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Friction Factor Diagram on Turbulent Flow by Different Reynolds Number in Small Pipes

Asaduzzaman[1], Dr. Md. Lutfor Rahman[2]

Department of Mathematics, Faculty of Science & Engineering, North Bengal International University, Rajshahi, Bangladesh

Department of Mathematics, University of Rajshahi, Rajshahi, Bangladesh

Abstract: ***This article presents proposed model and application of proposed model investigation of different Reynolds number of turbulent flow in periodically small pipes. Here we discussed a universal resistance equation relating friction factor (F), the Reynolds number (Re) and roughness height (ε) for the entire range of turbulent flow in small pipes covering regimes in smooth and rough. We have also discussed about the variation in friction factor F, used in the Darcy Formula with the Reynolds number in both laminar and turbulent flow. As discussed Colebrook-White formula deviates from Nikuradse experimental results in transition range of their difference in roughness factor. Hazen-Williams equation and review of equations on friction factor to be used. Such an equation is found to be sufficient to predict the friction factor for all ranges of Re and different values of (ε).***

Keywords: Friction factor, Turbulent flow, Reynolds number, Darcy formula. Colebrook equation, Hazen-Williams equation

1. Introduction

To study the differentiation in friction factor, F, used in the Darcy Formula with the Reynolds number in both laminar and turbulent flow. The friction factor will be temperance as a function of Reynolds number and the roughness will be calculated using the Colebrook equation. The loss of head resulting from the flow of a fluid through a pipeline is demonstrated by the Darcy Formula.

$$H_f = F\frac{LV^2}{D2g} \quad (1)$$

In this equation (1), where H_f the loss of head (units of length) is and the average velocity is V. The friction factor, F, varies with Reynolds number and a roughness factor, L is the characteristics length of the pipe, D is the diameter of the pipe, g is the acceleration due to the gravity. The friction factor (F) is a measure of the shear stress (or shear force per unit area) that the turbulent flow exerts on the wall of a pipe. The Hagen-poiseuille equation for laminar flow declares that the head loss is the unrestricted of surface roughness.

$$H_f = \frac{32\mu LV}{\rho g D^2} \quad (2)$$

Thus in laminar flow the head loss varies as average velocity v and inversely proportional to the pipe diameter D^2.Now comparing equation (1) and (2) we can get,

$$F\frac{LV^2}{D2g} = \frac{32\mu LV}{\rho g D^2} \Rightarrow FV=\frac{64\mu}{\rho D} \quad \Rightarrow F=\frac{64\mu}{\rho VD} \quad (3)$$

We know that, $R=\frac{\rho\bar{V}\bar{D}}{\mu}$

$$\frac{1}{R} = \frac{\mu}{\rho VD} \quad (4)$$

From (3) and (4) we get, $F=\frac{64}{R}$ (5)

From (3), declaring that the friction factor is amount to viscosity and conversely amount to the velocity ,pipe diameter and fluid density under laminar flow conditions .The friction factor is unrestricted of pipe roughness in laminar flow because the disorders motive by surface roughness are hurriedly humored by viscosity. Equation (2) can be solved for the pressure drop as a function of total discharge to receive.

$$\nabla P = \frac{128\mu LQ}{\pi D^4} \quad (6)$$

When the flow is turbulent the connection becomes more complex and is best shown by means of a graph since the friction factor is a function of both Reynolds number and roughness. Where as in turbulent flow(R>>4000) the friction factor, depends upon the Reynolds number(R) and on the relative roughness of the pipe,$\frac{\varepsilon}{D}$ Where,ε is the average roughness height of the pipe. The usual treatment of turbulent pipe flow in appearance of surface roughness is wall deposit. Nikuradse showed the dependence on roughness by using pipes not naturally roughened by binding a coating of uniform sand-grains to the pipe walls. The degree of roughness was specified as the ratio of the gravel corn diameter to the pipe diameter ($\frac{\varepsilon}{D}$). When ε is very small likened to the pipe diameter D .i.e.$\frac{\varepsilon}{D} \rightarrow 0$, F depends only on Reynolds number R. The connection between the friction factor and Reynolds number can be firm minded for every comparative roughness. When $\frac{\varepsilon}{D}$ is of a significant value, at low Reynolds number R, the flow can be considered as in smooth regime (there is no effect of roughness).The connection between the friction factor and Reynolds number can be resolute for every comparative roughness. As R increase, the flow becomes transitionally rough, called as transition regime. From these connections, it is apparent that for rough pipes the roughness is more important than the Reynolds number in resolutions the magnitude of the friction factor. At high Reynolds number (complete turbulence, rough pipes).The friction factor depends wholly on roughness and the friction factor can be received from the rough pipe law.

$$\frac{1}{\sqrt{F}} = 2\log\left(\frac{3.7D}{\varepsilon}\right) \quad (7)$$

In a smooth pipe flow, the viscous sub layer wholly skunks the effect of ε on the flow. In which the friction factor arises above the smooth value and is a function of both ε and the flow ultimately arrives a wholly rough regime in which F is unrestricted on R. In this case, the friction factor F is a function of R and is unrestricted of the effect of ε on the flow. Hence the smooth pipe law is.

$$\frac{1}{\sqrt{F}} = 2\log\left(\frac{Re\sqrt{F}}{2.51}\right) \quad (8)$$

The smooth and the rough pipes laws were developed by Von-Kerman in 1930. For transition Regime in which the friction factor varies with both Reynolds number R and $\frac{\varepsilon}{D}$, many pipe flow are in the regime sketch rated "transition zone" that is between the smooth and rough pipe laws. In the transition zone head loss is a function of both Reynolds number and roughness. Colebrook developed a technical transition function for commercial pipes. The moody diagram is plinth on the Colebrook equation in the turbulent regime. Moody (1944) [38] presented a friction diagram for commercial pipe friction factors plinth on the Colebrook White equation, Which has been pervasively used for functional petition, Because of Moody's work and the ascertained practicality of Colebrook-white equation over a wide range of Reynolds numbers and relative roughness value $\frac{\varepsilon}{D}$, the equation unanimously adopted is due to Colebrook and white (1937)[9] proposed the following equation.

$$\frac{1}{\sqrt{F}} = -2\log\left(\frac{\frac{\varepsilon}{D}}{3.7} + \frac{2.51}{Re\sqrt{F}}\right) \quad (9)$$

Equation (9) veils not only the transition region but also the wholly developed smooth and rough pipes. By putting $\varepsilon \to 0$, Equation (9) reduces to equation (7) for smooth pipes and as R$\to \infty$; equation (9) becomes equation (8) for rough pipes. Equation (9) has become the act of receiving unit of measurement for calculating the friction factors. It suffers; however, from being an implicit equation in F and thus requires an iterative solution. Their calculation results were however, thoroughly different from those received in the laboratory when using the Colebrook-white equations. The friction factor determined from laboratory data decrease with an increase in the Reynolds number even after a perfectly sure critical value, where as the friction factor of the Colebrook-white equation tends to be constant with an increase in the Reynolds number. The Colebrook equation can be used to resolute the absolute roughness,, experimentally measuring the friction factor and Reynolds number.

$$\varepsilon = 3.7D\left(10^{\frac{-1}{2\sqrt{F}}} - \frac{2.51}{Re\sqrt{F}}\right) \quad (10)$$

Since the mid-1970s, many alternative distinct equations have been developed to abandon the iterative procedure instinctive to the Colebrook-white equation. Alternatively the distinct equation for the friction factor derived by swam me and gain can be solved for the absolute roughness.

$$F = \frac{0.25}{\left[\log\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{Re^{0.9}}\right)\right]^2} \quad (11)$$

When solving for the roughness it is important to note that the quantity in equation (11) that is squared is negative.

$$\varepsilon = 3.7D\left(10^{\frac{-1}{2\sqrt{F}}} - \frac{5.74}{Re}\right) \quad (12)$$

Equation (10) and (12) are not equivalent and will yield slightly different results with the error a function of the Reynolds number.

2. Proposed Model

The established laws of velocity distribution for turbulent flows are given by,

$$\frac{u}{u_*} = A\ln\frac{\frac{yu_*}{\gamma}}{a} \text{ for smooth pipes} \quad (13)$$

$$\frac{u}{u_*} = A\ln\frac{\frac{y}{\varepsilon}}{b} \text{ for rough pipes} \quad (14)$$

Where, A, a, and b are constants, u is the velocity at a distance y, temperance from the pipe wall, u is the friction velocity, ε is the roughness height and n is the kinematics viscosity of the fluid.

As seen from the equation (13) and (14), the characteristic length l for non-dimensional sing the intensity y is $\frac{\gamma}{u_*}$ for smooth turbulent flows and ε for rough turbulent flows. So it is proposed that l is infarct a lineal unification of both ($\frac{\gamma}{u_*}$andε) with a rectification factor, reporting the all ranges i.e. smooth, transition, and rough regimes of turbulent flows, thus

$$l = \left(a\frac{\gamma}{u_*} + b\varepsilon\right)\varphi(R_*) \quad (15)$$

Where,R_* is the friction Reynolds number and defined equal to$\varepsilon\frac{u_*}{\gamma}$ .At$R_* \to 0$, pipe is said to be in smooth condition and $R_* \to \infty$ pipe is said it be in rough condition.

For large values of$\frac{\gamma}{u_*}$, the term $\frac{\gamma}{u_*}$ dominates making the second term bε negligible in resemblance with it. So also for small values of$\frac{\gamma}{u_*}$, the second term becomes important allowing the neglect of the first term. Thus the velocity laws reporting all the regions can be compressed as,

$$\frac{u}{u_*} = A\ln\frac{y}{\left(a\frac{\gamma}{u_*} + b\varepsilon\right)\varphi(R_*)} \to A\ln\frac{\frac{y}{\varepsilon}}{\left(\frac{a}{R_*} + b\right)\varphi(R_*)} \quad (16)$$

Now, if a condition that $\varphi(R_*)$= 1 for both when $R_* \to 0$ and $R_* \to \infty$ is imposed, equation (16) reduces to equation (13) and equation (14) respectively. From the relation $\lambda = 8(\frac{u_*}{u})^2$ Equation (16) can be exchanged into the equation for the friction factor reporting the whole ranges of turbulent flows. Thus the hindrance equation for pipes reporting the smooth, transition and rough regimes can be exposed as

$$\frac{1}{\sqrt{\lambda}} = 2\log\left(\frac{\frac{R}{\varepsilon}}{B_*}\right) \quad (17)$$

$$\text{Where, } B_* = \left(\frac{a + bR_*}{R_*}\right)\varphi(R_*) \quad (18)$$

By dissolved Nikuradse's data on pressure drop measurements in gravel roughened pipes, the following values of a= (0.333) and b= (0.101) has been found and $\varphi(R_*)$ is given by

$$\varphi(R_*) = 1 - 0.55e^{-0.33\left[\ln\left(\frac{R}{6.5}\right)\right]^2} \quad (19)$$

The legality of the manifestation for B_*along with $\varphi(R_*)$ is shown in Figure (1) by using the Nikuradse's experimental data

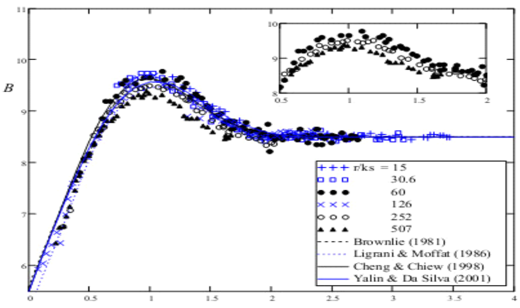


Figure 1: Validation of the proposed

The friction diagram plinth on Nikuradse's experimental data on the gravel roughened pipe is shown in

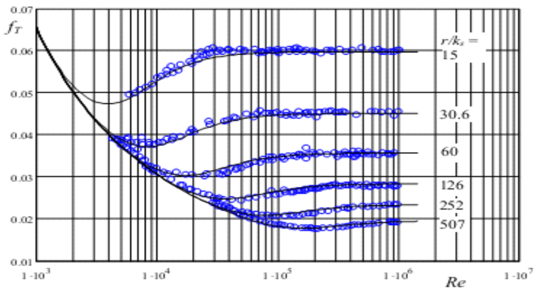


Figure 2: Friction factor diagram

The hindrance equation, as given by equation (17) pleasurably fits the entire data of Nikuradse's on sand roughened pipes for varying relative roughness heights. In addition to Nikuradse's experimental data, resistance equation is also conspired for the most current experimental pipe friction data on smooth pipes (McKeon.et al, 2004).Thus a universal resistance equation is developed in the form of equation (17).

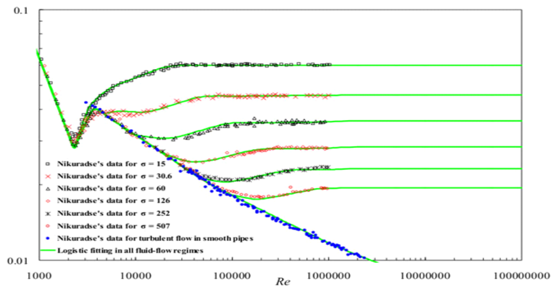


Figure 3: Friction Factor diagram

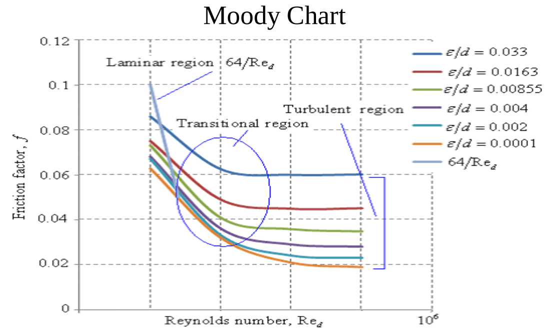


Figure 4: Effect of wall roughness on turbulent pipe flow

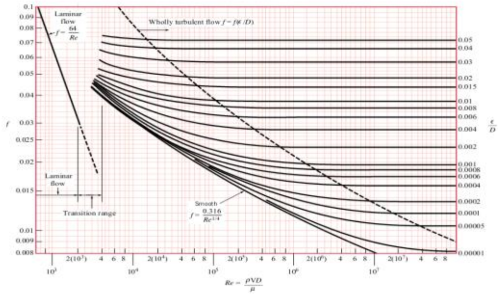


Figure 5: Friction Factor depends on relative roughness and Reynolds number

3. Review of Equations on Friction Factor

During the past year since Moody's chart the most promising equations on friction factor have appeared as follows:

1. Moody (1947): He proposed the equation as:

$$\lambda = 0.0055\left(1+ \left(2\times 10^4.\frac{\varepsilon}{D} + \frac{10^6}{Re}\right)^{1/3}\right)$$

2. Wood (1966): It is valid for Re>10000 and $10^{-5} < \frac{\varepsilon}{D} < 0.04$.

$$\lambda = .094\left(\frac{\varepsilon}{D}\right)^{0.225} + 0.53\left(\frac{\varepsilon}{D}\right) + 88\left(\frac{\varepsilon}{D}\right)^{.44}.R^{-\varphi}.$$

Where $\varphi = 1.62\left(\frac{\varepsilon}{D}\right)^{0.134}$

3. Eck (1973): He proposed the equation as:

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{\varepsilon}{3.715D} + \frac{15}{Re}\right)$$

4. Churchill (1973): He proposed the equation as:

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\left(\frac{\varepsilon}{3.71D}\right) + \left(\frac{7}{Re}\right)^{0.9}\right)$$

5. Jain and Swamis (1976): They proposed the equation covering the range of Re from 50000 to 10^7 and the values of $\frac{\varepsilon}{D}$ between 0.00004 and 0.05 as:

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{Re^{0.9}}\right)$$

6. Jain (1976): He proposed the equation as:

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\left(\frac{\varepsilon}{3.715D}\right) + \left(\frac{6.943}{Re}\right)^{0.9}\right)$$

7. Churchill (1977): The author claimed that his equation holds for all Re and $\frac{\varepsilon}{D}$ has the following:

$$\lambda = 8\left[\left(\frac{8}{Re}\right)^{12} + \frac{1}{(A+B)^{1.5}}\right]^{1/12}$$

Where, $A = \left[-2.457 \ln\left[\left(\frac{7}{Re}\right)^{0.9} + 0.27\frac{\varepsilon}{D}\right]\right]^{16}$

$B = \left(\frac{37530}{Re}\right)^{16}$

8. Chen (1979): He also proposed equation for friction factor covering all the ranges of Re and $\frac{\varepsilon}{D}$.

$$\frac{1}{\sqrt{\lambda}} = -2\log\left[\frac{\varepsilon}{3.7065D} - \frac{5.0452}{Re}\log\left(\frac{1}{2.8257}\left(\frac{\varepsilon}{D}\right)^{1.1098} + \frac{5.8506}{Re}\right)\right]$$

9. Round (1980): He also proposed the equation in the following form:

$\frac{1}{\sqrt{\lambda}} = 1.8 \log [\frac{Re}{0.135 Re(\frac{\varepsilon}{D})+6.5}]$

10. Barr (1981): He proposed the equation as:

$\frac{1}{\sqrt{\lambda}} = -2 \log [\frac{\varepsilon}{3.7D}+\frac{5.158 \log(\frac{Re}{7})}{Re(1+\frac{Re^{.52}}{29}(\frac{\varepsilon}{D}))^{0.7}}]$

11. Zigzag and Sylvester (1982): They proposed the following equation as:

$\frac{1}{\sqrt{\lambda}} = -2 \log [\frac{\varepsilon}{3.7D} - \frac{5.02}{Re} \log (\frac{\varepsilon}{3.7D} - \frac{5.02}{Re}\log (\frac{\varepsilon}{3.7D}+\frac{13}{Re}))]$

Or $\frac{1}{\sqrt{\lambda}} = -2 \log [\frac{\varepsilon}{3.7D} - \frac{5.02}{Re} \log (\frac{\varepsilon}{3.7D}+\frac{13}{Re})]$

12. Haalland (1983): He proposed a variation in the effect of the relative roughness by the following expression:

$\frac{1}{\sqrt{\lambda}} = - 1.8 \log [(\frac{\varepsilon}{3.7D})^{1.11} + \frac{6.9}{Re}]$

13. Serghide's (1984): He proposed the equation in the following expression:

$\lambda = [\psi_1 - \frac{(\psi_2-\psi_1)^2}{\psi_3-2\psi_2+\psi_1}]^{-2}$

Or $\lambda = [4.781 - \frac{(\psi - 4.781)^2}{\psi_2 - 2\psi_1 + 4.781}]^{-2}$

14. Manadilli (1997): He proposed the following expressions valid for Re ranging from 5235 to 108 and for any value of $\frac{\varepsilon}{D}$.

$\frac{1}{\sqrt{\lambda}} = -2 \log [\frac{\varepsilon}{3.7D}+ \frac{95}{Re^{0.933}} - \frac{96.82}{Re}]$

15. Monzon, Romeo, Royo (2002): They proposed the equation in the following expression:

$\frac{1}{\sqrt{\lambda}} = -2\log[\frac{\varepsilon}{3.7065D} - \frac{5.0272}{Re}\log (\frac{\varepsilon}{3.827D} - \frac{4.657}{Re}\log((\frac{\varepsilon}{7.798D})^{0..9924}+(\frac{5.3326}{208.815+Re})^{0.9345}))]$

16. Goudar, Sonnad (2006): They proposed the equation in the following expression:

$\frac{1}{\sqrt{\lambda}} = 0.8686 \ln [\frac{.4587 Re}{(S-0.31)^{\frac{S}{S+1}}}]$

Where, S=0.124Re$\frac{\varepsilon}{D}$+ln (0.4587Re)

17. Vatankhan, Kouchakzadeh (2008): They proposed the equation in the following expression:

$\frac{1}{\sqrt{\lambda}} = 0.8686 \ln[\frac{0.4587 Re}{(S-0.31)^{\frac{S}{S+0.9633}}}]$

Where, S=0.124Re$\frac{\varepsilon}{D}$+ ln (0.4587Re)

18. Buzzeli (2008): He proposed the equation as:

$\frac{1}{\sqrt{\lambda}} = \alpha - [\frac{\alpha+2\log(\frac{\beta}{Re})}{1+\frac{2.18}{\beta}}]$

Where, $\alpha = [\frac{(0.744 \ln(Re))-1.41}{1+1.32\sqrt{\frac{\varepsilon}{D}}}]$

$\beta = \frac{\varepsilon}{3.7D}Re + 2.51\alpha$

19. Avci, Kargoz (2009): They proposed the equation as:

$\lambda = [\frac{6.4}{\ln(Re) - \ln(1+0.01 Re\frac{\varepsilon}{D}(1+10\sqrt{\frac{\varepsilon}{D}})^{2.4}}]$

20. Evangleids, Papaevangelou, Tzimopoulos (2010): They proposed the equation in the following expression as:

$\lambda = [\frac{0.2479-0.0000947(7-\log Re)^4}{(\log(\frac{\varepsilon}{3.615D}+\frac{7.366}{Re}))^2}]$

4. Discussions

The correlation/friction factor relations shown in the literature have been developed by petitioning the successive substitution method to the Colebrook-white formula. The Colebrook curve corresponding to $\varepsilon_{s=7.5}\mu m$, the monotonic Colebrook curve makes a needy prediction for the transitionally rough treatment of this surface. At the point of going out from the smooth regime, At Red=1. 5×106, the Colebrook relation over evaluates the friction factor by approximately 10%. In the transitional regime, in lieu of following the Colebrook correlation, The data display an term national roughness, similar to the treatment of the gravel corn roughness flavored by Nikuradse(1933),in spite of the fact that neutered surfaces are often classified as, in Colebrook's terms, ''natural'' or 'commercial'' roughness. More purity can be achieved by using a large number of internal substitutions to the Colebrook-white formula .Thus a new distinct formula for calculating the friction factor. For a given relative roughness, the Nikuradse fully rough correlation. The Colebrook curves for the equivalent gravel corn roughness. In the transitional regime, the injustices between the Colebrook curves and those calculated with the method used here are significant. Whereas neutered surface roughness displays a term national friction factor connection, the Colebrook curves monotonically depart from the smooth curve and draw near the wholly rough value from above. As discussed, Colebrook-white formula deviates from Nikuradse experimental results in transition range, because of their difference in roughness factor Colebrook-white formula is for irregular surface roughness in pipes resulting from the growing procedure. For turbulent flow, the friction factor correlations are more complex as they are implicit in F. For turbulent flow in smooth pipes, the unanimous law of friction factor relates F and Re. For turbulent flow in rough pipes which is of greater practical interest, the Colebrook-white equation is by far the most widely used correlation to calculate F. It relates the friction factor to the Reynolds number and pipe roughness$\frac{\varepsilon}{D}$.We present a book of fiction ,mathematically equivalent agency of the Colebrook-white equation to calculate friction factor for turbulent flow in rough pipes. This new form is simple no iterative calculations are precise friction factor discrimination. A limiting case of this equation provided friction factor computes with a maximum absolute error of 0.029 and a maximum percentage error of 1% over a 20×500 grid of $\frac{\varepsilon}{D}$ and Re values $(10^{-6} \le \frac{\varepsilon}{D} \le 5 \times 10^{-2}; 4 \times 10^3 \le R \le 10^8$.This was more precise than the best recently available non-iterative approximation of the Colebrook-white equation(maximum absolute error of 0.058;maximum percentage error of 1.42%).present model is equally valid for commercial pipes and sand roughened pipes. By making correction factor $\varphi(Re*)$ =1, resemblance are made for prediction of λ over a wide range of $\frac{\varepsilon}{D}$ by equation (12) and Colebrook-White formula. As shown in Figure (6), present model predicts approximately the same λ as predicted by Colebrook-White formula. Figure (7) gives the percentage error in prediction of the friction factor by the present model. As shown, the error range from -0.12292 to 0.04884%, making the present model acceptable for commercial pipes.

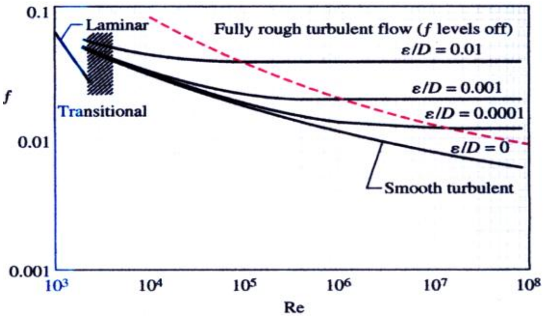


Figure 6: Prediction for commercial pipe

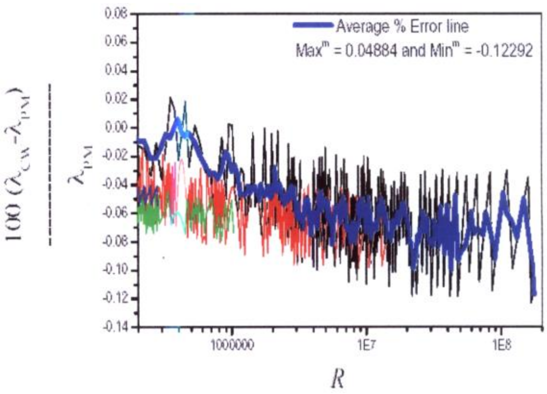


Figure 7: Percentage of error in the estimation of λ with Colebrook-white formula.

Example: (use of moody Diagram to find friction factor): A commercial steel pipe, 1.5 m in diameter, carries a 3.5 m^3/s of water at 20^0 c. Determine the friction factor and the flow regime. (I.e. laminar-critical, turbulent-transitional zone, turbulent-smooth pipe or turbulent rough pipe).Sol: To determine the friction factor, relative roughness and the Reynolds number should be calculated.

For commercial steel pipe, roughness height (ε) = 0.045 mm

Relative roughness ($\frac{\varepsilon}{D}$) =0.045 mm/1500 mm=0.00003

V=Q/A=(3.5 m^3/s)/[$\frac{\pi}{4}$ (1.5 m)^2]=1.98 m/s

$N_R=D_v/v$=[(1.5 m)(1.98 m/s)] / (1.00$\times 10^{-0.6}$ m^2/s) =2.97$\times 10^6$

From moody Diagram, f=0.011

The flow is turbulent-transitional zone.

As discussed, proposed model predicts reasonably well in the entire turbulent ranges of pipe flow and equally valid in case of commercial pipes as well as sand roughened pipes, this can be used as an alternative of Hazen-Williams formula in designing the pipe line.

5. Application of the Proposed Model

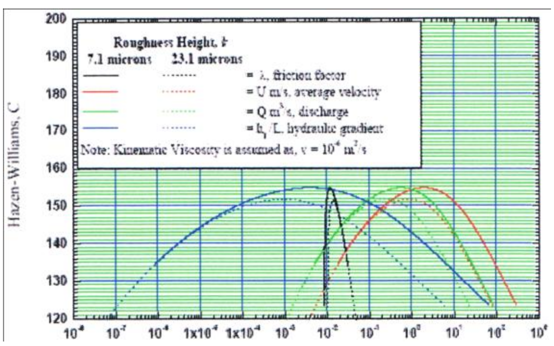
Discrimination of head losses due to friction in pipes important task in optimization studies and when in a state of rest dissolution of pipelines and water donation procedure. Energy loss resulting from friction in pipeline is commonly period the friction head loss. This is the loss of head motive by pipe wall friction and the viscous dissipation in flowing water. It is also called major loss. It is animate in new pipeline invent to have a good compute of powers of retention as the large part of the economics will be dependent on this. Solving for the flow in personal pipes of a looped, water bestowal procedure can be a very intricate procedure as each existing procedure or proposed procedure is unique with different layouts and composition materials. The Hazen-Williams equation was developed plinth on years durations of flows and head losses for water flow through pipes made of different materials. In most cases, when in a state of rest engineers use the Hazen-Williams formula to characterize the roughness of the pipes inner surface. Relatively precise results can be received for flow (Q) in personal pipes of a looped procedure by first making a skilled supposition for the flow in each pipe of the procedure plinth on continuity and then using successive substitution with new flow (Q) values received by the Hazen-Williams equation. Commercial software has been developed that can solve very intricate procedure using the Hazen-Williams draw near as well as other technically developed equations. It was developed for water flow in large pipes (D5 cm, approximately 2 in) within an abstemious range of water velocity (V3 m/s, approximately 10 ft/s). However, being technical, the Hazen-Williams equation is not dimensionally homogeneous and its ranges of practicality is limited (Lieu, 1998).Hazen-Williams equation, originally developed for British durations procedure, has been written in the form, $V = K * C_{HW} * R_h^{0.63} * S_E^{0.54}$

Where, V=Mean fluid velocity in the pipe, K=1.318 for U.S units and K=o.85 for S.I units.

C_{HW}= Hazen-Williams resistance coefficient, R= When in a state of rest radius (A/P, Where A is the cross-sectional area and P is the wetted perimeter)

S_E= Slope of the energy grade line or the head loss per unit length of the pipe (S=h/L).

By making use of equation (1), equation (7) and Hazen – Williams formula. C can be interpreted as $C = 14.07\,\lambda^{-0.54} R^{0.06}(\frac{\varepsilon}{D})^{0.01}\varepsilon^{-0.01}\gamma^{0.08}$, is implying that C is a function of R,$\frac{\varepsilon}{D}$,ε and Kinematics viscosity,γ, C is also found to be dependent on pipe diameter (Lieu, 1998).



Connection between Hazen-Williams C and when a state of rest parameters.

Figure 8: Variations in C

IS-SP35:1987(Handbook on water supply and Drainage with special Emphasis on plumbing) gives the values of Hazen-Williams constant C in some range for different types of pipe materials, i.e. fore cast iron new pipe, the recommended value of C is 130 and for design purpose, it is 130. As shown in Figure (8) assuming C as constant is hazardous.

Table of Hazen-Williams coefficients for different type of pipes

Pipe materials	C_{HW}
Asbestos Cement	140
Brass	130-140
Brick Sewer	100
Cast-Iron(common in older water line)	
New unlined	130
10-year-old	107-113
20-year-old	89-100
30-year-old	75-90
40-year-old	64-83
Concrete or Concrete-lined	
Steel forms	140
Wooden forms	120
Smooth	140
Average	120
Rough	100
Centrifugally spun	135
Copper	130-140

Table of Roughness Heights,ε for certain common materials

Pipe materials	ε (mm)	ε (ft)
Brass	0.0015	0.000005
Concrete		
Steel forms, Smooth	0.18	0.0006
Good join is average	0.36	0.0012
Rough visible form marks	0.60	0.002
Copper	0.0015	0.000005
Corrugated metal(CMP)	0.45	0.15
Iron(common in older water lines except ductile or DIP)		
Asphalt lined	0.12	0.0004
Cast	0.26	0.00085
Ductile, DIP-cement mortar lined	0.12	0.0004
Galvanized	0.15	0.0005
Wrought	0.045	0.00015
Polyvinyl chloride (PVC)	0.0015	0.000005
Polyethylene high density(HDPE)	0.0015	0.000005
Steel		
Enamel coaled	0.0048	0.000016
Riveted	0.9-9.0	0.003-0.03
Seamless	0.004	0.000013
C0mmercial	0.045	0.00015

6. Conclusion

Plinth on the Nikuradse's experimental data, an improved version of equation on friction factor covering the whole Turbulent flow range flow has been presented. The friction factor treatment of a nectar surface in the transitional regime does not follow the Colebrook relationship and in lieu of exhibits treatment more pattern cal of Nikuradse's gravel – corn roughness.

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