Equipment Design: Mechanical Aspects
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Lecture 17
Design of Support

Welcome to the second lecture of week 4 and in this lecture we will discuss design of support. Discussion on design of support we have started from the previous lecture and where we have discussed what are supports for vertical as well as horizontal vessels, and there we have also discussed one support that is bracket or lug support, which is used for vertical vessels of small height. Now in this lecture we will discuss design of support and here we will discuss design of support for horizontal vessel and that is the saddle support.

So let us start the discussion on saddle support.

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So general practice of supporting horizontal cylindrical vessel is by means of saddle support and number of support or number of saddle may be two or more. So basically this saddle support is used for horizontal vessels and how it looks like that we can see from these images. So if you see this image here we have the horizontal cylindrical vessel okay, different sections you can identify, this is the shell, this is head, and it is basically supported by these supports and these supports are called as saddle support okay.

So if you see saddle support is nothing but this structure okay and which has curvature and that curvature fits well with the cylindrical vessel. If I want to see separately the saddle support that you can see in this image and where this is basically the saddle and where this curvature will depend on the diameter of vessel okay. So this is basically the saddle support. Now if you focus on this image, here we have horizontal vessel and as far as stresses are concerned this horizontal vessel has longitudinal stress as well as circumferential stresses okay.

So this saddle support should be designed in such a way so that it can withstand or it can hold the vessel with all longitudinal as well as circumferential stresses. So from here onward we will discuss the stress analysis related to the saddle and according to these stresses what should be the condition that must be satisfied for completing the designing of saddle. So let us start the stress analysis for saddle.

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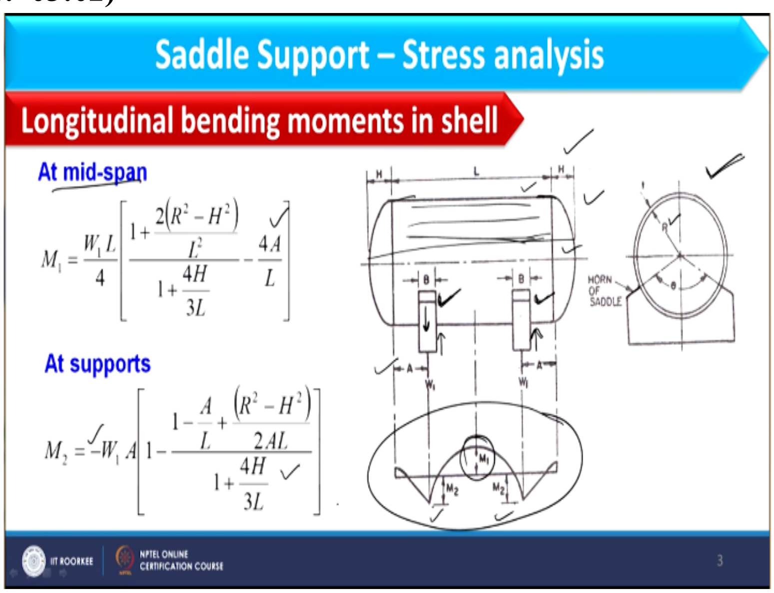

So as far as stress analysis of saddle is concerned we will first discuss the longitudinal stresses and then we will focus on circumferential stresses. Now as far as longitudinal stresses are concerned we will first speak on longitudinal bending movement and then that movement will be considered to compute stresses in longitudinal direction. So let us start the discussion on longitudinal bending movement.

And further we can see that these longitudinal stresses are available in shell. So whatever stresses are available in shell that should be supported by saddle okay. So in this case as far as longitudinal bending movement is concerned we focus that discussion on shell okay. So if you consider here I am having this shell which is horizontally placed, if you see this is the shell and where it is lie on two saddle that is this one as well as this one. Now the total weight of the shell will be supported by these saddles and that will be taken by these saddles.

Now as far as weight is concerned what that can be that includes the weight of shell, weight of head and whatever content is inside the vessel its weight should be added to that, and if I am having different attachment inside this, for example, if I am having tubes or some other assembly so weight of those assembly will also be included in total weight okay.

So here we can see the total weight and that total weight will be equally distributed to two saddles or if I am using three saddles so that will be distributed equally to three saddles okay. So for example, if I am having two saddles and total weight will be transferred to these two saddles equally I can make the movement diagram okay. Now to make the movement diagram it will be easier to consider shell as a beam which is lie on two supports okay.

Now if I am having a beam which is lying on two supports how I can make the movement diagram that we will discuss here. So for example, this is a beam which is lie on this saddle as well as this saddle now what happens total weight will be equally divided in these two saddles. Now what happens when the weight will act to these supports, the supports will give the reaction in opposite direction. So this will happen here and it will happen on second support also.

Now for drawing the movement diagram what we can consider that, for example, if this is the beam okay and you must understand that movement diagram we prepare from left to right, when we analyze the system from left to right. So what we have considered over here that shell is considered as a beam which is supported on two saddles okay. So as we have discussed that when weight is falling on the saddle, saddle will give a reaction in opposite direction.

So for example if I am having this beam or that you can consider as a shell which is we are considering as beam. Now this beam is basically supported at two places, this is one saddle, this is another saddle. So this is one saddle, this is second saddle. Now what happens when this saddle reacts upward and this saddle will also react upward okay and total weight of this shell will lie at the centre okay. So here I am having two reactions and at the centre I am having total load of the shell.

So when I am starting drawing the movement diagram I will start from left to right. So when I am starting from left the first reaction will occur due to first saddle and it is moving in upward direction okay. So it will try to turn this beam towards anticlockwise direction. I hope you are getting me. So when I am moving from left to right the first reaction will be due to the beam and as it is moving upward it will try to revolve it or move it in anticlockwise direction.

And further the second load I am having from this is the load at the middle of the beam that is the load of the shell okay. Now this load of the shell it is acting downward so it will try to make or it will try to rotate this beam in clockwise direction okay. And in the similar line if I keep on moving from here towards the end second saddle will give the reaction in upward direction and it will revolve beam in anticlockwise direction.

So when we draw the movement diagram what happens whatever anticlockwise movement that are denoted by minus sign and whatever clockwise movements those are denoted by plus sign that is the normal consideration. So the movements which are coursing through saddle support these will be denoted by minus sign and whatever will be created by weight of shell itself at the centre of beam it will be denoted by plus sign.

So considering this if I am focusing on this movement diagram, this M 2 and this M 2 will be negative, however, this M 1 would be positive based on discussion we have just done. Now further if we consider this assembly, if you consider here, what is this A, A is basically the distance at middle of the saddle from end of the shell, from this side as well as from this side okay. And then this H is basically the height of dome section and L is the tangent to tangent length.

Tangent to tangent length we have already discussed in previous lectures because this head is basically making tangent to the shell and therefore it is called tangent to tangent length. If we consider cross sectional view of this assembly, here you can see R is the inner diameter of vessel, theta is the angle which is made by support to the centre of vessel okay. So this is minimum angle of this support is 120 and then it keeps on moving.

And when support is attached to the shell this section we call as horn of the saddle okay. So as far as bending movement diagram, M 1 would be positive and M 2 would be negative. So at mid-span if I am considering, it means I am considering the centre part of this where M 1 will play its role and M 1 will have the positive sign and that would be denoted by this, which is equal to W 1 L/4, where W 1 is the weight on each saddle and (1+2 (R 2 – H 2)/L 2 / 1 + 4 H/3 L and – 4 A/L). So this is basically the movement at mid-span.

At support if I am considering where I am having M 2 and this is basically denoted by negative sign, why it is that we have already discussed and it is equal to – W 1 A (1 – 1–A/L + (R 2 – H 2)/2 AL / 1 + 4 H/3L). So these two expressions of longitudinal movement we have considered, which will be used for computation of longitudinal stress in shell.

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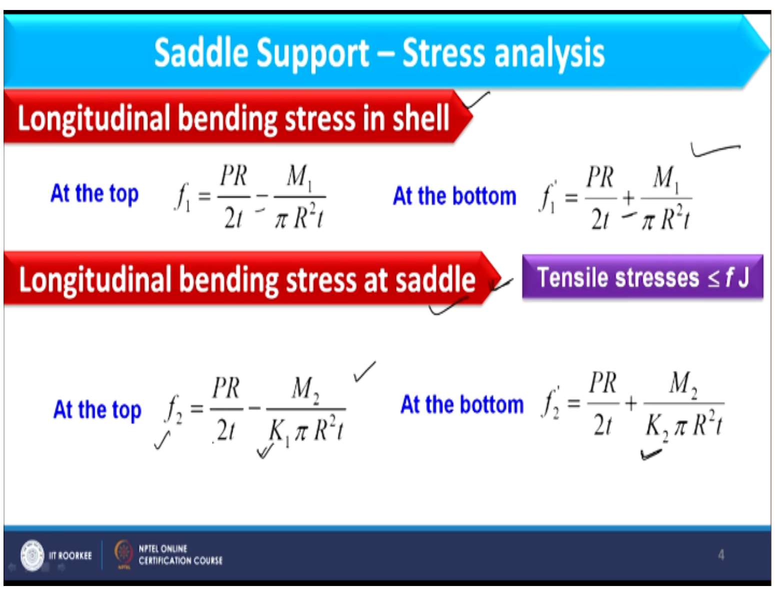

So here I am having longitudinal bending stress in shell. So here we have seen that longitudinal movements are occurring at two different places at mid-span as well as at support. So if I am considering mid-span, mid-span will have two section, if this is the vessel mid-span would be the at the middle of this total length and it has two section, first is at the top and second is at the bottom. Top it means top section or top point of, top point at middle of the vessel and bottom section we are considering at the centre or the middle point of the shell at bottom.

So stress at the top is given by f1, which is equal to PR/2t – M1/Pi R 2 * t okay. And at the bottom we will calculate f1 dash as a longitudinal stress and that is given by this expression. So here you see we have at the bottom plus sign and at the top we have minus sign. So stress at the bottom would be maximum.

Now we have longitudinal bending stress at saddle. It means wherever I am having the support, again this saddle will include two points, first is at the top of it and second is at the bottom of it. So at the top if I am considering it means I am considering top of shell which is just above the saddle okay. And bottom if I am considering it means bottom of shell which is attached to the saddle okay.

So here basically we are discussing these stresses in shell only, therefore all top and bottom are considered in shell only, whether it is lying in saddle or whether it is lying away from the saddle okay. So when I am having longitudinal bending stress at the saddle, at top we compute that in terms of f2, which is equal to PR/2t – M2/K1 Pi R 2 * t, and at the bottom we have this f2 dash where I am having constant K 2. So this K 1 and K 2 are design constants, which will be discussed later.

So for satisfactory design all these stresses that is f1, f1 dash, f2, f2 dash, all these stresses should be less than or equal to f J okay, where f is the allowable stress of shell. So in this way we calculate stress in shell in longitudinal direction. Now we will discuss stress in circumferential direction. So when I am considering circumferential stresses, it means throughout the circumference stress will form and which we have also discussed as hoop stress okay.

So whatever stresses are forming in a shell, all these stresses will be supported by saddle only okay. So due to shear all these stresses would be transferred to saddle only. So here we are considering two section, first is tangential shearing stress, which is for unsupported part, unsupported part means where saddle is not occurring or saddle is not available. And second we will consider circumferential stresses, which is just at the support or at the saddle. So let us start that discussion with tangential shearing stress which is related to unsupported part of vessel.

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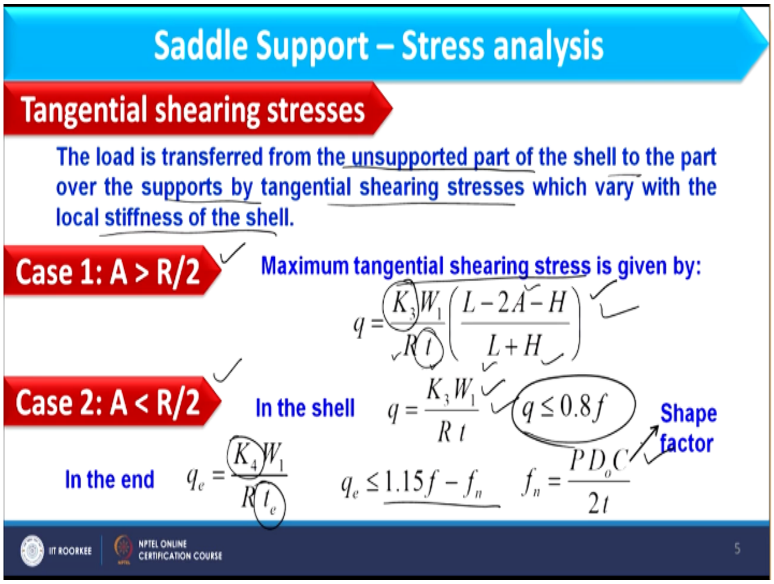

Now load is transferred from unsupported part of the shell to part over the supports by tangential shearing stress that we have discussed already, which vary with the local stiffness of shell. What is the meaning of that local stiffness. For example, if I am providing some structural support to the cylinder or to the vessel the load will be transferred or the circumferential stress will also be transferred to that structure okay.

So in that case what we can consider if I am having this much length and then I am having here head, so head is basically attached to the shell by welding okay. So that welding will provide structural strength to that support okay. So unsupported part in that case would be which is away from that edge where head is connected to the shell and which is not available at saddle. So whatever that part we have that we will consider as unsupported part.

So here I am having case 1, where A is greater than R/2. Now what is A, A if you remember we have discussed earlier that it is the distance from edge of shell to the middle point of the nearby saddle. So if that distance A is greater than R/2, which is basically internal diameter of shell if that distance is greater than R/2 we can calculate maximum tangential shearing stress as give by this expression where q is the maximum tangential shearing stress equal to K 3 W 1/R t (L – 2A – H/L + H). So all this L, H, A and R t, all these parameters you know.

Now what is this t, that appears in f1 and f2 expression also. This t is basically the minimum thickness of shell because we are discussing stresses in shell okay. So here we have this design constant K 3 that we will discuss further along with K 1 and K 2. Now second case I am having if A is less than R/2, it means if that saddle is close to the end or close to the head, so in that case I am having two section. So when A is less than R/2, it means the saddle is close to the end and at that point we will consider stress in shell as well as that in head.

So here we have two sections, shell as well as head. So in shell we can calculate shearing stress as K 3 W 1/R t as it is shown here, where q should be less than or equal to 0.8f okay. Now this condition will be applicable for this expression also and for this expression also because in both cases we have q. Now in the end or in the head we have stress as q e, which is equal to K 4 W 1/R te, where te is the minimum thickness of head and K 4 is again the design constant that we will discuss later on.

Now condition to be satisfied this q e is it should be less than equal to 1.15f – fn, where fn is denoted by this P D o C/2 t okay. And this C is basically the shape factor if you remember that shape factor we have discussed in design of heads. For different types of head we have different methods to compute this shape factor, so this shape factor will be computed based on procedure whatever we have already discussed okay. So in this way we will calculate tangential shearing stresses in shell as well as in head.

Now next point I am having is the circumferential stresses and these stresses are falling in shell, which is just above the saddle okay. So this is basically we can call as supported part.

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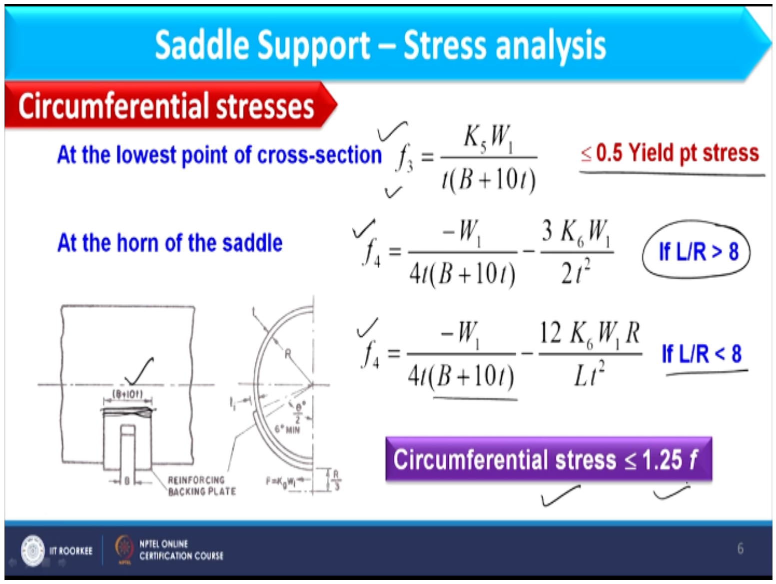

So at the support at lowest point of cross section we can calculate stress as f3, which is equal to K 5 W 1/t (B+ 10t) and that should be equal to 0.5 into yield point stress. And at the horn of the saddle, what is that at horn of the saddle, where edge of horn is appearing in shell, so that is basically the end of support in shell. So there we have circumferential stress as f4, which is equal to –W 1/4t (B + 10t) – 3 K 6 W 1/2t 2 and this expression we will use if L/R is greater than 8.

And in the similar line if L/R is less than 8 we will calculate f4 from this expression. Now what is this B + 10t, if you see this image here this B + 10t is appearing, B is the total width of the saddle and t is the thickness of shell, so B + 10t is this section. Now what is this section, it happens that when we weld the saddle to the shell wherever that welding occur it makes the shell weaker at that particular point, so for that purpose we provide a reinforcement strip of width B + 10t okay.

So sometimes we provide it if thickness of the shell is not significant and if it is significant we do not provide that reinforced strip okay. So that B + 10t is nothing but the width of reinforced strip and all these circumferential stresses should be satisfied or should be falling less than or equal to 1.25f. So in this way we will consider different stresses and their conditions to be satisfied. If saddle is designed very well, all these conditions must be satisfied.

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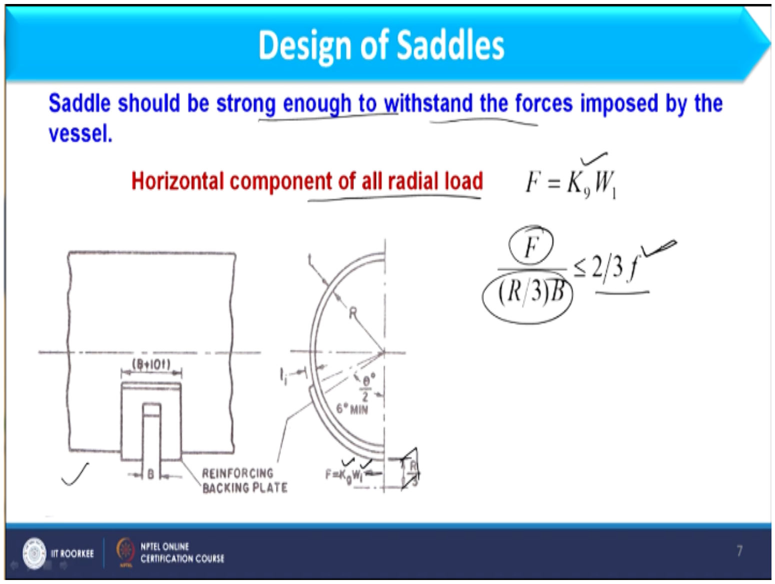

So till now we have discussed stresses which are falling in shell due to shell. Now we will discuss design of saddle because whatever stresses are occurring in shell or what as or whatever forces are apply in metal sheet of vessel or the weight of vessel itself that should be withstand by the support. So support should also be strong enough to bear all these loads. So for that purpose we have to satisfy the design equation which is related to saddle. So let us discuss that.

So saddle should be strong enough to withstand the forces imposed by vessel okay and for that purpose we have design equation and that is basically horizontal component of all radial load which are falling on saddle that should be F which is equal to K 9 W 1. Now if you focus on this image here we have this saddle support with reinforcement plate and here we have this cross sectional view.

Now if you consider this force it means the horizontal component of radial forces that would be F which is equal to K 9 W 1. So when I am having a saddle okay and when failure will occur it will fall either in one direction like this or like this okay. So in that sense or in that way we should consider horizontal component of all radial forces together and then we will apply the stress condition.

So total horizontal component of all forces will be given as F and that would be K 9 W 1 as it is shown here and that should be F and F/(R/3) * B that should be less than or equal to 2/3 f. Now this f is basically horizontal component and this is the acting area, now why it is acting area. If you consider this image, here we have this distance or this length R/3, R is basically inner diameter of vessel and its one-third part would be this height into B okay. So what is B, B is basically the width of saddle.

So this is basically the acting area for F, so F/(R/3) * B and that should be less than or equal to 2/3 f, where this f is the allowable stress of saddle material. So in this way we consider all stresses in shell, which is due to internal pressure or design pressure and due to saddle and further we have checked the strength of the saddle. Now whatever design equation I have considered in this lecture it includes some design constants like K 1, K 2 like that up to K 9. So what are the values of these constants that we can see from this slide. So let us discuss that.

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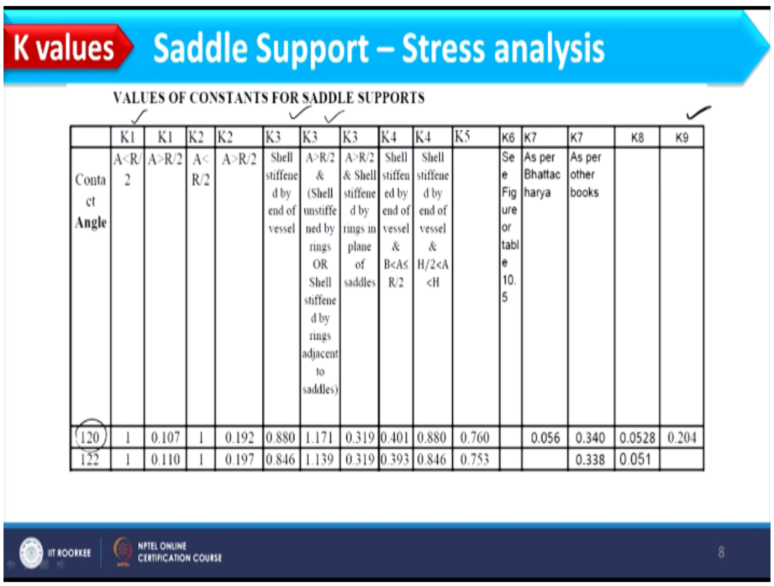

	K1	K1	K2	K2	K3	K3	K3	K4	K4	K5	K6	K7	K7	K8	K9
Contact Angle	A<R/2	A>R/2	A<R/2	A>R/2	Shell stiffened by end of vessel	A>R/2 & (Shell unstiffened by rings OR Shell stiffened by rings adjacent to saddles)	A>R/2 & Shell stiffened by rings in plane of saddles	Shell stiffened by end of vessel & B<A≤R/2	Shell stiffened by end of vessel & H/2<A<H		See Figure or table 10.5	As per Bhattacharya	As per other books		
120	1	0.107	1	0.192	0.880	1.171	0.319	0.401	0.880	0.760		0.056	0.340	0.0528	0.204
122	1	0.110	1	0.197	0.846	1.139	0.319	0.393	0.846	0.753			0.338	0.051	

Here we have values of constant for saddle support. So here we have contact angle that is 120 is the minimum angle and 122 and we have long table which I will show further. And here we have K 1, K 2 for different conditions like A is less than R/2 or other condition and then K 3 when shell is stiffened by end of the vessel and we have other conditions also. And similarly K 5, K 6, K 7, K 8 and K 9. So here you see values are available at 120 and 122.

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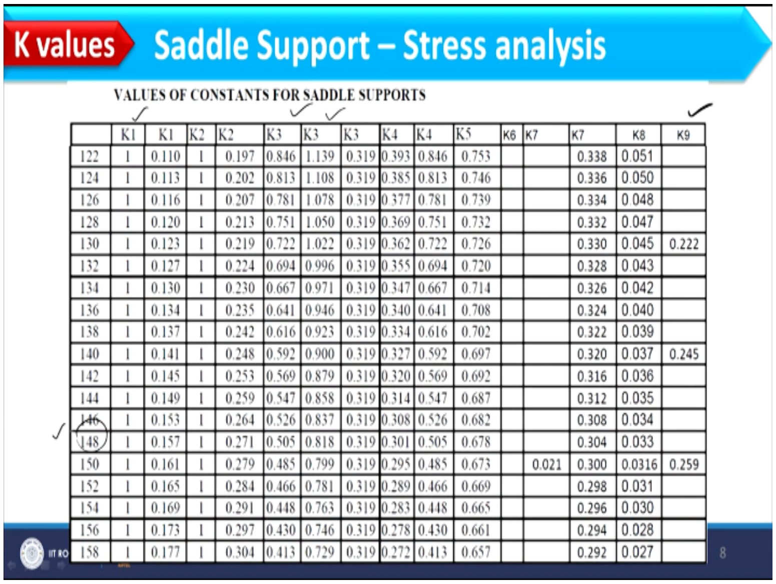

	K1	K1	K2	K2	K3	K3	K3	K4	K4	K5	K6	K7	K7	K8	K9
122	1	0.110	1	0.197	0.846	1.139	0.319	0.393	0.846	0.753			0.338	0.051	
124	1	0.113	1	0.202	0.813	1.108	0.319	0.385	0.813	0.746			0.336	0.050	
126	1	0.116	1	0.207	0.781	1.078	0.319	0.377	0.781	0.739			0.334	0.048	
128	1	0.120	1	0.213	0.751	1.050	0.319	0.369	0.751	0.732			0.332	0.047	
130	1	0.123	1	0.219	0.722	1.022	0.319	0.362	0.722	0.726			0.330	0.045	0.222
132	1	0.127	1	0.224	0.694	0.996	0.319	0.355	0.694	0.720			0.328	0.043	
134	1	0.130	1	0.230	0.667	0.971	0.319	0.347	0.667	0.714			0.326	0.042	
136	1	0.134	1	0.235	0.641	0.946	0.319	0.340	0.641	0.708			0.324	0.040	
138	1	0.137	1	0.242	0.616	0.923	0.319	0.334	0.616	0.702			0.322	0.039	
140	1	0.141	1	0.248	0.592	0.900	0.319	0.327	0.592	0.697			0.320	0.037	0.245
142	1	0.145	1	0.253	0.569	0.879	0.319	0.320	0.569	0.692			0.316	0.036	
144	1	0.149	1	0.259	0.547	0.858	0.319	0.314	0.547	0.687			0.312	0.035	
146	1	0.153	1	0.264	0.526	0.837	0.319	0.308	0.526	0.682			0.308	0.034	
148	1	0.157	1	0.271	0.505	0.818	0.319	0.301	0.505	0.678			0.304	0.033	
150	1	0.161	1	0.279	0.485	0.799	0.319	0.295	0.485	0.673		0.021	0.300	0.0316	0.259
152	1	0.165	1	0.284	0.466	0.781	0.319	0.289	0.466	0.669			0.298	0.031	
154	1	0.169	1	0.291	0.448	0.763	0.319	0.283	0.448	0.665			0.296	0.030	
156	1	0.173	1	0.297	0.430	0.746	0.319	0.278	0.430	0.661			0.294	0.028	
158	1	0.177	1	0.304	0.413	0.729	0.319	0.272	0.413	0.657			0.292	0.027	

And further we have the table from 122 to 158, we have different values for these constants.

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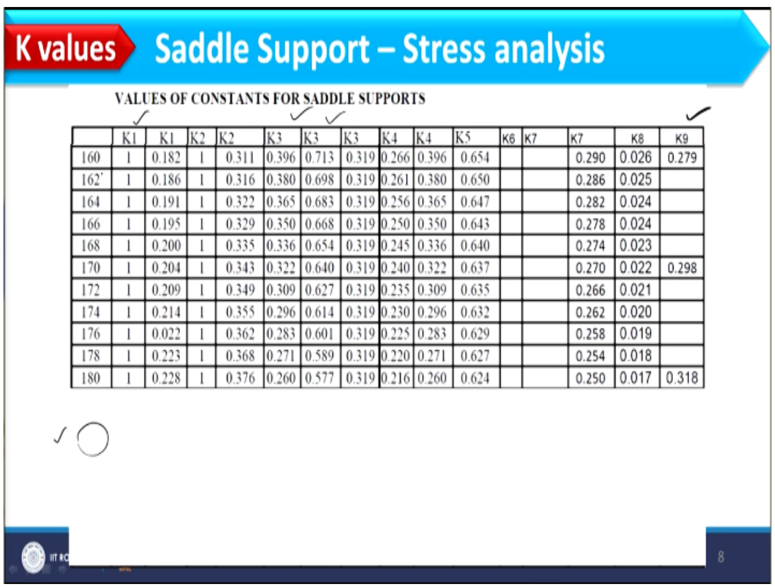

	K1	K1	K2	K2	K3	K3	K3	K4	K4	K5	K6	K7	K7	K8	K9
160	1	0.182	1	0.311	0.396	0.713	0.319	0.266	0.396	0.654			0.290	0.026	0.279
162'	1	0.186	1	0.316	0.380	0.698	0.319	0.261	0.380	0.650			0.286	0.025	
164	1	0.191	1	0.322	0.365	0.683	0.319	0.256	0.365	0.647			0.282	0.024	
166	1	0.195	1	0.329	0.350	0.668	0.319	0.250	0.350	0.643			0.278	0.024	
168	1	0.200	1	0.335	0.336	0.654	0.319	0.245	0.336	0.640			0.274	0.023	
170	1	0.204	1	0.343	0.322	0.640	0.319	0.240	0.322	0.637			0.270	0.022	0.298
172	1	0.209	1	0.349	0.309	0.627	0.319	0.235	0.309	0.635			0.266	0.021	
174	1	0.214	1	0.355	0.296	0.614	0.319	0.230	0.296	0.632			0.262	0.020	
176	1	0.022	1	0.362	0.283	0.601	0.319	0.225	0.283	0.629			0.258	0.019	
178	1	0.223	1	0.368	0.271	0.589	0.319	0.220	0.271	0.627			0.254	0.018	
180	1	0.228	1	0.376	0.260	0.577	0.319	0.216	0.260	0.624			0.250	0.017	0.318

Now we have values of all these constants from 160 to 180. So here you can see that contact angle of the saddle to the shell vary from 120 to 180.

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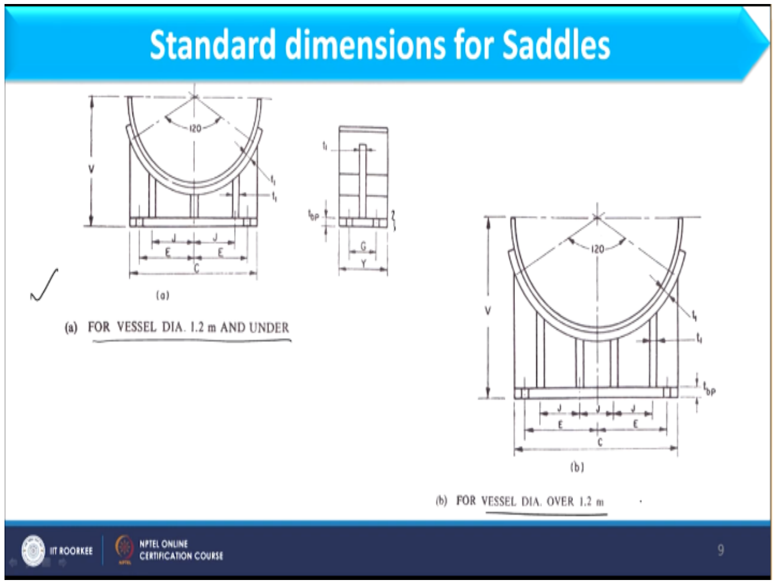

And now we will discuss different dimensions related to saddle and that can be better understood by these diagrams, which are shown over here. If you see this image, here we have the vessel diameter of 1.2 meter or lesser than that. Now what would be the standard dimension, dimension includes this J, E, C, G, Y, t bp that is the thickness of bearing plate. All these parameters have standard dimensions.

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Vessel Diam. (m)	Maximum operating weight (kN)	All dimensions in (m) V	Y	C	E	J	G	All dimensions in (mm) t_{bp}	t_1	Bolt Diam.	Bolt Holes	Slotted Holes	Fillet Welds
0.6	35	0.48	0.15	0.55	0.24	0.190	0.095	6	5	20	25	25 × 37	5
0.8	50	0.58	0.15	0.70	0.29	0.225	0.095	8	5	20	25	25 × 37	5
0.9	65	0.63	0.15	0.81	0.34	0.275	0.095	10	6	20	25	25 × 37	5
1.0	90	0.68	0.15	0.91	0.39	0.310	0.095	11	8	20	25	25 × 37	5
1.2	180	0.78	0.20	1.09	0.45	0.360	0.140	12	10	24	30	30 × 45	6
1.4	230	0.88	0.20	1.24	0.53	0.305	0.140	12	10	24	30	30 × 45	6
1.6	330	0.98	0.20	1.41	0.62	0.350	0.140	12	10	24	30	30 × 45	6
1.8	380	1.08	0.20	1.59	0.71	0.405	0.140	12	10	24	30	30 × 45	6
2.0	460	1.18	0.20	1.77	0.80	0.450	0.140	12	10	24	30	30 × 45	6
2.2	750	1.28	0.225	1.95	0.89	0.520	0.150	16	12	24	30	30 × 45	10
2.4	900	1.38	0.225	2.13	0.98	0.565	0.150	16	12	27	33	33 × 52	10
2.6	1 000	1.48	0.225	2.30	1.03	0.590	0.150	16	12	27	33	33 × 52	10
2.8	1 350	1.58	0.25	2.50	1.10	0.625	0.150	16	12	27	33	33 × 52	10
3.0	1 750	1.68	0.25	2.64	1.18	0.665	0.150	16	12	27	33	33 × 52	10
3.2	2 000	1.78	0.25	2.82	1.26	0.730	0.150	16	12	27	33	33 × 52	10
3.6	2 500	1.98	0.25	3.20	1.40	0.815	0.150	16	12	27	33	33 × 52	10

In the similar line when vessel diameter exceeds 1.2 meter, in that case all these parameters whatever are shown in this image. These are summarized over here, like here we have vessel diameter and then maximum operating weight V, Y, C. All these dimension which are available in previous images are summarized or shown in this table, and similarly other parameters also. So these are standard dimension used for design of saddle.

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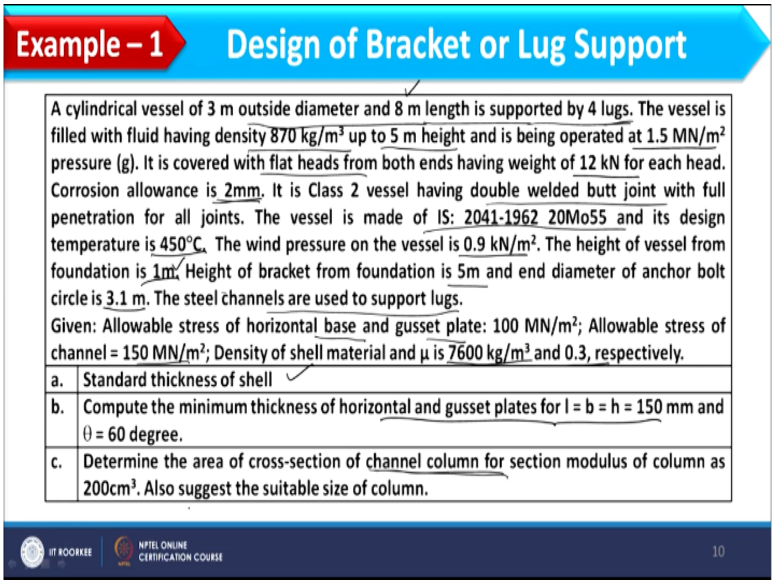

Now we will see few examples for support design. So here I am having example 1 and in this example the cylindrical vessel of 3 meter outside diameter and 8 meter length is supported by 4 lugs, so this example is basically related to bracket or lug support, which we have discussed in last lecture. So the vessel is filled with the liquid or fluid having density 870 kg per meter cube up to 5 meter height and is being operated at 1.5 meganewton per meter square in gauge.

It is covered with flat head from both end having 12 kilonewton of each head, corrosion allowance is 2 mm and it is class 2 vessel with double welded butt joint with full penetration and vessel is made with IS: 2041-1962 20Mo55 material and its design temperature is 450. Wind pressure on the vessel is 0.9 kilonewton per meter square, height of the vessel from foundation is 1. So total height of the vessel is 8 and height from the foundation is 1. So from foundation total height of vessel should be 9 meter.

So height of bracket from foundation is 5 meter, so this is basically length of the column, end diameter of anchor bolt 3.1 meter and steel channels are used to support the lugs. Now here we are given allowable stresses of horizontal base and gusset plate that is 100 meganewton per meter square, allowable stress of channel 150 meganewton per meter square, density of shell material and mue are given as this and this respectively.

What I need to find is standard thickness of the shell, then I need to compute the minimum thickness of horizontal and gusset plates for this dimension and we have to find out the area of cross section of channel column, for section modulus of column as 200 cm cube okay. Also we need to suggest a suitable column.

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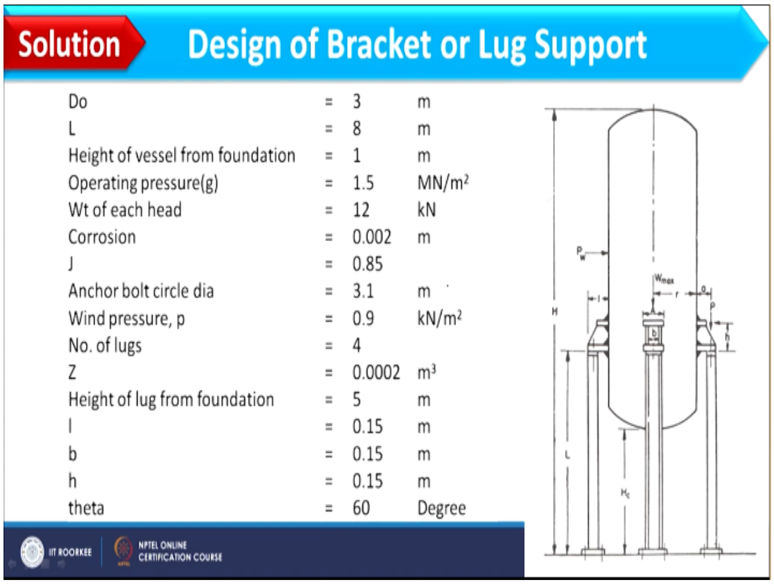

So here I am having different parameters where operating pressure and all other parameters are given, which we have discussed in the problem itself and let us start the solution of that.

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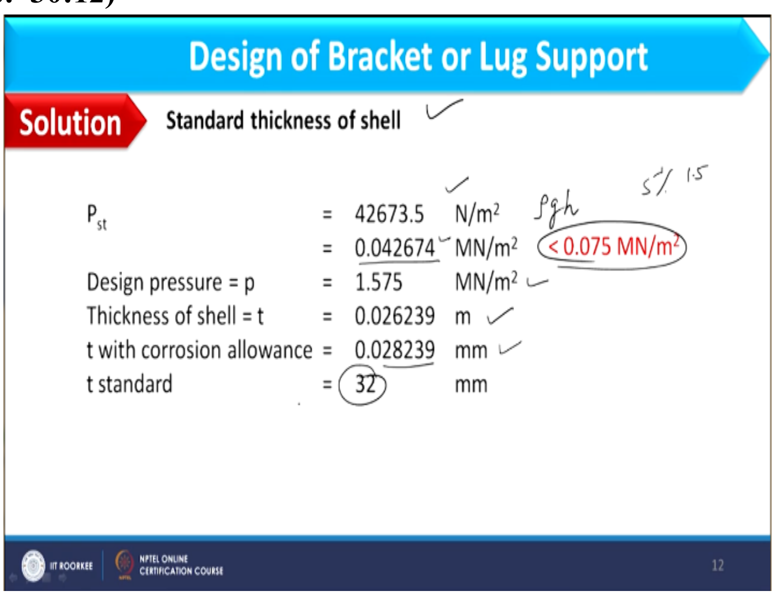

The first part is I need to find out standard thickness of shell okay. Now if you consider this problem, it has operating pressure as 1.5 meganewton per meter square and liquid is available up to 5 meter height, it means it has static load of liquid also okay. So when this type of condition is there when I am having operating pressure as well as static head of the liquid I have to compute the design pressure in slightly different way. For that first of all I have to find static load of the liquid that is Ro gh of the liquid and then I have to compare that with condition.

Now condition is when that load is greater than 5% of operating pressure I will add static head with the operating pressure to compute design pressure. Otherwise if it is lesser than 5% I will consider 5% extra as design pressure as we usually do. So static head would be Ro gh and that can be found as 42673.5 newton per meter square and which is equal to this much meganewton and when we consider 5% of 1.5 meganewton per meter square it comes out as this and as this value is lesser than this I will consider design pressure as 5% extra than operating pressure in gauge.

So here we have this is the design pressure and further calculation is similar as we have discussed in previous lectures for design of shell, so this is the minimum thickness of shell by standard expression, adding corrosion it gives 28.24 mm thickness and then standard is available at 32 in table B1. So standard thickness of shell is 32 mm.

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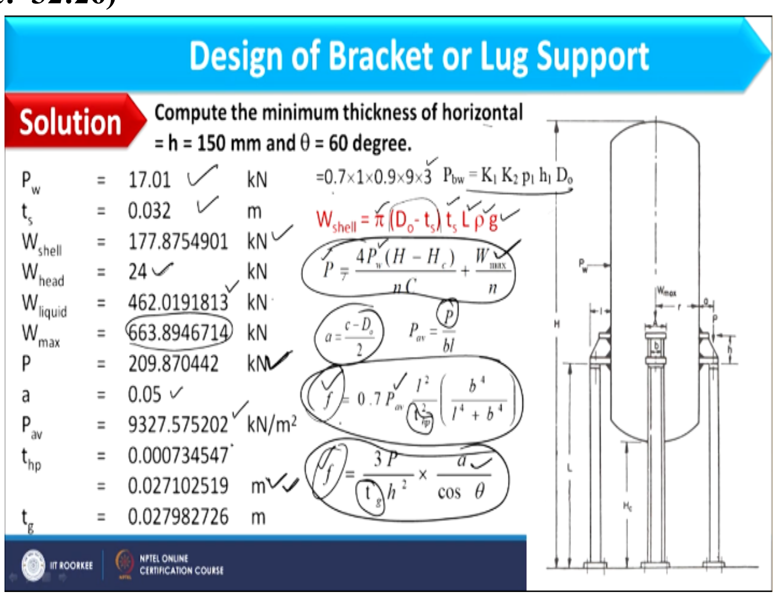

Now I need to find out thickness of horizontal as well as gusset plates. For that case if you consider this is the expression to find out thickness of horizontal plate okay. And to compute this I need to calculate P av first and for calculation of P av I need to find out total load on each lug okay and that is given by this particular expression.

In this expression we need to find out P W (H – H c) is the total height of the vessel, which is basically 8 meter, n is the number of lugs and c is the anchor diameter, W max is the maximum weight of shell and accessories. So first of all I need to compute P W and W max, so that I can find out value of P. So P W is coming as 17.01, which can be computed as 0.7 * 1 that is K 1, K 2, if you remember.

This is the expression K 1, K 2, K 1 0.7 for cylindrical vessel, K 2 will be 1 and P 1 which is the wind pressure, it is given as 0.9 and then H 1 is the total height of vessel from foundation and that is 9, D O outer diameter of vessel that is 3. Considering all these values we can find P W like this. Standard thickness of shell is given as 32 mm and then we need to find out maximum weight of vessel.

Now how I can find out maximum weight of vessel, it includes weight of shell, weight of head and weight of internal attachment. In this case internal attachments are not given, but liquid is given up to 5 meter height. However, for maximum weight we consider maximum possible situation and that could be when vessel is completely with the liquid okay.

So here we will consider weight of shell, weight of head plus weight of liquid when it is completely filled in the vessel. So to compute this, first of all we have to find out weight of shell. How I can find out that, that is given by this expression Pi D O – t s that is the standard thickness of shell. This is basically for average diameter, so that is periphery into t s is the area into total length, that is 8 meter and then this basically gives the volume into density of material of shell and then g, it will give value 177.87.

Weight of head 12 because one head includes 12 kilonewton, so it comes accordingly. Weight of liquid, how I can find weight of liquid that would be the internal volume of the vessel that is Pi/4 D O 2 – D I 2 * L * Rho that is density of liquid into g. So considering those parameters you can calculate weight of liquid, which comes out as 462.02. And similarly I can find out maximum weight.

Once I am having maximum weight I can find P as this. Now once I am having P, I can calculate P av and then t hp that is the thickness of horizontal plate and which comes out as 27.10 m. I am not adding corrosion to this because it is not coming in contact with the liquid. So directly next value available in table B1 that I can choose as horizontal plate thickness.

And similarly for gusset plate we have this expression, where I need to calculate a which is basically 0.05 and that you can find out from this expression okay and then cos theta, theta is 60 degree which is given and then you can find out this t g value, which is 0.02798 meter okay. Now what is this f. This f here we have considered allowable stress of horizontal plate and here it is allowable stress of gusset plate. In this case these both values are equal, otherwise we need to consider accordingly.

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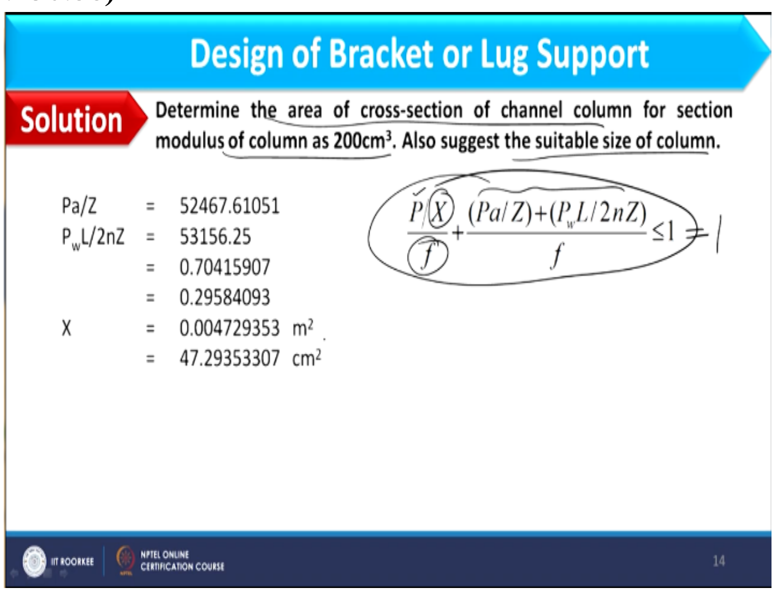

Next step I am having is to determine the area of cross section of the channel column for sectional modulus of 200 cm cube okay. And we need to suggest the suitable column for the bracket okay. So this is the expression to calculate the cross sectional area of column, where X is the cross sectional area of column. All these parameters we have already discussed in the last lecture okay.

So considering all these parameters where f is the allowable stress of column okay. So that you need to consider and solving this equation equating to 1 because that would be the extreme condition and accordingly I can find X as 47.29 cm square. So as cross sectional area of the column comes as 47.29 cm square, I have to choose the column which is higher than this area okay.

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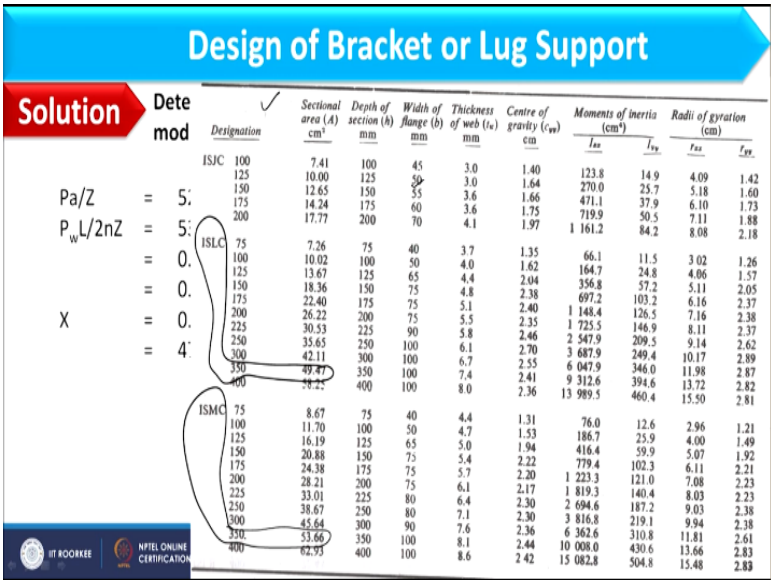

Designation		Sectional area (A) cm²	Depth of section (h) mm	Width of flange (b) mm	Thickness of web (t_w) mm	Centre of gravity (c_{yy}) cm	Moments of inertia (cm⁴) I_{xx}	I_{yy}	Radii of gyration (cm) r_{xx}	r_{yy}
ISJC	100	7.41	100	45	3.0	1.40	123.8	14.9	4.09	1.42
	125	10.00	125	50	3.0	1.64	270.0	25.7	5.18	1.60
	150	12.65	150	55	3.6	1.66	471.1	37.9	6.10	1.73
	175	14.24	175	60	3.6	1.75	719.9	50.5	7.11	1.88
	200	17.77	200	70	4.1	1.97	1 161.2	84.2	8.08	2.18
ISLC	75	7.26	75	40	3.7	1.35	66.1	11.5	3 02	1.26
	100	10.02	100	50	4.0	1.62	164.7	24.8	4.06	1.57
	125	13.67	125	65	4.4	2.04	356.8	57.2	5.11	2.05
	150	18.36	150	75	4.8	2.38	697.2	103.2	6.16	2.37
	175	22.40	175	75	5.1	2.40	1 148.4	126.5	7.16	2.38
	200	26.22	200	75	5.5	2.35	1 725.5	146.9	8.11	2.37
	225	30.53	225	90	5.8	2.46	2 547.9	209.5	9.14	2.62
	250	35.65	250	100	6.1	2.70	3 687.9	249.4	10.17	2.89
	300	42.11	300	100	6.7	2.55	6 047.9	346.0	11.98	2.87
	350	49.47	350	100	7.4	2.41	9 312.6	394.6	13.72	2.82
	400	58.25	400	100	8.0	2.36	13 989.5	460.4	15.50	2.81
ISMC	75	8.67	75	40	4.4	1.31	76.0	12.6	2.96	1.21
	100	11.70	100	50	4.7	1.53	186.7	25.9	4.00	1.49
	125	16.19	125	65	5.0	1.94	416.4	59.9	5.07	1.92
	150	20.88	150	75	5.4	2.22	779.4	102.3	6.11	2.21
	175	24.38	175	75	5.7	2.20	1 223.3	121.0	7.08	2.23
	200	28.21	200	75	6.1	2.17	1 819.3	140.4	8.03	2.23
	225	33.01	225	80	6.4	2.30	2 694.6	187.2	9.03	2.38
	250	38.67	250	80	7.1	2.30	3 816.8	219.1	9.94	2.38
	300	45.64	300	90	7.6	2.36	6 362.6	310.8	11.81	2.61
	350	53.66	350	100	8.1	2.44	10 008.0	430.6	13.66	2.83
	400	62.93	400	100	8.6	2 42	15 082.8	504.8	15.48	2.83

So for that purpose I have to see the table of channel, which is basically table C3 in B. C. Bhattacharya book. So here you see 47.29 was the minimum area, so here what I can suggest, I can suggest this one or I can suggest this one, which is greater than 47 cm square. So either ISLC 350 can be considered as suitable column or ISMC 350 can be considered as suitable column, so that depends on us that which column I should use, but both column I can use easily.

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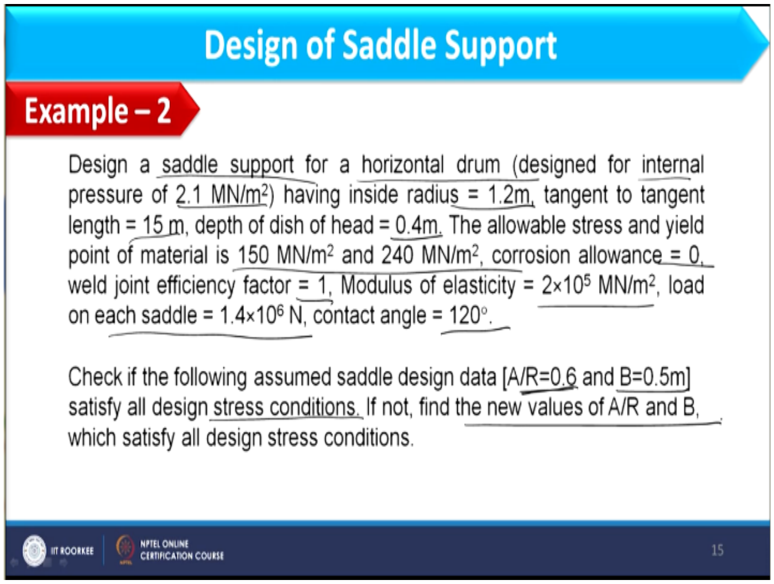

Now here I am having second example, which is on design of saddle and in this example I need to design a saddle support for horizontal drum, which is designed for internal pressure 2.1 meganewton per meter square, internal radius 1.2 meter is given, tangent to tangent length is 15, depth of the dish of head that is H as 0.4 meter is given, allowable stress yield point of the material are given as this.

Corrosion allowance is 0, joint deficiency factor 1, modulus of elasticity is given and total load on each saddle, which is given over here as 1.4 meganewton, contact angle is 120. So what I need to find is check if the following assumed saddle design data that is A/R equal to 0.6 and B equal to 0.5 meter, satisfy all design stress conditions. If not, find the new values of A/R and B, which satisfy all design stress conditions.

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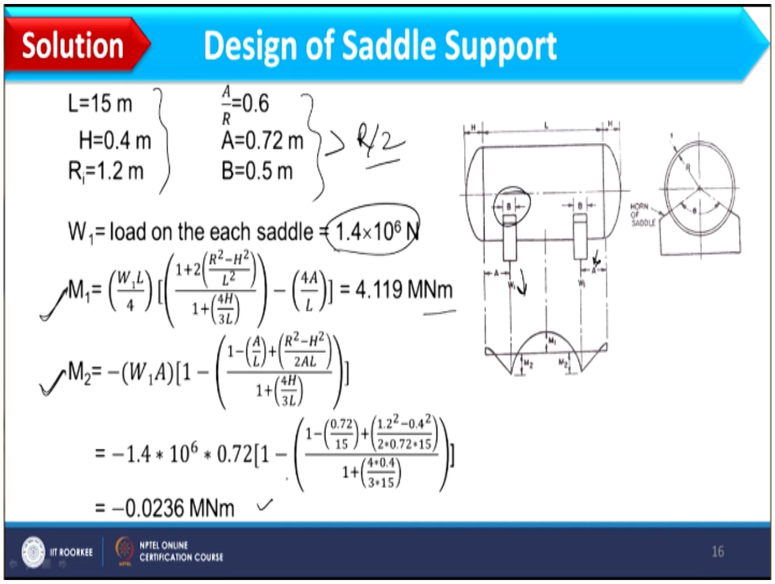

So let us start the solution of this. Here basically in saddle I need to compute different stresses and that should be satisfied with the permissible values okay. So let us start that. So here I am having all parameters, which we have just discussed and A/R is given as 0.6, so from that we can compute A, which is basically 0.72 and it is greater than R/2 because this condition I need to use. So here A is greater than R/2, B is given as 0.5 meter, which is the width of the saddle okay. So all parameters I guess you understand.

W 1 that is weight on each saddle is given as 1.4 meganewton, M 1 and M 2 I can find out directly through the expression and M 1 comes out as 4.119 meganewton meter and M 2 as -0.0236 meganewton meter.

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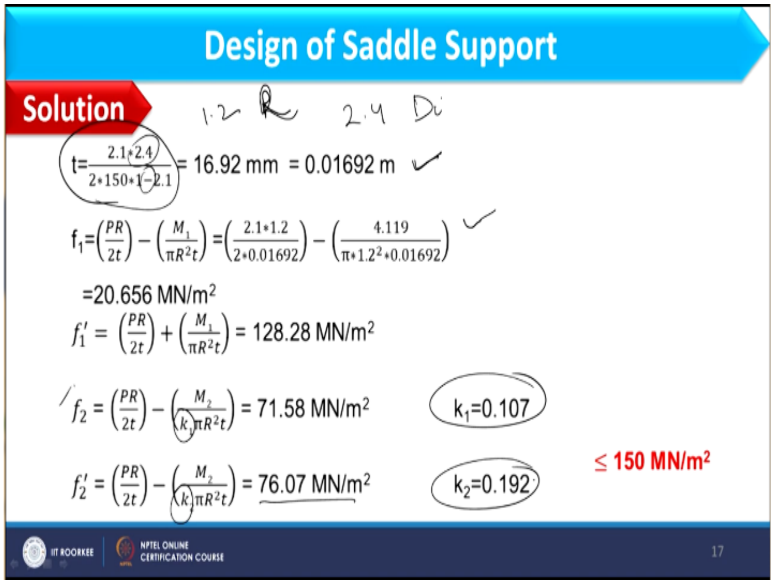

So considering these movements we will calculate all stresses, but these stresses will also require thickness of shell and therefore we can compute minimum thickness of shell using usual expression and here if you remember 1.2 meter R is given, which is internal radius, so internal diameter would be 2.4 okay. So that we have used over here and therefore this minus sign appears and minimum thickness comes as 16.92 mm.

Considering this value we can find out f1 as 20.656, f1 dash as 128.28 okay, f2 as 71.58 considering K 1 as 0.107 and f2 dash comes as 76.07 considering K 2 as 0.192. Now from where this K 1 and K 2 comes.

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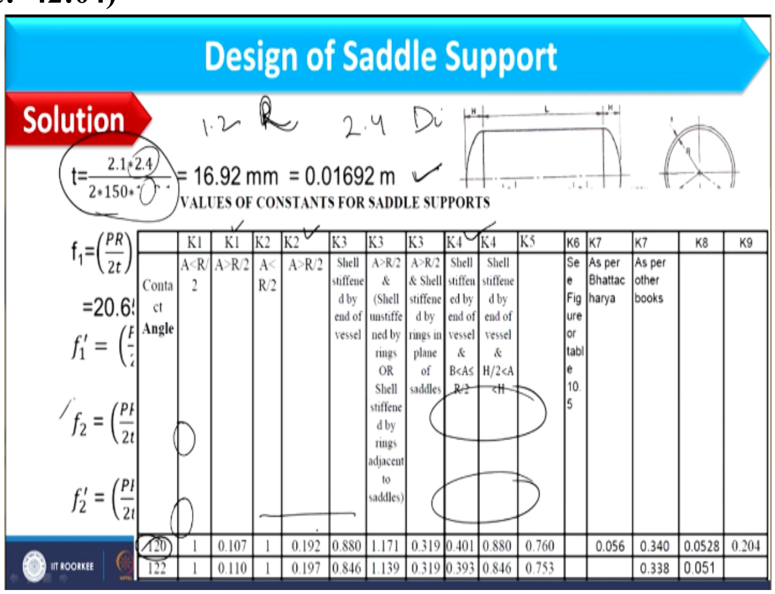

Contact Angle	K1	K1	K2	K2	K3	K3	K3	K4	K4	K5	K6	K7	K7	K8	K9
	A<R/2	A>R/2	A<R/2	A>R/2	Shell stiffened by end of vessel	A>R/2 & (Shell unstiffened by rings OR Shell stiffened by rings adjacent to saddles)	A>R/2 & Shell stiffened by rings in plane of saddles	Shell stiffened by end of vessel & B<A≤R/2	Shell stiffened by end of vessel & H/2<A<H		See Figure or table 10.5	As per Bhattacharya	As per other books		
120	1	0.107	1	0.192	0.880	1.171	0.319	0.401	0.880	0.760		0.056	0.340	0.0528	0.204
122	1	0.110	1	0.197	0.846	1.139	0.319	0.393	0.846	0.753			0.338	0.051	

If you see here I am having this K 1 where this condition will be applicable, a is greater than r/2 and this K 2 is given where A is greater than R/2. So K 1 0.107 corresponding to 120 degree angle and K 2 come as 0.192. So considering these value we can find f2 and f2 dash. Now you see this should be satisfied with f J, so that should be less than or equal to 150 meganewton per meter square. So all conditions are well satisfied.

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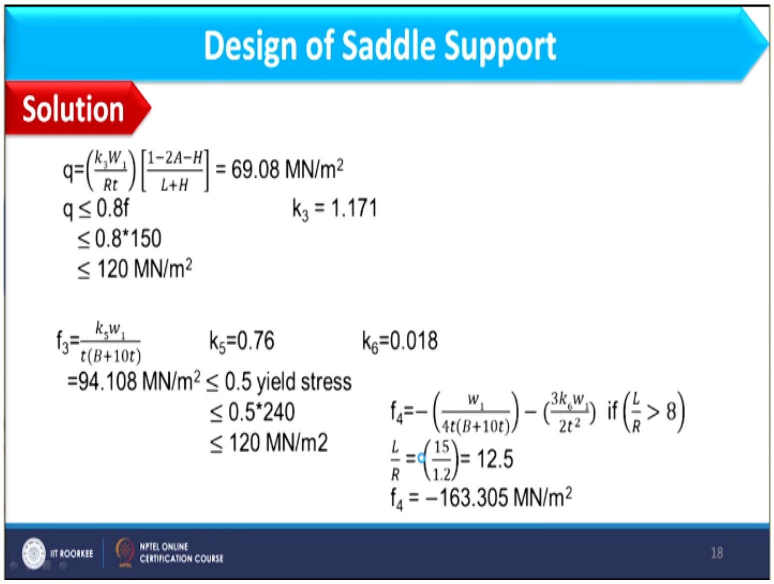

And further we have to find out tangential shearing stress and that case comes as when A is greater than R/2, so we will use this expression, where K 3 is 1.171 and that is given by this expression, where K 3 I am considering.

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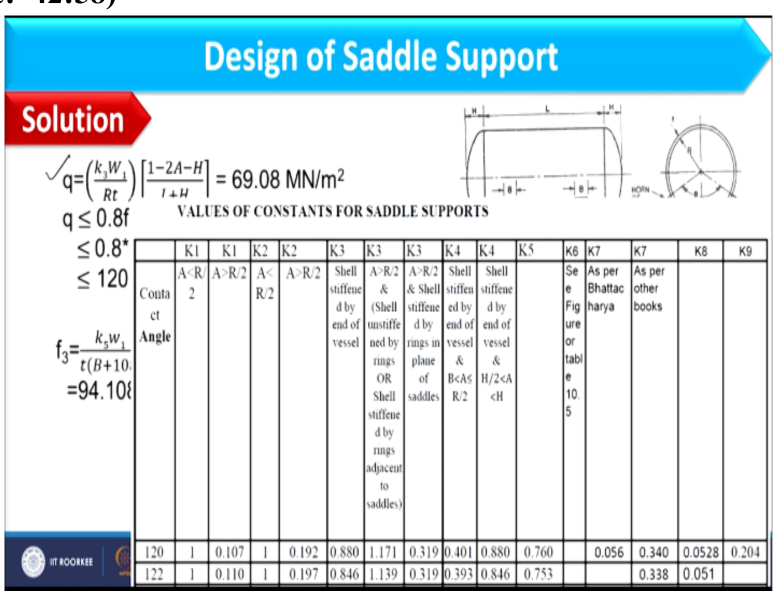

Here I have different condition I have taken this condition that is shell unstiffened by rings, where no rings is provided. If rings will be provided it will be given in the problem. So corresponding to 120 K 3 value comes as 1.171.

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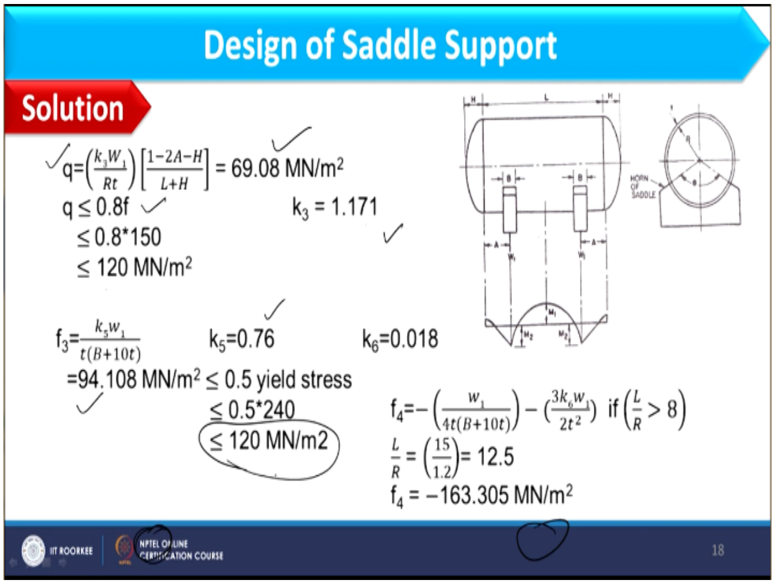

So considering K 3 as this we can find out q, which is coming out as this and this should be lower than 0.8 * f, so it is well satisfying the condition. Next we have the f3 value and f3 will be given as K 5 W 1/t (B + 10t) and K 5 you can see as 0.76 and here you can see K 5 as 0.76 from this table corresponding to 120 degree, and considering these points K 3 comes as 94.108, which is well satisfying the condition that is it is less than 120 meganewton per meter square.

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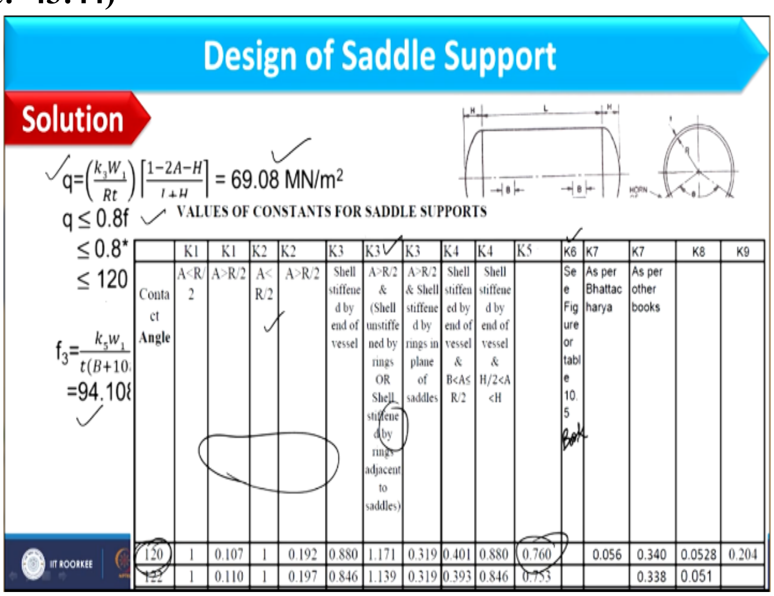

And further we will calculate f4, for this we need K 6 and K 6 is given as 0.18. So further you see this table, where K 6 we can see figure or table 10.5 from book okay and book is B. C. Bhattacharya book.

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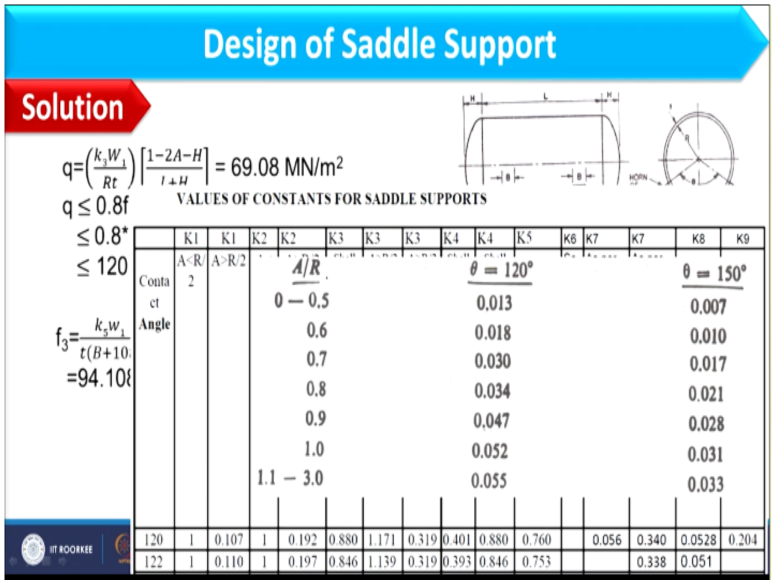

When A/R is 0.6 okay and theta is 120, so corresponding value of K 6 is coming as 0.018. This is the table from book okay. So considering this, you can calculate f4, which is coming as -163.305.

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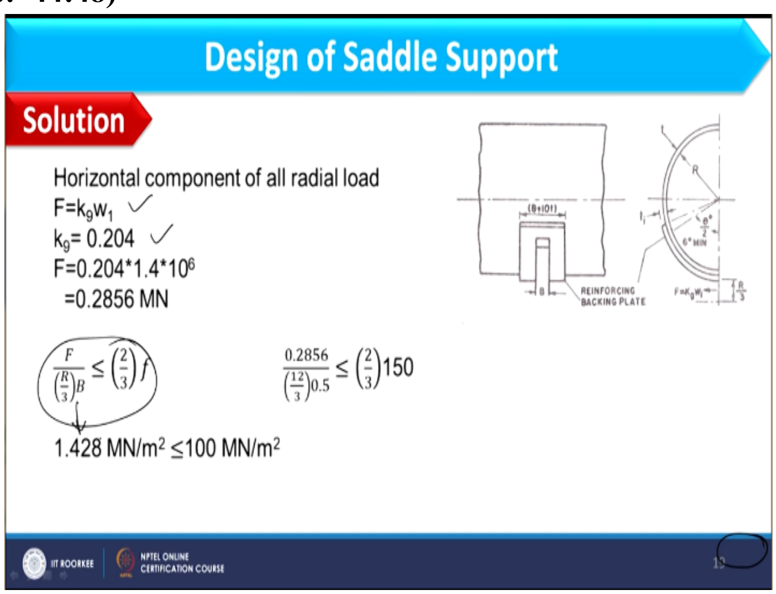

Now we have the horizontal component of all radial forces because till now we have discussed, we have computed stresses due to internal pressure as well as due to saddle in shell. Now we need to check for saddle strength and for this we have to calculate f4, for which I need K 9 and K 9 is given as 0.204 in this table okay.

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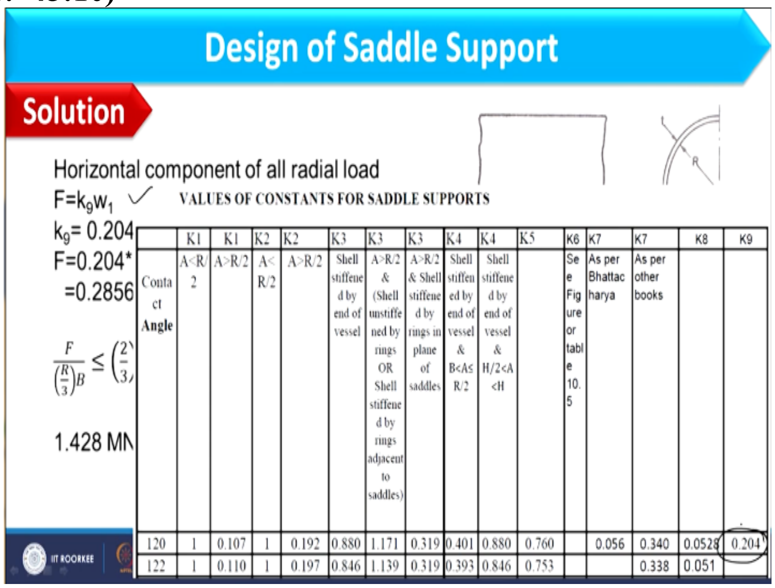

Considering that value we can find f as 0.2856 and then this condition we need to satisfy which is this expression comes as 1.428 and this expression comes as 100 meganewton per meter square, so it is well below the permissible limit. So in this way we can design the bracket as well as saddle support.

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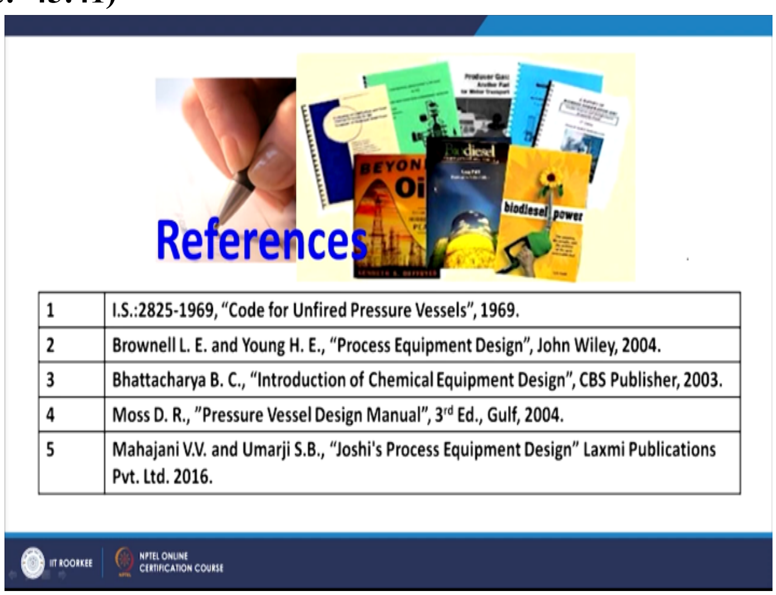

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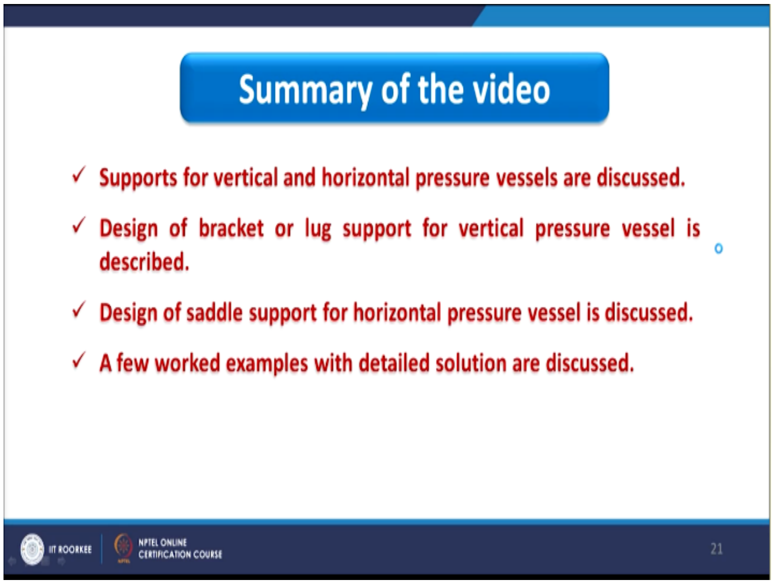

And here we have some of the references to study the topic and here we have summary of the video and this summary of lecture 1 as well as lecture 2 which is on design of support and it goes as supports for vertical and horizontal pressure vessels are discussed, design of bracket or lug support for vertical pressure vessel is described, design of saddle support for horizontal pressure vessel is discussed and then few worked example we have discussed with detailed solution. And that is all for now, thank you.