Risk and Reliability of Offshore Structures
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Module - 01
Lecture - 03
Uncertainties - ll

Friends, we are now discussing an online course on risk and reliability of offshore structures. We are focusing on lectures related to module 1. Today, I will discuss the third lecture on module one, which is titled as uncertainties part 2.

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In the last lecture, we briefly discussed and compared reliability with risk and failure. We said failure is a negative approach of non performance of an intended function of any system; whereas reliability is a positive dimension of the same approach, where it says the success of performing the intended function. Risk compared reliability addresses or diagnosis the failure of an existing event and leads to confined rules and regulations, so that such incidents or accidents may not reoccur. So, they lead to preparation of or prescription of rules. It diagnoses the problem in detail. There is no doubt about it.

But, when you compare risk with that of reliability, reliability actually opens a detailed engineering questionnaire, which shall lead to a better understanding of the failure. In fact, we can also say better understanding of probability of failure. So, very salient advantage of reliability compared to risk one can say reliability gives positive approach to the problem. It is a diagnosis tool which gives a deep insight. Therefore, it is one of the basic tools; whereas, risk is a prescriptive tool, which leads to preparation of rules and regulations, which can avoid such immediate accidents in the near future.

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We also said in the last lecture, reliability is circumscribed or governed by uncertainties. Uncertainties govern the reliability tools to judge the safe performance of offshore structures. In the last lecture, we also discussed about the types of uncertainties. If you can recall, we said the parametric uncertainties has a source, which arise from the input variables used for analysis and design. So, that remains as a source of this type of uncertainty.

The second type of uncertainty what we saw in the last lecture is the structural uncertainty. This has essentially the source from the mathematical modeling. So, that remains the source of this kind of uncertainty. The third type of uncertainty what we saw in the last lecture is algorithmic uncertainties. The essential source of this kind of uncertainty arises from the mathematical algorithms that are used in the analysis and design. So, that remains the source for this type of uncertainty. The fourth and the last type of uncertainty is experimental uncertainties. It has of course, a sub class what we call interpolation uncertainties, which we will discuss now in detail.

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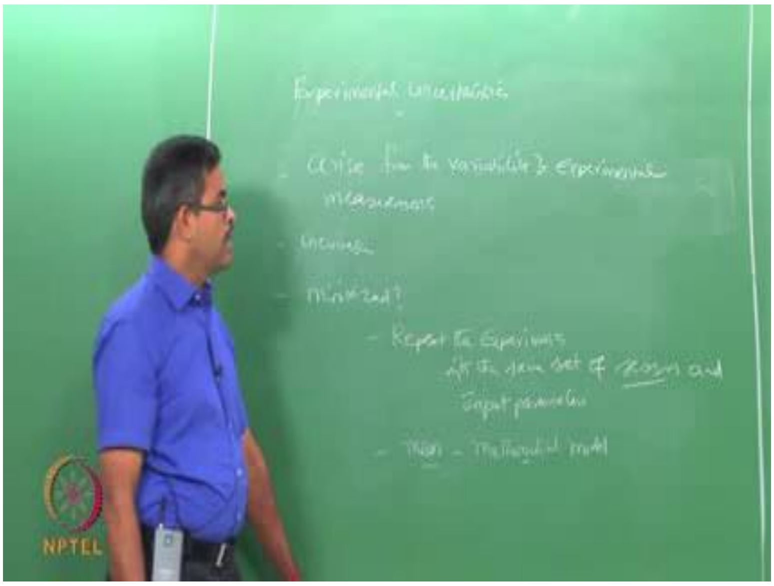

If we talk about experimental uncertainties essentially they arise from the variability of experimental measurements. We all know offshore structures need to be analyzed for different innovative forms. We discussed that in the earlier lectures. Offshore structures are unique in the design pattern. They are form dominated evolved designs. Therefore, any new innovative structural form always demands an experimental investigation.

Therefore, experimental studies are inevitable and become a very important part of the analysis of offshore structures. They are generally circumscribed by serious limitations that arise from the electronic sensors, which are used for measurements during experimental investigations. So, experimental uncertainties therefore, are inevitable. You cannot actually avoid them, we can control them. So, they are inevitable. They will be however present inherently in any experimental investigations. But, of course, the good news is they can be minimized.

Now, how to minimize this? Repeat the experiments with the same set of sensors and input parameters. The moment you have varieties of results, which has been evolving from the reputation of experiments from any type or set of sensors, then you try to take a mean of the results and this mean can be used in the mathematical models. If you add up these procedures, then uncertainties which arise from experimental investigations can be minimized. Interestingly, in a given system, you try to measure let us say acceleration of a deck of a given platform.

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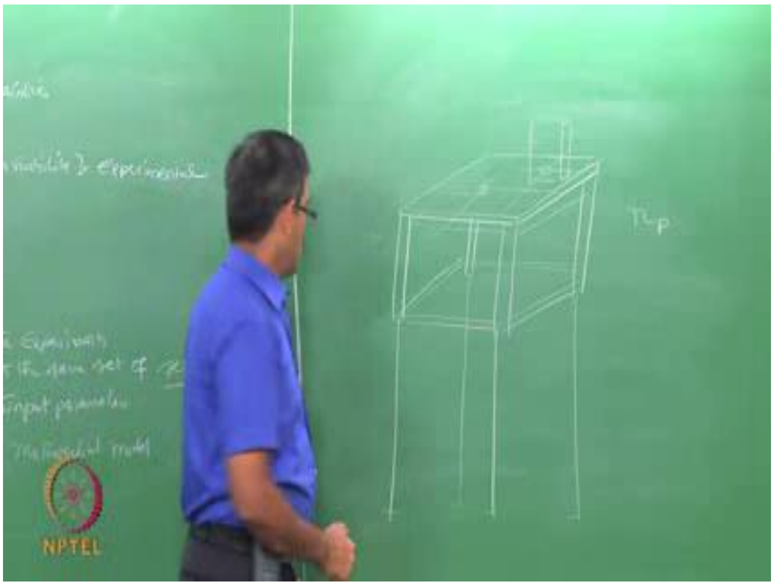

Let us say I have a platform model with some thickness and some lateral dimensions. The platform deck is obviously supported by the column members; and of course, there can be also a (Refer Time: 09:50) member at the bottom, which integrally connects the column members at the deck level as well as at the bottom level. The whole system now can remain afloat by anchoring these legs to the sea bed.

So, this can be a typical model or a scaled model of a complain system like a tension leg platform. I can always measure the deck acceleration at the mass center if I really wanted to find out what would be the acceleration, because of an additional mass kept on the deck at its CG. Then, I may have to put one more additional sensor to identify the influence of the presence of this mass on the whole dynamic response behavior of the platform. And the either wave loads or under wind loads. So, it all leads to the number of array of sensors what you are going to use to measure your experimental investigations. Now, this kind of complexities will also lead to what we call interpolation uncertainties.

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Now, the question comes – what is an interpolation uncertainty? Any data that is interpolated or extrapolated due to non-availability of the data in that range, will also lead to uncertainty. So, this is related to interpolation or extrapolation of data due to non-availability of that data in the required range of your interest. The lack of unavailable data collected from the computer model simulations or experimental measurements can lead to this kind of uncertainties. When these uncertainties are applied to certain class of analysis, the problem becomes more serious. I will give you an example.

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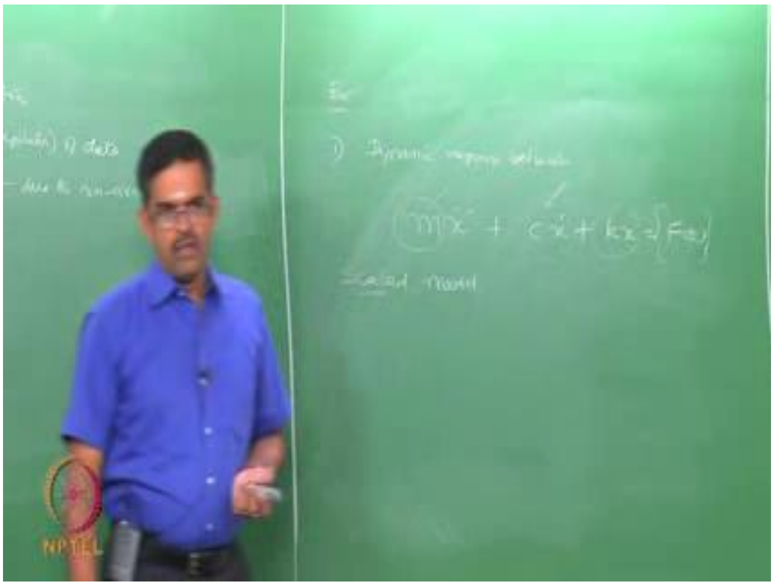

Let us take an example of how lack of knowledge about uncertainties can lead to very serious results of interpolation of the response behavior. Let us take. I am talking about dynamic response behavior of an offshore platform. The moment I say dynamic response behavior, I have got three essential characteristics present in a dynamic system. If you remember or recollect the equations of motion, which is a classical equation of motion for a single degree or multi degree of system provided the mass matrix, the stiffness matrix and the damping matrix will remain either a single element or an array of elements, if it is a multi degree freedom system.

So, this has got varieties of input parameters, which are important what we call characteristics of the dynamic system. It requires an inertia force, which is mass govern; it requires a restoration force, which is stiffness govern; it requires a damping force, which is damping constant govern. And of course, a system requires an external force, which excites a system. So, in the absence of these four characteristics, a system cannot or cannot be assimilated for a true dynamic response behavior. Amongst this, let us take two classical examples of one – the mass, other is a restoration or let us say damping. When you talk about scaled investigations or experimental investigations on scaled models, it is very very difficult for you to simulate all top side details of an offshore platform to the respective scale for which you are fabricating a model.

Now, unfortunately, if the physical model does not represent the appropriate mass; I am not saying the exact mass. I am saying the appropriate mass of that of the prototype; then, the dynamic response estimates what you get either from the analytical numerical or experimental can have very high uncertainties. I am not saying error.

Now, what is the difference between uncertainty and error? We will talk about that in the future lectures. I am saying if the physical model does not represent the appropriate mass of the prototype; then, the dynamic response behavior evaluated by you on numeric, analytical or experimental, can have very high uncertainties. Such problems are very common in experimental investigations of scaled models. You will not be able to represent the true physical model in terms of its mass. And, we all know. If you want to look at the dynamic response behavior, mass or the inertia force plays a very important role and the governing factor in such dynamic response analysis.

So, friends, we discussed about some important tools, which will open up the discussion for reliability and risk analysis or estimates of offshore structures. Let us quickly summarize them to understand what are the vital points, which we will round about and then we will take you forward in this particular course. We already said offshore structures are special class of structures. They are unique in the design and functionality. They should remain flexible; they alleviate; they encounter environmental loads acting on them. They also required to remain robust and safe during all levels of operations. Therefore, the whole factor of ascertaining offshore structure establishing – establishment is functional safety.

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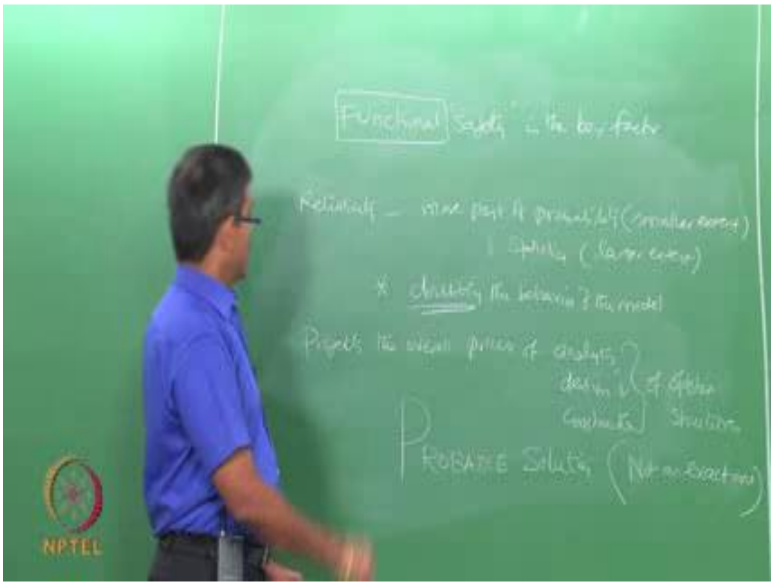

So, functional safety is the key factor. So, there are two keywords here. One is safety; other is safety while it remains functional. So, we are talking about functional safety. We also know offshore structures are classic in their nature because of the encounter environmental loads. The encounter environmental loads for example, wind load, wave loads, currents, impact loads from vessels and barges, machinery loads because of the drilling loads and derricks on the top sides make the response behavior of the platforms very complex.

Their estimates will also have high levels of uncertainties. Environmental loads are not completely known; only some features of them are known to an analyst. Randomness in the environmental loads increases these uncertainties in many facets of an offshore engineering domain; for example, during planning, during analysis and design and also nevertheless during construction stages.

Now, the question comes in offshore structure engineers mind – how to solve this kind of complexities, which arise from different domains of interests or different facets in offshore engineering domain. Reliability tools can handle this wide range of uncertainties very effectively. Reliability methods have many advantages, which we discussed in the last lectures. Of course, they also have few limitations. Most important point what you want to emphasize is that, reliability method has two components. It is more part of probability and statistics.

If you want to compare the contribution of probability and statistics on reliability methods, one can say probability is to a smaller extent; whereas, statistics is used in a larger extent. If a mathematician understands and simulates a problem, which also involves tools of probability and statistics, an interesting dimension what a mathematician would give to such problems would be – he can start doubting the behavior of the model with the background information what he has from the tools of probability and statistics. So, doubting alone will not help. As an engineer, we need to address these uncertainties in detail before we take it forward for commissioning a platform on a trial basis. Therefore, reliability tools explicitly underscores acceptance of risk, which actually an implicit factor, is an inherent inbuilt factor.

In general reliability methods project the overall process of design; it projects the overall process of analysis, design and construction. I am not talking about repair, rehabilitation, maintenance, decommissioning – all can be included in the same list of offshore structures only as a probable solution, not an exact one. Why this happens? It is because reliability we circumscribe with uncertainties. Uncertainties need to be expressed in therefore probabilistic terms for their better representation. There is another part of the whole discussion, which is a failure expression system.

Failure is also expressed therefore, in terms of probability. To understand reliability in probabilistic terms, it is always very important to understand failure also in probabilistic terms. Failure of a structure as we all know now is true only under certain specific conditions. Conversely, reliability is expressed in terms of success of a system to sustain the demand expected from the system. Reliability implies estimate of limit state probabilities of a structure under critical demand. Safety is another term, which is being used in the same context. Safety is generally used to indicate reliability as a conventional or a traditional concept. Reliability of course, is the probability of success of a system to perform the intended function over a specific period of time under the given situations.

Reliabilities also look as a traditional way in terms of risk on a given system. If I say the system is not reliable; the question asked by an engineer could be is a system is at risk. Risk of course, is a measure of magnitude of hazard. Hazard is a scenario. Therefore, reliability in offshore structures is only to assess the functional safety. So, we have got three terminologies now circling around: reliability, failure, safety or risk. So, we have discussed them independently.

We have also connected them to understand in a given pool of offshore engineering domain, where do they stand and how are they interconnected. Reliabilities of course, focused on those problems that are not realized with the society directly; but, those problems which challenge the safety in directly. It is therefore, interesting to know that, risk assessment from failure analysis does not generate discussions. It only leads to prescribing rules and recommendations.

But, reliability opens into an engineering questionnaire that shall lead to a better understanding of probability of failure. When we talk about uncertainties, we already know uncertainties govern the reliability tools to judge the safe performance of a given system. There are different types of uncertainties namely, parametric uncertainties, structural uncertainties, algorithmic uncertainties, experimental uncertainties and interpolation uncertainties.

We have discussed these details in the lecture. I hope you would have enjoyed all the three lectures as of now. We will take you forward in the next class. Thank you very much. Do you have any questions? Please post to the portal of NPTEL IIT, Madras on this course.

Thanks.