Determination of Reynolds Number in Closed PVC Pipe

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ABSTRACT

The fluid flow is categorised using the velocity of the streams which gives laminar and turbulent regimes. Reynolds number plays a vital part in determining the flow type. The Reynolds number has always been an important parameter in fluid flow mechanics which, here, is determined using an experimental set-up through a PVC pipe which includes a step input of potassium permanganate as dye and gives the transition from laminar to turbulence and fully developed turbulent flow. Also, Moody Chart is used to verify the theoretically calculated Darcy friction factor for laminar and turbulent flow using the obtained Reynolds number and the relative roughness of the PVC pipe. The Friction factor, thus obtained, is found inversely proportional to the Reynolds number, linearly and exponentially for specific ranges of Reynold number.

Keywords: Reynolds number; Laminar, Turbulent; Friction factor; Moody Chart; PVC pipe; Dye.

INTRODUCTION

Over the last hundred years, it was demonstrated both by hypothesis and practice, that Reynolds number plays basic function in liquid elements considering diffusive and convective impacts. The Reynolds number determines the structure of the stream, its dynamical conduct and its quality for a given limit conditions unambiguously [1]. Its approach exceeds that of natural applications like Reynolds number has a significant impact in the calculation of the grating element in a couple of the conditions of liquid mechanics, including the Darcy-Weisbach condition. Along with this, It has a significant influence in the testing of wind lift on airplanes, particularly in instances of supersonic flights where the rapid causes a confined expansion in the thickness of air encompassing the airplane [2].
In nature and in research, streams may happen under two altogether different systems: laminar and turbulent. In laminar streams, liquid particles move in layers, sliding over one another, causing a little energy trade to happen between layers. Laminar stream happens in liquids with high consistency, moving at moderate speed opposite to that of turbulent stream [3]. The dimensionless Reynolds number is utilized to group the condition of the stream. The Reynolds Number Showing is an exemplary investigation, in light of imagining stream conduct by gradually and consistently infusing color into a line. This investigation was first performed by Osborne Reynolds in the late nineteenth century [4]. This paper discusses verification of the range of Reynolds numbers for fluid (water) flowing inside the circular smooth pipe by providing a step input of potassium permanganate as a dye into a transparent PVC pipe fitted in a particular apparatus.. The calculation of friction factor along with the relation of Reynolds numbers and friction factor has been done depending upon the different Reynolds numbers with the help of a moody chart.

REYNOLDS NUMBER AND FRICTION FACTOR

Reynolds number is the essential boundary deciding the stream field geography and its development as expected unambiguously if just inertial, pressure and viscous impacts are included [5]. The Reynolds number can be characterized for a few distinct circumstances where a liquid is in relative movement to a surface that incorporates the liquid properties of thickness. Reynolds number is easily defined as the ratio of inertial forces and viscous forces, that depends upon the internal fluids movements due to the presence of different fluid layers [6].
Contingent upon the sort of stream (laminar, transient, and turbulent), the fluid velocity in a pipeline at a specific line cross-area will fluctuate along the line sweep. The fluid atoms at the line divider are very still and in this manner have zero speed. As we approach the middle line of the line, the fluid molecules are progressively free and accordingly have expanding speed. In laminar stream, the variety of speed at a line cross-area is explanatory. In a violent stream, there is

an inexact trapezoidal shape to the speed profile[7-9]. Laminar stream is otherwise called thick stream or on the other hand smooth out stream.

Reynolds number is defined as

$$\text{Reynolds Number (R)} = (\rho VD)/\mu$$

Where: V is average velocity, D is pipe internal diameter, ρ is liquid density, μ is absolute viscosity and R is Reynolds number (dimensionless value). By observing the formula above, Reynolds number depends upon pressure, temperature, velocity of ideal fluid and characteristic length [10]. The absolute energy in a liquid will stay consistent except if changed by outside powers. In this manner, the absolute weight will be consistent except if frictional or dynamic pressure misfortunes are available. Frictional losses are mainly determined by calculating the friction factor. Friction factor is commonly defined as the ratio of the shear stress on the walls of the circular pipe to the dynamic pressure of the fluid in the pipe (fanning friction factor) [11].

$$\text{Shear Stress} = (f\rho v^2)/2$$

Where, f is the fanning friction factor, ρ is the density and v is the velocity of the fluid.

Alternative friction factor comes into account is darcy friction factor and defines as 1/4th times the fanning friction factor. It is a dimensionless factor that depends upon the Reynolds number and the geometry of the pipe. The calculation of the Darcy factor takes place either theoretically and graphically. Theoretical calculation has the basis of laminar and turbulent formulas whereas graphical method uses the moody chart that has the dependency upon the relative roughness of pipe [12-13]. The Moody Diagram is generally used to decide the rubbing factor for liquid stream in pipes. The graph consolidates the impacts of Reynolds number and rela-tive harshness to decide the friction factor. The relationship is profoundly non-straight and seems to have a mind boggling collaboration among thick and limited harshness impacts. Relative roughness is the measure of surface harshness that exists inside the line. It is the ratio of absolute roughness to the diameter of pipe [14].

$$\text{Relative Roughness} = \varepsilon/D$$

Where, ε is the absolute roughness of material and D is the diameter of pipe.

METHOD

A water tank is installed with a transparent PVC pipe of diameter 0.025 m leading out of it. The entry point of the pipe is bellmouth shaped from where a dye container holding potassium permanganate is positioned at the input-side of the pipe. This dye container injects a thin filament of dye into the flow. The flow of water through the pipe is controlled by a valve at its output-side.

Initially, the pump is started to permit the water tank to load up with water after which the stream control valve is slightly opened. Once the water level in the water tank reaches the level of PVC pipe, inlet of the die injector is slightly opened, so that the dye stream moves in a straight line along the entire length of the tube showing the flow is laminar. The smooth and steady flow indicates laminar flow at the lowest flow velocity possible. It seems as if the water is flowing as a series of very thin layers, each slipping over the other, and the dye is injected between two of the layers. At this instance, a graduating cylinder is placed at the exit of the pipe to accumulate water and simultaneously a stopwatch is started to estimate the discharge time. The flow rate is increased per iteration of the experiment and each time volume and the corresponding time is noted down giving the volumetric discharge.

This procedure is repeated by slowly incrementing the flow rate of water through the regulating valve until visualization of transitional flow occurs and then, at higher stream rates, turbulent flow, portrayed by persistent and exceptionally fast blending of the dye. In the turbulent flow, the dye appears separated as the water spins around in an irregular way and is disseminated all through the stream.

The volumetric discharge gives us the velocity of the flow stream which in turn facilitates the Reynolds number. This data confirms the zone of each experiment whether the stream flow is in laminar, transition or turbulent region. Then, the frictional factor is quantified theoretically and verified using Moody Chart that involves using Reynolds number and relative roughness of the PVC pipe.

RESULTS AND DISCUSSION

The experiment performed using the potassium permanganate dye helps to study the behaviour of fluid in a closed PVC pipe. The flow of dye is used to determine whether the flow is laminar or turbulent. Various velocities have been taken for experiments in which dye has been injected. The interpretation of flow is matched with the moody chart after calculating the friction factor.

Figure: 1 Dye in Laminar Flow (marked by relatively darker shade of dye)

When the dye is injected in the PVC pipe, the appearance of flow in laminar has been described in Figure 1. As shown, initially, the dye colour is dark, which will get lightened as soon as it moves ahead in the pipe. The fading of colour shows the mixing of dye with water which helps in determining the laminar or turbulent flow.

Figure: 2 Dye in Turbulent Flow (marked by the lightened shade of the dye)

As the velocity increases, the flow tends to change its characteristics. Figure 2 describes the turbulent flow, at velocity, 0.1549 m/sec. The dye fades relatively faster in this region as compared to the laminar flow. In order to study the same characteristics in a Moody Chart (Figure 3), we need the relative roughness and friction factor to be calculated. The value of absolute roughness for the PVC pipe has been considered as ($1.524*10^{-6}$)m and hence the relative roughness is found to be 0.00006096. As discussed above, friction factor can be calculated by two means, graphically and theoretically. The Darcy friction factor can be calculated for laminar flow by Re/64 whereas, for turbulence, the formula below is used [12].

$$f(D) = (1/(-1.8 * log\ [((roughness/3.7)^{1.11}) + (6.9/NRe)]))^2$$

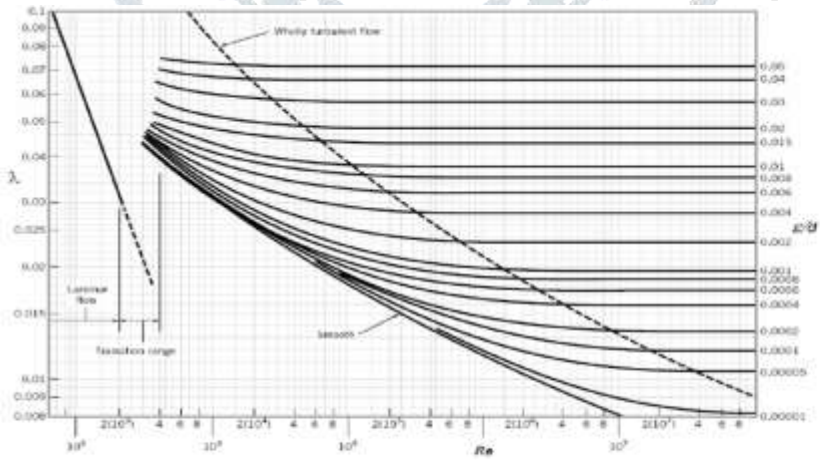

Figure 3: - Moody Chart

Graphically, the friction factor is defined by examining the Reynolds number and marking the point on the line of relative roughness. The intersection of both helps in determining the friction factor of a particular Reynolds number. The Darcy friction factor has been calculated for all the velocities and is shown in the table below. The region of flow is determined using the Moody Chart. The data given in Table 1 shows that at 1119.153 and 2015.590 Reynolds number, the flow is laminar, whereas, at 2352.449 and 3763.919, the flow regime starts transitioning. The turbulent region has been given for more than 4312.360 Reynolds numbers as per the given table. It has been observed that the region calculated from the Moody Chart is the same as that determined by the dye experiment.

Table 1:- Experimental and Moody Chart Observations					
Discharge m^3/sec	**Velocity (m/sec)**	**Calculation of Reynolds Number**	**Frictional Factor Calculated**	**Friction factor from chart (Darcy)**	**Region of flow**
1.97E-05	0.0402	1119.153675	0.05718606965	0.0578	Laminar
3.55E-05	0.0724	2015.5902	0.03175248619	0.0316	Laminar
4.15E-05	0.0845	2352.449889	-	0.049	Transition
6.64E-05	0.1352	3763.9198	-	0.0422	Transition
7.60E-05	0.1549	4312.3608	0.03952168341	0.04	Turbulent
9.64E-05	0.1963	5464.922	0.03677416418	0.035	Turbulent
0.000144	0.2943	8193.2071	0.03270312953	0.033	Turbulent
0.000747	1.5263	42416.481	0.02164917067	0.023	Turbulent
0.000944	1.9236	53552.339	0.02056851666	0.021	Turbulent
0.001057	2.1536	59955.457	0.02007680199	0.0198	Turbulent

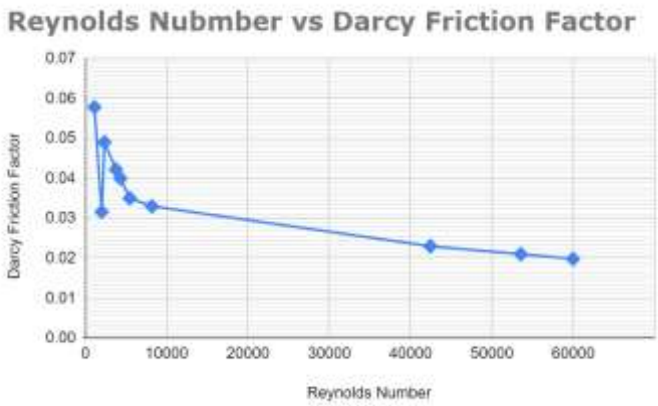

Figure 4: - Plot of Reynolds Number vs Friction Factor

The plot (Figure 4) has been drawn which relates the Reynolds number with frictional factor. As shown in the graph, the friction factor decreases linearly upto Reynolds number 2000 and then for more than 2000, friction factor starts decreasing exponentially from 0.05 approximate for PVC pipes (smooth pipes). Hereby, it can be said that Reynolds number is inversely proportional to friction factor for two different ranges, i.e. for Re<2000, it varies linearly and for more than 2000, the relation is exponential. This variation in relationship from linear to exponential is accounted for by the transition regime which marks its beginning approximately in the aforementioned region. Overall, it can be said that friction factor decreases as Reynolds number increases. With this, it can be concluded that friction factor depends upon the Reynolds number, and Reynolds number can be calculated from the dye experiment or from the Moody Chart.

CONCLUSION

The above paper discusses the determination of Reynolds number using the dye experiment and moody chart. In this experiment, laminar flow is obtained at a lower velocity of 0.0402 m/s (Re <2000) and as the velocity is increased, transition (2000<Re<4000) and turbulent flow (Re>4000) is reached. Darcy Friction factor calculated theoretically for laminar and turbulent flow is verified using Moody Chart and obtained approximately equal in the respected regions. Calculated Friction factor gives a linear decrease for Re<2000 and inversely proportional exponential relation to Reynolds number for Re>2000. This variation results because of the transition regime which begins when Re equals approximately 2000.

CONFLICT OF INTEREST

There is no conflict of interest

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