Pipeline hydraulics design basis engineering essay

It includes the pipe and flow characteristics of the transported fluid under specified operating conditions as established in the design basis.

Velocity

The pipeline has to be laid for the distance of 770km between Portland and Montreal, the fluid in the pipe is Light Crude Oil.

Velocity of flow in a pipeline is the average velocity based on the pipe diameter and liquid flow rate. Its selection is first step in the designing procedure of our project. The flow velocity can have both advantages and drawbacks. High velocities can cause turbulence, and the striking of the fluid on the walls of the pipe which will cause damage to the pipes and eventually erode away the pipe, while low velocity on the other hand can cause the deposition of particulates in the line and cleanliness of the fluid will be compromised. Therefore, to avoid these problemsliquid lines are normally sized to maintain a velocity sufficient to keep the solid particles from depositing and also to prevent the erosion of the pipe. Under these considerations the recommended velocity is in the range of 3ft/s to 8ft/s.

From this selected range of velocity we have to select a single velocity. The velocity we have selected for our line is 5ft/s. This is the intermediate velocity from the recommended range and all the further calculations will be done on this velocity.

Velocity Selection

The range as mentioned above is taken as 3ft/s to 5ft/s. The next step is to select a single velocity from this range. We have selected 5ft/s for our line. The reason for this velocity selection is the trade-off between pipe diameter and number of pump stations. According to continuity equation if we increase the velocity, the corresponding diameter will reduce but the pressure loss will increase due to which a higher number of pump stations are required. Similarly if we decrease the velocity, the number of pump stations will reduce but the diameter will increase for a given flow rate. Since the pipeline is laid over a long distance, the pipeline cost holds the major share of the capital investment therefore increasing the diameter will adversely affect the economics of pipeline. This trade-off is visible in the calculations shown in appendix A.

The other reason for choosing this velocity is that if the flow rate fluctuates in the future for any reason the diameter selected from this intermediate velocity will be able to accommodate those variations without affecting our system.

Diameter Calculation

Calculation of the diameter is the core of the hydraulic designing. The diameter selected should be able to support the stresses on the pipe, the capacity of the fluid and minimize the pressure losses.

Under given flow rate and assumed velocities, we can calculate the pipe diameter using continuity equation:

$$V = Q/A$$

V: Flow velocity

Q: Volume flow rate

A: Cross sectional area

The flow rate is given as 109, 000bbl/day or 7. 1ft^3/s. The diameters are calculated at 3, 4, 5ft/s velocities and the respective diameters are 20. 83″, 18. 04″ and 16. 14″.

Selection of Diameter

As mentioned above 5ft/s is selected as the recommended velocity and the corresponding internal diameter (ID) is 16. 14in.

Nominal Pipe Size

For the internal diameter subsequently we have to calculate the nominal pipe size. To calculate the nominal diameter we refer to the " Pipe Data" provided for the Carbon Steel. From the table shown in appendix B, it is found out that consequent nominal pipe size will be 18in.

Characteristics of Flow

Different flow properties are calculated to determine the regime of flow, losses in the pipes.

The nature of the flow can be laminar or turbulent. There are two types of the losses. Major losses include the losses due to friction in straight pipes and minor losses due to bends, valves, tees.

To calculate these we will be dealing with Reynolds number (for nature of flow), Moody diagram (for friction factor) and head loss calculations.

Losses

As the fluid flows through the pipe there is friction at the pipe wall and fluid interface in the straight portions of the pipe due to interference between the fluid and the walls of the pipe. This friction results in results in the loss of energy in the lineat the expense of liquid pressure and the losses are known as the major losses.

Pipe systems consist of components in addition to straight pipes. These include bends, valves, tees etc and add further to the losses in the line. These losses are termed as minor losses. Experimental data is used to calculate these losses as the theoretical prediction is complex.

Major Losses

The pressure drop due to friction in a pipeline depends on the flow rate, pipe diameter, pipe roughness, liquid specific gravity, and viscosity. In addition, the frictional pressure drop depends on the Reynolds number (and hence the flow regime). Therefore, the fluid in the pipeline will undergo pressure losses as it runs in the line and reduce the operating pressure. This loss needs to be recovered and to maintain the pressure pumps are installed at specific locations according to the requirement (pumps are discussed in Chapter ahead). These pressure losses are calculated by using the Darcy-Weisbach formula

â^†P = f(L/D)(V^2/2)Ï

Where,

f= Darcy friction factor, dimensionless, usually a number between 0. 008 and 0. 10

L= Pipe length, ft

D= Pipe internal diameter, ft

The pressure loss for velocity of 5ft/s comes out to be 9625. 15psi. All the relevant calculations are shown in appendix A.

Minor Losses

Real pipeline systems mostly consist of more than straight pipes. The additional components (valves, tees and bends) add to the overall loss of the system. These are termed as minor losses. In case of very long pipes, these losses are usually insignificant incomparison to the fluid friction in the length considered. But in case of short pipes, these minor losses may actually be major losses such as in suction pipe of a pumpwith strainer and foot valves. These losses represent additional energy dissipation in the flow, usually caused by secondary flows induced by curvature or recirculation.

Minor loss in diverging flow is much larger than that in converging flow. Minor lossesgenerally increase with an increase in the geometric distortion of the flow. Thoughminor losses are usually confined to a very short length of path, the effects may notdisappear for a considerable distance downstream. It is insignificant in case of laminar flow.

The pressure drop through valves and fittings is generallyexpressed in terms of the liquid kinetic energy V2/2g multiplied by a head loss coefficient K. Comparing this with the Darcy-Weisbach equation for head loss in a pipe, we can see the following analogy. For a straight pipe, the head loss h is V2/2g multiplied by the factor (fL/D). Thus, the head loss coefficient for a straight pipe is fL/D.

Therefore, the pressure drop in a valve or fitting is calculated as follows:

h= K(V^2)/2g

Where,

h= Head loss due to valve or fitting, ft

K= Head loss coefficient for the valve or fitting, dimensionless

V= Velocity of liquid through valve or fitting, ft/s

g= Acceleration due to gravity, 32. 2 ft/s2 in English units

The head loss coefficient K is, for a given flow geometry, considered practically constant at high Reynolds number. K increases with pipe roughness and with lower Reynolds numbers. In general the value of K is determined mainly by the flow geometry or by the shape of the pressureloss device.

Minor loss is generally expressed in one of the two ways

In terms of minor loss factor K.

In terms length, equivalent to a certain length of straight pipe, usuallyexpressed in terms of number of pipe diameter.

The minor losses for our system are calculated and result in a very low value and can easily be neglected.

Reynolds Number

Flow in a liquid pipeline may be smooth, laminar flow, also known as viscous or streamline flow. In this type of flow the liquid flows in layers or laminations without causing eddies or turbulence. But as the velocity increases the flow changes from laminar to turbulent with eddies and turbulences. The important parameter used in classifying the type of flow in the pipe is called Reynolds Number.

Reynolds number gives us the ratio of inertial forces to viscous forces and is used to determine the nature of flow using the recommended velocity and the internal diameter. Reynolds number is given by

Re = Ï VD/µ

Flow through pipes is classified into three main flow regimes and depending upon the Reynolds number, flow through pipes will fall in one of the following three flow regimes.

1. Laminar flow: R <2000

2. Critical flow: R> 2000 and R <4000

3. Turbulent flow: R> 4000

Friction Factor

Friction Factor is a dimensionless number required to calculate the pressure losses in the pipe. Tests have shown that f is dependent upon Reynolds number and relative roughness of the pipe. Relative roughness is ratio of absolute pipe wall roughness Îµ to the pipe diameter D.

For laminar flow, with Reynolds number R <2000, the Darcy friction factor f is calculated from the simple relationship

f= 64/R

For laminar flow the friction factor depends only on the Reynolds number and is independent of the internal condition of the pipe. Thus, regardless of whether the pipe is smooth or rough, the friction factor for laminar flow is a number that varies inversely with the Reynolds number.

For turbulent flow, when the Reynolds number R> 4000, the friction factor f depends not only on R but also on the internal roughness of the pipe. As the pipe roughness increases, so does the friction factor. Therefore, smooth pipes have a smaller friction factor compared with rough pipes. More importantly, friction factor depends on the relative roughness (Îµ/D) rather than the absolute pipe roughness Îµ.

In the turbulent region it can be calculated using either the Colebrook-White equation or the Moody Diagram.

Colebrook-White Equation

The Colebrook equation is an implicit equation that combines experimental results of studies of turbulent flow in smooth and rough pipe The Colebrook equation is given as:

1/âˆšf = -2log((Îµ/3. 7D)+(2. 51/Reâˆšf))

But the turbulent flow region (R> 4000) consists of three separate regions:

Turbulent flow in smooth pipes

Turbulent flow in fully rough pipes

Transition flow between smooth and rough pipes

For turbulent flow in smooth pipes, pipe roughness has a negligible effect on the friction factor. Therefore, the friction factor in this region depends only on the Reynolds number as follows:

1/âˆšf = -2log(2. 51/Reâˆšf)

For turbulent flow in fully rough pipes, the friction factor f appears to be less dependent on the Reynolds number as the latter increases in magnitude. It depends only on the pipe roughness and diameter. It can be calculated from the following equation:

1/âˆšf = -2log((Îµ/3. 7D)

For the transition region between turbulent flow in smooth pipes and turbulent flow in fully rough pipes, the friction factor f is calculated using the Colebrook-White equation given above:

1/âˆšf = -2log((Îµ/3. 7D)+(2. 51/Reâˆšf))

Moody Diagram

The Colebrook equation is an implicit equation and requires trial and error method to calculate f. To provide the ease for calculating f scientists and researchers developed a graphical method known as Moody diagram. The Moody chart or Moody diagramis a graph that relates the friction factor, Reynolds number and relative roughness for fully developed flow in a circular pipe. In the diagram friction factor is plotted verses Reynolds number. The curves are plotted using the experimental data. The Moody diagram represents the complete friction factor map for laminar and all turbulent regions of pipe flows.

To use the Moody diagram for determining the friction factor f we first calculate the Reynolds number R for the flow. Next, we find the location on the horizontal axis of Reynolds number for the value of R and draw a vertical line that intersects with the appropriate relative roughness (e/D) curve. From this point of intersection on the (e/D) curve, we read the value of the friction factor f on the vertical axis on the left.

Other Pressure Drop Relations

Hazen-Williams Equation

The Hazen-Williams equation is commonly used in the design of waterdistribution lines and in the calculation of frictional pressure drop inrefined petroleum products such as gasoline and diesel. This methodinvolves the use of the Hazen-Williams C-factor instead of pipe roughnessor liquid viscosity. The pressure drop calculation using the Hazen-Williams equation takes into account flow rate, pipe diameter, and specificgravity as follows:

h= 4. 73L(Q/C)1. 852/D4. 87

Where,

h= Head loss due to friction, ft

L= Pipe length, ft

D= Pipe internal diameter, ft

Q= Flow rate, ft3/s

C= Hazen-Williams coefficient or C-factor, dimensionless

In customary pipeline units, the Hazen-Williams equation can berewritten as follows in English units:

Q= 0. 1482(C)(D)2. 63 (Pm/Sg)0. 54

Where,

Q= Flow rate, bbl/day

D= Pipe internal diameter, in.

Pm= Frictional pressure drop, psi/mile

Sg= Liquid specific gravity

Another form of Hazen-Williams equation, when the flow rate is in gal/ min and head loss is measured in feet of liquid per thousand feet of pipe is as follows:

GPM= 6. 7547Ã-10-3(C)(D)2. 63(HL)0. 54

Where,

GPM= Flow rate, gal/min

HL= Friction loss, ft of liquid per 1000 ft of pipe

In SI units, the Hazen-Williams equation is as follows:

Q= 9. 0379Ã-10-8(C)(D)2. 63(Pkm/Sg)0. 54

Where,

Q= Flow rate, m3/hr

D= Pipe internal diameter, mm

Pkm= Frictional pressure drop, kPa/km

Sg= Liquid specific gravity

Shell-MIT Equation

The Shell-MIT equation, sometimes called the MIT equation, is used in the calculation of pressure drop in heavy crude oil and heated liquid pipelines. Using this method, a modified Reynolds number Rm iscalculated first from the Reynolds number as follows:

R= 92. 24(Q)/(DÎ½)

Rm= R/(7742)

Where,

R= Reynolds number, dimensionless

Rm= Modified Reynolds number, dimensionless

Q= Flow rate, bbl/day

D= Pipe internal diameter, in.

Î½= Kinematic viscosity, cSt

Than depending on the flow (laminar or turbulent), the friction factor is calculated from one of the following equations:

f= 0. 00207/Rm (laminar flow)

f= 0. 0018+0. 00662(1/Rm)0. 355 (turbulent flow)

Finally, the pressure drop due to friction is calculated using theequation

Pm= 0. 241(f SgQ2)/D5

Where,

Pm= Frictional pressure drop, psi/mile

f= Friction factor, dimensionless

Sg= Liquid specific gravity

Q= Flow rate, bbl/day

D= Pipe internal diameter, in.

In SI units the MIT equation is expressed as follows:

Pm= 6. 2191Ã-1010(f SgQ2)/D5

Where,

Pm= Frictional pressure drop, kPa/km

f= Friction factor, dimensionless

Sg= Liquid specific gravity

Q= Flow rate, m3/hr

D= Pipe internal diameter, mm