Modification of Setup for Major Losses in Pipes to Determine the Exact Value of Friction Factor

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Abstract— in this research paper we determine the exact value of friction factor through pipes for turbulent flow. Friction factor conceptually defined as the ratio of two forces acting, respectively, perpendicular & parallel to an interface between two bodies under relative motion or impending relative motion, this dimensionless quantity turns out to be convenient for depicting the relative ease with which the materials slide over each other under particular circumstances. This includes applications of various equations such as Darcy-Weisbach equation, Swamee-Jain equation, Colebrook equation, Reynolds equation. This formulae provide a base for statistical evaluation of exact friction factor for smooth as well as rough pipes. The Darcy friction factor for turbulent flow must be solved by using Colebrook equation by using iteration method. By using iteration method new equations are evolved. These equations can be further developed by using Blasius, Swamee-Jain & Haaland equations. All the three equations are applicable but the Blasius equation cannot be used for rough pipes whereas the Swami-Jain & Haaland equations are applicable for rough pipes and give good results in order to determine the friction factor for rough pipes.

Key words: Darcy Friction Factor, Major Losses in Pipes

I. INTRODUCTION

Our intension in this paper is to put on focus about the frictional losses caused in different pipes materials such as aluminium, stainless steel and galvanised iron. These frictional losses are caused due to resistance to flow by inherent surface roughness due to pipe fabrication, scale built up, losses due to bends and corrosion.

Friction loss has several causes, including:

- Frictional losses depend on the conditions of flow and the physical properties of the system.
- Movement of fluid molecules against each other.
- Movement of fluid molecules against the inside surface of a pipe or the like, particularly if the inside surface is rough, textured, or otherwise not smooth.
- Bends, kinks, and other sharp turns in hose or piping.

The tubing must be selected so that the production operation can be carried out effectively, it must be designed considering the tensile forces, internal and external pressure and corrosive actions.

An important and integral part of pressure drop in pipes involves the determination of friction factor. The friction factor thus helps us to understand the pressure or energy losses caused due to friction in pipes. This friction factor can be calculated by using Darcy-Weisbach equation. The Darcy-Weisbach equation provides the Darcy friction factor.

The exact solution of Darcy friction factor in turbulent flow is determined by using Moody diagram or by using Colebrook equation. In this paper we calculate the values of friction factor for aluminium, stainless steel and galvanised iron of the existing setup by using root mean square method for precise calculations. The setup is then modified in order to calculate the exact value friction factor, as the friction factor obtained on the existing setup is not near to the standard value. Then the values of friction factor obtained for different pipe materials on the modified setup are then compared with the values of friction factor on the existing setup and the values of friction factor nearer to the standard values are selected as the optimum friction factors for the pipes.

II. METHODS TO CALCULATE MAJOR LOSSES

In this experimental setup we determine the values of friction factor for different pipe materials [5]. For finding the friction factor flow will develop after 10 times of diameter of pipe due to this flow is fully developed [7]. These values can be determined by using the following equations-

A. *Reynolds Equation*

In fluid mechanics the Reynolds number is a dimensionless quantity which helps us to predict the flow patterns in different flow situations. This concept was introduced by George Gabriel Strokes in1851 but the Reynolds number is named after Osborne Reynolds (1842-1912), who popularised its use in 1883.

The Reynolds number is defined as the ratio of inertial forces to viscous forces and consequently quantifies the relative importance of these two types of forces for given flow conditions [1].

The Reynolds equation is given by,

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

Where,

Re = Reynolds number.
ρ = density of water, kg/m^3.
V = velocity of water, m/s.
D = diameter of pipe, m.
μ = Dynamic viscosity, n-s/m^2.

The Reynolds number tells if the flow is laminar or turbulent. If the Reynolds number is smaller than the critical Reynolds number Re_{cr}, the flow is laminar. After the laminar flow regime follows the transition region. There are flow switches between laminar and turbulent randomly. When the Reynolds number reaches a certain value flow turns from transitional to turbulent. For pipe flow the critical Reynolds number is often assumed to be 2300. The transition region ends approximately at the Reynolds number 4000 [2].

B. *Darcy-Weisbach Equation*

In fluid dynamics, the Darcy-Weisbach equation is a phenomenological equation, which relates the head loss or pressure loss, due to friction along the length of pipe to the average velocity of fluid flow for an incompressible fluid. The equation is known after Henry Darcy and Julius Weisbach [1].

The pressure loss in the flow is calculated using the known Darcy Weisbach equation. The equation is given by,

$$h_f = \frac{flV^2}{2gd} \qquad (2)$$

Where,

h_f = head loss due to friction in pipe.

f = Darcy friction factor.

l = length of pipe.

V = velocity of flow.

g = acceleration due to gravity.

d = internal diameter of pipe.

C. *Colebrook Equation*

The phenomenological Colebrook equation expresses the Darcy friction factor as a function of Reynolds number and pipe relative roughness, fitting the data of experimental studies of turbulent flow in smooth and rough pipes. The Colebrook equation can be used to determine the Darcy friction factor [1].

The Colebrook equation for fluid flow having Reynolds number greater than 4000 is given by,

$$\frac{1}{\sqrt{f}} = -2log_{10}\left(\frac{e}{3.7d} + \frac{2.51}{Re\sqrt{f}}\right) \qquad (3)$$

D. *Swamee- Jain equation*

Swamee and Jain have developed the following equation to the Darcy friction factor [3].

$$f = 0.25\left[log\left(\frac{e/D}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^{-2} \qquad (4)$$

Where, $\frac{e}{d}$ = roughness value

E. *Haaland Equation*

In the Haaland equation there is no need to iterate the Darcy friction factor. The accuracy of the Darcy friction factor solved from this equation is claimed to be within about ±2 %, if the Reynolds number is greater than 3000 [2].

The equation is,

$$\frac{1}{f} = -1.8log\left[\left(\frac{e/D}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right] \qquad (5)$$

F. *Moody's Chart*

In engineering, the Moody chart or Moody diagram is a graph in non-dimensional form that relates the Darcy - Weisbach friction factor *f*, Reynolds number *Re*, and relative roughness for fully developed flow in a circular pipe [4].

III. DESIGN

In Fig. 1 we are using three pipes having 1 meter length for calculation. This three pipes are aluminium, galvanised iron, stainless steel.

In Existing setup there are some drawbacks that are given below [8],

– Sudden L-bows at the start and the end of pipe.\
– Connector that is connected to manometer near to start and end of pipe.
– Due to this fully developed flow is not occurs.
– From this exact value of friction factor is not occur.

Due to this drawbacks friction factor we getting is having some error.

Fig. 1: Existing Setup

Fig. 2: Modified Setup

In this Modified setup we eliminate all drawback of previous setup. And we exceed the length of pipes to 4 meter and get optimum value of friction factor.

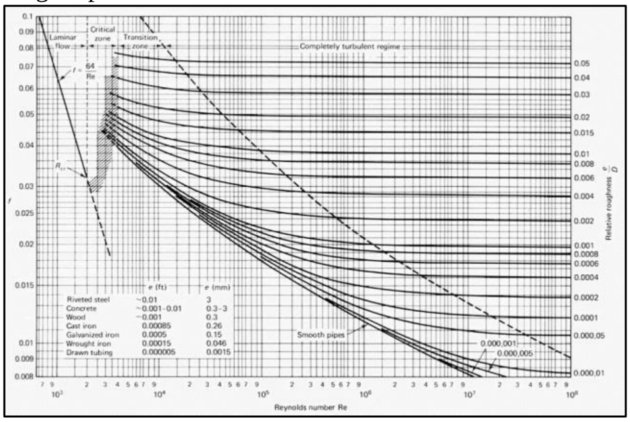

Fig. 3: Moody's Chart[9]

IV. RESULT AND DISCUSSION

In the previous model there were complications as listed above due to which the results obtained had large difference in the readings. This model is further developed and the results achieved are closer to each other as shown in above table. The complications in the previous model include improper position of connector, i.e. the manometer connector is not located at a distance of ten times of diameter of the pipe, and the discharge is calculated manually which increases the errors in the final calculations. These complications are eliminated in the modified setup by changing the position of the manometer connector and using rota meter for measuring the discharge due to these modifications accuracy of the setup is increased and precise results are obtained as shown in above table. As the Colebrook equation and Moody's equation both are based on Reynolds number there is not much difference seen in the results but as Darcy equation is based on the head difference so while comparing Darcy, Colebrook and Moody's result Colebrook and moody results will match at a great extent.

While studying on the results it is seen that in the existing model the readings of the Darcy Colebrook and moody is not much matching so the setup is having error but after removing error in modified setup as discussed above the results which are obtained on new modified setup are much closer to each other so the new modified setup is exact and can give exact friction value for the pipe materials . the difference between the results is about 22% to 25% which can be bearable.

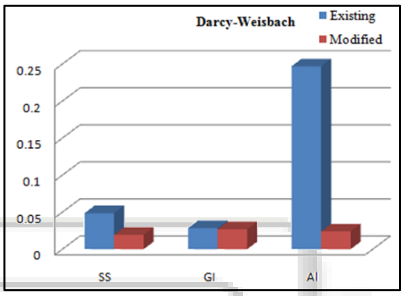

Fig. 4: Comparison using Darcy-Weisbach

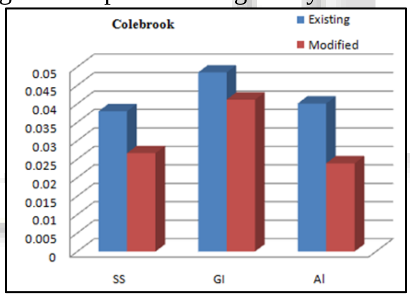

Fig. 5: Comparison using Colebrook

Fig. 6: Comparison using Moody's

Method	Darcy		Colebrook		Moody	
Material	Existing	Modified	Existing	Modified	Existing	Modified
SS	0.0486	0.0193	0.03799	0.02665	0.026869	0.026659
GI	0.0284	0.0269	0.04852	0.04114	0.04267	0.040565
Al	0.2469	0.0239	0.04009	0.02390	0.026188	0.02390

Table 1: Coefficient of friction values by different methods

V. Conclusion

The inaccuracy of result observed in existing setup is eliminated by implementing the following changes:

- Increasing the length of pipe to 4m give more accurate result due to better boundary layer generation.
- Preseremegerment after 10 times of diameter due to fully developed flow.
- Adding rota meter eliminates the human error.

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