

Fluid Mechanics & its Applications
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Lecture 20A
Losses in Pipe-Fittings

(Refer Slide Time: 00:20)

Head losses in pipe fittings

In any piping system there are additional head losses due to separation of flow from the walls of the pipes and the resulting eddies. Such separation occurs whenever there is a change in area of the pipe, or a change in direction of the flow.

Consequently, these losses are associated with pipe entrances and exits, sudden expansions and contractions, pipe fittings such as bends, elbows, tees and unions, open or partially-closed valves such as ball valves, gate valves, swing check valves and diaphragm valves and any other fittings.



Head losses in pipe fittings

Since the flow patterns through most of these *fittings* are too complex to be modelled analytically, the head losses are specified as experimentally-determined correlations. For turbulent flows, the condition most common in engineering piping-systems, the head loss for a fitting is usually specified as a fraction (or multiple) of K of the kinetic energy head.

The non-dimensional factor K is termed as the *loss coefficient* and depends, in general, on the geometry of the fitting and the Reynolds number Re_D . For practical flow calculations, however, it is conventional to use the highest (asymptotic) value of K independent of Re_D giving slightly conservative results.

$$h_L = K \cdot \frac{V^2}{2g}$$



Head losses in pipe fittings

The head loss in a piping system can be written as

$$h_L = \frac{v^2}{2g} \left(f \frac{L}{D} + \sum K \right)$$

↑
Minor losses



In any piping system, there are additional head losses due to separation of flow from the walls of the pipe and resulting eddies. Such separation occurs whenever there is a change in area of the pipe, or a change in direction of the flow, that is, at pipe fittings. Consequently, these losses are associated with pipe entrances and exits, sudden expansion and contraction, in pipe fittings such as bends, elbows, tees and unions; open or partially closed valves such as ball valves, gate valves, swing check valves, and diaphragm valves, and in any other fittings.

Since the flow patterns through most of these fittings are too complex to be modeled analytically, the head losses are specified as experimentally-determined correlations. For turbulent flows, that is the condition in most engineering piping-systems, the head loss for a fitting is usually specified as a fraction or multiple K of the kinetic energy head. The non-dimensional factor K is termed as the loss coefficient, and depends, in general, on the geometry of the fitting, and the Reynolds number. For practical flow calculations, however, it is conventional to use the highest asymptotic value of K , independent of the Reynolds number, giving us slightly conservative results.

Therefore, the head loss through any fitting can be expressed as h_L is equal to K times the velocity head. So, the head loss is $h_L = \frac{v^2}{2g} \left(f \frac{L}{D} + \sum K \right)$. $\sum K$ is called the minor losses, because in most piping system $f \frac{L}{D}$ is much larger than $\sum K$.

(Refer Slide Time: 03:10)

Loss coefficients at pipe entrances

Type	Shape	r/D	Typical K
Flush/Square-Edged		-	0.5
		0.02	0.28
Rounded		0.04	0.24
		0.06	0.15
		0.10	0.09
		0.15	0.04
		-	0.04
Re-entrant		-	0.78
Chamfered		-	0.25

We give here the head loss coefficients K for the various pipe fittings.

In this first slide, we talk of the pipe entrances. If I have a flush or a square-edged entrance as shown here, the typical value of K is 0.5. When the entrance is rounded, the value of K depends upon r/D , the radius of the rounding and the diameter of the pipe, and for r/D varying from 0.02 to 0.15, the values of K are 0.28 to 0.04, 0.28 when the radius of the round is least, and 0.04, a low value, when the radius is large. For a re-entrant pipe, one shown here, the value of K is quite large 0.78. For chamfered entrance, the value of K is 0.25.

(Refer Slide Time: 04:56)

Losses at pipe entrances

When a pipe exits in to a large reservoir all its kinetic energy head is lost. Since $\frac{v_{av}^2}{2g}$ represents the kinetic energy head based on average velocity, the true KE head is $\gamma \frac{v_{av}^2}{2g}$

Exit type	K
Exit in confined space 	KE correction factor, γ For laminar flows = 2 For turbulent flows = 1
Exit in unconfined space 	0

When a pipe exits into a large reservoir, all its kinetic energy head is lost. Since, $\frac{v^2}{2g}$ represent the kinetic energy head based on the average velocity, the true kinetic energy head is $\gamma \frac{v^2}{2g}$, where γ is the kinetic energy correction factor. So, when the exit is in a confined space, that is, the pipe is exiting into a tank, then all of the kinetic energy is lost. And we have kinetic energy factor equal to the value of K. For laminar flows, the kinetic energy correction factor is 2. For turbulent flow, the kinetic energy correction factor is 1. And when the flow exits into unconfined space, that is, it comes out as a jet, no energy is lost, and so, the value of K is 0.

(Refer Slide Time: 06:11)

Losses at sudden change in area

The slide contains two diagrams illustrating fluid flow through a sudden change in pipe area. The left diagram shows a sudden expansion from a smaller pipe to a larger pipe. Below it is the formula for head loss: $h_l = \frac{v_1^2}{2g} \left(1 - \frac{A_1}{A_2}\right)^2$. The right diagram shows a sudden contraction from a larger pipe to a smaller pipe. Below it is the formula for head loss: $h_l = \frac{v_1^2}{2g} \left(1 - \frac{A_1}{A_2}\right)$. A note below the contraction formula states: "This is valid up to $d/D = 0.76$, after which it merges with the equation for sudden expansion." The NPTEL logo is visible in the bottom left corner of the slide.

Losses at a sudden change in area. At a sudden expansion, the head loss is given by $h_l = \frac{v_1^2}{2g} \left(1 - \frac{A_1}{A_2}\right)^2$. This had been obtained in an earlier lecture. The losses at a sudden decrease in area, sudden contraction, is given by this formula. This is valid up to d/D is equal to 0.76, lowercase d is the value of the smaller pipe, D is the diameter of the larger pipe from which the flow is coming. When d/D is larger than 0.76, the result is like this.

(Refer Slide Time: 07:22)

Head losses in pipe fittings

Fitting	K	Tees	
Bends		Tee, flanged, dividing line flow	0.2
Return bend, flanged 180°	0.2	Tee, flanged, dividing branched flow	1
Return bend, threaded 180°	1.5	Tee, threaded, dividing branch flow	2
Elbows		Tee, threaded, dividing line flow	0.9
Elbow, flanged long radius 45°	0.2	Union, threaded	0.08
Elbow, flanged long radius 90°	0.2		
Elbow, flanged regular 90°	0.3		
Elbow, threaded long radius 90°	0.7		
Elbow, threaded regular 45°	0.4		
Elbow, threaded regular 90°	1.5		



Head losses in pipe fittings

Valves	K
Angle valve, fully open	2
Ball valve, 1/3 closed	5.5
Ball valve, 2/3 closed	200
Ball valve, fully open	0.05
Diaphragm valve, 1/4 open	21
Diaphragm valve, half open	4.3
Diaphragm valve, open	2.3
Gate valve, 1/2 closed	2.1
Gate valve, 1/4 closed	0.26
Gate valve, 3/4 closed	17
Gate valve, fully open	0.15
Globe valve, fully open	10
Swing check valve, forward flow	2



This table gives you the head losses for the various kinds of pipe fittings: bends, elbows, tees, unions. These are typical values. A piping engineer refers to the data supplied by the manufacturer of the fittings to determine what the actual value of K would be. Head losses in the valves vary widely depending upon how much closure is there. For example, a ball valve fully open results in a K value of 0.05, 0.05. But, while it is two-thirds closed, the value is as high as 200.

(Refer Slide Time: 08:32)

Head losses in pipe fittings

Determine \dot{Q}

$0 + 0 + 5 = 0 + 0 + 40 - h_l \Rightarrow h_l = 35 \text{ m} \quad h_l = 35 \text{ m} = \left(f \frac{L}{D} + \sum K_i \right) \frac{V^2}{2g}$

GI pipe: $\frac{\epsilon}{D} = \frac{0.15 \text{ mm}}{50 \text{ mm}} = 0.003$

Head losses in pipe fittings

Fitting	K
Entrance, well-rounded	0.09
Elbows, 2	2×0.7
Globe valve, fully-open, 2	2×10
Exit, submerged	1 ✓
TOTAL	22.49

Determine \dot{Q}

$h_l = 35 \text{ m} = \left(f \frac{200}{0.050} + 22.49 \right) \frac{V^2}{2g}$

Let us do an example. The diagram shows a piping system in which a 200-m, 50-mm galvanized iron pipe is connecting two reservoirs. One reservoir at an altitude of 40 m, and the other reservoir in which the level is at 5 m altitude. There are two globe valves, two 90-degree elbows into the system. There is an entrance, the water is flowing from the higher reservoir into the lower reservoir, and there is an exit.

So, there will be two kinds of head losses, one because of friction in the pipe, and the other the minor losses because of pipe fittings. First, we apply the Bernoulli equation between point 1 and

point 2 shown. At the exit, the total head consists of the pressure head, the velocity head, and the altitude head. This is at the exit.

And this is equal to the total head at the entrance minus the head loss. Total head at the entrance: the velocity at 0 at 1, 0 is the pressure at 1 which is open to atmosphere. Altitude is 40 m minus h_l . So, this gives you h_l is equal to 35 m. We are losing 35 m head in the flow of water. The head loss is given by this formula.

For the GI pipe, ϵ/D can be determined. ϵ is 0.15 mm for galvanized iron pipe. The diameter of the pipe is 50 mm, so ϵ/D value is 0.003. We determine the $\sum K$ for the minor losses. We have a well-rounded entrance that is given to us, so the value of K is 0.09 from the table. There are two large radius elbows. Each elbow has a coefficient of 0.7, so, for two elbows it will be 2×0.7 . We have two fully-open globe valves, each with K is equal to 10, and a submerged exit. And we have assumed the flow to be turbulent, the value of K is 1. $\sum K$ then would be 22.49. And from the head loss equation, we get this. We need the value of f to determine $\frac{V^2}{2g}$. We can follow the same process that we followed earlier.

(Refer Slide Time: 12:30)

Head losses in pipe fittings

$$35 \text{ m} = \left(f \frac{200}{0.050} + 22.49 \right) \frac{V^2}{2g}$$

GI pipe: $\frac{\epsilon}{D} = \frac{0.15 \text{ mm}}{50 \text{ mm}} = 0.003$

We start with $f = 0.026$ for fully-turbulent flow for $\epsilon/D = 0.003$.

f	V	Re	f calculated
0.026	2.330	116500	0.0273 ✓
0.0273	2.284	114177	0.0273 ✓

The resulting flow rate is
 $\dot{Q} = 4.50 \times 10^{-3} \text{ m}^3/\text{s}$ or $16.3 \text{ m}^3/\text{hr}$

And by iteration, we can determine the values. Since, D is given, an ϵ/D can be calculated. We look up the value of f for the fully-developed turbulent flow in pipes with ϵ/D , the relative roughness of 0.003, and we obtain f as 0.026. And then, we do iterations. From the first value we

get a velocity of 2.330, and the f can be calculated from either the Moody chart or the Colebrook calculator, and the value comes out to be 0.0273.

We use this as a starting value in the next round. The velocity now comes out to 2.284. The Reynolds number changes slightly, but the value of f is unchanged. And since the value of f has not changed, our iterations are over, and the results have converged. The value of velocity through pipe is 2.284 meters per second. Of course, the number of significant figures we have specified are much more than what is valid. With this velocity, the volume flow rate is 16.3 m³/hr.