Risk and Reliability of Offshore Structures

Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 02
Reliability theory and Structural Reliability
Lecture - 22
Variables in Reliability analysis

Friends, we will discuss the twenty second lecture on online course on Risk and Reliability of Offshore Structure.

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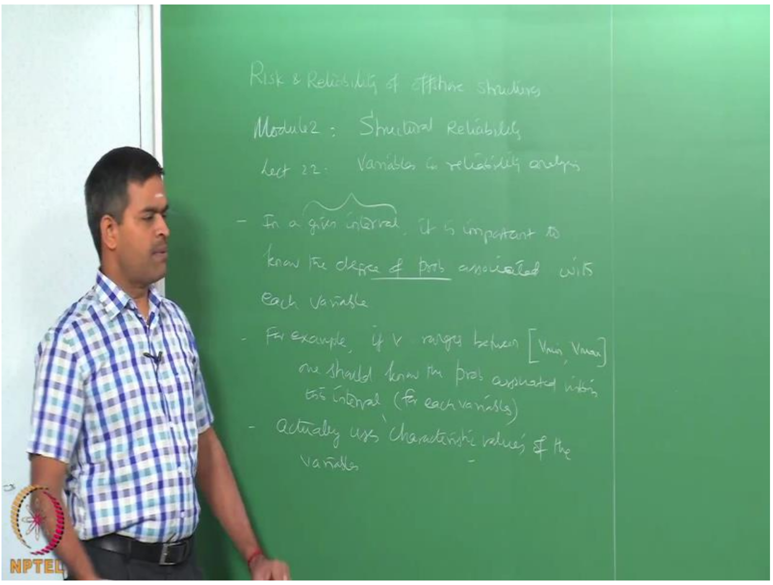

We are discussing lecture on module 2, where we are focusing on structural reliability. Today will be the twenty second lecture which will talk about variables in reliability analysis.

We already said the variables in reliability analysis, generally if you want to talk about structural reliability one can use bullion variables, which we expressed in the last lecture we said your system contains elements in parallel or elements in series in the elements are purely ductile. Then how one then estimate the probability of failure for a given system using a bullion variables, we also said in the last lecture the variables can be represented in 4 different forms sucting variables or sucting estimate fussi number characteristic value and over all the random variable. In a given interval it is important to know, what is the degree of the probability associated with each variable, it is very important that we must know the probability of occurrence of those variables or probability of fitness of these variables in a chosen interval that is very important.

For instance, let us say for example, if v ranges between; let us say v min and v max, one should be able to calculate or one should know the probability associated within this interval for each variable of course, there can be many variables in given system. Yesterday we saw different kinds of loads, different materials strength degradation, there can be many variables in a given system which can affect q or t affect r as well.

Therefore, depending on the approach to defend safety, one typically uses characteristic values. To avoid this conclusion or to get out this problem, one actually uses characteristic values. Characteristic values of the variables, characteristic values are those we say will have no probability of exeedence beyond 5 percent of the chosen value.

or example, if you say the load combination or the load or the stress value, is going to be 0.95 sigma y and I say there is no probability of exciding his values beyond the five percent during the service of the structure. So, characteristic values have a classical definition based on probabilistic angle. So, depending upon the approach to define safety one generally uses characteristic value obtain by increasing or decreasing a typical value, in more appropriate term is better to represent this variables by a known distribution with density function which is preferably.

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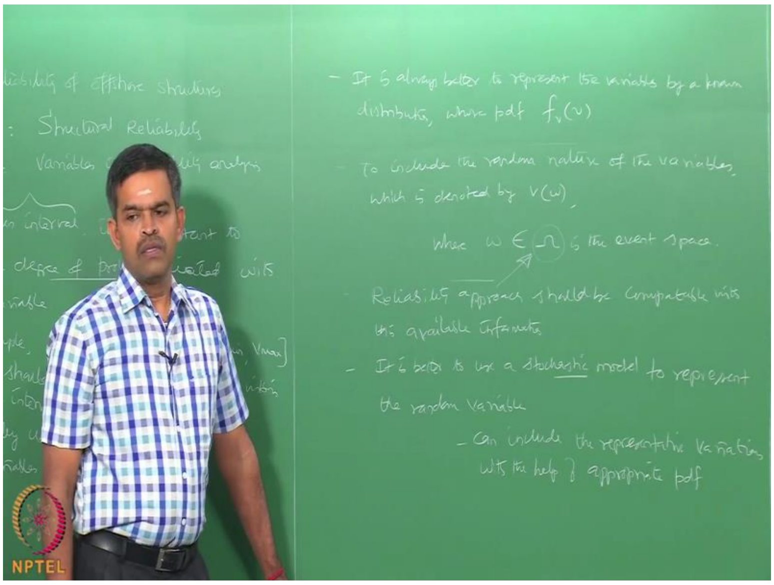

So, it is always better to express or to represent the variables by a known distribution. Whose probability function can be let us say f v, but we all know that the variable has got random in nature therefore, to include the random nature of the variables, which is denoted by let us say v of omega where omega is a element of sigma is the event space.

It is important that reliability approach, what we follow should be compatible with the available information because randomness of the variable is a subset of a space of elements and the approach. What we follow should be able to compatible with this space of this event. Therefore, people have chosen the use stochastic model. So, it is better to use a stochastic model to represent the random variable because they will able to include they representative variability with an appropriate probability density function, stochastic models can include the representative variations with the help of appropriate probability density function.

There are 2 main approaches to handle this whole problem.

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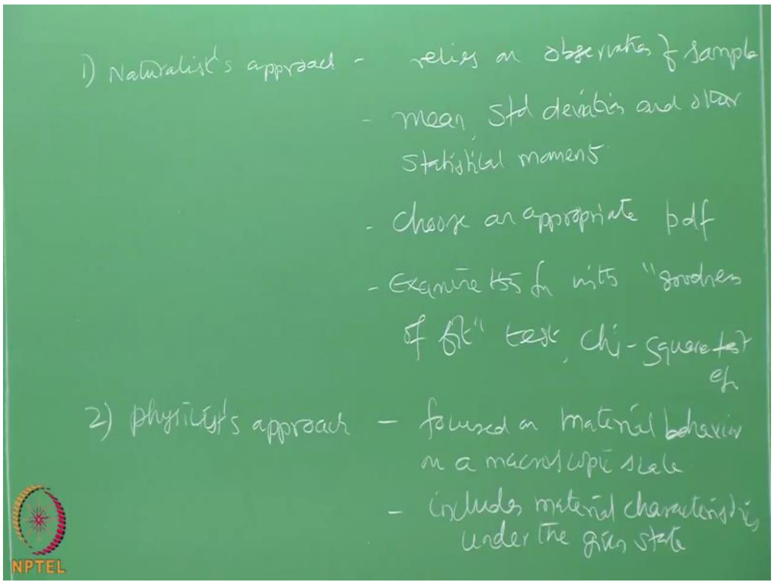

One is what is called naturalists approach; other is what is called physicists approach, physicists approach. Now naturalists approach relies on observation of the sample observation of the sample which estimates the mean standard deviation and other statistical movements, statistical methods of our estimates of random variable and their based on adjustment of an appropriate probability density function, which is determined and used for representing the whole model.

Therefore, the chosen probability distribution function should be verified with the goodness of fit test. Therefore, you choose an appropriate probability density function and examine this function with goodness of fit test chi square test etcetera. Whereas, alternatively the physicists approach relies on understanding the variable of the material behavior or focused on material behavior on a microscopic scale it includes the material behavior and characteristics under the given state of condition.

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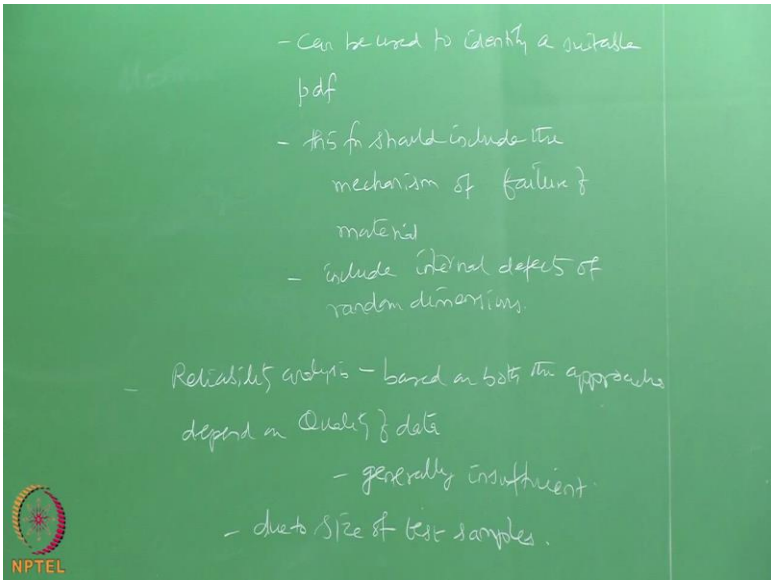

Let us say for example, Weibulls model this can be used to identify the probability density function, which we include the mechanism of failure of the material, which should rather include more precisely the internal defects of the random variables interestingly. Most of the geometric based and material based uncertainties can be included in the model, but the result of reliability calculations exclusive depend on the quality of the data which is generally insufficient. So, the reliability analysis based on the both the approaches essentially depend on quality of data unfortunately this is generally insufficient it may be mainly due to the size of test samples.

The main reason for this particular insufficiency is due to the, sample size of the n symbol list. What you have bigger the number of test or larger the sample greater the changes of stumbling point on a unsatisfied test of course, this can be resolved using a probabilistic approach which of course, shows a better accuracy of the information for instance let us take Gaussian distribution.

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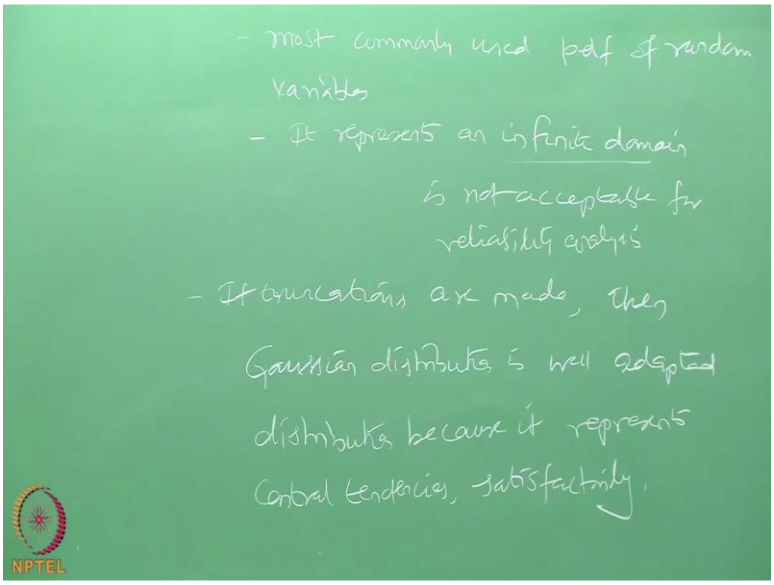

Gaussian distribution is one of the most commonly used probable density function, which can represent the random variable the difficulty with this is it represent infinite domain. Now this major defect an infinite domain is not acceptable for reliability analysis; however, if truncations are made then Gaussian distribution, certainly a very well adapted distribution. So, if truncations are made then, Gaussian distribution is well adapted distribution satisfactory results. Because it causes represents it represents central tendencies satisfactory.

Your typical Gaussian density plot looks like this.

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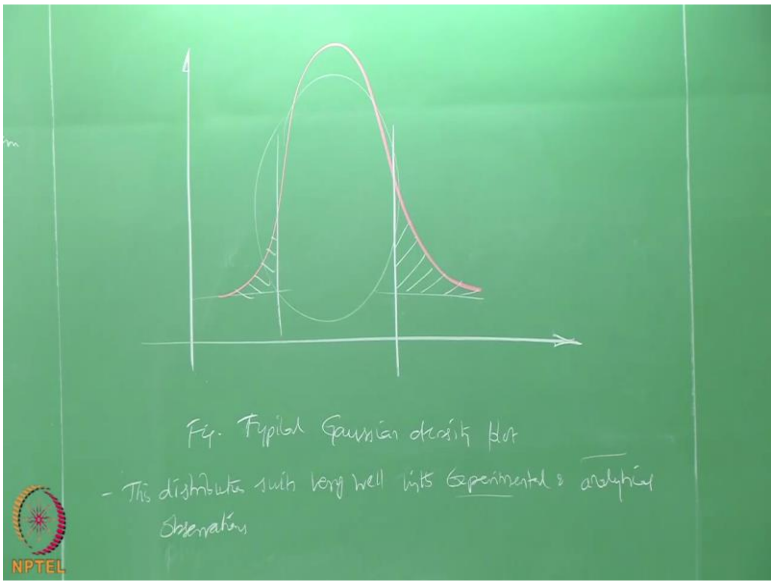

Well mouth curve this distribution suits very well with both experimental and analytical observations, that is not people have commented in the literature it one of the powerful density function. This can accommodate both experimental and analytical observations it is therefore, interest to note that for rare events reliability calculation, concerns the distribution tails.

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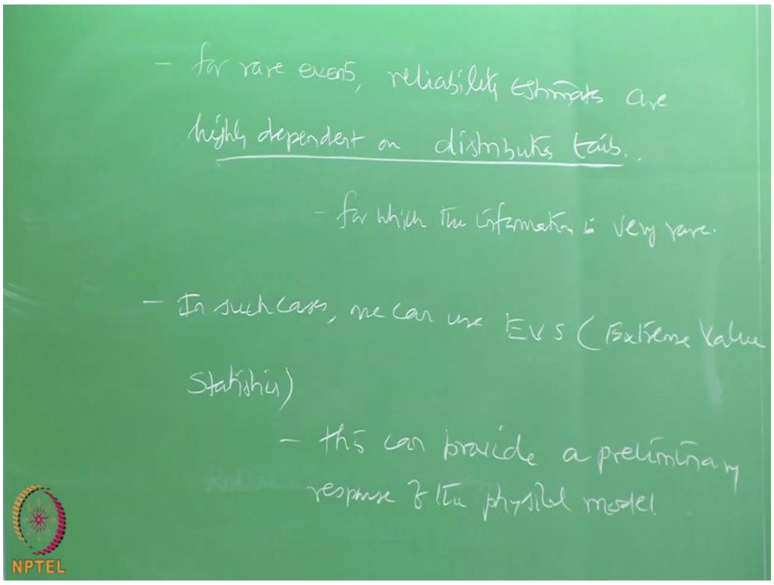

So, an important statement for rare events reliability estimates are highly dependent on the distribution tails. Look at this curve one is interested to focus the event of probability fixedness or probability of exidence on the lower value. So, of course, we look at the central tendency this plot represents decently the distribution of the data of the, whether it is experimental or analytical.

The problem comes when use this probability function for reliability analysis, where the events are very highly rare. When the rare events are modeled using this as a limit state function considering the random variables or Gaussian distributed, then the reliability analysis will essentially depend on the tail of the distribution for which information is evidently very rare that is why, when you do reliability analysis for rare events you can always land up in erratic results. So, what to do in such cases in such cases approach using extreme values statics is better. So, in such situation, one can use extreme value statistics this can provide a response of the physical model now interestingly it is possible to compare different assumptions to such for a better envelope in such cases.

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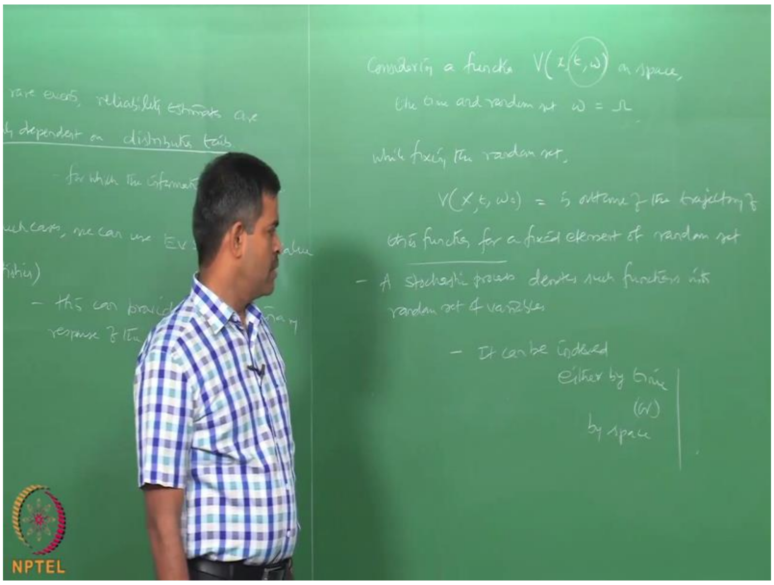

Let us say, considering a typical function which is v of x t and omega on space the time and random set, becomes element of omega becomes element of sigma therefore, while fixing the random set one can say v of x t omega naught is equal to be outcome of the trajectory of this function outcome of trajectory of this function for a fixed element of random set.

So, therefore, in such situations a stochastic process which also a random process denotes such a function. So, a stochastic process which also a random process denotes such functions with random set of variables that is why, under the given complicities of rare events reliability analysis generally becomes a tend to become a accurate. When use a stochastic process, but there is one important catch here the stochastic process can be indexed either by time or by space that is very important, but in this case the general complicities is got the both the variables in the subset. So, stochastic process which is also a random process denotes such a function which can accommodate the variable only in time or in space.

To understand this let us take a quick example.

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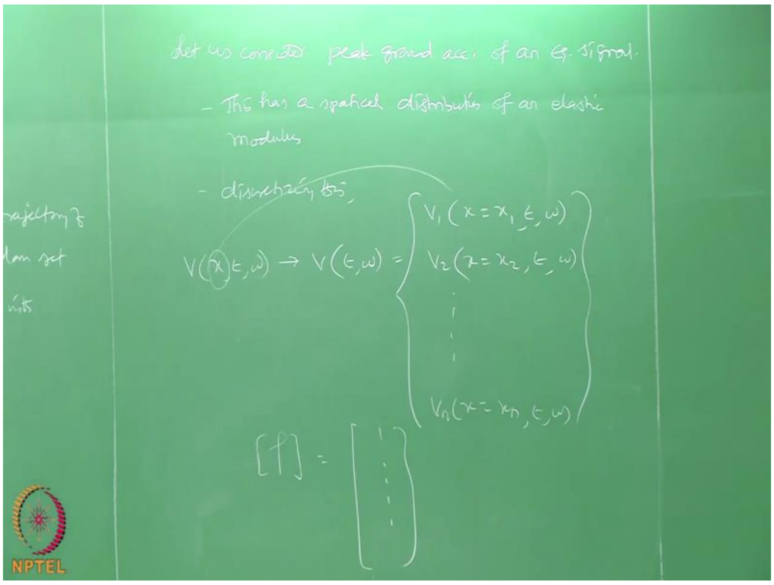

Let us consider peak ground acceleration of an earth quake signal this has a special distribution of an elastic modulus in such cases; one should perform discretization, because it is very special distribution. So, discretizing this we can say v of x t omega can be taken as v of t omega the special distribution no compromise as v 1, where x equals x 1 and of course, the variables are t and omega v 2 where x equals x 2 and of course, the variables are still t and omega and so on. Let us say, v n where x equals x n t omega. So, one of the distributions in terms of special distribution is compromise in this format to use it in the stochastic process and the cross co relation function can be said as and so on.

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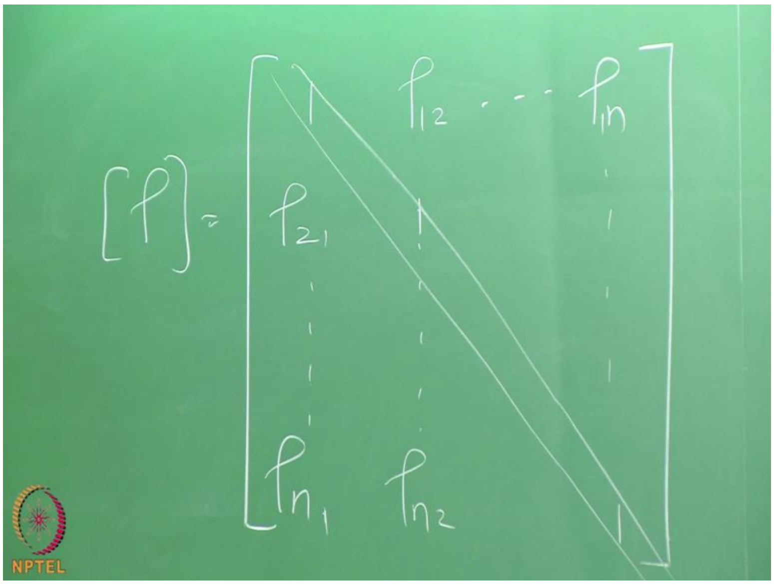

Which can be extended as, which tells me along this is going to be the unit value this band will be unit.

Therefore when a special distribution function or a variable is discretisize in the form as just we discussed this will quickly result in large vectors.

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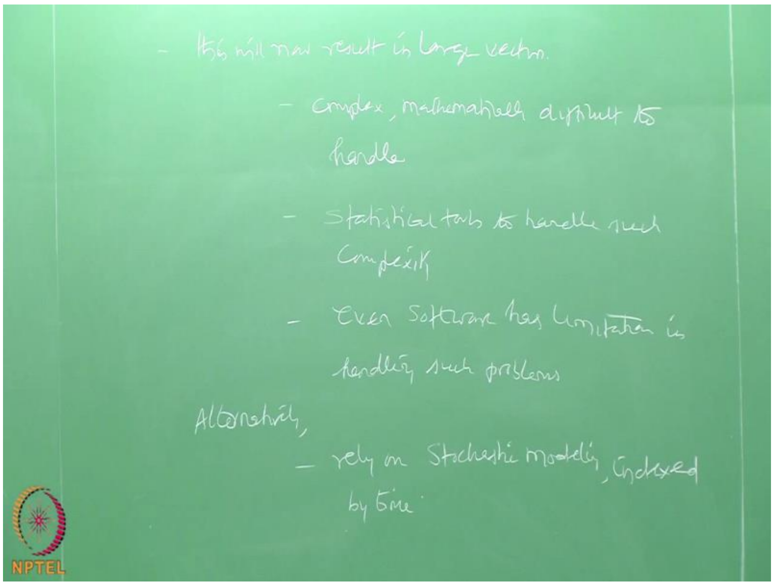

Now, what is the disadvantage of this they become complex mathematically difficult to handle. Then what to do one can use statistical tools to handle such complexity. If you think that one can use software for solving such problem please remind friends software have limitations in analysis problems, even software has limitations in handling such problems. Then what is the alternative alternatively it is a common practice to rely on stochastic modeling, which is indexed by time; however, in many situations it is possible to use an extreme value distribution to express the maximum and minimum within a given interval of time.

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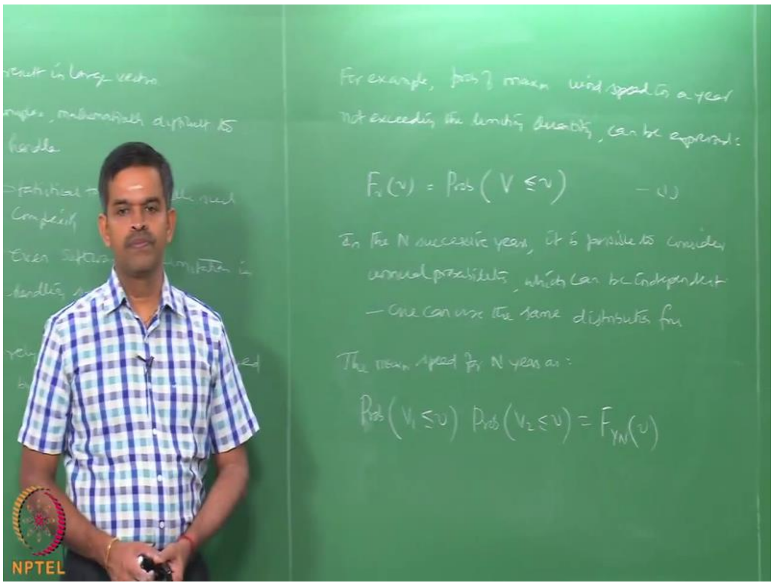

For example; probability of maximum wind speed in a year, in a year not exceeding the limiting quantity can be expressed as follows. Let us say, f v of v v stands for the wind velocity of speed is probability of capital v less than equal to v equation, one in the n successive years it is possible to consider annual probabilities which can be independent. Of course, one can use the same distribution function. So, therefore, one can model the maximum speed for n years as probability of v 1 less then v probability of v 2 less then v is as good as function of y n probability of v, where n n success of years where I have to consider the probability of exceedence of this wind speed for n consecutive years or n success of years, that that event should not exceed the maximum probable value.

So, therefore, study of extreme values that n tends to infinity has lead to what we call extreme value distribution some example for extreme value distributions can be.

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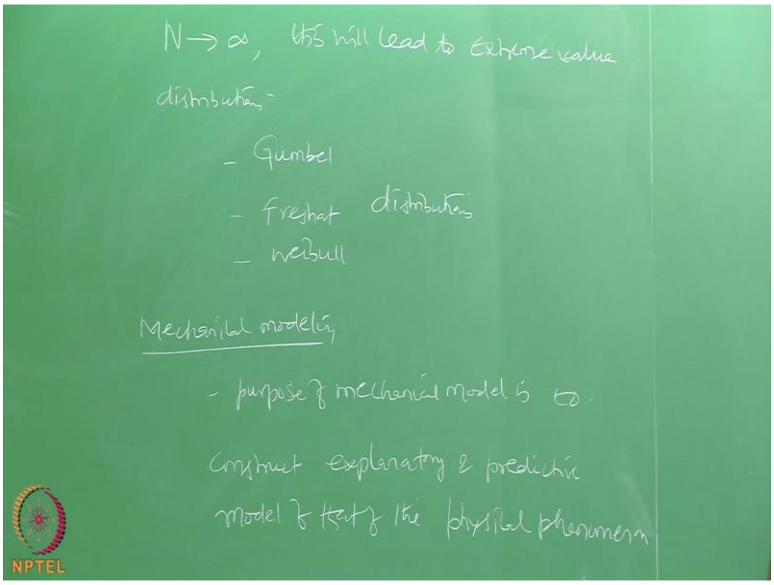

If you really want to know that the condition, where n tends to infinity then this will lead to extreme value distributions some of them are Gumbel Frechet and Weibull is therefore, possible friends to represent a repeated function of time by a random variable. This is one of the most important steps in reliability analysis now how to handle this in mechanical modeling.

Now, I want actually model even the mechanically. So, can you handle this in mechanical model the purpose of modeling is to construct explanatory and predictive model of a physical phenomena. The purpose of a mechanical model is to construct a explanatory and predictive model of that of the physical phenomena, but we attempt to do. So, there will always be a decent difference between the behavior of a mechanical model with that other physical model, or physical reality this modeling deviation is of course, very normal and acceptable provided the deviations or differences in observations or within the limits as governed by the designer or the modular or the researcher procedures for validations are of course, available. So, one can always validate the mechanical model with that of physical model by comparing certain threshold values which are very important for observation in the specific behavior of the model.

It can be easily seen that not a total random behavior is seen, but contains a systematic bias. So, interestingly if a mechanical model constructed is appropriate and governed all the modeling laws which can truly represent the physical phenomena of the specific behavior. One can see that even though there are variations between the behaviors of that of the mechanical and physical models, there will not be random totally, but they will contain some systematic bias on the other hand gross errors must be generally prevented while comparing this that what we call as quality assurance in a mechanical model when compare to express the behavior of that of physical model.

One can always approximate the representation of a physical reality using this curve. So, one can always approximate the physical reality using specific steps involved please pay attention the chart shown in the screen.

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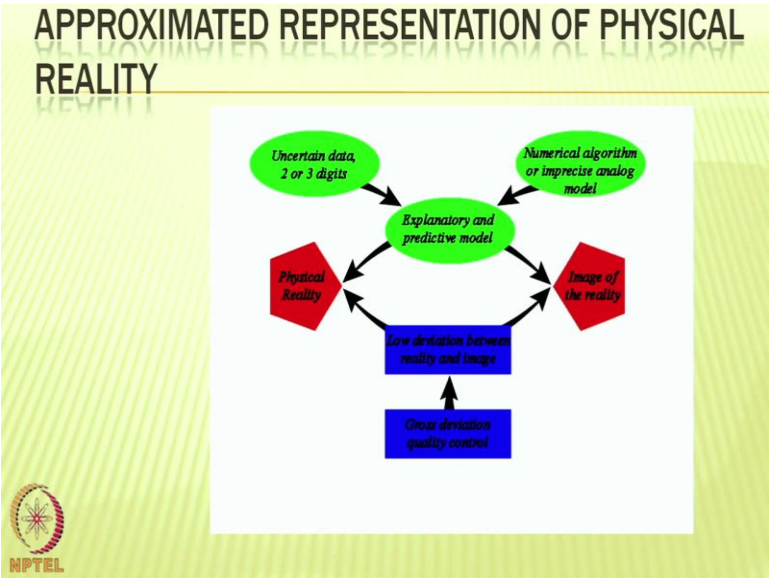

Now, for example, if we have uncertain data which have two three digits, if you have a numerical algorithm or imprecise analog model, if you want to explain the behavior of this in terms of predictive model then, one can either go for physical reality or image of the reality in both the cases. One should ensure that there is a low deviation it is a reality and the image. If you see any gross deviations then, one can say that the quality assurance or quality control in the mechanical model is not proper. So, the mechanical model should always give, whatever may be the case uncertain data in terms of three digits uncertain in the algorithm, whatever may be the case; it should give me a low deviation as far as possible between the physical reality and the image of the reality what we call it should appear in the mechanical model.

Friends in this lecture, we have interestingly seen the factors which dominantly lead reliability analysis towards stochastic modeling. How the variables of multiple in nature can be handled with a little bit of compromise either in space or in time in stochastic models. We have understood the necessity and importance of stochastic modeling in reliability analysis, because the classical distributions do not give information on rare events especially on the tail ends on the distribution curves.

So, reliability analysis if done, with this conversational distribution pdf's may give you error because the sensitivity of the rare data is not sufficient in terms of the distribution properties when use the standard probability density functions. So, one can go for stochastic modeling. So, stochastic modeling should be able to represent the physical behavior as close as inn case of mechanical modeling. So, one should try to limit the difference in behavior between this two models as far as possible.

We will also see in the next lecture, what are the complicities which arise from mechanical modeling. How certain things cannot be completely and truly mechanical model which represent the physical behavior, what are those constraints will shown an example problem. How we are solved this problem using experimental studies, will talk about this in the next coming lectures.

Thank you very much.