25/100

The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1) 0915361

Experiment Number (3)

Comparative fluid flow measurement

Type of the report: short report

Instructor: prof. Khaled Rawjfeh

Performing Date: 25-10-2022

Submitting Date :1-11-2022

Table Of Contents

Table Of Figures

Table Of Tables

Abstract

Flow measurement is an important topic in the study of fluid dynamics. We can used basic hydraulic system that consists of three very important flow measuring devices which are Venturi meter, orifice meter and rotameter, with a basic hydraulic bench which is a self-contained water supply device that allows recirculating water from a Sump Tank into different hydraulic devices. A centrifugal Pump moves water from the Sump Tank through a hose into a water Inlet at the top of the bench. The apparatus is able to demonstrate the flow measurement comparison by using a venturi device, orifice device and rotameter (Variable Area Flowmeter). From this experiment, we obtained the flow rate measurement with comparison of pressure drop by utilizing the three types of flow measuring techniques The fluid in motion was flow through different types of paths the loss coefficient can be determined when fluid flows through a bend by measuring flow rate on manometers. We could compare the flow rates of the flowmeter based on the results we get from the graph. It showed that venturi meter is more accurate compared to orifice meter which the flow rates of venturi meter is closer to the actual value of the flow rates. Our main goal was the determination of the discharge coefficient of a venturi meter and an orifice meter at different Reynold number. Also, we constructed a calibration curve for the rotameter.

Results

Table 1 : Data sheet

			venture meter		Diffuser		orifice meter		Bend and Rotameter		
Rotameter (mm)	Flow rate (L / min)	Q_{actual} (m^3/s)	h_A (mmH_2O)	h_B (mmH_2O)	h_C (mmH_2O)	h_D (mmH_2O)	h_E (mmH_2O)	h_F (mmH_2O)	h_G (mmH_2O)	h_H (mmH_2O)	h_I (mmH_2O)
10	12.4	0.0002067	218	172	209	212	214	162	170	169	67
20	14	0.0002333	222	160	210	212	215	146	157	155	54
30	15	0.00025	223	155	210	212	217	140	151	150	47
40	16.8	0.00028	227	142	213	215	220	124	139	136	33
50	18.3	0.000305	232	131	216	218	224	109	127	124	20
60	19.9	0.0003317	319	203	302	304	308	177	198	195	90
70	21.2	0.0003533	326	190	303	307	316	160	185	181	73
80	22.7	0.0003783	331	179	309	311	321	146	172	169	60
90	24.4	0.0004067	340	165	315	319	329	125	155	152	41
100	26.2	0.0004367	350	148	324	326	337	103	139	132	20

a) Venture meter

$D_A = 26$ mm , $A_A = 0.00053\ m^2$
$D_B = 16$ mm , $A_B = 0.0002\ m^2$

Table 2 : calculated data for venture meter

$h_A - h_B$ (mmH_2O)	$h_A - h_B$ (mH_2O)	$h_A - h_B$ (Pa)	C_v	u_A (m/s)	u_B (m/s)	ΔH	$\frac{u_B^2}{2g}$	K	Re
46	0.046	451.1059	0.39976	0.3888	1.0267	0.09202	0.0537	1.71278	10039
62	0.062	608.0123	0.52399	0.4514	1.19195	0.12403	0.0724	1.71278	11655
68	0.068	666.8522	0.58795	0.4727	1.2483	0.13603	0.0794	1.71278	12206
85	0.085	833.56525	0.73623	0.5285	1.39564	0.17004	0.0993	1.71278	13646
101	0.101	990.47165	0.87419	0.5761	1.52133	0.20205	0.118	1.71278	14875
116	0.116	1137.5714	1.01877	0.6174	1.63039	0.23205	0.1355	1.71278	15942
136	0.136	1333.7044	1.17517	0.6685	1.76536	0.27206	0.1588	1.71278	17261
152	0.152	1490.6108	1.33028	0.7068	1.86632	0.30407	0.1775	1.71278	18248
175	0.175	1716.1638	1.53428	0.7584	2.00254	0.35008	0.2044	1.71278	19580
202	0.202	1980.9433	1.77	0.8148	2.15149	0.40409	0.2359	1.71278	21037

b) **Orifice meter**

$D_E = 26$ mm , $A_E = 0.00031$ m^2
$D_F = 16$ mm , $A_F = 0.00211$ m^2

Table 3 : calculated data for Orifice meter

$h_E - h_F$ (mmH$_2$O)	$h_E - h_F$ (mH$_2$O)	$h_E - h_F$ (Pa)	C_D	u_E (m/s)	u_F (m/s)	ΔH	$\frac{u_B^2}{2g}$	K	Re
52	0.052	509.9458	0.09983	0.1518	1.02223	0.10409	0.0533	1.95429	7823.8
69	0.069	676.65885	0.12983	0.1748	1.17725	0.13808	0.0706	1.95476	9010.2
77	0.077	755.11205	0.14695	0.1847	1.24363	0.15409	0.0788	1.95476	9518.2
96	0.096	941.4384	0.18377	0.2062	1.38861	0.19211	0.0983	1.95476	10628
115	0.115	1127.7648	0.2191	0.2257	1.51982	0.23013	0.1177	1.95476	11632
131	0.131	1284.6712	0.25429	0.2409	1.62211	0.26215	0.1341	1.95476	12415
156	0.156	1529.8374	0.29562	0.2629	1.77014	0.31218	0.1597	1.95476	13548
175	0.175	1716.1638	0.33526	0.2784	1.87484	0.3502	0.1792	1.95476	14349
204	0.204	2000.5566	0.38908	0.3006	2.02423	0.40824	0.2088	1.95476	15493
234	0.234	2294.7561	0.44745	0.3219	2.16796	0.46827	0.2396	1.95476	16593

Table 4 : readings of the manometers for diffuser, Bend and Rotameter

Diffuser		Bend		Rotameter	
$h_C - h_D$ (mmH$_2$O)	$h_C - h_D$ (mH$_2$O)	$h_G - h_H$ (mmH$_2$O)	$h_G - h_H$ (mH$_2$O)	$h_H - h_I$ (mmH$_2$O)	$h_H - h_I$ (mH$_2$O)
-3	-0.003	1	0.001	102	0.102
-2	-0.002	2	0.002	101	0.101
-2	-0.002	1	0.001	103	0.103
-2	-0.002	3	0.003	103	0.103
-2	-0.002	3	0.003	104	0.104
-2	-0.002	3	0.003	105	0.105
-4	-0.004	4	0.004	108	0.108
-2	-0.002	3	0.003	109	0.109
-4	-0.004	3	0.003	111	0.111
-2	-0.002	7	0.007	112	0.112

Figures

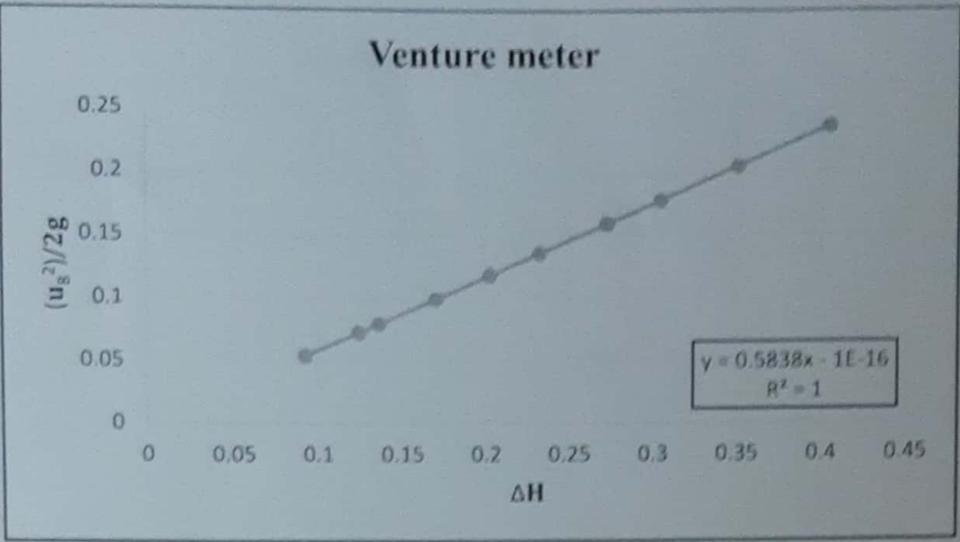

Figure 1 : ΔH against $u_B^2/2g$

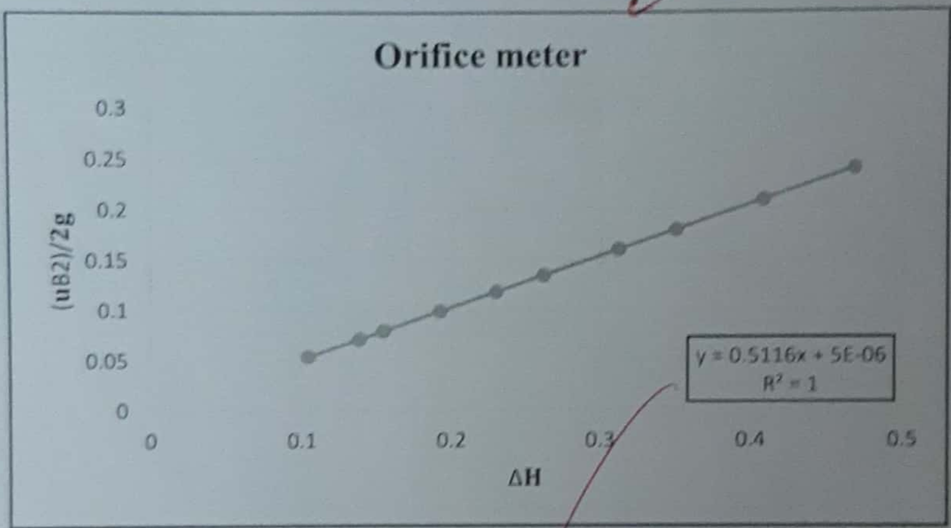

Figure 2 : ΔH against $u_B^2/2g$

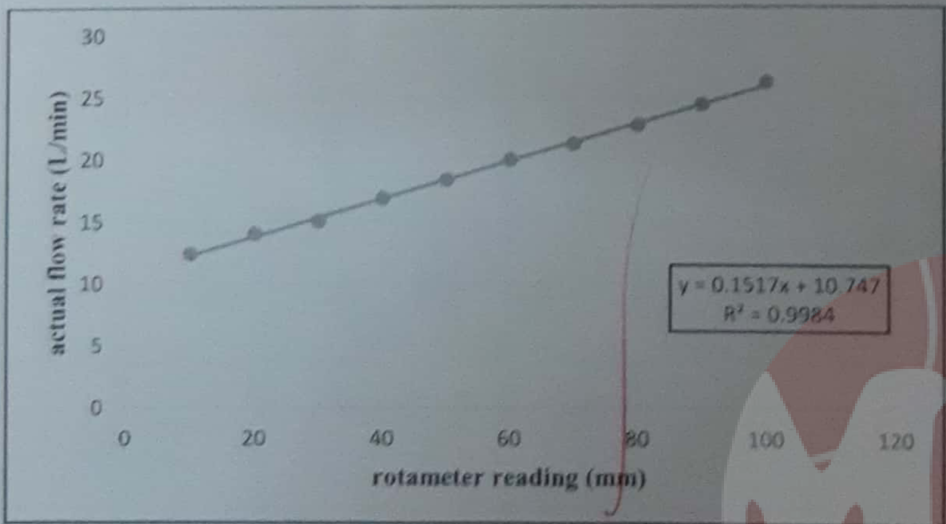

Figure 3 : actual flow rate (L/min) against the rotameter reading (mm)

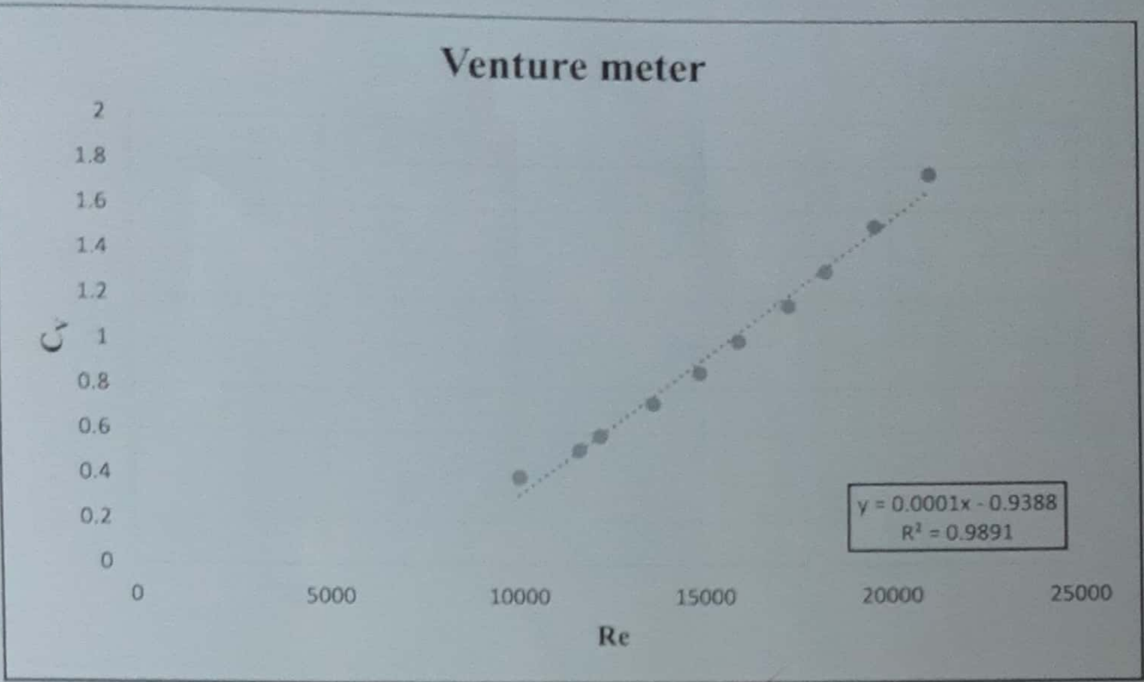

Figure 4 : Re against Cv

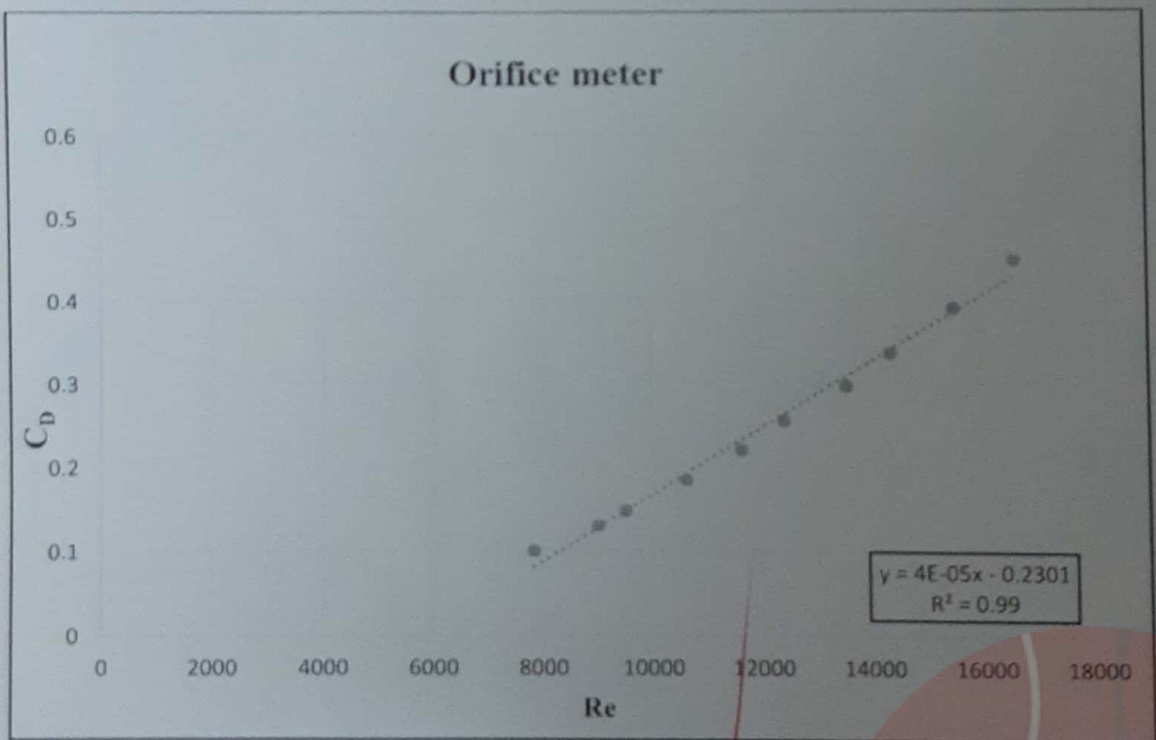

Figure 5 : Re against CD

Discussion

We successfully obtained the flow rate measurement with comparison of pressure drop by utilizing three basic types of flow measuring techniques which is rotameter, venturi meter and orifice meter. We use flow rates from the rotameter as the parameter to gain to flow rates for venturi meter and the orifice meter. The graph shows that all the flow rates of the flowmeters increase as the flow rates of rotameter increases. Although we set the flow rates of the rotameter to be the parameter of the experiment, however the actual flow rates that we gain deviates from the rotameter flow rates. Besides, the flow rates for venturi meter and orifice meter also deviate from the actual flow rates. This could be happening due to the friction and the no-slip condition as water flows through each of the flowmeters. We have to monitor the water level in the manometer ,in our experiment when the rotameter reached to 60 mm the water level in the last manometer (I) was too low , so we needed to adjust the water level by using the staddle valve. With the maximum measureable flow rate, retain the maximum readings on manometer.

Conclusion

According to the data, the orifice meter's high-pressure drop is not recovered because the flow rate is raised at the opening of the orifice meter when little energy is lost, but a lot of it is lost as the flow proceeds and begins to slow down. The energy losses for the rotameter were then noticeably higher than for the Venture and orifice flowmeters. The significant pressure decrease brought on by friction is what causes this huge energy loss. Due to the venture meter's streamlined shape, which almost eliminates boundary-layer separation and results in decreased pressure drop, form drag is considered to be insignificant, and as a result, the figure produced was closer to the actual flow rate. It has a converging and a diverging portion, and while there may be some pressure loss in the converging portion, a correctly designed venture meter will achieve some pressure loss back in the diverging portion. For high pressure and energy recovery, use this meter. Conclusion: When compared to orifice meters and rotameters, venture meter was more accurate.

References

1) Chemical engineering laboratory "1" (0915361); University of Jordan; faculty of engineering and Technology; Department of Chemical engineering.

2) Noel de nevers, (1991), Fluid Mechanics for Chemical Engineers. third edition, McGraw-Hill, (pp. 164-202).

3) Incropera, (2011), Fundamentals of Heat and Mass Transfer, John Wiley & Sons, Inc. , seventh edition, (pp. 1029-1030).

Appendix

- **Bernoulli equation:**

$$\frac{P_1}{\rho g} + \frac{u_1^2}{2} + Z_1 = \frac{P_2}{\rho g} + \frac{u_2^2}{2} + Z_2 + \Delta h_{12}$$

Where ($\Delta h_{12} = \Delta H + \Delta h_f$) , Δh_f is the head loss due to friction and it is neglected due to the small length. Also, potential difference is neglected.

- **Sample of calculation; taking the first raw of table "2" Venturi meter:**

➔ **The experiment was carried out at 21°C and 680 mmHg.**

➔ **$A_A = 0.00053\ m^2$, $A_B = 0.0002\ m^2$ (from manual)**

1) **$h_A - h_B$ (mmH_2O)**

$= 218 - 172 = 46\ mmH_2O$

2) **$h_A - h_B$ (mH_2O)**

$= \frac{46}{1000} = 0.046\ mH_2O$

3) **$h_A - h_B$ (Pa)**

$1\ mH_2O = 9806.65$ Pa

$0.046\ mH_2O = 451.1059$ Pa

4) **C_V**

➔ $Q\ (m^3/s) = \frac{Q\ (L/min)}{1000 \times 60} = \frac{12.4}{1000 \times 60} = 0.0002067\ m^3/s$

➔ $$Q_{act} = C_V \cdot A_B \cdot \sqrt{\frac{2g}{\left(1-\left(\frac{A_B}{A_A}\right)^2\right)} \times (h_A - h_B)}$$

$$0.0002067 = C_V \times 0.0002 \times \sqrt{\frac{2 \times 9.81}{\left(1-\left(\frac{0.0002}{0.00053}\right)^2\right)} \times (0.046)} \rightarrow C_V = 0.39976$$

5) **u_B**

$$u_B = \sqrt{\frac{2g}{\left(1-\left(\frac{A_B}{A_A}\right)^2\right)} \times \left(\frac{P_A}{\rho g} - \frac{P_B}{\rho g}\right)}$$

$$u_B = \sqrt{\frac{2 \times 9.81}{\left(1-\left(\frac{0.0002}{0.00053}\right)^2\right)} \times \left(\frac{451.1059}{998.02 \times 9.81}\right)} = 1.0267\ m/s$$

6) u_A

$\dot{m}_A = \rho \times u_A \times A_A = \dot{m}_B = \rho \times u_B \times A_B$

$u_A = u_B \frac{A_B}{A_A} = 1.0267 \times \frac{0.0002}{0.00053} = 0.3888$ m/s

7) $\frac{u_B^2}{2g}$

$= \frac{1.0267^2}{2 \times 9.81} = 0.05373$ m

8) ΔH

$\Delta H = (h_A - h_B) + \frac{u_B^2 - u_A^2}{2g} - \Delta h_f$

$= 0.046 + \frac{1.0267^2 - 0.3888^2}{2 \times 9.81} = 0.09202$ mH_2O

9) K

$K = \frac{\Delta H}{(u^2/2g)} = \frac{0.09202}{0.05373} = 1.71287$

10) **Re (take from throat)**

$Re = \frac{\rho D u}{\mu} = \frac{998.02 \times 0.026 \times 0.3888}{1.005 \times 10^{-3}} = 10039$