# Comparing fluid flow of smooth and rough pipes

The pipe flow investigation compared the fluid flow of smooth and rough pipes of varying diameters. The pressure drop across the pipes was recorded to find both the friction factors and Reynolds numbers. A moody diagram was plotted comparing the friction factor versus the Reynolds number. A graph of the experimental friction factor was compared to the theoretical friction factor for the transition of a pipe from smooth to rough.

It is assumed that the fluid used for the pipe flow was incompressible and pipes were entirely horizontal with constant diameters throughout the tested length. The energy equation is used to compare the steady, uniform flows at the inlet and outlet.

= pressure = density

= kinetic energy flux coefficient = average fluid velocity

= gravity z = vertical height of the pipe

= total head loss = specific work done by the control volume.

The change in pressure that is found for each pipe is equivalent to the loss of head across each respective pipe and related by the equation below.

. (2)

It is also assumed to have a constant volumetric flow rate, constant vertical height, no work involved in the flow of the fluid, and a constant flow velocity. By using the average velocity we can determine whether the fluid is laminar or turbulent. A Reynolds number below 2300 describes a laminar flow and that above 2300 is turbulent.

, (3)

= Reynolds number = pipe diameter = viscosity of the fluid.

Below is the Darcy or Moody friction factor, , which is valid for laminar flows. This equation is independent of the roughness of the pipe.

. (4)

The friction produced by the roughness in the pipes causes head loss. Unlike Eq. 4, the next equation is valid for turbulent flows with Reynolds values above 2300.

. (5)

The Colebrook equation covers transitionally rough regions which are between smooth and rough walled piping. This equation is implicit for .

, (6)

where the relative roughness of the pipe is .

## Methods

The Pipe Flow Lab equipment included: Four horizontal pipes of varying roughness and diameters arranged in a pipe flow apparatus with a self-contained water supply, valve to isolate pipe of interest, inlet flow control valve to control the flow rate, volumetric measuring tank collects water, sight tube, graduated cylinder, stopwatch, calipers, and electronic manometer to measure pressure.

The change in pressure of one rough and three smooth pipes of varying diameters were measured. These values helped compare the friction factors to the Reynolds number of the fluid. Each pipe was individually experimented on by allowing the water to run through that particular pipe until it reached a constant flow rate. The change of pressure was read off the electronic manometer and a stop watch was used to measure the time it took to fill the tank to a particular volume. The pressure was lowered by a given increment for each trial until it reached a given value and repeated for each pipe. The temperature of the water was measured at the end of the experiment.

## Results and Discussion

The data for the large smooth pipe, large rough pipe, medium smooth pipe, and small smooth pipe were compiled into Tables 1, 2, 3, and 4, respectively. Eq. 3 was used to find the Reynolds number and the friction factor was calculated using Eq. 5. These values were then plotted in Fig. 1, which is a Moody diagram comparing the Reynolds number to friction factor of all the pipes. The Reynolds number gives the value of a fluids transition from a laminar flow to turbulence. This value is approximately 2300 according to Fig. 1. Since all the points on the Moody graph are greater than 2300, we can conclude that all the flows in this lab are turbulent.

The decreasing straight laminar line was produced by using Eq. 4 which is independent of roughness. Then above the Reynolds number of 2300 is the theoretical rough turbulent and smooth turbulent lines. The smooth pipes follow the slightly downward slope of the smooth turbulent theoretical line. The small and medium tubes are for the most part above the theoretical line which is expected because there is probably build up in the tube causing a slight roughness which would increase the friction factor. The large smooth pipe's values are below the theoretical line, which is impossible because the tube cannot be smoother than smooth. This error could be a cause of human error or inaccurate lab equipment. The friction factors of the smooth pipes in increasing order were large, medium, and small. This is what would be expected because the larger diameter pipes should allow for easier flow than a smaller diameter pipe.

The large rough tube follows the theoretical rough turbulent trend. Since this tube is rough it should have more friction than the smooth pipes and an increased friction factor. Fig. 1 exhibits this fact because the large rough tube values are well above the smooth tube's values. As the Reynolds number gets very large, it becomes a function of only relative roughness e/D.

Eq. 7 was used to find the theoretical rough, turbulent flow trend and a relative roughness of e/D, of 0. 093 was determined. Table 2 shows the values that were recorded and has lower values for the experimental friction factor than the theoretical values. As with the large smooth pipe, this is not what we would expect and it is caused by lab errors. Both large pipes were located in the same Reynolds number region but with different friction factors. This is understandable since they have the same diameters but the only difference is the roughness inside the pipe causing friction. The fluctuations in friction factor values are due to errors that occurred during the investigation procedure.

An error that could have affected the results of this investigation would be the actual smoothness of the pipes. The smooth pipes could have build up from the years of use that would cause some roughness. The roughness would in turn interfere with the fluid flow. Another form of error was with the stop watch and volume reading to find the flow rate. There is a percentage of human error in these measurements and the electronic manometer was also fluctuating during the experiment. These errors can account for the fact that the experimental friction factors were lower than the theoretical values for the large pipes seen in Table 1 and 2. The equations used were approximations and could also account for a slight source of error.

## Conclusions and Recommendations

The values obtained in this investigation led to the calculation of the friction factors and Reynolds numbers for four different pipes. These values were then plotted in a Moody diagram to compare how the roughness and diameter of each individual pipe affected the flow rate of each. The small, medium, and large smooth pipes followed the smooth turbulent theoretical trend. The large pipe had values below the theoretical values. The experimental values should always have been above the theoretical since a pipe can’t be any smoother than smooth. These results could be caused by the lab errors that were listed above. The friction factors of the smooth pipes in increasing order were large, medium, and small. This is what would be expected because the larger diameter pipes should allow for easier flow than a smaller diameter pipe. The large, rough pipe followed the rough turbulent trend. As the Reynolds number became large the relative roughness became the relationship, e/D. This pipe also had experimental friction factor values below the theoretical values which is impossible and caused by errors in the investigation. The friction factor of the rough pipe was much greater than the smooth pipes, which means that there is more friction in rough pipes.

For future investigations, it would be beneficial to take more data points in order to more accurately represent the findings. This could also help keep the margin of error smaller since one or two inaccurate points could be disregarded with a larger data sample. More precise measurement tools would also be very beneficial since there was much uncertainty with the current apparatus.