Airstream Deflection Across a Cylindrical Surface

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ABSTRACT
A cylindrical airstream was blown across a cylindrical surface. The deflection angle, peak speed, and asymmetry of the airstream were measured while changing the location of the cylinder relative to the center of the wind column, and while changing the speed of the airstream. It was found that the closer the cylinder is to the center of the airstream, the greater the deflection angle, the lower the peak speed, and the greater the asymmetry of the deflected airstream. It was also found that the wind speed has no impact on the deflection angle when the cylinder remains in a fixed position.

Keywords: Coanda effect, fluid, deflection

I. INTRODUCTION

When a stream of Newtonian fluid travels across a surface, the stream is attracted to the surface. In the 1800's Thomas Young made reference to a phenomenon that seemingly pulled a candle to a stream of air [1]. This baffled scientists for many years until Henri Coandă made detailed observations of what is now referred to as the Coandă effect[2]: defined as the inclination of a stream of fluid to become attracted to a surface in its path due to a difference in pressure between the flow and the object.

While much work has been published on the behavior of wall jets flowing across air foils[3], and a variety of other surfaces[4], no literature was identified describing the behavior of a cylindrical air jet encountering a cylindrical surface (figure 2). This paper describes the behavior of the airstream as it crosses a cylindrical surface at different positions and speeds.

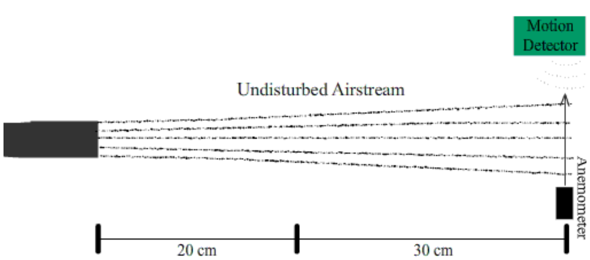

Figure 1 The undisturbed airstream was mapped by sliding an anemometer across the jet in front of a motion detector.

II. METHODS

A variable speed air blower emitting a cylindrical stream of air from a 3.4 cm diameter opening was used. The speed profile of the undisturbed air stream was mapped by slowly sliding an anemometer across the airstream at distances of 20 centimeters and 30 centimeters from the blower mouth while its position was being recorded by a motion detector as shown in figure 1. The peak speed at the center of the undisturbed airstream was 10.8 ± 0.5 m/s at 20 cm and 6.8 ± 0.2 m/s at 30 cm from the mouth of the blower. The diameter of the airstream, defined as the distance between where the airspeed dropped below 1 m/s on the left and right edges of the airstream, was approximately 10 cm at a distance of 20 cm from the blower mouth, and approximately 19 cm at a distance of 30 cm.

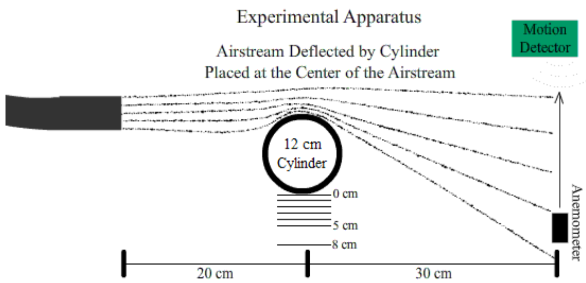

Figure 2 A 12 cm diameter pipe was placed at various locations in the airstream and the resulting deflection profile was mapped using the anemometer and motion detector.

A 12 cm diameter pipe was then placed so that its surface was at the center of the airstream, as shown in figure 2, and the anemometer and motion detector used to map the speed profile of the deflected airstream. This was repeated three times.

The cylinder was then moved back 1 cm at a time until the cylinder reached the edge of the air stream, at 5 cm. The speed profile of the deflected airstream was mapped for each cylinder position. Finally, the cylinder was placed at 8 cm from the center, approximately 3 cm from the edge of the airstream, and the airstream's speed profile mapped again. To test the effect of airstream speed, the cylinder was placed 2 cm from the center of the airstream, and the speed profile of the deflected airstream measured for peak airstream speeds at the position of the cylinder ranging from approximately 6 m/s to 12 m/s.

In figure 3 the speed profile when the cylinder was 2 cm from the center of the airstream is shown. The figure shows the peak speed of the airstream (6.10 m/s), the position of the peak speed (0.032 m from the center of the undisturbed airstream), and the skew (0.52) which is a measure of the asymmetry of the deflected airstream, and defined here as,

$$Skew = \frac{(x_{1/2\,peak(R)} - x_{peak})}{(x_{peak} - x_{1/2\,peak(L)})} - 1 \ , \qquad (1)$$

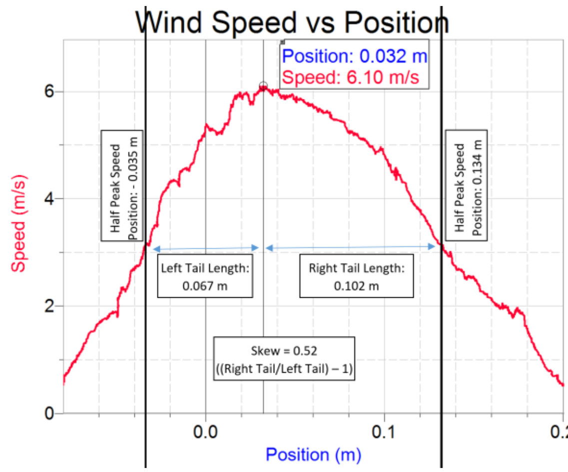

Figure 3. A speed profile of the airstream when the cylinder was 2 cm from the center of the airstream. Peak speed and position, and the method of calculating the skew using the graph are shown.

where, x_{peak} is the position of the peak speed of the airstream, $x_{1/2\,peak(R)}$ is the position on the right side of the airstream where the speed of the airstream is half of the peak speed, and $x_{1/2\,peak(L)}$ is the same for the left side of the airstream.

III. RESULTS AND DISCUSSION

For each cylinder position, the deflection angle and the speed of the point in the airstream with the greatest speed were determined. The asymmetry of the deflected airstream, as measured by its skew was also determined. Finally, the effect of the speed of the airstream on the deflection angle was determined.

Figure 4 shows how the position of the cylinder relative to the center of the airstream affected the deflection angle of the airstream due to the Coandă effect. When the cylinder is completely outside the airstream (8 cm), there is no deflection, but as the cylinder is placed further and further into the airstream, the deflection increases, reaching a deflection angle of just over 20° when the surface of the cylinder is placed in the center of the airstream (0 cm).

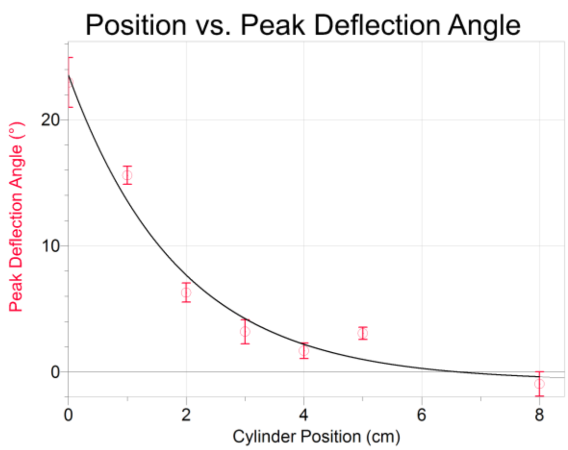

Figure 4. The deflection angle of the peak of the airstream increased as the cylinder approached the center of the airstream.

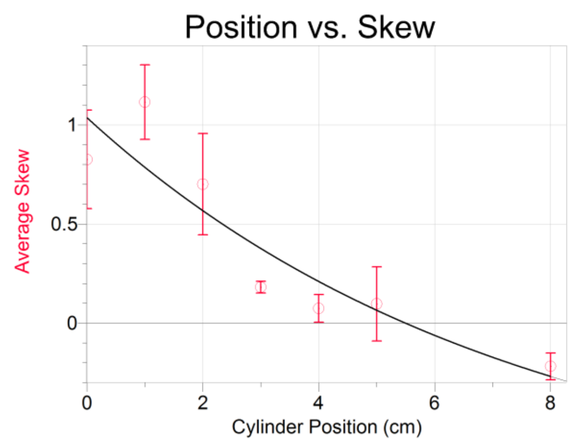

Figure 6. The asymmetry of the airstream became more pronounced as the cylinder approached the center of the airstream.

The effect of cylinder position on the maximum speed of the center of the airstream is shown in figure 5. As the cylinder is moved further from the center of the wind column, the recorded peak speed increases. This is due to the fact that the air stream becomes more spread out as it is more deflected. The Coandă effect seems to cause the part of the airstream that is closer to the surface to deflect more, while the part of the airstream that is further from the cylinder deflects less, resulting in an increasing widening of the airstream and a reduction in peak speed as the cylinder moves farther towards the center of the airstream.

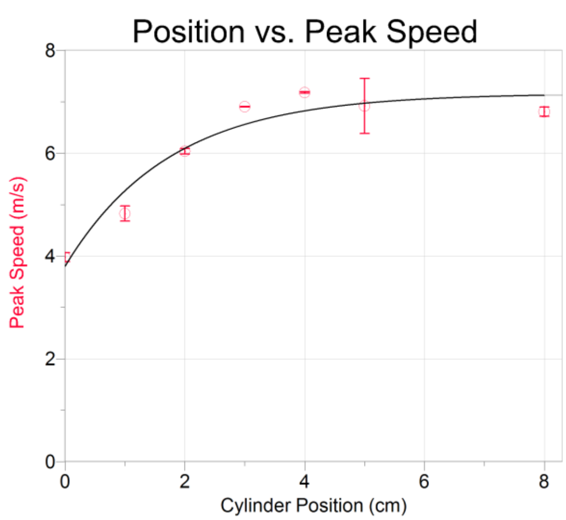

Figure 5. The peak speed of the airstream decreased as the cylinder approached the center of the airstream.

Figure 6 shows the effect that the position of the cylinder has on the asymmetric deflection pattern, skew, of the airstream due to the Coandă effect. As the cylinder gets further from the center of the airstream, the average skew decreases, approaching a skew value of 0, meaning a symmetric airstream, as the cylinder is withdrawn from the airstream. It must be noted that when then cylinder was completely withdrawn from airstream (8 cm), the airstream shows a negative skew, meaning it was asymmetric to the left. The anemometer was moved from right to left across the airstream in each trial, and even though the anemometer was moved very slowly, it was noticed that the inertia of the anemometer turbine made it take time to slow down as the airspeed reduced on the left side of the airstream. Ideally, trials should have been done sliding the anemometer both ways across the airstream and the results averaged, but the doubled time required made it impossible to do that here. The large variability in the uncertainty of the skew values should be noted here. The anemometer readings fluctuated significantly and unpredictably while in the airstream due to turbulence and instability in airflow patterns.

Finally, figure 7 demonstrates that deflection angle of the airstream remained constant, within uncertainties, for the range of airstream peak speeds tested. The Coandă effect does not appear to depend on the speed within this speed range.

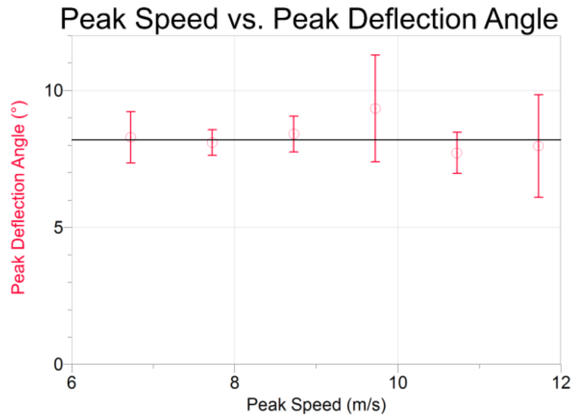

Figure 7. The peak speed of the airstream has no effect on the airstream deflection angle.

One issue is the fact that the anemometer was aligned parallel to the undisturbed airstream for all measurements. This meant that for highly deflected airstreams, the anemometer would have been measuring only the component of the wind speed parallel to the undisturbed airstream. While this would not be expected to have an effect on the peak position and skew values measured, it would have an effect on the peak speed values measured. Due to the unknown characteristics of wind flow and turbulence around the anemometer, it is not possible to calculate actual speed from the measured component with confidence, although it can be predicted that the measured peak speed values are increasingly below the actual values for increasing deflection angles.

This paper presents a preliminary description of several aspects of the Coandă effect for a cylindrical airstream flowing across a cylindrical surface. Further studies could be conducted investigating the effect of surface curvature, increased airspeeds, and for fluids other than air. Derivation of a mathematical model explaining this behavior is also important.

IV. CONCLUSION

In this paper, some characteristics of the behavior of a cylindrical airstream encountering a cylindrical surface are presented. It is shown that the closer the cylinder is to the center of the airstream, the greater the resulting angle of deflection, the lower the peak speed of the airstream, and the greater the asymmetry of the deflected airstream. Finally, it was also shown that the deflection angle is not affected by wind speed for the range tested.

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