Failure Analysis & Prevention
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Lecture – 36
General Procedure of Failure Analysis: Question for Analysis

Hello. I welcome you all in this presentation related with the subject Failure Analysis and Prevention. And we have now almost covered the different steps related with the general procedure of the failure analysis, and we have also talked about that how to integrate the various aspects related with the analysis for arriving at the conclusions regarding the causes of the failure.

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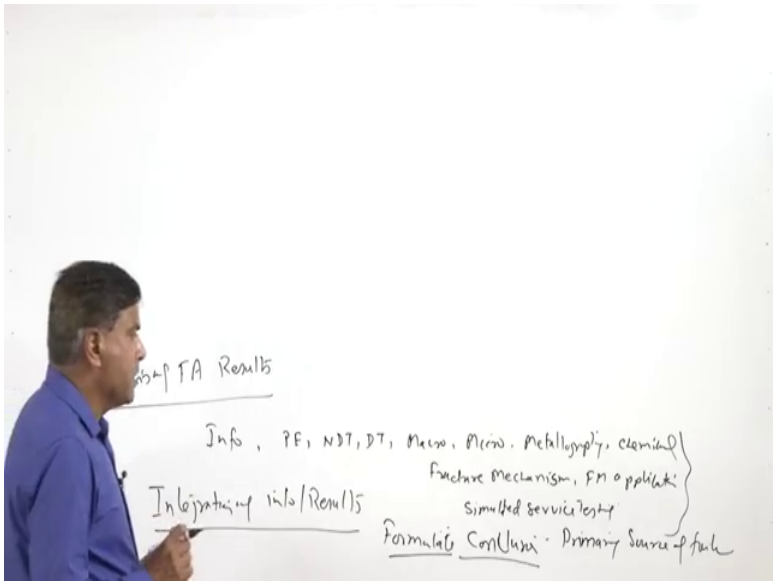

So, analysis of the failure analysis results this is what we have talked, but in addition to this we need; So what analysis involves like the information which we have collected from the different aspects either through the interrogations, through the talking and talking to the people, collection of the background information, preliminary examination, NDT of the component, DT of the component, failed component, then macroscopy of the failed component, microscopy of the failed component, metallography, then chemical analysis, fracture mechanism, determination fracture mechanism determination and the fracture mechanics, application in failure analysis and if required then the simulated service testing.

So, findings as per need; the findings of the different stages of the analysis is used basically for the integration of the results or the information identified through the different stages integration of the information oblige results obtained through the different tests and different interactions with the people who are involved. So, this integration will help to a systematically formulate the conclusions; conclusions regarding the primary sources of the failure.

So, but some times since the failure investigation will be running for a longer period of time. So, in order to avoid the possibility that none of the points are left out from the analysis. So, in order to ensure that all the aspects related with the failure possibilities are investigated thoroughly and thereafter only well informed conclusions are made regarding the fundamental sources regarding the primary causes of the failure it is good to know about the questionnaire, which is normally used questionnaire for failure analysis.

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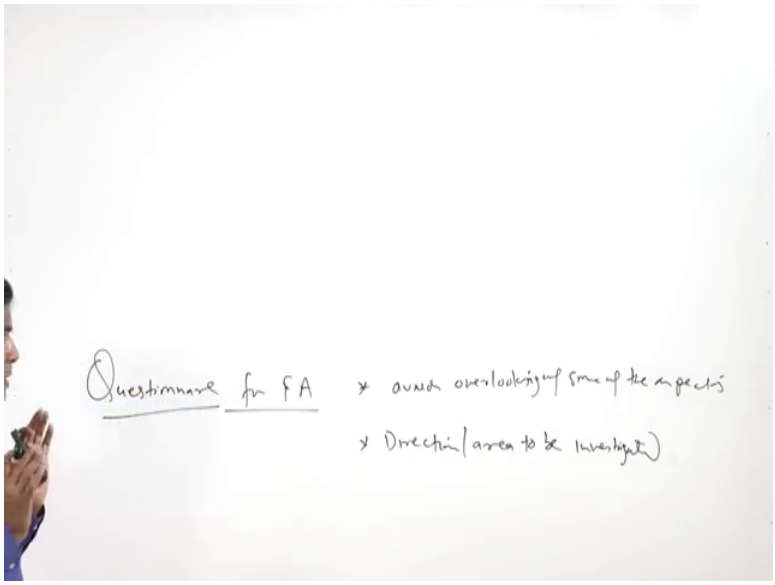

So, this questionnaire helps in the two ways: one is that it avoids the possibility of overlooking of some of the aspects and the second one is that, it also gives the directions of the areas which need to be explored during the failure analysis. So, these are the two aspects: one is the directions of link areas which can be investigated as per the case, and the second is avoids overlooking of some of the aspects related with the failure.

So, these are the two important things related with the setting of the proper questionnaire for the failure analysis. It reduces the possibility of overlooking of some of the aspects relate to the failure analysis and the second is the, it will have the better a clarity on the ways and the directions which should be investigated so that well informed conclusions can be made during the failure analysis.

So, now we will be talking about the different questions that need to be asked at the end of the failure analysis to see if we have looked into the various aspects of the failure analysis or not if some of the points are is still missing and which needs to be addressed or which need to be seen. So, there is a proper checklist of the questions which we need to ask.

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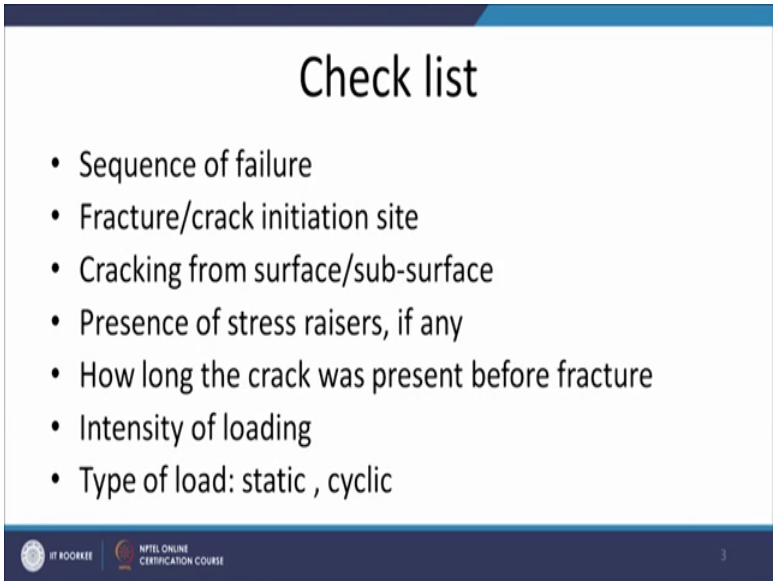

So, the first thing is that, we need to ask if the sequence of the events which have lead to the failure has been established or not and if not then we need to see what information need to be gathered additionally so that the sequence of event of the failures, sequence of the failure or sequence of the events are which have lead to the failure of a developed component can be established.

The second aspect is the, have we identified the location where from the fracture or the crack was initiated and which eventually caused the failure. So, the initiation of the fracture or the crack location has been identified or not, that is the second aspect. Third

is, if there was a cracking and as eventually the fracture has lead to the failure then whether the crack was located at the surface or in the subsurface region.

So, there may be possibility that crack would have been there right from the beginning and not due to the service condition. So, that also can be easily distinguished like if there is a crack which is present at the surface or if the crack is present inside the component here in this form.

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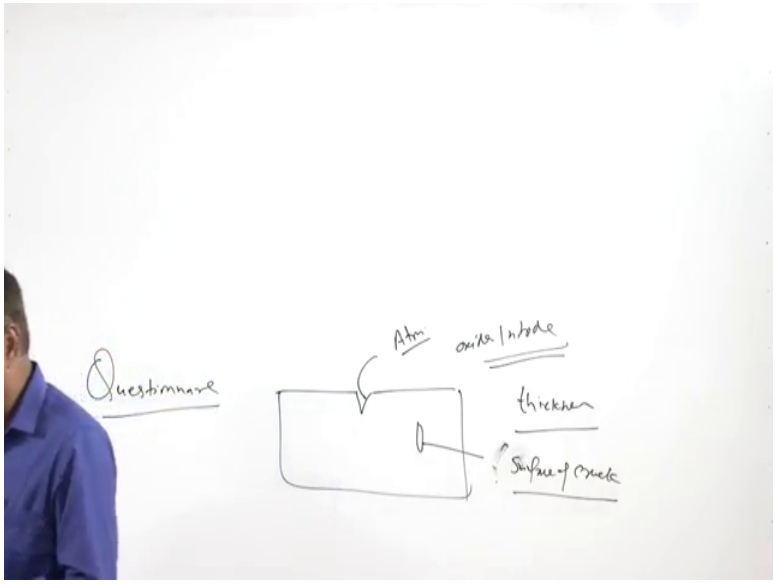

So, the crack which is exposed in the atmospheric condition so that will have the effect of the atmospheric gases may be in form of the oxides, nitrites, etcetera. It will show the different color, shades and presence of this compounds which also can be characterized using suitable techniques like exerted to see what kind of oxides and nitrates are present and their thickness also can be measured which can be used to see for how long the crack has been present here. But if the crack is inside, it will not be under the exposure of the atmospheric gases. So, basically in this case surface of crack will be nascent, will be clean, will be metallic and it will be free from the oxides nitrides. So, the crack which are present at the surface and which are present in the subsurface region they will look different.

So, we need to identify also if the fracture has been caused due to the crackings. So, whether the cracks were present at the surface or in the subsurface region. Also we need to establish, if there was any role of this stress riser in facilitating the crack nucleations?

So, these stress riser may be in form of like the toe of the weld or the location where change in cross section is taking place or a some key hole or any other key way or any other kind of hole is present which is acting as a stress riser and the third.

So, next aspect is if there was a crack then for how long it has been there before fracture occurred. So, for the determining how long crack has been there we need to do the measurement of the thickness of the oxide layer which is present or oxide which may be form of rust or any other form of any oxide or any other compound.

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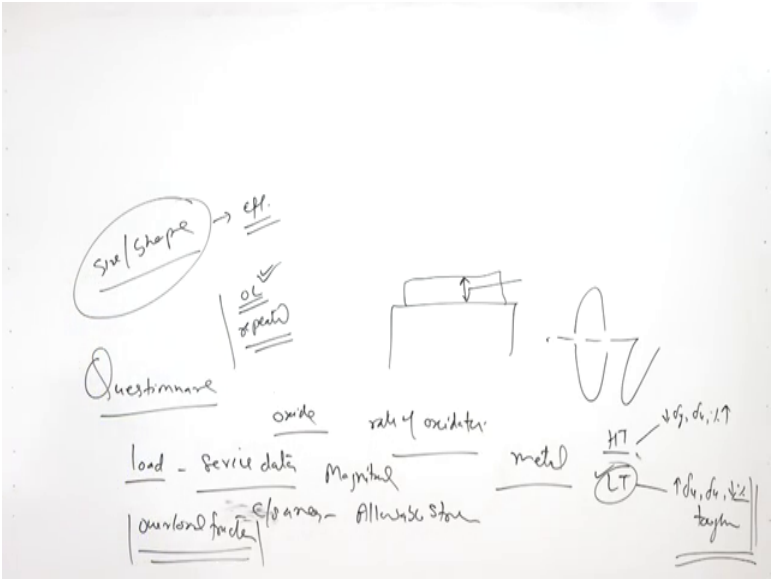

So, based on the rate of oxidation reaction for a given metal we can identify for how long crack has been there. So, like say this is the metal surface and depending upon the thickness of the oxide layer and using the, can it take rate of the oxidation reaction we can determine for how long the crack has been there at the surface. So, the next step is if the fracture has been caused by the cracking and if the cracking has occurred either due to the stress risers or it has been there in the at the surface for long. Then, for how long crack has been there before fracture that can be checked through the thickness of the oxide layer. If it has been exposed then, next is the intensity of the load.

There are two possibilities regarding this; if there can be overloading fracture? So, as far as intensity is concerned we need to see the service data regarding the kind of the magnitude of the load which is expected and using this service at and using the information about the cross sectional area of the component we can determine the kind

of the allowable stresses which had been there. But sometimes by seeing the fracture surface and especially the microscopy of the fracture, surfaces there are certain features which indicate if there has been overload of fracture.

So, overloading has been accidental or abnormal loading has taken place then, if that has caused the fracture that also can be identified. So, intensity of the load can be understood from the two ways; one is whether there has been overloading or there has been repeated loading under which the fracture has taken place. So, in this case of course, the under the repeated loading conditions the load magnitude will be lower than the yielding strength limit.

Yielding stress of the material and in overload fracture the material will be subjected to grip to the stresses greater than the ultimate tensile strength of the material. So, there are two ways to determine the intensity of the loading; one is to see the possibility of the abnormal loading or accidental loading or also another one is to see the macroscopy and microscopy of the fracture surface, to see there has been repeated load which was lower than the yielding strength limit or if there has been or the overloading, which have overloading which has caused the fracture of the component.

Then the type of loading also is to be identified. From the service data record we can identify if there are loading has been static or it has been cyclic in terms of the completely reversible or tensile to tensile or the fluctuating loading. So, that information also needs to be identified to see the possible conditions under which failure has taken place.

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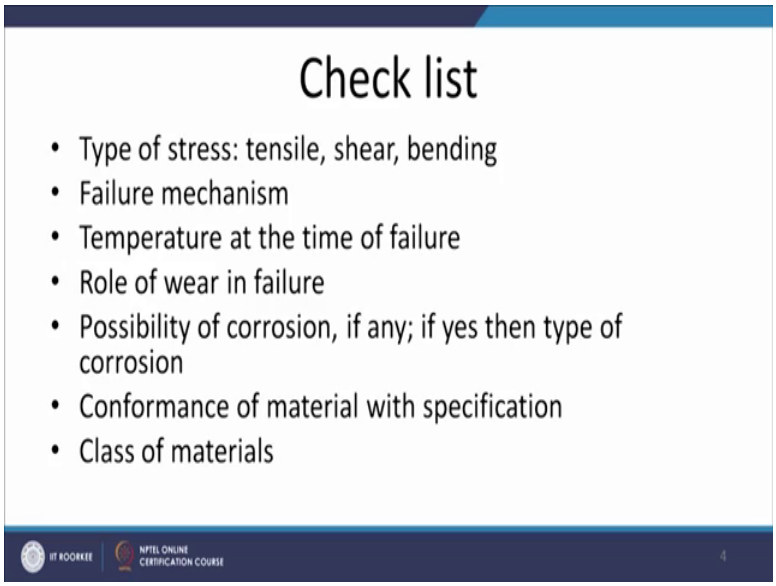

Then next aspect is to find out also to mention about the kind of a stresses which have caused the failure of the component and this may be in form of like tensile, shear, bending or things like that.

So, because the fracture surface will indicate the kind of the loading or the kind of a stresses under which the failure has taken place. For example, in case of the tensile load dimples typically show. The perpendicular dimples grow perpendicular to the fracture surface while in case of the shear loading they are inclined, while in case of the bending also the inclination is of the different type.

So, the shear fracture surfaces will have the orientation of the dimples in the different ways in on both the sides while in case of the bending it is also the different. So, just by look, so using the principles of the microscopy of the fracture surface, we can identify the kind of a stresses which were there. So, sometimes the people who speak as per their convenience to hide the information, but microscopy of the fracture surface can indicate the kind of a stresses under which the component has been exposed during the service and under which failure has taken place.

Then determination of the fracture mechanism or the failure mechanism is also important. We need to see if the failure has taken place due to the excessive loss of the dimensions, due to the wear or the failure has taken place due to the plastic deformation either loss of the mechanical properties or any other reasons. So, whether there has been

the loss of dimensions, plastic deformations or elastic deformation beyond the acceptable limit or there has been complete fracture or suppression, due to either overloading or repeated loading or loading under the fatigue condition. So, the failure mechanism is to be identified.

Another important thing is that, it is also to be identified whether the temperature at the time of failure has been identified or not. This is important because if the temperature is different from the ambient condition then in either way whether the temperature is high or low it will be affecting the mechanical properties of the component which will increase the tendency for the failure. For example, the high temperature will be reducing the yielding strength of the material, ultimate strength of the material or it will be increasing the ductility.

On the other hand the low temperature, so this is high temperature. On the other hand like low temperature conditions will be leading to the increase in yield strength, increase in ultimate strength also, but reduction in ductility percentage elongation, at the same time significant loss of the impact resistance also takes place.

So, those components especially which are sensitive to the temperature and if they are subjected to the transition from ductile to brittle behavior then, it is a very important to mention the temperature at the time of failure.

So, we need to identify basically the temperature at the time of failure has been specified or identified or not then, we need to also see when if there has been any role of the wear in failure and which has degraded the dimensions of the component and the change in the dimensions of the component will be leading to the size and the shape of the component. So, sometimes change in shape of the component does not lead to stop the working of the system, but it reduces the efficiency of the system. So, even a malfunctioning on the component can also start. So due to the wear there can be change in size and shape of the component, which can increase the tendency of the getting inappropriate results or reduce the performance.

So, that can be considered as failure. So, the role of the wear is to be identified in the failure of the component. Similarly, if the failure has been caused by the loss of dimensions, so we need to see if the loss of dimensions has occurred due to the corrosion and if the corrosion is the possible cause of the failure then, what type of the corrosion?

Whether it is crevice corrosion, pitting corrosion, galvanic corrosion or it is the general corrosion under which failure has taken place.

The next is the like the conformance of the material with the specification. We know that the components are expected to a perform under given set of conditions and that can be expected only if they are made of a particular kind of the material as per the design requirement.

So, it is important to see that if the failed component was made of the material as for a specification or not and for that we need to confirm the chemical composition of the failed components. So, that it can be established that if the failure has been contributed by the discrepancy or the deviation in chemical composition.

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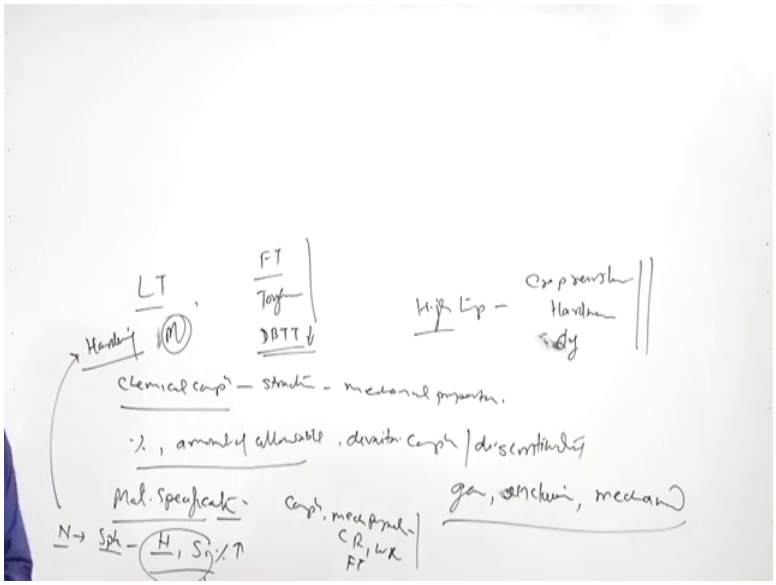

Since the chemical composition of the material directly affects the structure of the material and which in turn affects the mechanical properties response to the heat treatment and therefore, chemical composition is important and so through the chemical analysis of the failed component we will be able to know really if it has been confirming to the specification or not.

So, another question is that we need to identify, whether it has been identify or not that the composition of the material is confirming the specification or not? Then next is the class of the material. Class of the material is identified with regard to the percentage or

the amount of the allowable deviation in terms of the composition or the discontinuities, which may be in form of the disordered gasses or inclusions or in terms of the mechanical properties, toughness, ductility, etcetera. So, these will be indicating the class of the material like one common term is very generally used like the premium quality metal or the commercial grade.

The metal; so premium quality metals are much better as compared to the commercial grade metals. So, that is also general classification for public understanding, wherein which is generally based on the kind of the concentration or the percentage of the gasses, inclusions of the mechanical properties and microstructure of the material.

So, in addition to the class of the material, we also need to see whether the component design was perfect or not and for that it is required to see the load resisting cross sectionality of the component. If the load resisting cross sectional area was appropriate or not for a given service conditions that is to be identified through the design analysis of the design aspects.

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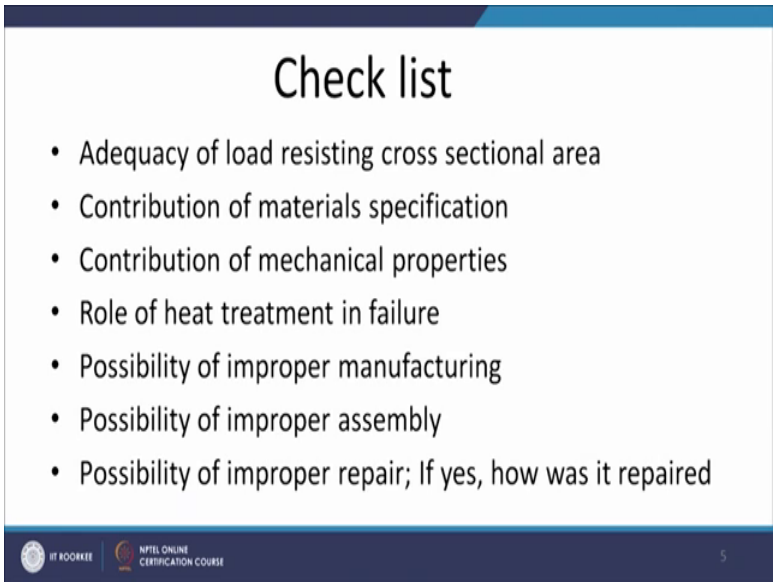

And then we also need to see, if the there has been any role of the material specifications on the failure aspect. So, this we need to see with regard to the like material specification means whether the material chosen for making a particular component was appropriate or not. So, this may be in terms of the chemical composition, mechanical properties, this may also be in terms of the corrosion resistance, wear resistance as per the case.

So, whatever material has been chosen had a required the mechanical properties or not that is what is identified and effects are made to establish if there has been any role of the material specifications or material properties which have been used for making a particular component on the failure. Then also we need to see, if there is any role of the mechanical properties, mechanical properties were appropriate for given application, given service conditions or not.

For example, material to be used or component to be used under the low temperature conditions must have the required fracture toughness. It must have the required the toughness also so that it has good resistance to the impact or fracture, at the same time it is ductile to brittle transition temperature has to be lower enough than the service temperature conditions.

Similarly for the high temperature conditions we need to see whether it has required creep resistance or not. It has required hardness at elevated temperature or not. It has rigid resistance to the deformation; we say yielding strength at the service temperature conditions or not. So, as per the service requirement whether the material properties were appropriate are not, that is what is identified through this one. Then the role of the heat treatment which means if the component has been subjected to the heat treatment, whether that heat treatment was proper or not?

So, the possibility of the inappropriate heat treatment is also to be explored if it has been subjected to the heat treatment and its possible role on the failure of the component, which may be in terms of like the steel which should have been normalized instead of the normalizing if it has been spheroidized, then intimately showing very low hardness or very low strength and although increase in ductility will be there. So, reduction in hardness and strength can degrade the performance significantly. Similarly instead of the normalizing, if it has been air hard and say for a normalizing was carried out by putting in air. But due to the lowing element in the steel say if it has been air hard and so that will be leading to the martensitic transformation and which can make the steel in brittle.

And therefore, we have to identify if the component has been heat treated in the manufacturing stage whether that heat treatment was proper or not. So, that possibility is also identified.

Then possibility of the improper manufacturing; which means that whether the correct kind of process has been used or the process parameters were appropriate or not. So, various aspects related to the manufacturing has to be explored and identified and in order to see if they have inappropriate manufacturing has anyway contributed towards the failure. Then the possibility of a inappropriate or improper assembly is also identified and for this purpose we know there is a proper assembly procedure. If the assembly is improper then it can lead to the shear is related to the (Refer Time: 24:36) related with the misalignment or it can lead to the absence of the some of the components which were required for a proper functioning of the component.

So, if there is a possible, so failure also needs to be investigated with regard to the possibility of the inappropriate or improper assembly. Then it is also important to consider if the failed component has been subjected to any recent repairs. Sometimes repair means like if a component has shown or some kind of crack during the service.

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So, it is obvious so part that it will be repaired, so if the crack has been there and it is repaired. So, repair procedure has to be developed properly and if the repair procedure is not proper then it will lead to that a additional stress results, additional discontinuities and which can further be source of the failure.

So, it is important to consider if there has been repair or not. If the repair has been properly carried out or not? Or the repair procedure was properly established or not. And

so the possibility of the failure from the location where recent repair has been carried out is to be explored. Then we know that whenever we use any new component it is subjected to the somewhat lower load and a lower service condition so that, it can be used to work under those set of the conditions and it is not subjected to any overloading in the beginning. So, if the proper run in condition have been applied for the new component that is also to be seen.

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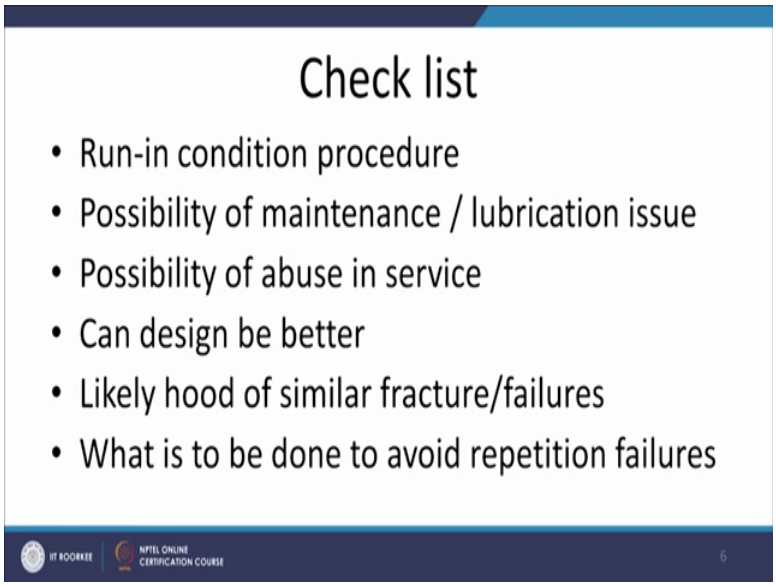

In inappropriate run in conditions can lead to the initial stage failure of the component. Then the possibility of the lubrication and maintenance is also to be explored. So, for this purpose we need to see when the maintenance was carried out? Whether the properly maintenance was carried out at a regular intervals or not? And if there was any lubrication issue then correct kind of lubricant was used or not. So sometime say, the wear related failures are sometimes caused by the absence of the proper kind of the lubricant or too long delay in proper feeding of the lubricant or inappropriate use of the inappropriate lubricant.

So, we to see really if the failure has been caused by these are inappropriate maintenance and the lubrication related issues. Then we also need to see the possibility of abuse in service which means the component is subjected for certain conditions, if it is expected that component will work under set of working conditions. But instead of that, if it has

been exposed to some other set of working conditions accidentally then that possibility is also to be explored.

So, the another question that needs to be asked is the possibility of the abuse in service need to be explored which will be in terms of the environment and it may be in terms of the temperature conditions, it may be terms of the loading conditions which may be like static load or dynamic loading or the type of a stresses also. So, because the component is to be used or the product has to be used as per the design.

Because every component is designed for certain set of the working conditions and if it is used in another set of the service conditions then there is a possibility of the failure of the component so that possibility is also established. Then we need to ask that if really the design has been perfect or not or is there a possibility to have much better design with regard to the factor of safety, with regard to the material which has been used, with regard to the design geometrical aspects of the design. So, various questions are asked to see if a design can be improved further so that the possibility of the similar kind of the failure can be avoided.

We also need to see really, what will be the possibility of the similar kind of the fractures or failures do occur that also to be asked so that the future failures can be avoided. The last question here is like what is to be done to avoid the repetition of the failure? So, in this case, we try to vitiate based on the potential causes of the failures which have been identified through the failure analysis. We also try to ask really, what are the specific things which can be done so that the failure in future can be avoided.

Now here I will conclude this presentation. In this presentation basically I have talked about the set of questions which a failure analyst should ask so that the various aspects the failure can be covered and none of the important points are overload during the failure analysis.

Thank you for your attention.