Failure Analysis & Prevention
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Lecture - 16
Industrial Engineering Tools for Failure Analysis: Reliability I

Hello, I welcome you all in this presentation related with the subject failure analysis and prevention, in this presentation I will be talking about the reliability which is very much related with the analysis of the failures which will help us also to see what is the possibility of the failure of particular product over a long period of the service. So, this is done based on the history of the failures of same kind of the products. So, that topic is basically the reliability.

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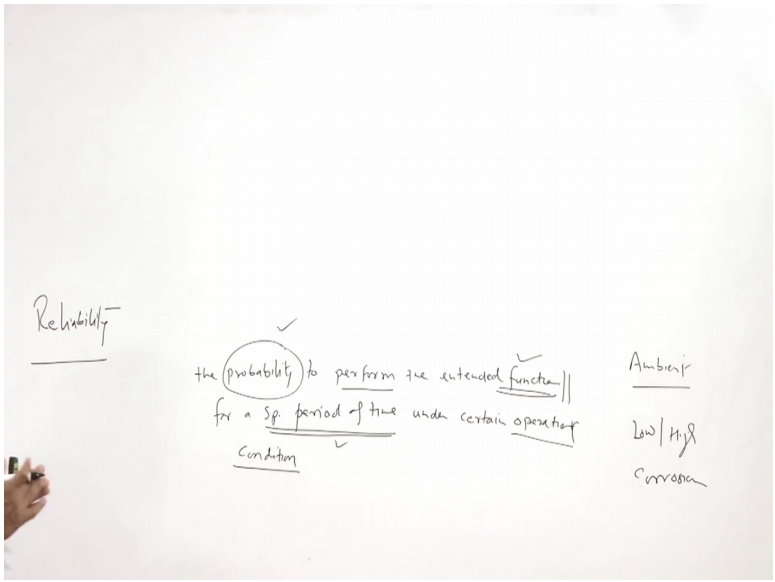

So, to understand the reliability first of all we need to see it is to be understood that how good a product is so, that it will perform the desired function for a certain period of time. How a product is reliable means, it will deliver the job it will deliver the goods it will deliver the services which are expected from it if a particular product is able to deliver the required function effectively for a specific period of time will say that product is a reliable.

So, but to define this is specifically like it is reliability is the probability basically probability to perform probability of course, of a product or of a system or of an

individual process so, to perform the intended function for specific period of time. So, it will be like 2 months or 2 years or 10 years or 2 hours like that only for a specified period of time under certain operating conditions.

So, they are certain constant also, so reliability will be comprising these 4 components, one is the probability to perform and the second is the performing the desired function. So, if the system is performing, but not giving that desired results or not able to deliver as expected, then will say that system is not performing well and it has failed for a specified period of time this is the another component. So, probability to perform, performing the desired function and for a specific period of time and then certain operating conditions.

Because if our operating conditions change then the this probability to perform may change like if some product is able to perform properly under the ambient conditions, but the same may not happen in case of the either low or high temperature conditions or in corrosive environment. So, the probability to perform the intended function will change with the change of the operating conditions or those a specific conditions for which the probability has been art means the reliability has been defined.

So, this is how reliability is a define and it primarily comprises certain things what are those there is probability means one numerical value which will be indicating the, which will be indicating the probability to do the job for a certain period of time. So, there will be of course, time period at the moment at a particular movement for which the reliability is being checked or the same, at the same time we need to also mention the conditions under which it will be performing.

So, the rate of failures may be different under the high or low temperature conditions as compared to those under the ambient conditions. So, we need to also specify the conditions under which this kind of probability of a product or system will be to perform for a specified period of the time under specific set of conditions. So, this is what has been presented in the slides like ability to perform.

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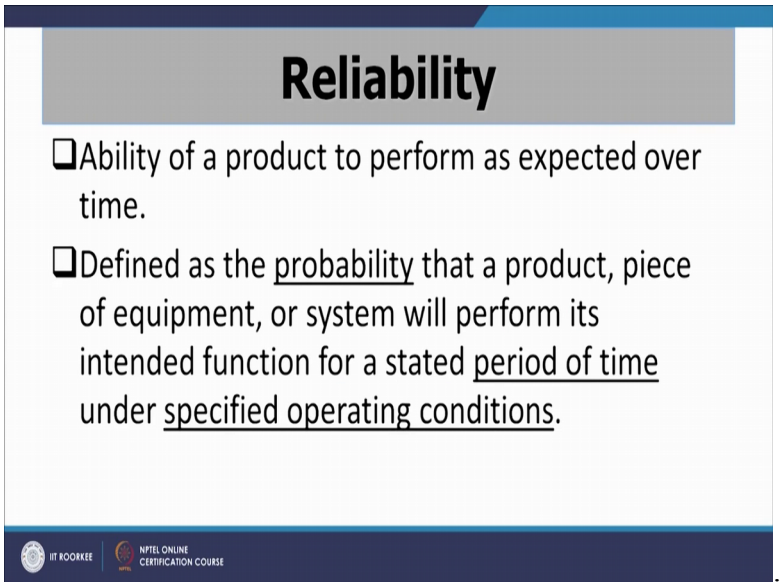

Ability of a product to perform as expected over a certain period of time and it is defined as probability of a product, or piece of equipment or system that will perform it is intended function for a specific period of time under a specific operating condition.

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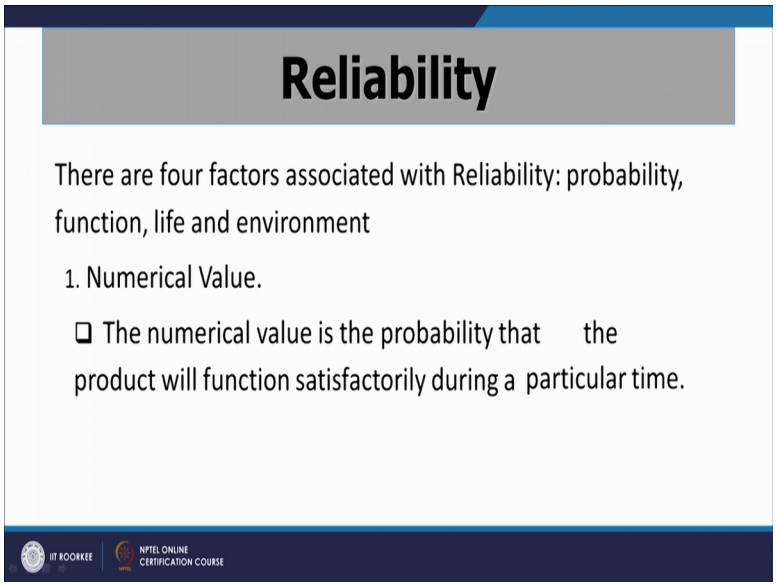

So, in this way the reliability comprises 4 components, one is the probability, it is like a numerical value that a product will perform satisfactorily for a particular period of time.

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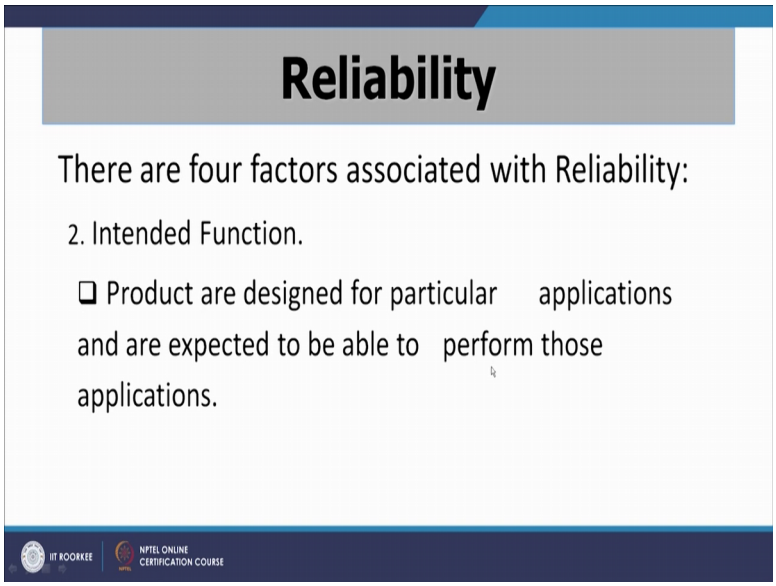

Second is the function the expected work or the job which will be done by a given product or the system and then the life.

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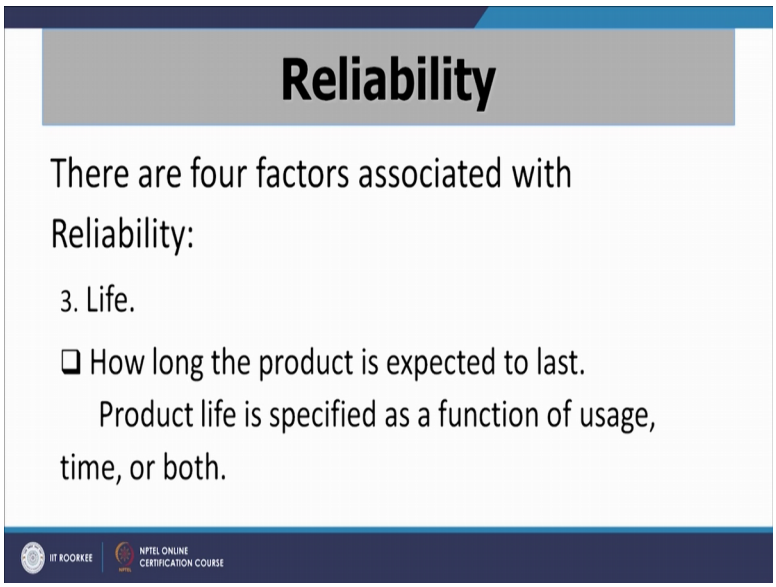

How long the product will perform and at which movement of the time we are trying to access the reliability of the product with regard to the performance. So, how long the product is expected to lost the product life is a specified as a function of use and the time or both. So, there can be any number of there can be n of ways to specify the life.

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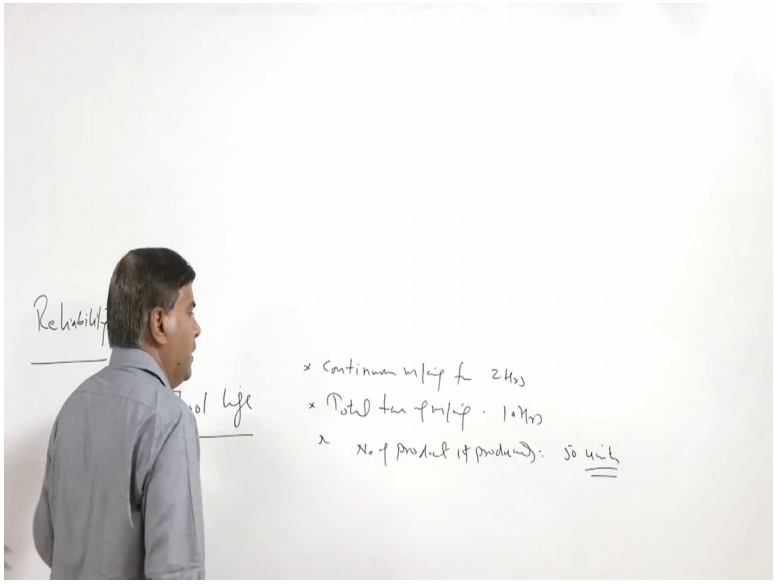

For example the tool life in metal cutting can be specified in the number of ways like continuous machining for 2 hours or if it is not the actual machining the total time of machining which also includes the idle time. So, it may be 10 hours or tool life can also be expressed a number of products it produces products it produces before getting failed or before it is life is over.

So, nice maybe like 50 units are produced by a particular product. So, one which is producing 60 will be offering better life under the identical conditions as compared to the one which is producing just 50 units. So, there can be number of ways to express the, that time period for which a particular product performs.

So, similarly like the life of the pressure cookers is also expressed it commonly like the number of years for which the warranty is given by the companies. So, they are different ways to express the life aspect related with the reliability and based on the reliability only the warranty kinds of things are specified.

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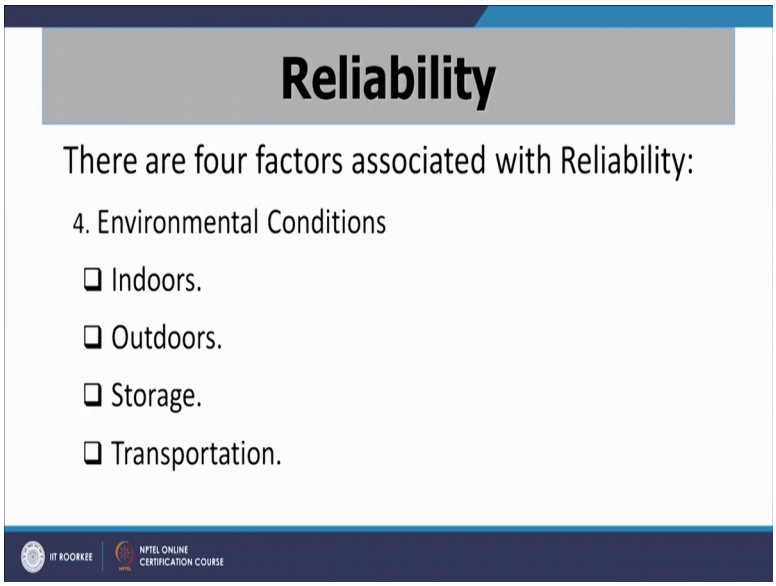

And the as far as the specified conditions under which the reliability is being express it mentions that kind of conditions in which the product will be working say indoor, outdoor or the storage conditions and the transporter conditions under which it will be used.

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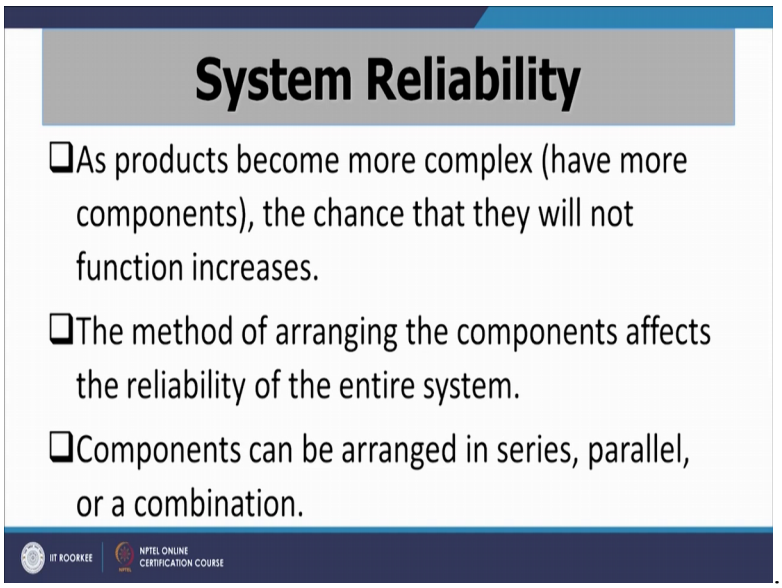

So, in order to understand the reliability different dimensions related with the reliability will consider one case.

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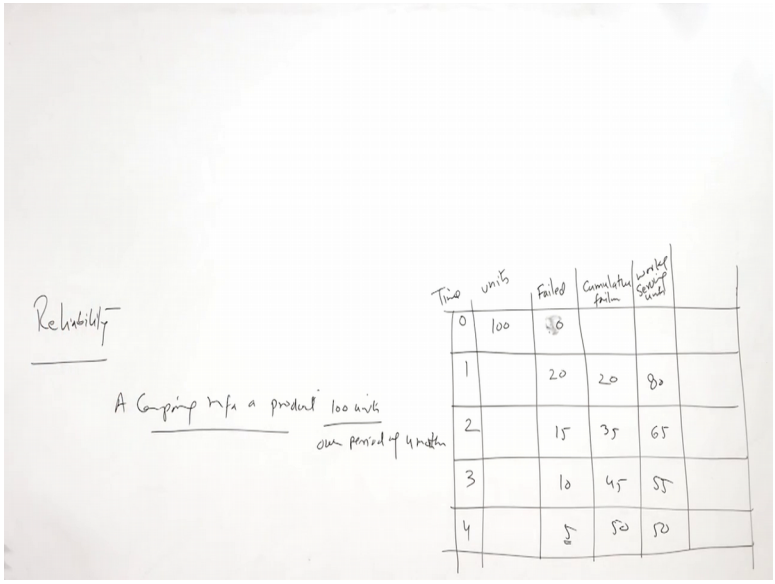

Where in say a company is manufacturing a product and it evaluates 100 units over a period of 4 months and the data regarding that is say generated. So, there are 100 units which are to be tested over a period of the time of 4 months during their function. So, here if we see the month wise here 0 time this is the first column is the time the initial stage then will have the first month, then second month, third month and say fourth month and the number of units in the beginning are. So, unit's number of units which need to be tested in the beginning these are say 100 and a number of units failing.

So, the failure of the units so, here in the beginning there is no failure and here we have say cumulative failure cumulative failure and then we can say working or surviving units number of units working or surviving. So, this kind of the data now can be used to assess the various parameters related with say the 100 units tested after a particular period of time say that is one unit say it may be 1 week or 1 month or 1 year like that.

So, if you are finding that 20 number of units that failed or life say 20, 20 failed. So, this data we can also mention here failed is here number of field is 0 in the beginning number of the cumulative failures will also be 20 and the number of units working is here say like 80. So, at the end of the one unit, one period of time, one unit period of time or the number of units failed is this much number of units cumulative failed are this much and the number of units working is this much at the end of the 2 unit of the period of time or at the end of the 2 months say.

So, our number of units failed is 15 to the cumulative failure is 35 and the number of units left is 65 say at the end of 3 again 10 failed. So, the cumulative failure is 45 and the number of units working is 55 and then at the end of the forth period of time say again 5 units failed and units during this particular period of time after that at the end of 3 and at the end of 4 the number of failures the units is 5 total cumulative failure is 50 and the left out units is also 50.

So, this is the kind of data of which is if he has been generated over a certain period of time when we are trying to assess like if there are 100 units in the beginning. So, as a function of time how many units are getting failed. So, to assess the failure behaviour, now we need to find out the various how to calculate the various parameters related with this, say the first one is the failure density.

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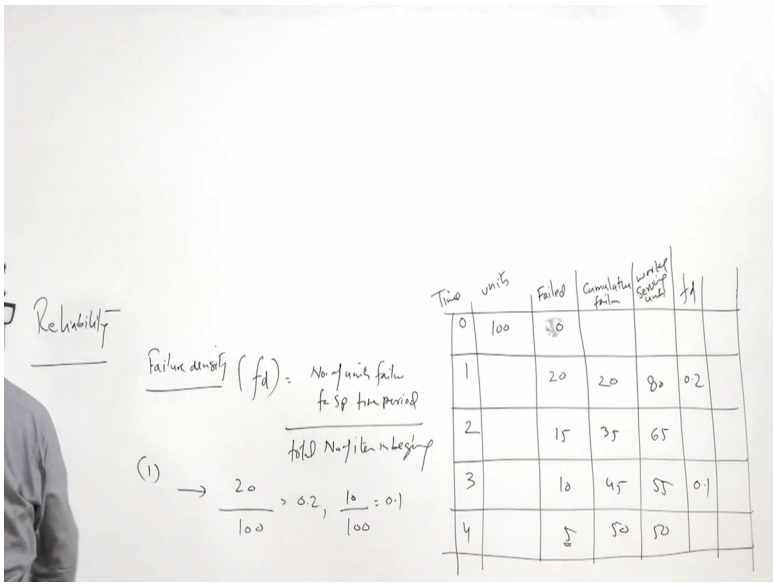

So, the failure density which we can say f d is calculated using the number of units failed for a specific time period divided by the total number of items in the beginning. So, say if we consider the first period of the time that is a after the first unit after first months. So, number of units failed is 20 and the numbers of units in the beginning are 100 so, the failure density will be 0.2.

So, if we mention here like f d, then it will be 0.2 at the end of the first month, similarly if we calculate the failure density for some other period of time like say some for third period of time. So, the number of units getting failed, at the end of the 2 and at the end of

the 3 number of units getting failed are 2 sorry 10 by 100. So, the failure density will be 0.1. So, this is how we can calculate the failure density, there is another parameter which is commonly used is a failure rate.

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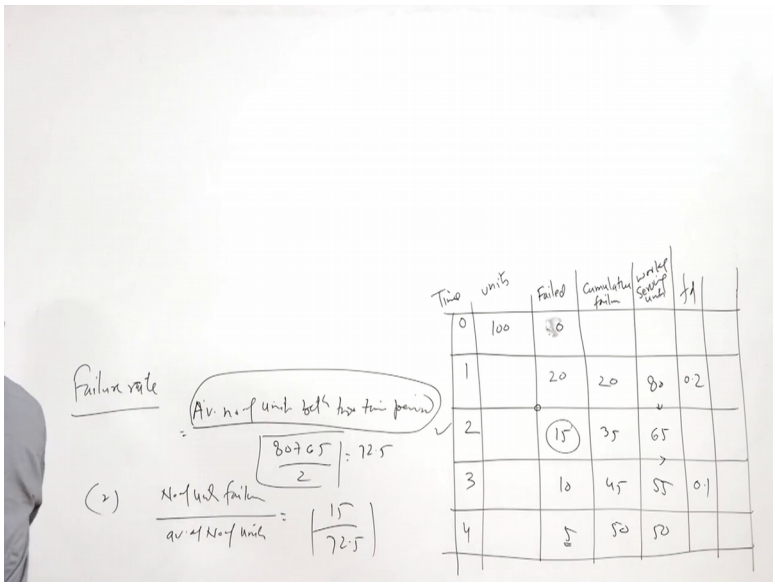

So, failure rate is calculated using the they are 2 ways basically to calculate the failure rate and that is like one is the average number of units between the 2 time periods say at the end of the first month we are having the number of the working units are at the end of the one first month we have the number of working units 80 and at the end of the second month we have the number of working units 65.

So, what we have to do average number of units at the end of the one month and at the end of the second month is obtained 80 plus 65 divide by 2 this will be the average number of the units which for which the average failure rate will be identified and at the same time we have to see for this particular period how many units are getting failed.

So, the number of units failed in this time period that is the second time period divided by average number of units which we are calculated number of units at the end of the president period and number of units at the end of this specific period. So, that will be like say here it will be 72.5 so, the average failure rate here for this can be obtained through the number of units failed during this specified period is 15.

So, 15 divided by 72.5 so, this is one way to calculate the failure rate where is where average number of units working units in that particular time period are used to calculate the failure rate. So, now will look into, how to calculate the reliability to perform a given function at a specific period of the time.

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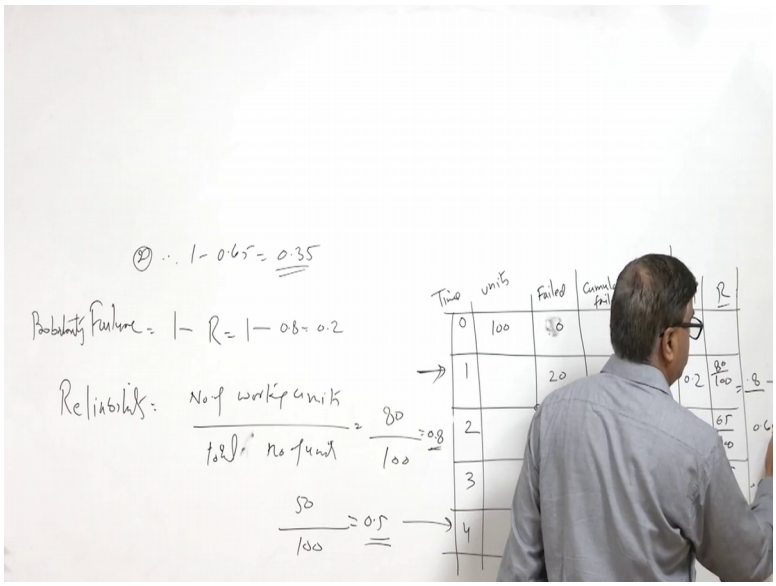

So, to calculate the reliability basically we have to consider the number of working units at a specified period at the end of the specified period of time and the total number of total number of units which were there. So, stay here in this case the reliability at the end of the first period is how much reliability the number of working units at the end of first period is 80 and the number of total units which were there is 100 so, the reliability is point 8.

So, at the end of the fourth reliability to perform at the end of the fourth time period and number of working units is 50 and the number of units which was there in the beginning was 100 so, it will be like 0.5. So, this is about the reliability about the number of units that will you working at the end of particular period. So, what is the reliability that particular product will be performing up to a particular period of time say in this case it will be.

So, if we just calculate the reliability here at the end of the first period 80 divided by 100, at the end of the second period reliability will be like points a 65 divided by 100, at the end of the third period it will be 55 divided by 100 and at the end of forth period like 50

divided by 100. So, what we can see your reliability is getting decreased as a function of time with the increase of the time.

So, here like say 0.55 and then 0. 5. So, gradually the reliability of the product to perform will keep on decreasing. So, the probability of the failure or the failure probability also can be obtained or unreliability can be calculated in different way or the reliability for a probability for the failure is obtained from the failure probability is obtained from the 1 minus the reliability.

So, if that is to be determined to the failure probability, probability of the failure at the end of the first period will be like say 1 minus 0.8 that will be equal to 0.2 and at the end of the second period it will be like 1 minus 0.65. So, the reliability the probability of failure will be 0.35 and likewise we will see that other probability of failure will keep on increasing with the increase of time here it was 0.2 then it was 0.35 then 0.45 and then 0.5.

So, the probability of failure will keep on increasing and the reliability will keep on decreasing as a function of time we know that most of the components are not made of the single units many times we need to bring the number of components together. So, that any useful function can be achieved through the products and the processes and therefore, instead of calculating the reliability of individual products reliability of the systems is also required to be obtained.

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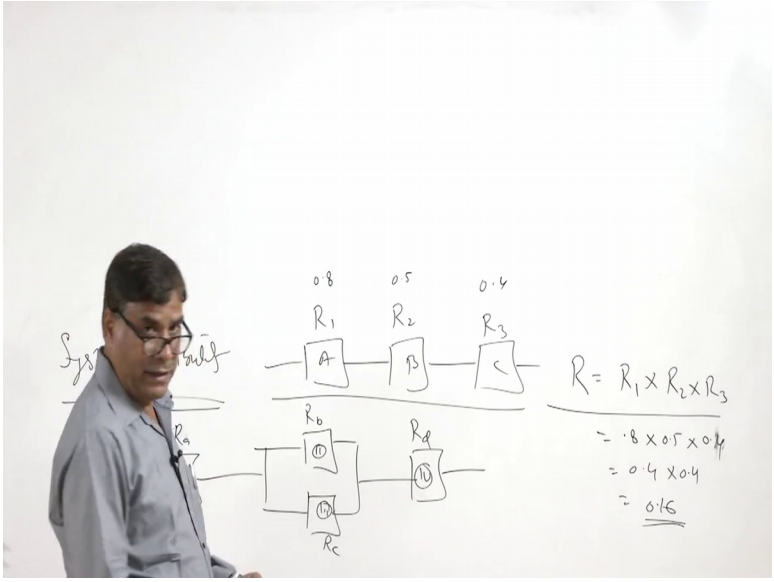

So, the system reliability is different so, next one is basically the system reliability we know that the system reliability means we are using the number of components like the component 1, component 2, component 3. So, the components can be arranged in broadly 2 ways or there can be combination of them like the components arranged in the sequence like in series like this or the components are arranged in parallel like this and so, this is the kind of system here if you this if you see broadly the component 1, component 2, component 3, component 4.

So 2 and 3 are in parallel and 1, 2, 3 and 4 are in series, similarly here the A B C all these components are connected in series. So, when we are having the number of components in a system and the reliability of the each component is different then, how to obtain the reliability of a system as a whole say R 1 R 2 R 3 is the reliability for this ABC components and like say what we can say like R a, R b, R c and R d is reliability of these 4 components which are connected in a series.

So, they are these are the 2 broadly 2 ways by which the systems are club together to make them useful for the different functions and depending upon the way by which the different components have been arranged reliability will vary. So, when the components are connected in series the reliability of the system as a whole R is obtained from the reliability from the product of the reliability of each individual a component like R 1, R 2, R 3 for the components when the components are connected in series.

Suppose the reliability of the product A is 80 percent at the end of a specified period, reliability of the product at 2 is 0.5 and reliability of the product 3 is 0.4 at the end of a specific period of time. So, in order to calculate the reliability of the system as a whole after certain period of time what we need to do 0.8 multiplied by 0.5 multiplied by 0.4. So, this is what will be giving us 0.4 multiplied by 0.4 for the system reliability will be 0.16 this is how do we calculate the reliability of the system when they are connected in series. So, this is what we can see here also when the system is connected in series this is how the reliability can be obtained.

So, here if we see if with this kind of reliability if in a system we have just 2 components.

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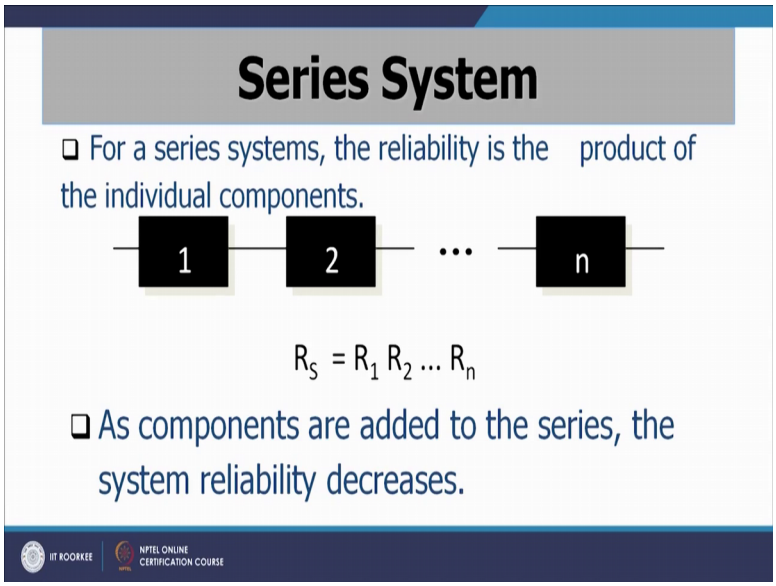

Then the reliability will be here what we can see the reliability in that case will be 0.4. So, in case of the series when the number of components are connected in series as the number of components increase there will be continuous there will decrease in the reliability. So, what is desired, it is always desired that the system is made of as few number of components as possible. So, that it can have the more reliability. So, this is the one kind of system where the different components are connected in series.

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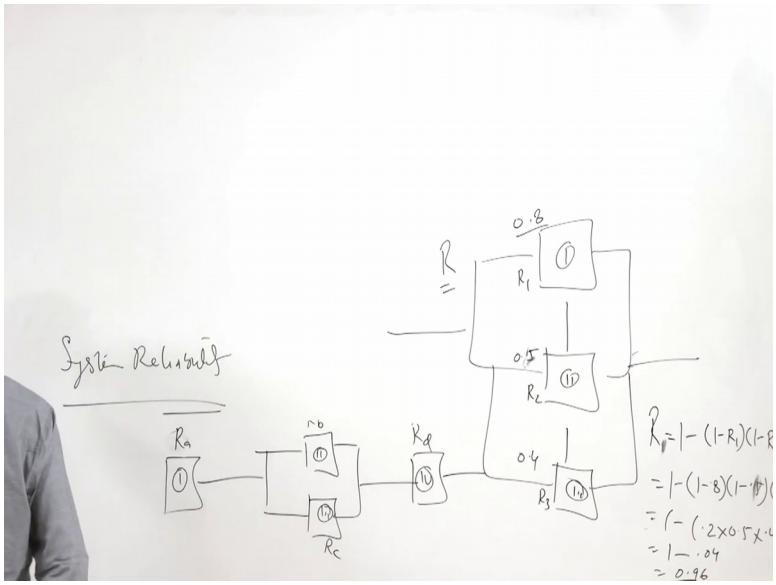

Then we will take up another system where like say the different components 1, 2 and 3, in this case other components are the series is like this where all of them are connected in parallel and this is how the system is made. So, in this case also the reliability of the each component will be different say it is R1, R2 and Rr3. So, in order to calculate the reliability of the system as a whole R will be obtained through the, this simple equation what we can see here when the system is connected in parallel.

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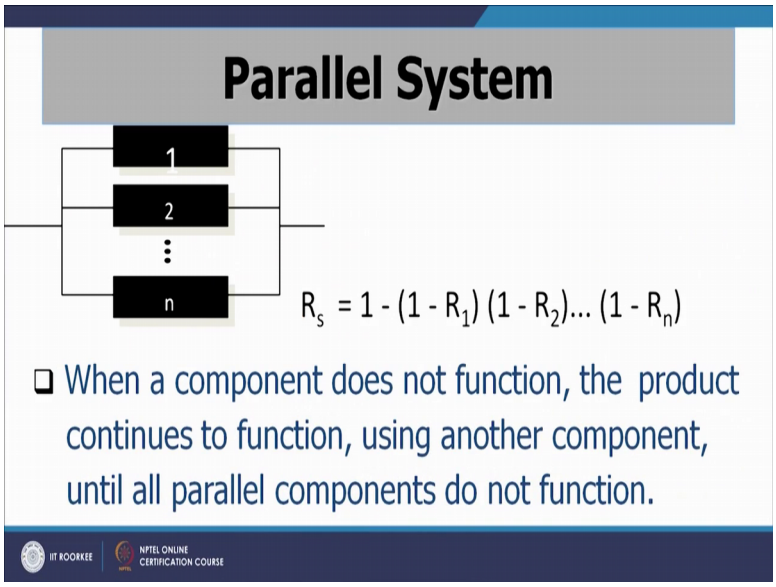

Then the reliability is obtained through the reliability of the system in parallel is obtained through the 1 minus 1 minus R 1 into 1 minus R 2 into 1 minus R 3. So, this is how the reliability of a system when they are connected in parallel is obtained, also here the similarly the values can be put in like if the reliability of the first component is 0.8, second component is 0.6 and third component 0.5 and third component is say 0.4.

So, in order to calculate the reliability of such kind of system when they are in parallel so, will be doing them 1 minus 8 into 1 minus 0.6 sorry 0.5 and into 1 minus 0.4. So, if we see 1 minus 0.2 into 0.5 into 0.4. So, this will be giving us 1 minus it will be 0.2, 0.4, 0.04. So, the reliability of the system will be high especially in this case 0.96 as compared to the case when the similar kind of reliability, but the components were connected in series the reliability was very less.

So, what we can see here when the components are connected in the series for the similar kind of the reliability of the individual components we get the match highest reliability

of the system. So, this kind of the arrangement of the systems for high reliability is used especially for those systems which are very critical for the performance and where there is a huge risk of the life and property.

So, especially the components like the spacecrafts and the aircrafts where the 2 engines are normally used for the passenger aircrafts. So, that even if one goes out of order, the second one can be brought in and can work in so, either in total the system reliability will be high and if one fails in another comes into the action so, that any kind of the mishap can be avoided.

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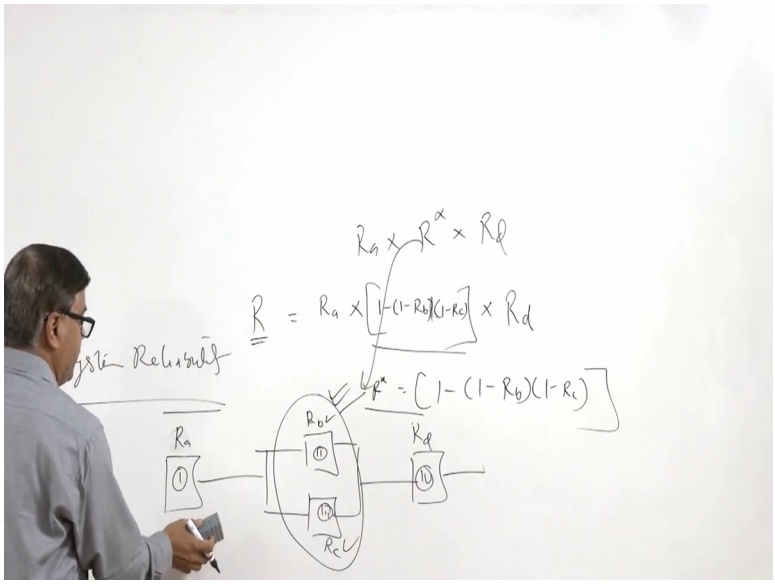

For those systems which are clubbed systems then in that case for the club systems if we see those which are arranged in parallel their reliability is obtained separately like for R b and R c because these 2 are arranged in separate and separate way and other remaining 1 and 4 are connected in series with this come combined arrangements.

In order to obtain the reliability in this case the R a multiplied by now liability for this one is to be obtained separately multiplied by Rd. So, this is how the reliability for the system clubbed systems where both series and parallel kind of arrangement has been used. So, in this particular case what we have to do, to obtain the reliability what again we to use the same equation 1 minus R b into 1 minus R c, R b and R c are the reliability of the components which are connected in parallel. So, their reliability of this combined system will be calculated separately.

So, if say R star is the reliability of this parallel system for which reliability is as can be obtained using simple equation as have just mention 1 minus R b into 1 minus R c, this is how we can determine for the combined system. So, we can simply replace this entire value with a Ra into R star into the Rd, R star represents the reliability of the system which is arranged in parallel.

So, this is how the reliability for the systems in series and reliability of the systems in parallel or the combined systems where both series and parallel kind of arrangement exist reliability of the system as a whole can be obtained. Now we need to see it is always desired that a product performs the intended function for a longer period of time without much tendency for the failure and for that purpose we need to see the certain aspects that will be affecting the reliability of the product and for that purpose there are 3 important factors.

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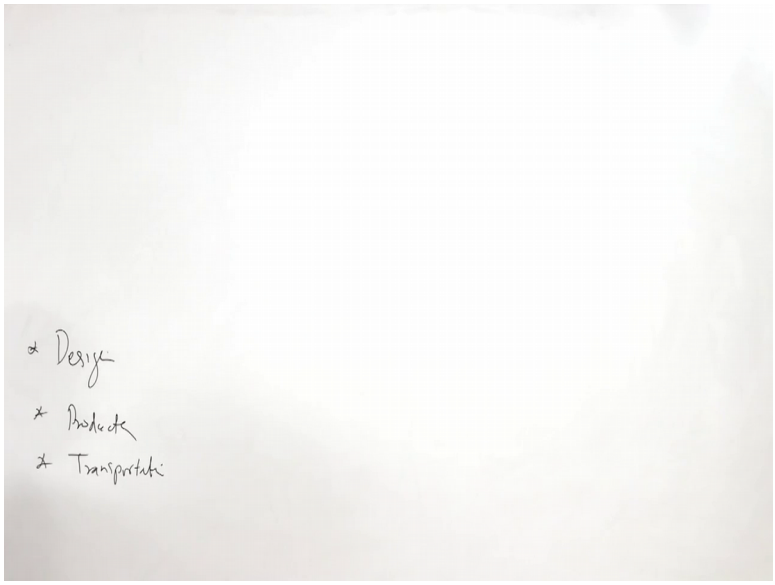

Related with the especially mechanical products, reliability of the product to a great extent is influenced by the design then the production and then a the transportation or the way by which it is installed and allowed to work in a particular kind of condition. So, as far as the design related aspects in this is very important because the kind of the factor of safety which has been used, kind of the tolerances which have been identified, the kind of material which is being used, kind of the arrangement of the different product is there whether they are arranged in series or parallel.

So, all those things will you affecting the reliability will be going through these factors related with the design one by one we can see simpler is the product greater reliability more the number of units relate with the product lesser will be the reliability. So, efforts are always made to design the products that they are simple in design. So, that they are easy to manufacture similarly the number of fewer number of the components it is always desired what we have seen.

Especially in case of series when done as the number of components increases the reliability of the system comes down, another way of increasing the reliability to have the high reliability we can have the parallel arrangement, but in parallel arrangement if there are 2 or 3 number of units connected in parallel. So, when is expected to perform others will be redundant. So, that will simply increase the cost, but in at the same time it will increase the reliability.

So, those systems which are critical from the property from the life and property point of view this kind of a parallel kind of the arrangement is used with regard to the kind of systems which are their then over design efforts are made that slightly extra the dimensions slightly better material is preferred for the design purpose.

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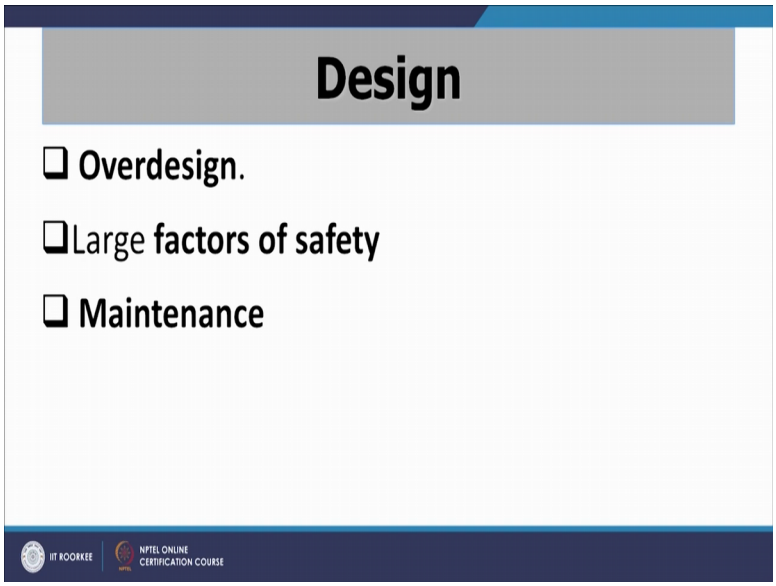

So, that it is it performs more effectively under the given set of the service is conditions use of the larger factor of safety means is also another way of going for over design where the dimensions were higher factor of safety will simply leading to the greater

dimensions improved, the design of the product so, increased possibility for proper working and it should recommend also that the proper maintenance is carried out and the kind of things which need to be done during the maintenance are specified properly. So, that the chances for the failure during the service are reduced.

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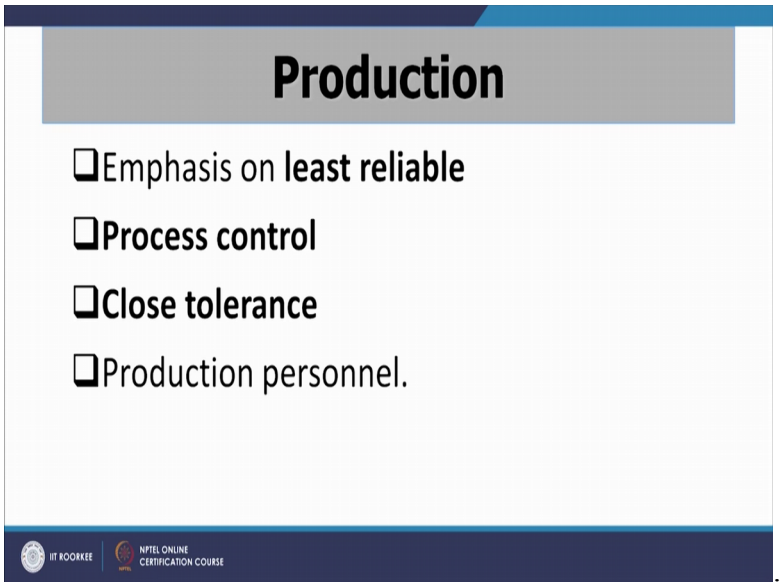

In production especially emphasis are given on those components which are less reliable like in system we have number of products and units all may not have their equal reliability. So, those which are less reliable there must be given enough attention at the time of manufacturing. So, that they can be made more reliable and for this purpose processor which is being used for their fabrication for their manufacturing is controlled in much better way.

So, we get what is better in terms of the quality in terms of the characteristics which are required for proper performance close tolerance is also in the same line if the product is being made with the much closer tolerance then it will have lesser variability and increase the chances for giving the desired performance.

And sensitization of the people and the personal all this stuff is also done so, that they take care of each and everything meticulously in order to make the products and processes feature will be performing the desired function. Similarly the transportation is another important aspect like how the components are packaged and shift. So, that the in course of the transporter in course of transportation they do not get damaged and their

capability to perform is not adversely affected. Now I will summarize this presentation in this presentation I have talked about the basics of the reliability and what are the factors which affect the reliability and what should be done in order to have the better reliability of product.

Thank you for your attention.