University of Ottawa

Faculty of Engineering

Department of Mechanical Engineering

Fluid Mechanics 1

MCG 3340

LAB 2 - Channel Flow

By:

Abstract:

The goal of this lab is to measure the pressure variation in a water flow through a channel of varying cross section. You will compare measured results to predictions made using Bernoulli's equation. We were able to prove that the bernoulli's equation holds true even though the assumptions needed for the equation are not necessarily complete, giving us an error as we moved down the channel at a maximum of 8%.

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Introduction:

The goal of this lab is to measure the pressure variation in a water flow through a channel of varying cross section. The measured results were compared to predictions made using Bernoulli's equation. We were able to prove that the bernoulli's equation holds true even though the assumptions needed for the equation are not necessarily complete. The assumptions that we made to generate the equations were;   . However, in this experiment we aren't able to say that these assumptions are completely true. Even though we couldn't make the assumptions we are still able to use bernoulli's equation. At every point along the channel, the combinations of pressure and velocity will add up to the same constant proved by using the equation

$$p + \frac{1}{2}\delta v^2 + \delta gz \ = Const$$

This equation take in

Methodology:

1) Measure and tabulate the elevation of the top wall of the channel at the locations of the pressure taps.
2) Measure and tabulate the elevation of the bottom wall of the channel at the locations of the pressure taps.
3) Start the pump and establish a steady flow of water. Using the tank-balance apparatus, measure the flow rate. This is done by closing the drain from the fill tank, when the balance tilts, quickly add a weight to the other side of the balance and start measuring the time. When the balance tilts a second time, stop your time measurement. The amount of water added to the tank in that interval is written on the weight you added (the number on the weight applies to the water, not the weight itself). You can use these measurements to calculate the mass-flow rate of water.
4) With the water flowing at a known mass-flow rate, measure the height of water above the top of the channel in each pressure tap.
5) Repeat the procedure for a second flow rate

Apparatus:

This experiment is conducted in a converging-diverging channel. The channel width is 38 mm. Vertical tubes, used to measure the pressure, extend upward from small holes in the top channel wall. The position of these pressure taps are tabulated in Table 3.1. The flow is maintained by a water pump. A balance and tank are used to measure the mass flow rate of water.

Results:

Table 1: Measured results of flow rate 1

Tower Height (mm)	163	162	161	160	158	155	153	153	163	164	165	162	163	163	164
Channel height (mm)	43	40	38	34	28	23	15	13	18	24	30	34	38	40	43
Position	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A

Table 2: Measured results of flow rate 2

Tower Height (mm)	214	214	215	217	219	218	215	214	224	230	228	226	226	228	230
Channel height (mm)	43	40	38	34	28	23	15	13	18	24	30	34	38	40	43
Position	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A

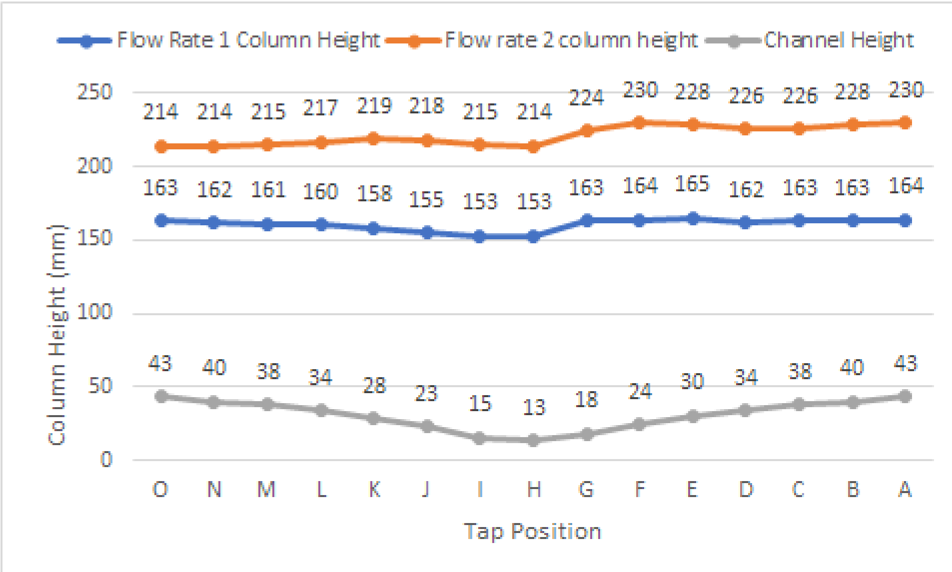

Figure 1: Tower height and Channel high relationship

Table 3: Flow Rates

Flow test case	Flow rate (lbs/s)	Flow rate (kg/s)
1	0.976	0.442
2	0.692	0.314

Table 4: Cross sectional area at taps

Cross sectional area (mm^2)	1634	1520	1444	1292	1064	874	570
Position	O	N	M	L	K	J	I

Table 5: Cross sectional area at taps continued

Cross sectional area (mm^2)	494	684	912	1140	1292	1444	1520	1634
Position	H	G	F	E	D	C	B	A

Result Calculations

Volumetric flow rate Q remains constant by $Q = SV$ where S is the cross sectional surface area and V is the velocity of the fluid. Q can be extrapolated from the mass flow rate by $Mass\,flow\,rate = \overline{m} = \rho Q$. Thus the velocities at the taps can be calculated as $V = \frac{\overline{m}}{S\rho}$

Pressure at taps as a function of column height = $\rho g h$

Pressures by Bernoulli's equation.

Bernoulli's equation, assuming constant water density is $p + \frac{1}{2}\rho v^2 + \rho g z$. Also, all points of analysis are on the same stream line along the top of the channel. Pressure at A is assumed to be error free and is used as a reference to compare taps B through O.

The pressure for the second position is given by:

$$\frac{P_1}{\rho} + 0.5V_1^2 + gZ_1 = \frac{P_2}{\rho} + 0.5V_2^2 + gZ_2$$

$$P_2 = P_1 + 0.5\rho\,[V_1^2 - V_2^2] + \rho\, g[Z_1 - Z_2]$$

Table 6: Computed velocities and pressures

Position	Velocity (ms^{-1})		Column pressure (N/m^2)		Bernoulli pressure (N/m^2)		Total pressure	
	Flow 1	Flow 2	Flow 1	Flow 2	Flow 1	Flow 2	Flow 1	Flow 2
A	0.27050	0.19216	1608.84	2256.3	1608.84	2256.3	1856.34	2485.67
B	0.29078	0.20657	1599.03	2236.68	1603.16	2253.44	1841.63	2470.97
C	0.30609	0.21745	1599.03	2217.06	1598.60	2251.14	1831.83	2461.17
D	0.34210	0.24303	1589.22	2217.06	1586.95	2245.27	1812.23	2441.57
E	0.38771	0.27543	1618.65	2236.68	1570.33	2236.90	1782.83	2412.17
F	0.48464	0.34429	1608.84	2256.3	1528.08	2215.59	1758.33	2387.67
G	0.64619	0.45906	1599.03	2197.44	1436.78	2169.59	1719.13	2348.47
H	0.89473	0.63562	1500.93	2099.34	1245.30	2072.90	1709.33	2338.67
I	0.77543	0.55087	1500.93	2109.15	1344.90	2123.15	1733.83	2363.17
J	0.50572	0.35926	1520.55	2138.58	1517.64	2210.32	1763.23	2392.57
K	0.41541	0.29511	1549.98	2148.39	1559.20	2231.28	1792.63	2421.97

L	0.34210	0.24303	1569.6	2128.77	1586.95	2245.27	1812.23	2441.57
M	0.30609	0.21745	1579.41	2109.15	1598.60	2251.14	1831.83	2461.17
N	0.29078	0.20657	1589.22	2099.34	1603.16	2253.44	1841.63	2470.97
O	0.27050	0.19216	1599.03	2099.34	1608.84	2256.3	1856.34	2485.67

Error between column pressure and Bernoulli's equation pressure:

$$Error\,\% \;=\; |(Column\ Pressure\ -\ Bernoulli\ Pressure)/\ Bernoulli\ Pressure| * 100$$

Table 7: Error between column pressure and bernoulli's equation pressure

Column pressure (N/m^2)		Bernoulli pressure (N/m^2)		Error %	
Flow 1	Flow 2	Flow 1	Flow 2	Flow 1	Flow 2
1608.84	2256.3	1608.84	2256.3	0	0
1599.03	2236.68	1603.16	2253.44	0.25848	0.74940
1599.03	2217.06	1598.60	2251.14	0.02663	1.53739
1589.22	2217.06	1586.95	2245.27	0.14264	1.27263
1618.65	2236.68	1570.33	2236.90	2.98464	0.01007
1608.84	2256.3	1528.08	2215.59	5.01944	1.80415
1599.03	2197.44	1436.78	2169.59	10.1466	1.27002
1500.93	2099.34	1245.30	2072.90	17.0313	1.25928
1500.93	2109.15	1344.90	2123.15	10.3954	0.66407
1520.55	2138.58	1517.64	2210.32	0.19125	3.35465
1549.98	2148.39	1559.20	2231.28	0.59523	3.85830
1569.6	2128.77	1586.95	2245.27	1.10556	5.47288
1579.41	2109.15	1598.60	2251.14	1.21526	6.73233
1589.22	2099.34	1603.16	2253.44	0.87736	7.34049
1599.03	2099.34	1608.84	2256.3	0.61349	7.47663

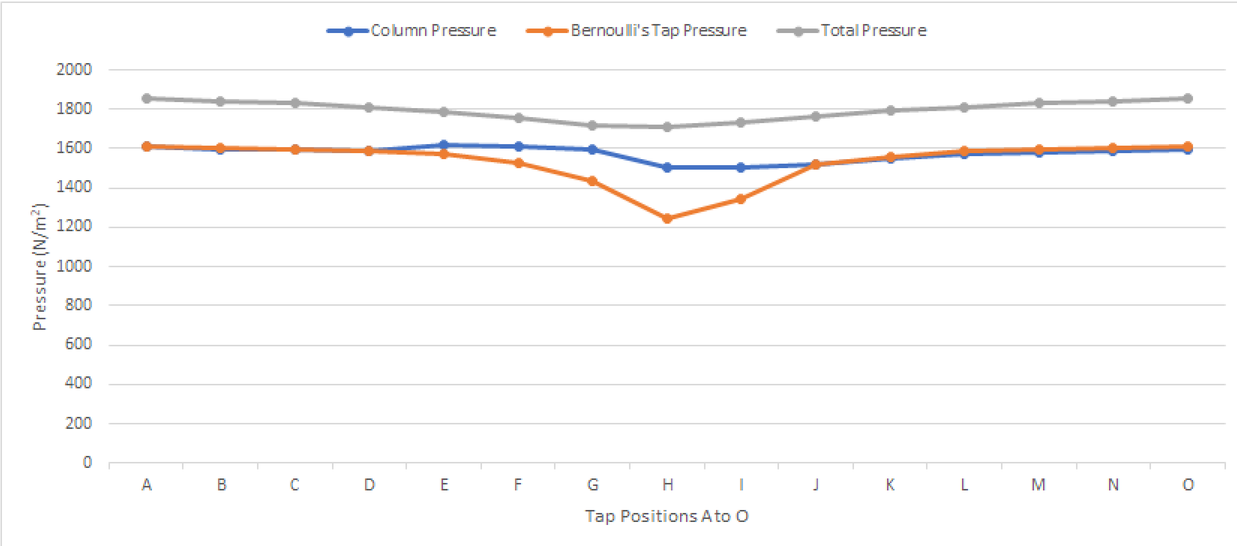

Figure 2: Pressure Graph for flow rate 1

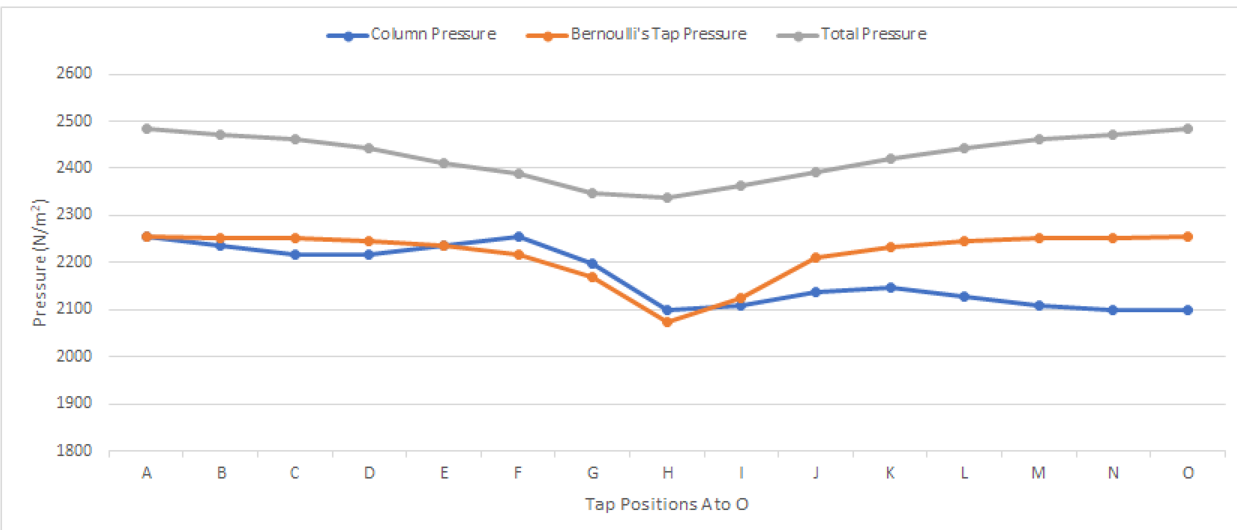

Figure 3: Pressure Graph for flow rate 2

Discussion:

The total pressures for both flow rates do not exhibit perfectly constant behaviours. The largest fluctuations resulted in 8% and 6% for flow rates one and two respectively. The error in these findings can be attributed to the occurrence of friction losses with the bottleneck of the channel. One possible source of experimental error is in the way we measured our finding. Most of the results were done by measuring with very inaccurate tools. The precision of measurement tools was limited to the millimetre scale.

Conclusion:

In this lab we tested bernoulli's equation. We founds out that even though bernoulli's equation makes the assumption of no fluid friction, the resulting error is still close enough to be used as an approximation with a maximum of 8% error. We have learned that these errors are due to pressure losses through friction of viscous fluids.