Flow through a venturi meter

Given a Venturi Meter, Cv , the Venturi coefficient can be determined to compare the actual and ideal values as per Bernoullis predictions, for a volume flow rate. For better comparisons, two separate trials were analyzed and Venturi coefficients for both were computed. Trial 1 and Trial 2 yielded a Cv of 0. 93 and 0. 92 respectively. In this experiment the values calculated were found to be less than 1. 0; this relatively high correlation between the experimental and ideal flows for the given Venturi meter however when compared to the ideal flow, the actual flow for this Venturi is not steady nor one dimensional. Therefore neither of these assumptions can be applied to any given actual flow.

Nomenclature

Variable/ Constant/ Symbol/Parameter

Values

Q

Volume flow rate (m3/s)

V

Velocity (m/s)

A

Area (m2)

Ï air

Density of air, 1. 23 kg/m3

Ï ‌ water

Density of water, 1000 kg/m3

Cv

Venturi coefficient

Po

Stagnation pressure (Pa) is Static Pressure plus Dynamic Pressure

Patm

Atmospheric pressure, 101. 325 KPa

Î” h

Height difference (m) between readings and Patm

g

Acceleration, 9. 81 m/s2

z

Elevation of Point (m)

(½)Ï ‌ V2

Dynamic Pressure (Pa)

P

Static Pressure

Flow Analysis

Bernoulli’s Equation relates two points alongside a streamline as

P1 + (½)Ï airV12+ Ï airgz1 = P2 + (½)Ï airV22 + Ï airgz2

z is negligible so Ï airgz cancels out on both sides leaving

P1 + (½)Ï airV12+ = P2 + (½)Ï V22

Rearranging:

P1 – P2 = (½)Ï air(V22 – V12)

Note that

Qideal = V1A1 = V2A2.

Solving for V2

V2 =

Subbing (5) into (3) and solving for V1

V1 =

Then

Qideal = A1

Flow Analysis (Cont'd)

For the derivation of Qactual, sufficient distance from the Venturi inlet is assumed for a fluid particle's relative velocity to be taken as zero. The same height (z value) as the Venturi will be taken for the particle.

P1 + (½)Ï airV12+ Ï airgz1 = P2 + (½)Ï airV22 + Ï airgz2

z is negligible so Ï airgz cancels out on both sides leaving

P1 + (½)Ï airV12+ = P2 + (½)Ï V22

as stated, the fluid particle's velocity at point 0 is assumed to be 0m/s

Patm = P2 + (½)Ï airV22

Solving for V2

V2 =

P2 is defined as the static pressure at the inlet, found to be

P2 = Patm + Ï watergÎ" h

Subbing (9) into (8)

V2 =

To find Qactual

Qactual = V2A2.

Sub (11) into (12) where A2 is the cross sectional area

Qactual = A2

Flow Analysis (Cont’d)

With values for Qactual and Qideal, Cv can then be calculated with the relation

Cv =

For ideal static pressures combine (8) having solved for P2 and (4) having solved for V2

P2 = Patm – (½)Ï airV22

P2 = Patm – (½)Ï air

Experimental Setup and Procedure

The experiment was carried out per the instructions outlined in the course manual. However due to a problem with the apparatus and a constantly fluctuating Venturi meter, a camera was used to take a photo. Measurements were taken from the scale viewed on said picture.

Figure Shows Experimental Setup

Results

For trial 1:

Qideal = 0. 01238 Qactual = 0. 01153

The Venturi Coefficient, Cv, was calculated by using the values found for Qideal and Qactual and substituting them into equation (14). This value obtained was 0. 93.

To find the stagnation pressure, P = Patm and V = 0; the total pressure at this point is represented by P0 = Patm + (½)Ï airV2, however since V = 0 , the stagnation pressure is P0 = Patm.

The Static Pressure is Patm = Patm – Ï watergÎ” h where the Î” h used is the value that corresponds with the throat. Therefore Pthroat = 99. 206KPa

For Dynamic Pressure, (½)Ï airVthroat2 = Patm – Pthroat = 2. 119KPa

Results(Cont’d)

For trial 2:

Qideal = 0. 01238 Qactual = 0. 01153

The Venturi Coefficient, Cv, was calculated by using the values found for Qideal and Qactual and substituting them into equation (14). This value obtained was 0. 92.

To find the stagnation pressure, P = Patm and V = 0; the total pressure at this point is represented by P0 = Patm + (½)Ï airV2, however since V = 0 , the stagnation pressure is P0 = Patm.

The Static Pressure is Patm = Patm – Ï watergÎ” h where the Î” h used is the value that corresponds with the throat. Therefore Pthroat = 96. 871KPa

For Dynamic Pressure, (½)Ï airVthroat2 = Patm – Pthroat = 4. 454KPa

Discussion

The two calculated Venturi Coefficients for both trials of differing flow rates were found to have close enough values to assume that said coefficients do not depend on the flow rate but rather on the Venturi meter in use. For ideal calibration methods, an average of values, 0. 92 and 0. 93 could be taken to compensate for ideal assumptions which have been determined to be inaccurate. This would aid the user to find actual values once ideal ones have been found.

Although these values are not 1. 0, they are relatively close. However despite this, it can be inferred that the idealistic conditions assumed at the beginning of the experiment are invalid as they do in fact incur a noticeable effect on the results creating an error. These assumptions included a one dimensional steady flow that existed in a frictionless environment; such implies no energy transfers.

Dimensions for the outlet and inlet were assumed to be equal however if the graphs are reviewed, there are discrepancies and a certain amount of irregularities. These further outline the existence of friction and energy loss which can be observed through the comparison of tables 1 and 2 in the appendix where the values of experimental and ideal static pressures are defined.

There was however another source of error that was introduced due to the faulty apparatus as was discussed in the Experimental Setup and Procedure section. Measurements were taken from a photograph to facilitate taking down said measurements from a fluctuating Venturi meter.

Bernoulli’s equation states that when a fluid in flow undergoes a rise in pressure, then its velocity must decrease. Said concept also applies the other way around. Figure 1 in the appendix illustrates this through a rough sketch.

Conclusion

Venturi coefficients such as the ones calculated in this experiment, 0. 92 and 0. 93 imply that the actual flow is lower than the ideal flow. Therefore the ideal conditions that were applied only give an approximation to the actual flows. The coefficients can be averaged for a more accurate way to calibrate the Venturi meter. The values found imply that the Venturi meter relates the actual and ideal values relatively well; however this may be due to the fluctuating meters. Also very likely, is the presence of a relatively low amount of friction and symmetrical dimensions in the Venturi meter.

References

University, Carleton, ed. MAAE 2300 Course Manual. Ottawa, 2011. Print.