Fluid Flow Operations
Dr. Subrata K. Majumder
Department of Chemical Engineering
Indian Institute of Technology, Guwahati

Module - 06
Lecture – 16
Different Losses in Pipes - Part 2: Various Losses due to geometric change

Welcome to massive open online course on Fluid Flow Operations. In this lecture we will discuss, the different losses in pipes, the discontinue us that is from previous lecture.

So, in this lecture we will discuss the various losses, whenever a fluid is flowing through the pipe, but the pipe will be of different geometry. The lecture includes on loss in oblong pipe, loss due to additional turbulence, loss with sudden change of area, loss with the gradual change of area, even loss due to though due to the direction change.

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So, as per a different geometry how the loss will be there whenever fluid will be flowing through the pipe and there will be some viscous effect and, because of which there will be loss and that loss we have discussed in the previous class, major losses like what will be the frictional resistance and, because of which how the energy will be loss for a straight or vertical pipe. How the energy will be changed and from that energy change, how the frictional coefficient and also I think we have discussed that Fanning friction equation even Weisbach equation, Darcy Weisbach equation and here in this case again we will continue this with different shapes of pipes.

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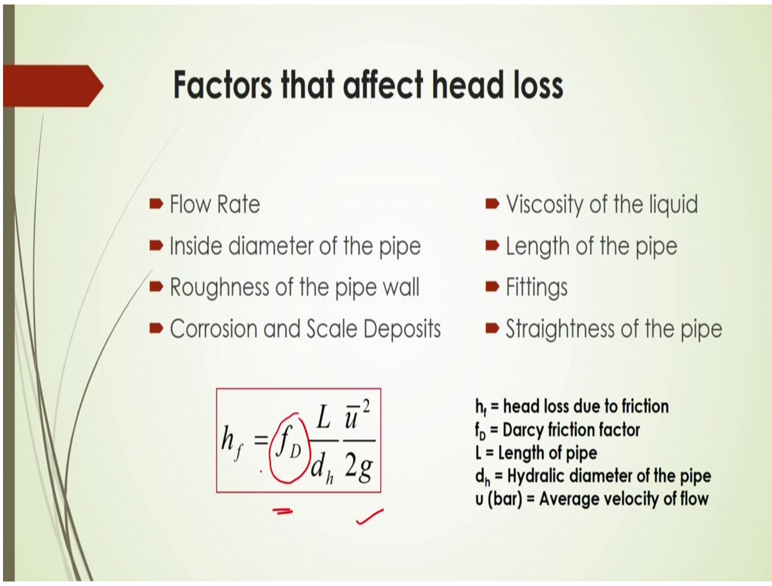

Now, we know that several factors that effect this head loss like a flow rate inside diameter of the pipe, roughness of the pipe wall even if is there any corrosion or scale deposits on the wall of the pipe that will affect the head loss.

And also this is a general case that viscosity is one of the major contribution for this head loss and, if you increase also the length of the pipe there will be a change of this head loss, because it will have more contact of liquid and more viscous or friction effect on the pipe wall and that is why the effect of length will be there significant for the head loss.

Even fittings we have different types of fittings whenever we are joining the two pipe pieces to continue its length then we are getting different types of fits even also to change the direction of the flow. We are fitting the different geometry of pipes to get it the flow or liquid from one location to another location.

So, in that case whenever we are adding some fittings in the pipe we will loss some energy and that energy of to have to calculate and for that how this energy loss is actually estimated that is being discussed here. And of course, another important point that straightness of the pipe for bend pipe or straight pipe or of curve pipe, there will be a certain change of the head loss due to the friction for that geometry.

So, general expression for the head loss is represented by this equation given here like h f that will be equals to f D into L by d h into u square by 2 g. So, in this case f D is equal to Darcy Weisbach friction factor. So, this if you know that Darcy Weisbach friction factor of course, you will be able to find out this friction loss from it's certain length and it's diameter and also what will be the velocity of the flow, whenever it will be flowing through the pipe.

So, h f is the head loss due to the friction and in this case the d h is called the general terms is hydraulic diameter of the pipe. Hydraulic diameter is generally being calculated based on the contact of the fluid to the surface of the wall of the conduit like; if it is pipe, it is square pipe or if it is suppose circular pipe or any suppose, the cross sectional area is something rectangular then how this effective diameter of the pipe will be there equivalent to the circular pipe. So, that will be considered.

So, in this case in the general terms we can consider that this head loss will be as a function of this hydraulic diameter also and this hydrous if hydraulic diameter increases that head loss will be lower, if other factors are being kept constant. And f D of course, depends on this the flow regimes that is whether the flow is laminar or turbulent or it is in turn transition. So, f D should be calculated based on that flow regimes.

We have already discussed in the previous lectures, that how this f D to be calculated; that means, Darcy Weisbach friction factor and even Fanning friction factor. How this Darcy Weisbach fan friction factor related to the Fanning friction factor? Either one of the friction factor you can use for the calculation of this head loss, due to the friction.

Now, of course, for turbulent flow even for laminar flow. Laminar flow it is very simple that this f D should be is equal to 16 by r e and for Fanning friction factor it will be there like 64 by Reynolds number, like that that we have discussed in the previous lecture. for turbulent flow there are several investigators, they have proposed different correlations based on their experimental data that we have already discussed.

So, you have to calculate this friction factor, Darcy friction factor from those correlations.

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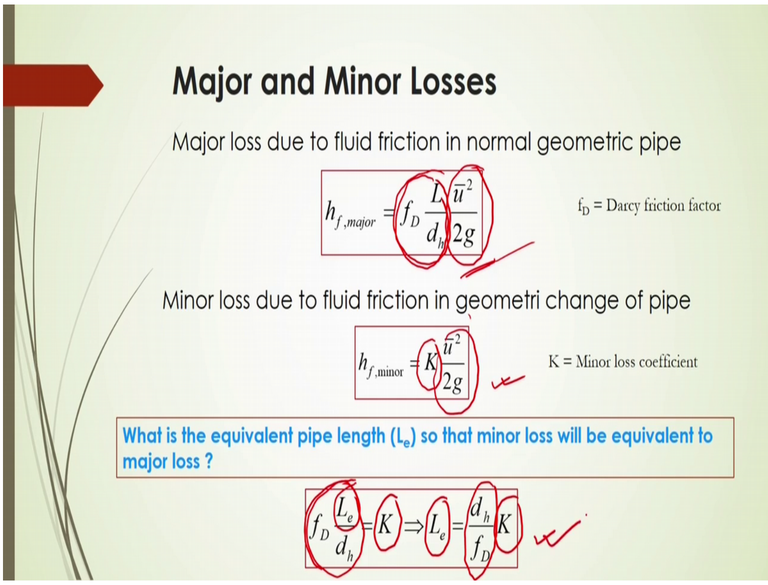

And now, we if we are coming to that division of this losses into two parts like; one is major loss and another is minor loss. Major loss is, generally is contributed, based on this viscous effect. So, it will be fluid friction in normal geometric pipe. So, it is represented by this equation here, this h f major that will be is equal to f D into L by d h into u square by 2 g and here f D is the Darcy friction factor whereas, minor loss will be due to the friction if your geometry of the pipe will change.

So, that in that case h f minor, it will be is equal to it will be proportional to the u square by 2 g, this terms here. So, here that proportionality constant, it is coming or it will be denoted by K, that K is called minor loss coefficient.

Whereas, in the major part, if we segregate this two parts here f D into L by d h and u square by 2 g. So, u square by 2 g and out of that these terms this f D into L by d h is another factor. It is called major a loss coefficient and out of which this only f D will be called Darcy friction factor.

Now, if we multiply this ratio of L by d h with this Darcy friction factor it will be represented by a major, a loss coefficient. And in this case if we compare with this major loss coefficient and minor loss coefficient then what should be the equivalent pipe length; so, that that minor loss will be equivalent to the major loss. So, in that case if we considered that there are a certain length for which this major loss will be equivalent to the minor loss in that case that equivalent length is it is considered as L e then we can write here f D into L e by d h. For these there will be some losses that losses will be equals to minor losses, if there is a coefficient K.

So, if you multiply this these terms with u square by 2 g and, if we multiply this K with this u square by 2 g then both will be same and it will be cancelled out. So, for this L e equivalent length, these two terms will be equal for that L e should be is equal to what d h by f D into K. So, equivalent pipe length where this major loss and minor loss will be equivalent only for those, there will be a ratio of this d h by f D and with this minor loss coefficient. So, these terms, this equations will give you the calculation of this equivalent pipe length for having the same minor loss and major loss.

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Now, other different geometric shape. Here, in this case, if we considered some oblong pipe like here. In the picture it is shown that there are different types of oblong pipes like here this, see here the cross sectional area is something this rectangular shape here, also it is rectangular shape, but this edges of the cross section. Something is sometimes will be a con shape, convex shape and where the pipes are also bent.

And the here cross sectional it is the sharp edged will be there with 90 degree angles and this is rectangular shape and here also it will be seeing that here this, what is that pipe will be bent with a certain angle and also here this, in the heat exchanger there will be pipe that may be certain shape. There maybe circular pipe or maybe a rectangular shape in pipe may be square, cross sectional area based pipe.

So, how can this loss we found for this type of different oblong or oval shape of pipe is there? So, these are oval different this cross sectional area this edge will be oval in shape. So, in this case it will be of course, the loss will be something different from that circular pipe.

So, here oblong pipe means here this oval cross sectional area of the pipe.

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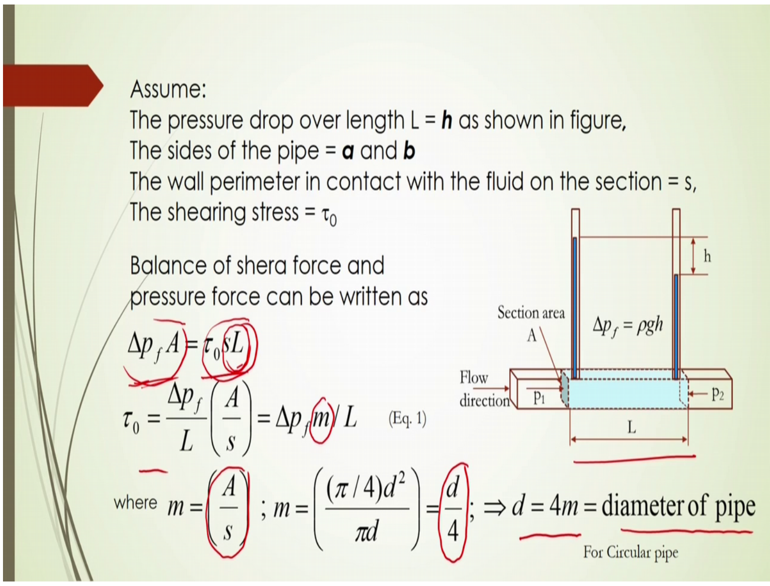

Now, let us consider the pressure drop over the length L that will be equals to h as shown in the figure here for a certain shape of cross section here.

So, in this case if I consider this length L up to this and the side of the pipe here if we consider that a and b and the wall perimeter in contact with the fluid on the section that is s, in the section s or cross section here then what should be the wall perimeter it will be represented by s. So, the shearing stress then tau 0 can be calculated based on the force balance over this cross section of this, over this strip of this pipe here.

Now, balance of area of shear force and the pressure force can be written as here delta p f into a that will be is equal to tau 0 into s L here delta p f is the frictional pressure drop a is the cross sectional area whereas, tau 0 is the shear stress and for that what will be the surface area that will be perimeter of this pipe and what will be the length, then it will be total surface area. Then total surface area into tau 0 it will give you the force.

So, total force here in this case it will be equal from this frictional force is the shear stress, shear force. So, both will be a same. So, in this case if we equate this two forces then from which we can calculate what should be the tau 0; that means, shear stress over there. So, shear stress is that is, it will be delta p f by L into A by s. So, it will be delta p f m by L, if we consider that A by s that is cross sectional area to perimeter or what is called that wall perimeter, which in contact with the fluid on the section s if we represent this then it will be considered as m. So, m should be is equal to A by s. So, m will be is equal to pi by 4 d square by pi d, because a is equal to pi by 4 d square and s is equal pi into d. So, ultimately it is coming as d by 4.

So, m will be is equal to d by 4 from which we can say that d will be is equal to 4 into m. So, d is equal to 4 into m; that means, diameter of the pipe. So, diameter of the pipe it will be 4 times of, ratio of cross sectional area to the surface area, that the perimeter wall perimeter of the pipe.

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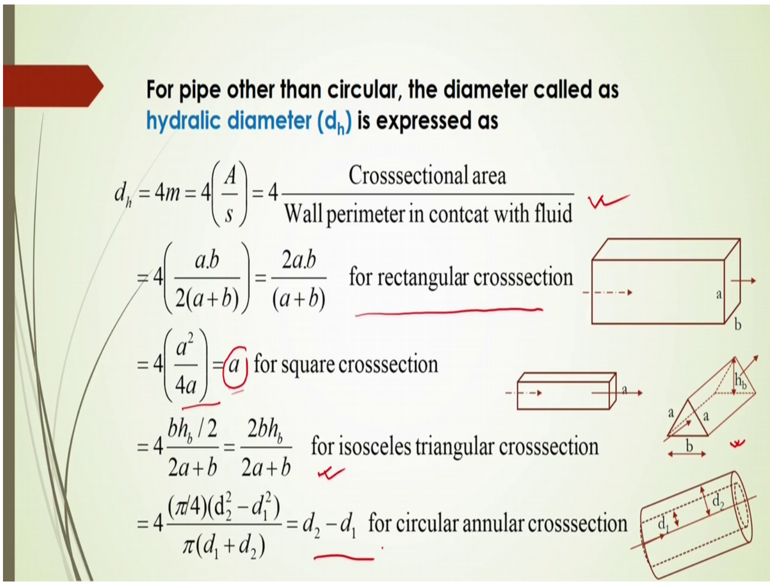

So, in this case, by this actually concept we can define that what should be the hydraulic diameter for that. Now, hydraulic diameter is defined as that four into a m that will be 4 into A by s; that means, what will be the portion of the cross sectional area ? If you divide by this wall perimeter in contact with the fluid, then it will be called as a hydraulic diameter.

So, for the pipe other than circular, you have to consider the hydraulic diameter as d h which is expressed by this equation here. So, d h will be is equal to cross sectional area by wall perimeter in contact with fluid and multiplied by 4 that this as per derivation here given in the slides for circular pipe. So, for the concept of circular pipe, if we use that hydraulic diameter calculation you can easily relate this hydraulic diameter to this a circular pipe diameter as this.

Now, in this case, if we consider the rectangular section or rectangular cross section in that case what should be the hydraulic diameter? So, you have to first find out the what will be the cross sectional area. So, for the rectangular cross section the cross sectional area will be a into b if we consider that there will be sides are a and b then a into b will be the cross sectional area whereas, the perimeter will be is equal to 2 into a plus b.

So, it will be coming as per definition of this hydraulic diameter it will be 2 into a b by a plus b. So, for rectangular cross sectional pipe the hydraulic diameter will be considered as 2 a b by a plus b. So, in this case you have to remember that it is not a circular pipe. So, to consider that calculation equivalent to that a circular pipe, you have to consider this hydraulic diameter.

Whereas for the circular pipe as per this definition of this hydraulic diameter, you can get it very simple that if we consider that 4 into cross sectional area for the circular pipe, it will be if the diameter of the pipe is d, then it will be simple, what is that cross sectional area will be is equal to pi by 4 d square divided by wall perimeter. It will be pi by 4 that is pi into d. So, here it will be simplify pi cancelled out then 4 cancels it will simple d. So, in that case d h will be is equal to d.

So, for the circular pipe, simply that hydraulic diameter is equivalent to simply that diameter of the pipe. Whereas, for the cross square cross section if the side of square is a then simple as for that definition you can get this cross sectional area will be is equal to a square whereas, the perimeter will be is equal to 4 a. So, after substitution and the, simplification you can get directly a value; that means, for cross section, square cross sectional pipe you can get the hydraulic diameter as it is what is the side of the pipe.

And for isosceles triangular cross section here, in this figure of the side a a and b then you can calculate based on this what will be the cross section that is b h b by 2 divided by 2 a plus b. So, in that case 2 b h b by 2 a plus b, where is that h b h b is the height of this triangular here, in this cross section as shown in the figure. So, it will be defined as d hydraulic diameter as by this equation and what the circular annular cross section? In that case the diameter d 1 and d 2, if the radius of the cross sections or diameter of the cross section has this d 1 and d 2 then we can have this hydraulic diameter as d 2 minus d 1.

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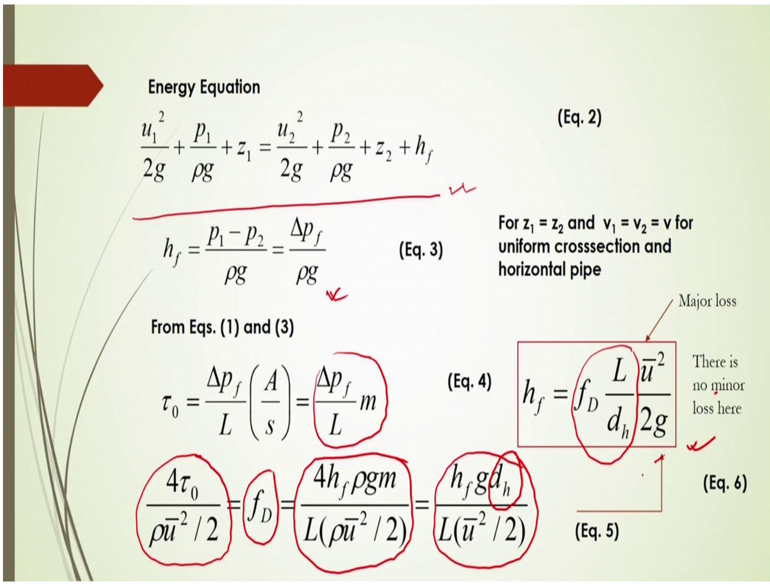

So, this is very simple to calculate this hydraulic diameter other than the circular cross sectional pipe. Now, coming to that energy equation to calculate the head loss or loss coefficient for the pipe other than the circular cross section; so, in that case the same equation to be used that is Bernoulli's equation to be used for the energy conservation equation. Here, if there is a cross sectional area and the part two section 1 and section 2 and the velocity u 1 and u 2, then we can write here for the pressure drop of p 1 and p 2, then what should be the head loss that is simple by equation number 2, that has already been discussed in the earlier lectures, even in previous lectures also.

So, here this energy equation to be represented by the equation number 2 whereas, in equation 3 based on the simplification of this equation 2 we can write this equation h f is equal p 1 minus p 2 by rho g in this case this is the horizontal pipe in z 1 will be equals to z 2 and v 1 will be equals to v 2 or u 1 is equal to u 2. So, in that case only pressure drop will be considered here. So, h f should be is equal to delta p f by rho g. So, from equation number now 1 and 3 from this equation number here 1 and 3 we can simply say that tau 0 will be is equal to delta p f by L into A by s.

So, that will be is equal to delta p f L into m, because m is denoted by this A by s ratio of this cross section to the wall perimeter. And here again, if we divided this both sides of this equation number 4 by half of rho u square then we can get this here, 4 tau 0 by rho u square by 2 here that will be is equal to f D that is Darcy Weisbach friction factor, as per definition and then it will be coming as what is that 4 h f rho g m by L into rho u square by 2.

So, that will be is equal to s f g d h by L u square by 2. Here, in this case very interesting that in the previous lecture whatever we have defined for this Darcy Weisbach friction factor for the regular pipe with the circular cross sections there, it was not the diameter of the pipe as of d h here, but in that case on the regular diameter of the pipe was considered, but in this case it is coming as that hydraulic diameter, because this shape is other than the circular pipe. So, here in this m terms will be coming and based on which we are having the definition of this Darcy Weisbach friction factor as h f g into d h divided by L u square by 2.

So, for pipe cross section other than circular simply, we are just having the diameter d h instead of only simple d. So, accordingly we can define that friction loss here that is called major loss is that h f will be is equal to f d into L by d h u square by 2 g. This is not the minor loss here it is the major loss here due to the friction factor. This is the viscose effect of the fluid that is frictional loss. Now, based on this we can then have this frictional losses, major losses, based on this hydraulic diameter or the other than the pipe which as that cross section is circular for other shape. We can calculate different way just by considering the hydraulic diameter instead of only simple diameter.

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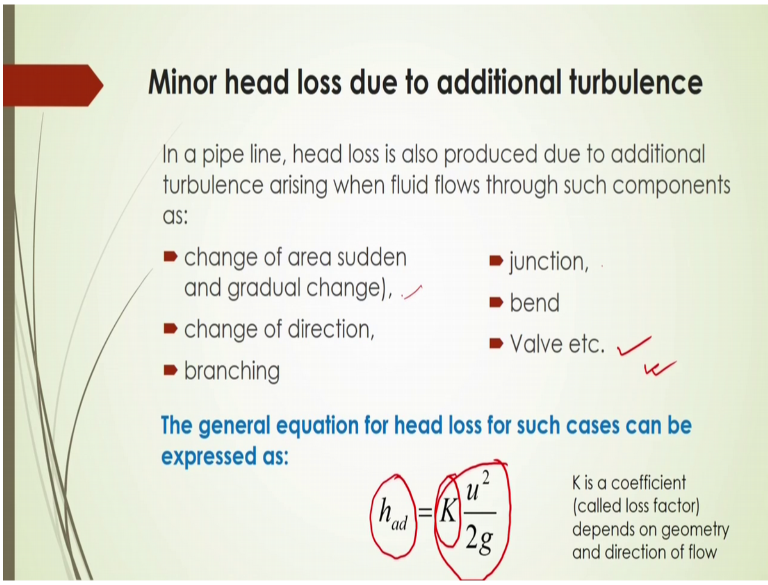

Now, we have to consider then what are those then minor head loss due to the additional some other means. So, that minor head loss will be due to the additional turbulence there. It will be created based on suppose f is the pipe is suppose bend in certain angle or the flow is changing it's direction from the higher cross sectional area to the lower cross sectional area, there will be a some creation of turbulence and, because of those turbulence you will see there will be a some loss of energy loss those loss will be considered as the minor loss here.

So, in a pipe line head loss is also produced due to the additional turbulence that is arised when fluid flows through such components are here given change of certain area and the gradual change of certain area also. And if is there any junction, if is there any end, is it is there any wall, or if is there any change of direction, if is the dancing of pipe or not. So, for those type of effect you will see there will be a some loss. So, it will be considered as a minor loss.

So, for those things also you have to have some coefficient of the loss. Earlier, we have seen that there will be a major loss coefficient it will be defined as a f D into L by d h. This is your major loss coefficient whereas, in the minor loss coefficient to be considered then it will be defined in this way that h a d that will be is equal to K into u square by 2 g. Here, in this case K will be is equal to coefficient that is called the loss factor and it will be called as minor loss coefficient or minor loss factor, that depends on this geometry and the direction of the flow.

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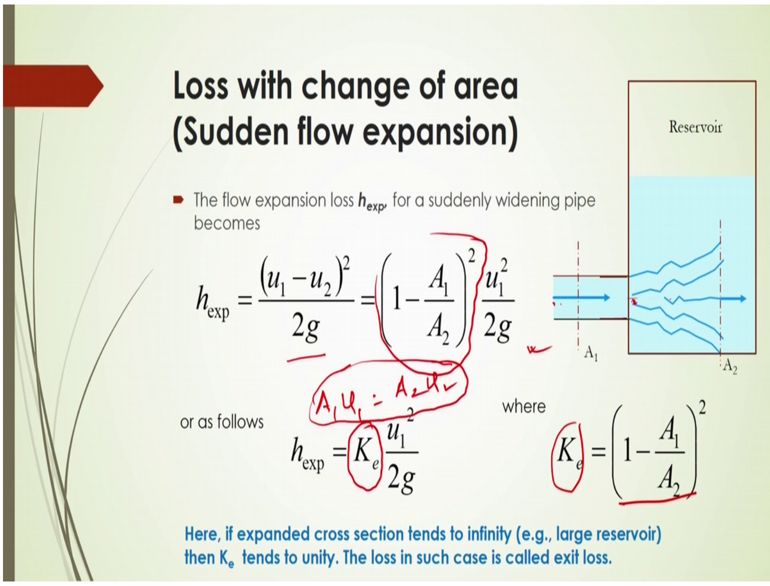

Now, you have to calculate those minor loss coefficient, what should be that? Suppose, if we consider that loss the change of area that is sudden flow of expansion here, as shown in the figure. The flow expansion loss will be denoted by s e x p for a suddenly widening pipe as shown in figure here this from this pipe portion the fluid will be flowing and it will be coming to a region where of wide cross sectional area.

So, in that case s e x p that we can use here u 1 minus u 2 by 2 g whole, here u 1 minus u 2 whole square divided by 2 g other terms are almost negligible, because this alignment of the here pipe or flow will be that is horizontal. So, the elevation energy will be 0 there and other pressure energy also will be negligible. Here this, in this case, this cross section and here in this cross section, the pressure whatever it will be coming that will be almost negligible. There will be no hardly a difference of pressure in there. So, there will be no frictional pressure in this cross section and then we can have then simply u 1 minus u 2 whole square divided by 2 g.

So, after simplification we can write and if we consider this mass conservation there you will see u A 1 into u 1 that will be is equal to A 2 into u 2 that is as per mass conservation law. So, we can simply use this relation here in this, that is expansion loss, then we can have this 1 minus A 1 by A 2 whole square in to u in u 1 square by 2 g.

So, from these if we compare with this equation of here this minor loss coefficient that here K into u square by 2 g in that case this minor loss coefficient will be represented by this terms only. So, K e that is the expansion loss coefficient that is denoted by K e will be is equal to, what is that 1 minus A 1 by A 2 whole square.

So, if you know the cross sectional area of this two section then you can easily calculate what should be the K e value. Very interesting that, in this case if both the cross sections are same then simply K e that is expansion loss coefficient should be is equal to 1. Whereas, if suppose A 2 is wide enough; that means, infinite then what will happen this A 1 by A 2 will be equals to what is that A 1 by A 2 will be equals to; that means, here 0 then only K e will be equals to 1 whereas, A 1 A 2, if both are same then this will be 1 1 minus 1 that is 0 then K e should be equals to 0 there. So, there will be no minor loss there. So, in this case since, the there will be change of cross sectional area not in a that is in infinite in shape or infinite in cross sectional area.

You can have some values, but up to infinite there will be a value then K e will be equals to 1. So, it will be 0 to 1 within this range that this expansion loss coefficient will be there. So, if the expanded loss, this expanded loss section cross section tends to infinite that is exam example here, if the flow is coming to that reservoir then in that case K e tends to unity and the loss in such cases is called that exit loss here.

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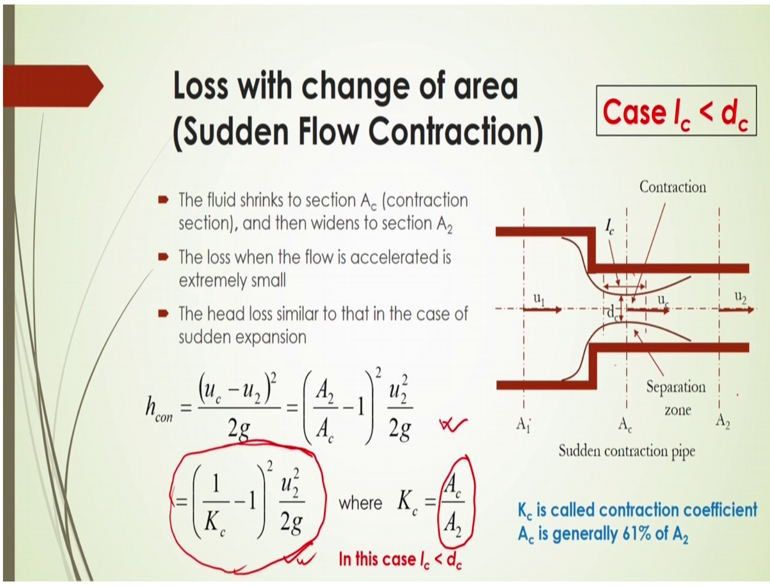

Now, loss with change of area, if we are considering that there will be sudden change of a cross sectional area from the higher cross section to the lower cross section. So, in this case as shown in figure. Here, in this case the cross sectional area, in this portion here you will see there will be a change and from this section here; that means, here the fluid sinks to the section A c that is contraction. Here, in this figure this comes in this, in this, in this portion this is called contraction A section.

So, the fluid sinks to section A c here and then again it will widens to section A 2 here. So, there will be A 3 sections here A 1 from this A 1 section, the fluid is coming and then it will go through this section, a contraction section that is Ac and again from this contraction section, it will be widen to it is to the mainstream and where the cross section is A 2.

So, this loss when the flow is accelerated, it will be considered and it will be extremely along a small. So, the head loss similar to that in the case of sudden expansion we can calculate here. So, what should be that loss due to this sudden flow contraction? Then again, the same way if we consider that the velocity in the contraction region is u c and the velocity at this that is fully developed region here in A 2 then we can say that the velocity difference is u c minus u 2. Then based on this 2 section, if we have apply that Bernoulli's equation here.

Then you can simply say that u c minus u t u 2 whole square divided by 2 g that will be is equal to A 2 by A c minus 1 whole square divided into u 2 u 2 square by 2 g. Again here, A 2 Ac. It is coming based on that mass conservation equation here; that means, u 2 into A 2 that will be is equal to u c into Ac, because the mass flow rate will be same as per mass conservation equation through the sections.

So, after simplification if we divide again by A 2 in this case section then 1 by Ac by A 2 minus here, it will be minus 1 whole square into u 2 square by 2 g here. So, we are representing, this is that is head loss due to the contraction as by this equation. Whereas, this K c will be is equal to Ac by A 2. Now, this K c actually is called contraction coefficient and is generally 60 percent A c is generally considered as 61 percent of the A 2 for the design of any pipe, in this case for like venture or other application. Very interesting that in the contraction region, you will see that sinking of the flow will occupy a certain length of this contraction region.

So, it will be denoted by this L c. So, here in the case where we are considered here, this equation contraction loss, if it is L c is less than dc; that means, the contraction length, if it is less than contraction diameter, then you will use this equation to calculate this contraction loss.

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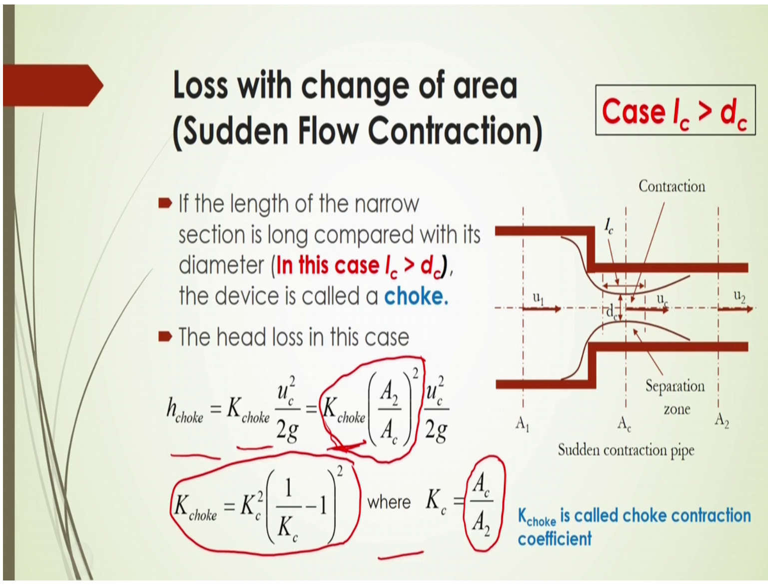

Whereas, if the case L c is greater than dc suppose, this sinking is occupying or that is the sinking will be more in length compared to the contraction diameter then in that case you can say that the length of the narrow section is long compared to it's diameter and that case the device is called that choke.

So, this phenomenon called to choke, if this L c is greater than dc. in this case head loss again to be considered based on that Bernoulli's equation and it would be generally represented by this h choke that will be is equal to K choke into u c square by 2 g and after substitution of this cross section of A 2 and A c based on the mass conservation equation, and then we can have this K choke into A 2 by A c whole square into u c square by 2 g.

And then we can have this portion, K choke K choke into A 2 by A c whole square, this will be considered as the another coefficient that is called the sudden flow contraction coefficient and it will be related to the choke.

And then if we again relate this with the previous that is sudden contraction, flow contraction coefficient here K c then this K choke will be related to this K c as by this equation here K choke that will be is equal to K c square into 1 by K c minus 1 whole square, where K c will be is equal to Ac by A 2. So, we are then having 2 cases, for the sudden flow contraction there will be what will be the loss coefficient and in that case, if the length of sinking is greater than contraction diameter, then it will be called a choke and for that choke coefficient will be related to that contraction, sudden contraction coefficient in the case where L c is less than dc and the relationship is given and from which you can directly calculated the choke coefficient without knowing the Lc value of for your design.

So, we are having this a minor loss coefficient for the different shape. Here, in this case only sudden flow contraction we have considered and previous one that we have considered that expansion loss coefficient. Similarly, other type of contraction we can get.

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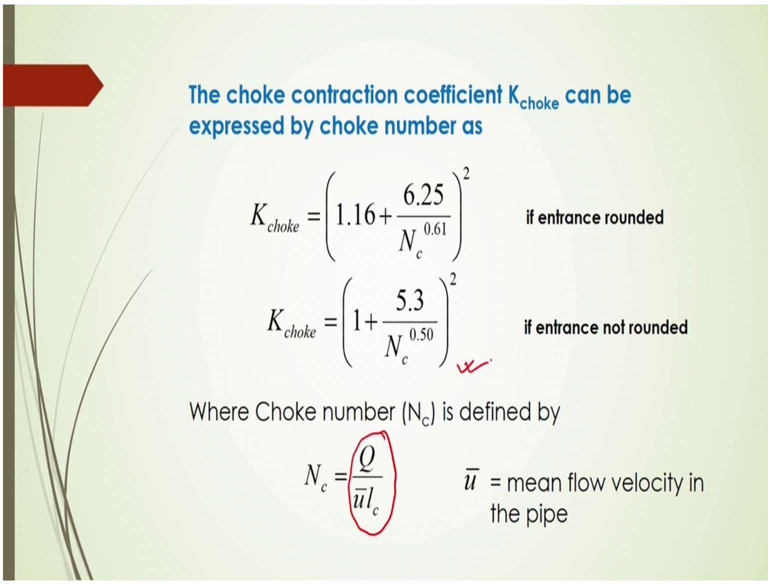

Now, in that case the choke contraction coefficient can be expressed by the choke number also. in that case if your entrance is rounded then this K choke will be is equal to 1.16 plus 6.25 n c to the power 0. 61 square though. So, this is n c, n c is called the choke number which is defined as this q by u c into. So, the choke number depends on the flow rate of the fluid and also the velocity of the fluid and mean velocity of the fluid through the pipe. And if the entrance not rounded then you have to use this equation to calculate the choke coefficient.

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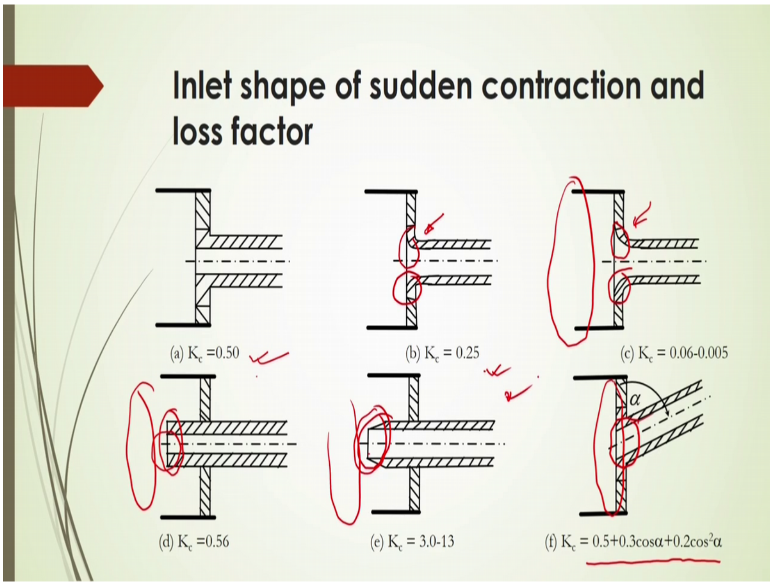

Now, other shape of the sudden contraction and loss factor you will see, if there is a contraction in that is sudden change of that flow due to this geometry. Here, in this case you will see there will be a short change of this contraction and here this change is something what is that those concave shape. This concave shape that depends on the radius what will be the radius? Here this radius is something else.

Here, this angle, this is sharp angle, at a certain angle here this there will be a nozzle type and here there you will see there will be a sharp change of this flow. So, this type of geometry if you are consider you will have different values of contraction coefficient and that is given here K c sometimes 0.5 0 0 0.25 25 0.06 to 0.062 0.005 here like this.

You have to calculate for a certain angle, if this pipe is changing its direction of the flow with angle alpha then K c should be is equal to what is that here this 0.5 plus 0.3 cos alpha plus 0.2 cos square alpha. So, here not only the change of direction, it is changing this. What is that cross sectional area change? Here from this cross section to this cross section it is changing here, also from this cross sections changing this cross section, from this cross section it is changing this cross section. So, whenever there will be a change of cross sections there will be a sudden change of geometry whether it will be concave shape or sharp bent of that cross section that you have to see.

So, this type of changing of a cross section with particular that is angle or that is with curve with certain curve, then you have to consider different values of contraction coefficient here.

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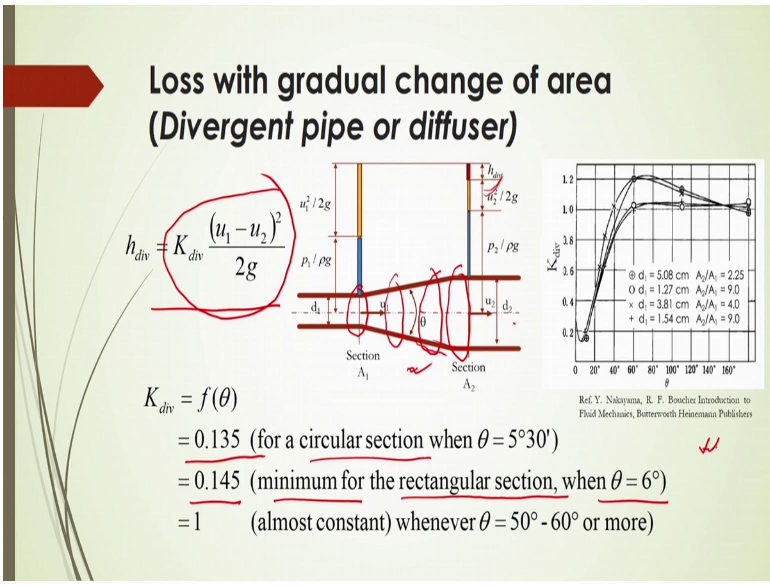

Now, if you are saying that the change of area will have a sudden gradual change in that case how the loss coefficient to be considered. So, in that case this if you are considered that, if there is a divergent of pipe where the cross sectional area is gradually changing. Here, see in this area there will be a cross sections whereas, this cross section is changing gradually, that is it is widen gradually.

So, here in this ere there will be a change of cross section, here also there will be change of cross section, here also there will be change of cross section. So, whenever fluid will be flowing from this cross section to the gradual change of cross sections and you will see there will be a sudden loss of change. Now, that change of course, the total energy will be remained constant by having that loss, a minor loss and according that major loss. So, total energy will be constant as per that energy diagram here u square by 2 g by here p by rho g.

So, again here in this case there will be some divergent; that means, whenever cross sectional area is changing from this section to this sections, that is divergent then there will be change energy loss, that energy loss will be considered as h divergent that is head loss. So, this head loss will be is equal what is that some coefficient it will be generally represented by this K divergent into u 1 minus u 2 whole square by 2 g. Now, this divergent coefficient divergent loss coefficient will be as a function of theta, because this cross sectional area will be changing with a certain angle theta here, as shown in the figure here.

So, it will function of theta. If it is this theta that is the angle is 5 degree 30 minute then we can say that it will be 0.135 for the circular cross section. Whereas, for the mean it will be minimum for the rectangular section when theta will be equals to 6 degree and it will be is equal to 0.145 and this kind K divergent; that means, divergent coefficient it will be 1 almost it will be constant whenever this theta will be wearing from 50 degree to 60 degree or more in that case. That means, higher degree will give you this divergent coefficient to the unity.

And in this here another graph is shown here. This graph is basically how the divergent coefficient in changing with theta here and it is shown here and for different diameter you will see how this cross sectional area ratio will change and based on which this how this divergent coefficient changing this profiles are given in this figure. Now, from this figure you can easily calculate for different cross sectional area ratio if you know and the diameter for the inlet flow if you know, then you can easily calculate what will be the divergent loss coefficient there.

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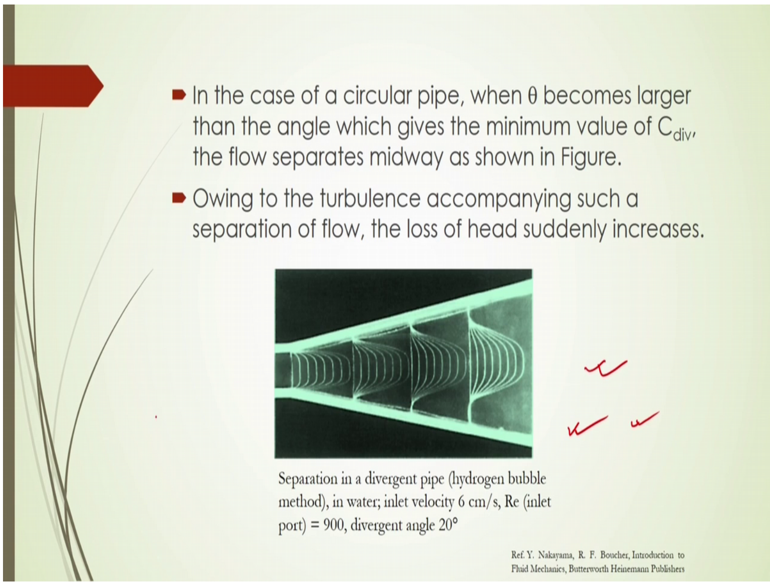

Now, in the case of the circular pipe you will see when theta becomes larger than the angle which gives the minimum value of c divergent the flow separates mid way as shown in the figure here the when do the turbulence accompanying such a separation of flow the loss of head suddenly will increase. So, in this case you will see the figure is shown here, the separation in a divergent pipe here in water inlet velocity of 6 centimeter per second, where Reynolds number is equal to 900 and divergent angle is at 20 degree this is the visualization observation that is given by Nakayama's.

So, he observed this type of a flow phenomenon. There will be occurrence of the turbulence and, because of which there will be a some change of energy, that is loss of energy and that in that case what should be the minimum value of that coefficient of divergent, that is calculated based on this equation here.

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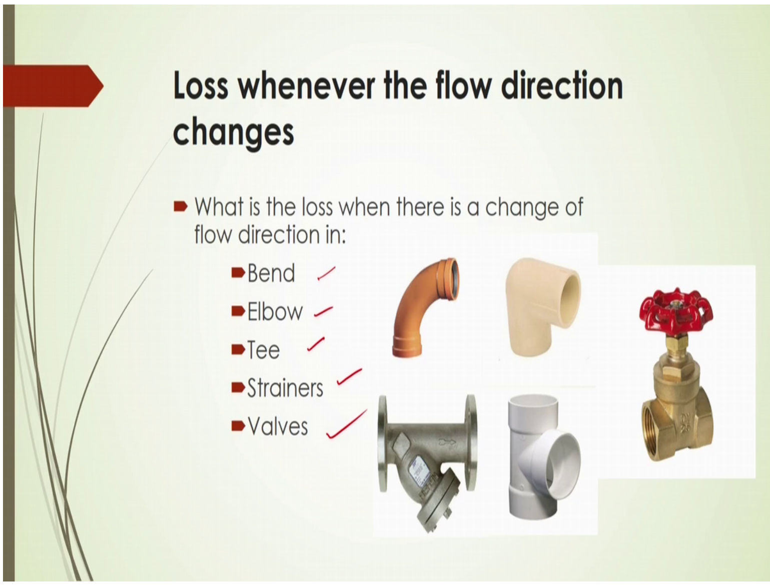

And again loss whenever the flow direction will be changes that also to be considered. So, what is the loss when there is a change of the flow direction like bend, elbow, tee strainers and walls here in this case? So, how that loss coefficient, minor loss coefficient to be considered or calculated?

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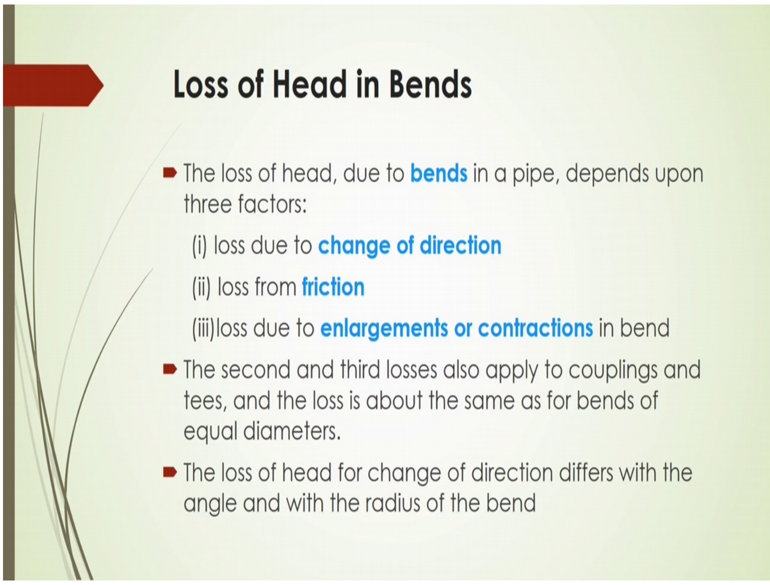

So, let us see here in the bends, the loss of head due to the bends in a pipe that depends on three factors; one is loss due to change the direction and loss from the friction and loss due to the enlargement or contraction in the bent. The second and third losses that is loss from a friction and loss due to the enlargement or contraction applied to the couplings and the tees and losses about the same as for the bends of the equal diameters there. In the loss of head for change of direction differs with the angle and the radius of the bend there.

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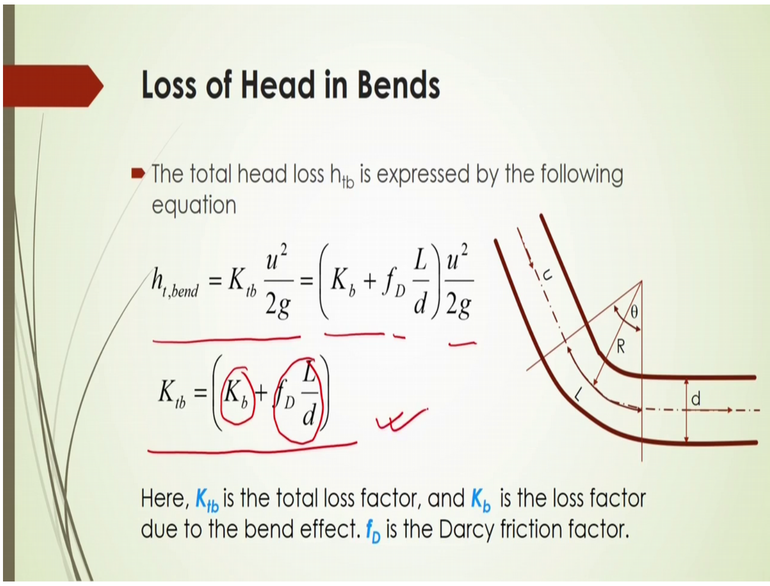

So, here see in the diagram. It is shown that there is a bend and the total head loss, it is denoted by h t b, which is expressed by this following equation here h t bend that will be is equal to K t b into u square by 2 g that will be is equal to K b plus f D into L by d that into u square by 2 g. Now, here in this case K b plus f D in to L by d. This K b is called the minor loss coefficient due to the bend and this f D into L by d, this is the major loss coefficient. So, total loss coefficient will be is equal to what is that, this K b plus f D into L by d.

So, here K t b is the total loss factor and K b is the loss factor due to the bend effect only and f D is the Darcy friction factor. So, the total loss factor you can calculate based on this equation.

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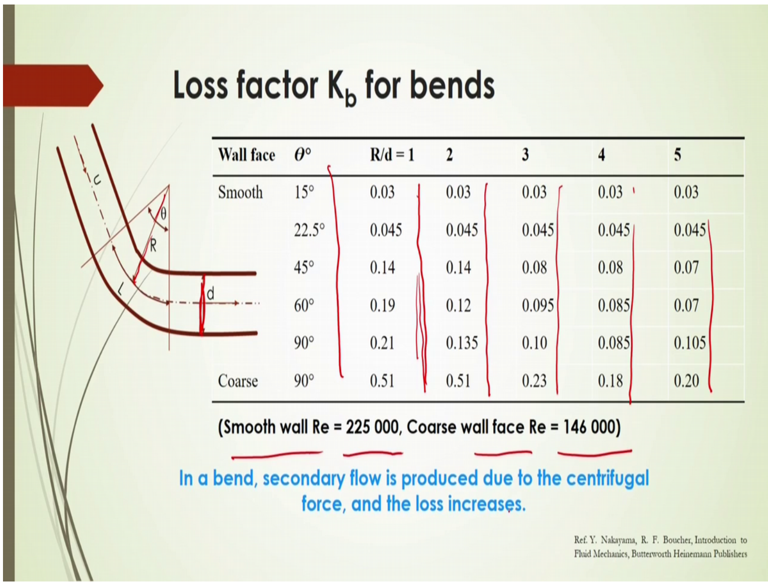

And some results of this loss coefficient loss factor, because of this bends for different angle theta here as shown in the figure then you can get a what will be the value with respect to theta here. You can get for the ratio of R by d as shown here R is here, it is shown in here in your figure and d is this diameter of the pipe, if R by d is changing then you can have different value of Kb also.

So, if you are having this R by d is equal to 1 that is R and d are same then you can get this K b value like this if it is ratio, if it's ratio is 2 then you can get these values, if it's ratio is then you can get these values again for or 4 5 like this. This chat will give you that value of minor loss coefficient due to the bends. Of course, these are applied only for smooth wall where Reynolds number is this and coarse wall phase where Reynolds number is this. For a bent secondary flow is a force produced due to the centrifugal force and the loss will increase because of that.

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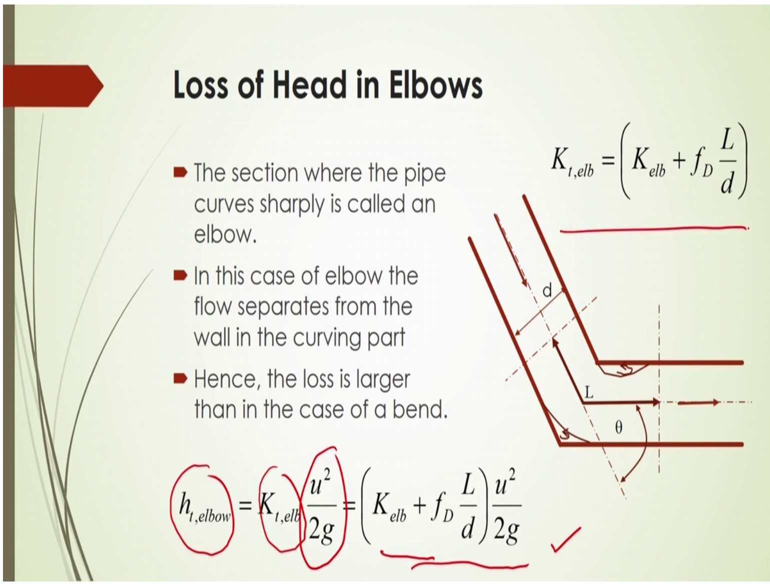

Now, if there is a bend like this elbows then what should be the head loss ?

That again the section where the pipe curves sharply, it is called elbow and in this case the elbow the flow separates from the wall, in the Caribbean part. Hence, we can say that the loss is larger than the case of the bend here. So, sharp bend and regular bend here that is the different issue. So, for sharp bend you will get there will be a larger loss than this regular bend. So, here in this case this h t elbow that is total head loss here, it will be Ktb elbow into u square by 2 g then again it will be Klb plus f D into L by d. Here, this will be your equation to calculate this total head loss due to this elbow of the sharp bends and then loss coefficient will be calculated by this equation.

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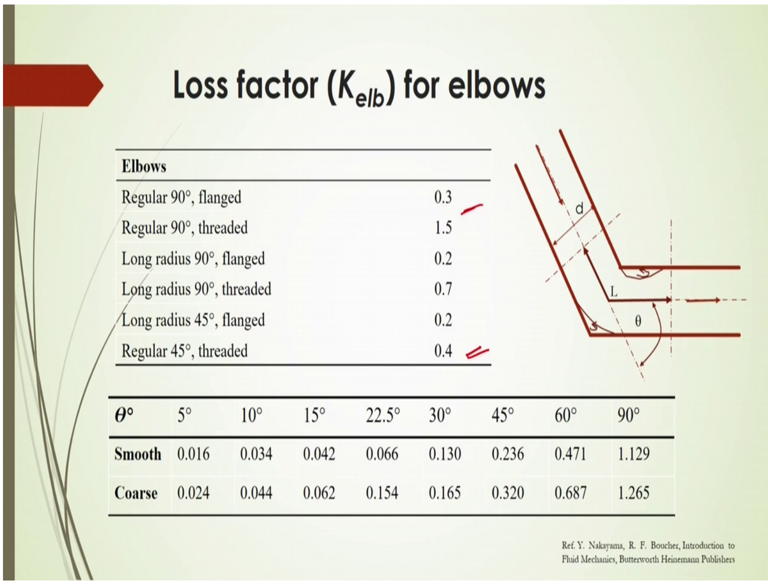

And again from some results it is given the reference, given here. So, for this elbows, if there is a regular 90 degree flanged type elbows then you have to consider this loss factor will be is equal to 0.3 whereas, regular 45 degree threaded then it will be 0.4. So, from this table you can have the values how to calculate or what we will be that loss factor for this elbows for different angle of pipe with different radius and also what is that with flanged and for smooth curve and also coarse curve, how it will be of value changing with this theta that you can have from this table.

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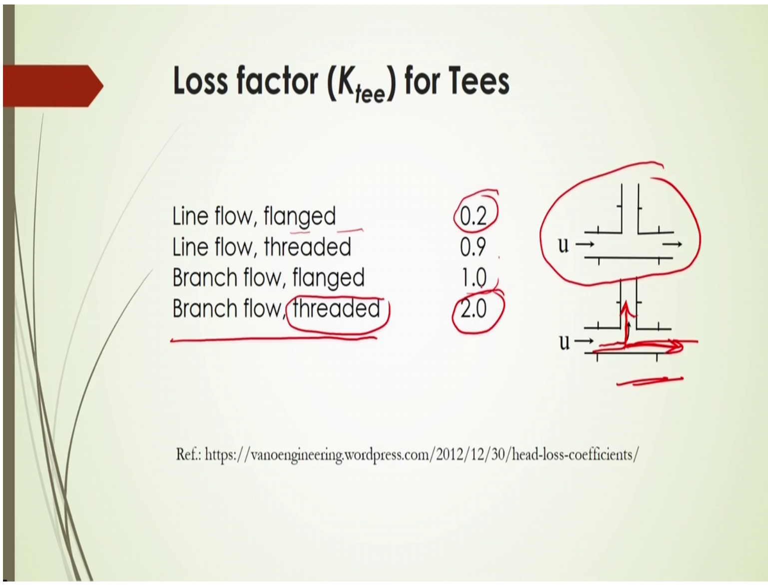

And what should be loss factor if you are considering that tees? There will be sometimes the pipe be used in such a way that you have to joint this two pipes as a tee to change this flow directions to here.

So, here if you are considering this tee in that case that is called line flow. If it is flanged then you have to consider this loss factor will be is equal to 0.4 2. Whereas, branch flow; that means, here if the flow is moving to this other direction instead of this straight flow then you can say that it is called branching, that is the flow will be divided into two parts in this direction and in this direction. So, branching of the flow if it is flanged type then you have to consider this loss coefficient as one whereas, if it is threaded then you have to consider this loss coefficient will be is equal to 2.0.

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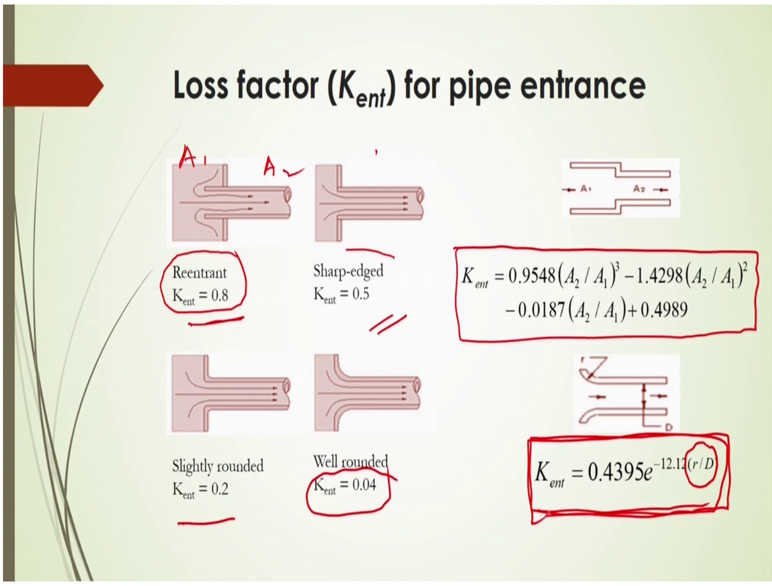

Whereas, if there is a loss vector if there is a pipe in transude suppose there is flow that is coming from some certain entrance then there will be a some loss whenever flow is just enter into the mainstream. So, there will be some entrance loss. So, if it is there is a reentrant type then you can say that entrance loss will be equals to 2.8, if there is a sharp edged entrance then you can consider this K entrance that is loss factor for this entrance will be is equal to 0.5 whereas, there if there is a slightly rounded then this entrance coefficient will be equals to 0.2

Whereas, if this entrance will be well rounded then it will be very small then 0.04 to be it's value. Now, this entrance loss actually depends on the ratio of this cross sectional area. That is, if the flow is coming from this cross section A 1 to A 2 A 2 then what will be the ratio? That is A 2 by A 1, this entrance loss coefficient depends on this ratio of this cross sectional area. Now, if you use this correlation here, one correlation is given. This, from this correlation you can easily calculate this entrance loss coefficient if you know the ratio of this cross sectional area.

Similarly, if there is a well rounded shape of this entrance then what should be the radius of this round shape of entrance and what should be the pipe diameter. If you consider then ratio of r by D, it will be very interesting then this ratio by r and D. Ratio of r and D will effect this entrance loss coefficient and how it will be related then K entrance will be exponentially related to this r by D ratio. this K entrance loss coefficient you can calculate from this correlation here.

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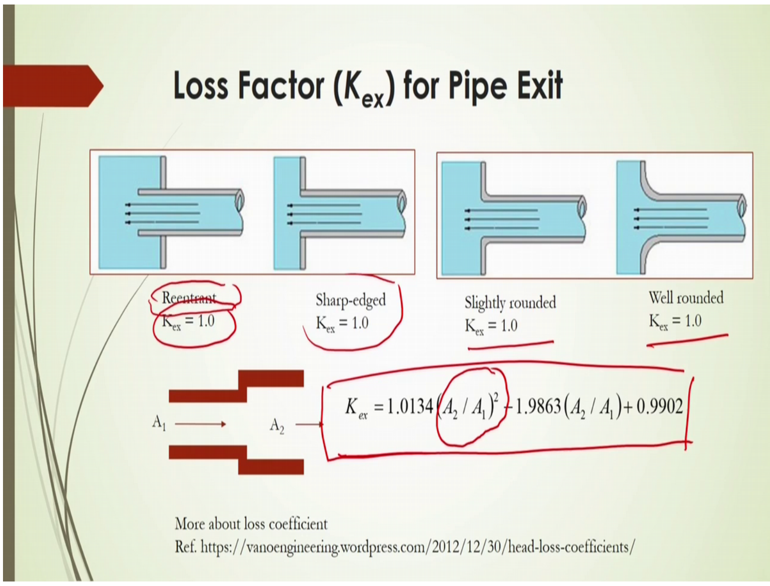

Again, if we are considering that there will be a exit, that is whenever a liquid is coming out from that is pipe and it will falls in a certain storage then there will be some exit loss. So, in that case this exit, if it is shaped as a reentrant type then this exit coefficient will be equals to 1. Again, if it is a sharp edged then K x will be equals to 1.

Similarly, slightly rounded again the same value well rounded it will be same value. There will be no change of this exit loss if there will be a sudden change of shape of this entrance, but it is related to the cross sectional area. If there is a cross section area change again, the ratio of this cross sectional it will be a two by a one then it will be related by this equation here K e x will be equals to 1.0134 into A 2 by A 1 whole square minus 1.0, what is that 9863 into A 2 by A 1 plus 0.992. So, from this correlations, you can easily calculate, what should be the exit loss, whenever fluid is coming out from the pipe.

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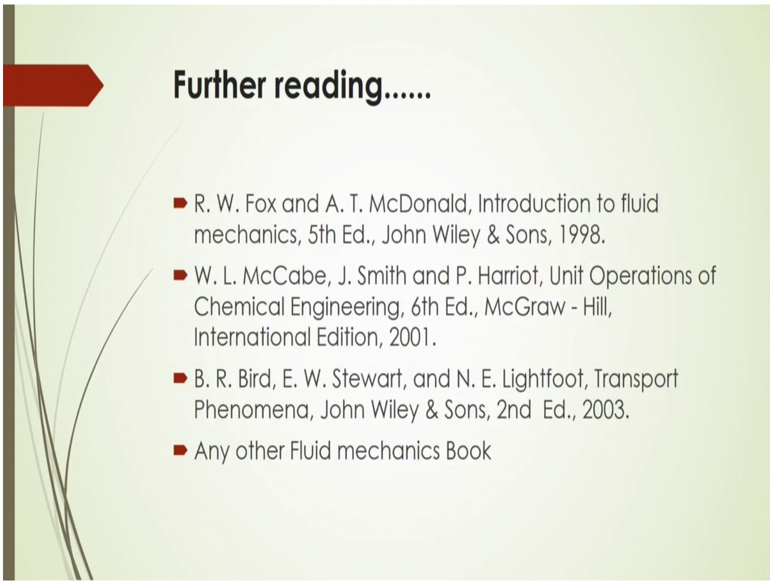

So, we have discussed in this lecture what will be the minor loss, what will be the major loss.

So, major loss will be that is based on the frictional loss whereas, minor loss that will be based on the geometry of the pipe changing. So, whenever you are going to; that means, consider for the flow through a certain conduit and to have this fluid from certain portion of this unit by using this pipe and you are calculating the pressure drop or energy loss or if you are considering that simulation of the energy, how it will be coming and what will be the energy loss for this friction, you can calculate from this for which you have to consider this what will be the minor loss and major loss there.

So, based on this lecture you can easily calculate what will be the minor loss major loss. So, I think we have discussed that different loss, whenever fluid is passes through the pipe and changing with this direction. So, next class on, on next lecture we will also discuss something more about this loss if is there any change of flow direction based on this branching of pipe or join, junctions of the pipe is there or not. So, I will suggest to read this contents for further understanding. Any other books you can also follow like here this text books are given there also you can get more information if you need so.

Thank you.