Design of Offshore Structures
Prof. Dr. S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 4
Lecture - 9
Tubuler Joint Design for Static and Cyclic Loads 9

Well, yesterday we were looking at the factor of safety, I think you could see this matrix inspectable, non inspectable and critical and not critical. So, you could decide a factor of safety of whichever the category we are looking at.

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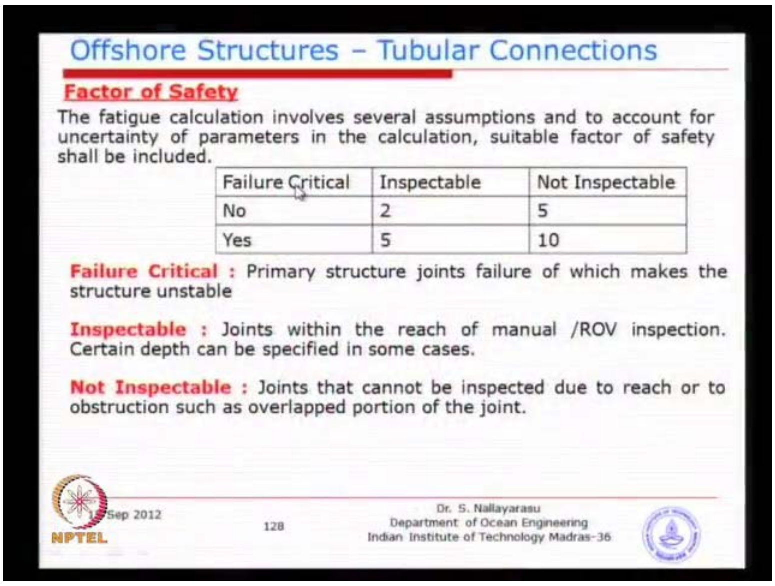

Further than this a p i also has given some guidance and type of platforms. For example, failure critical failures non-critical, you may have a platform, which is unmanned. A platform as nobody living there purely for the purpose of drilling, so you may actually consider non-critical because critical with respect to not the safety of the structure. Actually if you go back 1 step backward it is critical with respect to safety of human life.

So, suppose you have a platform where people are living there and the structure collapses or fails due to inherent deficiency in the structural design, then it is actually to be rectified. So, basically the critical or non-critical, the loss of life is to be avoided so that is why a p i is given a classification of structures class l 1 to class l 4, l 1 to l 4 depending on the criticality of the structure.

So, you can choose l 1 means very critical l 4 just a secondary structures you may have many secondary structures. For example, you may have a flat platform where I think I was shown you some structure where only flat boom will be there, there is nobody there always is going to be exhaust or when the gas and fire the gas. So, those type of platform you do not necessarily to be designed with the factor safety of 10 because loss of life is definitely not there, but subsequent to the damage of the structure if there is a vicinity there is another structure, which may actually have a problem.

So, you may have to consider not only the individual structure, but also the structure connected to the particular field in which these structures are located. So, basically overall you will do a risk assistance, which we call it quantitative risk assessment. And look at each of the component of the structure and if that fails what happens to the other part of the either that structure or neighboring structure come up with, whether it is critical or not critical what is the probability of occurrence then desired which factor safety supposed to be applied.

So, this exercise needs to be done by the owner and the owners engineer. Now, the a p i is not given mandatory that you have to applied 10 is up to the decided to desired which component requires higher of factor of safety which component may you can apply lower factor safety to just economizer design is basically that because you could ask why we need all this simply apply factors can be obtained 10 through a every part of the structure, they do not need to add everything is very safe. But that is not going to be that easy because supplying uniform factors safety of 10 may actually require substantial design change, which maybe not required and also not economical.

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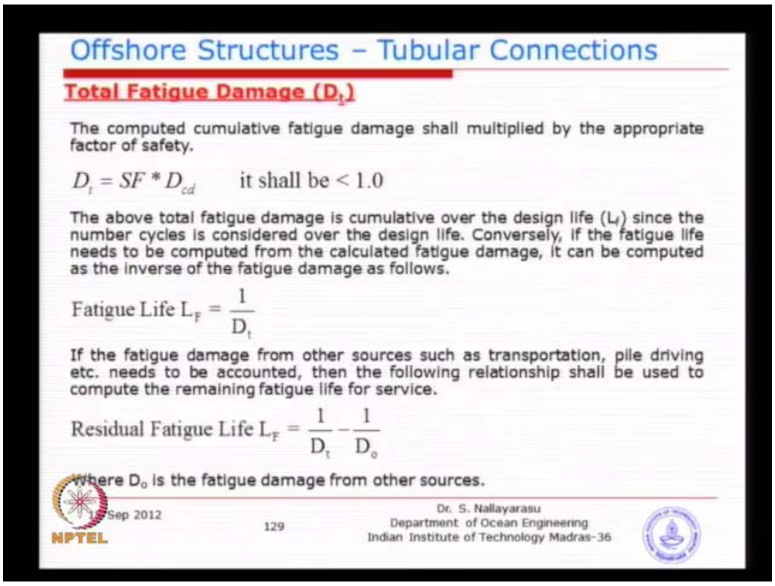

So, basically what they have done is we have calculated the fatigue damage based on number of cycles of loading, number of cycles to failure isn't I think that is the fatigue damage. Now, this number of cycles to offloading is based on certain duration of the designed life. So, maybe 20 years 25 years, now if you have this understood basically N is coming from number of cycles throughout the design life. That means the design life is included here depending on what is the time duration, you may have number of cycles per year multiplied by number of years. So, that is basically the number of cycles down here.

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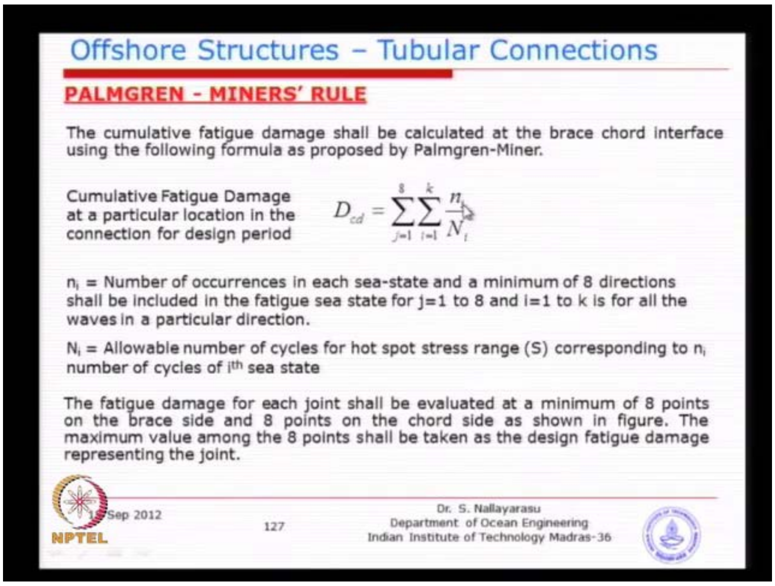

Is defecting indirectly the designed life isn't a so basically you have that. Now, if you know what is the designed fatigue damage you can actually find out in reverse, what is the design life. So, one by damage will give you the designed life itself so that is what we were going to rewrite the equation basically after multiplying the factor of safety because what we have learned is factor of safety is 2, 5, 10 whatever you require. So, basically the total damage is the damages is calculated from the ratio n by where allowable cycles multiplied by the factor of safety. That means this after multiplying by the factor of safety you should keep is less than 1, you know basically that is the idea.

So, suppose if you want to keep it under control 0.5 if you limit factor safety you will get 2, if you keep it 0.1 factor safety is 10. So, similar so basically that means in reverse you can actually find out the designed life will be is equal to 1 by fatigue damage, because the number of cycles applied is indirectly having the total design life itself. Sometimes why we need to calculate this because you know many times the jacket is fabricated in the yard, and then getting transported from the yard to the final location wherever is going to be installed.

And typical transportation I thing we might think depending on the location. For example, from middle east to southeast asia or elsewhere, you could easily see that the transportation time is about the month typically, 4 weeks, 6 weeks depending on the time. So, six weeks this jackets and topsides are going to be transported on the open sea condition on a birth on a ship. So, when it is moving it is subjected to cyclic loads, which we discussed I think few days back the different types of fatigue, fatigue due to roll and pitch motion of the transport vessel.

Of course there is no direct wave loading on the structure, but the wave loading on the ship, but because of the wave loading and the ship for the web barge the structure is subjected to inertia induced the dynamic loads. So, that would cause fatigue so that is why some times we may need find out the total damage minus the damage from other sources because already well before structure reaches the site, this is already expanded. That means already damages occur so you have to add that so many time transportation fatigue is become a very major issue. Especially when you have a transportation longer than two weeks. Normally you know certification agency is if the transportation is less than two weeks you can ignore because the damages is too small, but in cases of coming from south-east asia are to middle east normally take about 4 weeks.

So, 4 weeks you calculate the number of cycles you could be smaller, but unfortunately two things is a problem the basically the sea state condition can be higher number 1, number 2 the magnitude of stresses can be substantially larger compare to direct wave induced forces, wave induced forces does not depend on the weight of the structures. Whereas, the motion induced forces as you can see by inertia force is directly proportional to mass of the structures, and the role and pitch motion of the ship and cargo system.

So, larger the weight you will see that the structure will be subjected to larger inertia forces. So, stresses can be compared that that inertia induced forces compared to the direct wave loading, you will see that magnitude could be several times higher. So, that may actually push you to number of cycles smaller because you have see the S-N curve larger stress range the number of cycles to failure will certainly come down. So, when we do this transportation already some damages already occurred, when you go and installed jackets in the final in-service condition, you cannot allow the fatigue damage to 1 because already doing transportation, so much of damages happened. So, that means you can only incrementally add and that is what we are trying to find out, what will be the remaining fatigue life of the structure.

So, you have some damage during transportation go and install it and you can calculate back the fatigue life remaining is x years. So, this is a exactly the idea behind so that means does not only have mentioned here transportation from any other sources, if you have already got some damages due to or fatigue problem due to other sources of loading, then you just detect from fatigue life for the final in-service condition many, many times you required to do this.

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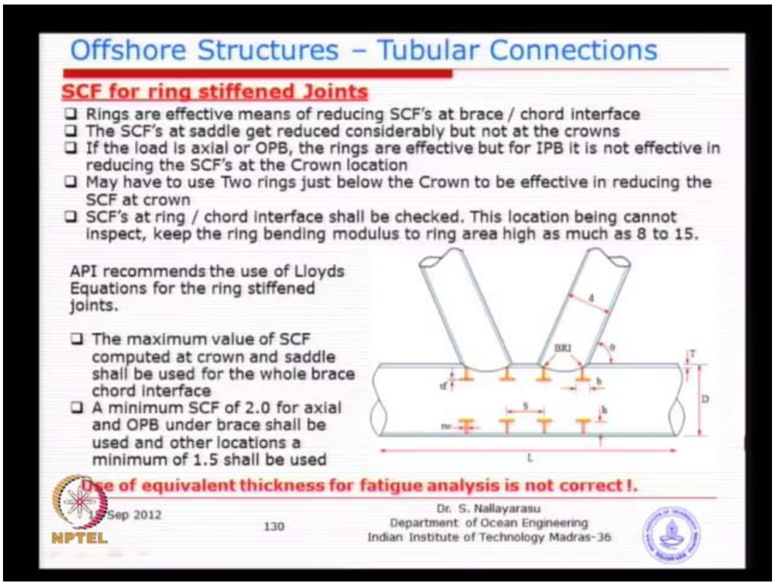

So, basically I think in summary you now should have an idea of the designing the tubular connection for cyclic loads in terms of fatigue damage. So, what we did we have actually learned about static design and cyclic design, both seems to be a complete different methodology. One is based on this stresses applied and stresses allowable, the other one another is based on cycles applied and cycles allowable corresponding to a particular stress range. So, one thing we have not addressed is before we go to that tubular joints stiffen with other sting stiffness and others forms of stiffening, one thing very important is available stresses applied to the structure.

You know basically what we have talked about to saw that S N curve all the time I am picking up a particular stress range number of cycles. Now, all this relationship the generation of S N curve was based on actually non-variable cyclic stresses. That means you take a you take specimen fabrication and put the lab and you apply constant stresses, it means stress ranges x amount you just keep on applied that and whenever the joint sales note on the number of cycles that it has taken to fail. And then you go and repeat that for different stress ranges of the this is not the sequence that is actually happening inside, it is not like today only hundred mega paschal stresses are occurring and tomorrow two hundred day after tomorrow ten.

So, the sequence of loading is that not exactly the simulation done by the researchers during generation of S N curve, nobody could actually predict what could be the sequence of loading small big, small big it is not the sequence that you can predict. So, that is exactly where there is an uncertainty, which we call it variable stress loading. Whereas, in the in simulation the laboratory is that generate S N curve or the to generate any testing, may not be able to exactly simulate what is happening in the field because you will not be able to find out what is the sequence of whether bigger a stress range happening first smaller next or smaller first and what sequence of stresses changing is not going to was easy to predict.

So, this is one of the area where a lot of studies even now going on basically stochastic modelling of stress range cycles, which we could relates to directly to our very close to the field data. So, basically that is one issue still pending even today when we are designing as per a p i or d n v or any other course, the variable stress loading is this is a parameter that as been accounted in today's design practice. And that is why sometimes we use a probability based on design because at least some amount of variable, it can be brought in, but unfortunately a p i as not recommended yet.

Basically will have to wait for the next revision I thing twenty second addition of the a p i at the cost committee is recommended a probability based fatigue design. So, it is wait and see the code at not least that we can stop their. And basically I think you should be able to understand and do a quick design 3 things in this in this model, one is estimation of fatigue damage based on number of cycles applied number of cycles allowable.

Estimation of stress concentration factor given in the here we know basically the tubular joint geometry and the empirical equations from either f t u or other equations, you should be able to go on compute and understand the variation of that ((Refer Time: 12:48)) along the periphery of the cod brace interface is not constant, and that you must able to differentiate between the previous s c f equations by a p i for simple which is actually constant s c f value for a single connection. There is no variation between card crown point and the saddle point similarly, for a brace crown point and the. Whereas, the empirical equation provided by a steam you and others have differentiated that that is not adequate, we have to interpolate for quarter points by a linear means basically just interpolate linearly. So, this 3 issues is able to understand and able to solve some problem, if data is given equations are provided I think it should be able to.

And the last one is the combination of the stress concentration factor with the applied stresses to find out the maximum hot spot stress range. I think you should know what is stress and what is stress range if it is sign saddle variation you can multiplied by 2 or otherwise you can find out the maximum and minimum the difference will give you the stress range. You should be able to go and read the S N curve to obtained the number of cycles to be failures and basically find out the fatigue damage you understand the idea. If the number of cycles is not given applied number of cycles for example, hypothetical case basically the wave is occurring in a particular site, wave period is ten second with a percentage of time occurring.

So, it is seventy percent over a year, if that is the only the information is given you should be able to calculate the number of cycles isn't very simple. Total duration in year multiplied by 0.7 divided by the wave periods will give you the number of cycles. So, you should know how indirectly things can be calculated given the duration of design life are time duration of the occurrence. For example, sometimes you may not be given full period of cycles, you will be given the wave data available for 3 months so you calculate 3 months time divided by the wave period, will give you the number of cycles occurring in 3 months, but then you have the multiply by the design life the structure which can be 20 years is 30 years, 50 years then you will get a total number of cycles applied.

So, you should start thinking rather than simply what we have learned in these few days course, you should just apply in your mind. So, we will move onto the next topic in this I think you should be able to finish this topic today, basically the rings stiffness the tubular connection. Last I think for static connection design we have learned about reinforcing the joint because the card wall thickness could not be increased, for several reasons which we have discussed last time. And now we have a problem of failure may be due to large stress concentration factor large stresses.

Now, what we need to do is we need to find out alternate means one of the means is to stiffen the joint as usual, what we have done for the static design or static loads. So, you could actually put stiffener in this relation typical arrangement just get an idea, but what happens is when you design static load we never bother about the stress concentration factor. What we were always looking the stiffening or to avoid local failure of the card from organization or by local punching.

Whereas, here done this exercise you need to make sure that the stress concentration between the card and the stiffener itself between the inside somewhere here or the inner face as to be make sure that it is not governing the design, because you always have the stress concentration factors calculated further brace and card interface. But if you forget the stress concentration factor under the card inside and you may actually start or initializing a failure in that particular location.

So, one of the problem is this connection cannot be inspected once you have installed the ring and closed the tubular, nobody is able to go and inspect inside. So, it is an un inspectable joint number 1 and that means it is risk the slightly is higher you may have see that factors safety required for such table of joints, should be increased because once you installed because this tubular is not open like this is welded to another column or a brace and this side is closed. So, nobody can go inside and verified during the life so that is one of the problem basically we try to avoid many of the owners, and clients, and consultants do not recommend stiffened joint. Something like unless otherwise is a last result that you have no other choice, then you can you use it, but otherwise normally not recommended.

The lights resister actually as to given some recommendations basically modified form of f t u equations. So, you have will f t u equations for an stiffened joint and there is a correction factor is a simple idea like what I have explained other day, un stiffened tubular addiction strength and multiplied by a enhancement factor similar here is exactly reverse, it can be forward depending on the location. For example, this stress concentration factor between brace and card can be reduced because the local ovalising in effect as been slightly improved. But then as long as the stress concentration factor between the card and the ring is smaller isn’t it because then you are actually reducing the total that is the effect.

Otherwise you may actually reduced the stress concentration factor on the brace card interface, but the stress concentration factor at just inside is very high in any cases not going to be useful. So, a p i as not given mandatory that you only as to use Lloyds equation, normally it is it is recommending it can use specific finite element analysis. The reason is such type of stiffening is not very common not recommended and when you have the large problem that you could not resolve, you have to provide rings and that means it is only a specific cases solids leaving to the designer that either you can use slides equations are you can generate s c f by doing dated finite element study. And many times minimum s c f of 2 for axial, and basically 1.5 for others locations recommended.

And basically this minimum requirements is given because it should comes to be less than that. So, other than that the joint design is exactly same as un stiffened design only replaced stress concentration factor, but there is something is not right in basically is effect of stiffening has not gone into your actual analysis stress calculations isn't, it is only have taken effect of the stiffening in the stress concentration factor only. There is no reduction in stresses are alteration in stress pattern a because of the presence of and that is why that is that is exactly why, many times we the recommendation for the stiff stiffened joint is not very good because still a lot of studies are going on many research is being done, but unfortunately nothing is come out as a usable form for design.

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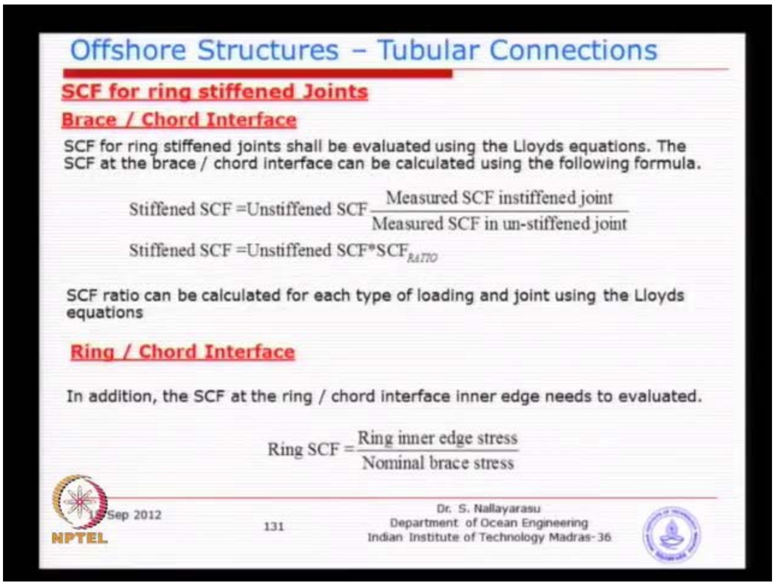

So, basically the stiffened s c f is un-stiffened s c f is multiplied by the ratio of measured s c f or a can do a measurement are you can do a f e analysis and un-stiffened joint and stiffened joint and versus un-stiffened joint. So, as the ratio is less than 1 you will see that you will always have a slight reduction in the brace card interface. At the same time if you are able to get the s c f at the ring versus the card is less than the is given for point then you are safe that means you are going to reduce the s c f by some amount, but if you're forgotten to do this probably problem.

And many times depending on the joint configuration depending on the type of whether it is a t section or a simple platform these stress concentration can be different. And also you may have look at the stress concentration factor at the interface between the planes and the web, at this junction which is also, sometimes can be the large.

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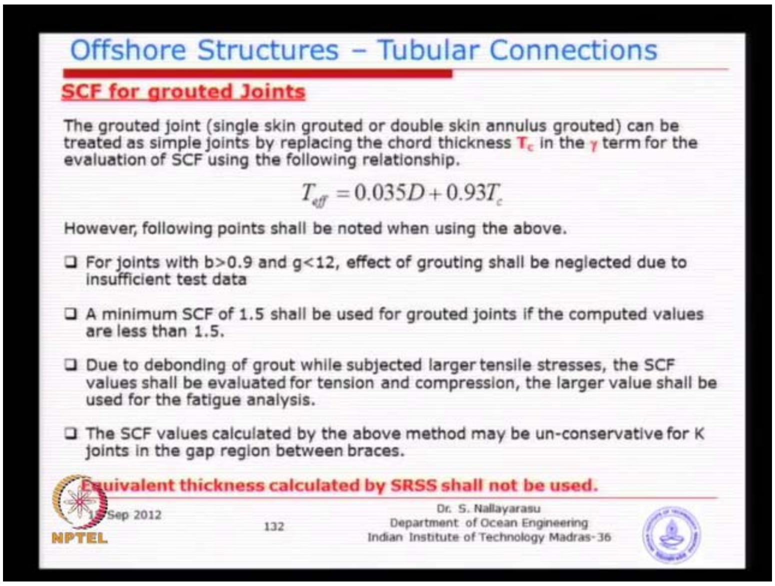

The next one is the stress concentration factor for grouted it joints. So, now you just look back what we did for the stiffened joint in static design for example, ring stiffened designed, we simply replace the thickness with the equivalent thickness that was the 1 of the easiest method, which were talking about. There were 4, 4 or 5 methods I was talking about and 1 of the method is just replacing the equivalent thickness and the other methods, when trying to do analysis using a ring formula and sheer capacity, I think there were 4 and 5 methods know.

So, among them replacing the thickness to the equivalent thickness was such a simple method because you do not want to do anything else, the effect of the ring is replaced by increased wall thickness of the card member isn't it. So, same thing a p i is recommending for the grouted joints here only thing is it is not using the s r s s equivalent, here based on some amount of testing is recommended that the equivalent, so called effective thickness is taken as 0.35 times diameter plus 0.93 times the card thickness. Basically file is inside know and the card is outside, so such an equivalence this based on predominantly several testing because it is a grouted joint, the behavior against specific is not exactly right static loading because the static loading is going to be 1 magnitude applied is constant.

Whereas, here may have tension and compression the grout may actually what will happen to the grout, after several cyclic of variable amplitude of stresses the grout may actually start cracking get separation to a inner tube and the outer tube may get separated, grout would not be affected depending on the magnitude of stress. Now, the problem is when the magnitude occurs if a larger magnitude occurs in a starting 2 cycles of the loading, the reminder of the life the thickness will be theirs.

Whereas, if the same thing exactly reversed there are so many smaller cycles of loading the magnitude is small, but only the larger magnitude occurs at the tile end of the life which we do not know on this is one of the major problem. And basically whenever we use this if you get the thickness of equivalent or thickness effective larger than 2 times, the thickness of the outer shell I think the there was a limitation in the static design of the normally we do not recommend.

For example, anyone calculate the this formula if the card thicknesses 50 mm and the equivalent thickness or effective thickness comes from a 150 m you should not be using 100. So, basically that limitation is by experience by a lot of references, but the a p i it was static design is given 2 whereas, here for cyclic design it has not given any of them reference here. But for sure you should not be using the s r s s which was permitted in the static design square root of t p square plus t c square, we were using know so that you should not be using here because of the grout failure, change in direction of the stresses or the magnitude of stresses from positive to negative.

The minimum s c f as 1.5 now you could see that menu calculative stress concentration factor, you may actually get less than 1.5 or some locations 1.2, 1.3. So, that is why every class a p i gives you a recommendation that minimum s c f use 1.5, if you get less than 1.5. So, these 2 classes of connections ring stiffened connections and a tubular and tubular inside with grouted on analyze because special type, only what you will replacing with either the increased or reduced stress concentration factor or increased card wall thickness. Once you do this then the problem becomes same as a simplified the people joint, where there is no stiffening is done just a substitution of parameter then you treat the problem same as the conventional joins.

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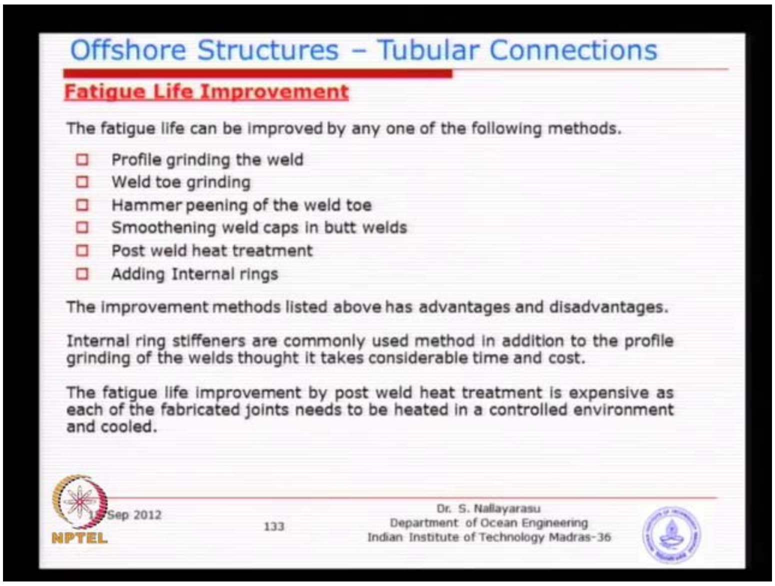

Now, once you have come to the stage that means you are designed to have fabricated at their was some changes required, either to improve the design life because the wall thickness provided in the certain design life, but unable to satisfy design requirements. When it will happen during the design normally does not happen because we have done a proper design should not be a problem, but what happens is there where there may be several restrictions given to you. For example, jacket length so 2 meter diameter, what could be the maximum wall thickness you can go for a 2 meter diameter, it will be able to idea no 2 meter diameter would be the maximum wall thickness you can, what will be there minimum ((Refer Time: 27:37)) you can apply. Nobody seems to have any idea, the minimum ((Refer Time: 27:47)) creation that you can go this 20 isn't it maximum d by d ratio is 60, when you are asked for a maximum wall thickness. That means you have to use the minimum d by d ratio so two thousand mm divided by d by d ratio is 20.

So, you can go for hundred mm thickness isn't it, so you have selected your file your selected your leg you are designed all you are system everything seems to be is fine, except few connections in the leg fatigue problem is there, or designed fatigue life is not satisfied. So, I want to increase the wall thickness hundred and fifty what I cannot increased the d by d ratio is supposed to the greater than 20 cannot be less than 20 for obvious reason I think you have already hopefully remember, why we cannot have a d by d ratio less than 20 because we cannot fabricate, we cannot roll because rolling stresses will be very very large, because of very thick plate, when you try to roll to 2 meter diameter you may get into our residual stresses, excessively high. And the machines to roll such a thick plate maybe not available. Hopefully I think is recollect if we do not remember so basic idea is we cannot go behind hundred, but design is not satisfied, but fortunately design is satisfied everywhere, except this fatigue particle joint isn't.

So, we do not want to go increase the diameter to 3 meter just for 1 joint or few joints which are giving problem in design against cyclic loads, but everything else is fine so that is a situation when, you start thinking alternate solutions to instead of increasing some hundred to hundred and fifty. Let us see any other alternate idea which cannot resolve problem, changing material isn't one of the idea, you can just simply go for better material by which it can provide you the required strength. But fortunately all the design requirement satisfied including strength except the fatigue, fatigue changing material is not going to help because you have only still of variety of yield strength changes.

Unfortunately the fatigue is not at all the related to strength of the material, it is basically the material characteristics against crack. That means even change the material is not going to help, so that is the time we need to start thinking of any other idea others than stress only the strength, which can help us increase the design fatigue life. So, some of the idea is providing rings for example, we just learned providing rings you are reducing the strength concentration factor, but if you have a jacket leg with a pile inside can you provide rings, we cannot provide rings we provide rings you cannot do the piles, that is exactly the problem.

So, all at that these of it externally something to do with the connection between the brace and the leg. So, that is what we are going to see how we can improve the improve the design life reduced the fatigue damage so that is the idea. Now, we have learned about reasonable understanding of the stress concentration factor and why it is occurring and where it is occurring isn't it, basically it occurring at the interface between the weld between the brace and the card the that is the area we are going to focus.

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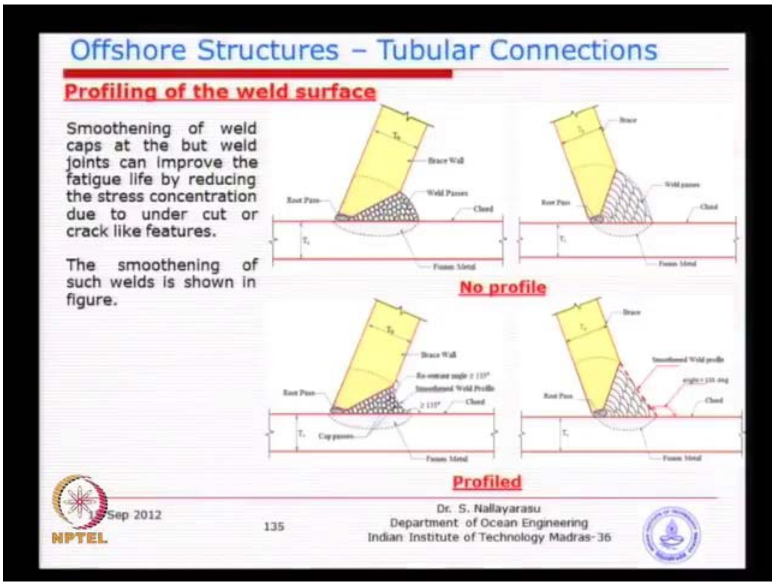

So, if you look at the simple picture something like this have shown you some photographs. 2 situations one is the 20 degrees other one is larger than 90 degrees something like this, if you take a tubular connection on this site will be less angle and other side will be larger angle isn't. Basically both the situations you can see first this, this particular connection where the angle of the wall thickness this is just part of the thickness so basically if i draw the picture is something like this.

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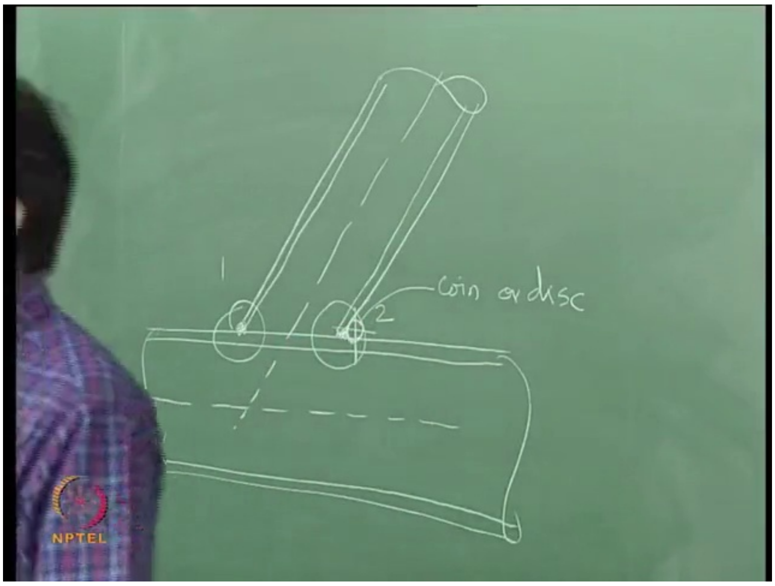

In a larger view so if I have the brace connection something like this, it will be just exaggerate-accelerate something like this so in this area and in this area. So, basically situation 1 and situation 2 so on the right-hand side we have situation 1 where the angle is larger than 90 degrees. And basically see here multi-pass welding I think by this time you have an understanding how the wedding is done because the is about probably 50 to 60 mm. So, every time you go around 1 cycle of welding second cycle of welding, third cycle 4th cycle, you will be able to understand is the weld deposits in this kind of form. And if you really seen the floors few you will see that the surface is not that smooth. Now, if you look at this venue just going to this particular junction just the connection between the brace and the weld, you will see that the surface you at that smooth and because of that you will see a increased value of stress concentration on that location.

And a long a weld you will see a several changing surfaces and finally, when its comes to connect to the that location, it is also an adds basically change in the angle of this much in that smooth enough. Now, if you just try to do grinding by means of removal of the weld material to form a smooth surface just take away to the material to get the surface tangential to the brace wall thickness and come and joined nearly tangential to the card wall thickness, it is not ground exactly hundred percent correct. But if you are able to get that corkage correctly joined smoothly with the brace and the card you could reduce substantial amount of stress concentration factors, this has been proved by several model testing, as well as by f e analysis of the weld. And that is why this is 1 of the best method from stress concentration factor of nearly say 9 and 10 most of braces if you calculate you will see the s c f of 9, 10 something like this.

Now, if you are able to reduce the concentration from 9, 10 to 2 and 3 you have a 3 fold reduction when you have a stress concentration factor reduction in 3 fold you will see that the a design life can jump very fast, which is very good idea. And also when you do this grinding you have improved to another thing the S N curve, remember S N curve includes some part of the weld connection some part of undercut, some part of the profile of the weld is already incorporated in the S N curve. So, that is why you have 2 S N curve provide by any code normal S N curve are improved S N curve the improved S N curve for profiles of this nature, you know the basically there are 2 ways coming into gather as long as your welding is nicely smoothed then you can improve the fatigue life substantially.

And one of the area is how do we do this out of a cut this, this is a very big problem is not going to be that easy because when you are making a cutting you may accidentally cut your parent material, and this is something as to be remember so that means the manual method. So, most of this grinding is done by manually, slowly not by simply taking one cutting machine and then cut away the material in this profile, is not feasible because the surfaces so complicated. So, that is why normally not recommended normally why not recommended is basically doing this is a very troublesome process, because time-consuming.

For example, is this if you remember from here to here distance would be hundred mm or maybe less than their hundred mm all around the brace, and going and the taking away the material by simple manual grinding, can take several days 1 joined will take several days so that is why it is not recommended, but when their recommendation comes into picture only when you have choice. But when we do not have choice because no other methods he seems to be giving to the design requirements then you will implement this.

So, we call it profile grinding sometimes the terminologies industries called profile grinding, what type of profile is it is not that I just go there and grind it according to my wish, it is not going to be acceptable. So, there are several requirements given in a p i, what should be the radius of this curvature at the joining point at the angles by some simple ideas are given, normally be do client test. If I do a profile like this we actually fit after profiling, we actually place in here this is coin or this for a given weld profile, after grinding to take the disc, disc number 5 it is fit it in its fit’s some roles properly then use the profile is the according to their requirements.

So, basically contest are disc test or the methods to test the curvature of joining profile from the weld to the card or well to the brace. So, basically that is one of the best normally done and just make sure that the profile is according to the requirement of the codes. So, this profiling of the weld surface is to be recommended as a last result with the design is unable to satisfy.

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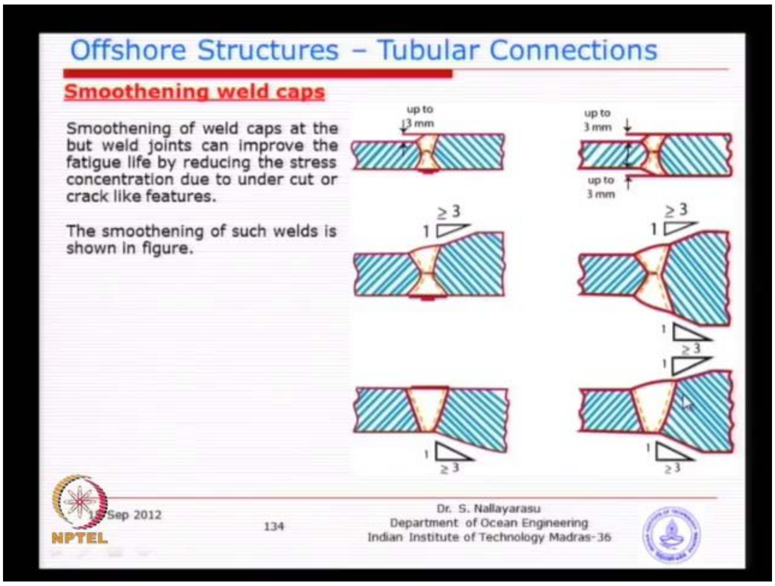

Or other ways smooth ring of weld card basically that is one of the area where can give you unsuitable reduction in stress concentration factors. Especially when you have a variable thicknesses thickness smaller, thickness bigger when you have to try to join in a smoother level by means of tapping the thicker material and joining here, instead of just keeping in like this make the joint which is going to give your larger stress concentration factors. But then that tapering the course recommend minimum tapering is 1 in 3, there slope sometimes 1 into our 1 into 3 because 1 into 3 is more work 1 in 2 means less work 1 in 4 means. So, even more length of fatigue which many times is not preferred suitable lot of grinding work, especially in manual grinding.

The other forms of basically improving design life is weld tau grinding, after doing this profile you go to the end of the weld and try to remove a any discontinuity you know at the tau of the weld there could be small gap, which can be removed by tau grinding. Hammer selling of their well-to-do just hammer it is that they lose material if you any will actually come out. So, though they are this 2 are given as an option quantification of such improvements are very smaller.

So, a p i does specify that you could use one of the method he's not giving you the year idea how much improvement that you can actually get. Whereas, the smoothening of weld caps is similar to the weld profiling in basically the surface profiling, all this 4 methods are mentioned in a p I, but directly giving their recommendation to calculate the design life is only for the first one is a profile weld there is a formula calculate, the increased design life.

The last one before we finish the weld improvement is basically the most weld each treatment which I think I mentioned about it last time after you fabricate the joint because of the inherent residual stresses, there could be potential cracks initiate. So, what we do is we take the joint taken into large oven and heat it relive the stresses, so that is one of the methods which is adopted like 30, 40 years back some of the joints fabricated golf of mexico the big jacket 450 meter jacket, they had a larger problem of weld cracks, even during welding itself.

So, what they did there actually heated the material and basically after welding and heated the joints and then cold down at a control. And then basically forced weld heat treatment is nothing but try to relax the weld after welding so that means you will heat the total assembly that means if you fabricated joint of 3 meter by 2 meter diameter which, so many braces connected. And the whole assembly is to be taken to the a shop where we can heat it too thousand five hundred or higher the temperature and then allow it cool very slowly not at the abrupt change. This post weld heat treatment normally not recommended because not everybody have the facility to heat and cool down because you need to create a big haven.

Whereas, normally use in a mechanical press services industry normally people use this when the pressure vessel is very thick, they fabricate the pressure vessel and heat it and cool down because pressure vessel carrying large presses you do not want to have the higher residual stresses. So, among this the first and the lost and first one and the last one is inherently easy to applied method to improve the design life as the others though idea is given, but use of them for real purpose is very limited I have given 2 example problems.

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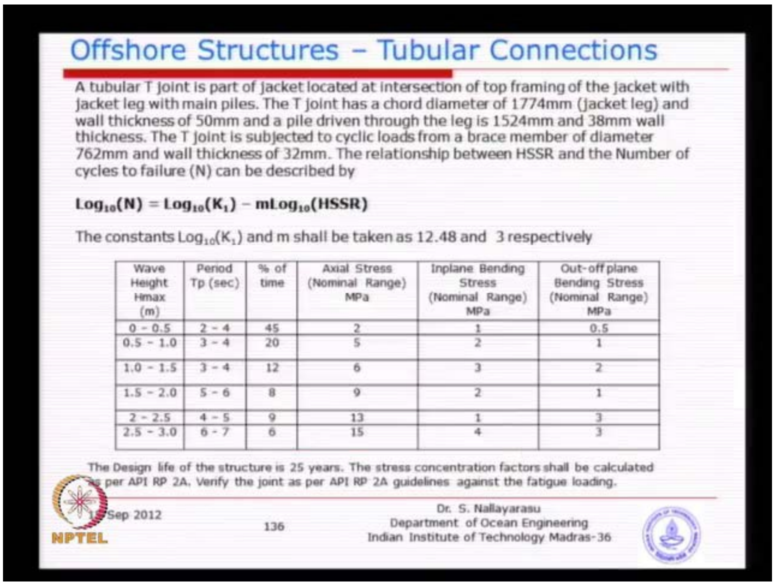

Hope you get ideas go through I think all of you that these slides know so do you now you are learned about the process by which we are doing the fatigue design, now if you read the this now we few able to understand and probably we will be discussing in one of our tutorial class to know. In brief what I have ask here you have 1 minute to go so basically is a tubular t joint, and basically what we have been given in the wave height, wave period, percentage of time, stressed main magnitude each of the cases.

So basically it is a complete scatter diagram including stresses is giving to you of course, you could ask you to calculate stresses, but that will take several days because you need to do a computer analysis come up with the stresses those stresses will be calculated and used. But in here for examination purpose the stresses also given so that means you have a tubular joint, applied stresses on a brace for a different wave slides is given to you understand the idea know and wave period is given and the percentages of occurrence for each of the wave period and wave height is the given.

Now, you could calculate the number of cycles I think because percentages of time is given period is given of course, I have given you the period in some range. So, you known to need to go for a mean period should just average period, and then stresses are given to know what is a geometry of the joint calculate the stress concentration factors. And then stress are now multiplied by stress concentration factors you can get the stressed range and you have got the equation for the S N curve, go and calculate the cycles of the failure to the joint, and calculate the fatigue damage for each of the steady state and cumulatively add. So, this is a very simple stride forward problem is no hidden issues down there.

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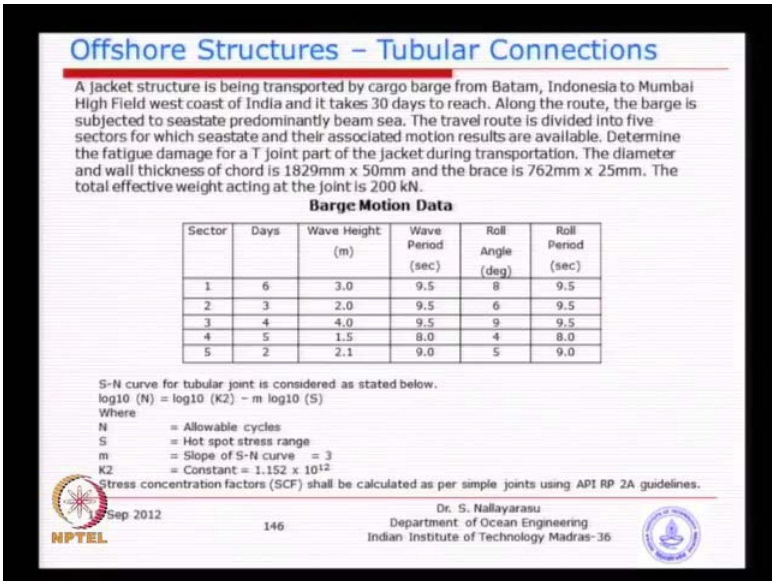

Another problem is similar except that this is due to transportation to know so you read it, and we will do something in the similar type given in the tutorial.