Fluids Lab 4: Flow Measurement

[redacted]

Lab Performed: [redacted]

Report Due: [redacted]

[redacted]

CE 3105 - 301

Table of Contents

Theory

Reynolds number can be used to determine if a fluid is in laminar or turbulent flow. Laminar flow happens when particles are flowing in a straight line, the fluid becomes turbulent when the velocity increases and causes vortices to form within the flow. For a circular pipe the Reynolds number can be expressed as:

$$Re = \frac{\rho v D}{\mu} \quad (1)$$

Or

$$Re = \frac{vD}{\nu} \quad (2)$$

With a Reynolds number less than 2000 it is near impossible for turbulent flow to take place, as the turbulence will be restrained by the viscous resistance. That said, there is a transitional stage where the fluid is transiting from turbulent flow to laminar flow, and vise versa, this stage is called transitional flow. For a smooth the common rule is:

- Laminar Flow, Re < 2000
- Transitional Flow, Re = 2000 – 4000
- Turbulent Flow, Re > 4000

For laminar flow, the head loss due to friction is directly proportional to the velocity:

$$i \propto v$$

For turbulent flow, the head loss due to friction is proportional to the velocity to a given power, n:

$$i \propto v^n$$

The variable n will vary between 1.75 – 2. In these equations i is the hydraulic gradient, it can be found as follows,

For the manometer –

$$i = \frac{(h_1 - h_2)}{l} \quad (3)$$

For the pressure manometer –

$$i = \frac{\Delta h}{l} \quad (4)$$

The flow velocity, u can be found from the continuity equation when the cross-sectional area of the pipe is known:

$$u = \frac{Q}{A} \quad (5)$$

The friction factor, f can be found using Darcy-Weisbach equation:

$$f = \frac{iD}{4v^2/2g} \qquad (6)$$

The necessary physical water properties corresponding to water temperature should be used, they can be found in tables from the book.

Apparatus

- Hydraulic bench pump
- Manometer
- Rotameter
- Balance
- Graduated cylinder
- Ruler
- Trim tank apparatus

Results

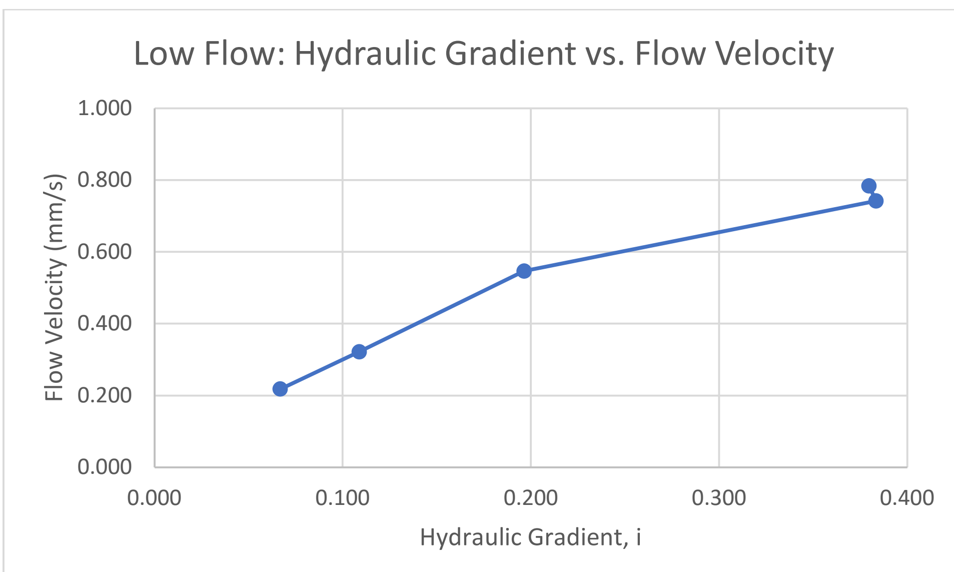
The tables and chart below show the results that were calculated from the lab data.

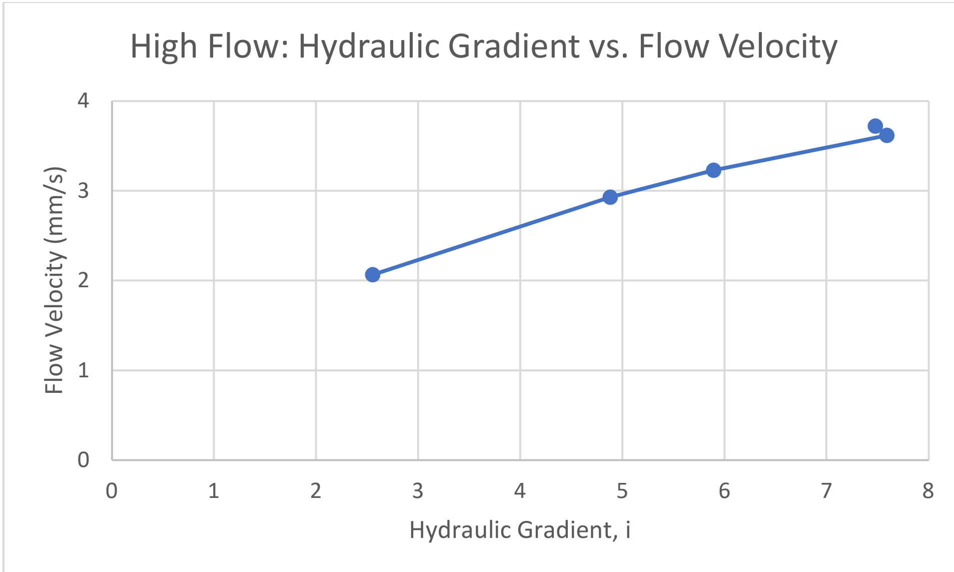
Lower Flow Rates

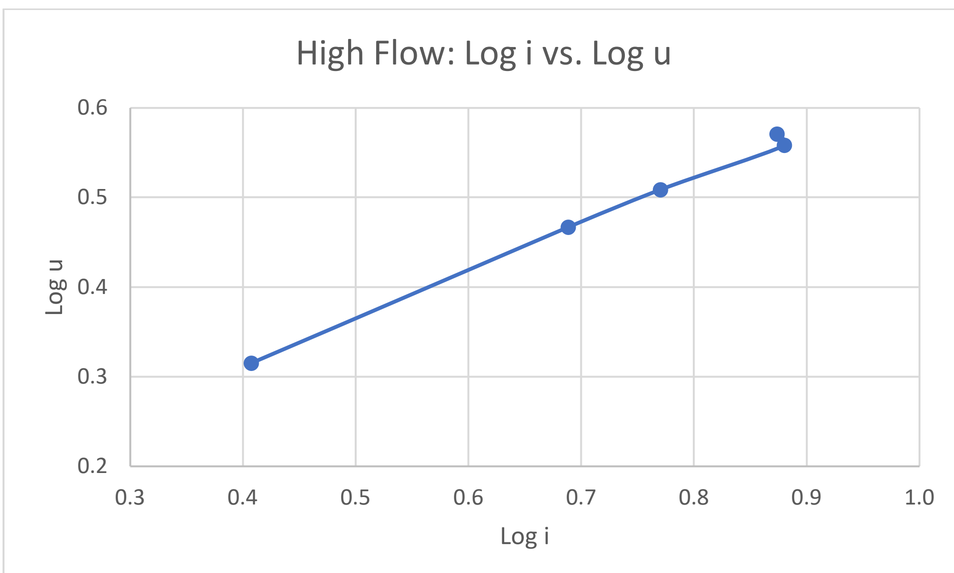
Volume (mL)	Time (s)	Flow Rate, Q (mL/s)	Flow Velocity, u (mm/s)	h_1 (mm)	h_2 (mm)	Δh (mm)	i	log i	Re	f
13	8.45	1.54	0.218	293	258	35	0.067	-1.175	653.7	20667.0
29	12.78	2.27	0.321	302	245	57	0.109	-0.964	964.2	15471.2
37	9.59	3.86	0.546	322	219	103	0.196	-0.707	1639.5	9670.6
49	9.35	5.24	0.742	382	181	201	0.383	-0.416	2226.9	10228.5
43	7.77	5.53	0.784	365	166	199	0.380	-0.421	2351.6	9081.2

Higher Flow Rates

Volume (mL)	Time (s)	Flow Rate, Q (mL/s)	Flow Velocity, u (mm/s)	Δh (m)	i	log i	Re	f
122	8.36	14.59	2.067	1.34	2.556	0.408	6201.1	8793.9
138	6.67	20.69	2.931	2.56	4.883	0.689	8791.6	8358.3
180	7.9	22.78	3.227	3.09	5.894	0.770	9681.9	8318.6
205	8.03	25.53	3.616	3.98	7.592	0.880	10848.1	8534.7
217	8.26	26.27	3.721	3.92	7.477	0.874	11163.4	7938.0




High Flow: Hydraulic Gradient vs. Flow Velocity
Flow Velocity (mm/s)
0
1
2
3
4
0
1
2
3
4
5
6
7
8
Hydraulic Gradient, i


High Flow: Log i vs. Log u
Log u
0.2
0.3
0.4
0.5
0.6
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Log i

Discussion:

During this lab we tested the difference in high and low flow rates, using these calculations can help in the design of the structure. In the low flow rate, we saw Q be in the range of 1.5 to 5.60 cube feet per second as the 5 trials were being conducted. The volumes during these 5 trials were in the range of 13-50 mL with the time span that was recorded 8:45 to 13:00 seconds respectfully per trial, knowing this information we can then calculate Q for each of the trials. For the high flow rate, we see the calculated Q to be in the range of 15:00 to 26:00 cube feet per second. With the time rage being similar to the low flow rate but having a larger difference in the amount of water ranging from around 120 to 220 mL. Seeing the difference in the volumes and the calculated Q's we can then determine the flow velocity, for the higher one ranging around 2.000 to 3.720 feet per second and the lower ranging around .2000 to .790 feet per second.

Interpretation Questions:

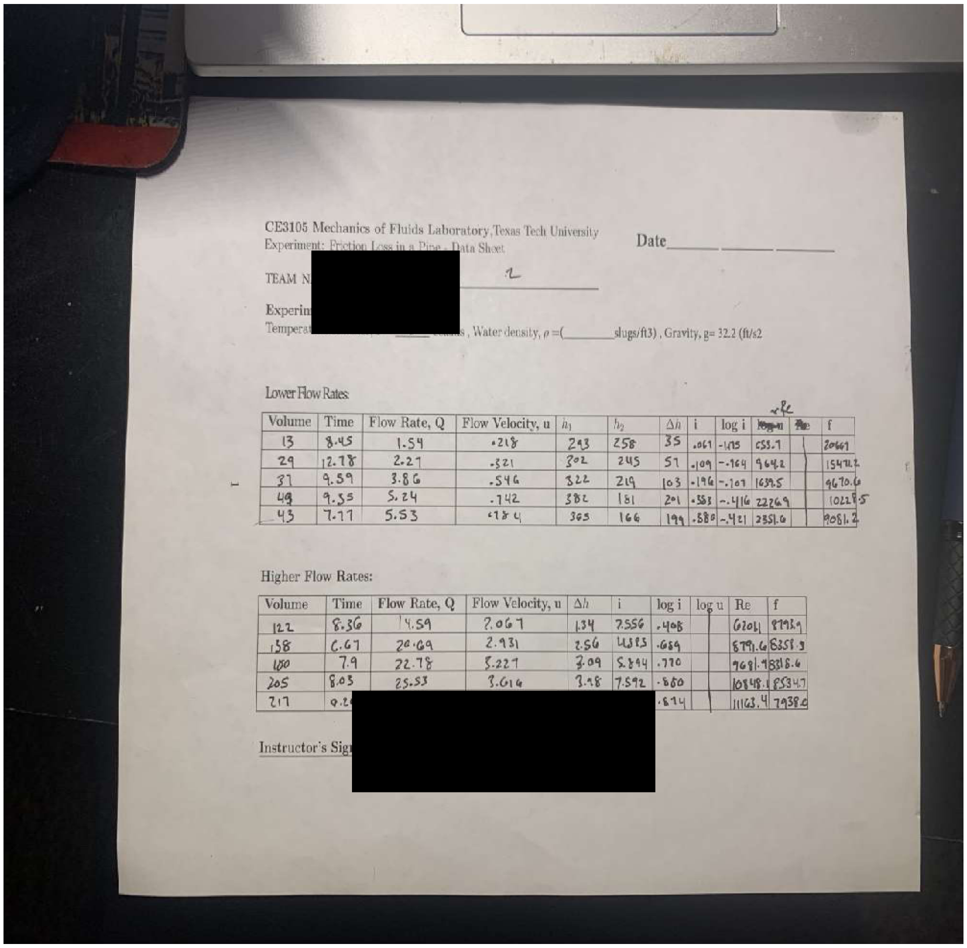
- The flow being turbulent or laminar the calculations came to be laminar flow as the Reynolds number was not greater than 2000.

- The two flow rates differ mostly in the volumes collected for each of the time trials, The calculated Q's are higher, and also the flow velocities are high as well when comparing the high and low flow rates to each other.

- When calculating the flow velocity since we had to know the diameter of the pipe prior to the experiment.

Data appendix

Original Data Sheet:



CE3105 Mechanics of Fluids Laboratory,Texas Tech University
Experiment: Friction Loss in a Pipe - Data Sheet

Date______ ______ ______

TEAM N[redacted] 2

Experim[redacted]
Temperat[redacted] ____ s , Water density, ρ =(________slugs/ft3) , Gravity, g= 32.2 (ft/s2

Lower Flow Rates

Volume	Time	Flow Rate, Q	Flow Velocity, u	h_1	h_2	Δh	i	log i	~~log u~~ Re	~~Re~~	f
13	8.45	1.54	.218	293	258	35	.061	-1.215	553.7		20661
29	12.78	2.27	.321	302	245	57	.109	-.964	964.2		15472.2
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205	8.03	25.53	3.616	3.98	7.592	.880		10848.1	8534.7
217	9.2[redacted]					.874		11163.4	7938.6

Instructor's Sig[redacted]

Sample Calculations

Reynold's Number

$$Re = \frac{\rho v D}{\mu}$$

$$Re = \frac{(0.218\ mm/s)(3\ mm)}{0.001} = \mathbf{653.7}$$

Hydraulic Gradient

$$i = \frac{(h_1 - h_2)}{l}$$

$$i = \frac{(293\ mm - 258\ mm)}{524.256\ mm} = \mathbf{0.067}$$

Flow Velocity

$$v = \frac{Q}{A}$$

$$v = \frac{1.54\ mL/s}{7.06\ mm^2} = \mathbf{0.218\ mm/s}$$

Friction Factor

$$f = \frac{iD}{4v^2/2g}$$

$$f = \frac{(0.067)(3\ mm)}{4(0.218)^2/2(9.8\frac{m}{s^2})} = \mathbf{20,667}$$