

Calculations & Results

Pipe diameter : 34mm
Atmospheric Pressure : 101325 Pa
Density of Air : 1.225 kg/m^3

	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
angle (degree)	0	0	45	45	90	90
location	inside	outside	inside	outside	inside	outside

Table 1: Apparatus Specifications

	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
gauge pressure (Pa)	-775	-470	-985	-360	-770	-465
absolute pressure (Pa)	100,550	100,855	100,340	100,865	100,555	100,860

Table 2: Experiment Readings for inlet flow velocity $\approx$ 30.5m/s

	Port 1	Port 2	Port 3	Port 4	Port 5	Port 6
gauge pressure (Pa)	-2180	-1315	-2700	-1000	-2130	-1280
absolute pressure (Pa)	99,145	100,010	98,625	100,325	99,195	100,045

Table 3: Experiment Readings for inlet flow velocity $\approx$ 50.5m/s

Pressure variation along the bend

The plot below shows the variation in Pressure along the apparatus. We can see and verify that the pressure on the outer wall is more than the pressure on the inner wall.

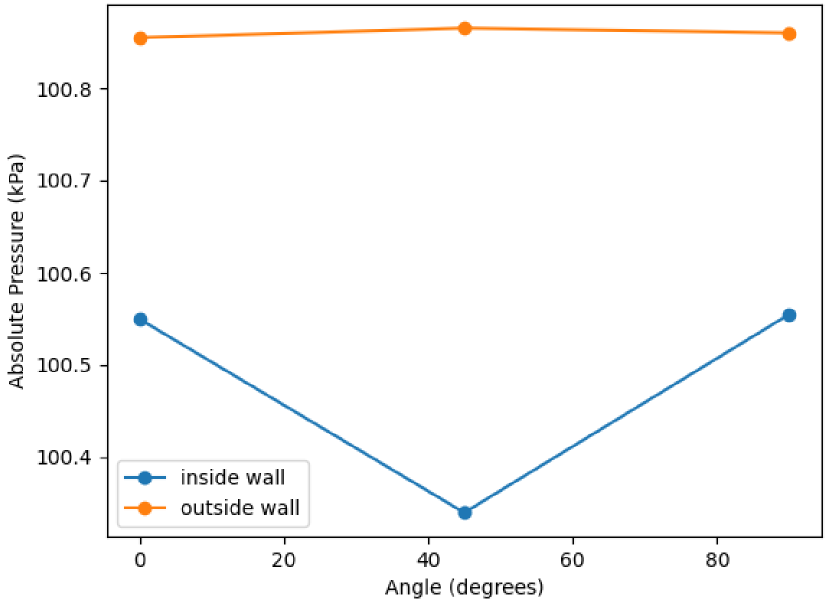

Figure 4: Pressure Measurements at inlet flow velocity $\approx 30.5\text{m/s}$

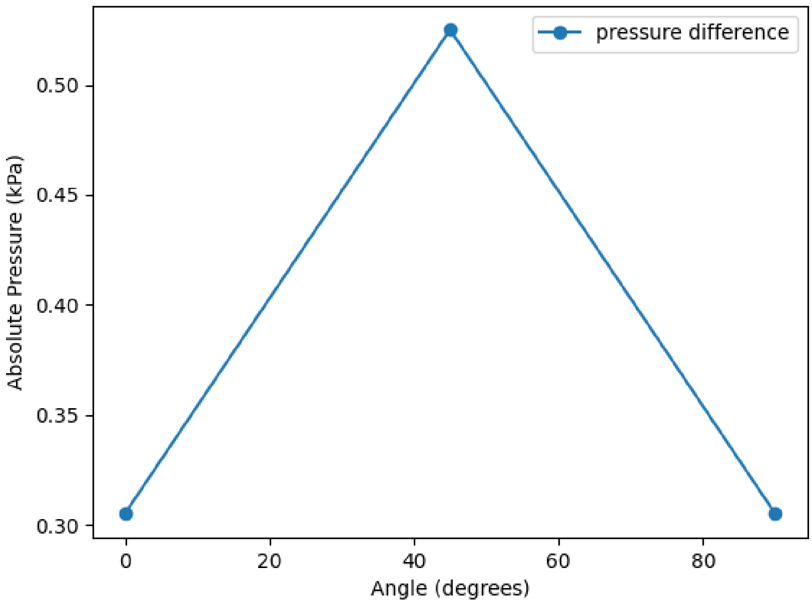

Figure 5: Pressure difference at inlet flow velocity $\approx 30.5\text{m/s}$

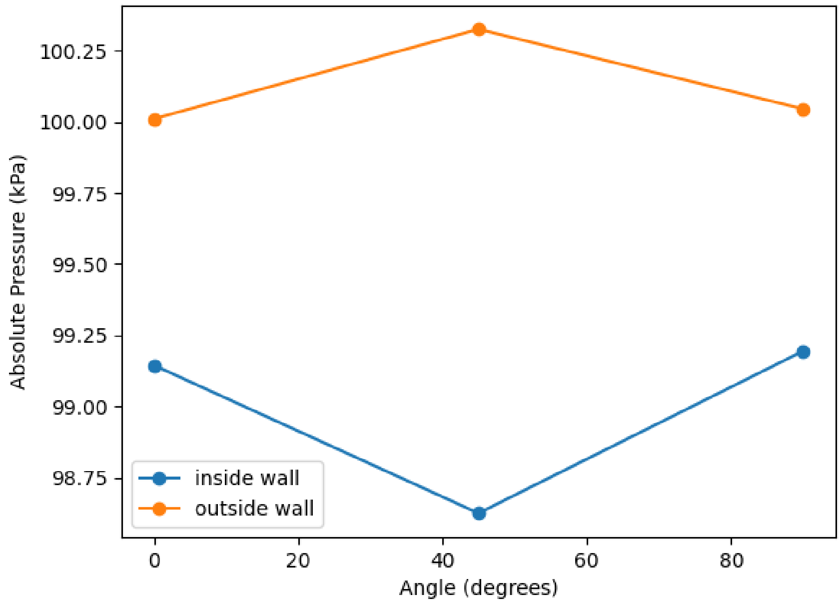

Figure 6: Pressure Measurements at inlet flow velocity ≈ 50.5m/s

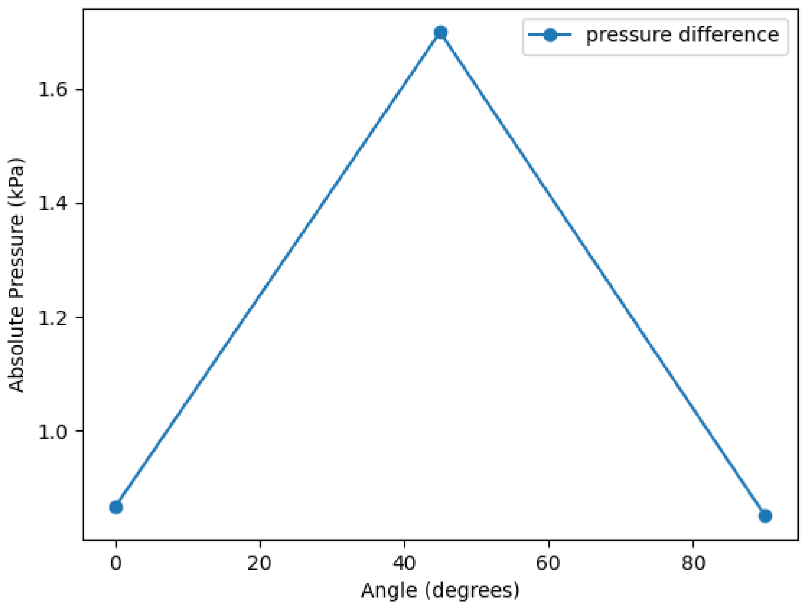

Figure 7: Pressure difference at inlet flow velocity ≈ 50.5m/s

Inference

We can see that the pressure on the outer wall is greater than the pressure on the inner wall. The Pressure on the outer wall further increases and the pressure on the inner wall further decreases near the apex of the turn.

Hence, the pressure difference also increases with it being maximum at the apex of the bend.