Industrial Engineering
Prof. Inderdeep Singh
Department of Mechanical & Industrial Engineering
Indian Institute of Technology, Roorkee

Module - 4
Lecture - 18
Reliability

A very warm welcome to all of **y**ou in this lecture on reliability. In the series of lectures, we have been discussing various topics related to industrial engineering and reliability is also one of the key aspects of industrial engineering. In our lecture on product design and development as well as on quality, we have seen that reliability is an important aspect of any product or of any system.

The product is said to be of very high quality if it is reliable; although reliability is 1 of the many aspects that dictate the quality of a product. But we need to understand that what do we mean by reliability? How do we define reliability? What is the reliability function? Then, we need to understand how, the reliability changes over a period of time with the help of bath tub curve.

Also we need to understand that if the components are connected in series, how do; we get the reliability of the system. And if in a particular system the components are attached in parallel, how would be evaluating the reliability of that particular system. So, just to start the discussion on the reliability; reliable a reliability is one of common word which is used by everybody. Sometimes we say that particular companies very reliable or the products made up that company were made by that company are very reliable

Sometimes in our social terms also, we use reliability as one of the key measure. Always we say that; that neighborhood, in the neighborhood that neighbor is more reliable as compared to the other. Sometime we say that these friends are more reliable than those friends. So, reliability is something; which is having its implication over a period of time. So, it is a time bound phenomenon. It is not that reliability is something which is constant; so with period where our reliability function is going to change.

So, in today's lecture, what we are going to discuss is; we are going to see that what do we mean by reliability? From the very basic definition, we would go on to build the various aspects of the reliability. Thereby, we would be seeing that what are the

measures of reliability? We would be seeing, how reliability or the failure rate varies over a period of time? Also we will be seeing that; if the components are connected in series, how do they look like and what is the reliability of the system? And if in a particular system the components are attached in parallel, how the reliability varies? So, that is the complete gambit of what we are going to discuss in today's lecture.

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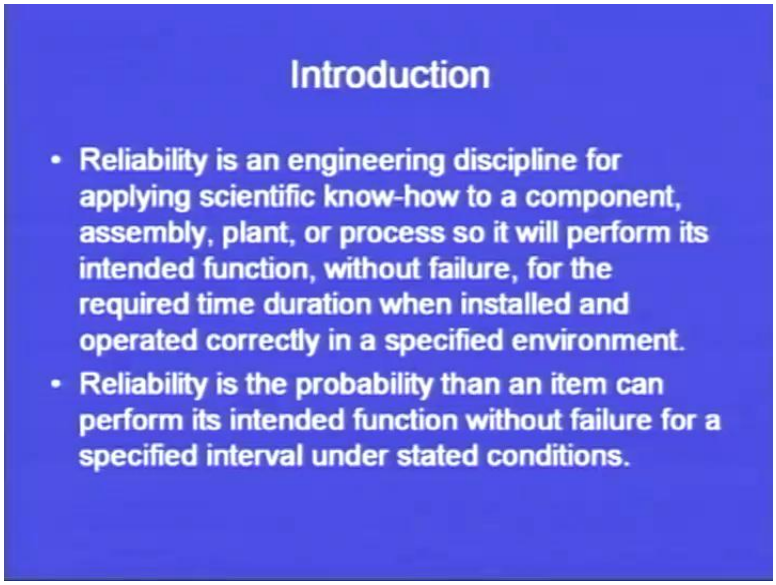

So, let us start with the very basic definitions of reliability. Reliability is quality changing over time or a motion picture instead of a snapshot. So, if we talk about some other properties which maybe snapshot; snapshot means they are constant. But, reliability is not something which is constant, it varies over a period of time and it is subjective to a time. So, reliability is quality changing over times.

So, initially we may have a system performing at some particular quality level and with the passage of time that quality may degrade. So, it is not constant; reliability is a. function which is always varying with time. So, reliability is a measure of the result of the quality of the product over a long run. So, it is a measure of the result of the quality over a long run.

So, if any product we have designed and we say this product is reliable, then that product should perform its intended function. What I mean to say is that it should be able to perform satisfactorily under the desired conditions over a substantial or we can say, specified period of time. So, reliability as you can see on your screen has been defined.

We will see some more definitions, in order to have a better understanding of the word reliability in terms of engineering sciences.

So, otherwise we, I have given you so many examples in our day to day to life. We say that friend is reliable, that friend is not reliable or that motion is that particular transposition system is reliable, bus system reliable; railway is unreliable or air: if you travel by air it less reliable as compare to travelling by train. So, subjectivity is there but, most of the time we use this word reliability in so many different aspects. But, here we are trying to study reliability in terms of engineering and in terms of products and services.

So, you can see that first thing that we have established till now, is that reliability is the time bound phenomenon and it is not a constant or independent of time phenomenon. So, reliability is a measure of the result of the quality of the product over the long run. So, reliability terminates with failure that is, unreliability occurs. So, what is the end point of the reliability; when the product stops to perform its intended function, at that particular moment of time, we say that now the unreliability has a occurred. At this moment of time we cannot say that the product is reliable because it has failed.

So, we can say that reliability is the active life of the product before, the actual failure or before its stops performing its intended function. So, till now we have just established one important aspect of reliability and that is that the product is going to perform over a period of time satisfactorily. So, it is a time bound phenomenon.

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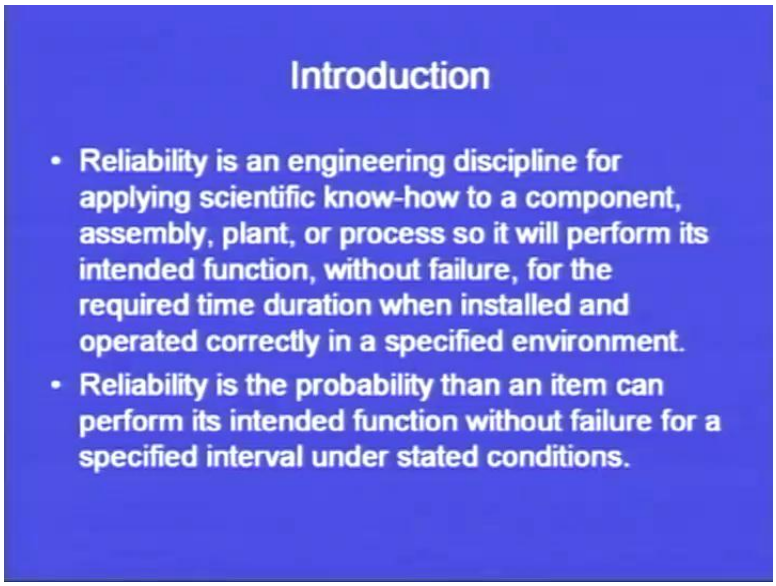

Reliability is an engineering discipline; again and again I am saying that we are talking reliability in context of engineering. We are not talking reliability in terms of our social life or in terms of our neighborhood. We are talking reliability in terms of engineering applications. So, reliability is an engineering discipline for applying scientific know-how to a component assembly, plant or process. So, it will perform its intended function without failure for the required time duration, when installed and operated correctly in a specified environment.

So, you can see that s o many different aspects have been given in this particular definition. So, you can see we are applying scientific know-how to the components. So, we have designing the component or an assembly plant or a process. So, we are basically designing using scientific know-how; a component or a process or you can say assembly plant. It will perform its intended function so that the product or the process or the assembly or any plant that we have designed; it performs it intended function.

If you remember the lecture, on value engineering, we have discussed this function word in great greater depths. So, intended function has to be performed by the product or the service or the plant or by the process without failure. So, as soon as failure occurs it becomes unreliable; the product becomes unreliable, the service becomes unreliable, the plant becomes unreliable. So, performance of the intended function, without failure for the required time duration; because it is a time bound phenomenon.

We are having a specific time that this product or this service is going to reliable for another 6 months or for 1 year. So, it is designed for that particular time span; so for the required time duration, when installed; so when it is operating. So, it is not that; we have designed a product and it is not operating, it is kept somewhere in a box and we have not operating it and then we say, yes its reliability is in terms of time; no, when installed and it is operating. And another important point is that it is operated correctly, because sometimes the failures may take place, because of wrong actions of the workers or of the system.

So, it is it has to be operated correctly and in a specified environment. So; so many aspects are there to perform the intended function, when it is installed over a period of time, when operated correctly and in the specified environment. If this, all these facets have been addressed and the product achieves its maximum life and its performance is satisfactory during that life, we can say yes this product has functioned reliably. So, that is the important aspect of reliability.

Then reliability is the probability, that any item can perform its intended function without failure for a specified interval under stated conditions. So, this definition is, again a summarized form of the definition that we have seen earlier. So, once again I would go through this so that you get the each and every aspect of reliability.

Reliability is the probability; that an item can perform its intended function, perform its intended function, so that it is able to justify the needs and requirements of the customer or the person who as acquired that process or plant or service. So, perform its intended function without failure. So, as soon as failure occurs we say, now the system is unreliable for a specified period of time; time bound and under stated condition.

So, the conditions have already been defined; they have already been specified that this product would be operating under these conditions. So, if the product operates under those conditions satisfactorily, then we say yes the product is reliable or the service is reliable. Now, from this definition or the definitions that we have already covered; we can very easily conclude that there are 4 or 5 different aspects related to reliability. Now, now those aspects we are going to cover in the subsequent slides.

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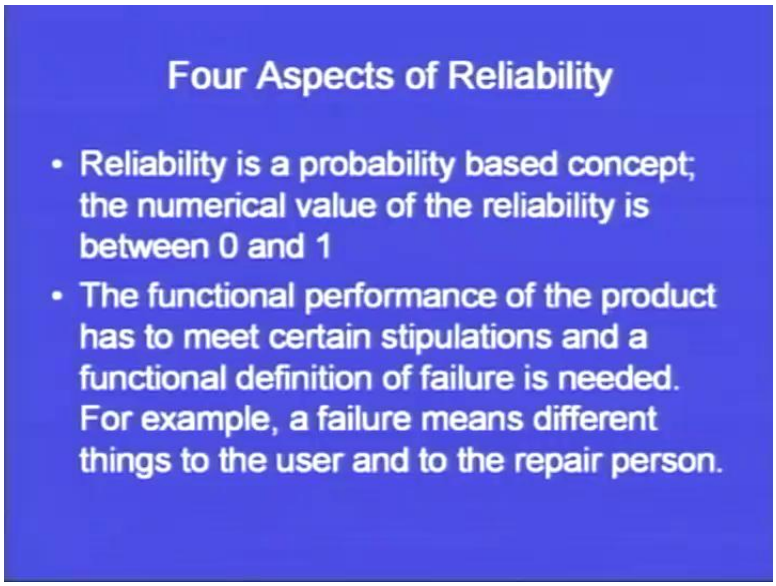

So, 4 aspects of reliability on the basis of the definitions that we have covered so far. So, reliability is a probability based concept. So, probability, if you have studied mathematics you might be knowing the basic information or the basic knowledge regarding probability. So, reliability is probability; concept the numerical value of reliability is between 0 and 1.

So, whenever we define system reliability, the value should fall between 0 and 1. Then, the functional performance of the product has to meet certain stipulations. Stipulations means: specifications or the requirements. So, the functional performance of the product has to meet certain stipulations and a functional definition of failure is needed. So, we have to understand and we have to fix that; yes at this moment of time and under these circumferences we are going to say that the product or the service has failed. So, the functional definition of the failure is needed. For example, a failure means different things to the users and to the repair person. So, the perceptions may vary from the users to the repair person.

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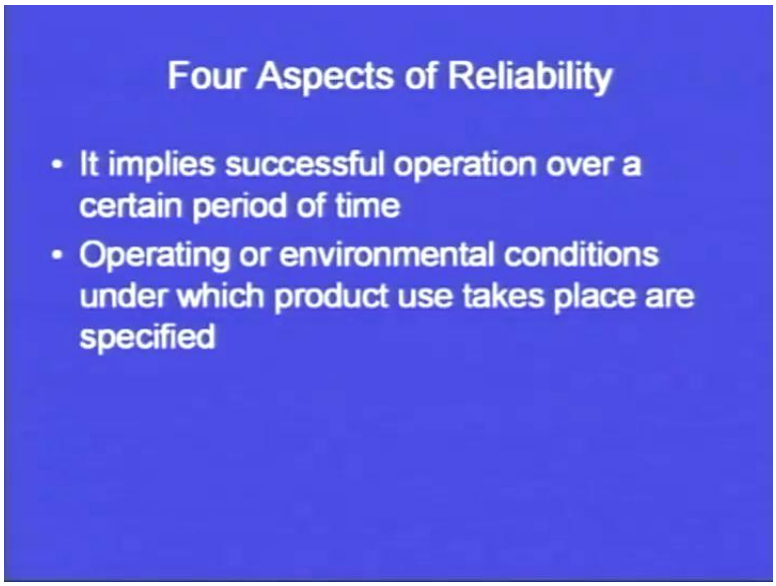

It implies successful operation over a certain period of time. So, again and again the probability of, a probability of function reliability is being discussed and it is varying over a period of time. So, it implies successful operation over a certain period of time. So, the product is performing satisfactorily and it is performing satisfactorily for a period of time. Operating or environmental conditions under which product use takes place are specified. So, the conditions; environmental conditions, operating conditions all are specified in the very beginning. So, what we have studied till now, are basic definitions of reliability. And as soon as the failure occurs, we say the product or the service has become unreliable.

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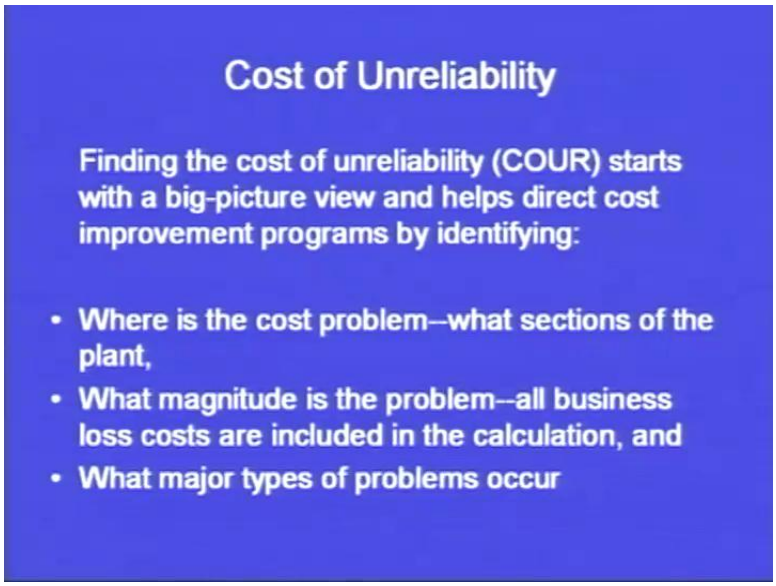

Cost of unreliability; now there are certain cost or certain damage or certain losses that are accountable to the company when the product or the service is unreliable. So, finding the cost of unreliability COUR starts with the big picture view and helps direct cost improvement programs by identifying. So, direct cost improvement programs are run by many organizations and we have to identify the following things; what are these things? Where is the cost problem-what sections of the plant?

So, where is this problem happening? Where we are spending more money the reliability is less. What magnitude is the problem like; what is the magnitude? And how it is going to have a influence on the cost structure of the organization? What magnitude is the problem? All business loss cost are included in the calculation and what major types of problems occur?

So, here in reliability or cost of unreliability we have to see that if a system or a process becomes unreliable, what are the costs associated with it? So, cost we can see, we can just summarize what we have seen, where is the cost problem? What sections of the plant? So, we have to pin point the area where the cost of unreliability is happening,, then what magnitude is the problem like, what is the extend what is level of the problem? So, all business cost are included in the calculation and what major types of problems occur?

So, we have to see, we have to pin point, we have to locate and then we have to see that particular location what are the different types of problems that are occurring, that are leading to the cost of unreliability. Then, we have seen that if the system or the process is unreliable; in those cases, the cost is building up and it may result into huge amount of losses and we have to cover up those losses, if we want to make our company a successful company. And how that is possible? That is possible, if you take into the accounts some important aspects that are useful in a improving the reliability of the product or the service.

So, we have to take into the account various aspects while designing the product. So we, we can say that there is specific set of tools and techniques, that we are to going cover now; which would help us to design the product, which will have a excellent amount of reliability. So, designing for reliability like; we have already seen design for manufacture in some of the previous lecture, design for assembly. So, similarly we can have certain inputs which would guide us in designing for reliability. So, what are these key ingredients that we should keep in mind?

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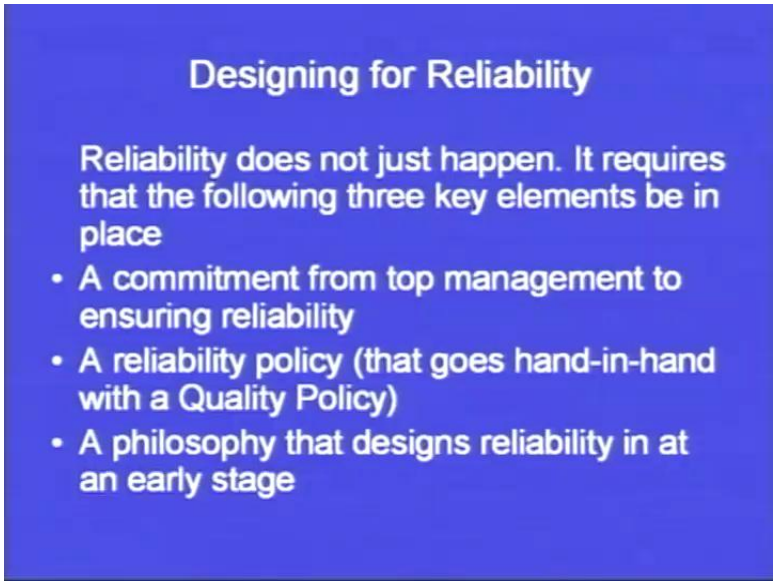

Reliability does not just happen, it requires that the following 3 a key elements to be in place. So, if this is the reliability is not automatically going to come into the system or the product. So, the reliability can come into the system if following 3 key elements are in place; a commitment from top management to ensuring reliability.

So, first thing is that the top management should make it a philosophy, should make it a point that each and every product or the service that there organization is providing is highly reliable. So, it means that if the top level of the management they are forceful they are trustful, they feel that yes the product and the service should be reliable. Then such type of commitment is going to percolate down into the shop floor or into the service team and the system or the service may become reliable.

So, the commitment from the top management is very essentially. Then a reliability policy, that goes hand in hand with the quality policy. Many companies have the quality policy that yes our product should lie in that this quality range or we are targeting this customer segment and this customer segment would except out product, if it is of such level of quality.

So, similarly a reliability policy should also be in placed that yes our product should be reliable up to this level and if that policy is framed, each 1 in the organization should adhere, should direct is actions towards achieving that much of reliability. So, first point is the commitment from the top management is required, second thing is the reliability policy like in terms of quality, policy a philosophy that designs reliability in an early stage. So, third important point is that there should be a philosophy in the organization that reliability should be in incorporated into the product and the service at a very early stage.

So these points if, are kept in mind or these 3 key element, if they are in placed in any organization, then the product or the service that they are producing would always be of, very high reliability. So, just to summarize these 3 points that the 3 key elements should be in place in order to make reliability a company function. What are these 3 points? These 3 points or these 3 key elements are a commitment from the top management, a reliability policy and a philosophy that designs reliability in at a early stage.

Now, we can say what are the ways to improve the reliability? We have seen, yes the top management is also interested in improving the reliability of the system. We also have a reliability policy on the bases of which our actions would be based and we have also formulated a strategy where, reliability would be inbuilt into the product of the service at a early stage. Now, what are the ways of improving the reliability? Use proven designs

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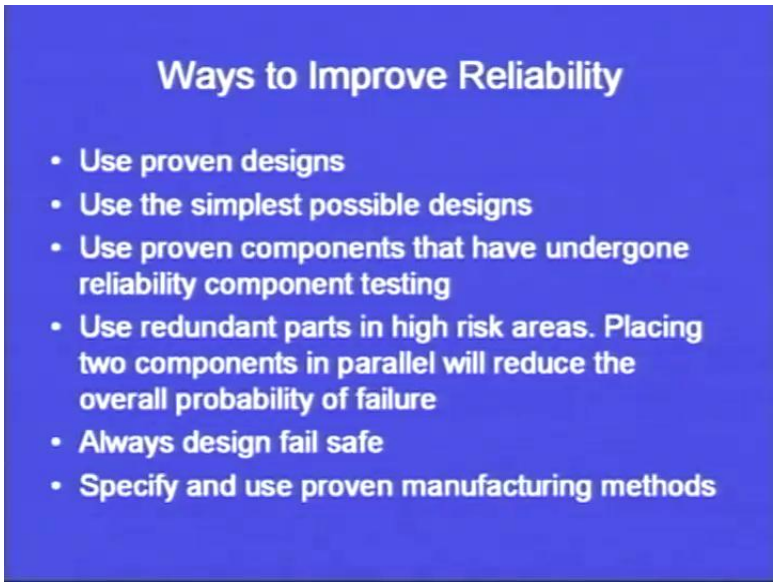

First point on your screen; so whenever we are designing a product, so many times we redesign the product finally we reach to a design which is optimal on most of the criterion. So, whenever we design a product we have to do a large amount of tradeoffs. So, whenever the product has been finally designed, a blue print of the product is ready, we say yes; this is the most optimal design for such type of product. Under certain set of requirements we say this is going to be the best design

So, we call that as the proven design, because it has taken care of all the constraints, it and it has taken care of all the criteria, it is satisfying the requirements for that are there for that particular product. So, whenever we have a proven design; we should use that the design instead going for relatively new design, in which we are not able to incorporate the factor of reliability. So, the very first point is that we should always go for proven design and we should not play around with different types of designs and later on we fall into the trap, where we are able to provide a very reliable product to the customers.

So, we should focus on proven designs. Second point is use the simplest possible design. So, again the first point is very applicable in this second point also that whenever a proven design is there it is a optimal design. All the various aspects and various facets of designing have been taken into account and it has come out to be the best design. Whenever we try to redesign; sometimes we tend to complicate the things or we tend to

complicate the design. Instead of a simple design, we may land into the very complicated design which may not at all be reliable.

So, the second philosophy is that always we should focus on the simplest possible design. So first thing is use the proven design, second thing is use the simplest design that is available for that particular product. Third thing is use proven components that have undergone reliability component testing. Know sometime the product is not directly made into integral part, it is made into different parts or different components and then these components are assembled together to make the final product.

Now, the reliability of this system or this product would depend upon the individual reliabilities of the components that have been assembled together to make this product. We need to understand that each and every component should have a true 1 track record of providing a reliable service. So, on your screen you can see the third point; use proven components that have undergone reliability component testing. So, forever system or product, we should use only those components which have undergone reliability component testing. If, we use those components; so their individual reliability is, would add up into the reliability of the complete package or other reliability of the complete product or the reliability of the complete assembly plot.

Fourth point is use redundant parts in high risk areas. Placing 2 components in parallel will reduce the overall probability of failure. So, taking an example of this we have a direct electricity or direct power connection in our house or in our laboratory or in our department or in our institute. So, direct connection is there for the power but, we have a back up option also, which can be diesel generation set or it can be and inverter in our in cases of our houses. So, what we are having? We having a back option that if there is no electricity or no power, still they we want be finding ourselves in dark; our back option would come and rescue us or it is going to help us.

So, the same thing has been given in point number 4. Use redundant parts in high risk areas. So, redundant part means: that 1 part is operational then there is a back up back up part or this part we can call as the redundant part. This part would only come into action, when this part fails; this fails, this would start functioning. So, redundant part would not result into the failure of the whole system. It would help us to make or to trouble shoot

the system. So, use redundant parts in high risk areas; so where this is essential, where the risk involved is too much; for example: in arrows space industry.

So, use redundant parts in high risk areas. Placing 2 components in parallel, 2 components in parallel will reduce the overall probability of failure. Always design fail safe. So, we have to design the product or the service in such a way that it is safe to failure. Specify and use proven manufacturing methods, so basically if we talk about any engineering product, how the product is manufactured? We start from the raw material, then we subject the raw material to a various or a spectrum of manufacturing processes and after the spectrum of manufacturing process is have done there bit on the row material, it comes out in the form of a final product.

So, whenever we have talking about reliability, already we have discussed, we have established that the components which are assembled to make a final product; the individual reliability should be proven and checked for each and every component. Similarly, the material or the raw material that we are using to make the final product should also be reliable. And lastly; the manufacturing processes that we are using to convert the raw material into the final product, should also be a reliable processes.

So, these are some of the ways, by which we can improve the reliability of the system. So, just to summarize these points; use proven designs, use the simplest possible designs, use proven components that have undergone reliability component testing, use redundant parts in high risk areas. Placing 2 components in parallel will reduce the overall probability of failure. Always design fail safe. Specify and use proven manufacturing methods.

So, if we are able to achieve these things or if we are able to take into account all these things, while we are developing a product, our product would be always be reliable or we can say our system would always be reliable.

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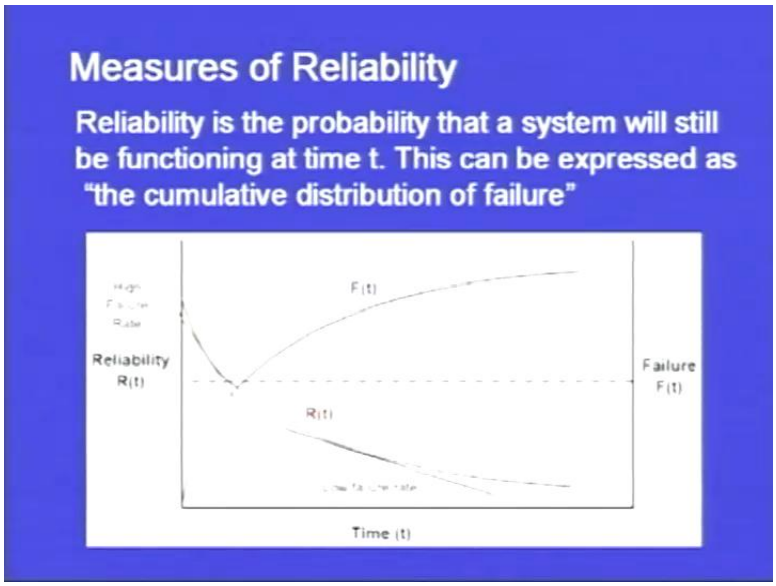

Now, we come on to the measures of reliability; how reliability is measured. We have till now seen that what do we mean by reliability? What are the 4 important aspects of reliability? Then we have seen cost of unreliability. We have also seen, what are the various ways of improving the reliability of the system? So, now we see that how we can measure the reliability?

Reliability is the probability; that a system will still be functioning at time t. So, we will say that if any time t the system is functioning we will say: yes it is a reliable system. This can be expressed as the cumulative distribution of failure. So, the cumulative distribution of failure is depicted by Ft in the curve. So, with passage of time, the reliability function Rt, we can say this is the reliability function Rt. This is decreasing over a period of time. So, here we see in the beginning, we have a high failure rate and with passage of time, we have a low failure rat. This we would also be seeing or this phenomenon we would also be seeing, in our discussion on the bath tub curve that we are going to see in the subsequent slide.

So, this is the reliability Rt which is decreasing over a period of time and this is the cumulative distribution of failure which is increasing over a period of time. So, the products would fail with the passage of time and reliability whose decrease over a passage of time.

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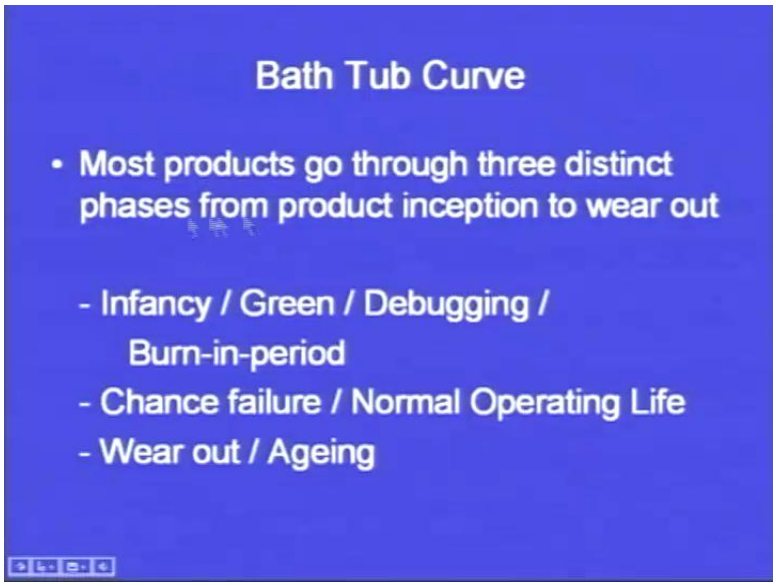

Bath tub curve: most products go through 3 distinct phases from product inception to wear out. So, 3 important phases are there. Product inception means: the product is introduced into the market and finally, it is wearing out. So, basically there are 3 important stages for each and every product. In our chapter on product or in our lecture on product design and development, we have seen that every product has a product life cycle. It is introduced into the marker and the demand for the product changes, with passage of time, it becomes stagnate and finally, the death of the product takes place.

Similarly, we have a bath tub curve. So, most of the products go through 3 distinct phases as a, there are 3or 4 distinct phases in the product life cycle also. So, here there are 3 clearly distinct phases from product inception to wear out. What are these 3 phases? We would see if these 3 phases and we would also be seeing that how the bath tub curve looks like and we will be seeing that what are these 3 phases?

So, first 1 is the infancy or the green phase, debugging or the burn in period. So, first phase basically can be named by any of these 3, 4 keywords that have been given here. So, we can call it as a infant stage or we can call it as a green stage or the debugging stage. So, debugging basically means: fixing up the problem. So, there may be some problems that may be there in the product, which maybe resulting in higher failure rate. So that is, we want to plug in those problems, we want to debug those problems, so that

at the product can perform satisfactorily they rough infant; infancy stage also infant mortality rate is something, by which we define the failure.

Then green, debugging as well as the burn in period. So, burn in period is the period of inception. Then chance failure or normal operating life. So, once the product goes through this initial phase or the first phase, then comes the second phase which is called the chance failure or the normal operating life. So, the failure rate is not that much in this chance failure or the normal operating life. So, it is nearly constant.

Then, the last stage is the wear out or the ageing stage. Now, wear out or the ageing stage means: that finally, the product has performed its function over a period of time and now the wear and tear has started to take place and with age the product has worn out and it is going to fail at certain movement of time. So, these 3 phases we have discussed, but now we are going to see them with the help of appropriate diagram.

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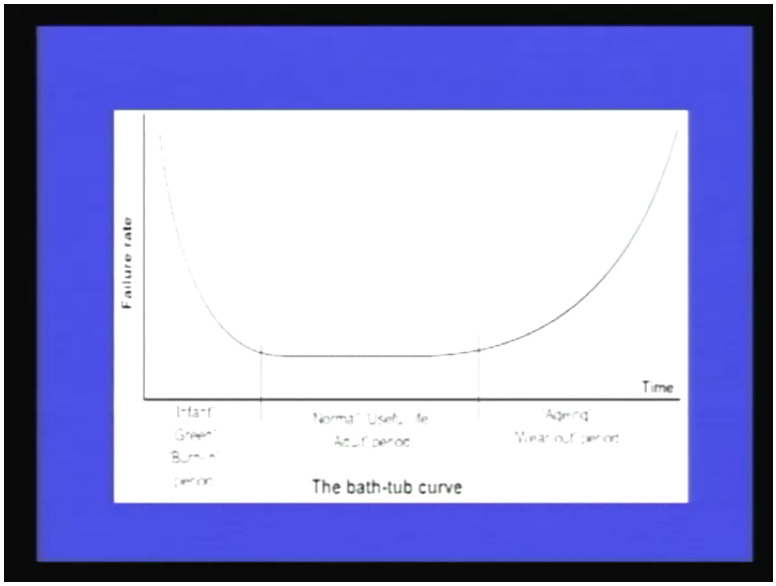

Now, on our screen a failure; on y axis we have a failure rate and on x axis we have the time. This is the time on your screen and this is the failure rate. So, we can see this is the bath tub type of curve. Clearly distinctive 3 phases are there: 1 first phase, second phase and the third phase. Now, first phase as we have already seen, it can be called as the infant phase, green phase or the burn in period.

So, we can see the failure rate is comparatively higher, but as soon as we go towards the normal useful or active period or adult period, it is nearly constant. And when we go to the ageing or the wear out period, again the failure rate increases. So, clearly we can see that 3 phases are there and in the bath tub curve we can see, the failure rate changes over a period of time. So, initially it is more, then during the adulthood or during the normal useful life or during the normal operational life of the product, it is nearly failure rate is nearly constant and finally, the due to ageing or wearing out, the failure rate increases. Why such a phenomena is taking place?

Initially, the product may have some complication, may have some problems which require debugging; as we see that the infant mortality rate is quite high. Infant mortality means: if we take the case of little children below the age of 5 years or below the age of 3 years, the mortality rate maybe higher, it was higher sometime that but now because of the development in the health services, the infant mortality rate has decreased. But, initially some years back it was more why because, the child has to adapt to the environment, the child to has, to adapt to the climate so that chances of death are more at the early stage. But once the child has passed through that age of 5 years or 7 years or 8 years, then it is difficult for him to catch some serious diseases or he becomes adaptable to the environment and the climate and then he performs his function satisfactorily.

Similarly, we have normal useful period or the adult period. So, this is that period in which the chances of death or the chances of failure are less. But, when the person becomes old, then because of the wear and tear, because of the some problems in the metabolism or anabolism of the person, we may have to have end our life. So, it is not that the person is having accidental death, but it is death caused by the natural ageing.

So, accidental death can take place anytime in this stage, this stage or this stage. But, the natural death is this period that we are talking about when the person has lived his entire life. Similarly, for product also we have 3 phases which we have. So, this is an important aspect for any product design. We need to have; we need to divide the total product life into 3 important phases: first 1 is the infant, green or the burn in period. Second 1 is the normal and useful life or the adult period and a third one is the ageing or the worn out period.

So, now we would be discussing in detail 1 all these phases 1 by 1. We have already seen that this can be compared to the human life also. So, let us now talk about the very first stage that is, the infancy or the burn in period. So, the bath tub curve can have 3 is having 3 different phases, out of which first one is the infancy or the burn in period.

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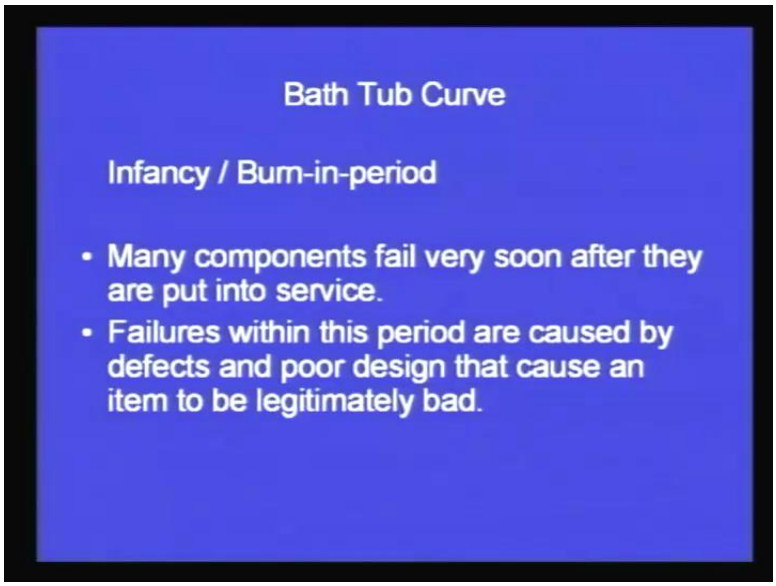

Many components fail very soon after they are put into service why, because of some wrong design, because of some wrong calculations or because of they are not able to adapt to the environment. So, many components fail very soon as soon as they are pressed into service. Failures within this period are caused by defects and poor design that cause an item to be legitimately bad.

So, if the product design is not good, then in that particular case the product is going to fail, as soon as it is pressed or as soon as it is passed into the market. We have seen, we have seen so many different products all around us, whose initial reports are not very encouraging why, because sometime we say we can take an example of a mobile phone. As soon as the mobile phone is put into the market by any company xyz, the software goes immediately. So, for suppose 1000 sets they have sold into the market, out of 1000 600 sets are such, in which the software is not of the adequate quality and the screen becomes blurred or the screen is completely washed out.

So, we say that at the inception stage only the product because of some wrong design, because of some wrong software writing or because of some wrong software

development the product is not able to perform its intended function. So, because of that wrong design that is, there on your screen because of the poor design, the product fails as soon as it is ask to perform its function. So, that is basically the burn in period, in which have seen that initially the failure rate is very high, but with the passage of time this failure rate reduces.

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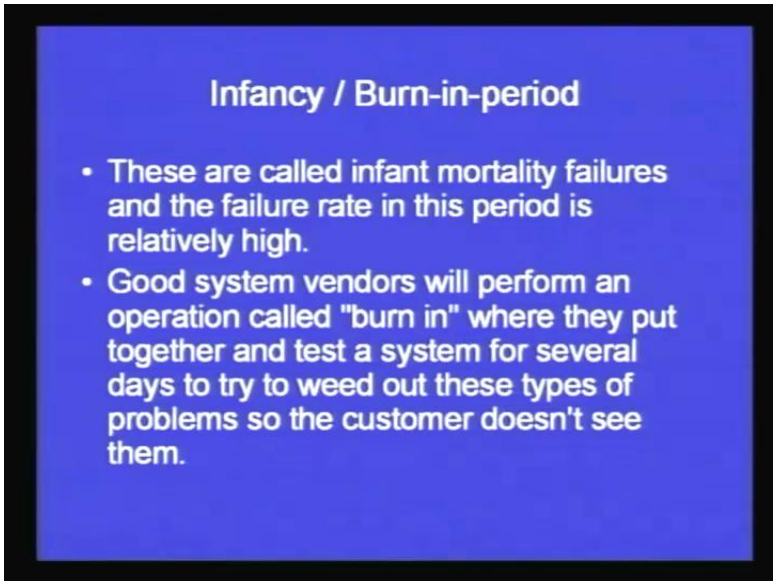

So, carrying forward a discussion related to the bath tub curve, some other important points that are to be discussed in the infancy or the burn in period are: that the failures that take place during the infancy or the burn in period are called the infant mortality failures. I have been using this term quite often in our discussion today in reliability in which, I have said infant mortality rate

So, basically we can call this failure that take place during this infancy or the burn in period, as the infant mortality failures. And failure rate in this period is relatively high, which we have already seen in the bath tub curve. Why it is high? That also we have discussed with the help of an example in which, a child we can say is more susceptible to failure or death at a early stage or is prone to different types of diseases at his early stage as compared to, when becomes an adult.

So, basically the failure rate is higher in the initial stage for any particular product or system or service. Then, good system vendors will perform an operation called “burn

in", where they put together and test a system for several days to try to weed out these types of problems, so the customer does not see them.

So, 1 thing is to do all these testing by putting the product into the market. But, the brand name of the company may get hit if; the product is not performing satisfactorily. And another thing is to do the accelerated testing within the companies premises and to weed out the problems or to debug the problems or to find out and rectify the problems that are existing in the product that may increase the infant mortality failure rates.

So, basically each every company would like to increase the service life of their product, they would like to reduce the failure rate at every stage of the product life cycle. So, basically each and every company would try to figure out all the difficulties the problems or the adaptability problems, where the product is not able to performs its functions satisfactorily in the environment or in the under the operating conditions for which it has been designed.

So, every company would like to do the testing at their own and only so that all the problems are rectified and when the product is launched into the market, at that particular time there is no such problem or the failure rate is very less. And the customer gets the product in the adult stage only and the failure rate is constant over a period of time. So, when it has led its life, the product has used or a has been use satisfactorily over a period of time or the designed life of that product is over, then after ageing and warn or being worn out it may have to fail or it may fail. But we want that the stage at which the company is handing over the product to the customer, the infant mortality failure should be less, it should be in the usable form and when it has led its life, it has completed its life, after that it may fail.

So, basically all these burn in and all these infant mortality or all these testing debugging of the problem, should be done at the company premises only, before the product is finally launched into the market. But because of stiff competition, in order to launch the product as early as possible, sometimes the company do some portion of the testing at their end and leave the product to perform its function within market. And because of some anomalies, some faulty designs the product is a big failure, as soon as it is launched into the market.

So, any good company would always like to do all the testing, all the debugging at there and only so that the product carries of very good image of the particular company and the brand image of that particular company is not hit. So, we till now we have discussed the basic aspects, that are integral part of infancy or the burn in period. Now, coming on to the second stage that is, the chance failure or the normal operating life failure

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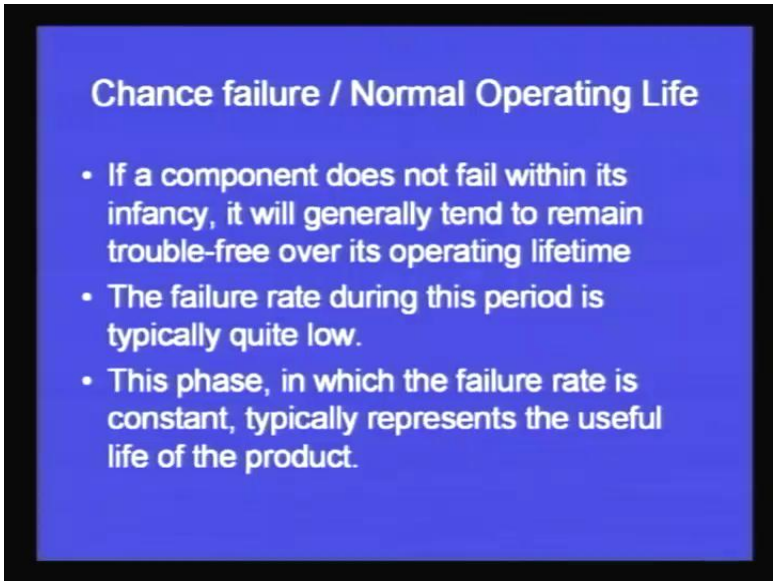

If a component does not fail within its infancy that is the first stage or the first phase of the bath tub curve it will generally tend to remain trouble-free over its operating life time. So, once the child has attained a particular life, after that he is going to leave for adulthood and till the old age. It will generally tend to remain trouble free over a operating lifetime. The failure rate during this period is typically quite low.

So, failure is going to take place, failure rates are there, it is not 0. But it is quite low. So, it may be, because of some chance failure or because of some accident or because of certain environmental degradation or because of some catastrophe take place. So, the failure is going to be there, failure rates are going be very less. So, failure is rate is high in the infancy stage. It is very low in the chance failure or the normal operating life. So, this phase in which the failure rate is constant, typically represents the useful life of the products. So, this is basically of useful life of the product for which it has been designed

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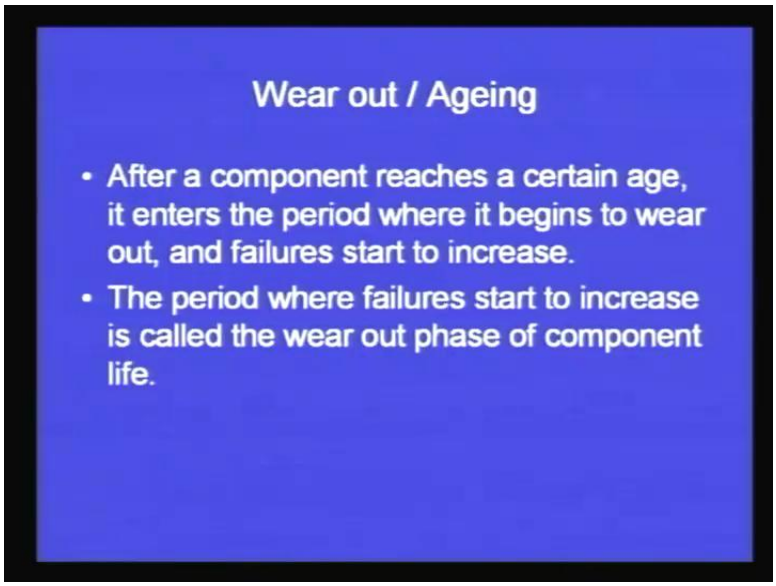

Finally the third phase is the wear out or the ageing. So, after a component reaches a certain age; it enters the period where it begins to wear out and failures start to increase. So, after the normal life is over in the bath tub curve, the wearing out or the ageing phase start in which the failure rate again increases.

So, 3 different phases are there: first, second and third and is a third phases such in which, the failure rate also subsequently increases because of the wearing out of the product or the wearing out of the system. So, the period where failures start to increase is called the wear out phase of the component life or the wear out phase of the product life. So, let us now summarize our discussion related to the bath tub curve.

In bath tub curve there are 3 important phases or 3 important stages. The failure rates are very high in the first stage that is called the infancy stage or the burn in period. Different aspects we have seen related to the burn in period and the infancy stage. Second stage is the normal operating life of the product or the useful life of the product in which, the failure rates are there, but the rate is very less as compared to the first stage.

Then finally, the third stage, when the product has completed its life because of the varying out action or because of ageing, the product will start to decay or the product would start to die down and that stage also the failure rate would be higher. So initially also, we have a higher failure rate, at the end also we have higher failure rate and in

between we have a lower failure rate during the operational life of the product. Now, let us wind up our discussion by referring to system reliability

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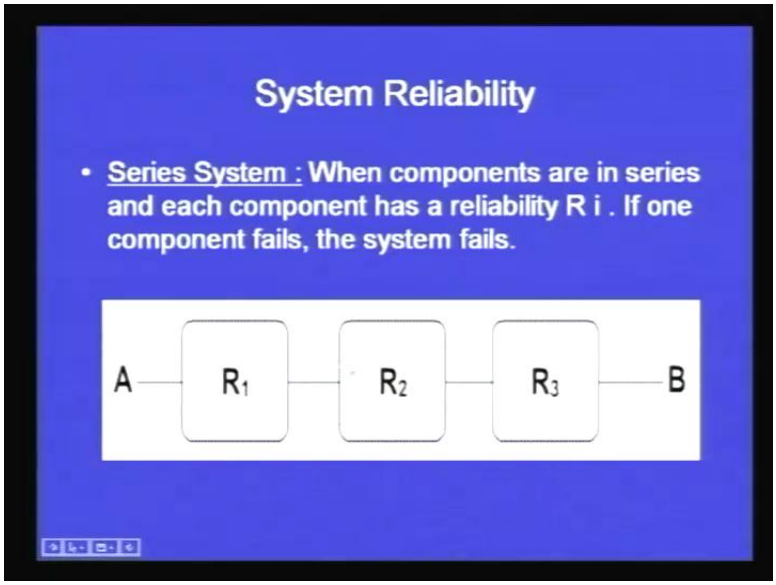

Now, suppose there a system AB which is made up of 3 components are R1, R2 and R3. So, there are 3 components in a particular system, that system we call as AB; so series system. This type of system is called as series system, because all the components as you can see, everybody knows have been attached in series. So, when components are in series and each component has a reliability Ri, if one component fails the system is going to fail.

So, you can see on your screen; there is simple diagram showing 3 components in series R1, R2 and R3. Out of these 3 components, if any one component fails the whole system would be coming to a standstill or the whole system would stop functioning. So, this is series system of reliability

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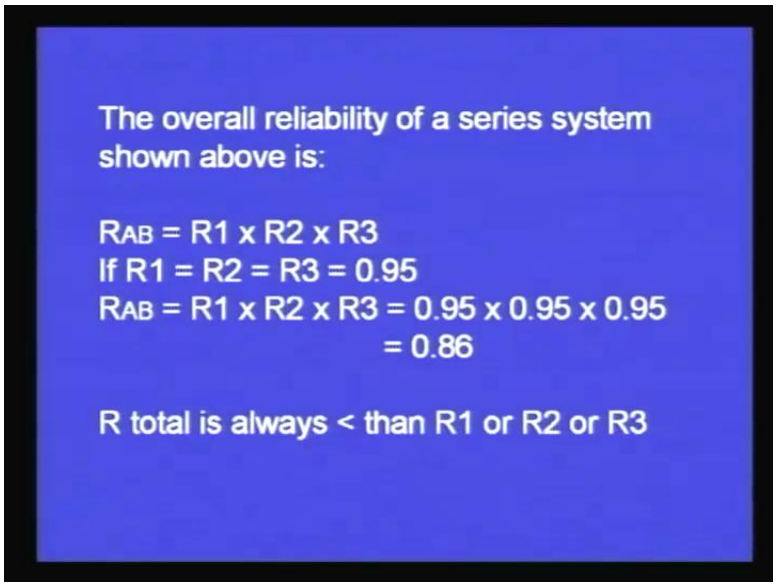

The overall reliability of a series system shown above or in the previous slide can be calculated as; the reliability for the system AB can be calculated as, reliability of system 1 multiplied by reliability of system 2 multiplied by reliability system 3. So, we have already seen that it is probability function the value is going lie between 0 and 1. So, if R1 is equal to R2 is equal R3 equal to 0.95 it means: that all the 3 components that are connected in series and that are forming a part of the system or those were forming the system AB, are having the same reliability, the value is 0.95.

So, the reliability of the overall can be found out and it is 0.86. So, R total is always less than R1 or R2 or R3. So, in the case also we can see that 0.86 is always less than 0.95. So, all the 3 components are having the reliability 0.95. But the overall reliability that of the system we are getting is, less than the individual reliability. So, the reliability of the system is less than the individual reliabilities of individual components.

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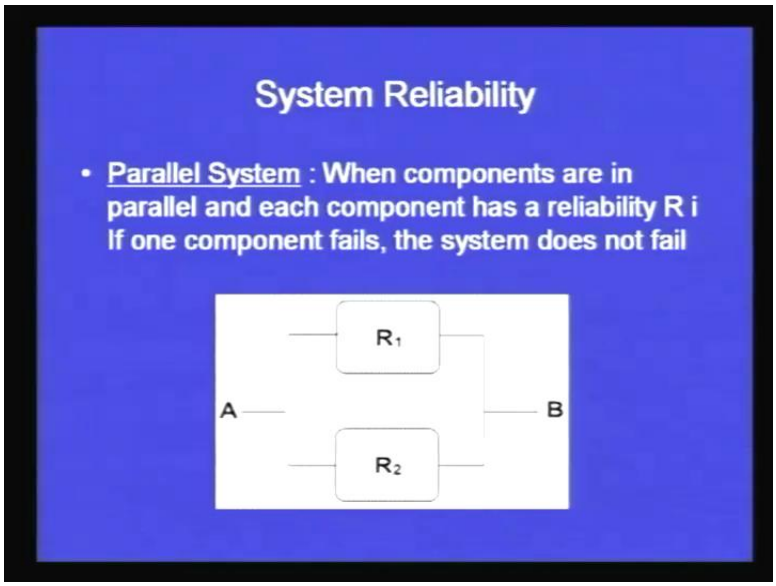

System reliability in context of parallel system; so when components are in parallel and each component has a reliability Ri. If 1 component fails the system does not fail. So, you can see on your screen; there are 2 components R1 and R2 in the system AB. So, we can say that if 1 component fails the other component would still be performing its function. So, the whole system would not come to the stand, still the whole would be working but, only already component R2 will be working, R1 will not be working. So, we have 2 components here having reliability R1 and R2 and in this we can we will see that how to calculate the overall reliability of the system RA RAB.

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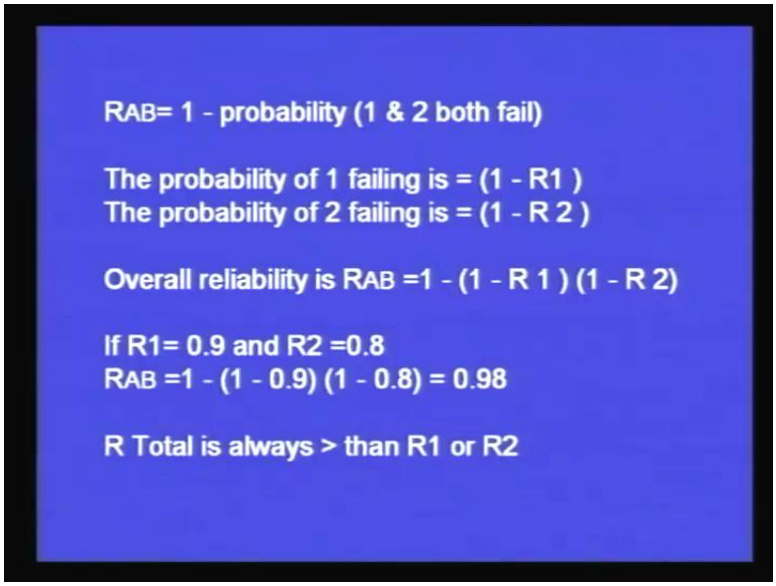

So, RAB is given by 1 minus probability; 1 and 2 both fail. So, now, we have to see that 1 and 2 both fail what is going to be reliability of the system? The probability of 1 failing is 1 minus R1. So, the probability of system 1 or the component 1 failing not the system, I am talking about the component; so the probability of component 1 failing. Now component 1 is having the probability R1; so it is 1 minus R1. The probability of the component 2 failing is 1 minus R2. The overall reliability or the system AB is 1 minus 1 minus R1 into 1 minus R2.

So, if R1 is given as 0.9 and R2 is given as 0.8, we can say RAB can be calculated as 0.98 using this formulation that is given here. So, R total is always greater than R1 or R2. In the previous case in series, we have seen that their overall reliability of the system is less than the individual reliability of the components. And in parallel system we have seen that the R total or the total reliability of the system is more than the individual reliability. So, you can see R1 was having or the component 1 was having reliability 0.9, component 2 reliability is 0.8. But, the total reliability of the system is 0.98.

So, what we have covered lets summarize, what we have covered in the system reliability. In case number 1 we have seen series reliability, in which there were 3 components 1, 2 and 3 having reliability R1 R2 and R3. We have calculated overall reliability of this series system and we have seen that the overall reliability was less than the individual reliabilities of the components 1 2 and 3. In the parallel system we have seen that there were 2 components 1 and 2 connected parallel, and we have calculated the reliability of this particular system and we have found out that the overall reliability of the system is more than the individual reliabilities of the component 1 and component 2.

So, with this we come to the end of this lecture on reliability. We have covered in today's lecture, some basic definitions of reliability. Various aspects that we can derive out of these definitions we have covered; we have seen cost of unreliability we have discussed at length ways of improving the reliability of the system, also we have covered the bath tub curve, how the failure rate changes over a period of time? What is burn in period? What is the normal operating life? And what is the worn out or the ageing stage? That we have covered in the bath tub curve. Then we have seen system reliability in which have seen 2 types of system reliabilities; components connected in series and components connected in parallel.

So, I wish and I feel that this particular lecture on reliability would be a introductory lecture for all of you and you would be able treat reliability as an important aspect of various design problems that you encounter in your engineering studies.

Thank you.