Failure Analysis & Prevention
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Lecture - 35
General Procedure of Failure Analysis:
Simulated Test and Analysis of Evidences / Results

Hello I welcome you all in this presentation related with the subject failure analysis and prevention and we are talking about the general procedure of the failure analysis. We have talked about the various aspects related with this general procedure of the failure analysis and I give just introduction of the simulated service testing and it is importance.

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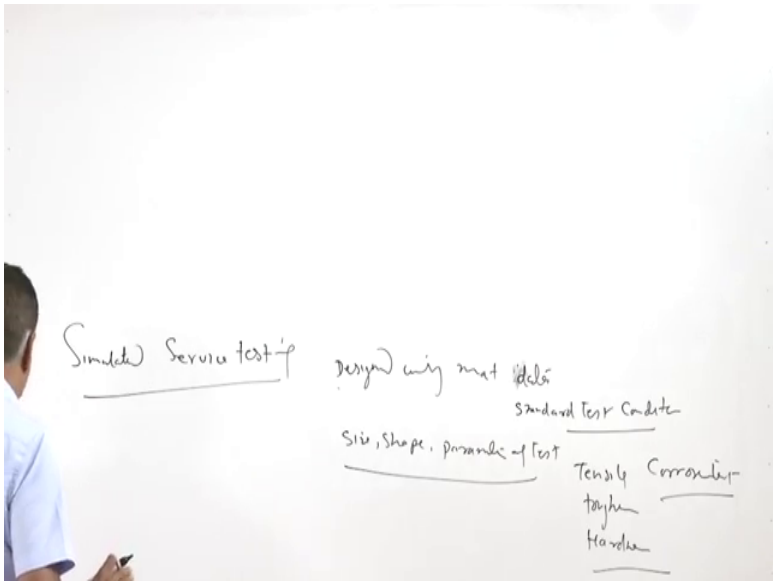

Now, we will see the simulated service testing, what is it is importance and the relevance here in failure analysis. We know that most of the products are designed using materials material data, which is developed under the standard conditions under the standard test conditions; where the size shape parameters of the test parameters of the test all these are fixed and the test results under the a standard conditions.

Show the behaviour of the material under those conditions only which may be informed like say the tensile test or the toughness test or the hardness test or corrosion test in particular environment. So, all these tests are normally conducted under set of a standard

conditions set of a standard laboratory conditions and they show the representative behaviour of the material under those conditions.

But when the component when the product made using such kind of the material is put in actual service, it comes across the conditions which are which may be completely different.

So, say if a component has failed on during the service and the material which has been used for making that component even after the test shows the, the behaviour under the standard test conditions which is matching with the design specifications and still we are not able to find where is the problem what are the issues because, of which failure has taken place.

So, this provides the opportunity or venue to understand that really the service conditions are leading to the different kind of behaviour of the material, then what is expected then what we are expecting and therefore, it becomes important to a study the behaviour of the material under the actual service conditions however it is difficult.

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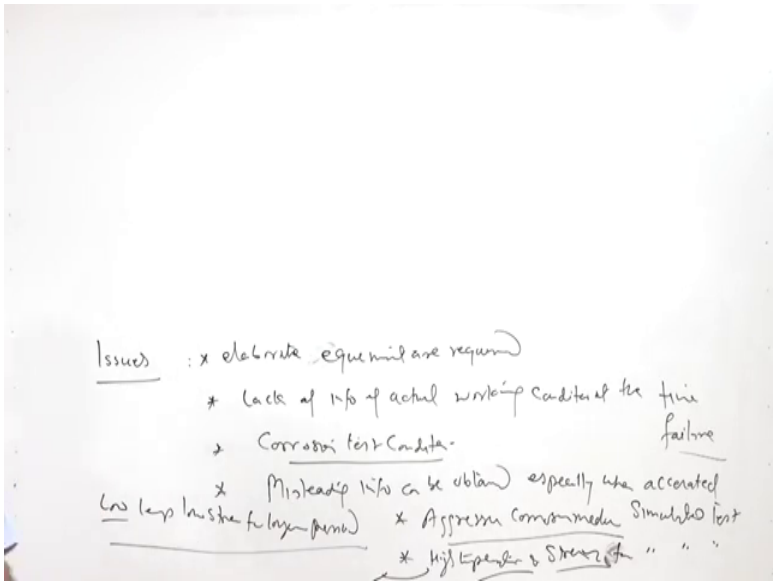

So, the problems or issues with the testing under the simulated conditions, include like very elaborate machine elaborate equipments are required; which may be difficult to have this and this condition may let lead to the situation where it is difficult to really replicate the actual service conditions.

The second aspect is lack of it is possible that we may not be actually aware of the conditions which were there in under which the failure has taken place. So, lack of information of actual working conditions at the time of failure and if this is the case, then even whatever simulation similarity studies are conducted that may not be very clear or that may be misleading.

So, this is the another aspect which is related with this the issues in the simulated testing, similarly the replication or the simulation of the corrosion test conditions are also difficult because, in actual service the kind of environment the kind of chemical species the kind of temperature, all these things are if cannot be estimated which over there and during the actual service conditions then this especially it is difficult to simulate the corrosion conditions.

Now if the component has failed by the corrosion or it may be you see issues may also be there when the simulated tests are conducted under the accelerated conditions, so misleading information misleading information can be obtained, especially when especially when the accelerated simulated tests are conducted.

So, accelerated simulated tests means if the corrosion behaviour is to be studied under particular temperature conditions, then we may use very aggressive corrosion media. So, the behaviour of the material under the highly corrosive or corrosive media the behaviour of the material may be completely different then what it was under the actual service condition.

So, use of the accelerated simulated test conditions through the use of more severe service conditions, like say use of the high higher temperature and the stresses at [fo/foe] for accelerated at simulated testing. So, in these situations may also show the different kind of behaviour of the material, then what has actually been experienced by it under the different conditions. Say higher temperature or high stress has been used to simulate that conditions by the tests, which would be conducted for a shorter period. But actually the component may be subjected to at a completely lower temperature lower stresses for longer period.

So, this is the difference in this will be the service condition and this will be the simulated test condition, since the behaviour of the material under these 2 conditions will

be completely different then what it has experienced, then it is accelerated simulated tests may also be may also give the misleading results.

Related with this we can consider one example which is related with the creep testing of the material. We know that for the creep test or to check the resistance of the material what we need we need the temperature, we need the stress during the test what is to be applied and the duration and the how long period means for how long that the test is applied. So, that difference will bring in lot of a change in behaviour of the material.

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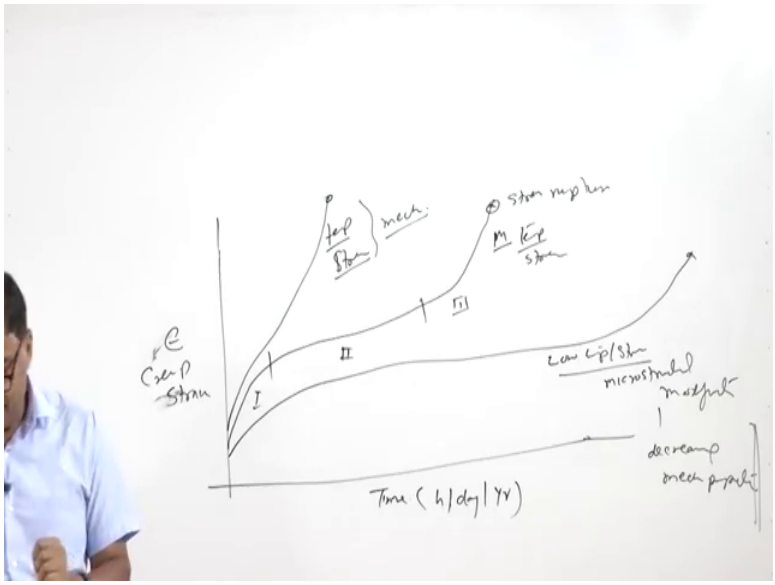

So, in x axis we have time it may be like say in hours in days or in years also or and here we may have the strain creep strain, creep strain. So, as soon as we apply load there is immediately elastic strain there after creep strain will be reducing, it will become constant and then again it will be the increasing.

So, there will be the 3 different stages second stage first stage and third stage and here this will be the stage of stress rupture. This is the one kind of behaviour which will which of material will be showing say, this is the moderate value of the moderate a temperature and stress values if we use a higher level of a stress and temperature.

We may find the test is going like this and for very low temperature conditions and lower stress conditions the test may go like this.

So, here this may go years this may go months and this may go in hours, so this is the difference like say the very low temperature and very low a stress this is the actual service condition. But to simulate the service conditions if you are using a accelerated simulated test, then it will be giving the completely different behaviour.

How it will be completely how it will be completely different, when we use too high temperature and the stress conditions there is a more mechanical failure of the material due to the thermal softening, while when it is exposed to the low temperature for longer period we will see that there is a micro structural stability.

Micro structural modification at high temperature, leading to the desolation of the precipitates coarsening of the grains which in turn will be degrading or decreasing the mechanical properties of the material and that in turn in long run will be leading to the increase in the creep increase in the creep strain.

So, materials will behave in completely different way at low temperature and high temperature as a function of the time. So, it is important to consider that accelerated test accelerated simulated tests can give the misleading results, but now as per that case only this kind of test may be suitable.

So, there are certain situations where simulated tests have been successfully used. So, we have need to see really how effectively and how far these simulated tests can be used together useful information about the actual service conditions and the behaviour of the material which is in use.

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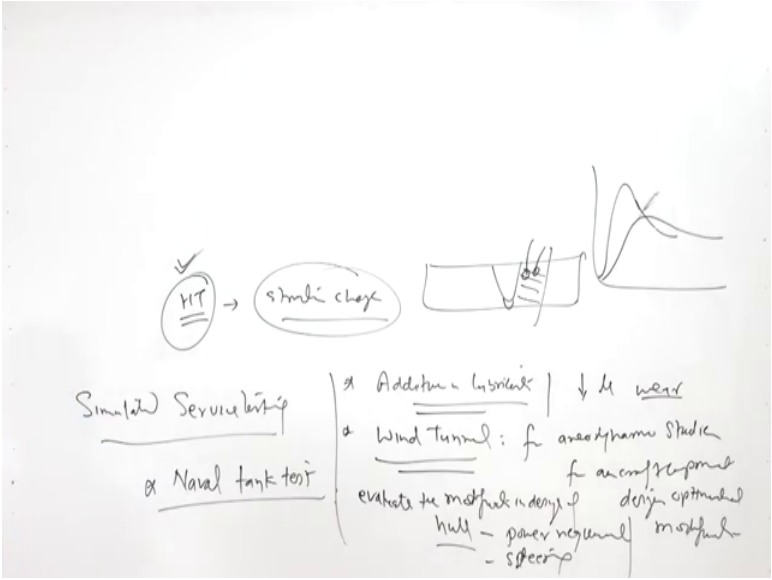

So, there are a few examples where the simulated service testing have been successfully applied, 1 of the typical example is application or addition of the additives in lubricants.

When it is added it modifies the physical properties of the lubricant and which is used for reducing the friction coefficient and the wear rate. So, such kind of that such kind of this studies have been very successfully conducted to see that what happens when the lubricant characteristics are modified, due to the various additions in course of the service, so such kind of the studies have been successfully carried out.

Similarly the application of the wind tunnel has been successfully used to study the aerodynamic behaviour of the components of the aircrafts, because wind tunnel in the wind tunnel very high velocity the air is passed through the different the geometrical objects so which are being studied.

So, the flow behaviour of the material for the different geometries is studies. So, the use of the wind tunnel for aerodynamic studies and fluid flow related studies for aircraft component, design optimization and modification these have been successfully used.

So, this is the second example third example is where in the naval tank test, naval tank test you see this test has been successfully used to evaluate to evaluate the modifications in design of holes, with regard to their performance regarding the power requirement and

steering capabilities how the steering capabilities will be a steerage will be affected when the whole design is modified.

Similarly it has. So, these are some of the conditions, where the simulated tests have been found to be extremely useful similarly in welding also the heat treatment has been successfully used to study the micro structural changes taking place in the heat affected zone under the different temperature conditions.

So, you know during the welding when the fusion welding is are perform zone which is affected by the heat is formed like this and different temperature different zones will be offering the different temperatures. So, the value of these temperatures is identified and the kind of thermal cycle being experienced by these points, by these points is a determined and based on the maximum temperature and the rate of heating and cooling.

The simulated studies on the heat treatment of the simple metal systems have been applied to study what kind of structural changes what kind of the structural changes and the change in mechanical lower part take place. So, this kind of study it means the studies of the heat affected zone through the controlled heating and cooling can also be applied, for investigating the way by which material will behave under the influence of heat for a shorter period.

So, when we find that the behaviour of the material under the actual service condition is not clear, it is a good idea to conduct the test under the simulated service conditions. So, that we can have idea about the way by which material would have behaved under the conditions which have led to the failure of the material. So, this is 1 aspect related with the simulated service condition.

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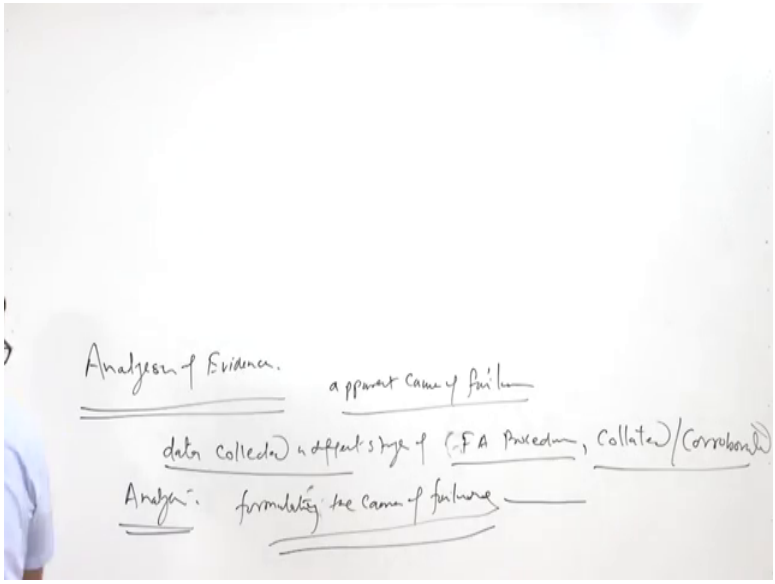

Now, another aspect is about the analysis of the analysis of the evidences. If we just have a glance at the way by which we have proceeded, like we initially we collected the information about the background of the product which has failed regarding the design, manufacturing the service conditions and after that we conducted some preliminary test studies, preliminary studies of the failed component and based on these 2 if we find that there are a few apparent causes of the failure.

So, if there are a few apparent causes of the failure these causes are identify means these evidences for these causes is established. So, basically the purpose of this analysis of the evidences is to see that what the data collected, in different stages of the general of the failure analysis procedure everything is looked at the same time.

So, that the data can be correlated corroborated to see that how the entire data is aligned with each other and what would have been the possible sequence of events, how the change in the mechanical behaviour of the material have taken place, so that it has led to the failure or the fracture. So, basically this kind of the analysis all the all this data which is collected is important, this analysis this analysis of the entire data will help in help in formulating the causes of failure not just formulating the causes of the failure.

But in sequence will be putting each and everything what were the conditions initially, what happened during the under the conditions of and what happened to the metal material. When the conditions at the time of failure over there and what has led to the

fracture or the failure of the component and what was the mechanisms and what should be done to avoid the failures. So, analysis basically help in formulating the causes for the failure. So, that in light of the evidences. So, in conclusive manner will be able to say what has led to the failure of the component.

So, how do we proceed in this regard that is what we have to see now. So, as I have said with regard to the analysis of the evidence, you see based on the collection of the background information and preliminary examination of the failed component, basically will be will be trying to identify some apparent causes of the failure and in light of those apparent causes of the failure efforts will be made to develop the suitable evidences.

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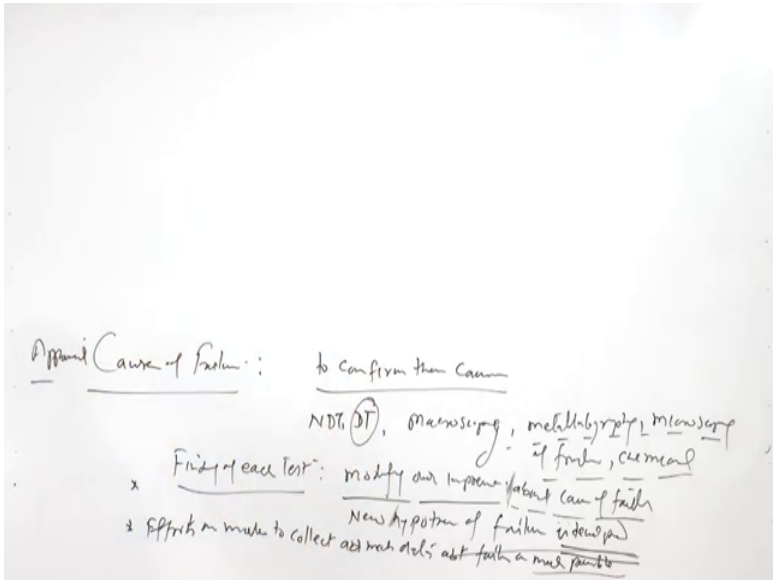

So, if we have if there are a few apparent causes of the failure, so investigation is they basically directed to confirm these causes and which may be in turn and for this purpose only we may we will be doing the NDT, we will be doing the DT we will be doing the macroscopy.

So, as per the need what is what which item which a stage of the analysis which tool is needed to confirm these operand causes. So, accordingly we need to collect the evidences, so DT NDT macroscopy or AG the metallography of the sample or microscopy of the fracture surface.

Microscopy of fracture surface chemical analysis mechanical property analysis all these, so information is collected basically on the different counts. So, that the possibility of the apparent causes either can be confirmed. So, we know that when we will be conducting these tests 1 by 1, so findings of each test will modify our impression about causes of failure initially.

If we have thought of that like failure would have taken place in this sequence of event and this would be the cause, so when we start the collecting evidences through the different tables and techniques we based on the findings of a each stage will be able to see that no either this whatever we have thought of in the beginning was right or wrong.

So, accordingly oh our we have to modify our impression about the causes of the failure and a new hypothesis of failure is developed. So, basically as we keep on progressing on the investigation our earlier impression may be modified and which will lead to the generation of the newer hypothesis for the failure and.

So, in the newer hypothesis these may be further modified or these may be altered and according to the evidences whatever is being obtained in each stage of the failure. So, basically what we say each stage of the failure analysis will be guiding the direction will be direct will be indicating the direction in which it should be taken up forward for collection of the further information.

So, basically efforts are made, so efforts are made to collect as much data about the failure about failure as much possible.

So, when this data is collected this will be very useful incorporating the things at the time of the analysis, initially we may find that some of the tests are negative and a this is wastage of the time and resources.

But in a failure analysis whatever data is collected at least it whether it will be will be leading to the positive or the negative leading to the positive or the, it will indicate the presence or absence of particular cause of the failure. So, either it will support the hypothesis or it will help to guide the help to alter the hypothesis and.

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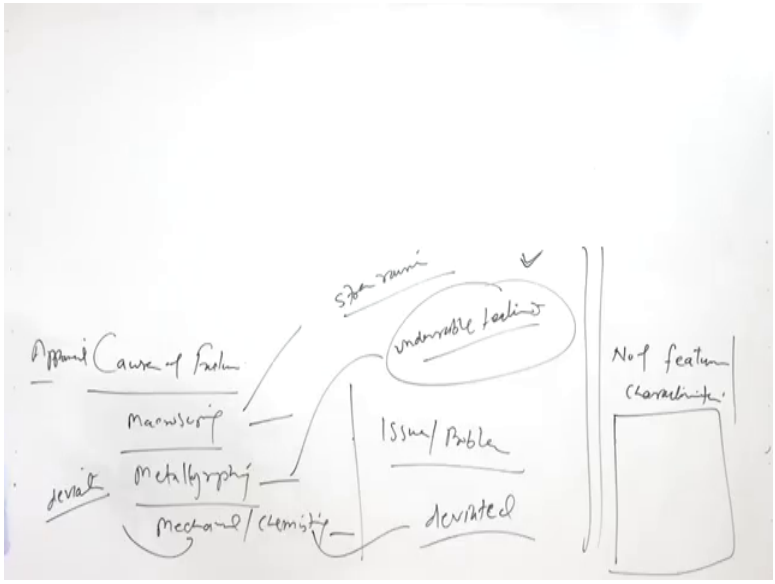

So, even redundant data even redundant tests in the beginning, may indicate the useful findings later on. So, therefore, efforts should be made to collect the information about the material which has failed and the conditions on which failure has taken place as much as possible, using the principle of the general procedure of the failure analysis and then there are certain other aspects like.

If the macroscopy through visual examination or the metallography metallography through the microscope or some mechanical test data or the chemistry data, if 1 of the 1 of the feature is indicating that there has been issue or the problem issue or the problem with the material or with the conditions; like in macroscopy you may find that there has been a huge stress raiser and because of which failure has occurred or in metallography you will find that lot of a unexpected the microscopic constituents were present or undesirable microscopic features are there.

In the metallography and so un desirable features are present in the material and which have led to the failure or chemistry is deviating from the a specified one, deviated from the specified one or the deviation in terms of the mechanical properties with respect to the specifiedone.

But if there is so if the characteristics which are there, if there is a dimension in one aspect, then this single aspect should not be used to indicate that entire failure has been caused due to just one kind of the undesirable feature.

Because, there would not be the just one reason, which will be leading to the failure and there will be some there will be other evidences also, which will converge towards the similar kind of the observation.

Wherein and all these things will be in indicating together towards the cause and the possible sequence of events and of the failure mechanisms. So, not just 1 aspect should be used to formulate the conclusion for as a primary cause of the failure. But number of the features or the characteristics which have been collected during the failure analysis, will suggest the possibility of the occurrence of cause due to one or few causes of the failure.

So, efforts should be made to identified those causes, which have which are indicating means which efforts should be made to put all those evidences together, which will indicate that failure has been occurred due to this sequence of event and this these were the set of the causes because of his failure has taken place.

So, not just one evidence should be used as a major cause of the failure, but number of the evidences will indicate the possibility of the similar type of the cause.

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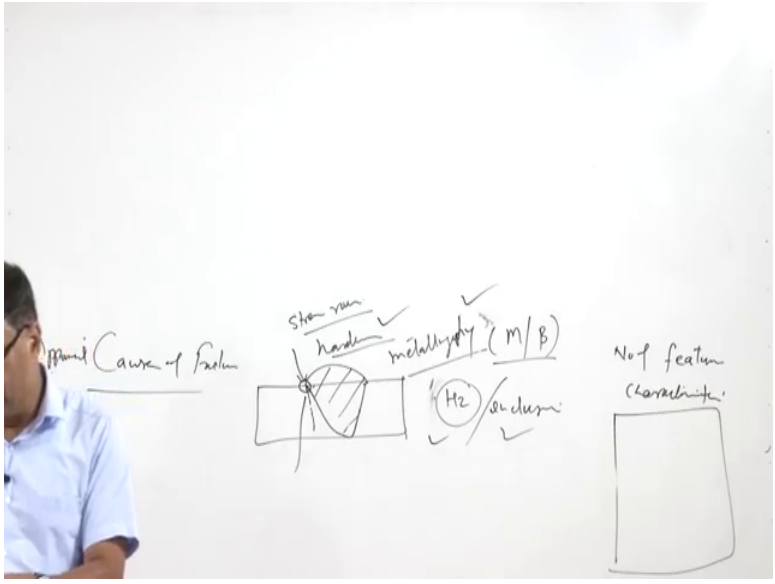

I will give you a example for this like here in a weld joint like this, if the cracking has taken place from this 2 of the weld and crack has progressed like this to cause the

fracture. So, now what so the in this case it is obvious that here the toe of the weld is acting as a stress raiser

So, even a stress raiser are not effective if the metal strength is low yield strength is low and hardness is low, but if the yield strength and hardness is high then this is stress raiser will be more dangerous and will be more damaging will be able to nucleate the crack easily. So, the hardness of the material in this zone is another important thing and hardness will not come on it is own it will be supported by the metallography, where it may show metallurgical we can simply write metallography.

Metallography will indicate that there is a martensitic transformation or the lower Bainite which is present to leading to the higher hardness of the material and at the same time there may be the possibility for the concentration high concentration of the hydrogen or some kind of the inclusions. So, all these are the undesirable features if they are here they will simply facilitate the crack nucleation and their growth. So, not just the presence of one feature which is obtained from the macroscopic observation like presence of a stress raiser.

But similarly other evidences will also indicate like the hardness metallography presence of undesirable constituents, all these really indicate that that these features have made the material more sensitive for a stress raisers and because of which the stress raiser has triggered the crack nucleation and the growth easily. So, it is important that the different evidences which have been collected all should indicate the primary cause of the failure in 1 direction.

So, here now I will conclude this presentation in this presentation basically I have talked about the 2 aspects 1 was the simulated test simulated service testing and it is importance and what are the issues and limitations of the simulated service testing and another aspect was like whatever data has been collected during the failure analysis, how to carry out the how to make the inferences and how it will help in proceeding with the failure analysis and how the conclusions should be how the formulation of the causes of the failure should be made.

So, and the next one I will be taking up the kind of questionnaire, which is to be used to identify if something has been missed or all the aspects are related to the failures have been considered in the failure analysis.

Thank you for your attention.