Equipment Design: Mechanical Aspects
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Lecture 10
Compensation for Opening

Welcome to the fifth lecture of week 2 and here we are continuing the discussion which we have started in lecture 4, which is on compensation of opening. So what we have observed till now that compensation for opening is required when whatever material available in the vessel and nozzle as extra material, if that material will be lesser than the material which I need to compensate, if that area is less than the area which I need to compensate then only I will provide compensation otherwise not.

So do I have any method so that I can judge whether compensation is required or not without performing detailed calculation okay. The answer is yes, I have a criteria and that criteria is defined or given in terms of a factor and that factor is called K dash, if you see.

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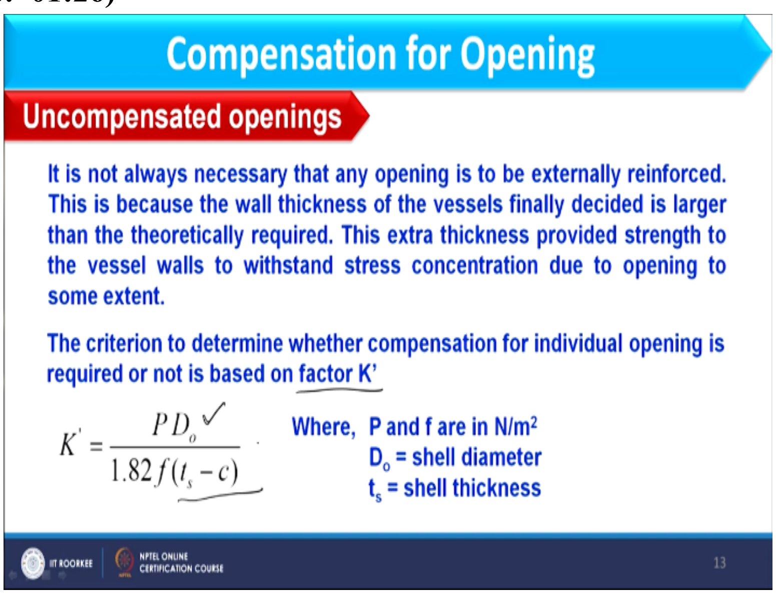

So what is K dash, K dash is basically defined by this expression, where K dash is equal to P D o/1.82 f t s – C, P is basically the design pressure, f is allowable stress, D o outer diameter of shell or where I am preparing that opening, t s is the standard thickness of shell or the part where I am creating the opening and C is the corrosion allowance. So based on this expression, first of all we will calculate K dash value and then based on that K dash we have different criteria. So let us focus on these criteria.

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So the criteria is if K dash is less than or equal to 1, for diameter less than 0.05 meter, need not be compensated. What is the meaning of this. It means that D is basically the diameter, which I need to compensate. If that diameter is less than 50 mm, I can remain that opening as it is, I do not need for compensation for that particular opening. So that is the criteria if you are having opening for 50 mm or less than that you can simply say that compensation is not required and therefore whole calculation you do not need to carry out.

Now if diameter varies from 50 mm to 200 mm, as it is shown over here, in that case it can remain uncompensated or unreinforced, which depends on the shell diameter, okay. So we have to focus on shell diameter to decide whether compensation is required or not. Shell diameter means if opening is made in shell, otherwise whatever component is having opening, diameter of that particular component we will consider.

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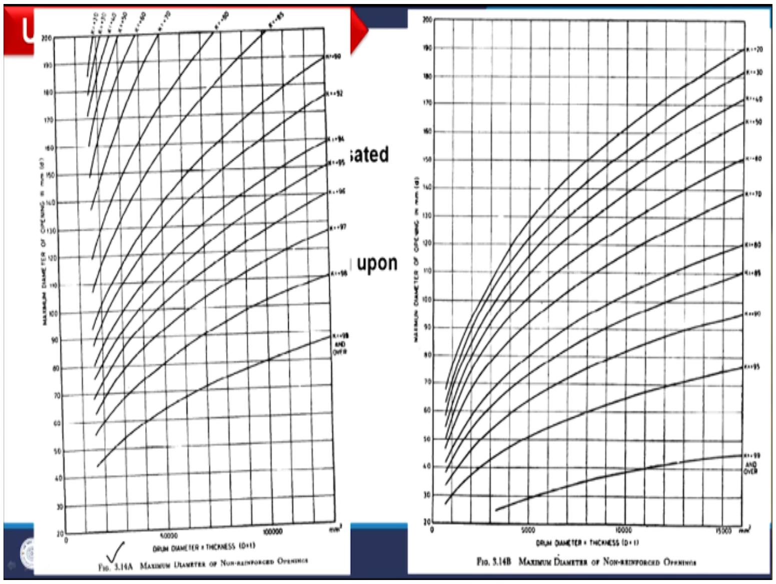

So that diameter we can decide or we can find in this image, which is figure 3.14A in code, this is given in IS; 2825, that figure you can tally, and second part is 3.14B, these figures are available in code. So if you consider this figure A, here we have large X-axis, however, for small axis we have this figure B okay. So how this figure I have to use, that we will discuss.

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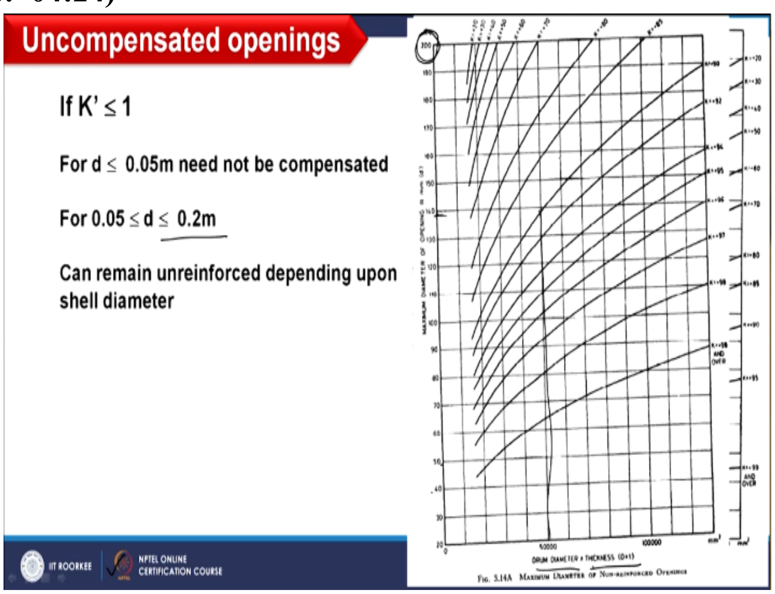

Now what happens, reinforcement is basically based on the diameter of component where opening is made. So for example if I am preparing opening in shell, so that would be the drum diameter, it means the shell diameter into thickness. So that thickness is basically standard thickness. So diameter as well as thickness I have to consider in mm and whatever value I am finding over here okay. Whatever value I am getting on X-axis corresponding to that value and corresponding value of K dash. Here basically instead of K dash, K is mentioned, but it is computed based on same expression.

So for example, if I am having this K value as 0.8 and let us say drum diameter into thickness is 50,000, so this we can consider over here and here we can see that this value will come around 138. So Y-axis shows the maximum diameter of opening. It means up to 138 mm, I do not need any compensation, if this is the condition for drum diameter as well as K dash. However, beyond 130 mm whatever opening is present that I need to compensate.

So this graph basically speaks about whether compensation is required or not. And if you see Y-axis of this diagram goes up to 200 mm. So that is the condition over here also that up to 200 if condition lies accordingly I will choose whether compensation will require or not required okay. And value available almost above 50 mm, so therefore below this compensation will not require. On the other hand, what we can see that beyond 200, okay because this figure speaks only up to 200, so beyond 200 mm or greater than 0.2 meter opening compensation must be required.

So let us say your opening is 0.21 or 0.22 and you are asked to examine whether compensation is required or not, in that case there is no need to calculate K dash value or see this graph, you can directly say that compensation must be required for this and therefore we need to carry out whole calculation up to ring pad area as well as thickness of ring pad. So in this way we decide whether compensation is required or not. And if it is required, then only I need to pursue whole calculation, otherwise we can stop while computing K dash and see the diameter of opening.

Now, to make you understand the computation more clearly, I am having a few examples, so let us start with example 1.

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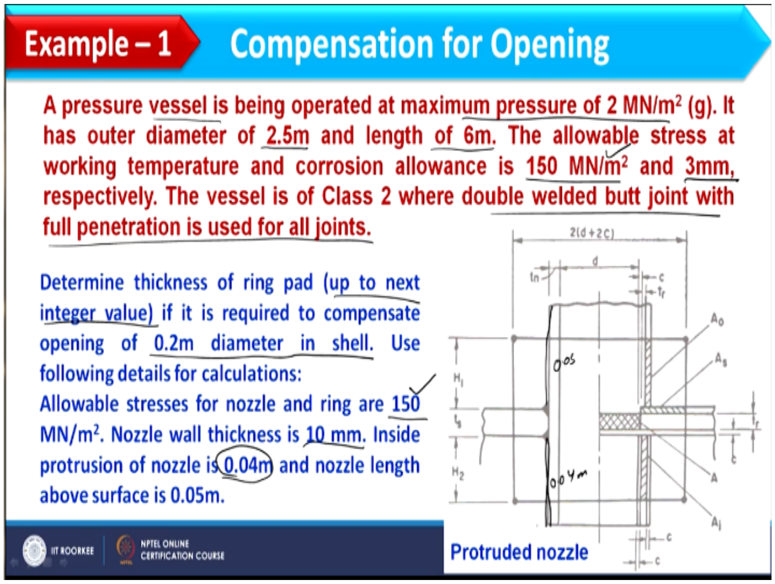

In this example, a pressure vessel we are considering which is operated at maximum pressure of 2 meganewton per meter square in gauge, outer diameter is 2.5, and length of shell is 6 meter, allowable stress at design temperature and corrosion allowance is 150 meganewton per meter square, and 3 mm.

It is class 2 vessel, where double welded butt joint with full penetration was used for all joints. So these joints are basically we can use for shell as well as for nozzle. What we need to find is, determine the thickness of ream pad up to next integer value, if it is required to compensate opening of 0.2 meter diameter in shell. So opening I am having 0.2 meter, and I have to examine whether compensation is required or not because the maximum value of opening is 0.2 available in the graph, so here we need to examine whether compensation is required or not.

For this calculation following values are given. Allowable stress of nozzle and ring are 150 meganewton per meter square. So here you see allowable stress of nozzle and ring pad as well as that of shell is equal. Nozzle wall thickness is 10 mm, which is nothing but t n, that is the standard thickness of nozzle. Inside protrusion of nozzle is 0.04 okay. So if you see this image, here basically this length of the nozzle it is given as 0.04 meter. However, length above the nozzle this value is given as 0.05 meter. So here we have to first examine whether compensation is required or not, and if required we will carry out the whole calculation. So let us start the solution of this example.

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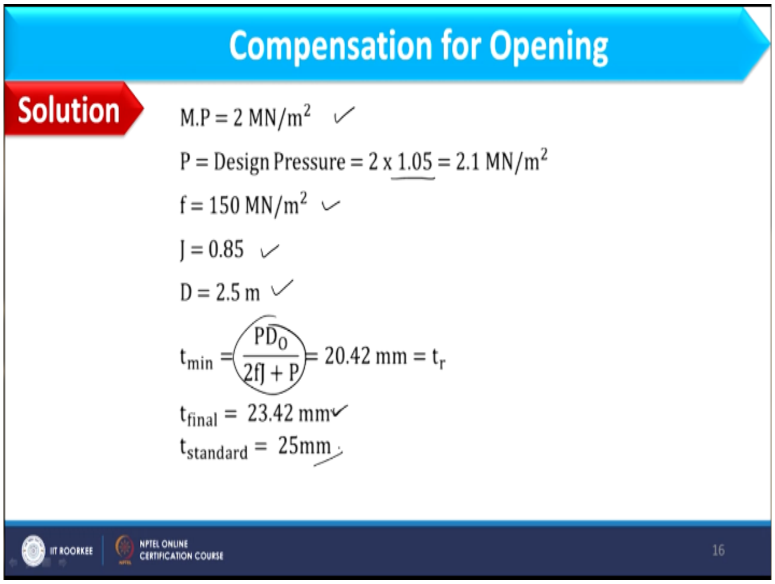

Now, in this problem maximum working pressure is given as 2 meganewton per meter square, design pressure we are considering 5% extra than this. So 2.1 meganewton per meter square is the design pressure. Allowable stress 150, joint efficiency factor 0.85 is given for double welded butt joint with full penetration, diameter 2.5 is given.

So considering this expression we will calculate minimum thickness of shell and that comes out as 20.42. Adding corrosion allowance to this, we have thickness 23.42 and then we will refer table B1 and we can choose 25 mm as standard thickness. So 25 mm is the standard thickness of shell, in which we have prepared opening of 0.2 meter diameter.

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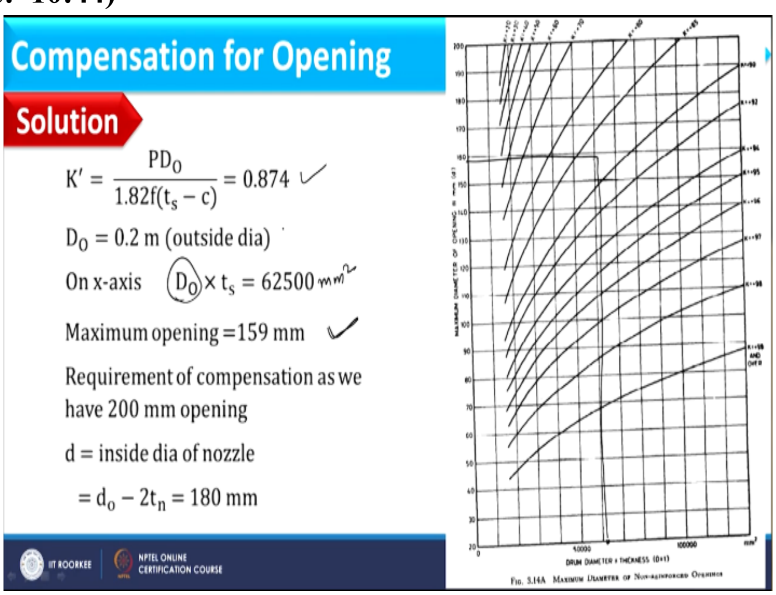

So first of all we will see K dash because I need to examine whether compensation is required or not. So K dash is computed like P D o/1.82 f t s - c, considering all these values over here, we can have K dash 0.874. Outer diameter is 0.2 meter, outer diameter of opening okay. So D o * t s that is outer diameter of shell, this is basically 2.5, so 2500 * 25, so that is 62,500 mm square. So now we will see figure 3.14, where D o * t s is 62,500, so here I have having this is 50,060, so somewhere here it will have 62,000 okay.

And this K dash value is coming as 0.87, so here I am having 0.85 and here 0.9. So somewhere value will lie over here, like this okay. So if you draw this line, corresponding to 62 and here if you see the value will come around 159 mm. So 159 mm is the value of opening that remain uncompensated. And as our opening is 200 mm, which is greater than this, so it means that compensation must be required.

So in this way we have examined whether compensation is required or not and once we have observed that it is required, we will carry out whole calculation. And if we compute the area required to be compensated in this, D is basically inner diameter of nozzle, not the opening. So 0.2 meter is the opening diameter and inside this I am having the nozzle and thickness of nozzle is 10 mm, so in that case 200 – 20 would be the diameter, which I need to compensate okay, so that would be value of d. So considering that we can calculate value of d as 180 mm.

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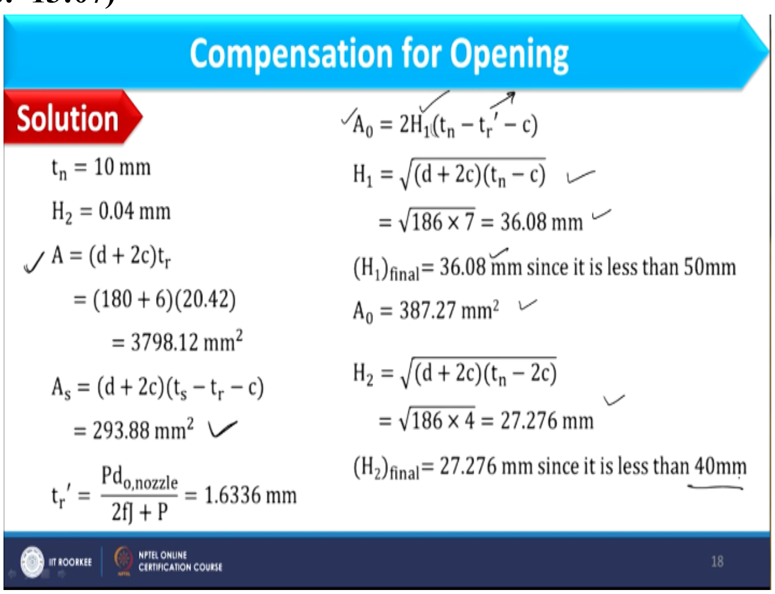

Now we need to calculate area required to be compensated, so that we can calculate through A, which is given as D + 2 C * t r, D is 180 we have just computed, C is 3 mm, so 2 C is 6, and t r 20.42 mm we have computed as minimum thickness of shell. So based on these values, 3798.12 mm square area I need to compensate. And then we will calculate how much area I am having as area of additional material. For that case I have to compute A s and A n, A s is basically area of additional material in shell and A n is the area of additional material in nozzle. So let us start the calculation of A s.

Expression of A s = D + 2 C t s – t r – C. So putting all these values we can have A s as 293.88 mm square. And further for A n, we have to calculate A o as well as A i. So A o how I can calculate, it is equal to 2 H1 (t n – t r dash - C). So t r dash is basically the minimum thickness of nozzle. So that I can compute using standard formula of thickness calculation and where D o nozzle is basically used as outer diameter of opening.

So this P is the design pressure because nozzle will have the same design pressure as that is used for shell. So D o nozzle that will be 200 mm/2 f J + P. So values we will put over here and then 1.6336 mm will be the minimum thickness of nozzle. So considering t r dash, so further for A o expression along with t r dash I also have to find out H 1 value, H 1 is given by this expression and the value comes as 36.08 mm.

And H 1 final would be 36.08 mm. If you remember H 1 is basically the boundary decided over the vessel okay. So that will be compared with the outer length of the nozzle. Outer length of the nozzle in this case is 50 mm. Now H 1 is less than 50 mm, so H 1 we will consider as 36.08. Considering these values, A o we can find at 387.27 mm square. And in the similar line I will calculate H 2 and that will be compared with the protrusion part, which is 40 mm. So 27.276 is less than 40 mm, so H 2 will be considered as 27.276 mm.

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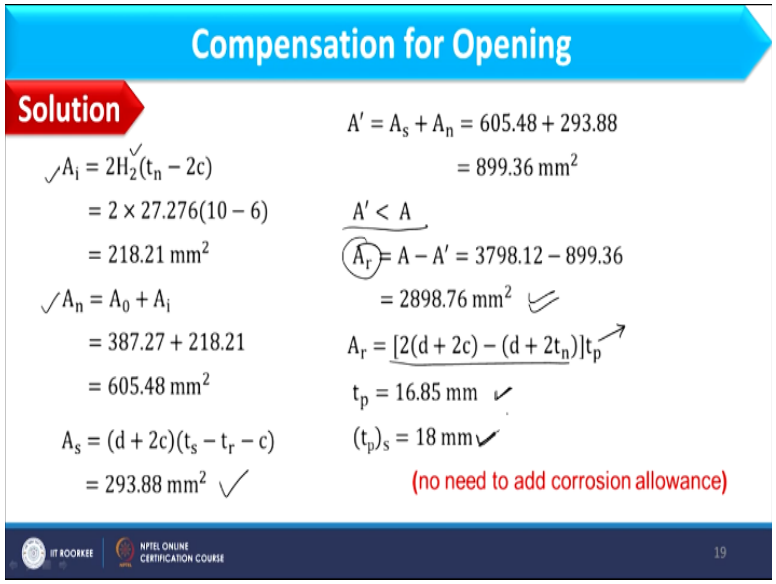

Once I am having H 2 value, I will find out value of A n, which comes out as 218.21 okay. So considering A o and A i, I will find A n and then A s we have already computed as 293.88 okay. So A dash would be A s + A n. Now I will compare A dash with A and I can found A dash will be significantly less than A, therefore I need to calculate A r, that is area of ring pad and that would be A – A dash. So this would be the area of ring pad.

So once I am having the area of ring pad, I will put that in the given expression, and then I will calculate thickness of ring pad and it comes out as 16.85 mm. Though in the problem we have to find out t p s as next higher value than this, but this value we have taken from table B 1, which is 18 mm. In that case no need to add corrosion allowance that is the main point to discuss. That 16.85 is the minimum thickness of ring pad. I have not added corrosion into this and directly I have taken next value than this available in table B1.

Why I am doing so because ring pad is placed over the vessel, are you getting. Ring pad is basically placed over the vessel. It means ring pad is in contact with the metal. It is not coming directly into the contact of the liquid or the fluid, which is filled inside the vessel, and therefore material of ring pad will not be wasted due to corrosion and therefore corrosion allowance will not be added to this. So whatever minimum thickness of ring pad I have computed, directly I have taken next value available than this in table B1 okay.

So in this way we calculate the thickness of ring pad. So till now whatever problem I have solved, in that case allowable stress of ring, nozzle as well as for shell, all these allowable stresses are equal. Now we will see if these value differ.

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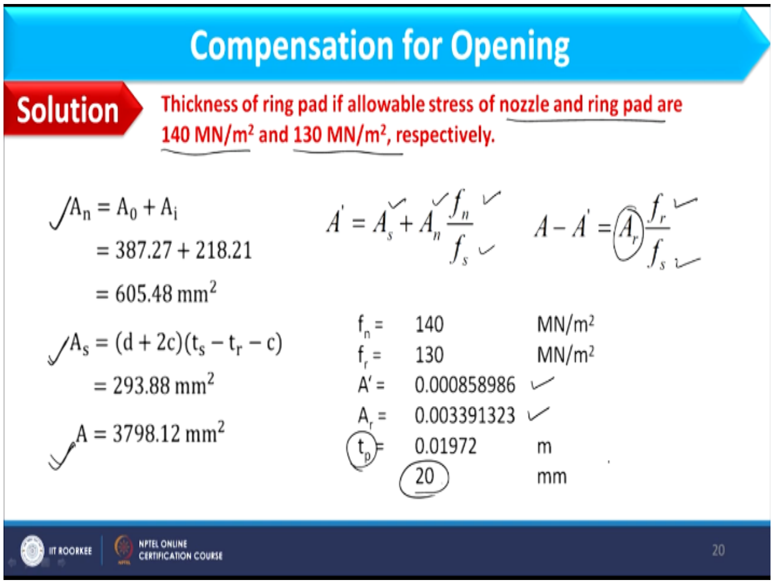

So we have to find thickness of ring pad if allowable stress of nozzle and ring pad are 140 meganewton per meter square and 130 meganewton per meter square respectively; however, for shell allowable stress value is given as 150 meganewton per meter square.

In that case, this is A n, this is A s and here we have the value of A. Now how I can find A dash, which is equal to A s + A n, f n/f s, f n is the allowable stress of nozzle and f s is the allowable stress of shell okay. Considering this, A s I have already calculated, A n I have already calculated, putting all these value we can calculate A dash as 0.000858986 okay. And A – A dash will be equal to A r f r/f s, f r is the allowable stress of the ring pad and f s is the allowable stress of shell material. A I know, A dash I know, all these two values I know already.

So from these I can compute A r. So A r will come as 0.0033913 and using the expression of A r as a function of t p I can compute t p as 19.72 mm and next value to this is 20 mm without adding corrosion allowance. So in this way we can calculate the ring pad thickness if allowable stress values vary for each section.

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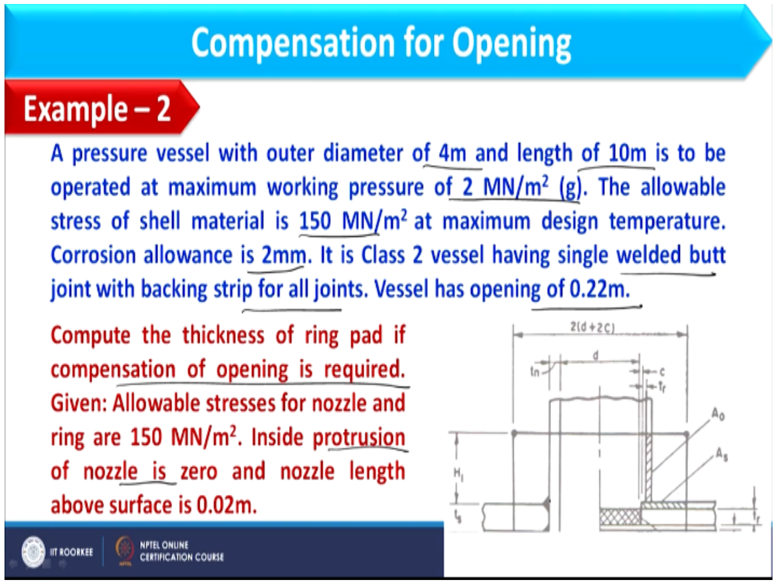

And here I am having second example, through which you will have more idea how to carry out compensation for opening. So in this diagram pressure vessel with outer diameter of 4 meter and length 10 meter is considered. And it is operated at maximum working pressure of 2 meganewton per meter square, allowable stress is 150 and corrosion is 2 mm, and this is again class 2 vessel with single welded butt joint with backing strip.

Vessel has opening diameter of 0.22 meter. We need to compute the thickness of ring pad, if compensation of opening is required. So again I need to examine this. Allowable stress for nozzle and ring pad are 150, inside protrusion length is 0, there is no protrusion part in this and nozzle length above the surface is 0.02. So in this case I only know the value of this nozzle length above the vessel. So let us start the solution of this.

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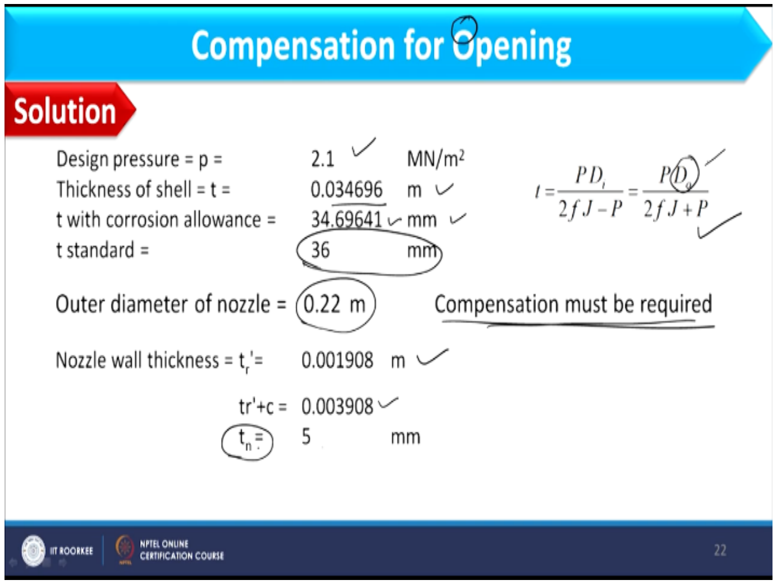

Here I am having the design pressure 2.1 as we have calculated in example 1, thickness of the shell comes out as 34.69 mm, this I have already explained how it is coming, there is no need to repeat that again and again. T with corrosion allowance, it will remain 34.696 mm as this minimum thickness is greater than 30 mm.

So we have not added corrosion into this, though it is given in the problem. And next value to this is 36, which is available in table B1, so this we have chosen as standard thickness for shell. Now outer diameter of nozzle is given as 0.22, so in this case though we are asked to examine whether compensation is required or not. So in that case there is no need to compute the value of K dash or refer the graph because it is equal to 0.22 meter, and if you remember that graph is available only up to 200 mm.

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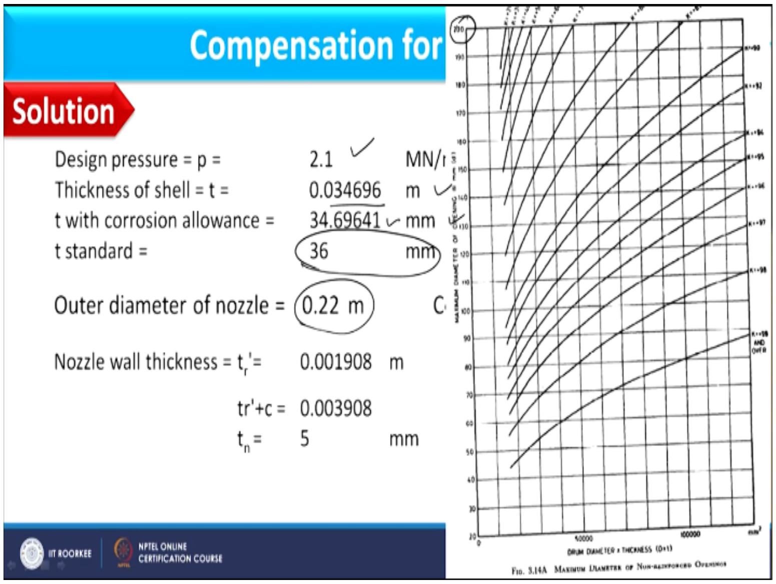

So up to 2 meter value we can see whether compensation is required or not through this graph. However, beyond this we should compensate and therefore in this case without computing I can say that compensation must be required.

Now in the calculation of area for compensation we need D value, D is the inner diameter of nozzle and inner diameter of nozzle is not given in this example, so for that purpose we will calculate minimum thickness of nozzle. Then if required corrosion will be added and then we can see the standard value available in table B1. So in that way we will proceed for computation of nozzle thickness.

So let us start this. T r dash we can compute using this same expression, where D o would be opening or outer diameter of nozzle and that would be equal to 0.22 meter. Considering that t r dash we can find out as 1.908 mm. T r dash plus corrosion is 3.908 mm and then next value to this in table B1 is 5 mm. So standard thickness of nozzle would be 5 mm. So to calculate D we will deduct 2 * 5 that is 10 mm from 0.22 meter. So in that case 0.21 would be value of D.

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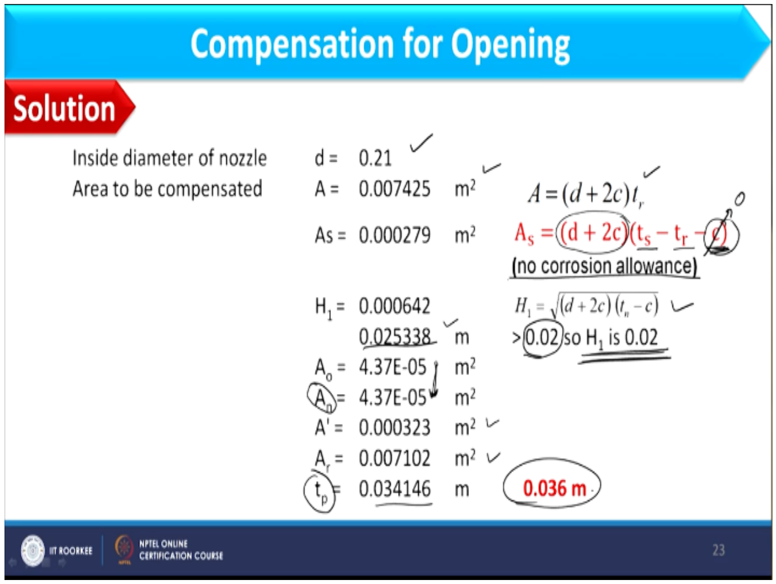

So here you can see this is the value of D 0.21. Area to be compensated, it will be calculated by D + 2 c * t r, so using the values of different parameters I can calculate A, which is coming out as 0.007425. A s will be computed using the expression as D + 2 c * t s – t r – c. Now in this case, t s is 36 and t r is 34.69 and c we have not added in this standard thickness. So in that case while computing A s value, we will not consider corrosion. So in that case this value would be equal to 0.

So D + 2 c * t s – t r, considering that we can find A s as 0.000279. However, we have considered c over here as well as here because that c corresponds to the corrosion available in nozzle. So in nozzle we have used the corrosion, but in shell we have not used the corrosion. Therefore additional material in shell will be calculated while neglecting corrosion allowance. And now I have to compute the value of A n, which is A o + A i.

So if you remember here in this case protrusion part is not given, so we will not compute A i, we will only focus on A o. And for that purpose, first I need to compute value of H 1. So H 1 is given as root over D + 2 c t n – c, considering that we can find H 1 as 0.025338 meter, and nozzle length outside is given as 0.02. So this calculated H 1 value is higher than this. So H 1 for calculation purpose is taken as 0.02.

So A o will be nothing but 4.37E–05 meter square, A n will only consider A o, so this value will be same as that of A o. So considering this we can find A dash as 0.000323 and then area of ring pad as 0.071, area of ring pad we can compute using regular expression. And further using expression of A r as well as t p we can find t p as 34.14 mm and next standard value of this is 36 mm. So in that way we can find thickness of ring pad as 36 mm.

Here I have again not added corrosion allowance, and the reason why I am not adding that I have already explained in example 1. So here we have seen two examples to calculate compensation for opening and I hope you have the idea how to compute this, how to examine the compensation requirement and how to compute this okay.

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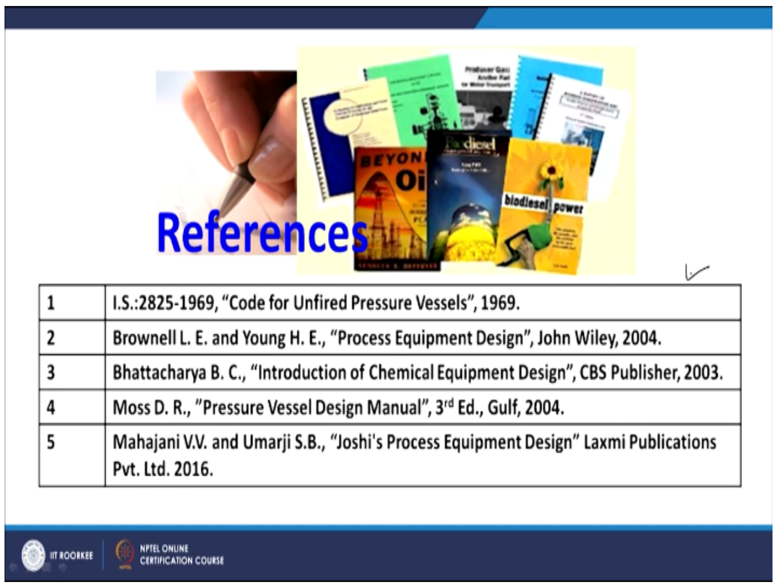

Here I am having a few references, which we have used to prepare this lecture. You can go through these references.

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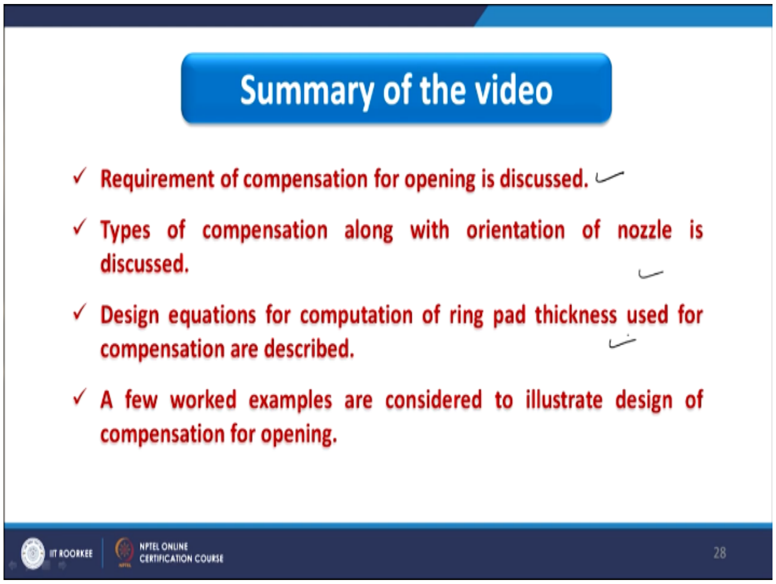

And here I am having summary of the video and this summary is related to the summary of lecture 4 as well as lecture 5. And it goes as requirement of compensation for opening is discussed, types of compensation along with orientation of nozzle is discussed, design equation for computation of ring pad thickness used for compensation are described, and further we have solved a few examples to illustrate design of compensation for opening okay. So that is all for now, thank you.