Water Supply Engineering
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Lecture-45
Problems on Pipe Flow and Water Distribution Network

Welcome back friends, so we are concluding the week 8 discussions today we have already talked about the theoretical concepts all like we discussed about water distribution systems this week and we initiated with the basics on water distribution system. Then we did talk about the water network what are the various layout of the networks what are the various comp1nts of a water distribution system.

Some of things like pumps or the storage systems we had discussed earlier. So, we skip this those in this particular week but other concepts we discussed we discussed about the network analysis how what are the different methods is specifically hardy-cross method for network analysis. We also discussed about the pipes and basically the series and parallel arrangements of pipe also we covered. We covered about the energy heads in the pipe flow. So, in this last class for this week we are going to take some practice problem on some of those concepts which we discussed.

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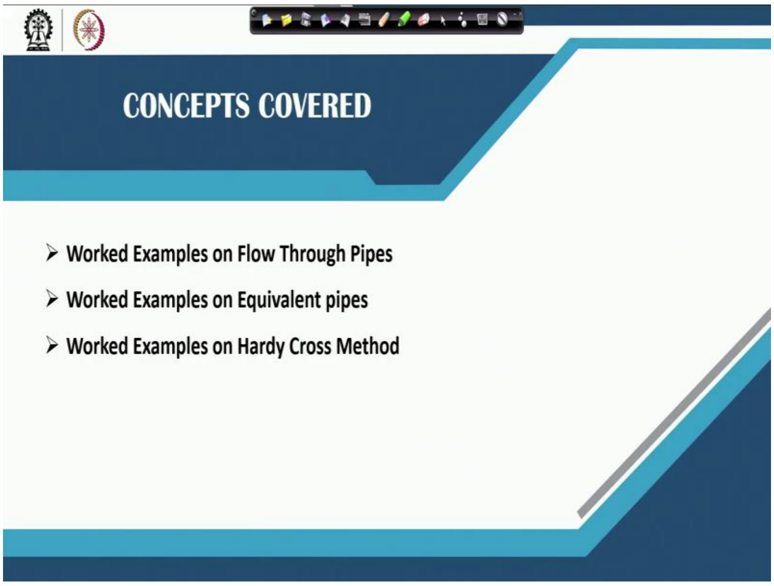

CONCEPTS COVERED

- Worked Examples on Flow Through Pipes
- Worked Examples on Equivalent pipes
- Worked Examples on Hardy Cross Method

So, will be basically taking about practice problems on flow through pipes than equivalent pipes and 1 example on Hydra cross method.

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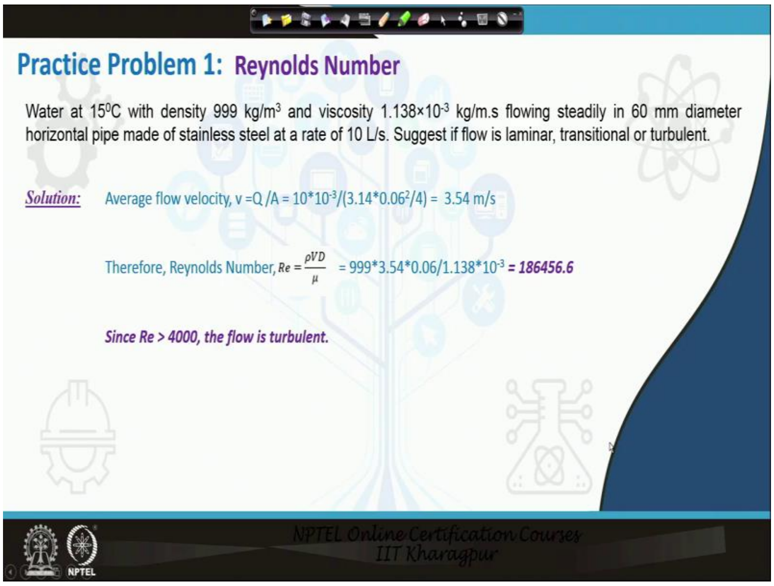

Practice Problem 1: Reynolds Number

Water at 15^0C with density 999 kg/m^3 and viscosity 1.138×10^{-3} kg/m.s flowing steadily in 60 mm diameter horizontal pipe made of stainless steel at a rate of 10 L/s. Suggest if flow is laminar, transitional or turbulent.

Solution: Average flow velocity, $v = Q/A = 10*10^{-3}/(3.14*0.06^2/4) = 3.54$ m/s

Therefore, Reynolds Number, $Re = \frac{\rho VD}{\mu}$ $= 999*3.54*0.06/1.138*10^{-3}$ **= 186456.6**

Since Re > 4000, the flow is turbulent.

So, to begin with the first problem that we are going to discuss is just based on the Reynolds number estimation. So, it says that water at 15 degree Celsius has a density of 999 kg per meter cube and viscosity is given. Then it is flowing steadily in 60 mm diameter horizontal pipe made of stainless steel at a rate of 10 liter per second. So, we need to suggest if the flow is laminar transitional or turbulent.

So, the average flow velocity is going to be discharge divided by the cross-sectional area discharge is 10 liter per second that means 10 into 10 to the power 3 meter cube per second is the discharge and cross sectional area is PI D square by 4 and D is basically 60 mm that means 0.06 meter. So, square of this into PI divided by 4 will give us the area and this is basically the discharge. So, the velocity comes as 3.54 meter per second.

Now Reynold number is Rho VD by mu so Rho is given 999 velocity is 3.54 meter and dia is 0.06 meter and then the viscosity is given 1.138 into 10 to the power -3. So, we get the Reynold number as 186456.6 now if you recall the discussions for Reynold number less than 2000 we call that flow as laminar if Reynold number is greater than 4000 we call that flow as turbulent and in between if it is in between these 2 numbers so that is basically the transitional flow.

Now since our Raynolds number is much, much greater than 4000 it is basically 186000 or 186000 we can say which is far more higher than 4000 so we can conclude that the flow is turbulent. So, that is how we basically we can use the concept of Reynold number for determining if the flow is turbulent or linear.

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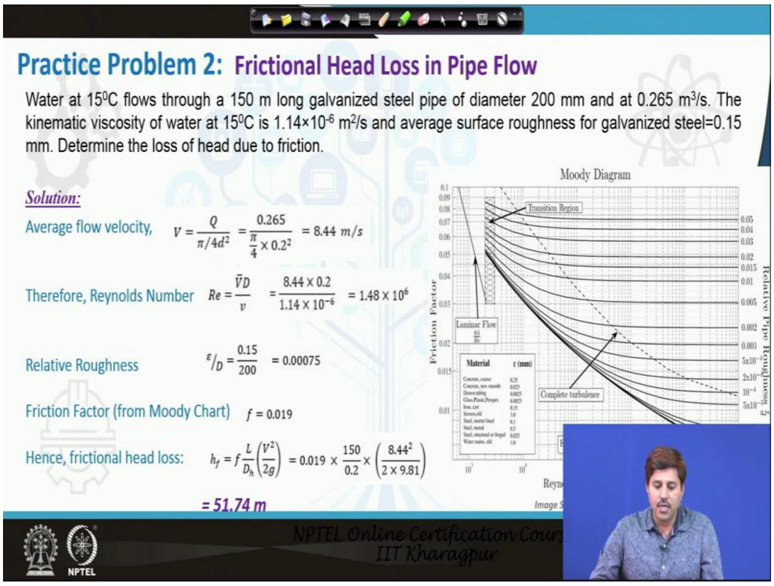

Practice Problem 2: Frictional Head Loss in Pipe Flow

Water at 15⁰C flows through a 150 m long galvanized steel pipe of diameter 200 mm and at 0.265 m^3/s. The kinematic viscosity of water at 15⁰C is 1.14×10^{-6} m^2/s and average surface roughness for galvanized steel=0.15 mm. Determine the loss of head due to friction.

Solution:

Average flow velocity, $V = \frac{Q}{\pi/4d^2} = \frac{0.265}{\frac{\pi}{4}\times 0.2^2} = 8.44\ m/s$

Therefore, Reynolds Number $Re = \frac{\bar{V}D}{\nu} = \frac{8.44\times 0.2}{1.14\times 10^{-6}} = 1.48\times 10^6$

Relative Roughness $^{\varepsilon}/_{D} = \frac{0.15}{200} = 0.00075$

Friction Factor (from Moody Chart) $f = 0.019$

Hence, frictional head loss: $h_f = f\frac{L}{D_h}\left(\frac{V^2}{2g}\right) = 0.019\times\frac{150}{0.2}\times\left(\frac{8.44^2}{2\times 9.81}\right)$

$= 51.74\ m$

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Now second problem is about the friction head losses in the pipe. So, we have water flowing at 15 degree Celsius through a 150 meter long galvanized steel pipe of diameter 200 mm at 0.265 meter cube per second discharge the kinematic viscosity is given and the average surface roughness for the GI material is also given as 0.15 mm. We need to determine the loss of the head due to friction.

Now for this purpose the frictional head loss is determined using like we can use this formula so FL Vsquare by 2 g D in this particular case we know the dia of the pipe dia of the pipe is given to us g value is given to us length of the pipe is given to us. Velocity we can determined from the discharge equation. So, we have the discharge as 0.265 Q divided by PI by 4 into d square and dia is 200 mm that means 0.2 meter.

So, 0.2 meter and we get a value of 8.44 meter per second velocity which is quite a high velocity. So, the velocity is given to us then what else we need is the friction factor. Now how we determine friction factor? If friction factor is not given as discussed we can use the Moody's diagram. So, let us say this is the Moody's diagram from here we can get the friction factor. Friction factor depends on the Reynolds number and the relative pipe roughness, the relative roughness.

And relative roughness is the average roughness divided by the dia average surface roughness is given to us 0.15, so 0.15 value is given and remember this value is in mm so this is 0.15 mm. So, we need to determine divide it with the dia and dia also has to be in mm because this roughness is in mm. So, 0.15 divided by dia is 200 mm so. 1 5 divided by 200 this gives us 000075 as the relative roughness. We also need Reynold number for determination of the friction factor.

Now Reynold number is just like in previous problem we saw Reynalds number is Rho VD by mu which can also be written as VD by mu divided by Rho and thing is known as the kinematic viscosity nu which is given to us. So, this will be V into D divided by nu. So, velocity we just estimated 8.44 dia is 0.2 meter and the kinematic viscosity nu value is given as 1.14 into 10 to the power of -6, so this gives us the Reynold number as 1.48 into 10 to the power 6.

So now we have the Reynolds number available with us and we have this a relative roughness available with us, so we can use the Moody's diagram, so here the random Reynold number is 1.48 into 10 to the power 6 means 1.5 into 10 to the power 6 around. So, this is the 1 into 10 to the power 6 this is the 10 into 10 to the power 6 this is going to be 2 into 10 to the power 6 so 1.5 into 10 to the power 6 is somewhere in between so this is the line say for your depending on the Reynolds number of the flow that we have estimated.

So this is our Reynold number now the surface relative roughness is 0.00075 so this is 0.0001 and this is 0.001 in fact this is going to be 0.0005 and we have .0007 so this we need to have it somewhere here in between Reynold number because this is 5 into 10 to the power -4 that means 0.0005 this is 5 into 10 to the power -4 so our number is larger than this but our number the next that you see is 0.001 so 001 or you can say 10 so this is 0.0010 this is 0.0005 our number is .007 so somewhere in between this.

Again so our number is somewhere here so from this thing our intersection is at this point or like the curve that will be going like this so our intersection is at this point and then from here we can estimate our friction factor which will be for this case around 0.019. So, we can use this friction factor now as just we were discussing earlier that we have already estimated V we know the length of the pipe 150 meter we know the dia of the pipe G value is known to us anyway.

Friction factor we have estimated so we can compute the head loss which is coming out at 50 1.74 meter in this case this is a very high head loss for 150 meter long pipe.

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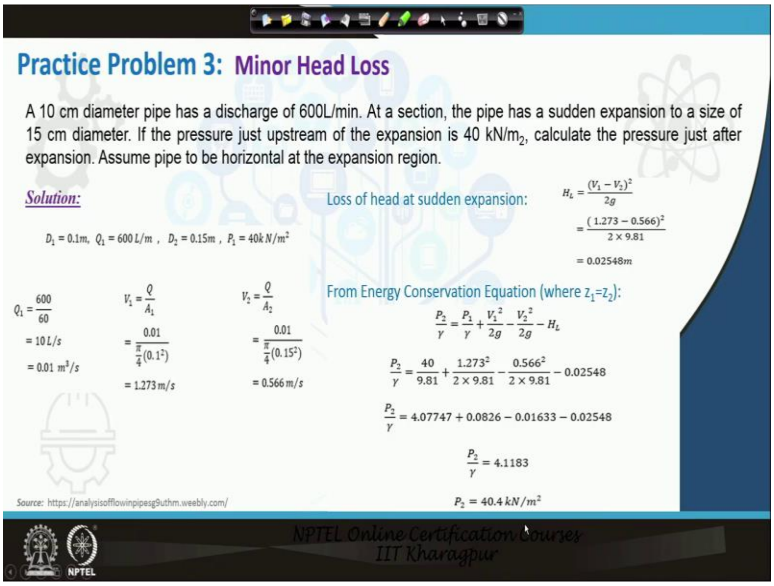

Practice Problem 3: Minor Head Loss

A 10 cm diameter pipe has a discharge of 600L/min. At a section, the pipe has a sudden expansion to a size of 15 cm diameter. If the pressure just upstream of the expansion is 40 kN/m$_2$, calculate the pressure just after expansion. Assume pipe to be horizontal at the expansion region.

Solution:

$D_1 = 0.1m,\ Q_1 = 600\,L/m\ ,\ D_2 = 0.15m\ ,\ P_1 = 40k\,N/m^2$

$$Q_1 = \frac{600}{60} = 10\,L/s = 0.01\ m^3/s$$

$$V_1 = \frac{Q}{A_1} = \frac{0.01}{\frac{\pi}{4}(0.1^2)} = 1.273\,m/s$$

$$V_2 = \frac{Q}{A_2} = \frac{0.01}{\frac{\pi}{4}(0.15^2)} = 0.566\,m/s$$

Loss of head at sudden expansion:

$$H_L = \frac{(V_1 - V_2)^2}{2g} = \frac{(1.273 - 0.566)^2}{2 \times 9.81} = 0.02548m$$

From Energy Conservation Equation (where $z_1=z_2$):

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - H_L$$

$$\frac{P_2}{\gamma} = \frac{40}{9.81} + \frac{1.273^2}{2 \times 9.81} - \frac{0.566^2}{2 \times 9.81} - 0.02548$$

$$\frac{P_2}{\gamma} = 4.07747 + 0.0826 - 0.01633 - 0.02548$$

$$\frac{P_2}{\gamma} = 4.1183$$

$$P_2 = 40.4\,kN/m^2$$

Source: https://analysisofflowinpipesg9uthm.weebly.com/

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Let us look at another problem on the minor head losses so here we have a 10 centimeter dia pipe that has a discharge 600 liter per minute at a section pipe as a sudden expansion. So, what we have is let us say we have this pipe and we have a sudden expansion here. Now the flow is going to remain constant in this case so whatever Q is flowing the same Q will remain the dia here is 10 centimeter and the dia here is 15 centimeter.

We have given the pressure just upstream of the expansion as 40 kilo Newton per meter square. So, pressure here is 40 kilo Newton per meter square and we need to determine pressure just downstream. So, let us say this is our section 1 and right here we have our section 2. So, if we apply the law of energy conservation or Bernoulli's equation here so we know that P 1 divided by gamma + V1 square by 2g + Z1 is equal to P 2 divided by gamma + V 2 square by 2g + Z2 + head losses which are happening.

Now in this case as it says that the assumed pipe to be horizontal at the expansion reason. So, horizontal means Z 1 and Z 2 is going to be same they are at same level then only the pipe is horizontal. So, if Z1 and Z2 is same so this gets cancelled now we have P 1 divided by gamma + V1 square by 2g is equal to P 2 divided by gamma + V2 square by 2g and + HL. So, this is what we have now in order to determine P 2 as we need to determine P 2 we can keep P 2 as 1 side and then shift this here.

So P 2 will be P 1 divided by gamma + V1 square by 2g - V2 square by 2g minus head losses. So, this is going to be our governing equation for this case. Now what we have in this equation P 1 is given to us and we need to determine V 1 V 2 and HL. So, as we said that if you are looking at expansion of this pipe ok so the discharge is same, now the dia here is different and dia here is different. So, the velocity through these sections will be different.

So let us say velocity at section 1 just upstream is Q divided by the cross-sectional area there Q is 0.01 divided by the PI by 4 means Q is basically the 600 liters per minute. So, 600 liter per minute you divide it with the second so we get 10 liter per second which is equal to 0.01 meter cube per second. So, that way we get Q a 0.01 meter per second and then PI by 4 D square. Now D is 10 centimeter again that may 0.1 into square.

So this comes as 1.237 meter per second velocity here so we know now the V1 also and similarly we can estimate V2 by Q by A2, Q remains the same and A2 will be PI by 4 in state of 0.1 square it will be 0.15 square because the dia is now 15 centimeter. So, we get 0.566 meter per second velocity here. So, we get the V2 value and head loss due to sudden expansion will be given V1 - V2 square by 2g so we know that V1 now we know the V2 now so we can estimate the head loss due to sudden expansion this is one of the minor losses.

So as we discussed basically there are going to be several type of minor losses this is one type of minor losses. And because we are looking the sections just upstream and downstream so there is not much frictional losses would be expected its expansion point and we are just looking at upstream to that and downstream to that. So, there is not going to be much of the frictional losses.

Because we are not considering any significant length of the pipe so friction losses depends on the length of the pipe also. So, we can like ignore the frictional losses for there if we can just consider the losses due to the expansion. Now losses due to expansion as we estimated is going to be 0.02548 meter so we know the head loss also now. So, in this equation we know all things will substitute this and then we will estimate the P2 by gamma and from there P2 by gamma comes as 4.11 and P2 comes at 40.4 kilo Newton per meter square.

So interestingly if you see after expansion there is a marginal increase in the pressure. Pressure here was 40 and pressure after expansion has become 40.4 that is because the velocity has head has decreased substantially. So, there is total energy loss because that from head loss also you can see so there is going to be total energy loss so total energy line will be lower but your pressure line is going to be increased because the velocity head which was earlier 1.2 has just reduced to 0.566 so that leads the increase in the pressure. So that is how basically we can use the concept of estimation of the minor losses.

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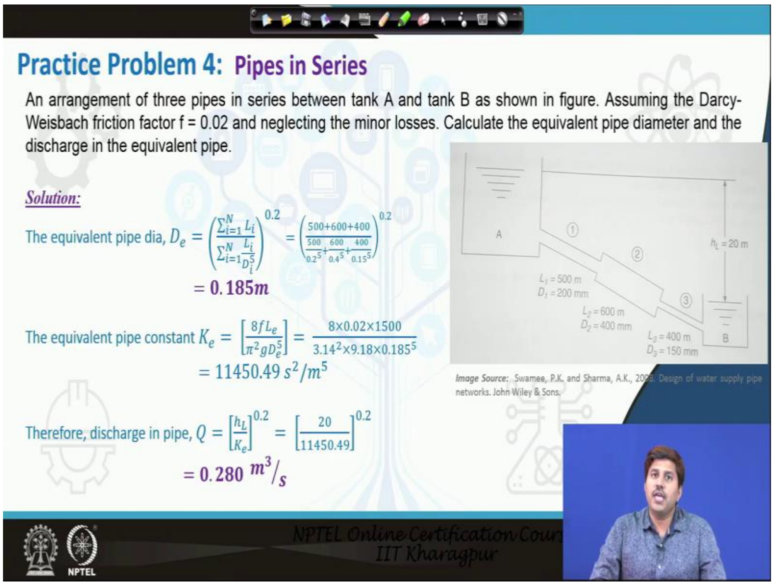

Practice Problem 4: Pipes in Series

An arrangement of three pipes in series between tank A and tank B as shown in figure. Assuming the Darcy-Weisbach friction factor f = 0.02 and neglecting the minor losses. Calculate the equivalent pipe diameter and the discharge in the equivalent pipe.

Solution:

The equivalent pipe dia, $D_e = \left(\frac{\sum_{i=1}^{N} L_i}{\sum_{i=1}^{N} \frac{L_i}{D_i^5}}\right)^{0.2} = \left(\frac{500+600+400}{\frac{500}{0.2^5}+\frac{600}{0.4^5}+\frac{400}{0.15^5}}\right)^{0.2}$

$= 0.185m$

The equivalent pipe constant $K_e = \left[\frac{8fL_e}{\pi^2 g D_e^5}\right] = \frac{8\times0.02\times1500}{3.14^2\times9.18\times0.185^5}$

$= 11450.49\ s^2/m^5$

Therefore, discharge in pipe, $Q = \left[\frac{h_L}{K_e}\right]^{0.2} = \left[\frac{20}{11450.49}\right]^{0.2}$

$= 0.280\ m^3/s$

Image Source: Swamee, P.K. and Sharma, A.K., 2008. Design of water supply pipe networks. John Wiley & Sons.

Next couple of problems we have on the pipe arrangement so the first 1 is the piping series. So, we have say 3 pipes of length 500 meter dia at 200 meter length 600 meter dia 400 meter and length 400 meter dia at 301 dia 150 millimeters dia is in millimeters in fact for all of these. So, and we have you can see it is connecting 2 tanks so in 1 tank head is somewhere and another tank so the total difference in the heads is 20 meters, so that becomes our total head loss or total head difference.

So, if we need to determine the equivalent pipe dia here so equivalent pipe dia will be the total length which is basically 500 meter + 600 meter + 400 meter that means 1500 meter is going to be the total length and divided by Li divided by Di to the power 5. So, for a specific pipe all right now length is 500 so that means 500 divided by the 0.2 to the power 5, 600 divided by 0.4 to the power 5 and 400 divided by 0.15 to the power 5 and overall power 1 by 5 or 0.2.

So this gives us 0.185 meter as the equivalent pipe daya. We can compute the equivalent pipe constant because we know that head loss is actually equal to K times Q to the power n which is many times has taken as 2. So, if that kind of system is there we can estimate this coefficient over here which is 8 FL means length of the pipe equivalent length of the pipe divided Pi square g into equivalent to the power 5.

So, we know everything here so we will estimate like we know 8 friction factor is given as 0.02 the total length of pipe is 1500 meter Pi we know g we know and the we have estimated so we will get the pipe coefficient and from here we can estimate the discharge then so Q will be HL divided by K to the power this and then from here we can estimate the value of as 0.280 meters cube per second.

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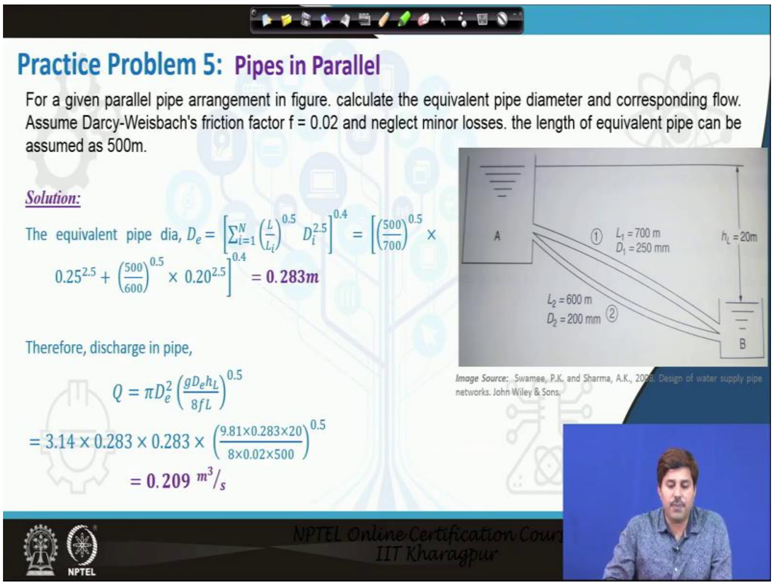

Practice Problem 5: Pipes in Parallel

For a given parallel pipe arrangement in figure. calculate the equivalent pipe diameter and corresponding flow. Assume Darcy-Weisbach's friction factor f = 0.02 and neglect minor losses. the length of equivalent pipe can be assumed as 500m.

Solution:

The equivalent pipe dia, $D_e = \left[\sum_{i=1}^{N}\left(\frac{L}{L_i}\right)^{0.5} D_i^{2.5}\right]^{0.4} = \left[\left(\frac{500}{700}\right)^{0.5} \times 0.25^{2.5} + \left(\frac{500}{600}\right)^{0.5} \times 0.20^{2.5}\right]^{0.4} = \mathbf{0.283m}$

Therefore, discharge in pipe,

$$Q = \pi D_e^2\left(\frac{gD_eh_L}{8fL}\right)^{0.5}$$

$$= 3.14 \times 0.283 \times 0.283 \times \left(\frac{9.81\times0.283\times20}{8\times0.02\times500}\right)^{0.5}$$

$$= \mathbf{0.209}\ {}^{m^3}/_{s}$$

Image Source: Swamee, P.K. and Sharma, A.K., 2008. Design of water supply pipe networks. John Wiley & Sons.

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Next problem is basically pipes in parallel so similarly we have say 2 pipe this time connecting in parallel length is 700 and 600 meters respectively and the dia is 250 and 200 mm respectively the head is 20 meter. So, equivalent pipe dia here can be estimated because length is different so the ratio of length square root of ratio of length into dia to the power 2.5 and whole to the power 0.4 that way so we can estimate this.

As we discussed during the lectures so equivalent pipe dia becoming as 0.283 and discharge equivalent discharge because once we know the equivalent pipe dia and we know the equivalent length head loss is given dia is available restriction factor we know G value we know so everything is known to us and we can calculate the discharge through pipe equivalent pipe as 0.1209 meter cube per second. So, that is how basically we use the concept of when we combine more than 1 pipe either in series or in parallel.

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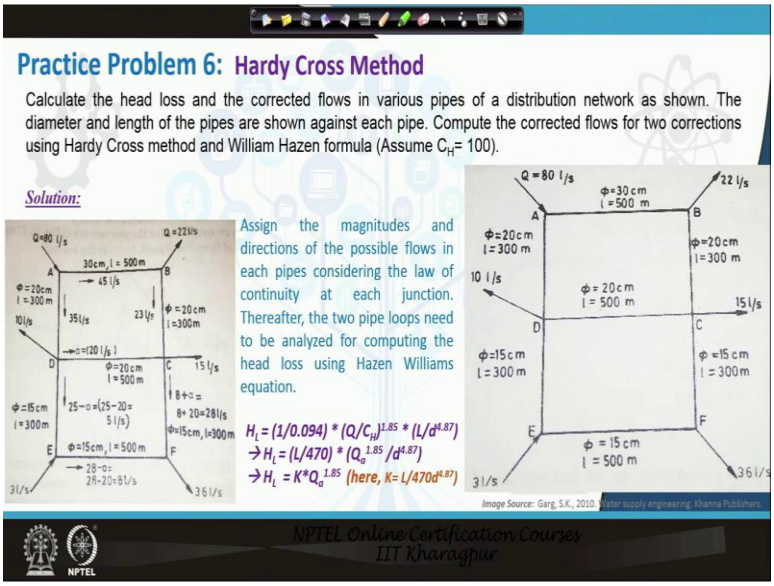

Practice Problem 6: Hardy Cross Method

Calculate the head loss and the corrected flows in various pipes of a distribution network as shown. The diameter and length of the pipes are shown against each pipe. Compute the corrected flows for two corrections using Hardy Cross method and William Hazen formula (Assume C_H= 100).

Solution:

Assign the magnitudes and directions of the possible flows in each pipes considering the law of continuity at each junction. Thereafter, the two pipe loops need to be analyzed for computing the head loss using Hazen Williams equation.

$H_L = (1/0.094) * (Q/C_H)^{1.85} * (L/d^{4.87})$

$\rightarrow H_L = (L/470) * (Q_a^{1.85} / d^{4.87})$

$\rightarrow H_L = K*Q_a^{1.85}$ (here, $K= L/470d^{4.87}$)

Image Source: Garg, S.K., 2010. Water supply engineering. Khanna Publishers.

Now the last problem for this class we have on hardy-cross method. So, the statement is that we have to calculate the head loss and corrected flow in the various pipe of a distribution network as shown the diameter and length of the pipe are sewn against each pipe and we need to compute the corrected flow for 2 corrections using hardy-cross method and we can use his and William formula where the constant can be assumed as 100.

So for his and William formula head loss is 1 divided by 0. 094 Q divided by CH to the power 1.85 and L divided by D to the power 4.87. So, in this particular case we because see is given to us 100. So, if we substitute see we can reduce this formula to here now you can see that for each pipe length is constant and dia is constant, length and dia is not changing. So, we can consider this as a constant for pipe it will vary from pipe to pipe but for 1 pipe the length and dia is going to remain same.

So if we take like L divided by 470 D to the power4.87 as 1 constant K. So, this is going to remain constant for that particular pipe irrespective of whatever flow is taking through that pipe right. So, we can write the head loss as K into Qa to the power 1.85 where Qa is the discharge which is taking place in that particular pipe. Now in hardy-cross method the first step that we take we assign the magnitude and direction of the possible flow so that the law of continuity at each junction is valid right.

Now how can we do that so let us say this is the junction 80 liter per second flow is coming at this junction. So, the flow that is leaving in these 2 pipe should be coming as a 80 either leaving 2 pipe or maybe let us say you never know if some 10 liter per second flow is coming here then this is going to be 90 but the point is that flow coming into the system. And flow leaving the system flow leaving that particular Junction should be equal.

So let us say a 80 is coming now you can divide it so divide in say 45 and 35 so that the summation becomes a 80. Now if 45 is coming here 22 is going there so this will automatically going to have is 23. This is 10 now 35 is coming here 10 is going there so remaining what is left is 25. If 25 is left let say we send 20 this side and 5 we assign 20 this side and 5 this side. Now for this particular junction 20 is coming from this side 23 is coming from this side 15 is going this side, so 28 will be flowing here.

And in this particular junction 28 is flowing here 36 is going there so that means this should have more flow 8 coming from this side in order to this equation be valid. And for this particular junction now you see so 5 is coming here 3 is coming from there so 5 + 3 8 + 8 is going there so continuity equation is valid on this particular junction as well. So, let us say a sign of flow these numbers may be different also we have just taken this number but it could be a different numbers as well.

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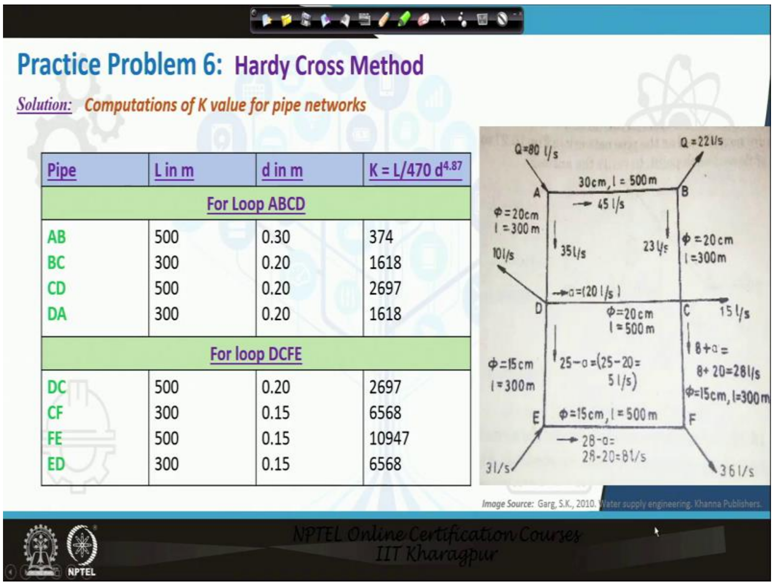

Practice Problem 6: Hardy Cross Method

Solution: Computations of K value for pipe networks

Pipe	L in m	d in m	K = L/470 $d^{4.87}$
For Loop ABCD			
AB	500	0.30	374
BC	300	0.20	1618
CD	500	0.20	2697
DA	300	0.20	1618
For loop DCFE			
DC	500	0.20	2697
CF	300	0.15	6568
FE	500	0.15	10947
ED	300	0.15	6568

Image Source: Garg, S.K., 2010. Water supply engineering. Khanna Publishers.

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We can estimate the K values which are pipe constants. So, we know the length for each pipe we know the dia for each pipe so we can estimate the K values for each pipe that way and here we have 2 loops so ABCD and then the then there is another loop and as per convention so clockwise flows are considered positive. So, this we are going to consider as positive this we are going to consider as positive this is becoming anti-clockwise so this will consider as negative and this we will consider as negative in here.

For this particular loop again clockwise positive, so flow here will be considered positive. So, remember that when this pipe we are considering in this loop it is a negative flow and when we the same pipe we are considering in this loop it is going to be a positive flow. So, this is positive this is also positive here the flow is counter clockwise so negative and here also the flow is counter clockwise so negative flow.

And we can estimate the pipe coefficients as L length divided by 470 into D to the power 4 0.87. So, that way we can estimate the pipe coefficients for each pipe all right.

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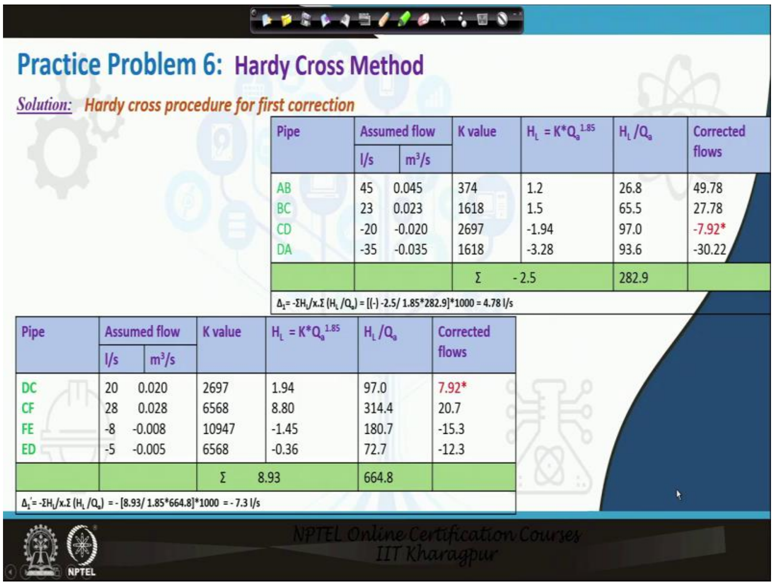

Practice Problem 6: Hardy Cross Method

Solution: Hardy cross procedure for first correction

Pipe	Assumed flow		K value	$H_L = K^*Q_a^{1.85}$	H_L/Q_a	Corrected flows
	l/s	m³/s				
AB	45	0.045	374	1.2	26.8	49.78
BC	23	0.023	1618	1.5	65.5	27.78
CD	-20	-0.020	2697	-1.94	97.0	-7.92*
DA	-35	-0.035	1618	-3.28	93.6	-30.22
			Σ	- 2.5	282.9	

$\Delta_1 = -\Sigma H_L/x.\Sigma(H_L/Q_a) = [(-) -2.5/1.85^*282.9]^*1000 = 4.78$ l/s

Pipe	Assumed flow		K value	$H_L = K^*Q_a^{1.85}$	H_L/Q_a	Corrected flows
	l/s	m³/s				
DC	20	0.020	2697	1.94	97.0	7.92*
CF	28	0.028	6568	8.80	314.4	20.7
FE	-8	-0.008	10947	-1.45	180.7	-15.3
ED	-5	-0.005	6568	-0.36	72.7	-12.3
			Σ	8.93	664.8	

$\Delta_1' = -\Sigma H_L/x.\Sigma(H_L/Q_a) = -[8.93/1.85^*664.8]^*1000 = -7.3$ l/s

Now once we have estimated these pipe coefficients then we can go for the first round off correction. So, correction is d1 loop wise correction factor is estimated loop wise so for first loop which is having for pipe AB BC CD and DA and assumed flow is 45 23 -20 and -35 is the assumed flow you can have this flow converting into meter cube per second as well. The K value we have already estimated.

Now as we discussed earlier so the correction is going to be equal to minus summation of the head losses which is occurring divided by summation of X times summation of head loss divided by Q. So, this is what is the correction. Now first we will estimate the head loss which is K into Q a to the power 1.85, so we got the values of head loss. For the pipe having negative direction flow the head loss will be negative means in the reverse direction and this is HL by Q.

So, HL by Q anyway comes positive and we have to consider this as a positive or we can basically take mod consider mod also for this. So, the head loss is known to us Q is known to us so we divide and we get the HL by Q value we take the summation of these numbers. So, summation of HL is say coming as -0.25 summation of this is coming as 282.9 now we can estimate the correction as minus summation of head loss which is -2.5 so minus minus will become plus actually.

So it is basically 2.5 divided by 1.85 into 282.9 this is in meter cube per second we multiply it with the 1000 we get in liter per second. So, the number is 4.78 liter per second. Now in each of these flow we will add that number so 45 will become 49.78, 4.78 will be added 23 will become 27.78, 20 we will talk about this in a while but 35 will add 4.78 - 35 so that will become -30.22. This particular pipe because if you see the loop way so we have like A B C and D.

So this particular pipe is common in the 2 loops so this like CD is actually there in the other loop also so the pipe which is common in the 2 loop receives correction from both the loops. So, it is not that just 1 correction or 40.78 value will be applied here it will receive correction from the second loop also. So, let us basically work out the correction from the second loop as well. So, for second loop the assume flow are 20 28 - 8 - 5 and K values are this.

Similarly we will compute the head losses summation of head losses is 8.93 we will compute HL by Q a dividing with the discharge in meter cube per second summation is 664.8 and then we will use this so minus this is plus number again so it is not going to get mine like here this value was minus so minus minus become plus and we got a positive correction. But here because this number is positive so - 8.93 divided by 1.85 into 664.8 into 1000 for converting it into the liter so we get -7.3 liter per second as the correction.

So this is the correction so 28 will become 20.7 -8 will become -15.3 -5 will become -12.3 will apply these corrections over here and this pipe. So, what we were just saying that this pipe will receive correction from both things. So, we have -20 from here -20 is discharged and then 4.78 was the correction so 4.78 was the correction. So, how much we left with will have to be the 4.87 was one correction and 8.93 was another correction sorry 7.3 was another correction.

So this and 7.3 now when this was minus the correction like if this number we consider as minus for this particular loop then this correction is the correction value was positive so it helped it will be basically subtracted from this. And this is positive here and correction value is negative. So, again it will be subtracted from this value 20. So, overall like if you if you account for both of these corrections if we account for let us say of 4.78 correction and 7.3 corrections.

So total correction that this pipe is going to receive is 11.08 and as a result this pipe will have a discharge of 7.93 so for CD part it will be -7.93 and for D part it is going to be 7. Sorry 7.92 so for DC part it is going to be +7.92. so, that is how this correction will be estimated in that common pipe. The now we have got a corrected flow after first correction now we will use this as the basic flow here for our second iteration.

So, this is the flow this is the flow that we are having for first loop and this is the flow that we are having for the second loop again you can notice here that this is -7.92 and this is 7.92 for the same. Common pipe this is the K values again will similarly calculate HL HL by a QA for both the loops and then we will compute the corrections. So, here the correction is coming -1.73 liter per second and here it is 0.95 liter per second.

So this correction will be applied to these like all 4 pipes and here also it will be applied to all pipes. Again this DC pipe is going to receive correction from both so that is like 7.92 is there an overall correction that it will have is 1.73 and 0.95 it is interesting to see that the like correction here is negative and correction here is positive. But that is because the direction so it is if the flow we have assumed the direction of flow in this pipe is like this. So, for this particular loop it is a counter current flow but for this particular loop it is a KO like it is a anti-clockwise flow but for this particular loop it is a clockwise flow.

So that means that is why we are taking this as a positive here and then applying a positive correction and this we are considering as a negative here and then applying again a negative correction. So, the total correction that will be applied is the summation of these 2 and then total value will be 10.6 in this particular pipe. So, that is how will be the value coming in for these different pipes.

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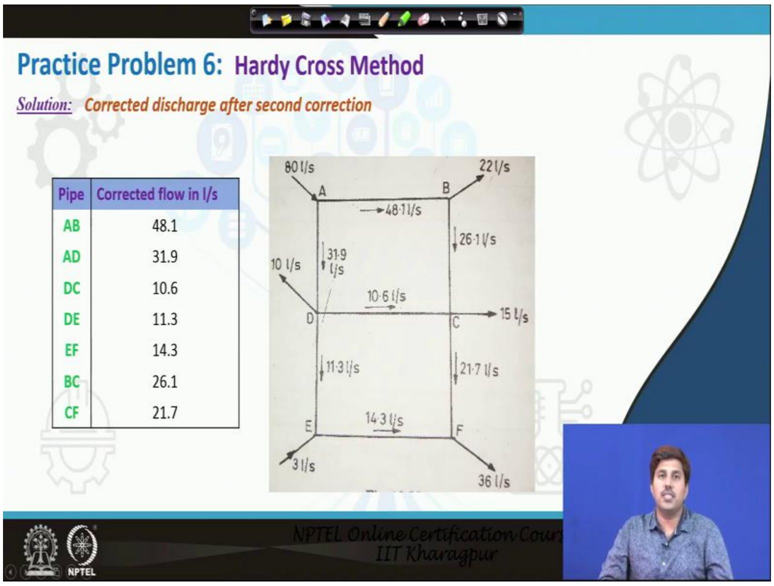

Practice Problem 6: **Hardy Cross Method**

Solution: *Corrected discharge after second correction*

Pipe	Corrected flow in l/s
AB	48.1
AD	31.9
DC	10.6
DE	11.3
EF	14.3
BC	26.1
CF	21.7

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So, these are the 2 iterations that we have done similarly we can go for further iterations unless the correction value becomes very, very little or minimum. So, this is the corrected discharge after the second correction in the different pipes. So, with this we conclude this particular week's content. We have talked about water distribution network and we could cover the network analysis the network layout structures and then the basic components of a network.

So, the in a water distribution system there are enormous amount of losses also that happens many times and the losses originate from different phases or different type of losses are there. So, we will discuss about the loss detection loss management or lost assessment in the water distribution network in the next week, discussions. So, thank you for joining and see you next week.