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Study of Pressure Losses in Piping System

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Abstract: ***Pressure losses are very important factories that effects on the flow in piping systems where concludes different length of pipes, diameters, fittings, elbows and valves.In this study water was used as a working fluid at room temperature and physical properties water was used. Different actual and theoretical pressure losses were studied and compared. Pressure drop measurement and prediction in curved pipes and elbow bends isreviewed for both laminar and turbulent single-phase fluid.***

Keywords: Piping system, pressure losses, Fittings, Reynolds number

1. Introduction

For curved pipe under laminar flow, the pressure loss can be predicted both theoretically and using empirical relations. The transitional Reynolds number can be predicted from an empirical relation. Turbulent flow in curved pipes can only be theoretically predicted for large bends but there are a large number of empirical relations that have proved to be accurate. Elbow bends have proven to be difficult to both measure and represent the pressure loss. Methods of overcoming such problems are outlined. There was no reliable method of theoretically predicting pressure drop in elbow bends. Experimental measurements showed considerable scatter unless care was taken to eliminate extraneous effects. Reliable data are highlighted and an empirical method is proposed for calculation of pressure drop in elbow bends1.Major losses in pipes come from friction in pipes over long spans while minor losses come from changes and components in a pipe system. If the pipe is long enough the minor losses can usually be neglected as they are much smaller than the major losses. Even though they are termed “minor”, for example, when a valve is almost closed the loss can be almost infinite or when there is a short pipe with many bends in it. There are three types of forces that contribute to the total head in a pipe, whichare elevation head, pressure head, and velocity head. Minor losses are directly related to the velocity head of a pipe, meaning that the higher the velocity head there is, the greater the losses will be. Units for minor losses are in length, such as feet or meters, the same as any of the three types of head2.Fluid flow in pipes is continuously impacted by the resistance to flow offered by the roughness of pipe at the walls based on the law of similarity [1], [2]. Smooth pipes offer little or negligible resistance to flow while rougher surfaces offer increasing resistance depending on the degree of roughness. Such resistance affects flow rate (Q) and velocity distribution of process fluid in the pipe [3]. The resistance increases for Q values in transition and turbulent regions. Studies elsewhere have shown that high velocities produce high resistances to flow in pipes and hence hLvalues for particular type of surface roughness [4]. Darcy- Weisbach, Hazen-Williams, Moody and Fanning showed that for any flow of fluid in a pipe exhibiting some form of roughness; head losses (hL) due to friction were produced [4]. Head losses due to gate valve, 45o and 90o elbows have also been dealt with by other authors [5]. Other losses include entry and exit losses. Such losses are commonly added to the pipe line in question in order to determine the equivalent length (Le) of a pipe. In this paper hL were evaluated in five poly-vinyl-chloride (PVC) pipes with different diameters (D) but same length (L) using water as process fluid at 25oC. A pumping source was used to produce different Qs in each pipe and elevation effects were neglected meaning that the pipe line was horizontal. Each loss due to pipe line, gate valve, 45 and 90o elbows and entry and exit losses were correlated to the flow rate and D of pipe in order to establish the relationships which could be useful to design engineers and plant operators during design and plant operation. Decisions could be made early about the size and type of roughness of the pipe and appropriate Q of the fluid during design or plant operation based on the correlations presented in this paper. The challenge with the delivery of fluids is either non delivery or insufficient delivery to the desired destination. Oftentimes, it is either the insufficient pumping due to faulty pumps or high friction losses in the delivery system. This may be caused by pipe blockage or increased roughness which may contribute to high friction losses or the system has a high positive delivery head or insufficient net positive suction head at the pump. The purpose of the study was therefore to establish levels of friction losses in different sizes of pipes fitted with fittings; gate valve, 45 and 90o elbows and exit and entry structures in order to determine the head losses that contribute to the increase of equivalent lengths of pipes that increase the delivery heads and hence problems of fluids delivery to desired destinations3.Pressure loss events can pose a serious threat to public health. A significant reduction or complete loss of pressure in a part of the distribution system may allow contaminants from an end-user or the environment to enter the distribution system. Microbial, chemical, or physical contaminants that enter the distribution system through unprotected cross connections, or through openings in the underground piping system, may cause widespread illness, injury, or worse.

1.1 Water system operators if a pressure-loss event occurs

- **Identify** who is in charge.
- **Find** the cause of the pressure-loss problem. Call us if you need help (see page 2).
- **Identify** the affected area and work to restore pressure as soon as possible.

- **Call** our regional office (working hours) or our after-hours number (see page 2). We'll help you decide which customers you need to contact and whether to issue a health advisory. Your first priority is to protect your customers' health.
- **Communicate** with affected customers about what happened. Tell them what they should do to protect their health, and what system operators are doing to correct the situation.
- **Flush** affected parts of the distribution system to remove any contaminants. Your flushing plan should effectively move any known contaminants to the nearest point of discharge without unnecessarily spreading contamination through the distribution system.
- **Disinfect** affected parts of the system to reduce the risk of waterborne disease. If you don't normally disinfect, you should notify your customers before adding a disinfectant.
- **Sample** the distribution system after you restore normal operating pressure, including coliform samples and possibly certain chemical samples, to confirm your system meets drinking water standards[4].

Selection of piping system is an important aspect of system design in any energy consuming system. The selection issues such as material of pipe, configuration, diameter, insulation etc have their own impact on the overall energy consumption of the system. Piping is one of those few systems when you oversize, you will generally save energy; unlike for a motor or a pump.

Piping system design in large industrial complexes like Refineries, Petrochemicals, Fertilizer Plants etc are done now a day with the help of design software, which permits us to try out numerous possibilities. It is the relatively small and medium users who generally do not have access to design tools use various rules of thumbs for selecting size of pipes in industrial plants. These methods of piping design are based on either "worked before" or "educated estimates". Since everything we do is based on sound economic principles to reduce cost, some of the piping design thumb rules are also subject to modification to suit the present day cost of piping hardware cost and energy cost. It is important to remember that there are no universal rules applicable in every situation. They are to be developed for different scenarios[5].

2. Theory

Assuming steady-state, incompressible, and 1D flow, the energy equation becomes:

$$\frac{p_1}{\rho}+\frac{V_1^2}{2}+gz_1=\frac{p_2}{\rho}+\frac{V_2^2}{2}+gz_2+\frac{p_{loss}}{\rho}$$

where P loss is the pressure loss between sections 1 and 2, V is the average velocity, z is the elevation from a reference point, and, is the density. Two main sources exist for pressure drop in pipelines[6]:

1) Friction loss and wall shear stress.
2) Minor loss, which is caused by changes in the geometry.

For fully-developed flow in channels frictional pressure drop can be calculated from Darcy-Weisbach equation:

$$p_{friction}=\rho f\frac{l}{d}\frac{V^2}{2}$$

Where f is the friction factor, d and l are channel diameter and length, respectively. The friction factor is related to the flow regime. Reynolds number is a good criterion for prediction of flow regime[7]:

$$Re=\frac{\rho V d}{\mu}$$

where □ is the viscosity of the fluid. For laminar flows where Re<2300, f is calculated as

$$f=\frac{64}{Re} \tag{4}$$

In turbulent flows, i.e., Re>2300, f is a function of both Reynolds number and pipe roughness, k. For hydraulically smooth pipes, $Re<65d/k$, and a Reynolds number in the range of $2320<Re<10^5$ the pipe friction coefficient is calculated using the Blasius formula:

$$f=\frac{0.3164}{\sqrt[4]{Re}} \tag{5}$$

For rough pipes the pipe friction coefficient is read from Moody diagram or evaluated usingColebrook formula:

$$f=\left[2\log\left(\frac{2.51}{Re\sqrt{f}}+\frac{0.27k}{d}\right)\right]^{-2} \tag{6}$$

Special pipe components and fittings such as pipe bends or elbows, pipe branches, changes in cross- section, and valves alter flow geometry and produce additional pressure losses apart from the wall friction losses. These minor losses can becalculated from the following relationship:

$$p_{minor}=\rho\zeta\frac{V^2}{2} \tag{7}$$

where □ is the coefficient of resistance. Therefore, when a fitting or a connection exists in a pipe of length l and the total pressured rop in the system is known, the coefficient of resistance of the fitting is found from the following equation[6]:

$$\zeta=\frac{2p_{loss}g}{\rho V^2}-\frac{fl}{d} \tag{8}$$

3. Apparatus

A piping system was designed and installed as shown if fig (1)

Figure 1: Piping system used

Water was used in the piping system as working fluid at room temperature.

4. Procedure

a) Fill up water tank.
b) Connect to power supply.

In this piping system, pipes made of PVC with a diameter of ¾” The measuring length is 2m, with fittings 90^0& 45^0, and ball valve.

a) Connect the double tube manometer to the pressure glands on the pipes.
b) Start the pump and measure the pressure drop across the pipe in a certain water flow rate
c) Repeat the experiment for different flow rates[8].

Plot the measured values of pressured rop versus Reynolds number and compare it with the values obtained from theoretical relationships.

a) Connect double tube manometer or differential pressure sensor
b) Measure pressure drop for several volume flow rates and evaluate the resistance coefficient of pipe tube, and ball valve.

5. Results and Discussion

Figure 2 shows the pressure losses theoretical and actual in the system with different flow rates, shows that actual pressure losses are greater than theoretical one because of the disturbance and pattern of water flowing through the fittings and elbows.

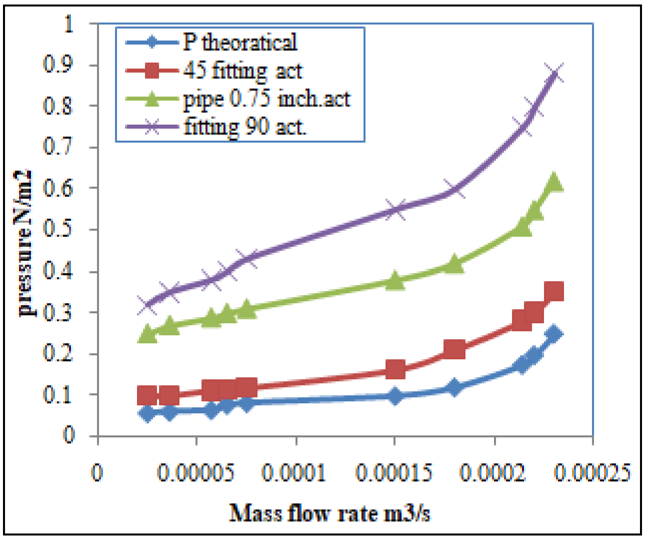

Figure 3: Relation between pressure losses with mass flow rate

Figure 4 shows the effect of Reynolds number to the friction losses in theoretical work.

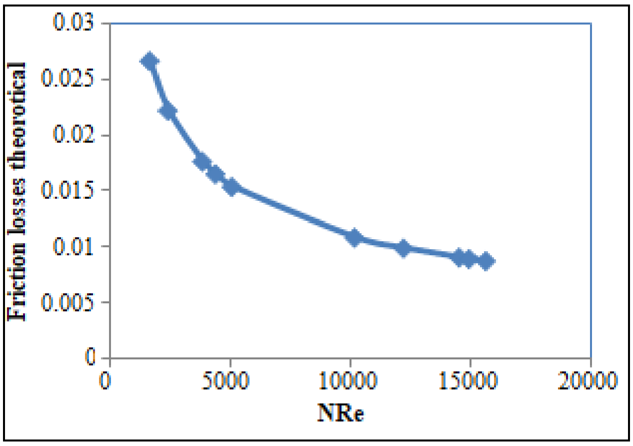

Figure 4: Relation between Reynolds number and the friction losses in theoretical work

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Figure 5.shows the comparison between fittings, elbows and valve with Reynolds number in the system

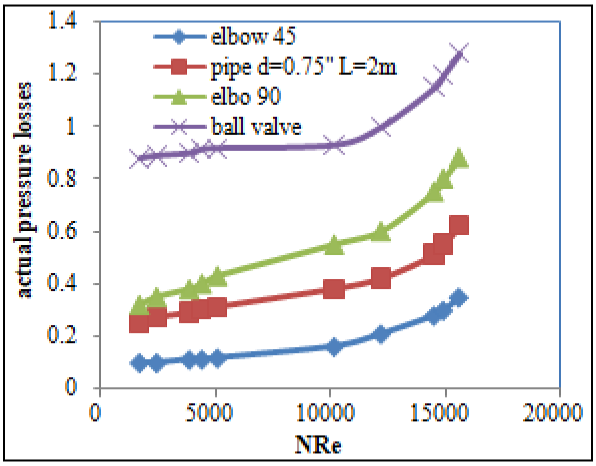

Figure 5: Values of actual pressure losses in different fittings, elbows and valve

6. Discussion

1) Starting from differential equations governing fully-developed flow in circular pipes, with different flow rate of water it was found that the actual pressure losses values are higher than the theoretical values where obtained from equations used in literature.
2) Reynolds number was sketched with friction losses were the friction losses started to be decreased with increasing the values of Reynolds number.
3) Actual Pressure drop increased using different fittings and valves were vortex and turbulence increases in the different shapes and cross sections that causes loss in pressure.

7. Conclusions & Recommendations

7.1 Conclusions

1) The behavior of the friction factor for the transport of water by pipes as a function of the Reynolds number exposes maximum values of the friction coefficient when the Reynolds number is less than 500; the values of the coefficient converge when the Reynolds number is greater than 2500. The results obtained are satisfactory for the calculation of the pressure variation in industrial facilities where water transported.
2) The specific pressure losses increase with the volumetric flow, the significant values are related to the pipe diameter through which the water is transported. The specific pressure losses reach the values of 1200 Pa/m for a diameter of 0.75” decrease to 250 Pa/m . The effect is attributed to the mixing between layers that the water manifests as it flows through the pipe.

7.2. Recommendations

1) Use different liquids in the piping system and compare difference in pressure losses.
2) Use carbon steel pipes and find turbulence of water stream flowing and pressure losses between systems
3) Use QVF pipes (transparent) to view the turbulence of water stream flowing and pressure losses.

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