PIPE FRICTION LOSS

Contents

List of Figures and Tables

1. Introduction

The objective of the experiment was to study friction loss in a small-bore horizontal pipe at various flow rates and also to measure the risk of a practical laboratory session. The frictional energy loss generated by the viscous effects of the fluid and the roughness of the pipe wall causes significant losses. Because the pressure must strive to overcome the frictional resistance, major losses cause a pressure drop along the pipe. The Darcy-Weisbach equation is the most often used formula for calculating energy loss in pipe flow. The friction factor (λ), a dimensionless variable, is employed in this equation to represent the friction loss in a pipe. In laminar flows, λ is just a function of the Reynolds number and is unaffected by the pipe's surface roughness. In completely turbulent flows, λ is affected by the Reynolds number as well as the relative roughness of the pipe wall. The loss of head due to pipe friction and viscous dissipation in flowing water is generally referred to as the major loss (h_f), which is the loss of energy through friction throughout the length of the pipeline. Major head loss, also known as friction loss, is the loss of pressure or "head" in pipe flow caused by the influence of the fluid's viscosity near the pipe or duct's surface. The following factors influence major head losses: flow regime (i.e., Reynolds number), flow velocity, pipe diameter and length, friction factor. Friction and the many singularities encountered in pipelines used to carry fluids (water, oil, gas, etc.) are the main causes of energy losses in these systems. The head of the flow is often reduced as a result of these losses. The ability to calculate the required power for the transportation of the fluid between two places is made possible by knowledge of the data resulting from such transformation (Spurk, 2019).

2. Apparatus

Friction loss apparatus consisting of: -

- Small bore horizontal pipe with two pressure tappings
- Precision needle valve to control flow rate
- U-tube manometer (for low flow rates)
- Bourdon gauge (for higher flow rates)
- Header tank
- Measuring vessel with stop watch
- Hydraulic Bench

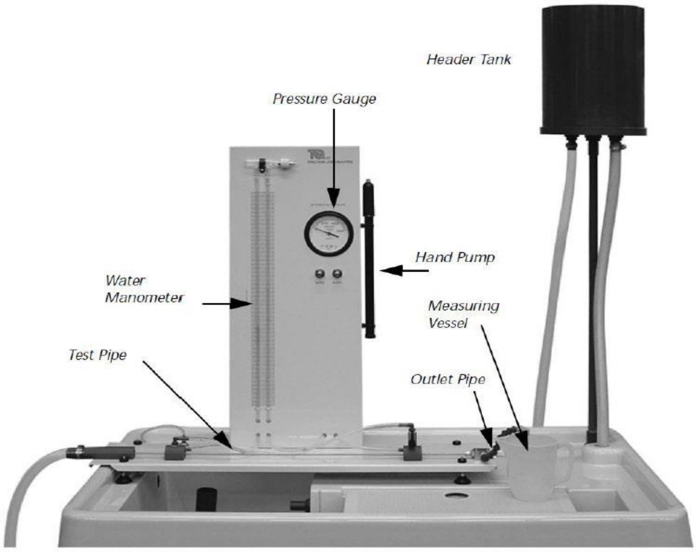

Figure 1: Apparatus

3. Method

1. Prior to attending the practical session, the laboratory was risk assessed.

Lower Flow Rates

2. The apparatus was connected by the technician to the header tank which provided a source for the water flow through the horizontal pipe.
3. After carefully adjusting the needle valve to provide a differential head of around 450 mm on the water manometer, the valve was fully opened. Values were noted down.
4. A stopwatch was used to timing the collection of an appropriate amount of water from the output pipe using the collection and measurement containers that were provided. The collected water's temperature was measured and noted.

5. The needle valve was used to reduce the differential in roughly 30 mm steps, to give at least ten sets of results. Taking results at around 30 mm differential was stopped. At each step, differential, the flow rate and the water temperature were recorded.

Higher Flow Rates

6. The apparatus was connected by the technician to the hydraulic bench which provides a source and sinks for the water flow through the horizontal pipe.
7. The needle valve was fully opened. The hydraulic bench supply valve was adjusted to get a reading of around 2000 mm on the bourdon gauge. This value was recorded.

8. The collection and measuring vessels supplied, and a stopwatch was used to time the collection of a suitable quantity of water from the outlet pipe. The temperature of the collected water was measured and recorded.
9. The needle valve was used to reduce the differential in roughly 200 mm steps, to give at least ten sets of results. Taking results at around 400 mm differential was stopped. At each step, differential, the flow rate and the water temperature were recorded.

4. Results

Pipe specifications: -

- Diameter of the pipe (d) = 3 mm =$3 * 10^{-3}$ m
- Area of the pipe (a) = $7.06858 * 10^{-06} \mathrm{m}^2$
- Distance between pressure tapings (l) = 524 mm = $524 * 10^{-3}$ m

Table 1: Data for low result

Difference in head (mm)	Volume collected (ml)	Time (s)	Temperature (°c)	Volume flow rate Q $\left(\frac{m^3}{s}\right)$	Velocity v $\left(\frac{m}{s}\right)$	Hydraulic gradient i	Friction coefficient λ	Viscosity of water µ (mPa.s)	Reynolds Number Re
30	80	73	21	1.10E-06	0.15504	0.05725	0.1402	0.98	474.60
61	105	50	21	2.10E-06	0.29709	0.11641	0.0776	0.98	909.46
90	145	50	21.5	2.90E-06	0.41027	0.17176	0.0601	0.9685	1270.83
118	135	36	21.5	3.75E-06	0.53052	0.22519	0.0471	0.9685	1643.31
150	100	22	21.5	4.55E-06	0.64305	0.28626	0.0407	0.9685	1991.90
180	90	17.6	21.5	5.11E-06	0.72343	0.34351	0.0386	0.9685	2240.88

210	150	28	21.5	5.36E-06	0.75788	0.40076	0.0411	0.9685	2347.59
242	135	23.5	21.5	5.74E-06	0.81271	0.46183	0.0412	0.9685	2517.42
274	200	33	22	6.06E-06	0.85740	0.52290	0.0419	0.957	2687.78
248	100	31	22	3.23E-06	0.45636	0.47328	0.1338	0.957	1430.59
330	175	21	22	8.33E-06	1.17893	0.62977	0.0267	0.957	3695.69
360	180	29	22	6.21E-06	0.87810	0.68702	0.0524	0.957	2752.65
390	145	22	22	6.59E-06	0.93242	0.74427	0.0504	0.957	2922.96
418	190	28	22	6.79E-06	0.95998	0.79771	0.0509	0.957	3009.35
442	185	27	22	6.85E-06	0.96934	0.84351	0.0528	0.957	3038.68

Table 2: Data for high flow rate

Gauge pressure (mm)	**Volume collected (ml)**	**Time (s)**	**Temperature (°c)**	**Volume flow rate Q** $\left(\frac{m^3}{s}\right)$	**Velocity v** $\left(\frac{m}{s}\right)$	**Hydraulic gradient i**	**Friction coefficient λ**	**Viscosity of water μ (mPa.s)**	**Reynolds Number Re**
2000	315	20	22	1.58E-05	2.2282	3.8168	0.0453	0.957	6984.86
1800	280	19	22.5	1.47E-05	2.0848	3.4351	0.0465	0.946	6611.53
1600	285	21	22.5	1.36E-05	1.9200	3.0534	0.0488	0.946	6088.68

1400	300	24	22.5	1.25E-05	1.7684	2.6718	0.0503	0.946	5608.00
1200	290	26	22.5	1.12E-05	1.5779	2.2901	0.0541	0.946	5004.06
1000	290	29	22.5	1.00E-05	1.4147	1.9084	0.0561	0.946	4486.40
750	285	36	22.5	7.92E-06	1.1200	1.4313	0.0672	0.946	3551.73
500	295	37	22.5	7.97E-06	1.1279	0.9542	0.0441	0.946	3576.99

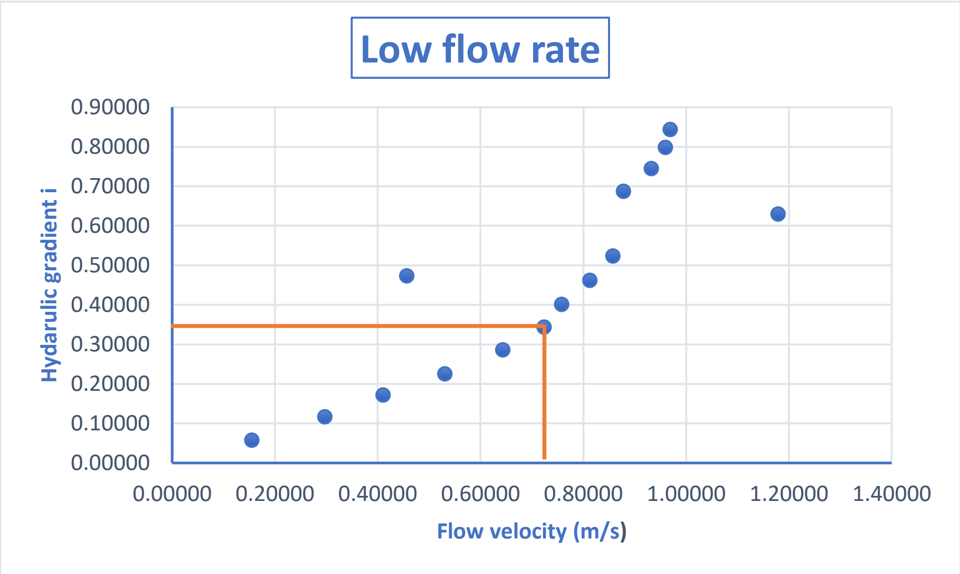

Figure 2: Graph of hydraulic gradient against flow velocity for low flow rate

- Transition point from the laminar to turbulent from the Figure 2, Re = 2240.88

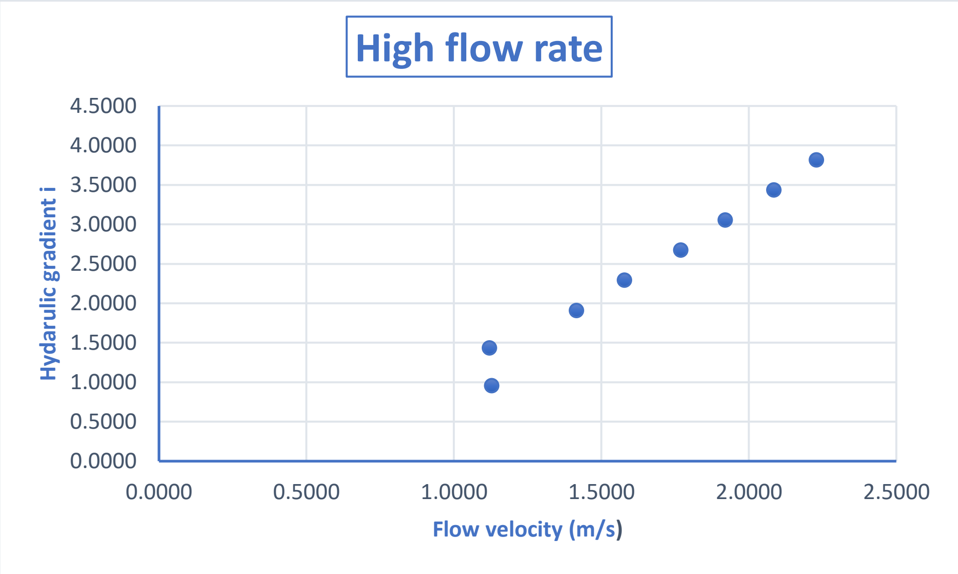

Figure 3: Graph of hydraulic gradient against flow velocity for high flow rate

5. Calculation

Sample calculation

[1] Cross-sectional area (a)

$$a = \frac{\pi}{4} d^2$$

Or

$$a = \frac{\pi}{4} * (3 * 10^{-3})^2$$

Or

$$\boldsymbol{a = 7.06858 * 10^{-6}\ m^2}$$

Table 1

[2] Volume flow rate (Q)

$$Q = \frac{Volume\ collected}{Time}$$

Or

$$Q = \frac{(80 * 10^{-6}) m^3}{73\ s}$$

Or

$$\boldsymbol{Q = 1.10 * 10^{-6} \frac{m^3}{s}}$$

[3] Flow velocity (v)

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

Or

$$v = \frac{(1.10 * 10^{-6}) \frac{m^3}{s}}{(7.06858 * 10^{-6}) m^2}$$

Or

$$\boldsymbol{v = 0.15504 \frac{m}{s}}$$

[4] Hydraulic Gradient (i)

$$i = \frac{30\ mm}{524\ mm}$$

Or

$$\boldsymbol{i = 0.05725}$$

[5] Friction coefficient (λ)

$$\lambda = \frac{(\mathrm{id} * 2\mathrm{g})}{\mathrm{v}^2}$$

Or

$$\lambda = \frac{0.05725 * (3 * 10^{-3}) * 2 * 9.81}{0.15504^2}$$

Or

$$\boldsymbol{\lambda = 0.1402}$$

[6] Viscosity of water (μ)

At temperature (T) = 21 °c

$$\boldsymbol{\mu = 0.980\ mPa - s = 0.980 * 10^{-3} Pa - s}$$

[7] Reynolds Number (Re)

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

Or

$$Re = \frac{1000 * 0.15504 * (3 * 10^{-3})}{0.98 * 10^{-3}}$$

Or

$$\boldsymbol{Re = 474.60}$$

Table 2

[8] Volume flow rate (Q)

$$Q = \frac{Volume\ collected}{Time}$$

Or

$$Q = \frac{(315 * 10^{-6})m^3}{20\ s}$$

Or

$$\boldsymbol{Q = 1.58 * 10^{-5} \frac{m^3}{s}}$$

[9] Flow velocity (v)

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

Or

$$v = \frac{(1.58 * 10^{-5})\frac{m^3}{s}}{(7.06858 * 10^{-6})m^2}$$

Or

$$\boldsymbol{v = 2.2282 \frac{m}{s}}$$

[10] Hydraulic Gradient (i)

$$i = \frac{2000\ mm}{524\ mm}$$

Or

$$\boldsymbol{i = 3.8168}$$

[11] Friction coefficient (λ)

$$\lambda = \frac{(\mathrm{id} * 2\mathrm{g})}{\mathrm{v}^2}$$

Or

$$\lambda = \frac{3.8168 * (3 * 10^{-3}) * 2 * 9.81}{2.2282^2}$$

Or

$$\boldsymbol{\lambda = 0.0453}$$

[12] Viscosity of water (μ)

At temperature (T) = 22 °c

$$\boldsymbol{\mu = 0.957\ mPa - s = 0.957 * 10^{-3} Pa - s}$$

[13] Reynolds Number (Re)

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

Or

$$Re = \frac{1000 * 2.2282 * (3 * 10^{-3})}{0.957 * 10^{-3}}$$

Or

$$\boldsymbol{Re = 6984.86}$$

6. Discussion

Theoretically, the laminar flow inside the pipe must have a linear fluctuation of hydraulic gradient with respect to flow velocity. The slope of this linear variation line must switch to a high gradient line at a certain flow velocity. A definite transition point from a laminar to a turbulent flow is what this particular location is known as. Additionally, it has been shown that, theoretically, the Reynolds Number at which turbulent flow starts to happen in circular pipes in most applications is quite close to 2000. The turbulent flow is responsible for this steeper area. Figure 1 illustrates how the graph between hydraulic gradient and flow velocity matched the theory. The experimentally determined Reynolds number in around of this transition point was 2240.88. It was discovered that there was a 12.04% discrepancy between the theoretical and experimental values of the transition point. It may be claimed that the experiment's results were rather similar to those predicted by theory.

The assumption that the water's density would remain constant might be the source of the inaccuracy. Water density varies with the water temperature. This presumption caused the computed Reynolds number to deviate from the real value. Before the water reaches the pressure taps in the pipe sections, it goes through a fitting and loses a tiny amount of pressure. This can be also the cause of the mistake. Both the hydraulic gradient and flow velocity were impacted by this loss. The incorrect calibration of the U-tube manometer and bourdon gauge was another potential cause of mistakes. The reading should be repeated and recorded for the same value of head and gauge pressure variation in order to minimise instrumental error. To correctly measure the volumetric flow rate, the flow metre must be a part of the test ring.

7. Conclusions

The objectives of the experiment were to investigate friction loss in a small-bore horizontal pipe at different flow rates and to assess the risk of a practical lab session. Risk assessment was done for the lab. A stopwatch was used to time how much water was collected from the outflow pipe using the provided collecting and measurement containers. The water that had been collected had its temperature monitored and noted for both low and high flow rate. The flow rate, water temperature, and difference were all noted at each stage for both low and high flow rate. The flow velocity, hydraulic gradient, friction factor and Reynolds no. were calculated with the help of formula and raw data. The graphs between the hydraulic gradient and the Reynolds no were plotted for low and high flow. The Reynolds number around the transition point was 2240.88, according to experimental analysis. Between theoretical and experimental values of the transition point, it was found that there was a 12.04% difference.

8. Risk Assessment

- Electrical shock from untested appliances
- Hydraulic bench moving and causing injury
- Electrical shock from sockets
- Spillage of water
- Legionella bacteria inhaled
- Smashing of glass thermometer

9. Reference

Habib Ahmari and Shah (2019). *Applied Fluid Mechanics Lab Manual*.

Granet, Irving. *Fluid Mechanics*. Englewood Cliffs, N.J., Prentice Hall, 1996.

Robert Alan Granger, and Robert A Granger. *Fluid Mechanics*. New York, Dover, 1995.

Spurk, Joseph. *Fluid Mechanics*. S.L., Springer, 2019.