Experiment B

Flow meters

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1 Introduction

The main purpose of this experiment is to investigate the operation and characteristics of three different types of flowmeter: venture meter, orifice plate meter and variable area meter. By studying the experimental data of these three flow meters at different water pressures, the energy loss of the water flowing through the meters was determined.

2 Theory

There are three different types of flow meters, each with a pressure tube in front of and behind the meter to visualise the water pressure, as shown in figure 1,2 and 3.

The water enters from the venturi flow meter and flows through variable area, the orifice, then out of pipe. It should be noticed that there is an elbow between the venturi and variable area.

The definitions of the symbols are shown in table 1.

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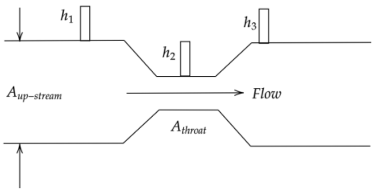

Figure 1: Venture meter

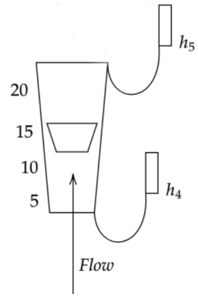

Figure 2: Variable area meter

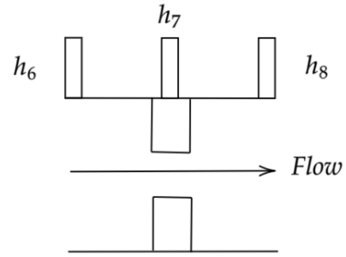

Figure 3: Orifice plate meter

Symbols	Definition	Expression
H_{Qv}	Head difference in venture	$h_1 - h_2$
H_{Qo}	Head difference in orifice	$h_6 - h_7$
H_v	Head loss in venture	$h_1 - h_3$
H_o	Head loss in orifice	$h_6 - h_8$
H_a	Head loss in variable area	$h_4 - h_5$
H_e	Head loss in elbow	$h_3 - h_4$

Table 1: Symbol definitions

In Bernoulli's and continuity equations, for the venture meter,

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} \tag{1}$$

$$Q_1 = Q_2 = A_1 v_1 = A_2 v_2 \tag{2}$$

Define ΔH as $h_1 - h_2$, Hence,

$$\Delta H = \left[z_1 + \frac{P_1}{\gamma}\right] - \left[z_2 + \frac{P_2}{\gamma}\right] \tag{3}$$

From equation (1),(2) and (3),

$$v_2 = \sqrt{2g\Delta H} * \frac{A_1}{\sqrt{A_1^2 - A_2^2}} \tag{4}$$

Due to the existence of discharge coefficients for the venturi and orifice, it is assumed that $C_d = 0.98$ for venture and $C_d = 0.63$ for orifice.

$$Q_{actual} = C_d Q_{theoretical} = C_d A_2 V_2 = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2g\Delta H} \tag{5}$$

Finally, the Q_o and Q_v could be write as

$$Q_o = \frac{0.63A_2\sqrt{2g\Delta H_{Qo}}}{\sqrt{1-(\frac{A_2}{A_1})^2}} \tag{6}$$

$$Q_v = \frac{0.98A_2\sqrt{2g\Delta H_{Qv}}}{\sqrt{1-(\frac{A_2}{A_1})^2}} \tag{7}$$

For the variable area, there is a visual scale display. This gives a very visibly readable indication of the flow of water.

For the elbow, head loss can be represented as

$$H_e = h_3 - h_4 = k\frac{v^2}{2g} \tag{8}$$

Which k is the coefficient of the elbow loss.

3 Method

In this experiment, a pressure tube was installed at each of the flowmeter. Starting the pump, adjusting the flow rate so that the scale on the variable area was 5, and recording the water pressure data for the 8 different pressure tubes. Finally, the actual flow rate was measured by using a stopwatch and a measuring cylinder.

Repeat the experiment, controlling the scale on the variable area to 10,15,20. Record the data.

4 Results

The experiment data is shown in the following table.

flowrate (L/min)	h_1	h_2	h_3	h_4	h_5	h_6	h_7	h_8
5	220	203	211	209	155	155	145	149
10	248	199	228	220	164	165	132	143
15	294	187	255	240	175	180	106	130
20	355	160	300	270	197	205	68	117

(Unit of h: mm)

Table 2: Recording of pressure tubes

V_1(l)	T_1(s)	V_2(l)	T_1(s)	$Q_{average}= \frac{V}{T}$ (L/s)
6	63	7	70.06	0.097576
11	63	11	64.47	0.172613
15	60.25	16	63.03	0.251405
22	65	22	64	0.341106

Table 3: Real flow

5 Analysis

5.1 Regression analysis

For experimentA1, Plot a scatter chart with $\sqrt{gh}$ as the horizontal coordinate and x as the vertical coordinate based on the data from Table 4. And a regression analysis and linear fit was performed on the data, as shown in Figure 4 and results in Table 7.

Take the average of the data and take it into equation (**??**) to get $C_v = \frac{slope}{2}$. The final C_v is 0.955.

For experiment A2, it is the same as experiment A1, with the horizontal coordinates replaced by $\sqrt{h}$ and the vertical coordinates replaced by Q the data of regression analysis is in Figure 5 and results in Table 8.

Use equation (**??**) to caculate the $C_d = \frac{Slope}{A_0\sqrt{2g}}$ and the final C_d is 0.615 (3mm) and 0.8816 (6mm).

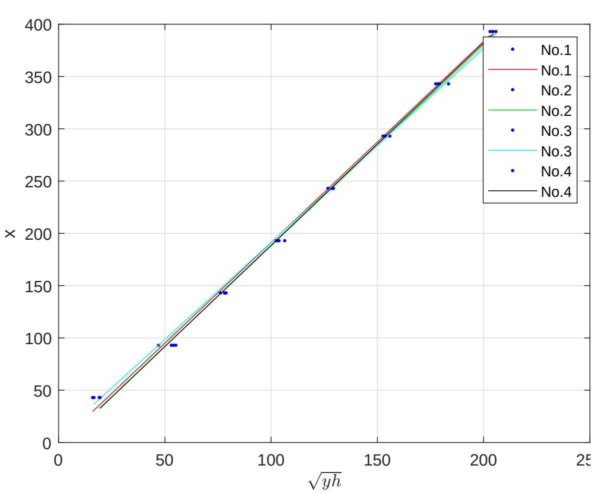

Figure 4: ExperimentA1

(Unit:mm)

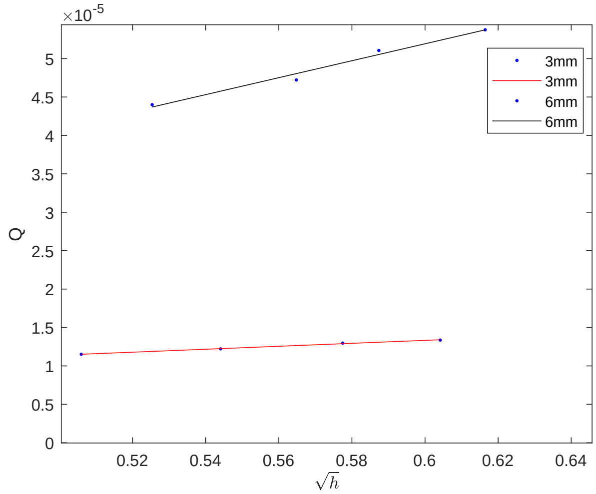

Figure 5: ExperimentA2

(Unit:$\sqrt{m}$ and m^3/s)

	Slope	R-square
1	1.923	0.9968
2	1.923	0.9976
3	1.855	0.9985
4	1.936	0.998

Table 4: result of A1 regression analysis

	Slope	R-square
3mm	0.00001924	0.9955
6mm	0.0001103	0.9811

Table 5: result of A2 regression analysis

5.2 Error analysis

• Inaccurate recording of water trajectory to the sheet due to not looking horizontally at the top point of the needle.

• Inaccurate calculation of the flow rate due to residual water in the measuring cylinder.

• When calculating the flow rate, errors caused by the stopwatch timing not being fully synchronised with the water collection time.

6 Conclusion

From the results of the regression analysis, the R-square value of both experiment A1 and A2 are larger than 0.98, which demonstrates a strong linear correlation between the x and y axes. Additionally, from the above it follows that $C_v = 0.955$,$C_d = 0.615$(3mm),$C_d = 0.8816$ (6mm). Both of the coefficient are less than 1.This satisfies the hypothetical conditions.

Therefore, the data from the regression analysis is valid.

For C_v, due to vena contracta , the real area that approximates the area of the orifice with a little smaller, and its value of 0.95 is consistent with the reality.

For C_d(3mm), the value is 0.615, whereas it should actually be between 0.8 and C_v, probably due to experimental error. This should be done several times for the 3mm diameter orifice to avoid experimental coincidence and make it more accurate.

For C_d(6mm), the value is 0.8816, which is less than C_v and indicate the $C_c < 1$(**??**).This data is inaccurate but should not be significant.