Lecture-Six

Applications of Viscous Turbulent Flow in Pipes

1- *Application-1*

A pump delivers water from a tank (A)(water surface elevation=110m) to tank B (water surface elevation= 170m). The suction pipe is 45m long and 35cm in diameter the delivered pipe is 950m long 25cm in diameter. Loss head due to friction $\boldsymbol{h_{f1}} = 5m$ and $\boldsymbol{h_{f2}}$ = 3m If the piping are from
pipe(1)= steel sheet metal
pipe(2)= stainless – steel
Calculate the following

i) The discharge in the pipeline
ii) The power delivered by the pump.

Sol.

Given

$\nu_w = 1.007 * 10^{-6} \frac{m^2}{s}$

$d_1 = 35\ cm = 0.35m\ ;\ d_2 = 25cm = 0.25m$

$L_1 = 45m\ ;\ L_2 = 950\ m$

From table 1, $\epsilon_1 = 0.05\ mm$

$\epsilon_2 = 0.002\ mm$

$\frac{\epsilon_1}{d_1} = \frac{0.05}{350} = 1.428 * 10^{-4}$

$\frac{\epsilon_2}{d_2} = \frac{0.002}{250} = 8 * 10^{-6}$

Assume $f_1 = 0.013;\ f_2 = 0.008$

$h_{f1} = f_1 \frac{L_1}{d_1} . \frac{V_1^2}{2g}$

$5 = 0.013 \frac{45}{0.35} . \frac{V_1^2}{2*9.81} ---\rightarrow V_1 = 7.66 \frac{m}{s} --\rightarrow Re_1 = \frac{V\ d}{\nu} = \frac{7.66*0.35}{1.007*10^{-6}}$

$Re_1 = 2662363 = 2.66 * 10^6$

$h_{f2} = f_2 \frac{L_2}{d_2} \frac{V_2^2}{2g} = 0.008 \frac{950}{0.25} . \frac{V_2^2}{2*9.81} = 3.0m$

$V_2 = 1.39 \frac{m}{s} \quad Re_2 = \frac{1.39*0.25}{1.007*10^{-6}} = 3.45 * 10^5$

1st Trail

$\left(Re_1 \& \frac{\epsilon_1}{d_1}\right) --\rightarrow f_1 = 0.0138$ from Fig.1

$\left(Re_2 \& \frac{\epsilon_2}{d_2}\right) -\rightarrow f_2 = 0.014$ from Fig.1

$h_{f1} = 5 = 0.0138 \frac{45}{0.35} . \frac{V_1^2}{2*9.81} -\rightarrow V_1 = 7.435 \frac{m}{s} ---\rightarrow Re_1 = 2.58 * 10^6$

$h_{f2} = 3 = 0.014 \frac{950}{0.25} \frac{V_2^2}{2*9.81} --\rightarrow V_2 = 1.051 \frac{m}{s} --\rightarrow Re_2 = 2.6 * 10^5$

$2^{nd}\ trial$ and from fig.1

$\left(Re_1 \& \frac{\epsilon_1}{d_1}\right) \quad f_1 = 0.0165\ , f_2 = 0.015$

From ***f₁ &f₂***

$h_{f1} = 5 = 0.0165 \frac{45}{0.35} \frac{V_1^2}{2*9.81} \rightarrow V_1 = 6.8\ m/s$

$h_{f2} = 3 = 0.015 \frac{950}{0.25} \frac{V_2^2}{2*9.81} \rightarrow V_2 = 1.01\, m/s$

$Re_1 = 2.36*10^6$
$Re_2 = 2.52*10^5$

3^{rd} *trial*
$\left(Re_1 \& \frac{\epsilon_1}{d_1}\right), \left(Re_2 \& \frac{\epsilon_2}{d_2}\right) \rightarrow f_1 = 0.0169, f_2 = 0.015$
From Darcy-equation gives V_1=0.6.72 m/s, V_2=1.016 m/s.
$Q = A_1 * V_1 =$ **0.6462** m^3/s
From energy equation

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \frac{V_1^2}{2g} + z_2 + h_f$$

$\frac{(6.72)^2}{2*9.81} + 110 + h_p = \frac{(1.016)^2}{2*9.81} + 170 + 8$ Since $p_1 = p_2$
$\boldsymbol{h_p}$ = 65.75 m
$P = \gamma Q h_p = 9810 * 0.6462 * 65.75 = 416.8\, kW$ The power delivered by the pump.

2- ***Application-2***

In a pipeline of diameter 350mm and length 75m, water is flowing at a velocity of 2.8 m/s. Find the head lost due to friction, using Darcy-Eq.& Moody chart, pipe material is Steel–Riveted kinematic viscosity υ= 0.012 stoke

Sol.

$h_f = f \frac{L}{d} . \frac{V^2}{2g}\ ; d = 0.35m\ , L = 75m; V = 2.8 \frac{m}{s}$
From table 1 for steel riveted ∈=3.0 mm
$\frac{\epsilon}{d} = \frac{0.003}{0.35} = 8.57 * 10^{-3}$
$1 \frac{m^2}{s} = 10^4\ stoke\ \therefore \upsilon = 0.012 * 10^{-4} \frac{m^2}{s}$
$Re = \frac{Vd}{\upsilon} = \frac{2.8*0.35}{0.012*10^{-4}} = 816666 = 8.1 * 10^5$
$at \left(Re\ \&\ \frac{\epsilon}{d}\right) \longrightarrow f = 0.0358$
$\therefore h_f = 0.0358 \frac{75}{0.35} \frac{2.8^2}{2*9.81} = 3.0m$
By determine the value of ***f*** by Eq. 7.45. ref. [1]

$$\frac{1}{f^{\frac{1}{2}}} \approx -1.8 \log \left[\frac{6.9}{Re_d} + \left(\frac{\frac{\epsilon}{d}}{3.7} \right)^{1.11} \right]$$

$$\frac{1}{f^{\frac{1}{2}}} = -1.8 \log\left(\frac{6.9}{8.16*10^6} + \left(\frac{8.57*10^{-3}}{3.7}\right)^{1.11}\right) = 5.2646$$

f=0.036 ***Δf*** = 0.0002

3- ***Application-3.***

Oil having absolute viscosity 0.1 Pa.s and relative density 0.85 flow through an iron pipe with diameter 305mm and length 3048 m with flow rate $44.4 * 10^{-3}\,\frac{m^3}{s}$. Determine the head loss per unit weight in pipe.

Sol.

$V = \frac{Q}{A} = \frac{44.4*10^{-3}}{\frac{1}{4}\pi(0.305)^2} = 0.61\,\frac{m}{s}$

$Re \;\; = \frac{Vd\rho}{\mu} = \frac{0.61*0.305*850}{0.1} = 1580$

i.e the flow is laminar .

$f = \frac{64}{R_e} = \frac{64}{1580} = 0.0407$

$\therefore\; h_f = f\,\frac{L}{d}\frac{V}{2g} = 0.0407 * \frac{3048}{0.305} * \frac{(0.61)^2}{2g} = \; 7.71\,m$

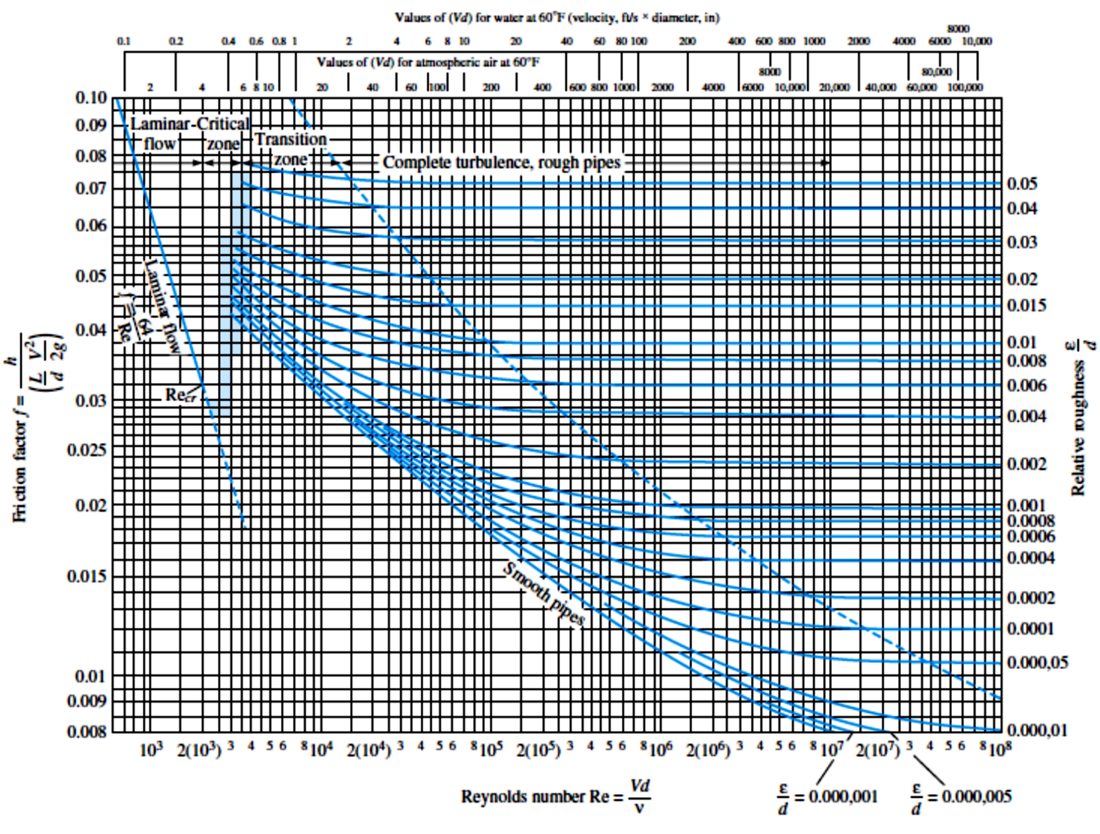

Figure (1): The Moody chart for pipe friction with smooth and rough walls.

Table 1: Recommended roughness values.

Material	Condition	ϵ ft	ϵ mm	Uncertainty, %
Steel	Sheet metal, new	0.00016	0.05	± 60
	Stainless, new	0.000007	0.002	± 50
	Commercial, new	0.00015	0.046	± 30
	Riveted	0.01	3.0	± 70
	Rusted	0.007	2.0	± 50
Iron	Cast, new	0.00085	0.26	± 50
	Wrought, new	0.00015	0.046	± 20
	Galvanized, new	0.0005	0.15	± 40
	Asphalted cast	0.0004	0.12	± 50
Brass	Drawn, new	0.000007	0.002	± 50
Plastic	Drawn tubing	0.000005	0.0015	± 60
Glass	—	Smooth	Smooth	
Concrete	Smoothed	0.00013	0.04	± 60
	Rough	0.007	2.0	± 50
Rubber	Smoothed	0.000033	0.01	± 60
Wood	Stave	0.0016	0.5	± 40