Venturi meter coefficient discharge experiment

Aims and Objectives:

In this experiment the flow (k) and discharge (Cd) coefficients of a venturi meter will be assessed by comparing the real discharge measured in the experiment with the theoretical discharge calculated by deriving venturi discharge formula from Bernoulli and continuity equations.

Apparatus:

The apparatus used in this experiment are:

Stopwatch – It is used to calculate the time required for a specific volume of water to be supplied, to measure the rate (actual) of flow (Qa).

Venturi apparatus – The venturi apparatus is connected at six different points to the manometer

Thermometer – Thermometer is used to measure the temperature of the water, the Reynolds number will be calculated by the resulting kinematic viscosity.

Hydraulic bench – The hydraulic bench contains water pump and tracks the volume of water collected. The jet apparatus rests on it.

Venturi Meter

Method:

Place the meter horizontally, in such a way that at point 1 and 2 the z values are the same.

Open the inlet valve and leave at it maximum flow.

Release the air from the manometer and venturi tube.

Tightly close the air purge valve on the upper manifold.

Allow the water to flow by switching on the bench supply valve.

Make sure to close apparatus control valve.

Allow some air to enter by slowly opening the spindle once more

With the stop match measure the discharge by recording the time required for a specific volume of water to be collected.

To measure the discharge use the stop watch to record the time required for a specific volume of water to be collected. (Volume of the water is measured by a meter beside the supply valve.)

Repeat this 16 times and measure the flow rate. Along with it, measure h1, h2 and h3.

Where,

h1 = Height of water in manometer tube A (inlet)

h2 = Height of water in manometer tube D (throat)

Results & analysis

Theory

According to the Bernoulli equation:

-For a non-viscous, incompressible fluid in steady flow, the sum of pressure, potential and kinetic energies per unit volume is constant at any point-

From this we can conclude that the reason of variation in pressure between two points is the convergent or divergent in the venturi meter.

So, continuity equation can be used to measure the discharge between two points. At any time per second, the discharge moving through a specific cross sectional area at two points is equal, therefore:

Continuity Equation: $V1A1 = V2A2 = V3A3 = Q$ ___________(1)

From the diagram of the venturi meter it is clear that point 1 has a certain discharge due to contraction in the pipe, which minimizes the throat cross section. From the diagram, for point 2 the discharge Q will change because the velocity did not increase which will cause the area of this section to change. Now, according to the continuity equation, for Q to remain same as point 1 with the decrease in cross sectional area, an increase in velocity is required.

Bernoulli Equation:$(v^2 1)/2g + h1 + z1 = (V^2 2)/2g + h2 + z2 = (v^2 3)/2g + h3 + z3$ ____ (2)

Where:

$z1$ = potential energy, $h1$ = pressure energy and $(v^2 1)/2g$ = Kinetic energy

From the first equation the throat section to equal 2 and the upstream section equal to 1:

V1 = A2V2/A1_____(3)

By substituting this equation in equation 2, assuming Z as constant:

(A2V2/A1)^2/2g+ h1= ? V2?^2/2g+ h2 -..(3

(v^2 2)/2g- (A2V2/A1)^2/2g = h1-h2

(v^2 2)/2g X (1-(A2/A1)^2) = h1 – h2

V2 = (1-(A2/A1))^(-1/2) X v(2g(h1-h2))____ (4)

We get a proportional relationship between discharge (Q) andv(h1-h2) as A1 and A2 are constants, which means that the theoretical discharge does not include energy loss in the system e. g. friction.

The discharge of flow in the venturi meter will be calculated as:

Qactual = Cd X ((A2 X v2g))/? v(1-A2/A1)?^2 X vh1-h2______(5)

In a pipe there are two types of flow brought about by varying velocities. These flows are called laminar and turbulent flow.

Flow Classification:

Turbulent flow Re > 4000

Laminar flow Re < 2000

Using Reynolds equation,

Re = (V x D)/v_____ (6)

Where

V = velocity,

D = diameter,

v = kinematic viscosity.

Re is proportional to the velocity as v and D are constant.

Coefficient of energy loss k must be found as the Bernoulli-s equation does not account for the energy loss in the real life:

K = ((h1-h3))/v^(2/2g) _______(7)

Where,

h1-h3 is the pressure head,

v^2 = kinetic energy

The coefficient of discharge is a comparison between reality and theory, it includes the energy loss and the factors causing energy loss e. g. unsteady flow viscous fluids and turbulent flow.

Cd = Qactual/Qth ____ (8)

Where:

Qth = the theoretical discharge value of the venturi meter,

Cd = Discharge coefficient

Results:

Run No h1 (m) h2 (m) h3 (m) h1-h2 (m) h1-h3 (hL m) t1 (sec) t2 (sec) t mean Qa (m^3/s) Q theoretcial

1 0. 226 0. 005 0. 191 0. 219 0. 035 16. 87 17. 12 16. 995 0. 000441306 0. 000440753

2 0. 225 0. 022 0. 193 0. 2 0. 032 18. 13 17. 94 18. 035 0. 000415858 0. 0004212

3 0. 224 0. 043 0. 195 0. 179 0. 029 19. 19 19. 16 19. 175 0. 000391134 0. 000398474

4 0. 221 0. 06 0. 195 0. 159 0. 026 20. 34 20. 06 20. 2 0. 000371287 0. 000375554

5 0. 22 0. 081 0. 197 0. 137 0. 023 21. 91 21. 75 21. 83 0. 000343564 0. 000348605

6 0. 219 0. 102 0. 198 0. 115 0. 021 24 23. 81 23. 905 0. 000313742 0. 000319391

7 0. 215 0. 119 0. 199 0. 094 0. 016 26. 38 26. 31 26. 345 0. 000284684 0. 00028876

8 0. 225 0. 14 0. 21 0. 083 0. 015 27. 72 27. 69 27. 705 0. 000270709 0. 000271339

9 0. 206 0. 158 0. 198 0. 046 0. 008 38. 59 38. 59 38. 59 0. 000194351 0. 000202

10 0. 206 0. 17 0. 199 0. 034 0. 007 43. 66 43. 59 43. 625 0. 00017192 0. 000173665

11 0. 212 0. 205 0. 21 0. 005 0. 002 126. 81 126. 66 126. 735 0. 000059178 0. 000066597

12 0. 205 0. 191 0. 202 0. 012 0. 003 72. 09 72. 13 72. 11 0. 000104008 0. 000103173

13 0. 2075 0. 2035 0. 207 0. 002 0. 0005 182. 94 182. 91 182. 925 0. 000041 0. 00004212

14 0. 214 0. 2025 0. 211 0. 0095 0. 003 81. 87 81. 75 81. 81 0. 000091675 0. 000091798

vh1-h2 1/t mean ? h*t^2 V1 m/s Cd V1 (velocity m/s) Reynolds K

0. 467974358 0. 058840836 10. 10905088 0. 87092895 1. 001254763 0. 87092895 19405. 1679 0. 905319

0. 447213595 0. 055447741 10. 4083592 0. 82070627 0. 987317141 0. 820706266 18286. 1563 0. 932124

0. 423083916 0. 052151239 10. 66273813 0. 7719133 0. 981580525 0. 771913299 17199. 0002 0. 954905

0. 398748041 0. 04950495 10. 60904 0. 73274443 0. 988639344 0. 732744431 16326. 2787 0. 950096

0. 37013511 0. 04580852 10. 9606247 0. 67803195 0. 985538971 0. 678031951 15107. 2299 0. 981582

0. 339116499 0. 041832253 12. 00042953 0. 61917747 0. 982313592 0. 619177473 13795. 8933 1. 074702

0. 306594194 0. 037957867 11. 1049444 0. 56183099 0. 985883712 0. 561830993 12518. 1563 0. 994506

0. 288097206 0. 036094568 11. 51350538 0. 53425149 0. 997678517 0. 534251489 11903. 6574 1. 031095

0. 214476106 0. 025913449 11. 9135048 0. 3835563 0. 962130821 0. 383556297 8546. 01785 1. 066917

0. 184390889 0. 022922636 13. 32198438 0. 33928797 0. 989949231 0. 339287966 7559. 67516 1. 193054

0. 070710678 0. 00789048 32. 12352045 0. 11678926 0. 888590855 0. 116789262 2602. 18156 2. 876889

0. 109544512 0. 013867702 15. 5995563 0. 20526193 1. 008095562 0. 205261926 4573. 44098 1. 397023

0. 04472136 0. 005466721 16. 73077781 0. 08091453 0. 973409133 0. 080914525 1802. 85653 1. 49836

0. 097467943 0. 012223445 20. 0786283 0. 1809229 0. 998655444 0. 180922904 4031. 14323 1. 79818

Calculation for the fourth Line on the spreadsheet:

Qa (Discharge):

Volume Collected = 7. 5 liters

T mean = 19. 175 sec

Qa = (volume collected (m^3))/(t mean (s))

= 0. 0075/20. 2= 0. 000371287? m?^3/s

V1 Calculation:

V1= Qa/A1

Qa = 0. 000371287 m^3/s

A1 = (p d^2)/4=

0. 000371287 /(p ?(0. 0254)?^2/4)= 0. 732744431 m/s

Reynolds number Calculation:

Re= V1 x D/v

D/v = 22281

V = 0. 732744431 m/s

0. 732744431 x 22281= 16326. 278667111

Calculation of K:

K = ((h1-h3))/v^(2/2g)

H1-h3 = 0. 026 (m)

0. 026/(? 0. 732744431?^2/(2 x 9. 81))= 0. 950096

Qtheoretical Calculation:

Qth= (A2 v2g)/(v1-?(A2/A1)?^2) x vh1-h2

Qth = 0. 0000941832 x 0. 398748041= 0. 000375554

Cd Calculation:

Cd = Qa/Qth

0. 000371287/0. 000375554= 0. 988639344

Graphic analysis:

Plot Qactual against Qtheoretical and measure the slop of the best fit line:

From the Qactual-Qtheoretical plot, it is visible that the best fit line is 0. 988, which is quite fairly accurate and close to, that enhance the efficiency of the operation.

The best estimate of Cd:

From v(h1-h2)-V-Qactual , it is visible that the slope of the best line of the plot is 1087. 3. According to the theory:

v(h1-h2)/Qactual= 1087. 3

By multiplying by 1061. 7596 best estimate of Cd will be found.

1/(v(h1-h2)/Qactual)= 1/1087. 3 x 1061. 7596

Best estimate of Cd= 0. 9886398004

Best discharge equation for the meter:

Qa = best estimate of Cd x (A2 v2g)/(v1-?(A2/A1)?^2) x vh1-h2

– Qa = 0. 9886398004 x (A2 v2g)/(v1-?(A2/A1)?^2) x vh1-h2

Simplest form of the discharge relationship for the meter

Qa = Best estimate of Cd x vh1-h2

Qa = 0. 9886398004 x vh1-h2

Discussion/conclusion:

By the results obtained in the laboratory and the proceed data, a variation the values of Cd is seen throughout the procedure. From the plot of Qactual against Cd a change in Cd is seen due to the change of the value of K, and concluding to the energy loss in the meter also the discharge coefficient takes into account these changes in energy loss.

The least value of K from the spread sheet which is run 1 of a 0. 905319 value and a value of Cd of 1. 001254763 was the second highest recorded in the spreadsheet, also run 11 shows the heights K value 2. 876889 and Cd value of 0. 888590855 was the lowest Cd value recorded.

Energy loss occurs in the meter because of the friction, turbulent and the viscosity of the flow.

Because of the Laminar flow and the turbulent flow, which causes energy loss the venturi meter indicated varying values of Cd. From the best estimate of Cd 0. 9886398004, we can assume that energy accumulated in the pipe are insignificant and also that the has incrementally little energy losses

Evaluation:

The venturi meter experiment has opened my mind and it has helped me better understand the continuity equation and the Bernoulli equation.

The experiment has also increased my knowledge about the turbulent and laminar flow and their causes. I have also learned that the value of Cd does not remain constant.

I have learned how to best estimate the value of Cd, the value of K and the value of Re by using either one of the two equations and applying all the theory and calculation required. It has increased my understanding of the equations required to accomplish the objectives of this experiment.