Design of Offshore Structures
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Module - 04
Lecture - 07
Tubuler Joint Design for Static and Cyclic Loads VII

So, the last week we were looking at the wave scatter data, two parameter verses three parameters. Two parameter basically linking the wave period and wave height with the number of occurrences of course, what we really require is the distribution across the structure.

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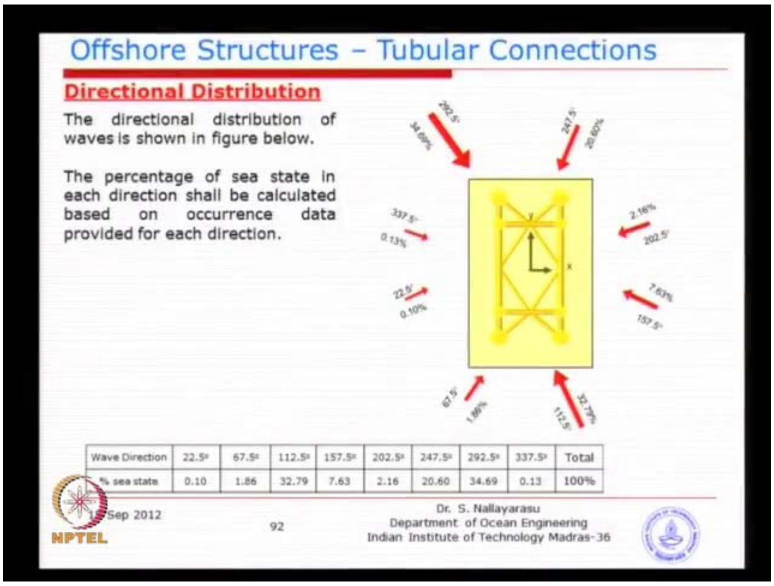

So, if we see these diagrams you can see that the wave approach to during various times of the year is varying, in these directions the percentage of occurrences could be differing. So, one such wave scatter data if you go to the data shown in this few pictures each direction is given with respect to wave height and wave period, again you can see a slight differences in this particular wave scattered diagram.

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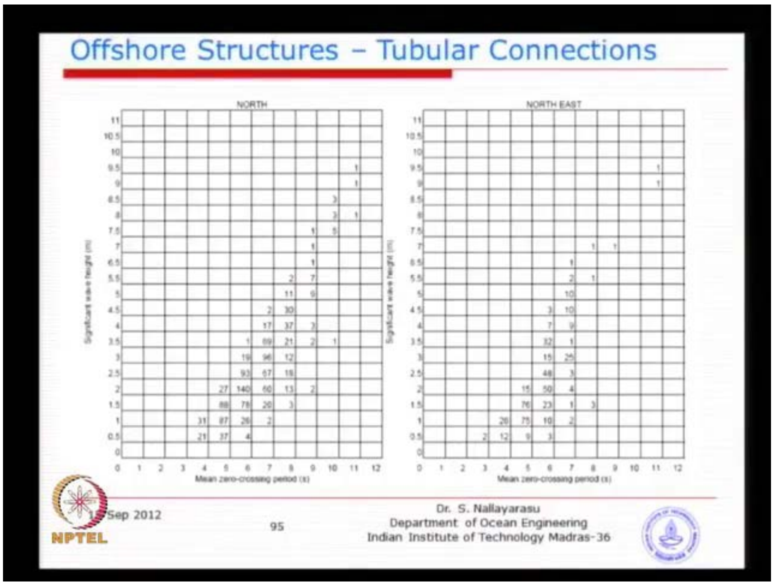

We have got significant wave height rather than the maximum wave height, I think as you know very well the wave spectra is described by significant wave height and the peak period. Whereas, the deterministic wave data is maximum wave period and zero crossing maximum wave height and the zero crossing wave period. So, depending on what is the data available you should try to establish, of course you can convert this data into a maximum wave right data by simply multiplying the significant wave height with corresponding factor depending on what is the stomp period. If it is a 3 hours stomp period you can find out the multiplication factors to be 1.86, 1000 waves.

So, basically the data what we require is a link between the wave height and wave period and the corresponding occurrences either in terms of absolute number in terms of percentages. Sometimes, you will see now the exactly like this kind of number will be there, it could be a fraction of 1. The total occurrence is 1 or 100 or 1,000 or 1 million, depending on what we are looking at is the fraction of time the corresponding wave associated. If the height and period is occurring in here we have got just numbers hold number like 2, 10, 30 like this. You can even have 0.1, 0.3, 0.4 ultimately what we are looking at is the fractional time period.

It is 1 year or 100 years, it does not matter what we are looking at is the ratio; ultimately we can convert into numbers. For example, instead of giving this kind of numbers here you can have a fraction 0.3, 0.1, something like this. Ultimately, you can multiply by the total time period of the duration of the denied life divided by the wave period you will get the corresponding number of occurrences.

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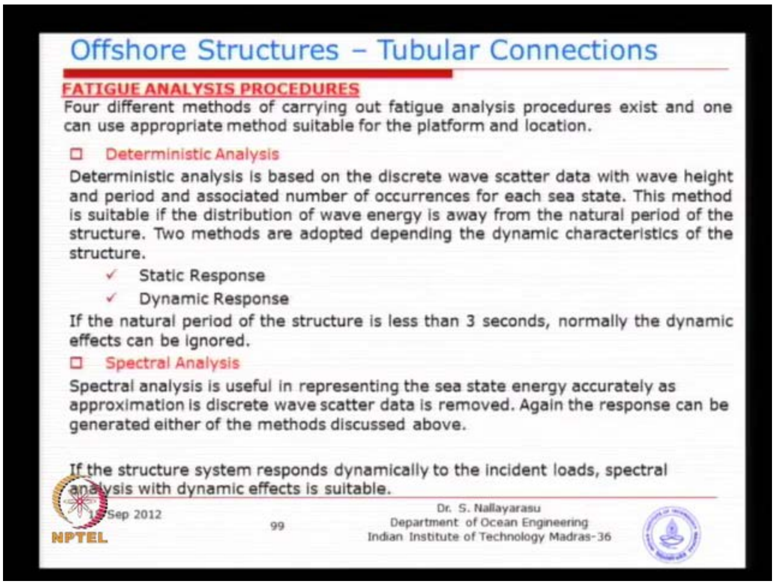

Now, the analysis procedures, so all of you hope you understand the necessity of such thing. What we are ultimately looking at is the cycles which are applied to the structure number of cycles for each of the wave height and each of the wave period set. And based on which you are going to calculate the stresses come back and calculate the allowable cycles. Then, we can find out the petty damage, now how do we determine the aphetic damage depends on. What type of drape data available as we see there just now deterministic is a specific discrete data available each wave is associated with a corresponding zero crossing period.

That wave is a maximum wave for example, if you take one year you may have several waves each wave is taken as individual wave rather than representative significant wave height. Now, if you have only significant wave right for the particular period of time and basically you can describe the sea state with spectra rather than the individual wave. So, you can do as spectral analysis the transformation of structural response in terms of transfer function or spectral response depends on that type of structure. For example, if you have a rigid structure not responding to the sea state that means the structure is too rigid compare to the loading applied.

Then, you do not need to really go on look at the spectral responsibility, because any way for given frequency of loading the structure frequency is very far or disassociated with the dynamics. So, you do not need to really look at the spectral response were as you can quickly do a determination response because irrespective of whatever the frequency the structure is not responding to it displacement becomes too small. So, we need to see the classer problem for example, if you take a fixed structure jacket type of structure versus a ship.

Now, if you look at the natural period, I hope you have gone through the dynamics of single reader freedom structures, at least you can see the fixed structure got a frequency or a period somewhere around say 2 seconds or less or 3 seconds or less. When you look at a ship the natural period in at least in role or if you will be able to easily calculate you will be around 10 plus. So, you can see now floating structures natural period of vibration or motion about 10 seconds, 15 seconds see than the right side where as the fixed structures. If you go and calculate a simple continues structure, you will the period is say 2 seconds, 3 seconds, 4 seconds.

You can see most of the sea state conditions, what we have learnt through the gravity waves the wave period may be from 5 seconds to 15 seconds or may be 4 seconds to 12 seconds. So, you are not in the range of the big area where the energy is higher, so fixed structure is normally not going to be sups table to any the resonance area, where the response is very large. So, that is why most of the fixed structures we try to do at deterministic analysis where fixed frequencies is going to be expectable. Whereas, when you have the natural period or the vibration characteristics are going to be coinciding with the incident waves, when you better do a spectra response most of the floating structures.

We do a spectral response whether it is a ship or spot type of platform or other you know basically deep water structures like TLP and so on, where as fixed structures we try and limit ourselves to simplified deterministic analysis. That means a static response is good enough dynamic response is required whenever you have the structure is becoming slightly cylinder. I think you might have some pictures in that earlier lectures jacket structures in 15 meter, 100 meters, 200 meters, 500 meters also jacket structure do exists. So, when you look at a five hundred meter jacket structure they may exhibit vibration frequency of more than 4 seconds, 5 seconds.

So, such type of structures you may actually want to do a dynamic response not necessary that you not need to go to spectral. But you can do a dynamic response by several frequencies to selection of this method which method you want to adopt to find out the structural response is left to the designer. I do not ask you to do this or that because you only have to evaluate how the structure behavior. But most of the time for picture structures is quite simple because you can find out the free vibration analysis Eigen frequency you can find out and more safes, you can determine whether a structure is susceptible to dynamics or not.

Now, you will just quickly look at what is the methodology adopted in terms of solution to the simple structural problem. I think most of you might have studied the structural mechanic metrics method of analysis or some of you might have got some knowledge of finite element analysis. You may actually take few courses later on during this M. Tech, but you will see that the basic fundamental principal lies in stiffness method of analysis.

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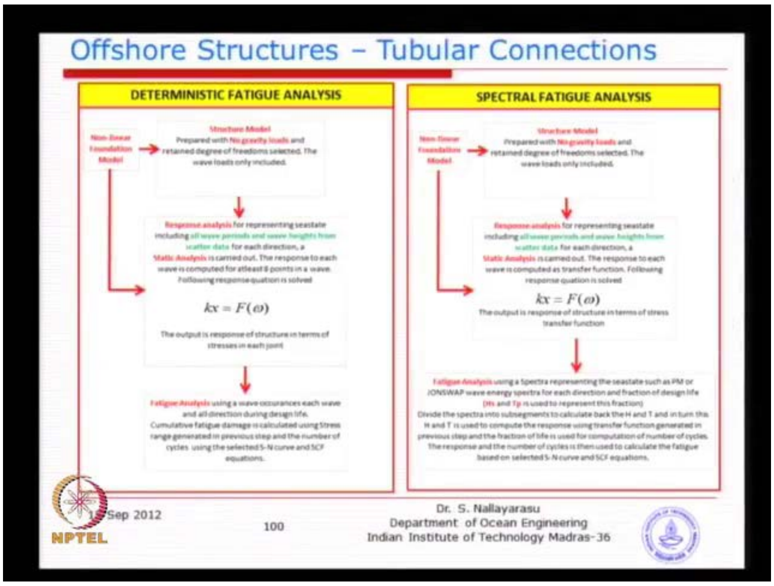

You might have studied the structural mechanics in your bachelors' degree, so if you look at the equation that is normally you can see here stiffness multiplied by displacement and right hand side you have a forcing function with respect to frequency. So, you can actually solve for v time domain analysis or frequency domain, so that you can easy to solve because if you are structure is independent of frequency. It is not responding, it is a small deflection problem then you can simply disassociate the frequency only look at the amplitude of response. So, you can take the maximum wave force among all the frequencies, so you look at the all your wave periods you are not worry too much about the frequency domain because your response is so small.

So, you can look at the maximum force because we know how to calculate the wave force variation over one cycle, I think we have already learned about it, take the amplitude of maximum force and come and solve the structural problem. So, k x is equal to F because you becoming independent of frequency because it is not going to be susceptible to dynamics.

So, you see here the k is the stiffness of the structure x is your displacement and F is your force and if you go back to your basic structural mechanics. What you are studied metrics methods actually deal with this same equation only think is the notation is different k is your stiffness. For example, if you take a cantilever we can easily solve k is the flexural or bending stiffness if it is a column then you take actual stiffness. If it is a combined column beam then you take 2 by 2 or 6 by 6 depending on how many degree of freedom you want to take, column means actual degree of freedom bending means lateral degree of freedom.

You may have lateral displacement you may have lateral rotation at one point, so you can keep on adding number of degrees of freedom this equation becomes larger instead of single degree of freedom you are going to increase. So, that is exactly metrics method metrics method is just an evolution from what we are trying to study today as a finite element. You go back 20 years back nobody was talking about finite element; we are talking about simple metrics solution to stiffness problem. So, this deterministic fatigue analysis what we are trying to take is you saw one big table showing wave height wave period number of occurrences.

So, one wave period corresponding wave height go and solve the problem here trying to find out the displacement of the structure once you know the displacement you can find out the stresses. Once you know the stresses we can solve the fetid issue, so here this particular step is very important because we desired at the jacket is non responding to the dynamics because it is too rigid period is very less.

So, we selected a deterministic fatigue analysis because we do not need to look at the dynamics of the systems on the right hand side you see here. You do exactly the same instead of doing individual wave you are going to solve the problem in frequency do mine, you will do spectral response again you are going to solve this same thing. Only thing is you are not going to use individual waves, you are going to do a spectral response. That means you are your input will be your wave spectra output will be your transfer function relating the stress and the particular frequency of wave.

So, basically here is have an amplitude of force going there here are going to be the incident wave spectra both are exactly say only thing this here. We disassociated the frequency, we take only one wave amplitude corresponding force, whereas here each frequency you will find the response because we feel that there may be potential chance that secondary modes of the structure. I think might have a studied Eigen frequencies you got first mode or first frequency, and then associated secondary modes and secondary frequencies, they may also contribute depending on the type of structure you are involved.

So, for example, if you take one simple cantilever you take only one degree of freedom all what we have assumed is all the association of the mode ships. The frequencies are associated with single mode which may not be true that is what normally we do hand calculations, but when you do a computer analysis when you are trying to take out the associated secondary modes. You may see that you may find the mass effect could be associated with second third or fourth mode, which you may ignore if you say that only the first mode is contributing to the dynamics of the problem.

So, that is why you will see that when you do spectral response you will include associated second modes third mode and associated other modes because that may be accurate. So, there may be losing response here you may actually account for all the response in the spectral method. So, basically both are deterministic only here you are going to use the spectral analysis rather than individual waves, but both are not dynamic response included both. This is also static response, this is also static response only we are just doing the analysis in individual wave versus spectral.

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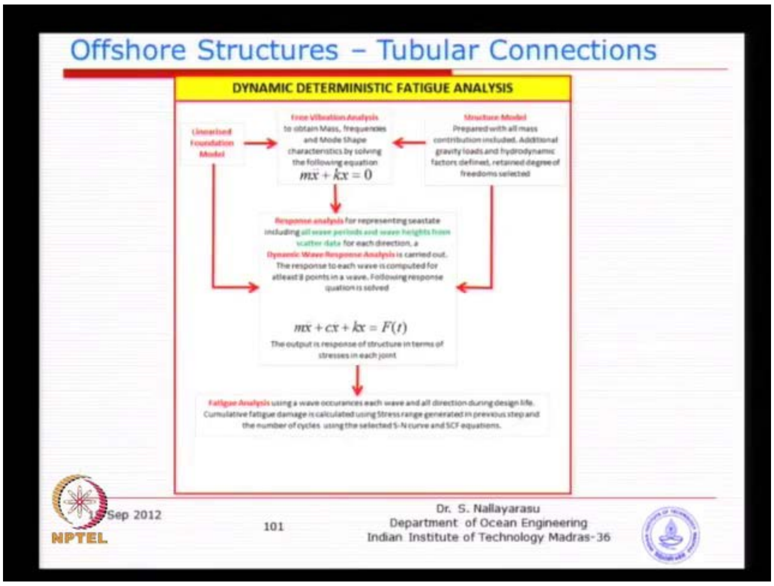

Now, you go to the next slide will do a deterministic only thing is we will include the mass effect. So, instead of solving the simple stiffness equation will solve the equation of motion which includes the mass effect damping effect. Once you introduce the mass you will have the dumping effect and then solve for the displacements here still we have not included the spectral. You are only just solving for individual waves, so in here why I have put time do mine basically you will take one cycle of wave, like what we did the wave force calculations earlier.

We were trying to do wave force calculations from 0 to 1 cycle, so you will pass through that one cycle of wave try to find out the response for each of the point instead of use of calculated. The force on applied the maximum force on the structure this is what we have just done here, we have taken the maximum force for that particular frequency. Whereas, here you will have to calculate the response for each of the point on the wave and find out what is the response.

So, basically a slight difference, so one wave cycle you are trying to find out what is the response incorporate in the mass effect. That is called the inertial effect the reason why the mass coming into picture the inertia of force is contributing to the total response whereas; here the inertia of forces is not coming. Now, contribution coming to the displacements, so basically that is the idea behind the last.

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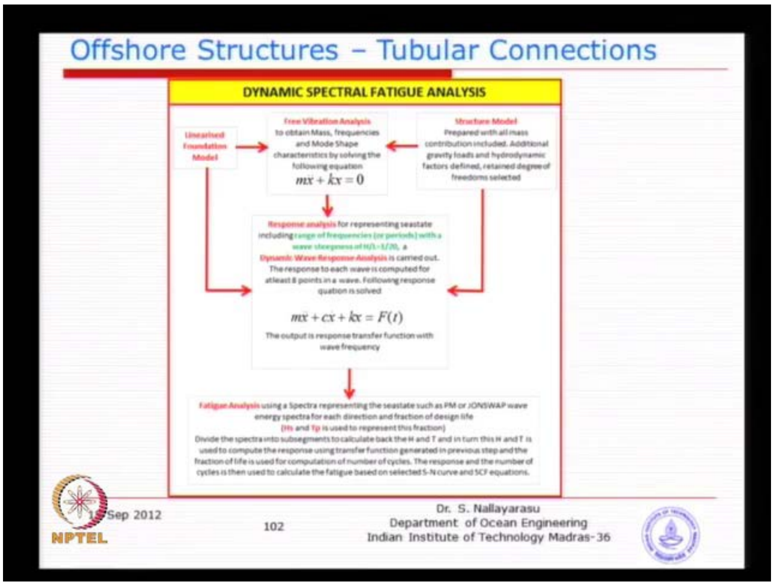

Once again we will do a same thing, only thing is instead of individual wave will put a spectra into the incident wave instead of one wave you will put the spectral response. So, all four methods we have two desired which one is applicable to so dynamic included dynamic not included the first slide was dynamic is not included no dynamic response that means the inertial components of the responses is too small. So, that is why we have ignored whereas, when the motion is too large and basically the large amplitude response will include acceleration and velocity. Once you have acceleration and velocity that means the inertial components of the response is higher e include here whereas, the first one is the response is so small.

In fact that is where we go back to our basic bending theory when you have derived the simple beam in bending equation our first assumption was the displacement is too small the beam can considered not deflected. So, original say is used so that is exactly the idea that is when we are trying to solve this first setoff response calculation the displacement is so small structure responses is quite addicts small. That we can assume that no acceleration no velocity whereas, when the large amplitude response is there an automatically you will have acceleration deceleration during the process of response.

You will the derivative will give you the velocity and acceleration from the displacement. So, basically this four methods needs to be will reviewed upon for each class of structures each type of structure floating versus fixed, and then desired upon with which method to find out.

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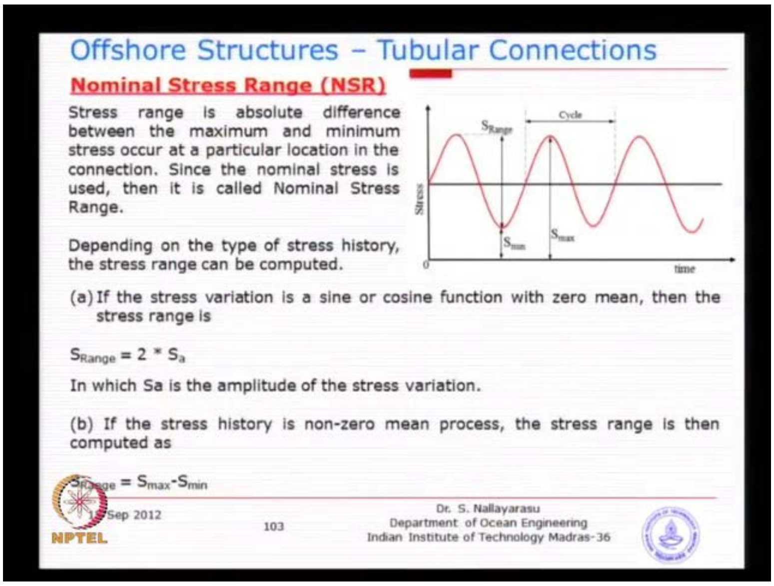

Ultimate aim is to find out the response of the structure in terms displacements and stresses because for fetid, or for design what we required is the stresses on the members and the stresses on the joints. Now, how do we calculate the stress range basically stress ranges from one side of the zero line, it could be positive negative or it could be mean zero, non zero mean process by which you may actually have an acceleration either in positive or in negative.

So, if you have a zero mean process simply like our sign wave then the stress range becomes two times the amplitude is not it is very simple you have a sign variation. So, it take the top portion because its symmetric, if it is asymmetric then you may not be able to take this you may have to take the amplitude on the crust and the turf and sum it up, but most of our simple array wave.

You may get this kind of conditions not necessary that the stresses needs to very like this you may actually have a step function you know like you later on we will go and look at the lifting object by crane the stresses goes from 0 to some x value. Then, comes down to 0 when you are unload it is not it, so basically you do not need to have always sign or co sent functions you may have what we are looking is the maximum stress and the minimum stress. It can be positive, it can be positive negative or it can be negative both of them what we are looking at is the variation across so basically if there is non zero mean process.

Then, you may actually just simply find out the difference between the maximum stress and the minimum stress, what we are looking as the range going from here to here that will give you. So, called the reason why we call it nominal stress range because we are not multiplied by concentration factor. So, basically that is what we call it so this stresses are away from the joint slightly away, so how much distance we normally take in a design consideration at least one diameter you go away from the joint. So, if you have a diameter the member is 1 meter, so you just go away because the effect of local concentration. I think we have shown you some pictures last time the effect of local concentration of the stresses is predominantly at the brace and chord interface junction.

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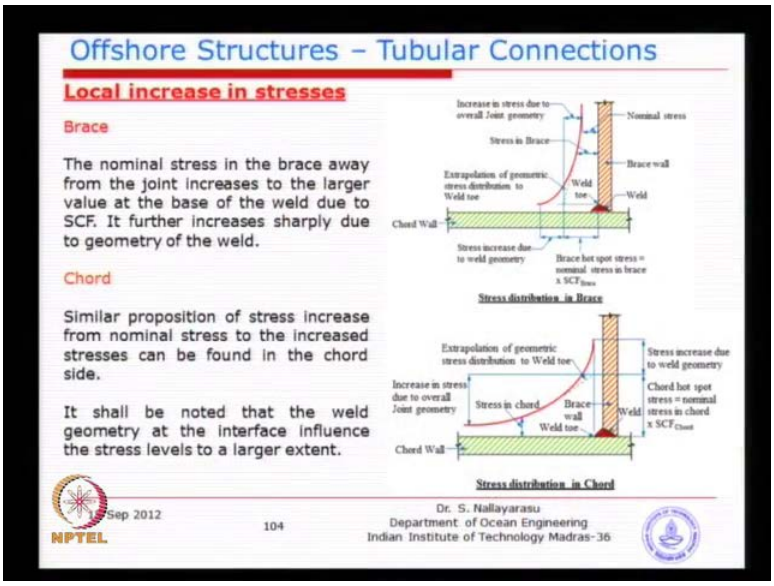

So, if you look at these two pictures one on the chord side and the other on the brace side, so if you look at the brace one the nominal stress is somewhere here. Basically the distance from the face to this line I have just noted as a stress as soon as you just keep on coming closer to the joint you can see here this red line goes very much higher. So, the increasing stresses indicate that the local effects are coming into picture and if you look at that near to the two of the weld joining the brace.

So, that is the intersection line you could see that the blue line drown there is the magnitude of stress increase this stress compared to the nominal stress which is somewhere here. So, it could be two times three times or four times the reason why we do not want to take this red line as the maximum stress we need to understand very carefully any finite element analysis what we are trying to do we do not model the weld effect. I think I have explained to the other day modeling the weld effect is the one of the biggest problem in the analysis.

So, we do not want to take into account that so the stress concentration factor is normally not incorporating the weld effect practically 30,40 forty years people are trying to do such studies using advanced the IT software's they were unable to model. So, what their what has been done in the past remove this the weld effect and keep it one side we will treat it separately in other ways, but the stresses due to the connection is taken oddly at the footprint of the brace. You just draw a line and take that intersection that is the maximum stress that will be part of your stress concentration factor.

So, what will happen to the weld effect this weld effect has been incorporated in the SN curve, when we are somebody is doing an experiment and do one experiment using the actual welding and the effect of the weld is taken in to the SN curve. So, we do not need to really bother too much and same effect you can see here on the chord stress the chord nominal stress is somewhere here, but when you go closer and closer at the phase of the weld you can see here that is a increases. So, this is the increases stress this is the nominal stress.

So, the ratio will give you now when you do your own F v analysis next time when you want to generate a SCF, if you have not incorporated your weld effect you should not look at the stress at the intersection between this line and this line. So, you will come here and look at the stress you should not look at it the reason why I am explain here you should look at whatever the weld you need to find out go out words and read the stress at this point. So, that will be the reflective of the actual stress concentration if you read the intersection stress. For example, at this point exactly at the inter section somewhere here you will find high stresses, it will be higher than the stresses that you may read.

If you read it at the at the phase of the weld you come outside either a brace side or an chord side, so that is why I have just shown you this picture wave where you should read. So, you need to find out what is the weld length and go away and that is the stress representing the brace side is to be red on that side chord side to be red on the this side.

So, that you represent the either the brace concentration factor or chord concentration factor.

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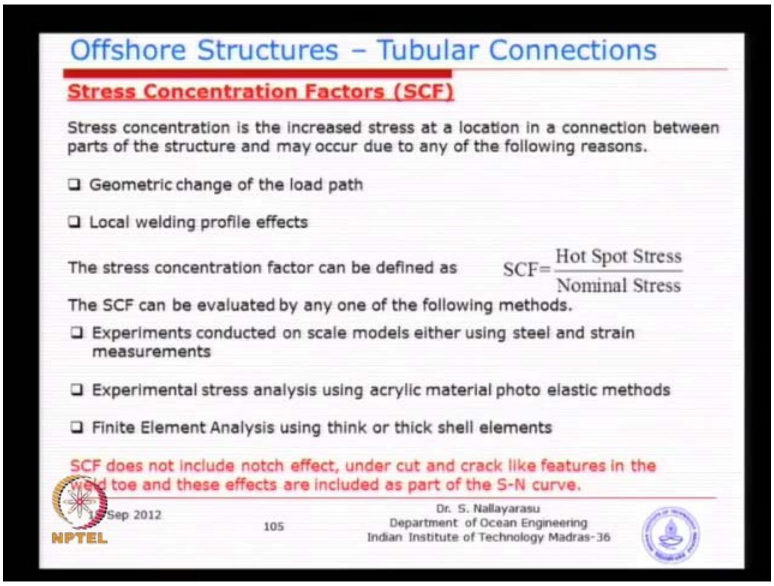

So, the stress concentration factor is typically defined as the hot spot stress divided by nominal stress I think which is very easy for definition purpose. Basically, how you find out stress concentration factor is by few means you either can do experimental model fabricated steel phase weld it, put strain cages and measure the stresses at the point of interest which is normally done in a full scale because we need a scale is definitely difficult to get the strain cages. For example, you make a one in hundred model such strain cases are quite difficult to get.

So, normally you have a full scale model that is why very expensive if you actually make 10 meter long half meter diameter steel phase and try to do the testing not every place. You have a such a machine to test we need to go to biggest testing machine you may not in everywhere, so if you go around you will find in very few places you can find such type of machines. So, that is one of the area where the full scale model is difficult to do, but of course, in the past at least not the 100 percent scale model reduce this scale model like one in five one in ten people have done.

So, instead of doing 5 meter diameter tubular do it in a 1 meter diameter half a meter diameter tubular, but not like 100 mm or even further reduced to which will not produce correct result are use experimental stress analysis using photo elastic methods. I think some of you might have studied fringe pattern based on you know acrylic material. Basically, it will come in one of the course I think experimental stress analysis course if you are going through now our next semester you will get more ideas. You can do that also without wasting a strain cages based on the characteristics of the material.

We can get the fringe pattern and then extrapolate to stresses and extrapolate to corresponding strange the third one is the finite element analysis, which I think I have shown you some pictures which will reveal the stresses at these points either under chord side or under brace side. So, you can also do a finite element analysis, now this stress concentration factor basically incorporates the German trick changing the load path. And local weld profiling effects wherever it comes and joins, but not actually going into the weld profiling itself.

SCF does not include the mach effect or any undercut or defect in the weld and any cracks in the weld itself. So, that means this SCF what you are calculating is only on the reflective of away from the weld no defects due to the weld itself has not been taken into account because that is how all those people who have done research in the past 20 years. We have developed because is very hard to include these effects in their equations because very few of them have done experiments every one of them have done only a few studies and because of that they have ignored those effects.

So, what the organizations like API DNV or other organizations have done the SCF does not include those effects then at least those effects is to be included in the some other way. So, what they have done is they have included those effects in the SN curve by incorporating those tests in the generation of SN curve. So, that is why you will find that these are the areas the earlier SN curves and the new you SN curve why there is a difference because there is an improved amount of testing available.

So, every time you do a testing you have a slightly different result that different result is why you might have fabricated a same t joined or same y joint that testing done 20 years back and testing done now. So, slightly different result or it could be substantially different result if there are improved methods of good measurements and repeatability you fabricated a same time you do previously and you do now.

You might actually find different result because the welding is different material costing is different results. You are not using the different material the material coming from particular mill or particle production is slightly different. So, you will see that you are going to get a different result that is why this SN curves where actually revised five times over the last 30 years, they kept on update because all those information give you slight modification.

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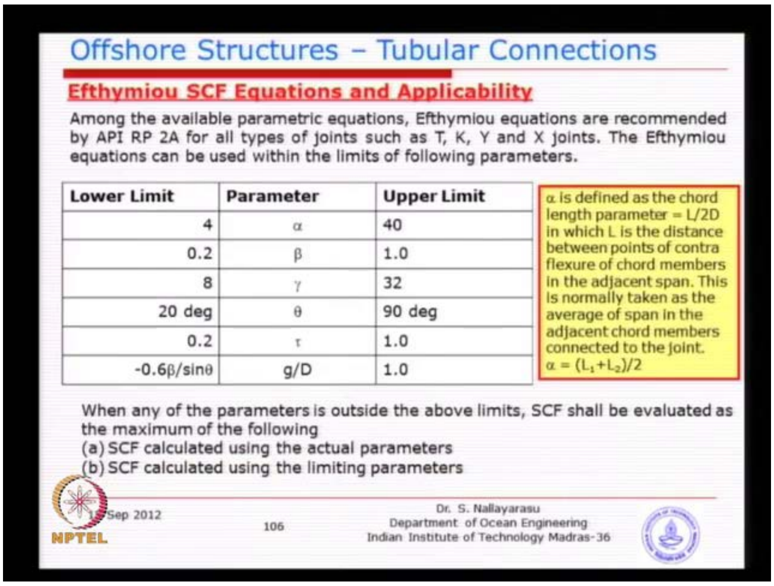

Now, if you look at the SCF equations developed by this Efthymiou is one very genius person. He has worked in lots and lots for the last 30, 40 years. He is now with the company called ASL international and he still working on live projects. Basically, he has done extensive finite element studies benchmark to growth very few experimental studies done by others and he came out with this is equation as early as 1980s published in one of the OTC paper. Later, he joined this company and during those process he as further point into those equations and published as a internal journal from cell.

Later it was adopted by API, basically even now until the previous revision of API, API as not actually reproduce this equations this equation was available as a separate manual. In the recent times Efthymiou as actually revised some of the corrections he has done over the last 5, 6 years. Now, the API is actually taken this equation in reproduced in the chord itself just to avoid a confusion which version because this equations cut two or three revisions or two three versions available.

So, they have just reproduce the equations in the appendix part of the API chord, now this equations quite good for most of the joints. We are talking about k joints, y joints or x joints with the limitations being mentioned in his original paper something like alpha. I think alpha is a parameter which you might not have been introduce it, so we will just talk about it just now, but other parameters all of you are very familiar beta is the ratio of diameter of the brace to diameter the chord.

Then, this gamma basically d by 2 t cylindereness of your chord and then theta is definitely is he has actually parameter 20 degrees, but if you look at API. They have done allowing to go beyond 30 degrees, but original equations what he derived actually he can go up to 30 degrees, but because of the fabrications related issues, we normally restrict ourselves to 30 degrees here. The ratio of wall thickness of the brace to chord and basically he do not really want to have thickness of the braced higher than thickness of the chord itself.

For sure not very good idea and then the gap parameter you might have seen the gap parameter. Basically, earlier in the join design static design, we had a equation, we had a limit point minus 0.6 to higher values here, they have just corrected using the beta in Efthymiou equations, he gives the limit something like this what is the alpha parameter is very important one to understand. You know basically alpha parameter is nothing but the length to diameter ratio basically how much is the length of the member that is being active in producing chord stresses, I will just make a one simple sketch is to make you understand.

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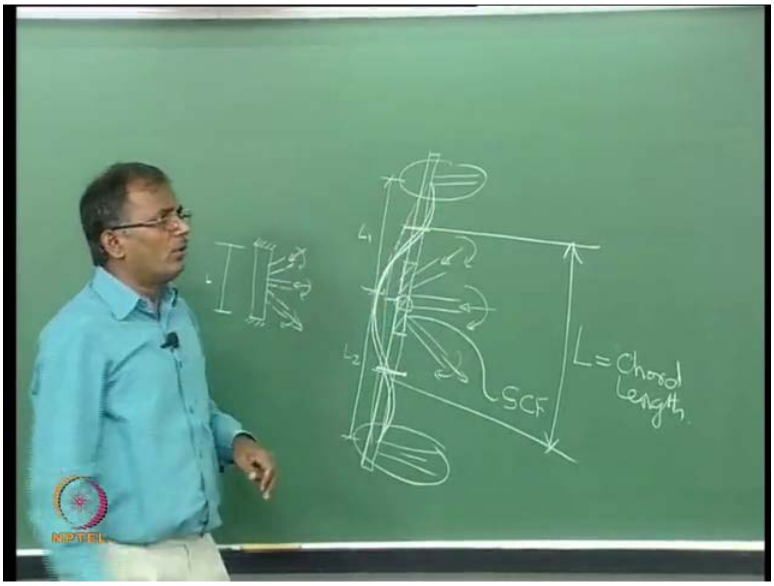

So, if you look at the a jacket, one of the leg something like this and may have several levels, but I am going to just draw only three levels of jacket you may have braces coming like this and I am just concentrating on design of this particular joint. For example, this is the joint I am interested in, when I apply actual force of moment something like this is a joint I am interested in designing static and dynamic and fetid. Basically, this is the spam, so one this is a spam l 2, now you look at it when you do a finite element analysis, when you isolate it, something like this, you put the boundary condition.

Here, all this moment components will you get the same response for this and this for sure you will get a increased response because you are going to have a global bending because the length of this member and this member is longer. You may get partial support because there is a brace here there is a braces here holding. When you have a loading applied in this particular brace you will see that the flexibility of this member will come in to fix in the introduction of additional chord brace interface stresses.

You understand the idea, now it is look like this are end supports and this is applied load, so stresses at the middle will be for sure maximum. So, this we call it the chord length factor effect, here you see here this is you just only say call it l small portion of the chord has been taken when you do a f v analysis of this. You will find stresses will be say some amount when you do the whole thing model than the analyzed, it you will see the stresses will be higher or smaller definitely higher. So, we need to take into account such global effect when we are talking about the stress concentration at this point because there will be a increased stresses due to the length of the chord on the bottom and top of the joint.

Basically, this is the joint which is in consideration, you will take the span in front and span at the back and that is what we need to desired because as given correction factor called chord length correction factor. The chord length is smaller correction factor will become smaller chord length becomes longer the chord, there is the correction factors become larger. So, basically originally equation developed by Efthymiou was assuming this all is F E analysis, he never bothered about what will be the configuration of that because nobody knows when he does that analysis, nobody is able to identify what type of jockeyed somebody will designing in future.

So, he assumed all is joins to be something like this assuming you short chord he assumed a small length and made an F E analysis for convenience. In fact, if you if you want do yourself you want to make a F E model you make the model, very big, it may take several days to run and those days. Those computers where shows poor in memory and you know ship efficiency, so making a big model is not very good idea. So, they wanted to make it smaller reduce and that is why it is called the equations were based on short chord.

So, here is come up with the correction factor c called short chord correction factor, somebody is coming with the long occur called you go on multiply this equations with the modifications in factors. So, that is why we call it this alpha factor is very important he bought, he actually understood was forum is idea. He wanted to find out something like this there may be a negative the moment. So, I just draw one more time is idea of the line is basically the location of point of contra flexure that is what you were calling is chord length the chord length is between the point, most of you might have studied point of contra flexure changing moment.

When you are studying in mechanics, he wanted to find out that point and that is how he has defined originally, but in practical conditions is very hard to find this point because if you have a three dimensional structure. Look at every one of the member to find the point of contra flexure becomes very tedious. So, what normally we do it in our design practice, we take half the member length on this side, half the member length on this site and just use it as the representative chord length for correcting the stress concentration factor.

So, if you are given a practical problem, you do not go and look for the bending moment diagram draw the bending moment diagram find out where the bending moment diagram changes the sign and find of contra flexure because it may takes a lot of time. Especially, when you want to design a jacket, every time you have to look at manually or writing a computer program to search for it which becomes real problem. So, that is why it is acceptable to take basically the length half length under top half length under bottom will be used for calculation of alpha. Now, whenever you deviate from this, so this is only a guidance given by a Efthymiou, do not use his equations.

If you have any of the parameter, go beyond this limit, suppose in practice if you come up with the situation where you are exceeding this limits, then what we need to do is we need to find out the SCF base on actual parameters. The limiting parameters given in the table and find out whichever produce us highest stress concentration take that and use it. So, that is the only possible recommendation given by API, try to trick to this because in many cases you will try to deviate because actual situation you are unable to come under this limitations.

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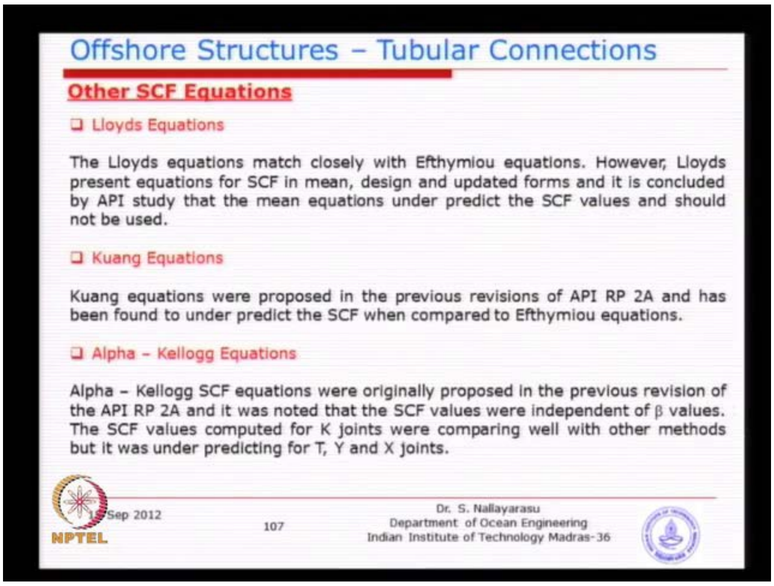

There are other works done by so many other people which are available in the literature, one such is basically the Lloyds equations Lloyds register. I think some of you might have heard of this is a is a company in UK very similar to which is in Norway, American bureau of shipping in US. These agencies private agencies which you know basically regulate the basically registrations of ships originally, but now actually the certifying after installation for Ireland gas purposes Lloyds was originally basically developed for the shipping purpose. Then, they are come in to off shore business, so they have got a historically research division in UK.

They were doing quite a bit of work in 1980s on stress concentration factors, they have come up with this similar equations, but unfortunately there were in the recent studies shows some differences. Similarly, Kuang and other people like alpha Kellogg have done reasonable research in the recent time is like last 15 to 20 years specifically some of the areas where Efthymiou equations are weaker we try to use this equations. In global we normally use an Efthymiou, most of the owners recommend Efthymiou, you questions to be used.

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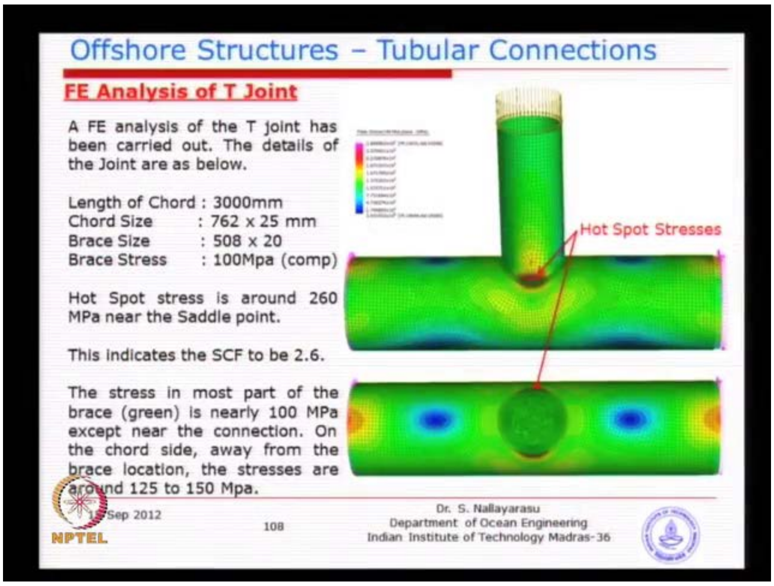

This is a typical joint which you can see from the fixed for a comparison purpose I have just done to different joints k joint and t joint and y joint, just to see how the SCF varies. So, basically you can see here for convenience we have just modeled only up to the smaller portion which now you might have understood because you make the model bigger and bigger, you take several hours to make it, then run it. So, the effect of chord length can be corrected later on as it is the basically simple bending behavior.

So, you see here the length of the chord is taken 3,000 millimeters and the size that given again I have just applied hundred mega Pascal. So, you can see here the stresses in this vicinity is becoming nearly two and a half to 3 times, and you can see symmetric pattern because is the very simple joint t joint pattern of stresses to the blue color is the lowest spot of stress. So, you can see in the top view this side and that side is saddle points have higher stresses and if you just go to the computer and zoom it, basically you will see a stresses slightly away from the interface will be higher. You can even see the similar pattern and the hot side.

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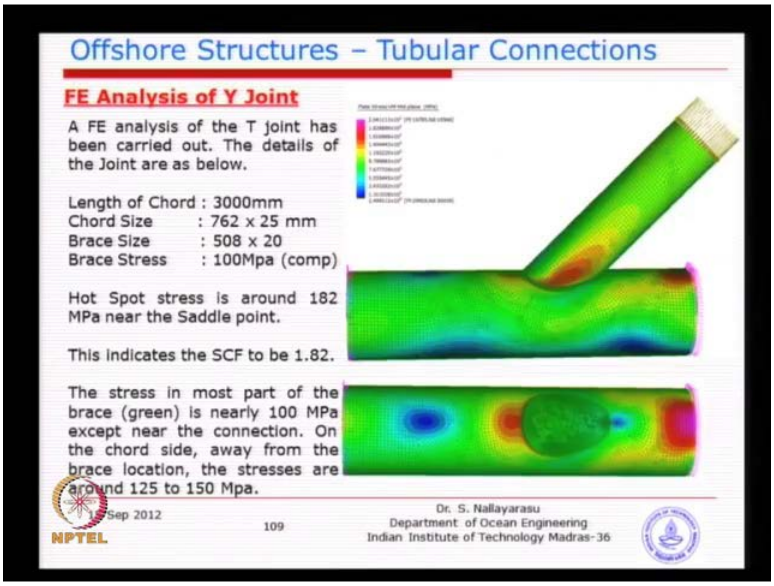

Now, you just look at the same geometric parameters only what has changed is the angle of the braces will change nothing else brace diameter chord diameter wall thickness everything is same only just changed to I think it is 45 degrees. So, you see here the stress concentration has come down to somewhere around 180, now you can see here one important idea is the normal stresses transfer to the chord is the most important parameter.

When it becomes 45 degree, the actual load or when you actually have a same hundred mega Pascal applied as an actual load the brace some of the point horizontal some of the component is normal. So, the normal component only creates more problems because the normal component is trying to vowelize the cell. Whereas the tangential component goes as the actual press to the chord member. So, that is where you can see a very simple idea the more the normal component, you are trying to get the local bending of the chord itself that mean the novelization will happen.

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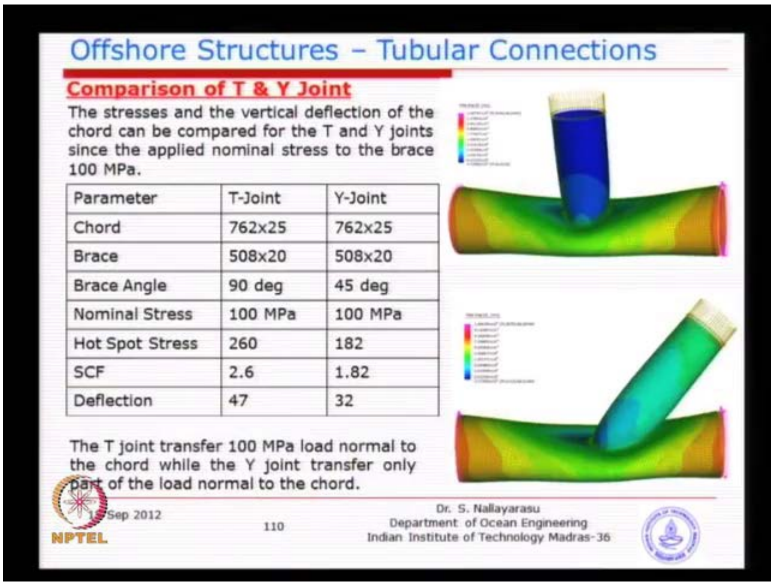

When you actually compare you can see here the deflection for the normal case is 47 mm, whereas the deflection for the y joint is 32 mm. So, you can see the normal component as long as it reduces, you can see here stresses are smaller deflection is smaller and corresponding stress concentration factor is smaller. Basically, this is the deflected safe of the t joint and this is a deflected safe of the y joint, which you can easily realize.

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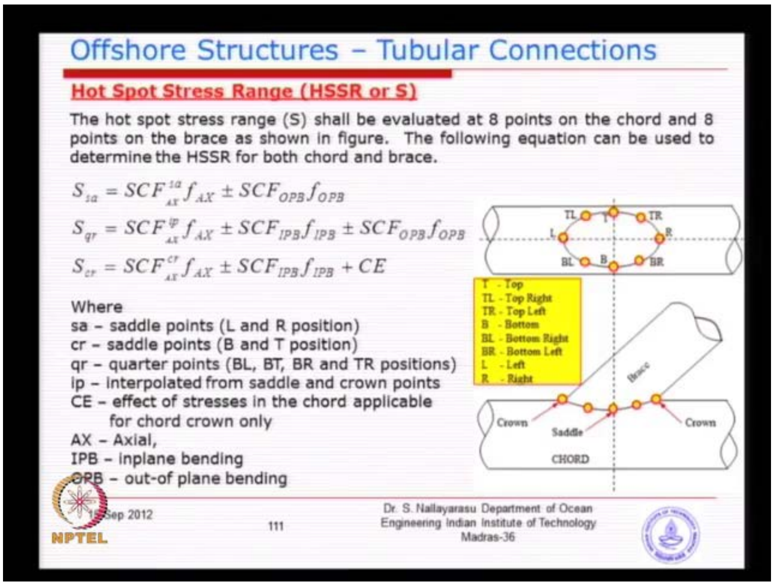

Now, hot spot stress range what we need to find out is basically how we compute we know how to calculate now SCF either by empirical equation or by doing it yourself. Now, you look at this interface, basically the brace and the chord interface I have just identified four points on the orthogonal locations to crowns to saddles, I think all of you are familiar and then four more quarter points because if we look at this picture is important. You also evaluate this diagonal points, maybe we do not know whether they will govern or not.

If it is only a actual load, you know very well that points you know very will only one point is going to be maximum, but if you have a implant bending and you have a out of out of plain binding, what will happen is one of the diagonal point. For example, if there is a moment implant moment is going to create comparison stress, here in addition the actual compression stress. And you have a bending moment in the perpendicular direction on the corner point, this point or any of this is going to combine actual plus bending one and bending two in plane out of plane.

So, that is exactly the idea behind you need to find out the stress concentration on all eight points and whichever gives you the maximum and go on, and start making the design of how do we calculate is a very simple linear arithmetic superposition. So, stress concentration part each of the locations, this is a means saddle c means is croon and basically SA is saddle points left and right position. That means this is l and r and the bottom and top position this is basically bottom left and bottom right and top left and top right.

You can actually identify because you need to remember each point is going to have a different stress concentration factor and corresponding stresses. You will you will take from the analysis and then combined them with a linear superposition. Normally, you might have studied simple circular shape need to take this kind of linear superposition. You can actually take as RSS value square root of bending stress in implants square plus bending stress in out of plane, but because this is an elliptical shape or a rectangular shape. If you get you normally have to find out the actual stresses and have it linearly, so basic idea is you find out on all are eight points.

I have just given only three point that is why I have put plus minus depending on where you are depending on the moment direction moment is in all in one. Basically, this point will get additive the other point will get add or minus, so basically that is the idea behind, so a pi require minimum eight points like what I have shown here to be looked upon when you are doing on fetid design. Unfortunately, what happens is the SCF equation is given by Efthymiou light resistor one and other people they do not give you the SCF for the quarter points, the points which I have identified whether it is BRT, RT, LBL. They do not have a equation for they have only given for saddle point and crooned point brace side chord side.

So, what will we have to be doing is we have two find out the stress concentration factor for the quarter point by a simple linear interpolation that the maximum we can do, you find out the stress concentration factor for this point. We find out the stress concentration factor for that point by looking at this fixed is not a bad idea to do linear interpolation between this and this point to get this stress concentration factor for that point.

That is the practically most of the softwares do the design in that way, because the empirical equations available are given by those past studies have not identified the quarter points does not mean that you will simply ignore. We still have to device a methodology, sometimes if it is a complicated joint you can do a FE analysis. We find out what is the concentration factor for that particular joint because many times fetid analysis, or fetid design is going to be governed by one of this quarter point and that is where the issue is…