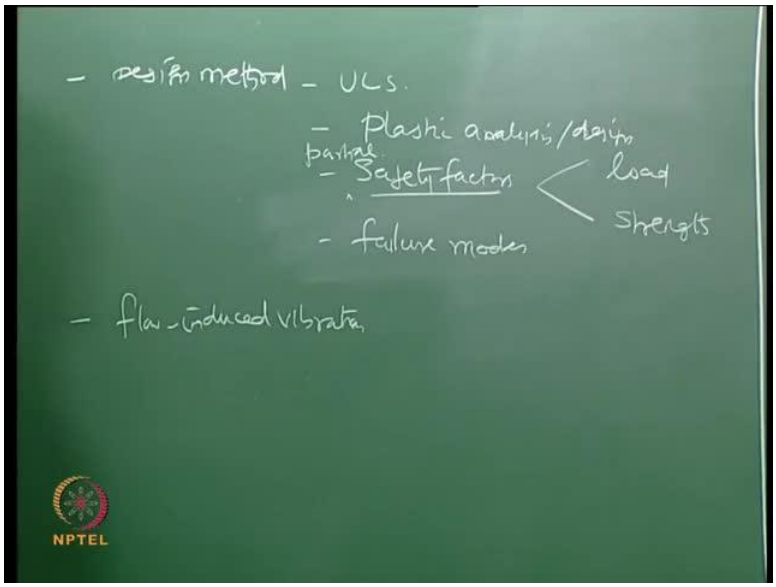
Advanced Marine Structures
Prof. Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology Madras

Lecture - 1
Introduction to Reliability - I

So, we have successfully completed two modules on the NPTEL course on advance marine structures. In the first module very briefly, just let us highlight what we discussed.

(Refer Slide Time: 00:23)



We discussed about one of the important, new design methodologies which is ultimate limit state. We have understood that, how the post elastic behavior or the plastic analysis and design is useful in estimating, the maximum load carrying capacity of a given section, under uniaxial tension or compression or under the combined action of tension or compression in bending. So, we also discussed something about the safety factors. We put them as partial safety factors, because they do not account for all kinds of uncertainties, which are available in estimating.

These may be material characteristics because safety factors are associated with two things, one is associated with the loadand other is associated with the strength of the material. Essentially safety factors are accounting for various uncertainties involved in

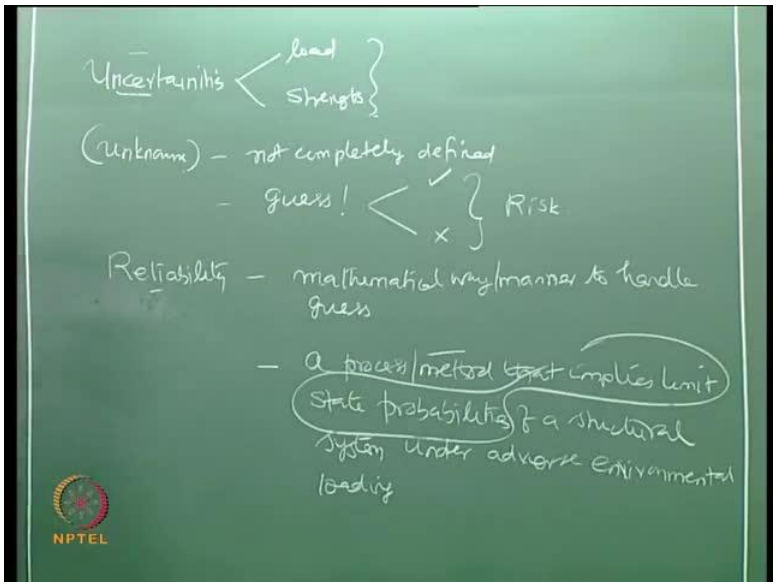
estimating the loads or estimating the strength of the material. We have also seen different theories of failure, and therefore why in certain cases their discrepancies existing in the second and fourth quadrant will govern or will dominate the failure phenomena, may be in what kind of loading etc. We have also very briefly looked into the impact analysis of structures, marine structures.

In addition to this we have also seen different forms on marine structures, where we have understood that in the analysis and design of marine structures, the advancement term relates not to any new form, but new methodology of analysis and design etc. We have already said that in marine structures, it is a form based design. Actually it is a geometric innovation, which happens to cater to the expected loads, which are counter acting or which are acting on the members of the marine structure, at different sea states. So, people generally take a proven, tested, geometry or the prismatic layout of the members and try to modify intelligently and innovatively to take care of the forces which are encountering these members or the structures at deeper waters.

One such example could be an off shore tracer on top, other could be a response control using tuner mass dampers, tuner liquid mass dampers etc. In the second module we discussed about, the flow induced vibration characteristics. How are they controlled practically? What are the different aspects of controlling this? Why they should be controlled and what are the different ways by which they can be controlled? And one of the intelligent way, what people have practiced in recent past is, how to use perforated members or perforated cylindrical covers on existing members, which in addition in above reducing the flow inducing vibration, it also reduces the force acting on the inner cylinders.

So, there have been experimental numerical, and analytical studies, report the literature which has been discussed briefly for your outline to understand, that how this can be ?… So, the reinsistant was in this particular module was the flow induced vibration and its effects or consequences on the structural action of the member. So, the domain of interest for us in the discussion of module 2 was about the structural response of the members or the structures. And it is not the hydro dynamic response hydro dynamic characteristics of, computing or estimating the fuller velocities and disturbances around the (( )) region of the member. That has got to be addressed by a separate course, where you can understand them in hydro dynamic aspects in detail.

(Refer Slide Time: 04:29)



Now, having said these two modules clearly understood, most important question now comes here is, there exist uncertainties in the load as well as in the strength. How are they addressed actually in the design and analysis? The moment they say uncertainty, I can say they are unknowns. They are not very clearly note, they are not completely define, that is why we have call them as uncertain. The one which is not completely defined, will always have a guess. Is it not? The one which is not completely defined can always have a guess, the guess can go sometimes right, sometime it can go wrong also. It means there is always a risk associated with any parameter that is guessed, but can this risk or alternatively, can this guess be mathematically handled?

Can I handle this guess mathematically? That is where reliability plays a role. In simple terms, reliability can be defined as mathematical way or manner to handle guess, which otherwise results in risk. So, conventionally reliability is defined as a process or a method that implies, limit state probabilities of a structural system under adverse environmental loading. So, there are three key words here, which one has to understand before we discuss reliability in this unit slightly in detail. Of course, reliability of marine structures itself is a full course of three credits, which will not be discussed usually in this particular course on advanced marine structures. There is only one small module where we are going to discuss in about 6 to 7 lectures.

So, we will very briefly discussed about reliability in this particular course, the key words when we talk about conventional definition of reliability is it is actually a method. Is it an analytical technique or design technique? Whenever I say a method is it meant for analysis or is meant for design? Is it useful for mathematicians or useful for engineers? When I say design, I focus on engineering practicing professionals, when I take about analysis I focus on mathematicians or analysts or researchers. Is this method a design technique or an analytical technique? We must understand to define this very clearly. Now, this implies a limit state of probability.

We are already have understood there are different limit states, one important limit state which is essentially practiced in marine structure design is, ultimate limit state, ULS which we discussed in first module very much in detail. So, this implies limit state probabilities, it means a guess which is uncertain on certain parameters are handled using some theory. So, there is rational way of handling these uncertainties. That is why it says probability. Now, onwards we have got have a very close pair of understanding, whenever we I talk about reliability, I will always carry forward talking about probability, along with reliability.

So, reliability is not a certain format of answer it is a guess. It is always some value of probability of accuracy, is always associated with reliability. That is why the term reliable is given. It is very clear that it is not a definite, close form, discrete, deterministic, result on any process. It is always having a probability of value attached to this process. So, it is a mathematical way of handling this, the guess is not handled rationally. The uncertainties are not handled at random as the wish of the designer. There are some methods, there are some techniques of handling them, using probability theory.

The moment I convert the uncertainties mathematically through the tools of probability, what will I get is, I get limit state of whatever we want, may be limit ultimate limit state, limit state of serviceability, whatever wish I wish. It means reliability is a technique which bridges the uncertainty between the researchers on loads and strength, to that of uncertainties to the designer. It is actually connecting analysis and design. It is a bridge, which connects analysis and design or analyst and designers, right? How accurate is a technique, what are the parameters which can affect the accuracy of a reliability method, this is what we are going to see.

But it is very very important for me understand the moment, I associated probability to the term reliability automatically, as a pair as a couple it is understood that my guess can go 100 percent wrong, 100 right. So, there is again a superlative probability attached to whole process of reliability, that the whole the process what your trying to follow may be totally wrong. That should be not happen, because we are actually using this as a tool to only eliminate uncertainties. If this tool itself can take an answer to me or give me an answer to me which is completely randomly wrong, then the tool is not effective.

Therefore, there are discrete well defined procedures in the text, in the literature through which reliability can be performed. So, the probability of your reliability technique applied on structures going 100 percent wrong does not exist. Alternatively, the probability of this technique giving a 100 percent right answer is also does not exist. So, the variation is anyway between 0 and 1 or 0 and 100 percent, but people have used this tool successfully, intelligently, that the guess or the probability what you adopt in this method lead you to answer more or lower 70, 80 percent accuracy. This has been established, so it is a mathematical technique, it is a rational way of handling uncertainties.

Now, interestingly uncertainties will be high in order, when the loads become critical. When the loads are non critical, when the loads are not maximum, when the loads are not collapse loads, in terms of plastic analysis and design then associating uncertainties are the order of correction to this in a probabilistic tool is not required. Now, that is what designers have been doing. Designers are not been using or reliability as a tool to design a structure. They have been using partial safety factors as a part of addressing these uncertainties so far, is it clear? So, partial safety factors are the technique of using partial safety factors, to address uncertainties on the load and strength has been already in practice, since eighties what we called as limit state design procedure.

So, as a designer, as a practicing professional, I am already using or accounting for non in your eighties, which come from these two sources mainly on a given structural system. Then what is new, about reliability as a new tool? Reliability as a new tool will address how accurate is this. It is focusing or highlighting or inserting the accuracy, the factors, the dependency and the reliability of these factors itself, is that clear? So, far people have been saying I will use partial safety factor of material as 1.5 for loading is 1.15. Whether these numbers are accurate? So, people are not bothered about the

number, people are bothered about the process based on which these numbers have been derived. How reliable are these numbers?

So, they are used probability tools to guess to gauge to judge to rank, the accuracy of this safety factors. So, if you ask me a question whether reliability is design process and analytical process, the answer is reliability should be a design process. Because as long as you do not account for the load and strength simultaneously to land up in a structural system, which would perform it is intended function, under the given adverse environmental loads, it means I am talking about the functional aspect of the structure. Functional aspect of the structure is always a design parameter.

For example, if you want to design a bicycle; how many wheels a cycle, should have what should have the diameter, how many spokes, what should be the tire rear, and front tire pressure, what should be the chain diameter, what should be the chain's sprocket ratio, what should be the height of the handle bar, what should be the length and weight of the cycle, all are analysis parameters. Their functionality is cycle should be driven smoothly on an uphill and should be safely driven on a downhill functionality. So, when I talk about effective disposal of these loads with the in effect strength availability in the material, under the adverse combination of environmental loads, I am talking about the function of the problem or the structure, so reliability should be a design method, is that clear?

That is why reliability is focusing or showcasing the accuracy of the partial safety factor, which is again a design method only partial safety factor, is used only. In the design not for the analysis, I want to find the member cross section, I have the working load coming on the structure, I do a plastic analysis, I multiply them with the safety factors find the collapse load or do an analysis using upper bound or lower bound kinematic theorems and get the design value which I called as a collapse load. For the design value get the plastic section modules, design the section, so all these parameters are associated with the design. So, reliability should be a design method, is that clear?

Because it is addressing most importantly one of this is this, but reliability is not correcting the accuracy of the partial safety factors, reliability methods will not yield, will not give you safety factors at all. It gives you something different, we will talk about that. Therefore, be very clear that reliability tool is not to obtain the safety factors, safety

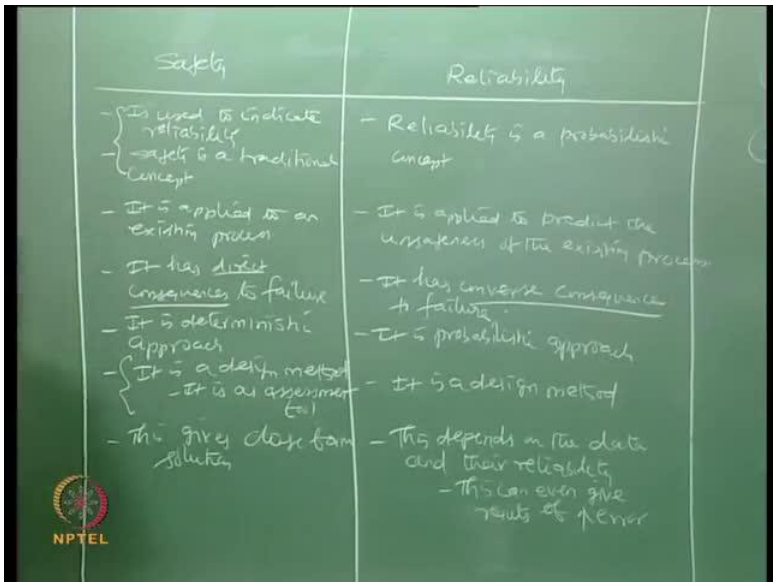
factors is examined using reliability tool. Look at this as reverse process. So, this has not been a new engineering idea, which is springing up only the late 2000 etc, this has been in practice since 70, indirectly we design us by accounting for this. One may ask a very intelligent question, sir structures are been designed for many years for 30, 40 years without even using this as a design tool, why we now look at this as a design tool?

Why cannot we continue with this for the entire future? What is the problem reliability will give you confidence in your design? How confident you are about your statements in the design, so for safety factors can never support your confidence level. One may question, why have you taken 1.5, why not 3? Why not 5, why not 50? No answer, because they have been purely based on the strength characteristics and loads, which has been studied for the past 50 years, 40 years, 100 years etcetera. Reliability has a power to fore see and to back see, the behavior of these variations with the large sample because it is taking support of probabilistic tools.

And probability statistics can handle all these data in a very convenient and close form manner, which we all know from the advanced engineering mathematics. So, reliability is a design tool, it is evident essential that I must understand this tool as a designer to improve my confidence level in the design process. So, it is not addressing any of the analysis tools at all, but there are different levels and methods of reliability which tops the analysis level, which takes you forward to the design level.

There are different levels at which reliability can be done, so reliability is nothing but addressing or rationally handling the uncertainties in two important parameters. Load and strength, is it clear? Any questions here? Having said this, let us talk about, what is then the difference between safety and reliability?

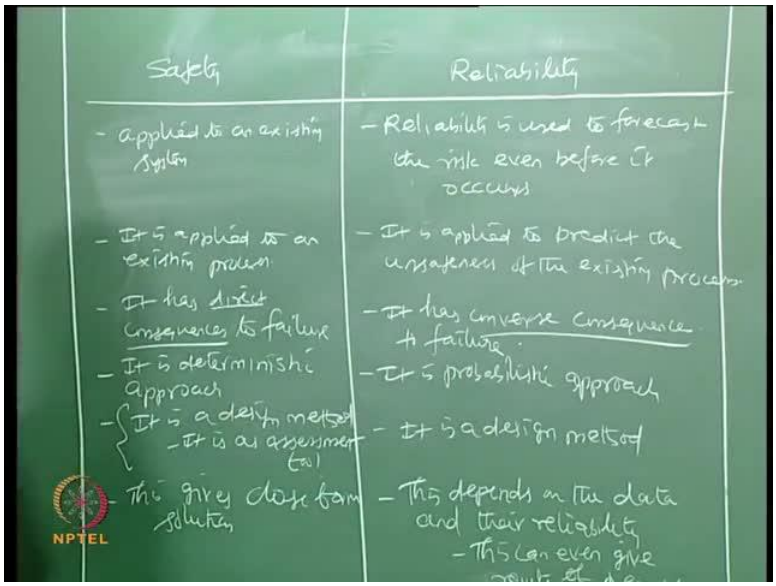
(Refer Slide Time: 19:48)



Let us divide a line and try to explain this simultaneously. What is the difference between a safety and reliability ? Are reliable design safe ? Is there any marginal difference between this? There are tremendous amount of variations between the statements of safety and reliability? Many variations are there, they are not same at all. Let us see there at least 10 variations, we will see one by one. Safety is used to indicate reliability, it is a count safety is a traditional concept where as reliability is a probabilistic concept. So, I can compare these points as a single point against reliability.

Most importantly it is applied to an existing process. It is applied to predict the un safeness of the existing process. This has direct consequences of to failure it has got direct consequences; this has got converse consequences, that is very important. It is deterministic approach, it is probabilistic approach. It is not a design method it is an assessment tool, it is a design method this gives a close form solution. It means it gives a fixed answer to a given problem this depends on the data and their reliability. How reliable are the data? Therefore, this can even give results of high error that is possible erroneous results are possible with reliability tool.

(Refer Slide Time: 24:49)



Safety is applied to an existing system reliability is used the forecast the risk even before it occurs. So, one can say if a results are safe or the structure is safe, let us say if I read a statement saying the structure is safe I can may, I can declare the statement is non technical. If I say the structure is reliable, I can declare the statement as technical statement, safe or safety is related to the existing system, under the given process of loads and strength reliability addresses. The possibility of failure of the system even before any such failure is been recorded or addressed, so it is one step ahead of safety, it is one it is marching forward compared to safety, right?

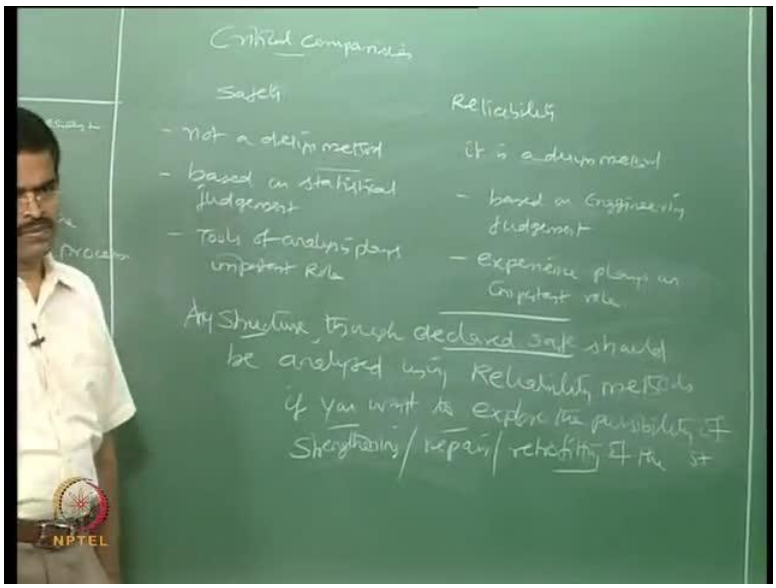
That is actually, there are many differences as we listed here between safety and reliability. People generally confused these two adjectives that if I say reliable it is definitely meant to be safe or if I say safe it is addressing that is it is reliable, they are different entirely. So, the most important differences amongst all these will be this indicates direct consequence of failure. If the structure is unsafe if the structure is unsafe it is got direct consequences to its failure, where as this has got converse consequences of failure I will talk about that because reliability is 1 minus probability of failure? We got a converse consequence of failure, right?

So, it is a very important difference between safety and reliability, remaining all you can see very clearly that there is got different tools and safety. Since, examining the given system which is present already, the solutions can be more or less accurate, where as

your process is not proper, if your tools are not properly used. It can give you a result of very high error as well. So, reliability may not be dependent result, may not give you independent result, if your tools employ to perform reliability analysis is not properly chosen. So, it needs some training it needs some certain level of understanding of mathematics. If you really want to do reliability, study as I said in the beginning reliability is addressing the design process safety is not which is very important for an engineer's prospective, right?

So, one must talk about reliability, based design where as partial safety factors are not reliability based design the term safety itself. I think now will you realize that partial safety factors, which have been using in ultimate limit states etc. Addresses safety not reliability there is nothing, the reliability factors, so this table clearly or distinctly tells you where we are deviating from safety in terms of reliability any questions here.

(Refer Slide Time: 29:01)



So, let us quickly look at the critical comparison between safety and reliability, not a design method. It is a design method safety is based on statistical judgment this is based on engineering judgment. Since, it is statistical tools of analysis plays important role here, experience plays an important role, most importantly an over ruling judgment where the battle between reliability and safety has been won by reliability is any structure though declared safe should be analyzed using reliability. Methods if you want

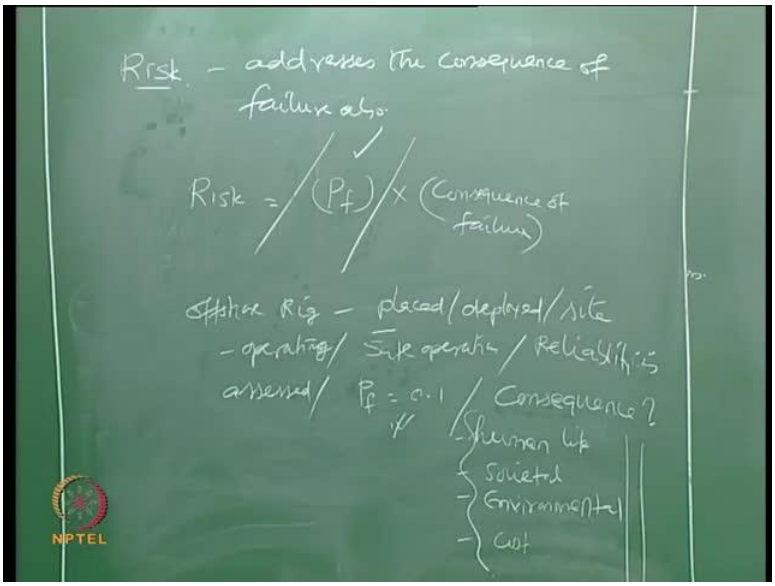
to explore, the possibility of strengthening repair retrofitting of the structure. What does it mean?

The statement is a very important judgment gave between the battle fought between the safety and reliability. Now, it is very important and interesting to note when the structure is declared safe, there is no necessity for repair when the structure is declared safe, there would be practically no necessity and requirement or demand. For repair or strengthening is it not, but still if you really want to repair and strengthening on account of extending the service life of the structure extending the capacity of the structure etc or making the structure safe for the futuristic loads etcetera, you have to perform reliability analysis.

It means reliability methods very interestingly and dominantly override, overruled safety declaration statements. If you really want to strengthen or repair a structure, a retrofitter structure, you must perform reliability analysis. So, safety of the structure is only a declaration as on the present state reliability of a structure is an assessment based on the present and futuristic state concerning, all uncertainties of load as well as strength of the material. So, it is a large domain which covers uncertainties in a more mathematical manner, more rational manner.

You may wonder that this is using statistical tool, this compared to be more rational manner, but this addresses a problem on the present state. This force is the problem on the futuristic state. Therefore, it is much more advantageous much more superior compared to safety methods, is that clear? I think we have made it very clear that, how reliability supersedes safety. They are two different things, having said this then let us talk about the question.

(Refer Slide Time: 34:13)



What do we understand by risk? Then what do you understand by risk? Reliability is superior to safety. Risk is again a term associated to safety, only if I say any specific process or event is risky, what I physically mean, mentally mean is that the process unsafe, so converse reliability is also a converse. Then how reliability and risk are different? Risk addresses the consequence of failure also. So, on the other hand risk is nothing but a product of probability of failure into consequence of failure, where as reliability stops here, it does not talk about consequence of failure and reliability is converse of failure.

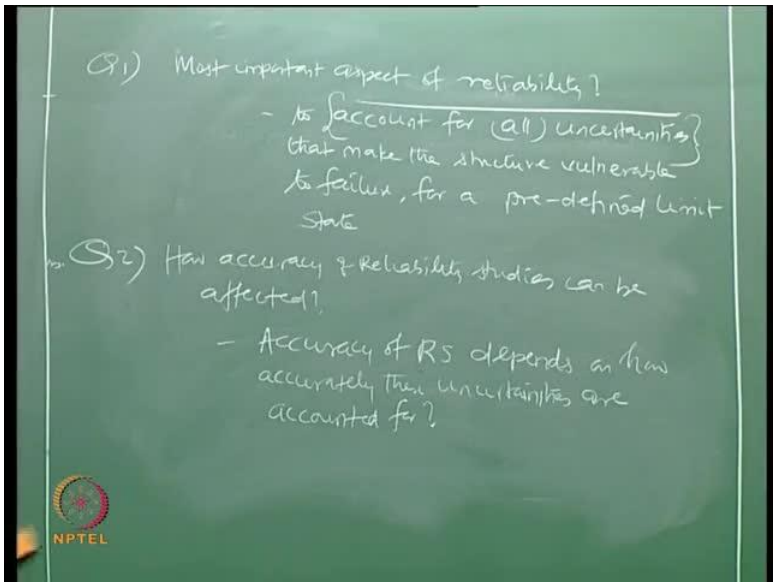
That is 1 minus probability of failure is reliability that will come later, but it stops in this domain here. It does not extend beyond to oversee or to look insight of what is a consequence because of this failure I can give a very simple example. Let us say an offshore rig is placed or deployed at a specific sight it is operating, but still when they are permitting this rig to operate, people have checked and prove that it is under safe operation. Is it not, it is safe, but still on the basis of uncertainties applied to this process, in terms of mechanical systems, in terms of structural systems, in terms of environmental loading coming on the system in terms of impacts, caused with the ships and boats or vessels on the systems etc. How reliable it is? Reliability is assessed though safety is already is there.

But still reliability is assessed I think you are understanding. Now, so it is very clear that it is a go ahead path of safety. It is beyond safety and it has been declared that the probability of failure is may be 10 percent. There is been assessed and found of whether probability of failure is 10 percent, it means it is safe and reliable by 90 percent. The question here is, when such failure occurs, what would be the consequence of this failure? The consequences can be on human life on society. Society means it can cause a oil spill over the rig and break the rig can get a shutdown, it can cause environmental impact, it can cause, it can cause cost factors also can be financial implications.

All these aspects, which are the end product of any accident, end plot of any system because as a common man, as an administrator, as a legal personnel, as a user, I look only the end product of any system, the end products or essentially seen all the consequences. So, reliability will say that the rig is operationally safe and reliable by 90 percent. So, there is a 10 percent risk associated with this, which is addressing the consequences of failure, which is not exploded by reliability studies. So, risk is in addition a value added to reliability study. Now, we can far compare this with safety, it is far inferior right. So, risk is an add on to a safety, which order also addresses the engineering prospective, the societal prospective, the human the environmental and financial prospective, to the statement made against safety.

So, risk and reliability should be seen together as a prose of evaluation, you cannot independently look at them, but without risk looking at it reliability alone for engineering judgment, it is fine for an financial implication. It is not complete, so reliability does not give me the out bound products or results of deliverables as desired on certain segments by the administration or legal authorities. It gives me purely technical out of bounds, so to understand reliability you must have a good practical experience and a good engineering judgment, otherwise you cannot understand, what the outcome of the reliability study, is it clear? So, reliability is highly technical risk, is more or less non technical and mostly towards financial.

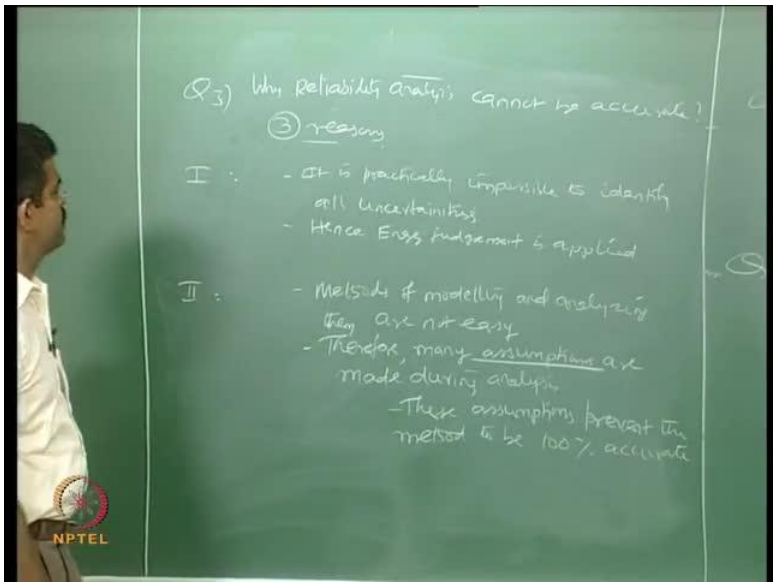
(Refer Slide Time: 40:59)



One can ask a question, what is the most important aspect of reliability? Most important aspect, the most important aspect is to account for practically all uncertainties that make the structure vulnerable to failure for a predefined limit state. That is the most important aspect, it should account for all uncertainties that is the most important aspect of reliability state. Then one may ask a question, what would be these parameters, which will affect the accuracy of the study, how accuracy of reliability study can be affected? The answer is very simple, the accuracy of the reliability studies I am putting R S here.

Reliability studies, see these short forms you got to actually understand because it is important. I keep up need not keep on writing, I want it to expanding it in your literature and keep on writing properly accuracy of reliability studies, depend or depends on how accurately these uncertainties are accounted. For the answer to the second question, will be the answer to your primary question, you have to account for all uncertainties. How accurately you are accounting for them that will give you what is your accuracy of a method, very simple.

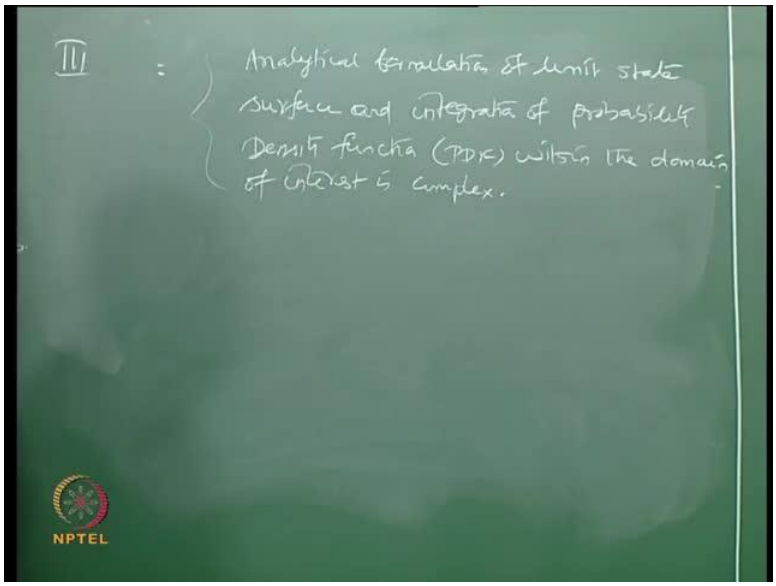
(Refer Slide Time: 44:09)



Now very interestingly, a very sarcastic question, why reliability analysis cannot be accurate? Why it cannot be accurate? What is the problem? There are actually three reasons for this. So, it means that reliability analyses though, I say analyses a design method please understand this, so it is a tool reliability analysis cannot be 100 percent accurate, there are principally three reasons for this. Reason number one, it is practically impossible to identify all uncertainties, hence engineering judgment is applied, and that is the first reason.

The second reason could be methods of modeling and analyzing them means the uncertainties are not easy. Therefore, many assumptions are made during analysis. These assumptions prevent the method to be 100 percent accurate that is the second issue.

(Refer Slide Time: 47:01)



Analytical formulation of limit state surface and integration of probability density function, within the domain of interest is complex, is not that easy. I will show you the probability, density function accounting for different levels of uncertainties will make the integration of this PDF very, very difficult. It will not be possible at all, so these three reasons clearly and explicitly declare that reliability analysis can never be 100 percent accurate. There is always a probability of accuracy attached to reliability methods by default and that accuracy can never be 100 percent and all these reasons cannot be corrected, also.

You cannot say I will do analysis and modeling without any assumption and idealization at all, just not possible because every modeling or every analysis tool has what we call structural idealization or certain assumptions. All these assumptions will prevent accuracy or will not take you towards 100 percent accuracy. This of course, you will understand one say, showing you some expressions of probability density function, then you will see what is the complexity involved. Now take it granted that it is having a very high degree of complexity, when you attempting to integrate the PDF over a specific domain of failure.

This is actually a psychological or physical or an inferential reason, that you will not be able to actually declare that you have accounted for all uncertainties because uncertainty itself is a term, which is not defined. You cannot say can you define uncertainties? There

will be uncertainty even in the definition; uncertainty itself is a term which does not have a close form explanation. So, one cannot say, yes I have considered all possible uncertainties. The moment you are not sure about it, your analysis cannot declare or cannot be declared as 100 percent accurate. So, reliability methods are not 100 percent accurate.

There are problems we have understood, we have started introducing to you how reliability is different from safety. And why partial safety factors which has been accounted by the designers for the past 30, 40 years in design principles, need to be revisited reinvestigated using reliability as a tool, why? Because reliability is far ahead of safety, but reliability and risk together will form a complete explanation, and solution for a given engineering process.

So, reliability is purely a technical solution, which can be understood, which can be also prepared only by people who are having enough practical experience in design and who can apply judicially, the engineering judgments on a given process because that is demanded. Whereas, safety is simply a statistical tool, that is what we will discuss in this lecture will take you forward in the next lecture explaining few more factors which are important for reliability analysis.

Thank you.