 THE UNIVERSITY OF MELBOURNE

ENGR30002 FLUID MECHANICS

EXPERIMENT 1: FLUID FLOW IN A SMOOTH PIPE

Group number: Group 56

Data: Group E sample data

Group Member:

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# Abstract

This project is a study on the relationship between Reynold’s number and the Fanning Friction factor. An apparatus is developed to conduct an experiment which measures pressure change against flow rate through a pipe with a circular cross section.

The data attained is then used to calculate Reynold’s Number and Fanning friction factor, which are then plotted against each other on a log-log scale. The linear relationship constant between the two variables is calculated by using a line of best fit through the laminar region. The experimental value was found to be , which was compared to the theoretical value . The error was calculated to be 200% and considered within acceptable precision range.

Using the relationship constant, an example calculation is completed for maximum flow rate, and a hypothetical scenario is studied, where a required pressure drop is calculated for a specified flow rate with the help of the previously found Re-f relationship.

# Aim

The aim of this investigation was to explore the relationship between pressure gradient on the fluid flow in a circular pipe. The factors that affect the pressure gradient include velocity of fluid, pipe diameter and length and friction coefficient of the pipe’s interior.

In this experiment, the diameter and length are fixed, while the initial flow rate of fluid is a controlled independent variable. By measuring the head loss or pressure difference in the pipe at varying flow rates, the fanning friction number as well as the Reynold’s number is calculated, and the function which relates the two is studied. To do this, the fanning friction number is plotted against the Reynold's number—Re. The varying flow rates allow a study of the transition from laminar to turbulent flow states.

# Discussion

## 1.) Schematic diagram of the apparatus used in experiment

The following schematic diagram was constructed to represent the apparatus used in this experiment. All components including material flow and flow direction are shown and labelled:

Diagram, schematic

Description automatically generated

Figure 1. Schematic diagram of Apparatus

## 2.) Log-log plot of f vs Re

The pressure difference results were measured in terms of pressure drop or head loss, depending on the measurement device at each range of flow rate. After converting all head loss values into pressure difference in (Pa), the results were used to compute the Reynold’s (Re) numbers and fanning friction numbers (f) to each flow rate. The following equations were rearranged then used to perform these computations.

The complete detailed calculations were done in excel with the above formulas and can be referred to Appendix A.

The data is then used to populate a scatter plot with a log-log scale as shown below.

Figure . Experimental log (f) vs log (Re) graph

When the Reynolds number is less than 2000, flow is laminar flow, and represented as blue. When the Reynolds number is between 2000 and 3000, flow is transition flow, and represented as orange. When the Reynolds number is greater than 3000, flow is turbulent and represented as grey.

A linear line of best fit of the laminar region was created with a R2 value of 0.6473. The line is observed on the graph to be parabolic, although it is a linear best fit line representing the linear relationship between f and Re. The line has a slope of .

## 3.) Theoretical relationship and experiment results

The theoretical relationship between the Fanning’s friction number and the Reynolds number in the laminar flow regime for pipe flow follows the following equation:

Theoretical fanning number was calculated and a graph was sketched (Figure 3). The table of calculations can be referred to Appendix B. A best fit line is also sketched.

Figure . Theoretical log(f) vs log(Re) graph for laminar region

The slope of the best fit line is and has a R2 value of 0.7717. This plot is compared with the experimental data plot by finding the error of the line of best fit’s slopes:

There is a 200% error between the extracted experimental data and theoretical data.

This difference is likely due to experimental errors such as inconsistent measurements of head loss and possible limitation of measuring equipment.

## 4.) Sample calculation at maximum flow rate (1600 L/hr)

A sample calculation is produced for the data point at maximum observed flow rate. The calculations for Velocity, Reynold’s number, fanning friction number and head loss are shown.

**Experimental value calculations**

**Parameter values:**

**Velocity (v):**

**Reynold’s Number (Re):**

**Head Loss (HL)**

**Fanning Friction Number (f):**

**Theoretical value calculations**

Using the Moody Diagram with smooth pipe curve used:

Chart

Description automatically generated

Figure . Moody diagram for theoretical Fanning Friction number

**Comparison**

Percentage difference for Fanning friction value:

Percentage difference for head loss, hL:

The difference between the experimental data and the theoretical data in terms of the Fanning friction value and head loss value have a similar percentage difference, a 17.5% and 17.2% difference respectively.

## 5.) Viscous liquid pressure drop calculation

In a hypothetical study, a certain flow rate is specified. Using the previously calculated Re-f relationship, calculations are conducted to estimate the required driving force in terms of driving force per unit length.

**Parameter values**

**Reynold’s Number (Re):**

As the Reynolds number is less than 2000, the flow is **laminar.**

Fanning friction factor is extracted by using linear interpolation from two data points from the table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Q (m^3/s) | Velocity (m/s) | Re | head loss (hL) (m) | fanning friction factor (f) |
| 1.66667E-05 | 1.347E-01 | 1.894E+03 | 3.170E-03 | 7.165E-03 |
| 1.38889E-05 | 1.123E-01 | 1.578E+03 | 2.965E-03 | 9.653E-03 |

Figure . Excerpt from Table 1

**Driving Force (Pressure drop per unit length):**

Assume horizontal pipe and constant velocity of fluid:

# Conclusion

This experiment was a successful investigation into the relationship between fanning friction number and Reynold’s number. The experiment was conducted with a wide range of controlled flow rates, which allowed for a comprehensive analysis and distinction of different flow types. An apparatus involving three different pressure measurement devices was used to accurately read pressure across the large range. Derivative equations of the Bernoulli equation were used to solve for Re and f, before the relationship was studied.

Specifically, the laminar flow region was compared to theoretical values. Although there was an error margin, it can be explained by insignificant experimental errors, and can still be used as a somewhat reliable representation of the f-Re relationship. A reliable comparison was not able to be made for the turbulent data points as the greater velocity of fluid would be affected more considerably by the roughness of the pipe interior. The results gained in the exploration of the Re-f relationship was also able to be successfully used in the study of a hypothetical situation where a required driving force was calculated in response to a specified flow rate in terms of pressure drop per unit length.

Overall, the investigation was successful and provided insights on the affects of friction on the pressure difference and flow rate in a fluid flow situation. This information may serve as basis for further studies in varying fluid flow scenarios. An improvement to the experiment may be to consider measuring the interior pipe roughness so that an effective comparison of results in the turbulent region can be attained and studied further.

# Appendix

## Appendix A. Detail calculation of the discussion part 2



Figure . Detail calculation of the discussion part 2

## Appendix B. Table of calculation of theoretical relationship of Re and f in the laminar region

|  |  |
| --- | --- |
| Re | theorectical fanning number (f) |
| 5.051E+04 |  |
| 4.735E+04 |  |
| 4.420E+04 |  |
| 4.104E+04 |  |
| 3.788E+04 |  |
| 3.473E+04 |  |
| 3.157E+04 |  |
| 2.841E+04 |  |
| 2.526E+04 |  |
| 2.210E+04 |  |
| 1.894E+04 |  |
| 1.578E+04 |  |
| 1.263E+04 |  |
| 9.471E+03 |  |
|  |  |
| 7.892E+03 |  |
| 7.103E+03 |  |
| 6.314E+03 |  |
| 5.525E+03 |  |
| 4.735E+03 |  |
| 3.946E+03 |  |
| 3.157E+03 |  |
| 2367.72 |  |
|  |  |
| 2209.87 |  |
| 1894.18 | 8.45E-03 |
| 1578.48 | 1.01E-02 |
| 1262.78 | 1.27E-02 |
| 947.09 | 1.69E-02 |
| 631.39 | 2.53E-02 |
| 315.70 | 5.07E-02 |

Figure . Table of calculation of theoretical relationship of Re and f in the laminar region

# Reference

Vennard, J. and Street, R., 1995. *Elementary Fluid Mechanics*. Wiley.