NC STATE UNIVERSITY

Mechanical Engineering Systems
BSE At Havelock

(MES-400 Engineering Lab)

Minor Pressure Losses

9/25/21

Mohammad Sheikh

I have neither given nor received any unauthorized assistance on this report.

Table of Contents

Abstract

When a fluid flows through a pipe fitting the pressure of the fluid drops based on the geometry of the pipe fitting. The purpose of this experiment was to investigate the pressure losses associated with several pipe fittings. For the experiment a Hampden Flow Measurement system that contained a 180 U, Short 90, sudden contraction, sudden expansion, and long 90 fittings. The pressure loss was recorded with changing flow rates for each different fitting. The minor loss coefficient was calculated, and all the delta pressures were compared. There were large percent differences in all the fittings for both the minor losses and delta pressure. It was found that the theoretical data should not be used for real world pipe applications and rather the loss coefficient should be derived experimentally for piping systems.

Introduction

Objective

The objective of the experiment was to determine the minor pressure losses of water through different pipe fittings.

Background

Fluid flow is an important concept to engineers because many practical applications such as vehicles, plumbing systems in houses, etc involve fluid flow. It is important to investigate the pressure losses due to friction as this is important in a variety of engineering calculations.

Relevant Theory

The minor loss is given by

$$\Delta_p = K_l \frac{1}{2}\rho V^2 \quad (1)$$

Where:

Δ_p is the pressure difference

K_l is the loss coefficient

ρ is the density of the fluid

V is the velocity

For a contraction/expansion the pressure loss is a function of the inlet and outlet diameters.

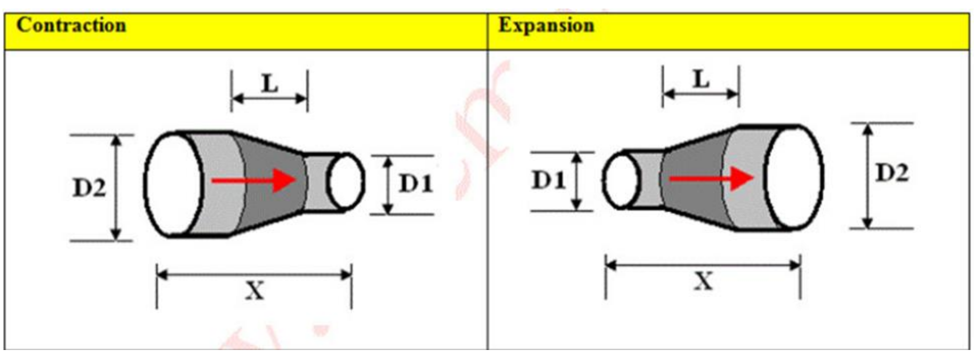


Figure 1: Contraction and Expansion Fittings [3]

Since $\theta = 75°$ the equation is

$$\text{Contraction: } K_l = \frac{0.5(1-\beta^2)}{\beta^4}\left(\sin\frac{\theta}{2}\right)^{0.5} \qquad \text{Expansion: } K_l = \frac{(1-\beta^2)^2}{\beta^4} \quad (2)$$

$$\beta = \frac{D_1}{D_2} \tag{3}$$

Where:

D_1 = Smallest Diameter

D_2 = Biggest Diameter

Reynolds number is given by:

$$R_e = \frac{\rho V D}{\mu} \tag{4}$$

Where:

Re is the Reynolds number

ρ is the density of the fluid

V is the velocity of the fluid

D is the hydraulic diameter

μ is the dynamic viscosity of the fluid

Methods

Experimental Procedure

1. The pipe inlet water valve was turned on to allow flow through the pipes
2. The valves located on the top left were turned and tuned until a desired flow was read
3. The pressure difference was read from the 180 U fitting
4. The flow was adjusted by -1 GPM and the pressure was read from the same fitting
5. This was done for all fittings until there was 5 data points per fitting

Results/ Discussion

Table 1: Delta Pressure Percent Error

Theoretical Data		Experimental Data	
Shape	**Δ Pressure (N/m^2)**	**Δ Pressure (N/m^2)**	**Percent Error %**
180 U	0	0	0
	154.824	723.975	368
	126.830	592.970	368
	99.454	475.755	378
	76.967	372.330	384
	57.433	275.800	380
Short 90	231.818	172.375	26
	209.635	137.900	34
	187.313	124.110	34
	167.824	141.348	16
	150.151	120.663	20
Contraction	317.452	668.815	111
	258.281	572.285	122
	204.696	468.860	129
	155.552	365.435	135
	115.620	296.485	156
Expansion	28.551	151.690	431
	25.713	134.453	423
	23.127	127.558	452
	20.774	99.978	381
	18.273	82.740	353
Long 90	154.855	393.015	154
	125.990	320.618	154
	99.355	289.590	191
	75.879	206.850	173
	55.748	158.585	184

The delta pressure percent error is shown in table 1, equation 1 was used to solve for this after solving for velocity at 10 gallons per minute and an area of 1 in, all the units were converted to their metric counterparts. Table 1 shows percent error between the experimental and theoretical delta pressure. There are big errors because the theoretical loss coefficients are only used to help getting the design started. The given k values in the textbook do not instill enough confidence to use in design, it seems that it would be better to perform an experiment such as this one to determine the loss values.

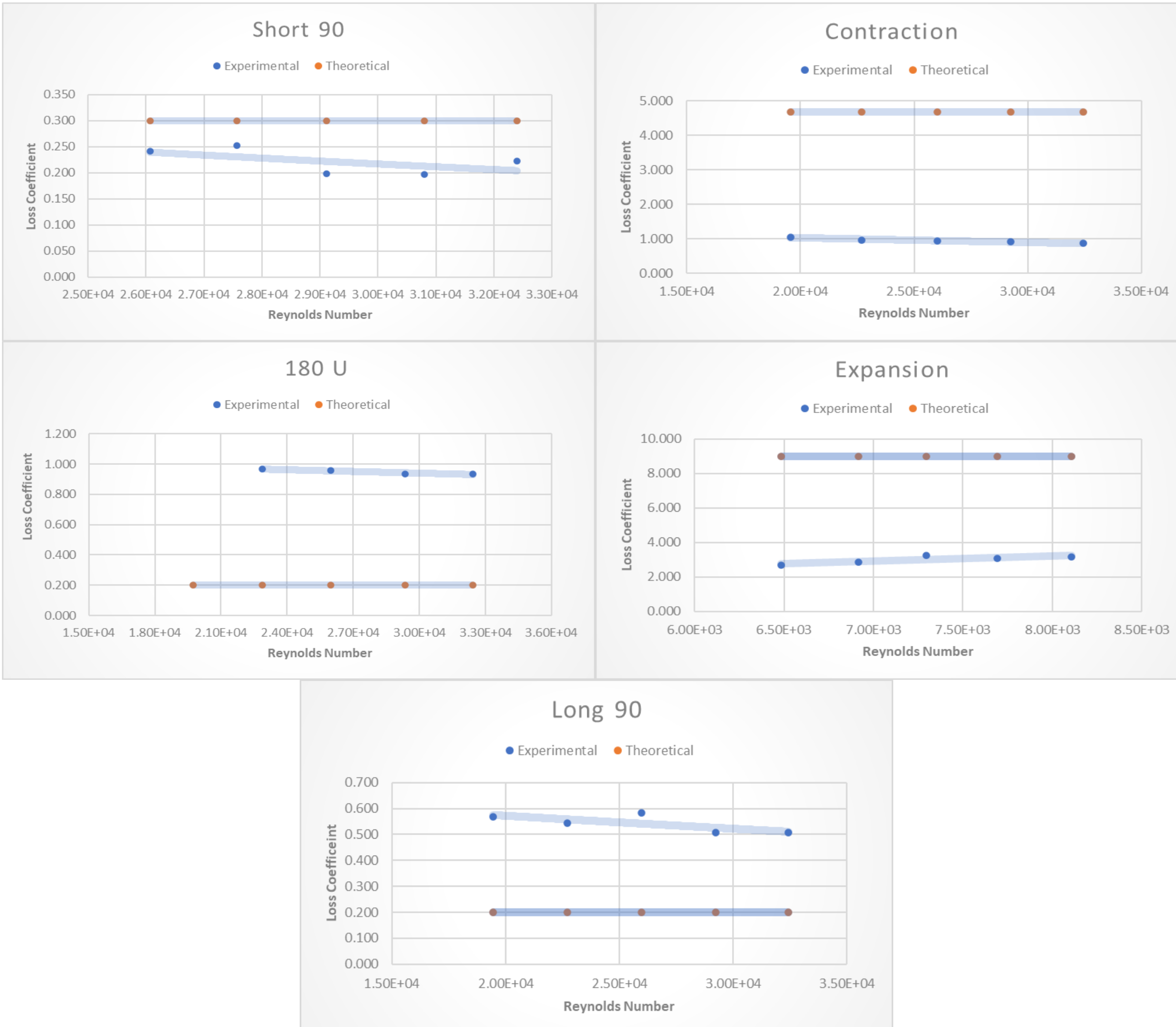


Figure 2: All Pipe Fittings Loss Coefficient vs Reynolds Number

Figure 2 shows the experimental and theoretical loss coefficient plotted against the Reynolds number, in all the cases the theoretical loss has a linear trendline, while the experimental loss coefficient begins to curve down or up as the Reynolds number increases. The flows in this experiment were never fully turbulent even at 10 GPM, most of the flows were in the transition zone.

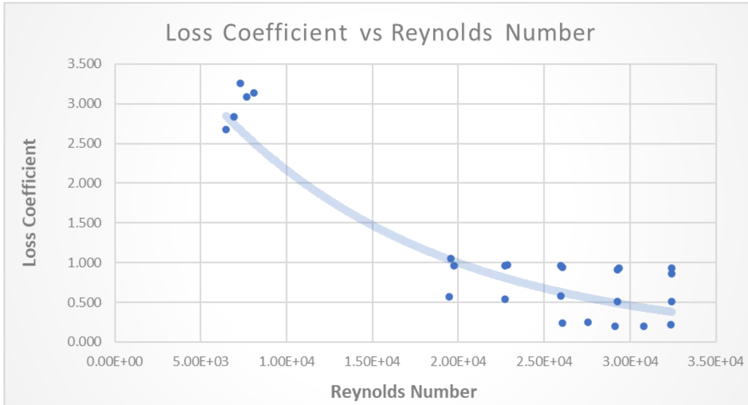


Figure 3: All Loss Coefficient vs Reynolds Number

The loss coefficient was calculated by solving for Kl in equation 1 and Reynolds number was solved using equation 4. Figure 3 shows the loss coefficient vs Reynolds number for all the pipe fittings. The loss coefficient decreases as the Reynolds number increases which means that the pressure loss also decreases as the Reynolds number increases. This makes sense because since the fluid becomes more turbulent the molecules are more random and chaotic. The molecules are less likely reverse flow at the slight bends for each fitting.

Table 2: Experimental vs Theoretical K Values

Shape	Minor Loss Experimental	Minor Loss Theoretical	Percent Error	Shape	Minor Loss	Minor Loss	Percent Error
	KL	Kth	%		KL	Kth	%
180 U				Short 90			
	0.935	0.2	368		0.223	0.3	26
	0.935	0.2	368		0.197	0.3	34
	0.957	0.2	378		0.199	0.3	34
	0.968	0.2	384		0.253	0.3	16
	0.960	0.2	380		0.241	0.3	20
Contraction				Expansion			
	0.864	4.7	82		3.135	9	65
	0.908	4.7	81		3.085	9	66
	0.939	4.7	80		3.254	9	64
	0.963	4.7	79		2.839	9	68
	1.051	4.7	78		2.672	9	70
Long 90							
	0.508	0.2	154				
	0.509	0.2	154				
	0.583	0.2	191				
	0.545	0.2	173				
	0.569	0.2	184				

Table 3 takes the percent differences for the theoretical and experimental loss coefficients. There are significant percent differences between the two. In the cases of the 180 U, and Long 90 the percent errors are over 100 percent, while the loss coefficients for the rest are less than 100 percent. It seems like the longer the pipe is, the more loss error there is.

Conclusions

The 180 U had the most percent error as the experimental losses were over 300 percent more, the short 90 had the least percent error as it was below 50 percent. It was learned for the expansion fitting that the pressure drops on the bigger area side, this is expected due to the relationship between pressure, velocity, and area. The expansion and contraction valve were found to have a 75-degree angle, if it was 90, then the loss coefficient would be close to 1.

The delta pressure drop percent error is large for all the pipe fittings, with most being over 100 percent. This is expected because of the delta pressure and minor loss relationship. The theoretical data is not reliable for practical real world pipe applications.

It was noted in figure 3 that the overall loss coefficient will decrease when the Reynolds number is increased. Overall, the experiment was a success because the loss coefficient was observed, and it was learned that the theoretical coefficients are not to be used in a real design. The loss coefficients should be experimentally derived for fluid systems to achieve the experimental k for that system. Each system will be different because the roughness of steel, copper, pvc differs.

References

1. https://moodle-courses2122.wolfware.ncsu.edu/pluginfile.php/417545/mod_folder/content/0/ASME%20MFC-3M-2004.pdf?forcedownload=1
2. https://moodle-courses2122.wolfware.ncsu.edu/pluginfile.php/417545/mod_folder/content/0/FFM-6%20Minor%20Losses.pdf?forcedownload=1
3. https://www.linkedin.com/pulse/contraction-expansion-pressure-drop-saeid-rahimi-mofrad

Appendix A: Data Collection Sheet With Calculations and Notes

Shape	Flow	Pressure	Minor Loss Experimental	Reynolds Number	Minor Loss Theoretical	Percent Error
	M^3/s	Pa (N/m^2)	K_L	Reynolds Number	K_{th}	%
180 U	6.309E-04	723.975	0.935	3.24E+04	0.2	368
	5.710E-04	592.970	0.935	2.93E+04	0.2	368
	5.056E-04	475.755	0.957	2.60E+04	0.2	378
	4.448E-04	372.330	0.968	2.29E+04	0.2	384
	3.842E-04	275.800	0.960	1.97E+04	0.2	380
Short 90	6.303E-04	172.375	0.223	3.24E+04	0.3	26
	5.994E-04	137.900	0.197	3.08E+04	0.3	34
	5.666E-04	124.110	0.199	2.91E+04	0.3	34
	5.363E-04	141.348	0.253	2.76E+04	0.3	16
	5.073E-04	120.663	0.241	2.61E+04	0.3	20
Contraction	6.309E-04	668.815	0.864	3.24E+04	4.68	82
	5.691E-04	572.285	0.908	2.92E+04	4.68	81
	5.066E-04	468.860	0.939	2.60E+04	4.68	80
	4.416E-04	365.435	0.963	2.27E+04	4.68	79
	3.808E-04	296.485	1.051	1.96E+04	4.68	78
Expansion	6.309E-04	151.690	3.135	8.11E+03	9	65
	5.987E-04	134.453	3.085	7.69E+03	9	66
	5.678E-04	127.558	3.254	7.30E+03	9	64
	5.382E-04	99.978	2.839	6.91E+03	9	68
	5.047E-04	82.740	2.672	6.49E+03	9	70
Long 90	6.309E-04	393.015	0.508	3.24E+04	0.2	154
	5.691E-04	320.618	0.509	2.92E+04	0.2	154
	5.054E-04	289.590	0.583	2.60E+04	0.2	191
	4.416E-04	206.850	0.545	2.27E+04	0.2	173
	3.785E-04	158.585	0.569	1.95E+04	0.2	184

Appendix B: Hand Calculations

$$K_L = \frac{h_{L minor}}{\frac{V^2}{2g}} = \frac{\Delta p}{\frac{1}{2}\rho V^2}$$

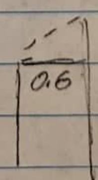
$$h_{minor} = K_L \cdot \frac{V^2}{2g} \qquad (8.36)$$

Frictional losses through a pipe is the

Equation 8.36 is different because it does not need

~~Reynolds number~~ The friction factor is very large for a fully turbulent flow. So for equation 8.36 you would express the loss coefficient as a function of temperature

Short Radius
Elbow
long Radius Elbow
180°R
Expansion
Contraction



$$\tan^{-1}\left(\frac{0.5}{0.6}\right) = 75°$$

Angle for contraction / Expansion

Equipment

Equipment used:
Water Flow Bench Dial Calipers