**Risk and Reliability of offshore structures**
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**Module – 01**
**Lecture – 13**
**Modeling of environmental loads**

Welcome to the 13th lecture on module 1 on the course title Risk and Reliability of offshore structures.

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We are talking about lectures and module 1, which is focusing on probability theory and possible reasoning. Today we will discuss about lecture 13 which is focusing on modeling of environmental loads. In the last lecture, we discussed about variety of classification of loads, which is permanent loads or P class loads, L class loads, environmental loads, deformation loads and accidental loads. These are all different class of loads. We already said those some of the class of loads which can be computed accurately that can act on a given system.

However, there are some degrees of uncertainties associated in computing on class of loads. So, the uncertainties associated with estimation of class of loads can be handled or addressed using characteristic value as recommended by the design course.

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When you are talking about the characteristic value of these kinds of loads, such as already said there, one should go for the maximum value, so that uncertainty associated with these kind of variables which are input further reliability analysis can be handled in the nice manner. So, their probability of failure resulting from exceed of these loads of variables will also be estimated fairly to high degree of accuracy.

Environmental loads that act on offshore structures can be classified as P class, L class, G class, E class and A class as you see here. So, there are different uncertainties associated with them. Let us see, what are those factors which lead to these uncertainties? Why we cannot compute these classes of loads accurately? So, the factors associated with the uncertainties, let us talk about this firstly, variability within material quality with respect to the strength and other engineering properties like sub velocity area of cross section is one important variable. So, one important variable is the variability of material strength and engineering properties within the material quality, so that is one uncertainty.

Secondly, there can be variability's in geometric properties of the components say, variability in geometric properties of the components of the system are to be very precise. We can say members of the structure which arise during the fabrication process we know welding is one such process which induces hot spot stresses. So, interestingly these variations can also be one of the reasons which result in uncertainties which cause which prevent the accurate estimate of different class of loads. The next point which contributes uncertainty is one which arises from the change of load with respect to the C state. So, change of loads with respect to C states and operational conditions that is another variation we have.

The next one comes from the ideally of real structure into a model for analysis for doing analytical or numerical studies. We idealize the real structure into a mathematical model. So, idealization of the real structure into mathematical model or numeric model for analysis that is another way measure issue, where we come across uncertainties the set. The next one can be which arise from the numerical and analytical computations itself, errors that arise from numerical and analytical computation.

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The next important item which contributes as a factor for uncertainty is quality of workmanship and lastly and most importantly there is a degradation of strength. I should say both the member and the structure due to aging effect corrosion, etcetera.

Now, the question comes there are many factors listed on the black board here, which contribute to uncertainties or presence of uncertainty in estimating the load class or input data which is necessary for reliability analysis. There is one more main issue which we have to again focus based on which the environmental loads or the E class loads are actually defined as a given input to the system. This is what we call as return period, let us talk about return period for few minutes. Environmental loads are associated with one of the main uncertainty that arise from its re occurrence with a similar magnitude within the service life of the structure.

So, we are talking about a major issue here. The major issue is re-occurrence of the load with the same or to be very precise similar magnitude within the service life of the structure. Offshore structures are very sensitive to this data because this is very vital in assigning the design loads to the given system. So, it is very vital you have to specify this very clearly because this will govern the assignment of design loads to the given system especially in analysis in design of offshore structures. Therefore, one is bother about a combination of different events as I said in the previous lecture, we are talking about different class of environmental loads may be arising from waves which arise from wind which arise from earthquake, etcetera.

All these events may be defined, but different phenomena either by nature or we by manmade disasters; obviously, the occurrence of a specific magnitude of interest within the service period of the structure for that of a wave or wind or earthquake may not be same. If I say RT is a return period, let us say of earthquake, it may not be same as that of return period of the wave, it may not be same as that of return period of the wind, but unfortunately we have to realize that environmental load or E class load, what you see in offshore structures which is one of the important input for reliability analysis is a combination of these kinds of forces.

We do not study only wave loads or only wind load or only earthquake loads because in nature they are all present in a combined form. It means you cannot have an offshore structure existence without the presence of wave and wind; you rather should design an offshore structure as an inherent system which can sustain design basis earthquake that is a design guideline given by many international courses. Therefore, one cannot think about these events in isolation. So, I have to now look for what is call mean return period.

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Mean return period is expected value or the expected number of years between which seasonal maximum is like I talk of is the expected number of years between which a given seasonal maximum is likely talk of. So, the keyboard may be the expected, it is a guess maximum within the service period is likely talk this is a likelihood say, for example, if the return period is 50 years, what it physically mean, it means that the characteristic load, why I am saying characteristic, the moment I use characteristic I am covering the uncertainty in estimating this load.

So, the characteristic load is expected to occur only once in fifties. So, one can have a question is a designer that the service lay of offshore structure is only let us say 25 years then why should I bother about an event which is going to occur only once in 50 years because this period is much longer or larger than that of design period of the structure. Here a gentleman is very important to realize that that fiftieth year, where this event is going to reoccur can be the current year where your structure is design. So, why not sure when this will reoccur, but we are only sure that it will reoccur only once in the period, but we re do not know which is that year exactly will occur we would fall within service period of the structure we do not know.

Now, instead of looking at the return period, let us talk about the inverse of this. There is more interesting let us talk about the inverse of the return period.

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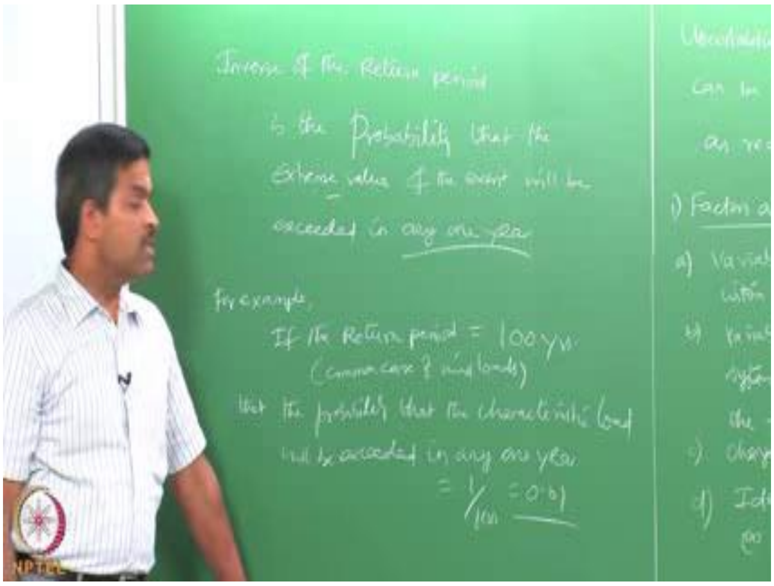


Inverse of the return period is the probability that the extreme value, why I am saying extreme value because you please see the definition of return period it is the seasonal maximum. So, I can always use in equivalent word extreme. So, inverse of the return period will be the probability that the extreme value of the event will be exceeded in any 1 year, this is the clue, and this is where we are interested.

Let us see, for example, if the return period of any event is 100 years, one can say why it is so high? This is very classical example because this is a very common case of wind loads as advocated by many design courses. So, if I know the return period of the wind load as an event which is 100 years then I can say that the probability that the characteristic load will be exceeded in any 1 year will be equal to 1 by 100 which is 0.01.

So, what does it mean? It means that there is a probability that the maximum or the extreme value of that event will be exceeded in any 1 year is only a vote 1 percent that is 0.01. So, ninety nine percent there is a guaranty that this extreme value event what you consider as a return period with that of the wind load event will not exceed in any 1 year of a design you understand now we are trying to connect the probabilistic exceed of this value with that of its return period, but the design is not happy with this I will come to know, I will come to explain you what actually designer wants as a designer.

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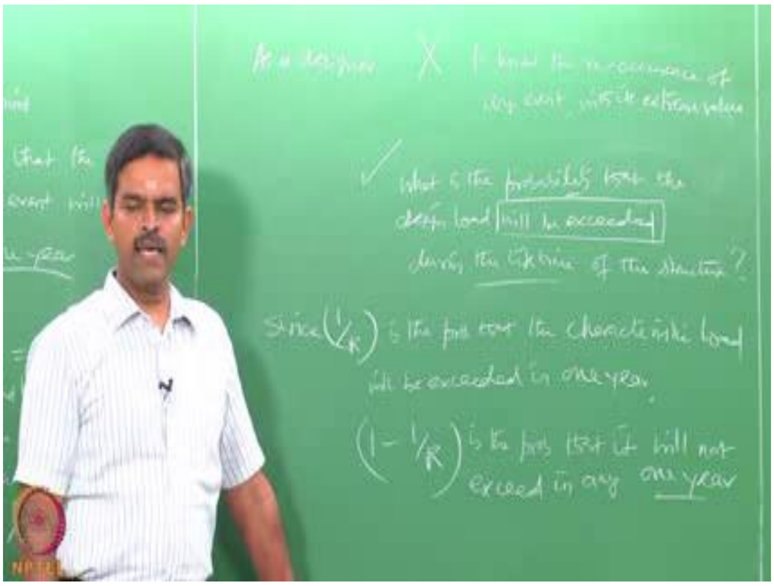


One may not be interested to know the reoccurrence of any event which is extreme value, one is not interested to know the reoccurrence of any event with is extreme value, then what is he interested in? He is interested to know, what is the probability that the design load will be exceeded during the life time of the structure? So, he will be interested to know, what is the probability that this will be exceeded during the life time of the structure? Now, how to estimate this, since 1 by r is the probability that the characteristic load will be exceed in 1 year, 1 minus 1 by r will be the probability that it will not exceed in any 1 year. Let us say, the life of the structure is denoted to be 0 letter n, let n denotes life time of the structure.

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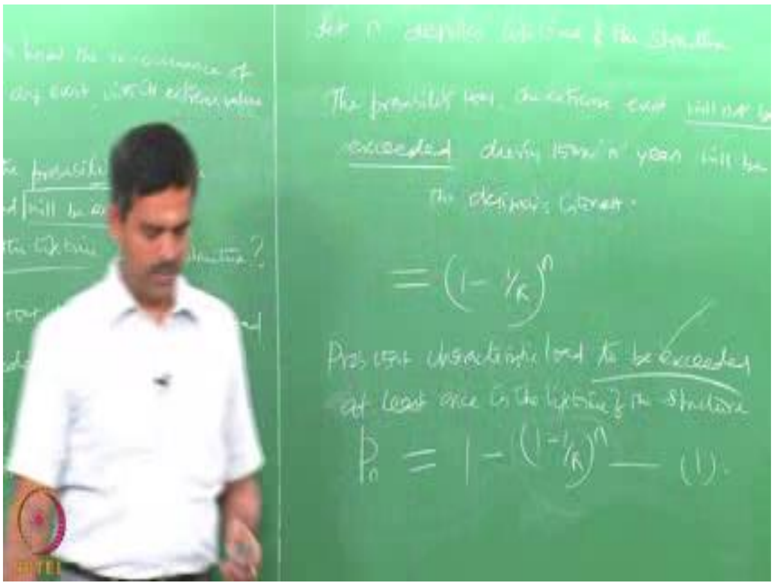

So, the probability that the extreme event will not be exceeded during those n years because that is the interest of the designer will be the designer’s interest.

So, this can be easily given by 1 minus 1 by r to the power n therefore, probability that characteristic load to be exceeded at least once in the life time of the structure is given by p n 1 minus 1 minus 1 by r because you have already seen this value is non-exceedance, but now I am looking for the probability of exceedance. So, 1 minus 1 by r to the power n, return period can be connected to probability of exceedance and further connected to the life time of the structure is in this equation, if we call the equation 1, let us say return period of a structure I mean for which an event is designed is 50 years of any event.

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So, the characteristic load whose return period is 50 is known to us and let the life time the structure be 20 years which is very common in case of offshore structures because the oil reserve which use for exploration does not be consistent beyond a period of above 25 years. So, therefore, we say the service life of an offshore platform can be approximately equal to above 20 years. So, what is the designers interest the designers interest is probability that this design load whose characteristic values known is exceeded because you should design it for exceedance at least once during the 20 years, why 20 years because of the service reverse structure is given by p 21 minus 1 minus 1 by 50 raise to the power 20, you can calculate this becomes 0.33.

So, ladies and gentlemen look at this particular example and event whose characteristic value will not exceed or will not reoccur, or it will occur only once in 50 years of the same magnitude even though a service period of the structure is much lower than this the probability of this value being exceeded during a service life is about 33 percent. So, therefore, you have to address this kind of uncertainty very carefully as an input data for reliability analysis, if you are not able to account for this uncertainty in the input variable for reliability analysis of offshore structures your probability of failure of the given structure and of the given load combination system will not be accurate.

So, you may not be happy knowing that event, whose certain period is far away from that of my life time structure because there is always a probability of exceedance of this at least once within 20 years is about very high number. So, one has to account for these uncertainty in the analysis for sure when you especially do estimate of probability of failure. Therefore, it is clear from this illustrated example that there is a chance that the design load exceedance from its characteristic value at least by 33 percent, once within the life time of the structure as a designer. This is quite important as this percent is phenomenally high for reasonable estimate of the sited example therefore, how there accounted in the design people use what is call safety factors. So, this is addressed or this complexity is addressed by using what we call safety factors in the design.

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However different course address this safety factor by using a term call partial safety factor, why it is called partial because this does not account for all uncertainties which are associated with this safety factor because even calibrate safety factory itself has got mathematically uncertainties.

So, you can look at this as the reference Srinivasan Chandrasekaran, my own book on Advance Offshore structures reference indicated as 2015, see in the NPTEL website do not. So, look at Marshall, 1976, you can also look at Pasman et al 2009. So, there are various researchers who have illustrated, why the safety factors still cannot account for all uncertainties accurately, but here we leave a note saying that is very alarming that the exceedance of probability of any specific given is very high in number for a given chosen example, which is very common application for offshore structures. Therefore, one should account for this uncertainty by using what is called safety factor in the design advocated by many international courses for design of offshore structures.

Having said this, let us talk about one more important characteristic which is estimate of distribution parameters. So, we already said for doing reliability analysis you need have a data which you call n symbol or the input value. The input value generally can be a random number or random generated simulations numbers they should follow or they should obey or there should closely adhere to a specific kind of distribution whose probability density function is known to us because it becomes easy from me to estimate the distribution parameters.

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So, let us talk about the estimate of distribution parameters, probability distributions are vital part of statistics there are very few practical applications of this. Let us say, probability distribution has few vital applications, one; they are required to compute the confidence interval for parameters, two; they are also required to calculate the critical regions for hypothesis test.

For a univariate data, it is often useful to determine a reasonable distribution model for the data whereas, the statistical intervals on hypothesis test or often based on specific assumptions of the type of distribution that shell follow. So, therefore, before computing in interval is the test based on this assumption, one should verify the justification of the assumption for the given data set. This does not mean that the distribution needs to be the best fitting distribution for the chosen or for the given data, but it is very important to know an adequate enough models should be assume, so that the statistical technique is valued conclusions, for example, if a set of data follows a normal distribution, if your distribution assume the analysis does not obey a normal distribution the conclusions derived from the analysis may not be completely value. It is therefore, important to use the simulation studies with random numbers that are generated using a specific probability distribution.

There are various methods both numerical and graphical for estimating the parameters of a given probability distribution. Let us see quickly what are they? So, we are now talking about methods which are useful for estimating the parameters of a probability distribution method of movements.

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Maximum likelihood functions, least squares, probability plots, let us quickly see one by one. Let us talk about methods of movements.

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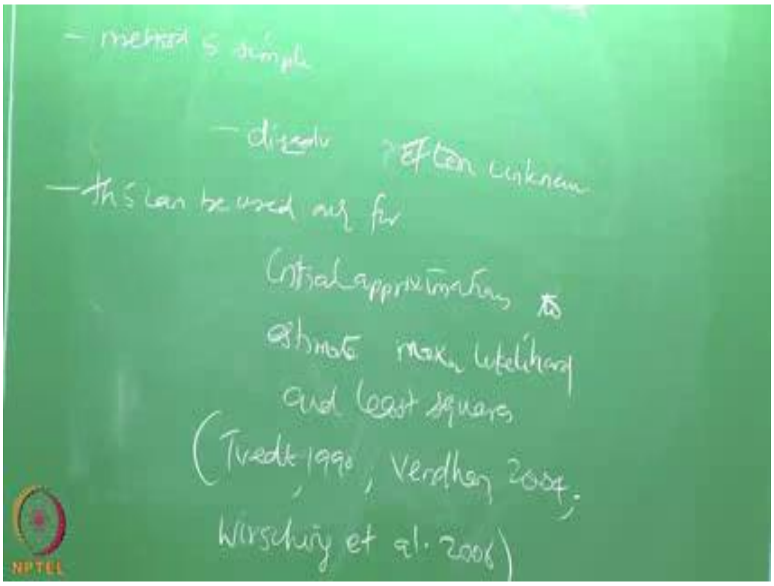

Method of movements equates the sample movements to that of the parameter estimates. It tries to equate the sample movements to that of the parameter estimates. We have got a primary advantage the primary advantage is the method is very simple, whereas the main disadvantages they are not often known, even they are known they do not qualify to half the desirable properties of maximum likelihood and the least squares estimators. Therefore, the primary use of method of moments is only useful for initial approximation. So, this can be used only for initial approximations to estimate the maximum likelihood and least to squares that is what many researchers has commented with it 1990 then 2004, wishing at all 2006.

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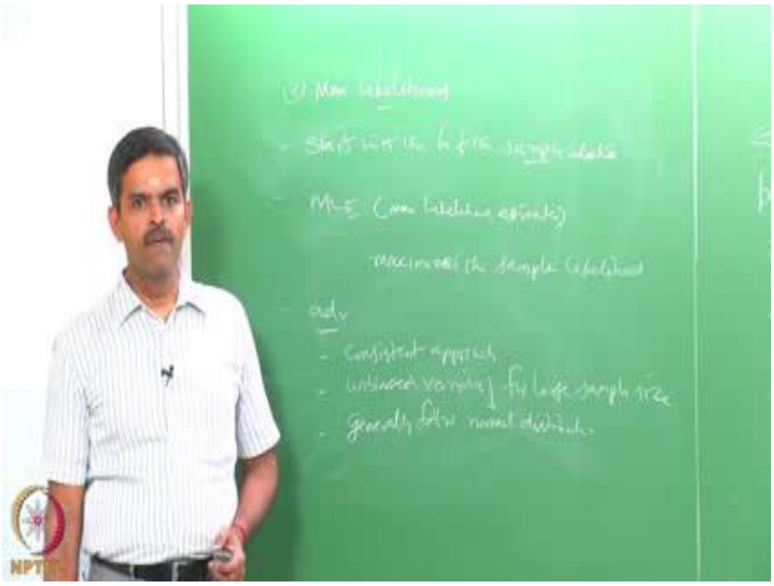


Let us talk about the next method; maximum likelihood, maximum likelihood estimate begins with the likelihood function of the sample data. It starts with the function of the sample data likelihood a set of data is nothing, but the probability of obtaining that particular set of data from a given or a chosen probability model. So, what is that likelihood that the chosen data will follow a standard free assume probability model that is the likelihood function this contains unknown parameters whose values that maximize the sample likelihood which are known as maximum likelihood estimates.

So, it has got to calculate maximum likelihood estimates which are nothing, but to maximize a sample likelihood to follow a pre-assume distribution, maximum likelihood provides a consistent approach. So, that is an advantage it has a consistent approach to the parameter estimation problem which enables it to use for a large variety of estimation simulations therefore, maximum likelihood material method is desirable mathematically and its optimally better they show minimum unbiased variance estimates for large sample size unbiased variance is minimum for large sample size.

Now, we are considering a very large number of random samples to replace the original sample population. The average value will match closely to that of the population value there is an advantage when use the likelihood method as this will show a minimum variance. It expresses the narrowest confidence interval of all the type and the next advantages they generally follow the normal distribution. Therefore, sample variance can be used to generate confidence bounds and hypothesis test for the parameters.

Several popular statistical software packages provide excellent algorithms for estimating maximum likelihood estimates for many of the commonly used distributions that is an advantage. Therefore, this helps ready use of estimating MLE for a given probability distribution. This helps to mitigate the computational complicity for finding out the MLE’s, but there are some disadvantages.

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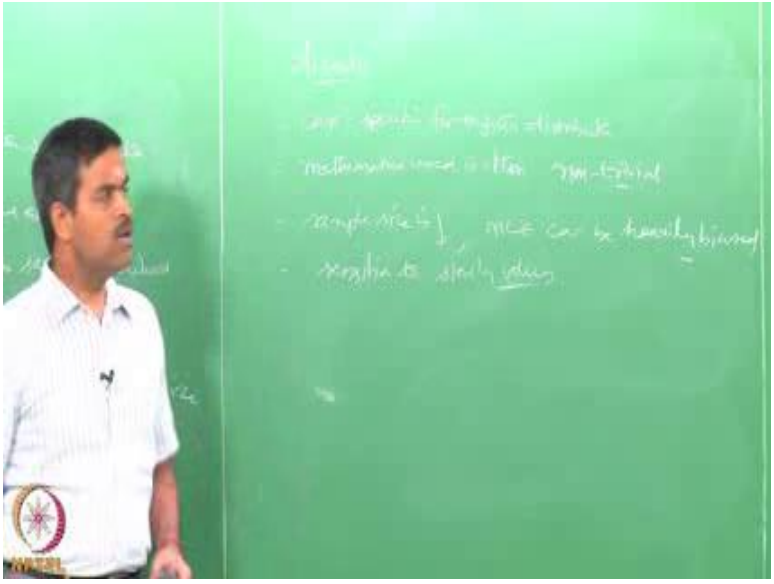

Likelihood equations are case specific for a given distribution, so they cannot be generalized. Secondly, the mathematics is being used is often non trivial particularly if confidence intervals for the parameters are desired except for a few cases, where the maximum likelihood estimates or in fact, simple in general best relay on high quality statistical software are being used to estimate MLE’s.

Fortunately, high quality maximum likelihood softwares are available and they are being commonly used, but maximum likelihood estimates can be heavily biased, if the sample size is small the MLE can be heavily biased is suitable for large samples. They are also highly sensitive the choice of the starting value. So, sensitive to starting values the third one is least squares and the fourth one could be the probability plots. We will talk about this in the next lecture, we will try to compare them and see how they can useful in computing the sample distribution. So, I urge that you should follow the reference materials given in the website, read the papers in parallel and also the text books advocated to you in the NPTEL website of this specific course. Try to develop your capacity building in parallel to the classroom lectures, anything you want to share or discuss, kindly post it in the website of NPTEL, so that your doubts can be answered then and there.

Thank you very much. See you in the next class.