Report on air flow rig and bernoullis

[Environment](), [Air]()

Air Flow Rig – Pitot Static Tube & Venturi Meter Introduction In this report I will use a pitot-static tube and a Venturi meter set up within an air flow rig to demonstrate the application of Bernoulli's Equation and the assumption of inviscid flow. The air flow rig was set up and an imaginary matrix was defined across the cross sectional area of the air flow at the pitot-static section. The matrix had 4 cells going across (A, B, C, and D) the width and 5 cells down the height of the rig (1, 2, 3, 4 and 5).

The pitot-static tube will be moved around to the centre of each cell so we can then take a reading for the pressure at that particular point, which can then be used to calculate the velocity across the matrix. This will enable me to determine how the pressure and flow performs in a non ideal situation by comparing the assumed volumetric flow rate at the pitot-static section with the calculated volumetric flow rate at the venturi. This will allow me to further discuss issues relating to why the values are different if they give different results. Theory

Bernoulli's equations are based on ideal flows, this means the gases in question obey the equation of state; Pressure x Volume = Constant, and also suggests the flow has zero drag. In most cases flow does have some form of friction, either due to the viscous nature of the fluid or due to the turbulent behaviour of the flow (Sherwin & Horsley, 1996). The continuity equation is a form of the conservation of mass, applied to flowing fluids. In the flow the mass flow rate of the fluid entering and leaving the system must be the same (Sherwin & Horsley, 1996).

It states the product of the density, area and velocity of a fluid is a constant in each particular case: ? 1A1v1=? 2A2v2 Bernoulli's energy equation is the conservation of energy applied to fluids and is shown as the following: P1? +v122+z1g= P2? +v222+z2g This shows that the sum of the specific flow energy, the specific kinetic energy and the specific potential energy is a constant in a steady system. A steady system, however, assumes the following characteristics: * The flow has zero friction; * The fluid is incompressible; * There is no heat transfer; There is no work being done on, or by, the system. We can multiply through by density to give a total pressure equation of the system at any particular cross section of the flow. It includes the static pressure - the potential pressure exerted in all directions by a fluid, the dynamic pressure - the difference in pressure levels from static pressure to stagnation pressure caused by an increase in velocity, and the hydrostatic pressure - the pressure which is exerted on a portion of a column of fluid as a result of the weight of the fluid above it: total pressure= P+? 22+pzg For systems that cohere to the assumptions above, the total pressure for any situation where the flow area takes a steady change is constant (Sherwin & Horsley, 1996). A pitot tube is a velocity measuring device based on utilizing a pressure difference in a flow. It is a tube with an open end pointing into the direction of the flow and connected to a form of pressure measuring device, in the case of this investigation manometer using water. The equation for finding the velocity from the pitot-static tube for an incompressible flow is: v= 2(P1-P)?

Where P1-P is the difference between the static pressure and the total pressure. (Bentley, 2005) The other type of device used is a venturi meter;

this works on the principle of reducing the cross section of the flow so that there is a measurable pressure difference. There will be a measuring device incorporated into the pipe, with one end in the throat and the other in the wider cross section of the pipe, this measures the pressure difference. We can link this pressure difference in the following equation for volumetric flow rate: Q= A1v1= cdA22(P1-P2)? 1-A2A1

This equation includes the coefficient of discharge, which is a correcting factor because the velocity at the venturi will be slightly less than that in the assumed equation, Av= Q, due to frictional effects in the converging part of the venturi. To find the discharge coefficient (cd) we can divide the volumetric flow rate from Q= A1v1 by the volumetric flow rate from the venturi (Sherwin & Horsley, 1996). The value of the discharge coefficient on the venturi meter being used in the investigation is known to be 0. 98. To take readings of the pressure differences, manometers were used.

Manometers rely on the height of a column of liquid to measure the pressure difference. The columns were set to be inclined to decrease the errors in reading as it will increase the distance the fluid is displaced; we then use trigonometry to convert the readings into a vertical height. By knowing the density of the fluid, the distance displaced the angle of inclination and the acceleration due to gravity, I can use the following equation to find the pressure difference in the manometer: P=? gh P=? g(hsin?) Results Air Pressure in the room = 76. 1 cm of mercury

The following tables show the results of the pressure difference inside the air flow rig in mmH2O displaced. Result 1 (mmH? O)| Cell| A| B| C| D| 1| 27. 5|

33. 0| 33. 0| 30. 0| 2| 28. 0| 36. 0| 38. 0| 33. 0| 3| 32. 0| 41. 0| 40. 0| 25. 0| 4| 34. 0| 38. 0| 36. 0| 26. 0| 5| 18. 0| 19. 0| 19. 0| 17. 0| | | | | | Result 2 (mmH? O)| Cell| A| B| C| D| 1| 25. 0| 31. 0| 32. 0| 29. 0| 2| 31. 0| 38. 0| 38. 0| 33. 0| 3| 31. 0| 39. 0| 39. 0| 32. 0| 4| 33. 0| 38. 0| 38. 0| 29. 0| 5| 17. 0| 20. 0| 19. 0| 17. 0| | | | | | Result 3 (mmH? O)| Cell| A| B| C| D| 1| 26. 0| 30. 0| 31. 0| 29. 0| 2| 30. 0| 37. 0| 38. 0| 31. 0| 3| 31. 0| 39. 0| 40. 0| 28. | 4| 33. 0| 34. 0| 36. 0| 29. 0| 5| 17. 0| 18. 0| 19. 0| 16. 0| | | | | | Result Average (mmH? O)| Cell| A| B| C| D| 1| 26. 2| 31. 3| 32. 0| 29. 3| 2| 29. 7| 37. 0| 38. 0| 32. 3| 3| 31. 3| 39. 7| 39. 7| 28. 3| 4| 33. 3| 36. 7| 36. 7| 28. 0| 5| 17. 3| 19. 0| 19. 0| 16. 7| Venturi (mmH20)| Result 1| 185| Result 2| 185| Result 3| 185| Result Average| 185| Venturi (Pa)| Result 1| 315| Result 2| 315| Result 3| 315| Result Average| 315| Calculations Density of Air: Pressure of Air was read in cm of mercury. Density of Mercury= 13534kgm3 P= ? gh P= 13534kg m-3? 9. 81m s-2 ? 0. 761m= 101036. 9 Pa PV= MRT & ? = VM ? P=? RT ? ? = PRT ?= 101036. 287. 05 ? (21+273)= 1. 197 kg m-3 Converting the manometer reading of mmH2O to a vertical height reading: H= Lsin? where L= manometer reading and ? = angle of manometer. The equation was used in a spreadsheet and gave me the following table: Result Average after Conversion (mmH? O)| Cell| A| B| C| D| 1| 6. 3| 7. 6| 7. 7| 7. 1| 2| 7. 2| 9. 0| 9. 2| 7. 8| 3| 7. 6| 9. 6| 9. 6| 6. 9| 4| 8. 1| 8. 9| 8. 9| 6. 8| 5| 4. 2| 4. 6| 4. 6| 4. 0| I now need to convert these readings into a useful unit; Pascal. To do this I can use the same equation as used for cm of mercury to Pascal. P= ? gh Density of Water= 1000kg m-3 P= 1000kg m-3 ? 9. 81m s-2 ? Height in mmH2O ? 0. 001) Again I used an equation inside a spreadsheet to give me the results in the following table: Result After Converted to Vertical Height

(Pa)| Cell| A| B| C| D| 1| 62. 1| 74. 3| 75. 9| 69. 6| 2| 70. 4| 87. 8| 90. 2| 76. 7| 3| 74. 3| 94. 1| 94. 1| 67. 2| 4| 79. 1| 87. 0| 87. 0| 66. 4| 5| 41. 1| 45. 1| 45. 1| 39. 5| Now that the results are in Pascals I can now determine what the velocities were in each cell across the air flow using Bernoulli's Equation: Pb= P+12? V2 Where Pb – P is the pressure difference. So this means if we rearrange it we can get the subject of the equation to be Velocity. V= 2(Pb-P)?

The Velocities are recorded in the following table: Velocity of air in each Cell (m/s)| Cell| A| B| C| D| 1| 10. 2| 11. 1| 11. 3| 10. 8| 2| 10. 8| 12. 1| 12. 3| 11. 3| 3| 11. 1| 12. 5| 12. 5| 10. 6| 4| 11. 5| 12. 1| 12. 1| 10. 5| 5| 8. 3| 8. 7| 8. 7| 8. 1| To find the volumetric flow rate at the pitot-static section I can use the continuity equation, ? Av= constant ? Q= Av Q= 114mm ? 127mm? 10. 8ms-1 Q= 0. 1564m3s The discharge coefficient in the venture meter can be calculated using the following equation: Q= cdA22(P1-P2)? (1-m2) Q= cd?? 0. 044522(314. 8)1. 197(1-? 0. 04452? 0. 07022) Q= cd? 6. 2211? 10-3629. 61. 197(1-0. 40412) Q= cd? 6. 2211? 0-3882. 66 Q= cd? 6. 2211? 10-3? 29. 709 0. 1564= cd? 0. 1848 cd= 0. 846 Discussions Using the velocity results across the matrix I created a 3d graph (Chart 1) showing the cross section of the pitot static section as the base showing the velocities as a vertical height. The flow came from below the grid, with the right hand side of the graph being the bottom edge of the pitot-static section. There is a large drop in velocity at the bottom section; this indicates that there is some form of pressure loss at the bottom. One of the reasons for this may be due to leakages in the system, meaning air is escaping and thus energy is exiting the system.

If the decrease in energy was purely down to viscosity the graph would show a more symmetrical view but Chart 2 shows the mean cross section of the horizontal path of the air flow, and the chart is not symmetrical. The chart also shows that calculating the mean velocity by simply adding up all the velocities and dividing by the number of cells may be insufficient for working out the volumetric flow rate as there are drops on the outer edges. To see what effect disregarding the outer edges had on the discharge coefficient I recalculated the mean using just the inner velocities.

The new mean is 11. 6ms-1. Q= cd?? 0. 044522(314. 8)1. 197(1-? 0. 04452? 0. 07022) 114mm ? 127mm? 11. 6ms-1= cd? 0. 1848 0. 1679= cd? 0. 1848 cd= 0. 91 The number then gets closer to the known discharge coefficient of the venturi meter which is 0. 98. This value is given from the venturi supplier and therefore should be assumed to be accurate (meaning I will take the 98 per cent efficiency as a known value), which could lead to me believing the 7 per cent decrease in my value is due to effects as the fluid flows down the pipe from the pitot-static section towards the venturi meter.

The cause of the decrease on the outer edges of the pipe may be due to the viscosity of the fluid. Viscosity is a measure of the resistance of a fluid which is being deformed by shear stress. On the immediate walls of the pipe the velocity of the fluid will be zero. This is due to the adhesion of the molecules to the surface because they are in contact. As the fluid gets further away from the surface each subsequent layer will increase in velocity and shear past lower layers [(Sherwin & Horsley, 1996)]. Surface Velocity As the flow travels down the pipe more layers are affected by the viscous shearing of the fluid layers.

Eventually the fluid increases from zero velocity at the edge to the ‘ free stream’ velocity of the flow. This gap between the free stream and the edge of the pipe is known as a boundary layer (Sherwin & Horsley, 1996). Although the velocities near the walls of the pipe are significantly decreased, the mean of the velocities across the pipe should be what we can assume, due to the phenomenon of laminar flow. To maintain continuity in the flow, the regions in the centre should be of velocity greater than the entry velocity (Granger, 1995).

Laminar flow depends on a number known as the Reynolds number which depends on the velocity, pipe diameter and fluid properties. The lower the Reynolds number is, the more likely it is of laminar flow. Therefore knowing this, I can assume that the velocity in the pipe should still give me a mean velocity the same as a linear flow. The velocity of the fluid is not high enough to allow a turbulent flow. Another possible reason of the discharge coefficient is the fact the rig has two right angle corners, meaning there is a potential argument that the change in direction could cause the reduction in energy of the flow.

During a bend in a pipe the flow is no longer symmetrical about the centre line; a secondary flow takes place across the bend. This is because on entering the bend different levels of centrifugal forces are felt by different layers of the flow. This creates an outward movement of the fluid causing an asymmetric velocity profile. For the flow to maintain continuity though there must be a secondary flow around the wall. The two flows cause a disturbance to one another which leads to a overall pressure drop due to the bend, with a sharp right angled bend (like the one on the air flow rig) would cause a greater disturbance. Sherwin & Horsley, 1996) Other reasons which relate to a lower discharge coefficient are the experimental errors that had an effect. When taking the readings we used a standard ruler with mm as the smallest unit. This means that each recorded value has an error reading of ±0. 5mm. It was also noted that the water in the manometer fluctuated while the readings were being taken, this could also have an effect big enough to push the discharge coefficient value further away from the true value of the venturi. Conclusions

Upon reflection I think the overall test gave reasonable results which presented me with enough room for discussion. Although the discharge coefficient was a fair bit lower than what was expected, the reason for it being lower will be put down to small errors in reading values and leaks in the system. The other effects mentioned in the discussion might not have much effect because of continuity within the system, which cannot be fully determined if true or not because of the external energy losses from the leaks.

I compared my results to what other people got and noted there was a slight changeability in the velocity readings, upon further investigation I realised this was down to the baffle at the end of the air flow rig. The baffle can be set to different distances from the end of the rig which means they will have different pressure readings. If I was to do the test again, I would repeat the test a couple of times with the baffle set in different places to ensure it doesn't have an overall impact on the discharge coefficient.

Other things that could be done to improve the test is ensure the rig is air tight with no leaks, without the leaks we could expect to get to a much closer value to 0. 98, which could lead me on to understanding the only reasons there would be a drop in the value of the discharge coefficient would be internal energy losses. These could be such as the effect of boundary layers and viscosity and we will be able to know the extent to which these have an impact on the discharge coefficient. References

Bentley, J. P. (2005). Principles of measurement systems. Pearson Education. Granger, R. A. (1995). Fluid Mechanics. Courier Dover Publications. Sherwin, K. , & Horsley, M. (1996). Thermofluids. Chapman & Hall. Bibliography URL Links to pages which contained resources which I used: https://wpb1. webproductionsinc. com/danforthfilter/secure/store/Air-Filter-GQ. asp ultra-nspi. com/info_central/glossary/d. php science. nasa. gov/newhome/help/glossary. htm en. wikipedia. org/wiki/Viscosity