**Advanced Marine structures**
**Prof. Dr. SrinivasanChandrasekaran**
**Department of Ocean Engineering**
**Indian Institute of Technology, Madras**

**Lecture - 2**
**Fatigue failure**

So, in the last lecture, we discussed about fatigue and facture. We said that those a construction of a material, are the construction material used for manufacturing a machinery compared that of an.Let us say construction of a marine structure, may be steel material is common. Butstill assessing the fatigue failure and understanding the fatigue damage or designing for a fatigue behavior, will be different in both this cases. Because, though the material is similar inboth the cases, butin the case of machinery, you will know that the stress variation or fluctuations or in a specific state of or state on a specific range. And this is cost by the range of stressesapplied on the material or on the machinery for a given design life. And one can easily estimated to limb, by limiting thestress levels within the endurance limit, whereas this concept cannot be applied to marine structures. Because in marine structures,there is a mixture of different kinds of stresses and fluctuations happening and therefore, one must estimatedin a different manner.

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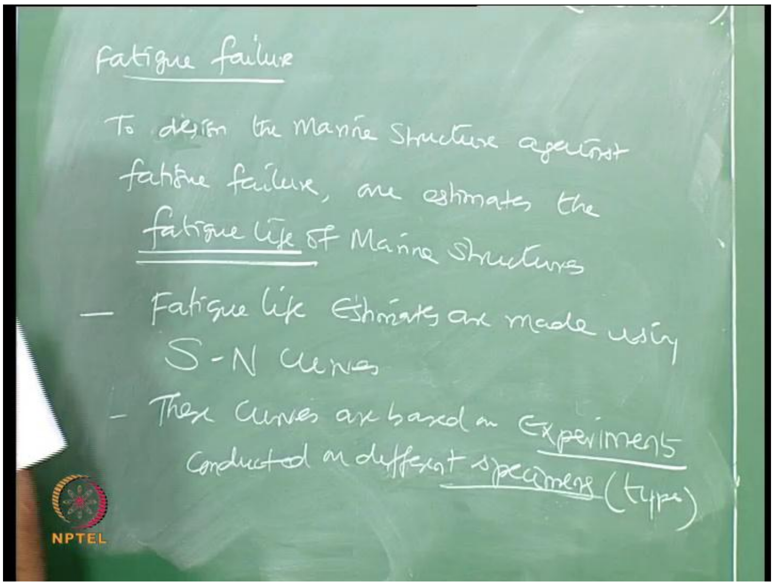

Now,todesignthe marine structure,againstfatigue failureor fatigue damage, oneestimatesthe fatigue lifeof marine structures.So, we estimate fatigue life. Usually,thefatigue life estimates are done,are madeusing S N curves.These curvesare based on experimentsconductedon different specimens.We can even say differenttypes of specimens to be very specific.

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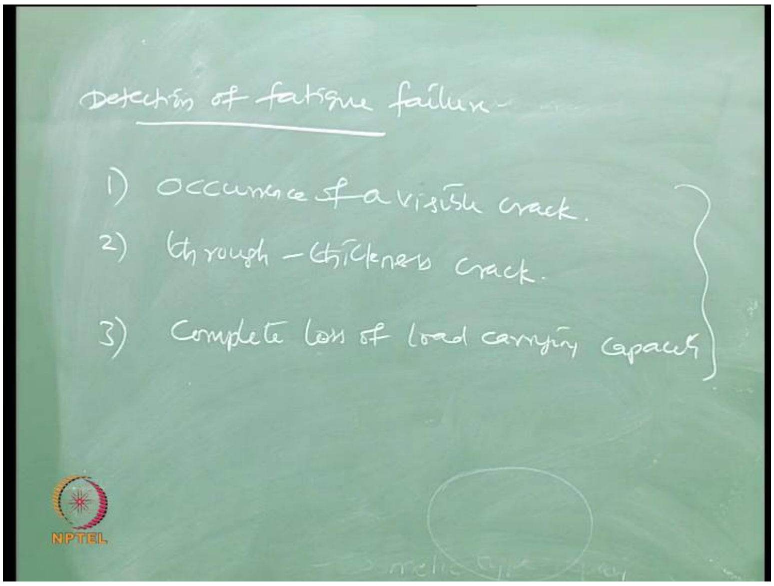


How one can detectfatigue failure?How one can detect that the material or themember of the structure failed to be fatigue? Fatigue failure can be detected by three ways andcan detectfatigue failure by looking observation3 ways. When, you notice an occurrence of avisible crack,when you notice a visible crackor, if you notice througha thickness crack and you notice a complete lossof load carrying capacity.Thenwe can infer that the material or the member or the structure is failed by fatigue. So, these are detections of a fatigue failureof a structural member.

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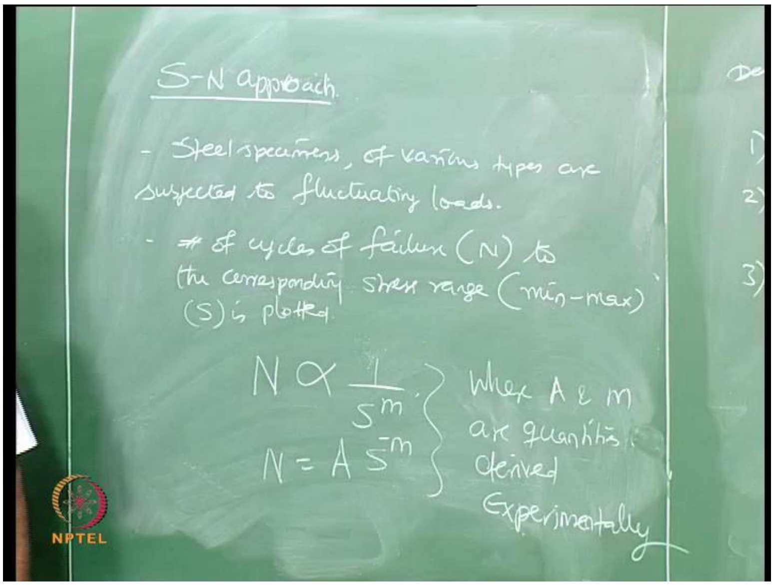


Now, lets us talk about S N approach. S N approach;Steel specimens,of various typesare subjected tofluctuating loadsusually, tensile in nature,number of cyclesof failure,which we call as Nto the corresponding stress range.The moment I say range,I am talking about the values ofminimum to maximum. It is not a specific stresses value,it is a range always, which is called as Sis plotted which we call as a S N curves.So, Nseems to beproportional tosome power of m. So, N isequal to some constant of,so whereA and mare quantitiesderivedexperimentally, supposein marine structures.

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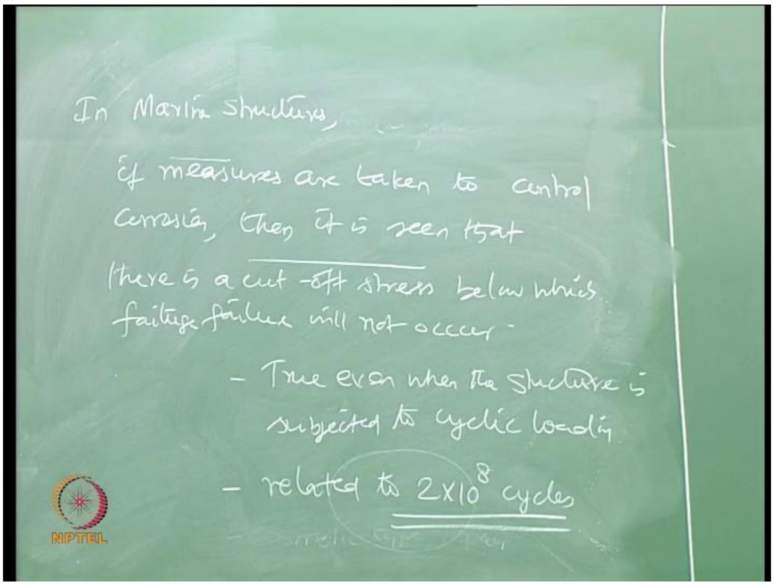

In marine structures,if we take measures to control corrosion.There are many techniques by which control corrosion can be controlled. If I adopt, all those measures to control corrosionin a marine structure. Thenit is seen that,there is a cut off stressbelow whichfatigue failure will not occur,this is true even whenthe structureis subjected tocyclic load.And that cut off stressis related to2 into 10power8 cycles.So, that cut off stress corresponding to 210 power 8 cycles in a same curve is the threshold value.

If you are able toemployee a measures to control corrosion and the stress level is below. This, which is corresponding to 10210 power 8 cycles, then fatigue failure will not be initiated in marine structures.So, the stress level should be kept to that cut off valueand that corresponds to 210 power 8 cycles in a; in a same curve. This is true, only when measures to control corrosion are adapted, without that it is not correct.If you are able to do that, then this is the value.

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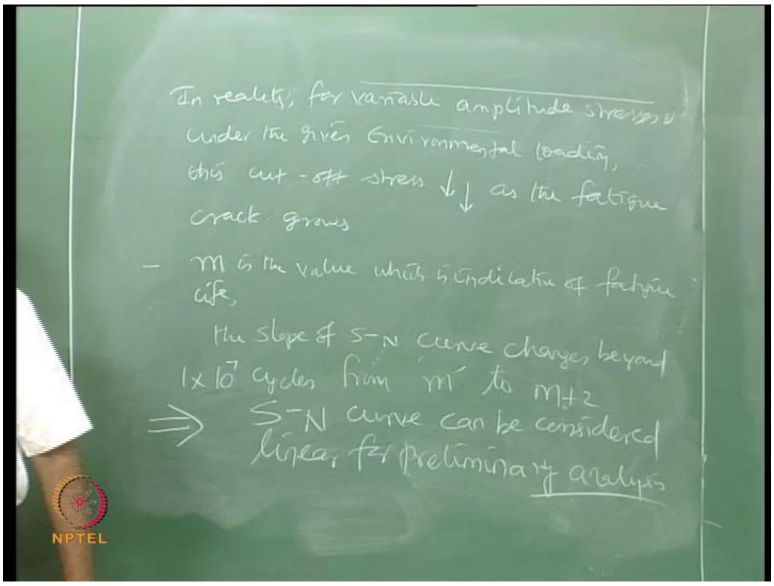


Now, in realityfor variable amplitudestresses andunder the givenenvironmental loading,this cut off stressdecreases,asthe fatigue crackgrows.So,there will be reduction in this stress carrying capacity, or a stress range capacity, when they are subjected to real environmental loading. And it is subjected to variable amplitude stresses.Interestingly,as m is thevalue,which is indicativeoffatigue life, the slope of the S N curve,actually changes,beyond10 power 7 cyclesfrom mto m plus2,the slope changes,what does it mean is that.The S N curve can be considered.Linearforpreliminary analysis,it changes only beyond a specific number of cycles. Until, than it remains the straightline. So, it can be consider as linear.

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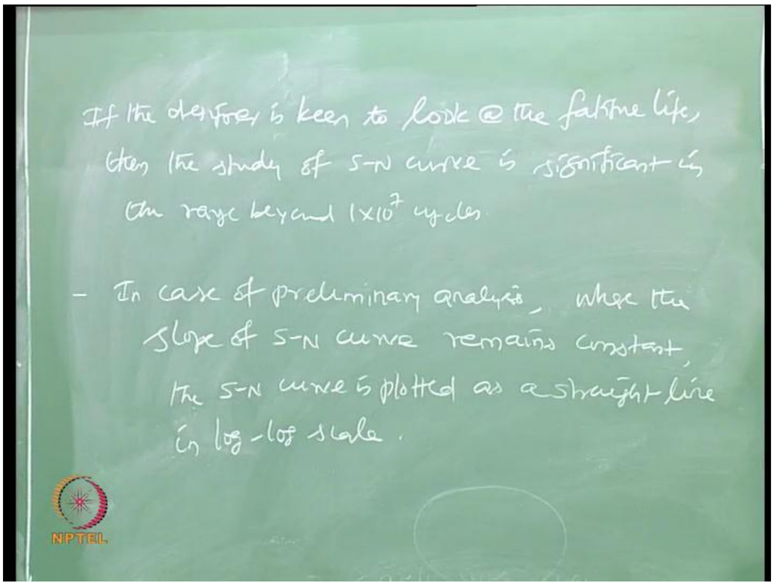


If the designer is interested,look at the fatigue life,than the studyof S N curveis significant.Inthe rangebeyond,10power 7 cycles. Now let us look at in case of preliminary analysis,wherethe slope of the S N curve remains constant, that is what they have said here. The S N curve is plotted as straight line.

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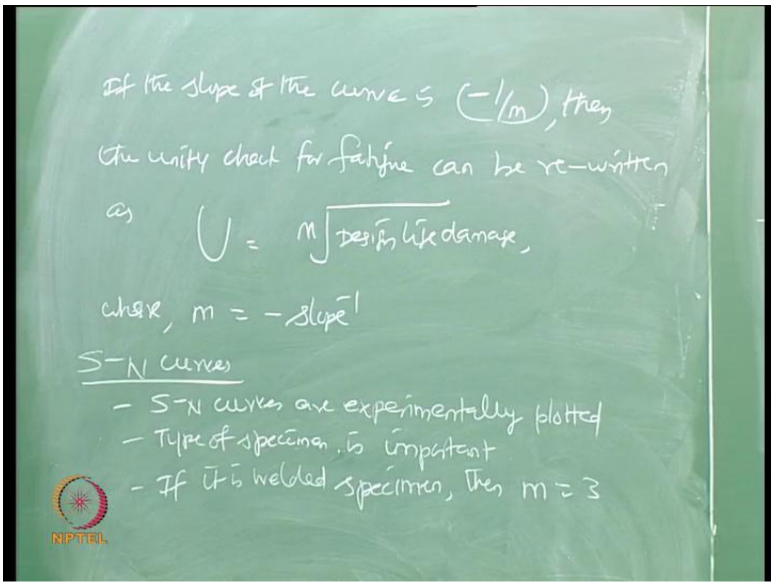

In a log  scale, slope of the curveis minus 1 by m.Then the unity checkfor fatiguecan bere written asUmth powerdesigned life damage, where,m is minus of slope inverse,in this equation. If the slope is corrected to be S minus 1 by m.now, let us look more about the S N curves. Before you plot one and show how they look like. S N curves are experimentally plotted.That is the first observation, which we must know.In the type of specimen, which is used to plotis important, because this can also govern the slopeof the S N curve.For example, ifit is a welded structure,than m is 3.

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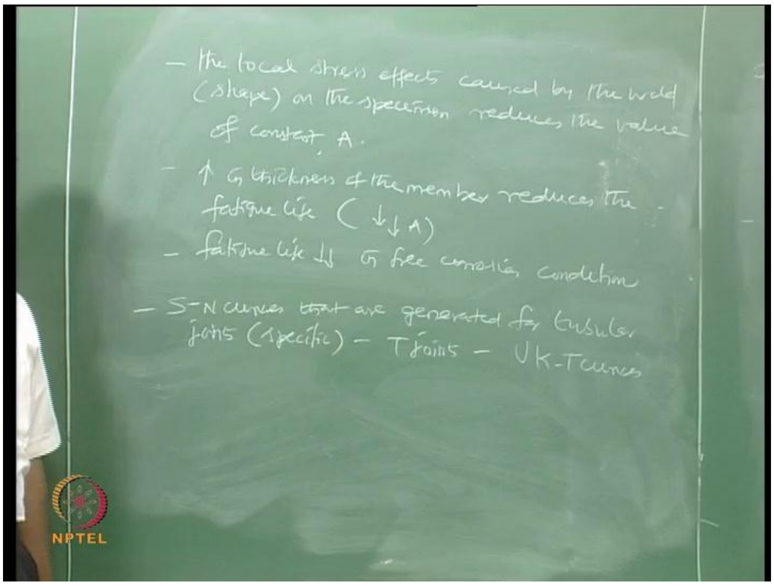


Now, interestinglythe local stress effectscausedby the weld or I should say by the shape of the weld on the specimenreducesthe value of constant A.A is a constant.We saw in the equation earlier. Next point is increase in thicknessof the memberalso effects S N curve. It reduces the fatigue life,that is it reduces a significantly. The value of A, A is a constant. And as we all know fatigue life is decreasedin free corrosion condition.Many international codes are focused S N curves to be very specific on tubular joints, because as you know S N curves are influenced by the type of specimen, and they have also influenced by the shape of the weld. So, there are specific curves generated by conducting experiment on T joint or tubular joints. So, there are S N curvesthat are generated fortubular joints very specifically,especially forT joint. For example, one can look at, what we call as UKT curves. A typical T curve or UK T curve looks like this.

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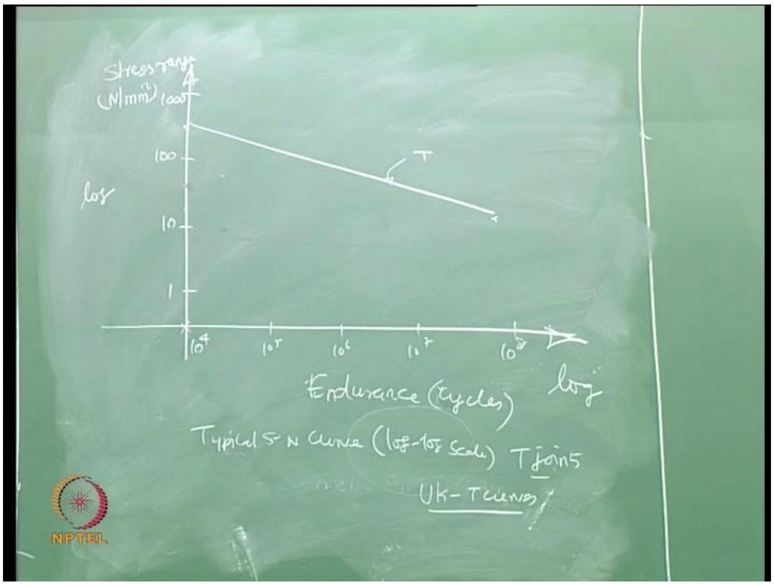


So, log log scale is also log scale. This is also a log scale. So,let ussay this value is 10power of 4.Let us say, this is 10 power 8567110100. Let us say 1000,so typical curve 40 joints,so typical curve.So,typical S N curveplotted on a log log scale,which is forT joints source UK T curves.

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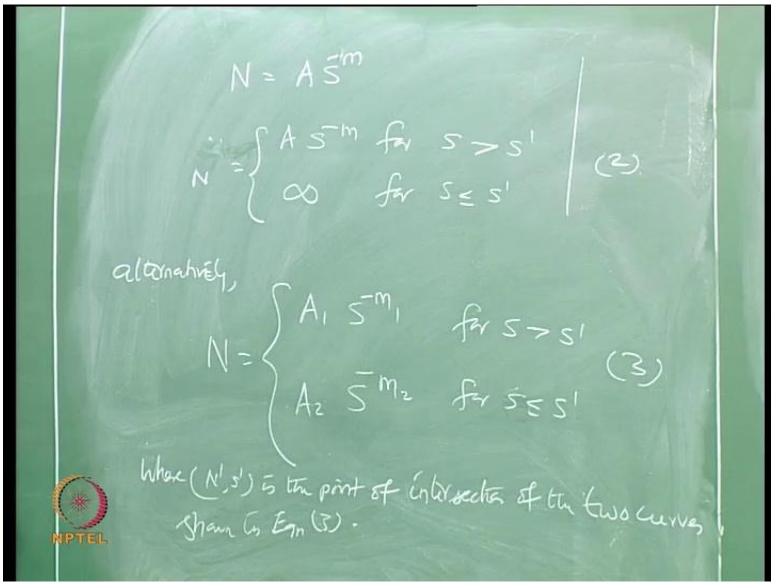


So, we known that, N isequal to AS power minus m, N also beAS power minus mfor S greater than S dash,which is equal to infinity for S less than S dash. Let us see equation number 2.Alternatively,N can be also written asA 1Sm 1 or A2 m 2 for S greater than S dash.For Sless than equal to S dash.WhereN dash S dashis the point of the intersectionof the 2 curvesshown in equation 23,we can also.

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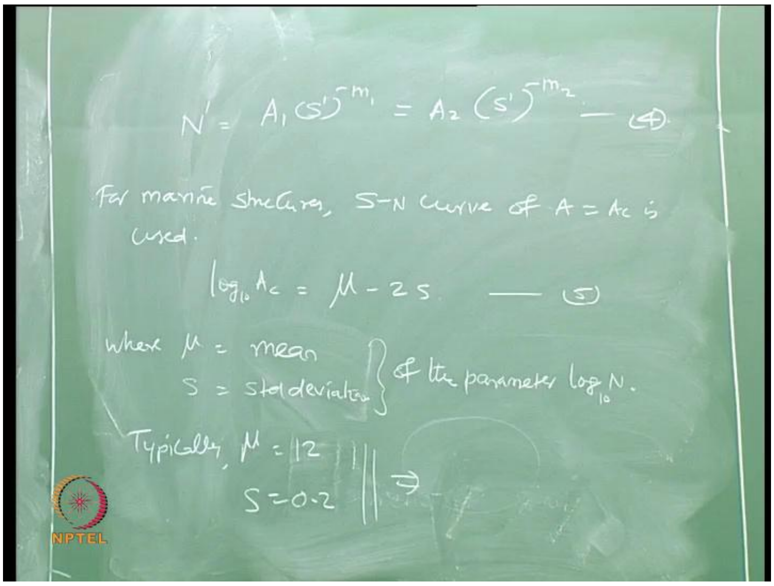


WriteN dash can beA1S dash minus m 1.That is also equal to A2 S dash minus m 2. For marine structures,your common equation, which defines S N curveof A equal A c is used.Whereas the equation connects A cis given by,where mu is the standard deviation, sorry mean.And S is the standard deviationof parameter log N2 the base 10,typicallymu is12and S is 0.2,which gives me.

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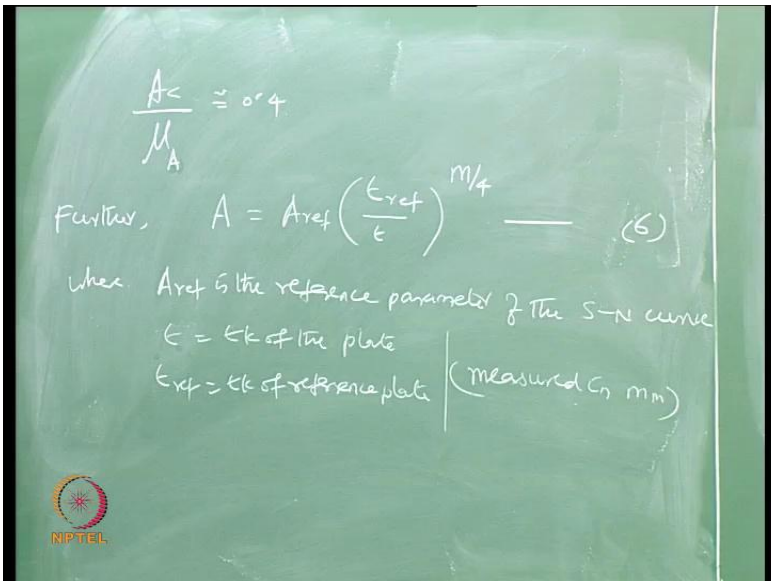

A c by mu A is it not, mu A, that is deviation of ofa is approximately 0.4.Further,we already know that A is influenced by the thickness of the material of the member.Therefore, Ais also given by a reference t reference by t raise to the power ofm by 4,equation number6.WhereA referenceis the reference parameterof the S N curve. Tis the thickness of the plate,which is being used for study. And T referenceis thickness of the reference plate based on which S N curve is plotted both of them are measured in millimeters.

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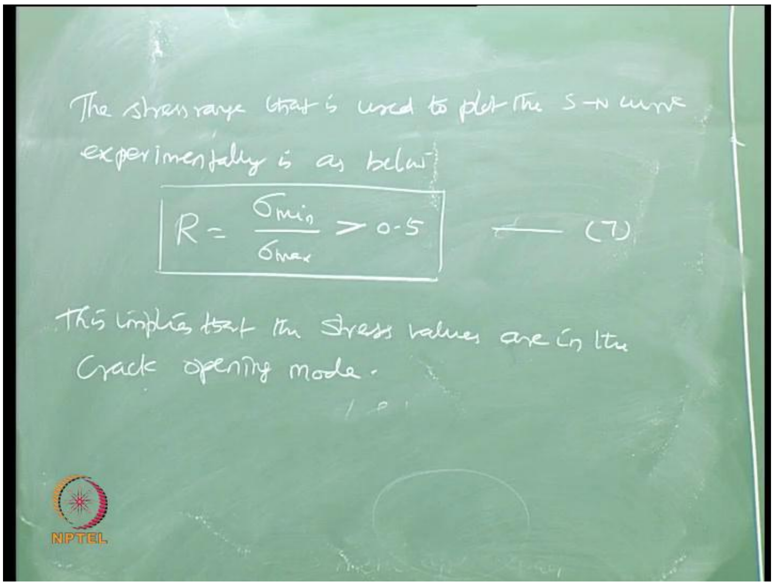


Now, we already said that, S N curvesare experimentally generated or plottedon different types of specimenfor a specific stress range.So, the stress rangethat is usedto plot the S N curveexperimentallyis as below.R is the range which isstress min to stress max, which is greater than 0.5,that is the stress rangewe has been usedgenerally to plot S N curves.This implies thatthe stress valuesare in the crackopening mod having understood that the stress strain or say S N curves are plotted experimentally, shape of the specimen, type of the specimen, shape of the weld, thickness of the reference member, all influences S N curve then.

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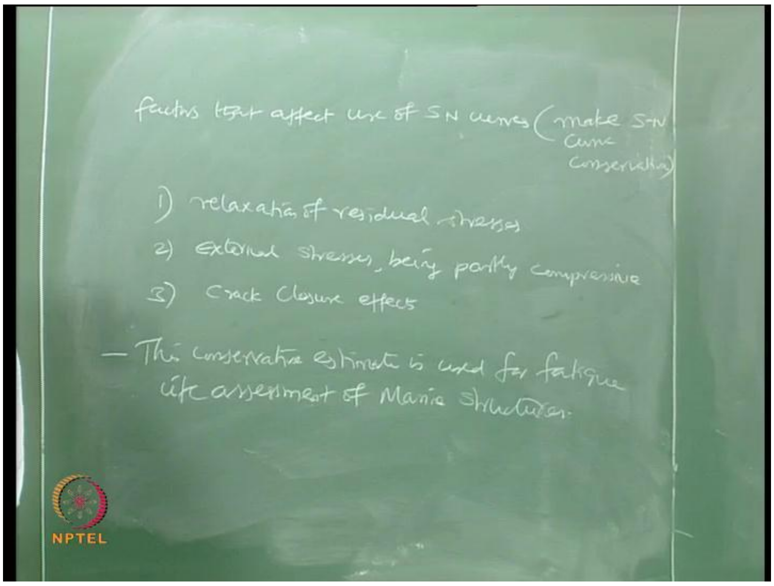


Let us quickly see, what are the factorsthat affect use of S N curves?Are the factors which makes, the factors that make S N curves conservative, I mean safe, the for most factor isrelaxation of residual stresses. That is the first factor which makes S N curves plotted as conservative gotS.The second one is external stresses being partly compressive. See whenever a crack is formed of propagated us initiated. Let us say, if I apply for that tensile stresses, there is a probability that the crack will get propagated or extended or expanded.When you apply a partially compressive stress rate, there is a possibility that the propagation of cracks will not be as fast as that of tensile stress.

In reality, if you see this always reversalof forces.So,the stress does not remain always tensile, it can also become compressive.Therefore, S N curves which are plotted based on stress ranges purely tensile will become conservative stresses.The third point,which is addressing the crackcloser effects,there can be some parameters, which can influence the closing of crack also, which is completely ignore, because the stress range which our construing in S N curves plots, or essentially on the crack opening modes.

So, you are compulsory casting range of stress, which results in opening of cracks. Butin reality, there can be a possibility that closer effect cracks can be there, which we do not consider in the experimentalmanner of plotting S N curves.Therefore, if use S N curves, to find out the fatigue life for a given stress range, how many number of cycles the structure can withstand. The values what you get form the conventional S N curve given in the code will become a conservative estimate. And therefore, this conservative estimateis used for fatigue life assessmentof marine structures.

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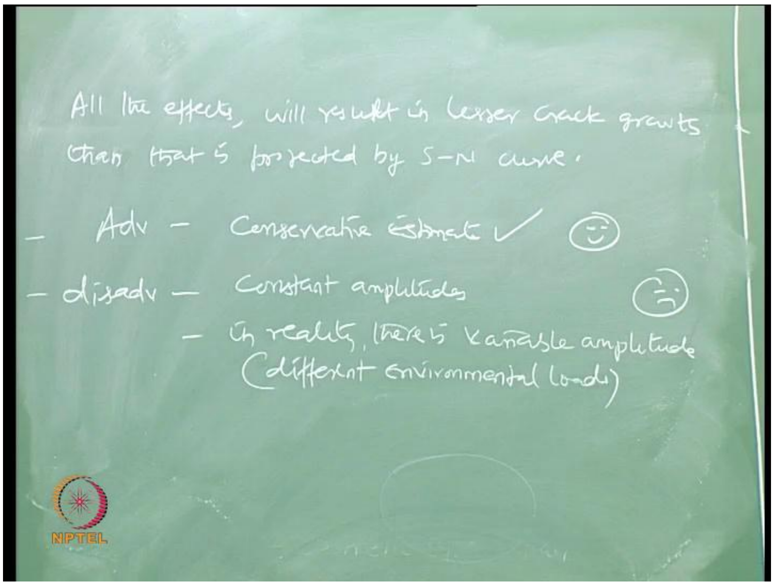


So, all this effects;all this effects will result inlesser crack growth, thanthat is projectedby a conventional S N curve.So, all S N curves are generally considered to be conservative estimates.Now, there are some, specific problem associated with S N curve. One advantage, S N curve haves is,it is in conservative estimate.That is good, the other disadvantage what we have is. S N curves are generally plotted forconstant amplitude. Butin reality,there is variable amplitudewhich is essentially caused by different environmental loads,so that is a demerit.Now, how to handle this issueminus rulehave been applied is a correction to the S N curve that is a last topic what we will discuss today in this lecture.

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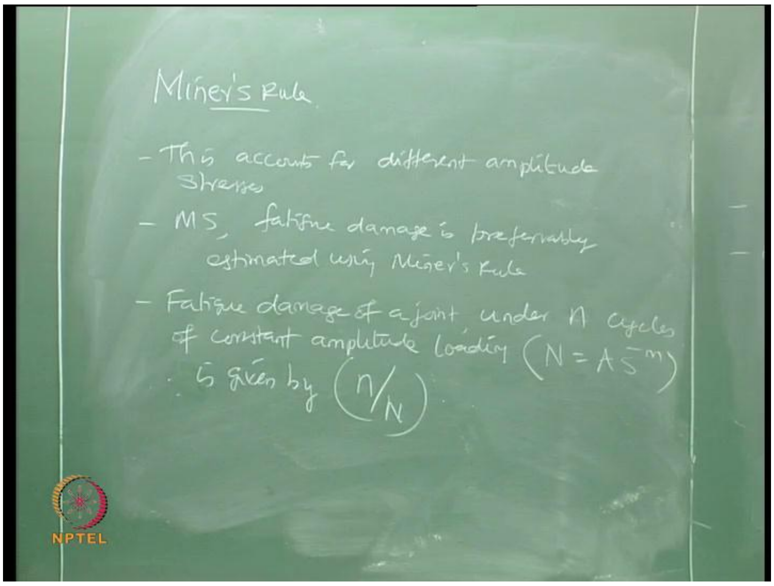


So, there is something called a miners rule,which is apply as a correction factor to the estimate of time from S N curves. So,this accounts fordifferentamplitude stresses which conventional S N curve does not.Therefore, for marine structures, fatigue damageis preferably estimatedusing miners rule. Let us see, what is a miners rule? If you looking for fatigue damage of a joint,under N cycles of constant amplitude loading, which could beN is equal to A S minus m.That is the estimate we already know the S N curve estimate based on this equation. Where m is the or minus 1 by m is the slope of the curve. So, the fatigue damage of a joint and the N cycles of constant amplitude loading which can be given by this equation for.Let us put it as small n here, is given bysimply n by N.

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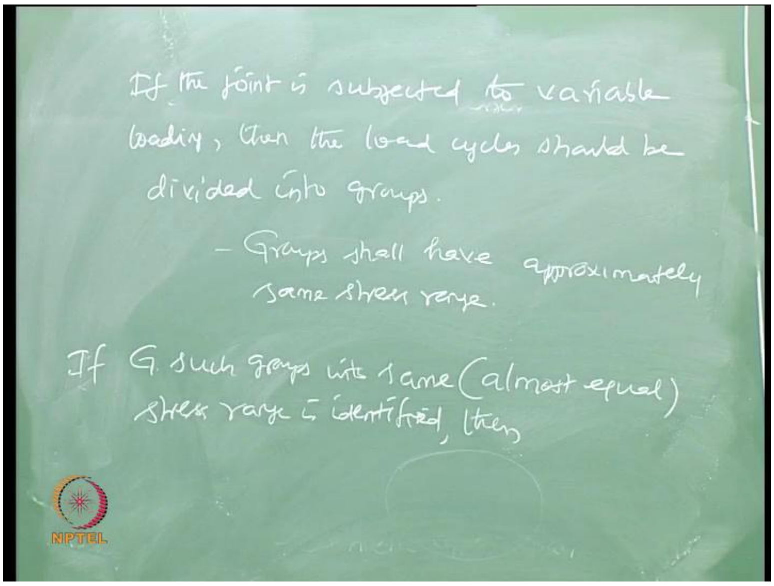


If the joint is subjected to variable loading,as the case of marine structures under environmental loads, then the loads cyclesshould be divided into groups.These groupsshall haveapproximately,same stress range. If that is the case, ifGsuch groupswith same or almost equalstress rangeis identified, then.

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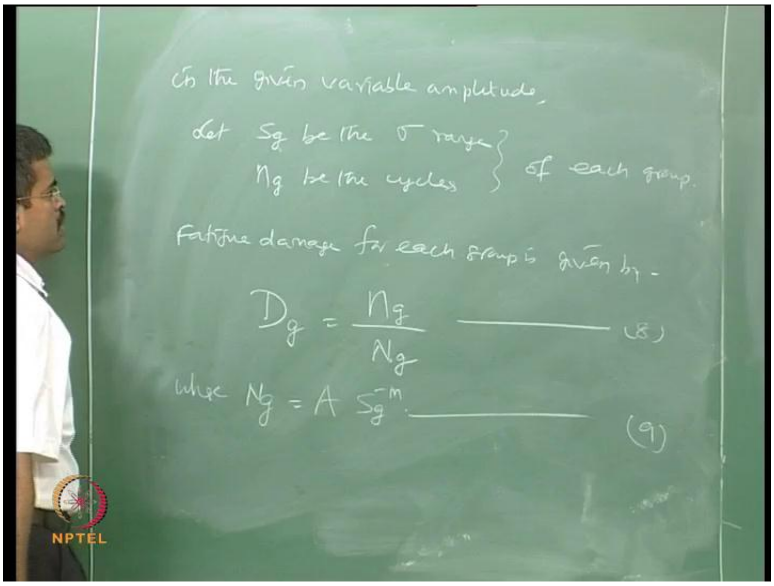


In the givenvariable amplitude,let S g be the stress range.And n gbe the cyclesof each groupsfatigue damage.For each groupis given byD of each groupis simply n gby N g. Where, what is equation number here fine wherewhat is that?8sir,8,where n gis AS g minus m and I calls this equation number 9.So, you have got g's as groups.Each group you knowthe stress range s g and the number of cycles for the stress range n g. So, for each group the fatigue damage is simply with this number. ButI want to find the fatigue damage of the whole structure or the member for submitted tovery well amplitude in that case.

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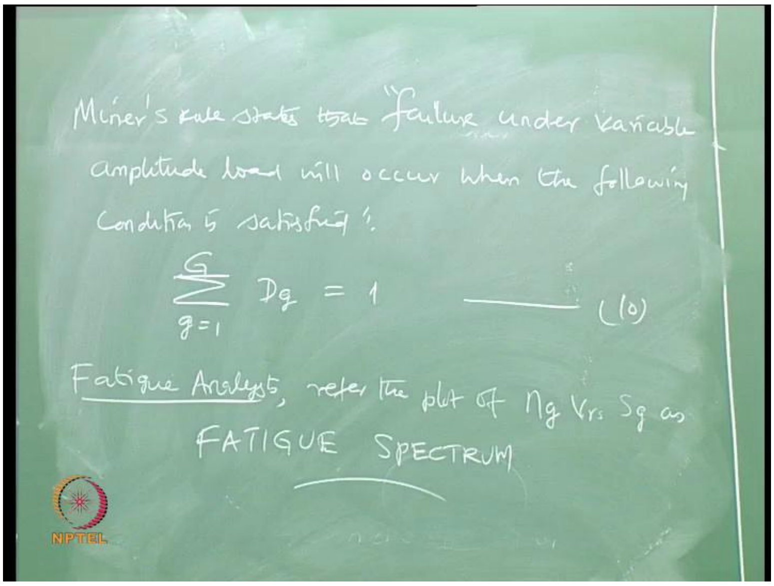


Minersrule states that failure and the variable amplitude loadwill occur.When, the following conditionis satisfied.The condition isnow interestingly,the fatigue analystsrefer,the plot of n g verses s gas fatigue spectrum. So, in this lecture, we have understood that, how the fatigue assessment or the fatigue failure on marine structure can be estimated. Why S N curves from a very major part in estimating the fatigue life of a marine structure, even though; marine structure can be constructed which steel is a material, which is similarly, to that of missionary where indolence limit is always consider as one of the criteria to find of the cut of stresses.

Because here the main componentis, the stress variation range is very large.And we are getting mixture of small and large amplitude low defects on the members. Whereas in the other cases in missionary. This kind of variety of amplitude variation does not occur. So, S N curves play a very important role.In estimating the fatigue life say estimate the S N curves remains linear up to a specific number of cycles, which has been seen by experimental experiments conducted on test specimens.

And we have also seen, what are the factor with that influence S N curves formation. And if a marine structure is controlled under corrosion, or against corrosion. Than one can say that, the stress range correspond a specific number of cycles, if the stress range is not reached or not exceeded. Let us say, then the fatigue damage will not be cost to the marine structure. However, when the variety of combination of loads and variation or variable in this loads occur are load effects occuron marine structures. The constants which form a part of the S N curves, which remains linear of to a specific value or 10 power 7 cycles, where the slop changes from m to m plus 2.

As it is been seen in experiments, the constants A and m the slop and the constant get seriously affected by variety of parameters.Two important parameters could be thickness of the member or the material, which you are assessing. And other could be even the shape of the weld. Therefore, S N curves can be used only as a pulmonary analysis of fatigue failure or fatigue damage or essentially to estimate fatigue life. Butin reality in marine structures, we have got composition or mixture of variables of load effects, whereas S N curves are plotted on a specific manner on type of specimen.Where, essentially the forces are remaining as tensile stresses. Buthere we have got other information’s, where the stresses can be compressive as well and as a mixture.

So, the S N curve conventionally available, though they remain conservative, cannot be applicable to marine structures.Therefore, minus rule is an modification on S N curves, which is applied for estimating fatigue life of marine structures. Man; marines rule say that yougrouped, the stress range and the corresponding number of cycles of each group, separately from a given stress history or stress range time history. And for the each group estimate the fatigue damage. By this equation, if you really wanted to know. What is the fatigue damage of the entire structure, which is having different group of such groups than you have to fulfill this condition?If this comes to around one are closer to one it is showed that the groups of the stress ranges will result in fatigue damage of the member.

In the next lecture, we will talk about the fatigue assessment, on time history scale as well as frequency response in the next lecture. That will be our focus on the following lecture. Do you have any questions here, in this lecture?The experimentscannot match in the real time, buthereexperiments.Yes, you meant to say, why it is so.I repeat again the same explanation, what I gave as you correctly said. Yes, the experiments conducted on the lab scale to estimate fatigue damage cannot map exactly the behavior and the environmental loads on real time structures. Agreed, but S N curves are done under control environment, experimentally on varies types of specimen only to estimate the preliminary damage or the preliminary fatigue life of a given member.

So, only you to estimate the preliminary fatigue life, one can use S N curves as a design phenomenon.If you really wanted to look at, the fatigue estimate on the design prediction of the structure into cyclic loading. One should look for the non-linear component of the variations of slopes components in S N curves. Where the S N curves does not remain on the same slope, are will not acquire the same slope.So, in the lab scale the experiment conducted to estimate S N curves cannot directly map the behavior and reality. Butstill to a greater agreement, international codes to recommend fatigue life estimates based on S N curves.

Thank you.