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COMPUTATION OF FRICTION FACTOR AND ITS EFFECT ON DESIGN OF WATER PIPE LINE

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Abstract - *The title of our Major Project is 'calculation of friction factor in different and its effect on design of water Pipe line '. Form friction factor we can calculate friction loss and friction loss is the energy loss of fluid inflow in Pipe. When a fluid flows through a pipe it came across lot of resistance like be bends, turns, change in pitch, roughness, friction and other factors like diameter, velocity, viscosity and density of fluid causes fluid inflow to decelerate down which affect in loss of energy or simply further energy is needed for the fluid inflow. This loss of energy is known as energy loss. The significance of friction factor in pipe design is that we can be suitable to find out the pressure loss in the pipe by knowing the values of friction factor. Consequently, One can calculate the pumping power needed or demanded to carry the fluid in the pipe and thereby we can elect the pump of needed power and capacity. In this Project, by using various empirical equations, friction factor for various pipe diameter, different pipe material and by considering smooth and rough pipe is determined. The result obtained by empirical equations is validated by actual performing the test and for friction factor in the laboratory. By using various friction factor the most economic diameter is obtained. It is recommended that Darcy-Wiesbach equation is more reliable and gives the optimum diameter of the pipe network.*

Key Words: Calculating Friction Factor by different equation.

1. INTRODUCTION

Friction loss is a measure of the quantum of energy your pipeline system loses because your fluids are meeting resistance. As fluid overflows through your pipes, it carries energy with it. Unfortunately, whenever there's resistance to inflow rate, it diverts fluids and energy escapes. These opposing forces beget friction loss in pipes. It may not be egregious, but friction loss can bring you time, plutocrat, and effectiveness. Then are a many ways friction loss strips plutocrat out of your pipeline system.

1.1 What Causes Friction Loss:

All kinds of things can cause friction loss, but there are a few friction factors that tend to affect your pipe flow the most. Here's a closer look at the common causes of friction loss:

1) Viscosity: The density of the fluid you 're transporting can contribute to friction loss. Put simply, density describes the consistence of the fluid your pipes are transporting. Fluids with advanced density will be more likely to meet resistance than those with a low density. For case, water is more likely to rush un defied through pipes than thicker fluids, similar as oil painting.

2) Internal pipe diameter: Basically, the lower face your fluids have to run over, the lower the chance of friction loss. That's why pipes with a lower periphery generally have further friction loss.

3) Internal pipe roughness: The rougher the internal shells of your pipes are, the harder fluids need to work to slide around or over them. That's why internal erosion and buildup can beget resistance and friction loss.

4) Changes in pipe slope: If your pipes change in elevation, it can force liquids to work against graveness, and you can lose energy along the way. That's why uneven or sagging pipe runs can stink energy out of your system.

5) Pipe length: The farther fluids have to travel, the harder they've to work. Longer pipe runs will naturally have advanced eventuality for friction loss than shorter runs.

6) Valves and fittings Internal pipe walls are not the only effects that contribute to friction loss. faucets and fittings can also inhibit inflow and beget further friction.

1.2 How to reduce friction Loss in Pipe:

By precluding friction loss at every pass, you'll boost the effectiveness of your pipeline system, ameliorate product, and save plutocrat. Then are a many ways to cut down friction loss and encourage steady pipe inflow:

1) Reduce Interior Roughness: By smoothing out interior pipe shells, you'll pave a clearer path for liquids to flow. That means drawing pipes completely and keeping them free from debris. It also requires a visionary approach to fighting pipe erosion. When pipes erode, it causes expensive dips and blockages. That's why it's important to keep erosion from creeping into pipe shells and eating down essence.

2) Increase Pipe Diameter: Diameter By widening pipe compasses, you insure that liquids do not have to work as hard to squeeze through pipes. In turn, you'll reduce inflow resistance and friction loss in pipes. Just be sure you're supporting larger pipes with strong, effective pipe supports.

3) Reduce Turns: By uncurling out pipe runs and clearing your pipe's path, you can avoid friction loss. Negotiate this by removing tees, fittings, and other sharp turns whenever it's possible.

2. LITERATURE REVIEW

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3. EMPIRICAL FORMULAS:

Table-1: Different Friction Factor Formulas without Roughness

Equation Name	Equation
Relative Roughness:	$k = \varepsilon/D$
Newton - Raphson Equation:	$\frac{1}{\sqrt{f}} = 2.log\left(\frac{3.7}{k}\right) - 2.log\left(1 + \frac{9.335}{k.Re.\sqrt{f}}\right)$
Gregory-Forgarasi Equation:	$\frac{1}{\sqrt{f}} = -2.log\left(\frac{k}{3.7065} - \frac{5.0452}{Re} logA\right)$ Where, $A = \frac{k^{1.1098}}{2.8257} + (\frac{7.149}{Re})^{0.8981}$
Colebrook & White Equation:	$\frac{1}{\sqrt{f}} = -2.log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re.\sqrt{f}}\right)$
Blasius Equation:	$0.184Re^{-0.25}$
Nikuradse Equation:	$\frac{1}{\sqrt{f}} = 1.74 - 2.log\left(\frac{2\varepsilon}{D}\right)$
Jain Equation:	$\frac{1}{\sqrt{f}} = 1.14 - 2.log\left(\frac{\varepsilon}{D} . \frac{21.25}{Re^{0.9}}\right)$
Von Karman equation:	$\frac{1}{\sqrt{f}} = 2.log\left(\frac{D}{\varepsilon}\right) + 1.74$

Table-2: Different Friction Factor Formulas with

Equation Name	Equation
Bernoulli's Equation:	$hf = (\frac{P1}{r} + \frac{V1^2}{2g} + z1) - (\frac{P2}{r} + \frac{V2^2}{2g} + z2)$
Hazen-Williams formula:	$V = 0.849Chw R^{0.63} S^{6.54}$ & $hf = \frac{10.68 LQ^{1.852}}{C^{1.852}D^{4.87}}$
Manning's Formula:	$V = \frac{1}{N} R^{2/3} S^{1/2}$ & $hf = \frac{10.29N^2 L Q^2}{D^{16/3}}$
Darcy-Weisbach equation:	$hf = \frac{fLV^2}{2gD}$
Hagen-Poiseuille equation:	$hf = \frac{32\mu LV}{\rho g D^2}$
Blasius Equation:	$f = \frac{0.316}{Re^{0.25}}$
Prandtl equation:	$\frac{1}{\sqrt{f}} = 2.log\left(\frac{Re.\sqrt{f}}{2.51}\right) = 2.log(Re.\sqrt{f})$
Nikuradse equation:	$\frac{1}{\sqrt{f}} = 2.log(Re.\sqrt{f}) - 0.8$

Roughness

1] Bernoulli's Equation: Bernoulli's principle states that: The total mechanical energy of the moving fluid comprising the gravitational potential energy of elevation, the energy associated with the fluid pressure and the kinetic energy of the fluid motion, remains constant.

2] Hazen-Williams formula: It is an empirical relationship which relates the flow of water in a pipe with the physical properties of the pipe and the pressure drop caused by friction.

3] Manning's Formula: It is an empirical formula estimating the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid, i.e., open channel flow. However, this equation is also used for calculation of flow variables in case of flow in partially full conduits, as they also possess a free surface like that of open channel flow.

4] Darcy-Weisbach equation: In fluid dynamics, the Darcy–Weisbach equation is a phenomenological equation, which relates the major head loss, or pressure loss, due to fluid friction along a given length of pipe to the average velocity. This equation is valid for fully developed, steady, incompressible single-phase flow.

5] Hagen-Poiseuille equation: It is a physical law that gives the pressure drop in an incompressible and Newtonian fluid in laminar flow flowing through a long cylindrical pipe of constant cross section.

6] Blasius Equation: Blasius determined an equation from experiments on smooth pipes. The Blasius equation is the most simple equation for solving the Darcy friction factor because the Blasius equation has no term for pipe roughness, is valid only to smooth pipe.

7] Prandtl Equation: Prandtl derived a formula from the logarithmic velocity profiles and experimental data on smooth pipes.

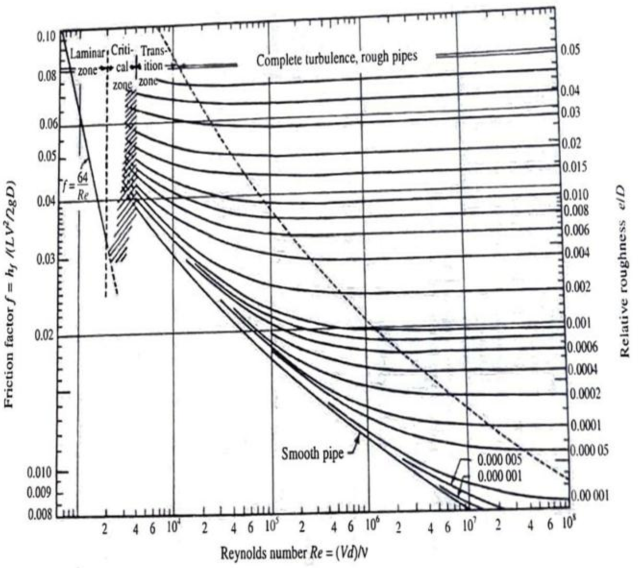
8] Nikuradse Equation: The development of approximate equations for the calculation of friction factor began with Nikuradse's turbulent pipe flow investigations in 1932 and 1933. Nikuradse had verified the Prandtl‟s mixing length theory and proposed the following universal resistance equation for fully developed turbulent flow in smooth pipe.

9] Von Karman Equation: The following form of the equation is first derived by Von Karman (Schlichting, 1979) and later supported by Nikuradse‟s experiments. Von Karman's relation was widely used for turbulent regime in rough pipes.

10] Colebrook & White Equation: Colebrook and White (1937) proposed the equation for transition regime in which the friction factor varies with both R and €/D. The equation universally adopted for calculating the friction factor.

3.2 MOODY CHART

The Moody Chart eventually handed a system of chancing an accurate friction factor and this encouraged use of the Darcy-Weisbach equation, which snappily came the system of choice for hydraulic engineers. The introduction of the personnel computer From the 1980's onwards reduced the time needed to calculate the friction factor and pipe head loss. This itself has widened the use of the Darcy- Weisbach formula to the point that utmost other equations are no longer used.



4. PROBLEM STATEMENT:

Friction factor plays an important role in design of pipe line. The computation of pressure drop in pipe line depends on friction factor. A number of correlations for friction factor determinations in smooth and rough pipes have been available in the literature. It is the need of time to check the more suitable and reliable equation for determination of friction factor and its effect on design of water pipe, when it is running full condition.

5. METHODOLOGY:

In our Major Project, beside finding research Papers, different formulas to calculate friction factor, study materials what we did we took two problems with different diameter of pipe with same data and same fluid i.e. water. We calculated/solved each example by different friction factor formulas for different Pipes for calculation friction factor. The different friction factor formulas we found out on some research papers and some on study materials. The problems, we calculated them by both analytically, practically and experimentally to find out friction factor. After calculating friction factor, we compare the result to find out which analytical and experimental method gives more accurate result and how much deviation happens in each result.

After that, we took Pipe distribution network problem, we calculated the diameter of pipe for network by different friction factor we obtained by different formulas, experimentation and Moody's chart. Then we compare the diameter to find out which friction Factor gives more economical and accurate result for the design of water pipeline distribution Network.

5.1 PROBLEMS:

5.2 PIPE-1: Find the Head loss and friction factor value of different pipes in which water is flowing. The Head Loss & Friction Factor is calculated by following Formulas **(without Considering the Roughness)**

1) Darcy-Weisbach equation:
2) Hagen-Poiseuille equation:
3) Blasius Equation:
4) Prandtl equation:
5) Nikuradse equation:

The Friction Factor is calculated by following Formulas (**With Considering the Roughness**)

1) Newton - Raphson Equation:
2) Gregory-Forgarasi Equation:
3) Colebrook & White Equation:
4) Nikuradse Equation:
5) Jain Equation:

Inside diameter, D= 0.022 m
Density of water, ρ = 1000 Kg/m3
Velocity, V= 0.8 m/s
Viscosity of water, μ = 0.001003 Ns/m3
Length of Pipe, L = 1.25 m

5.3 PIPE-2: Find the Head loss and friction factor value of different pipes in which water is flowing. The Head Loss & Friction Factor is calculated by following Formulas **(without Considering the Roughness)**

1) Darcy-Weisbach equation:
2) Hagen-Poiseuille equation:
3) Blasius Equation:
4) Prandtl equation:
5) Nikuradse equation:

The Friction Factor is calculated by following Formulas (**With Considering the Roughness**)

1) Newton - Raphson Equation:
2) Gregory-Forgarasi Equation:
3) Colebrook & White Equation:
4) Nikuradse Equation:
5) Jain Equation:

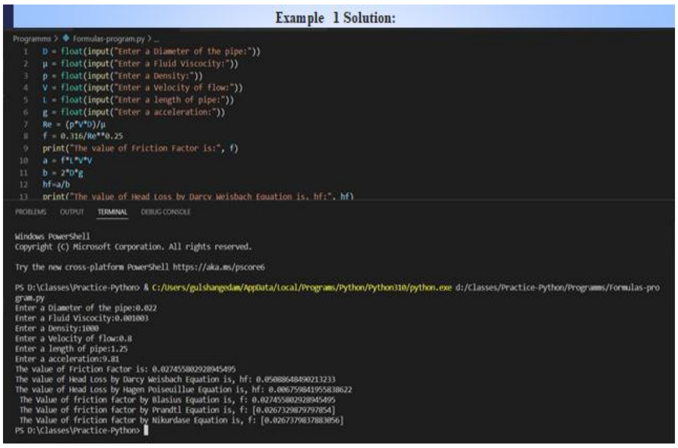
Inside diameter, D= 0.016 m
Density of water, ρ = 1000 Kg/m3
Velocity, V= 1.4 m/s
Viscosity of water, μ = 0.001003 Ns/m3
Length of Pipe, L = 1 m

5.4 PYTHON COADING:

For calculation of friction factor by different formulas we used python programming language.

```
Programms > Formulas-program.py > ...
D = float(input("Enter a Diameter of the pipe:"))
μ = float(input("Enter a Fluid Viscocity:"))
p = float(input("Enter a Density:"))
V = float(input("Enter a Velocity of flow:"))
L = float(input("Enter a length of pipe:"))
g = float(input("Enter a acceleration:"))
Re = (p*V*D)/μ
f = 0.316/Re**0.25
print("The value of Friction Factor is:", f)
a = f*L*V*V
b = 2*D*g
hf=a/b
print("The value of Head Loss by Darcy Weisbach Equation is, hf:", hf)
a = 32*μ*L*V
b = p*g*D*D
hf = a/b
print("The value of Head Loss by Hagen Poiseuillue Equation is, hf:", hf)
f = 0.316/(Re ** 0.25)
print(" The Value of friction factor by Blasius Equation is, f:", f)
# NOW
#loge
from sympy import symbols , Eq, solve, log
x = symbols('x')
s1 = solve(2 * log((Re * (x ** 0.5) / 2.51), 10) - (x ** -0.5), x)
print(" The Value of friction factor by Prandtl Equation is, f:",s1)
s2 = solve(2 * log((Re * (x ** 0.5) ), 10)- 0.8 - (x ** -0.5), x)
print(" The Value of friction factor by Nikurdase Equation is, f:",s2)
```

5.5 OUTPUT:



6. EXPERMENTATION:

COMPUTATION OF FRICTION FACTOR BY EXPERIMENTATION:

PIPE 1: 1) Diameter of Pipe: 0.022 m
2) Length of Pipe: 1.25 m
3) Area of Measuring Tank: 0.077 sq.m

Average friction factor=0.0368

PIPE 2: 1) Diameter of Pipe: 0.016 m
2) Length of Pipe: 1 m
3) Area of Measuring Tank: 0.077 sq.m

Average friction factor=0.0239

7. MOODY'S CHART:

From Fig.1 (p.g-4)

For Pipe 1:
1) Reynold's Number = **18000 i.e 10^4**
2) Relative Roughness = Roughness/ Diameter
= 0.000045 / 0.022
= 2.045 x 10^-3
= 0.002045

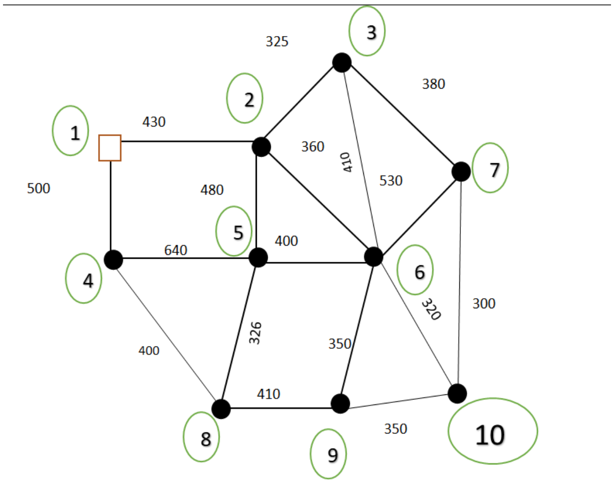
By Comparing Relative roughness with Reynold's Number we get Friction Factor **= 0.0350**

For Pipe 2:
1) Reynold's Number = **23000 i.e 20^4**
2) Relative Roughness = Roughness/ Diameter
= 0.000045 / 0.016
= 2.812 x 10^-3
= 0.00281

By Comparing Relative roughness with Reynold's Number we get Friction Factor **= 0.0270**

8. DESIGN OF PIPE NETWORK:

For the network shown below find the tree having minimum path (by Path concept). Determine Primary and secondary pipe, if available HGL at source is 100m & HGL at demand nodes are 2-96, 3-93, 4-96, 5-93, 6-94, 7-90, 8-93, 9 -92, 10-89. find the nodal HGL values.



For Pipe 1: Diameter obtained by different friction factor

SR. No.	Path	Length (m)	Discharge Q (m3 / min)	Head Loss HL (m)	For f = 0.0350 [From Moody's Chart]		For f = 0.0305 [From Newton – Raphson, Gregory-Forgarasi & Colebrook & White Equation]		For f = 0.0368 [From Experimental Readings]	
					Friction Factor f	Diameter D (m)	Friction Factor f	Diameter D (m)	Friction Factor f	Diameter D (m)
1	1-2	430	16.5	2.97	0.0350	0.501	0.0305	0.487	0.0368	0.506
2	2-3	325	3.5	3.18	0.0350	0.251	0.0305	0.244	0.0368	0.254
3	2-6	360	7	2.49	0.0350	0.355	0.0305	0.346	0.0368	0.359
4	2-5	490	2	4.03	0.0350	0.208	0.0305	0.202	0.0368	0.210
5	3-7	390	2	3.58	0.0350	0.200	0.0305	0.195	0.0368	0.202
6	6-10	320	2.5	5.54	0.0350	0.196	0.0305	0.190	0.0368	0.198
7	6-9	380	3	2.54	0.0350	0.255	0.0305	0.248	0.0368	0.257
8	1-4	500	4.5	3.85	0.0350	0.291	0.0305	0.283	0.0368	0.294
9	4-8	400	2.5	7.00	0.0350	0.195	0.0305	0.190	0.0368	0.197

For Pipe 2: Diameter obtained by different friction factor

SR. No.	Path	Length (m)	Discharge Q (m3 / min)	Head Loss HL (m)	For f = 0.0270 [From Moody's Chart]		For f = 0.0306[From Newton – Raphson, Gregory-Forgarasi & Colebrook & White Equation]		For f = 0.0239 [From Experimental Readings]	
					Friction Factor f	Diameter D (m)	Friction Factor f	Diameter D (m)	Friction Factor f	Diameter D (m)
1	1-2	430	16.5	2.97	0.0270	0.475	0.0306	0.488	0.0239	0.464
2	2-3	325	3.5	3.18	0.0270	0.238	0.0306	0.244	0.0239	0.233
3	2-6	360	7	2.49	0.0270	0.337	0.0306	0.346	0.0239	0.329
4	2-5	490	2	4.03	0.0270	0.197	0.0306	0.202	0.0239	0.192
5	3-7	390	2	3.58	0.0270	0.193	0.0306	0.198	0.0239	0.188
6	6-10	320	2.5	5.54	0.0270	0.186	0.0306	0.191	0.0239	0.181
7	6-9	380	3	2.54	0.0270	0.242	0.0306	0.248	0.0239	0.236
8	1-4	500	4.5	3.85	0.0270	0.276	0.0306	0.284	0.0239	0.270
9	4-8	400	2.5	7.00	0.0270	0.185	0.0306	0.190	0.0239	0.181

9. RESULT AND DISCUSSION:

9.1 Comparison of Friction Factor Without Roughness:

SR. NO	EQUATION NAME	For Pipe 1 [Diameter = 0.022 m] FRICTIPON FACTOR, "f"	Percentage Deviation	For Pipe 2 [Diameter = 0.016 m] FRICTIPON FACTOR, "f"	Percentage Deviation
1	Darcy-Weisbach equation:	0.02744	0 %	0.0258	0 %
2	Hagen-Poiseuille equation:	0.02744	0 %	0.0258	0 %
3	Blasius Equation:	0.02744	0 %	0.0258	0 %
4	Prandtl equation:	0.02670	2.6 %	0.0251	2.7 %
5	Nikuradse equation:	0.02673	2.5 %	0.0252	2.3 %

From following result it shows that the friction factor obtained by empirical equations without roughness are approximately same only 2% - 3% deviation happens in the result for both Pipe 1 and Pipe 2.

9.2. Comparison Of Friction Factor With Roughness:

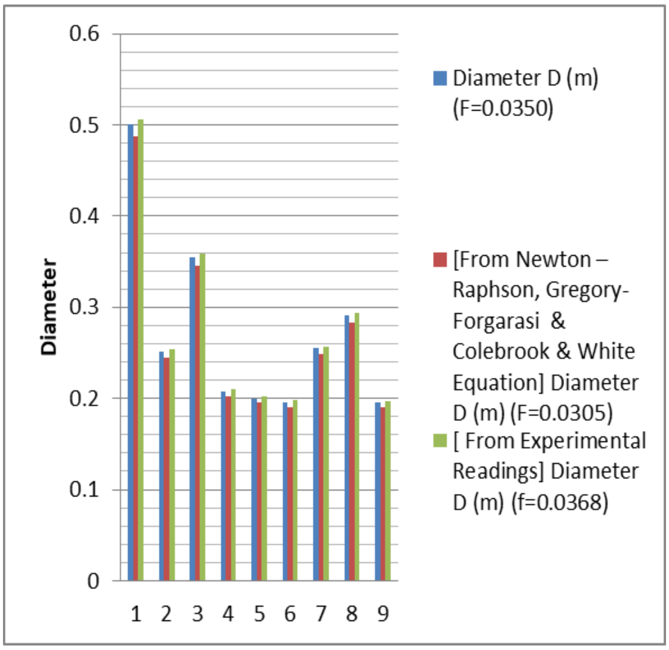
Sr No	Equations Name	For Pipe 1 [Diameter = 0.022 m] Stainless Steel Pipe	Percentage Deviation	For Pipe 1 [Diameter = 0.016 m] Stainless Steel Pipe	Percentage Deviation
1.	Newton - Raphson Equation:	0.0305	0 %	0.0307	0 %
2.	Gregory-Forgarasi Equation:	0.0305	0 %	0.0306	0.3 %
3.	Colebrook & White Equation:	0.0304	0.3 %	0.0307	0 %

From following result it shows that the friction factor obtained by empirical equations with roughness are approximately same only 0. 3% deviation happens in the result for Newton - Raphson Equation, Gregory-Forgarasi Equation, Colebrook & White Equation in both Pipe 1 and Pipe 2. For Nikuradase and Jain equation the deviation in the result is too much so they will be avoided for the calculation of diameter in further network.

9.3 Comparison of Diameter Obtained Different Friction Factor:

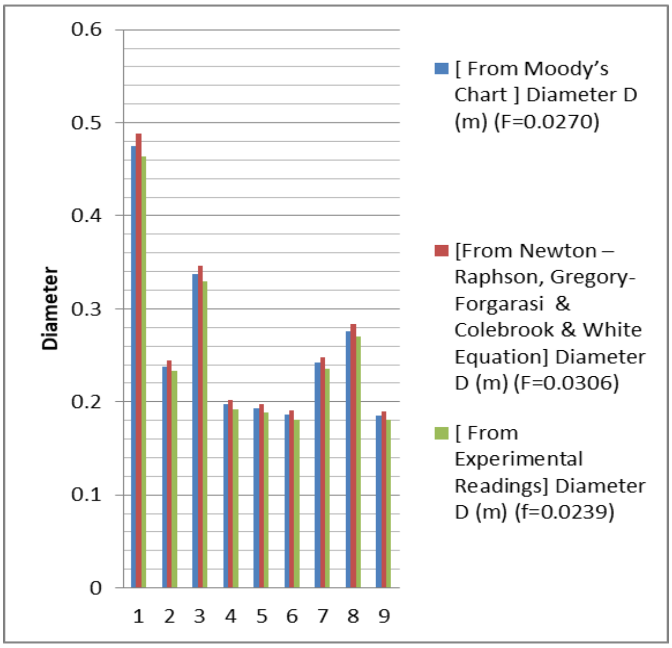
For Pipe 1:

[From Moody's Chart] Diameter D (m) (f=0.0270)	[From Empirical Equation] Diameter D (m) (f=0.0306)	[From Experimental Readings] Diameter D (m) (f=0.0239)
0.475	0.488	0.464
0.238	0.244	0.233
0.337	0.346	0.329
0.197	0.202	0.192
0.193	0.198	0.188
0.186	0.191	0.181
0.242	0.248	0.236
0.276	0.284	0.270
0.185	0.190	0.181



For Pipe 2:

[From Moody's Chart]	[From Empirical Equation]	[From Experimental Readings]
Diameter D (m) (f=0.0270)	Diameter D (m) (f=0.0306)	Diameter D (m) (f=0.0239)
0.475	0.488	0.464
0.238	0.244	0.233
0.337	0.346	0.329
0.197	0.202	0.192
0.193	0.198	0.188
0.186	0.191	0.181
0.242	0.248	0.236
0.276	0.284	0.270
0.185	0.190	0.181



DISCUSSION:

1. It is observed that friction factor increases as the roughness of pipe is considered.

2. The deviation in friction factor is for smooth pipes observed in the range of 2 to 3 % by considering various empirical equations.

3. The deviation in friction factor is for rough pipes observed in the range of 0.2 to 0.3 % considering various empirical equations.

4. If the diameter of pipe increases the friction factor increase.

5. The friction factor obtained by various empirical equations is very close to the experimental result.

6. The Friction factor obtained by all empirical equation is almost same.

7. As the roughness of the pipe material increases the friction factor of the pipe is also increases.

8. The friction factor obtained for Rusted pipe and Cast Iron Pipe is more as compared to the stainless steel pipe.

9. Plastic Pipe has lowest friction factor and relative roughness as compared to the other pipes considered.

10. CONCLUSION:

By studying all the empirical equations it is observed that the friction factor obtained by using all equation is very close to each other, therefore any equation can be used for the determination of friction factor.

However the friction factor calculated by using Moody's Chart and Darcy Wiesbach equation is match with the Experimentation.

The diameter obtained by Darcy-Wiesbach equation is optimal and hence it is recommended that Darcy-Wiesbach equation must be used for the determination of friction factor.

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