Experiment No.: 02

Experiment Name: Flow Through a Venturimeter

Objective

The objective of this experiment is to,

1. Determine the coefficient of discharge C_d.
2. Plot Q_a against H on log-log graph paper to determine the value of n and C.
3. Calibrate the meter by determining actual coefficient of discharge C_d.

Scope

The scope of venturimeter and this experiment includes:

1. Demonstrate the relation between flow rate (Q_a) and pressure head loss (H).
2. Measure flow in pipelines using the same meter for future uses of both ideal and real fluids.
3. Application in industries such as water supply systems, oil and gas processing.
4. Limitation includes high installation cost and permanent frictional loss in the pipeline.

Calculation

From the two points (P_1 and P_2) on log-log graph, we get:

1. $H_1 = 2.0 \times 10^{-1}$, $Q_1 = 3.1 \times 10^{-4}$ and
2. $H_2 = 4.4 \times 10^{-1}$, $Q_2 = 4.6 \times 10^{-4}$

The exponent of H can be calculated using the formula,

$$n = \frac{\log \frac{Q_2}{Q_1}}{\log \frac{H_2}{H_1}}$$

Applying the value of Q_1, Q_2, H_1, and H_2, we can get,

$$n = \frac{\log \frac{4.6 \times 10^{-4}}{3.1 \times 10^{-4}}}{\log \frac{4.4 \times 10^{-1}}{2.0 \times 10^{-1}}} = 0.501$$

The calibration parameter C can be calculated using the formula,

$$C = 10^{\log Q - n \log H}$$

Applying the value of n, $Q = Q_2$ and $H = H_2$, we can get,

$$C = 10^{\log 4.6 \times 10^{-4} - 0.501 \times \log 4.4 \times 10^{-1}} = 6.940 \times 10^{-4}$$

Now, the cross-sectional area of the intel,

$$A_1 = \pi \left(\frac{0.0284}{2}\right)^2 = 6.335 \times 10^{-4}\ m^2$$

Comparing with the calibration equation $Q_a = CH^n$ and $Q_a = C_d K H^n$, the average coefficient of discharge can be calculated using,

$$C_d = \frac{C}{K} = \frac{C}{A_1 K_1}$$

Applying the value of C, A_1 and K_1, we can get,

$$C_d = \frac{6.940 \times 10^{-4}}{6.335 \times 10^{-4} \times 1.109} = 0.988$$

Discussion

In this experiment, the venturimeter was calibrated by determining the average coefficient of discharge C_d and the exponent n. The values of average C_d and n were determined to be 0.988 and 0.501, respectively. These constants are unique to the venturimeter used. Now, the actual discharge can be calculated by only measuring pressure head loss, H using this formula:

$$Q_a = C_d K H^n = C H^n = 6.940 \times 10^{-4} H^{0.501}$$

Probable errors

There are several potential sources of error when performing this experiment:

1. The experiment involves the use of fluid friction apparatus, venturimeter, stopwatch — damaged or poorly calibrated equipment can lead to inaccuracies.
2. There can be inaccuracies when taking manometer readings due to parallax errors.
3. Human errors include delays in starting or stopping the stopwatch.
4. Presence of air bubbles in the manometer can affect pressure head readings.

Formation of cavitations

Cavitation is the formation of liquid bubbles when pressure in a liquid drops too low. While it was not observed, it is highly possible that cavitation formed near the throat region when performing this experiment.

It typically occurs in region of high velocity (and thus low pressure). As pressure drops below the liquid's vapor pressure, vapor bubbles form in the fluid. And when these bubbles move to region with higher pressure, they implode violently.

Practical vs experimental results

The experiment yielded values of discharge coefficient, C_d, ranging from 0.916 to 1.034. The theoretical expectation is that C_d should be below and close to 1 due to frictional losses:

$$H = H_{actual} + H_L$$

Here, H_L is the head loss due to frictions. Hence, the H we considered during calculation of theoretical discharge (Q_t) was slightly higher than actual value causing some C_d values to drop below 1.

On the other hand, the C_d had exceed 1 possibly due to:

1. Misreading of pressure heads.
2. Poorly calibrated or damaged apparatus.
3. Errors in measurement of Q_a such as timing errors.

However, the average discharge coefficient was determined to be 0.988. It aligns with the concept of frictional losses and can be used to produce near accurate flow rate.