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DETERMINATION OF LOSS COEFFICIENT FOR FLOW THROUGH FLEXIBLE PIPES AND BENDS

S. Ahmed, M. Q. Islam and A. S. M. Jonayat

Department of Mechanical Engineering, BUET, Dhaka, Bangladesh

ABSTRACT
The aim of this paper is to investigate and standardize the head loss and friction factors for locally available straight flexible pipes of different dimensions(1 inch, 0.75 inch , 0.5 inch diameters). In addition to that, minor loss coefficients for different bend angles(90°,60°,45°) of these pipes are ascertained. To determine friction factor (f) and minor loss coefficient (k) an experimental set up has been developed. Frictional losses & friction factor coefficient was determined by Darcy-Weisbach equation and minor loss coefficient was calculated by Darcy's equation. The experimental data shows that for a given pipe size (diameter, D), with the increase of Reynolds number (R_{Ne}) head loss per unit length increases. For a given Reynolds number, with increase of pipe diameter the head loss per unit length decreases. In case of a certain bending angle and pipe diameter, minor loss coefficient decreases with the increase of Reynolds number. For a given pipe diameter minor loss coefficient increases with increase of bending angle and for a given bending angle minor loss coefficient increases with decrease of pipe diameter.

Keywords: Flexible Pipe, Bends, Frictional Loss, Friction Factor, Minor Loss Coefficient.

1. INTRODUCTION

The purpose of this paper is to investigate the head loss and friction factors for locally available straight flexible pipes of different dimensions. In addition to that, minor loss coefficients for different bend angles of these pipes are ascertained. Losses occur in any straight pipes and ducts are referred as major (frictional) losses and in system components (elbows, valves, bends, tees, etc) are referred as minor losses. Friction factors and minor loss coefficients determined in this thesis will help to establish more convenient use of locally made flexible pipes in local industries.

Flexible pipes and bends are used in the piping units of pumps or engines. These flexible pipes can be easily bent in any direction. The standard values of head loss, friction factor and minor loss coefficients of various flexible pipes are available in many pipe hand books and internet. But head loss, friction factor and minor loss coefficients of locally made flexible pipes are not available. So, this research work is performed with a view to determine the friction factors and minor loss coefficients for locally available flexible pipes of different dimensions (0.50 inches,0.75 inches, 1.0 inches diameter) at straight position and minor loss coefficient for different bend angles (45°, 60°, 90°) of different dimensions (0.50 inches, 0.75 inches, 1.0 inches diameter). Khan and Islam [4] made an experimental investigation of flow through flexible pipes and bends. In their work they used metal made flexible pipe. Rizwan ,

Ishfak and Pranay [9] did their work on locally made PRR pipes and bends to calculate friction factor and minor loss coefficient respectively. Hafiz, Roy and Hossain [8] determined minor head loss and friction factor for locally available PVC pipe reducer. Jaiman, Oakley and Adkins [5] did CFD modeling of corrugated flexible pipes. In their work they constructed a numerical model of the corrugated flexible pipe and did simulation to show variation of velocity distribution throughout the pipe. The authors approach is close to the one used by [4], but in this paper the authors used locally made PVC pipe instead of using metal made flexible pipes as used by [4].In the present experimental investigation, the flow through the flexible pipes and bends are assumed to be uniformly distributed.

2. METHODOLIGY

The experiment is conducted by choosing three specimens of different diameter (1 inch, 0.75 inch and 0.5 inch) andminor loss coefficient of three bends (45°, 60° and 90°) are ascertained. Detail specification of these three specimens are given in Table1.
Flexible pipes(3 pipes: D=0.5 inch,0.75 inch,1 inch)

Table 1: Detail specification of of the flexible pipes.

Parameters	1 inch dia. Flexible pipe	0.75 inch dia. Flexible pipe	0.5 inch dia. flexible pipe
TPI(Thread Per Inch)	7	7	7
Inner diameter (inch)	1.008	0.812	0.6163
Outer diameter(crest to crest) (inch)	1.225	1.083	0.8136
Outer diameter(bottom to bottom) (inch)	1.125	0.895	0.644

The experimental set up consists of three reducers (2 to 0.5 inch, 2 to .75 inch, 2 to 1 inch), gate valve, U-tube manometer with mercury as working fluid, a centrifugal pump, weight measuring instrument (platform scale), bucket. Get valve is used to control the flow of water. Manometer is used to measure the pressure difference. Frictional losses & friction factor coefficient is determined by Darcy- Weisbach equation…

$$h_f = \frac{fLv^2}{2gD}$$

The term friction factor $"f"$, instead of being a simple constant depends upon seven quantities –

$$f = f(v, D, \rho, \mu, \epsilon, \epsilon', m)$$

Since "f" is a dimensionless factor, it must depend upon grouping of these quantities into dimensionless factors. This can be done like following –

$$f = f(vD\rho/\mu, \epsilon/D, \epsilon'/D, m)$$

So, friction factor maintains a functional relationship with Reynolds number. These observations can be verified with Nikuradse's Sand-Roughed-pipe tests and Moody diagram both of which show that in turbulent section the friction factor becomes almost constant in high Reynolds Numbers. [1]
The relation between the head loss and minor loss coefficient is given by equation
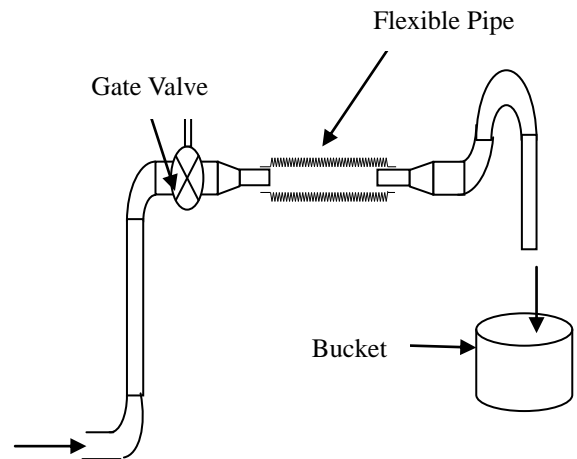
$$h_m = K \frac{v^2}{2g}$$

Fig 1. Schematic diagram of experimental setup for determining friction factor

3. RESULTS AND DISCUSSION

From Figure 2 it has been observed that for a given pipe size with the increase of Reynolds number head loss per unit length increases which is consistent with the relationship between velocity of flow and frictional loss, since Reynolds number is proportional to flow velocity. With the increase of velocity the flow pattern become more turbulent which in turn causes more head loss. While comparing the Head loss per unit length versus Reynolds no. of three different diameter pipe sizes (Figure -2) we observed a clear relationship between pipe diameter and head loss. In case of a given flow rate, with increase of pipe diameter the head loss per unit length decreases. This behavior can be verified by Darcy-Weisbach equation which states that head loss varies inversely with diameter.

From the Figure3 it is observed that in this experiment maximum Reynolds number is approximately 1.31×10^5 and from the Moody diagram (Appendix C) maximum Reynolds number at which friction factors become constant approximately after 1×10^6. For a particular Reynolds number maximum friction factor is attained for 1 inch diameter flexible pipe and minimum friction factor is attained for 0.5 inch flexible pipe. This deviation from Moody diagram can be explained by the fact that friction factor f increases as average roughness height $\in$ increases. For our case $\in$ are 0.121, 0.11315 and 0.09865 inch for 1, 0.75, 0.5 inch pipe respectively. The associated structural deformation and vibration of the flexible pipe which we did not account in our calculation caused by the fluid flow also contributed to this deviation.

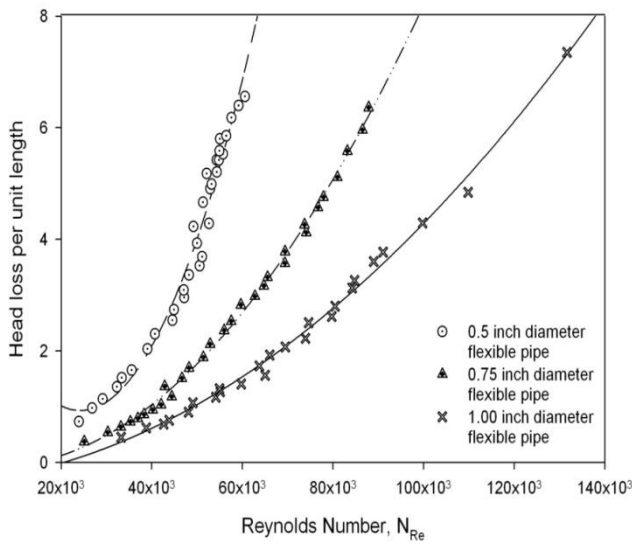Head loss per unit length Vs. Reynolds Number

Fig 2. Head loss per unit length Vs. Reynolds Number for flexible pipes of diameter 1, 0.75 and 0.50 inch

For a given diameter the variation in Minor loss coefficient with respect to bending angle was plotted with respect to Reynolds number variation in Figure 4, Figure 5 and Figure 6 respectively. As seen from these figures, increase in bending angle increases minor loss coefficient because bending introduces more resistance to fluid flow. From observation for 90° bend has maximum value while 45° bend had minimum value for minor loss coefficient for a given Reynolds number.

Minor head loss coefficient Vs. Reynolds Number

Fig 4. Minor head loss coefficient for bends (45°, 60°, 90°) Vs. Reynolds Number for 1.00 inch diameter flexible pipe.

Figure 7, Figure 8 and Figure 9 represent variation in minor loss coefficient for a given bending angle with respect to Reynolds number. For a given Reynolds number and bending angle maximum value of minor loss coefficient was observed for 0.5 inch diameter flexible pipe and minimum was observed for 1.00 inch diameter flexible pipe which conforms to the relation that for a fixed radius of curvature the value of minor loss coefficient will increase with decrease of diameter.
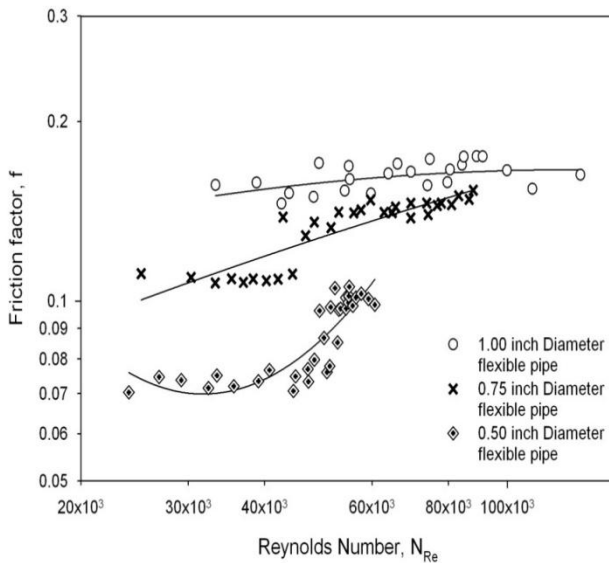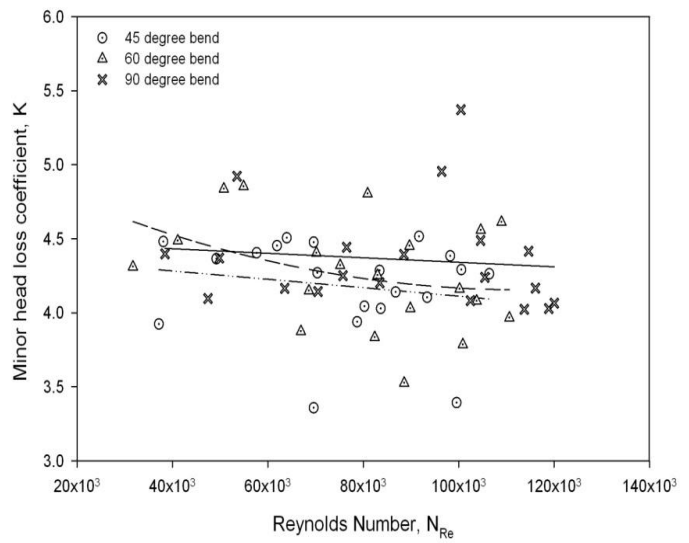
Friction Factor Vs. Reynolds Number

Fig 3. Friction factor vs. Reynolds Number for flexible pipes of diameter 1, 0.75 and 0.50 inch

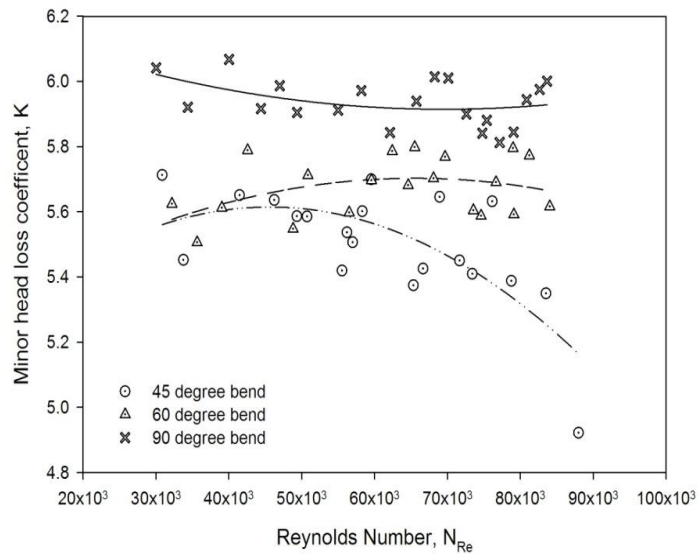Minor head loss coefficient Vs. Reynolds Number

Fig 5: Minor head loss coefficient for bends (45°, 60°, 90°) Vs. Reynolds Number for 0.75 inch diameter flexible pipe.
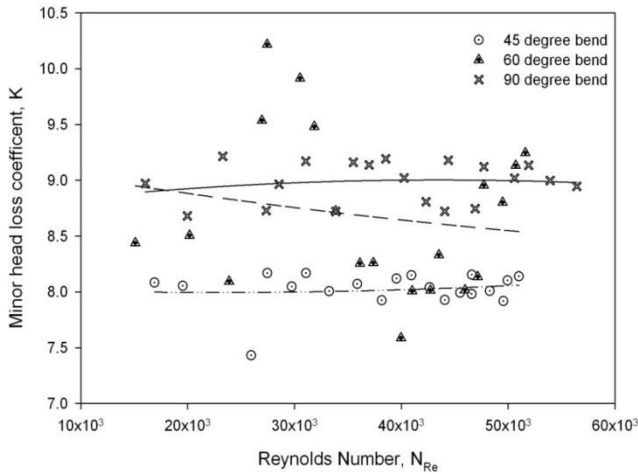
Fig 6: Minor head loss coefficient for bends (45°, 60°, 90°) Vs. Reynolds Number for 0.50 inch diameter flexible pipe.
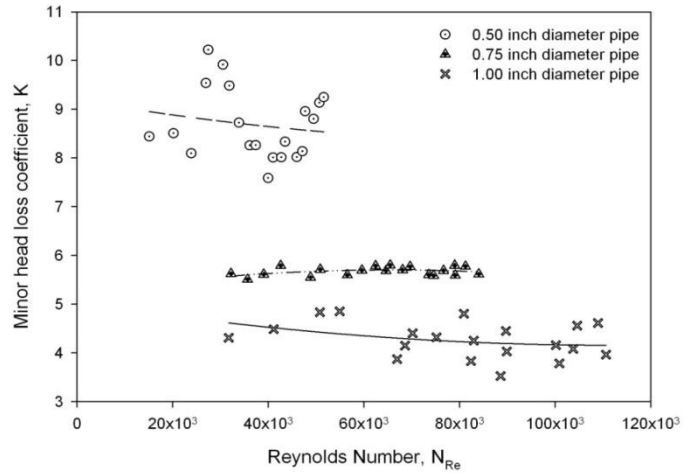

Fig 8. Minor loss Coefficient vs. Reynolds Number for 60° bend of 1.00, 0.75 and 0.50 inch diameter flexible pipes
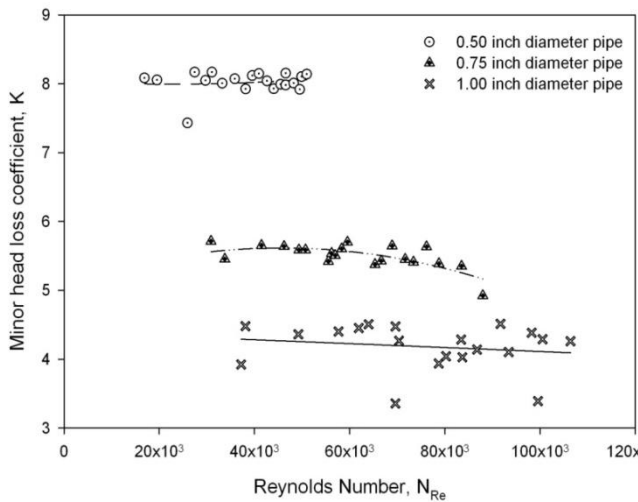

Figure 7: Minor loss Coefficient vs. Reynolds Number for 45° bend of 1.00, 0.75 and 0.50 inch diameter flexible pipes
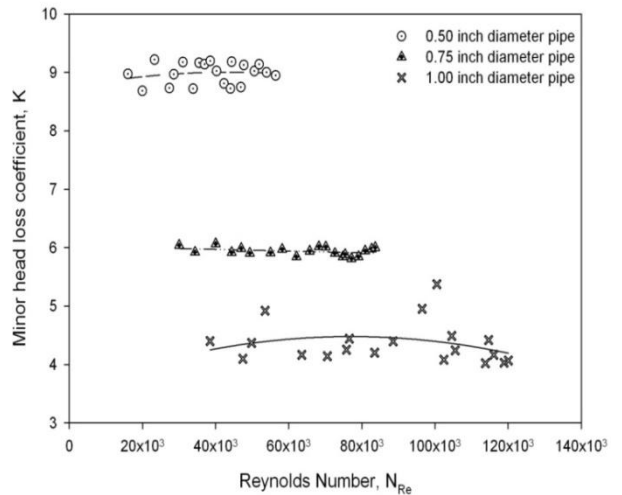

Fig 9. Minor loss Coefficient vs. Reynolds Number for 90° bend of 1.00, 0.75 and 0.50 inch diameter flexible pipes

4. CONCLUSION AND RECOMMENDATION

For a given pipe size with the increase of Reynolds number head loss per unit length increases

- In case of a given Reynolds number, with increase of pipe diameter the head loss per unit length decreases
- Frictions factor becomes constant at high Reynolds number.
- Minor loss coefficient in general shows a decreasing trend with respect to Reynolds number for a given angle and pipe diameter.
- For a given pipe diameter increase in bending angle increases Minor loss coefficient.

- For a given bending angle Minor loss coefficient increases with decrease of pipe diameter.

The thesis work center on the major and minor losses occurred in locally available flexible pipes. Therefore, it will be beneficial for calculating total head loss developed in a piping system using flexible pipes and power of the pumping system. As the experimental part was performed in this thesis, it provides scope for future work in CFD modeling in simulating software like COMSOL Multiphysics or Fluent. This will provide scope for comparing the experimental values with the theoretical values. If the values are identical the simulation model can be used for any given pipe size or bending angle, which will be more feasible and practical for determining major and minor losses. Part of this simulation has been done which shows the pressure and velocity distribution in the flow area.

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6. NOMENCLATURE

Symbol	Meaning	Unit
D	Inner diameter of pipe	(m)
h_f	Head loss	(m)
f	Friction factor	
L	Length of pipe work	(m)
V	Velocity of fluid	(m/s)
g	Acceleration due to gravity	(m/s^2)
μ	Viscosity	(Pa·s)
ρ	Density	(Kg/m^3)
ϵ	A measure of size of the roughness projections	
ϵ'	A measure of spacing of roughness elements	
m	A form factor	
K	minor loss coefficient	
h_m	Minor loss for a fittings	(m)