Failure Analysis & Prevention

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Lecture - 11
Fundamental Sources of Failures: Poor Assembly, Service Conditions and Maintenance

Hello I welcome you all in this presentation related with the subject Failure Analysis and Prevention. And in this subject we are talking about the fundamental sources of the failure and we have talked about various sources of the failures and in this presentation we will talking about the failures which are occurring due to the poor assembly, poor service conditions, and the poor maintenance which is carried out during the service.

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So, we will be starting with the poor assembly or assembling related issues. Improper assembly poor assembly related issues. So, we know that for making any system it is required that number of subcomponents are brought together for this purpose we may use various joining approaches like mechanical or there may be thermal approach mechanical approach involves the like use of nuts and bolts etcetera. In thermal it may be brazing shouldering welding and, but at the same time the 2 components when brought together they must be they must be kept in proper position and they should maintain the relative movement as per requirement.

But if the assembly is not proper then the difference of components which have been assembled will not remain in their positions as well as it is also possible that the relative movement whenever it, occurs the relative movement also is not controlled properly. So, most of the assembly related issues or poor assembly related issues are encountered in the components where relative movement exist between the different components.

So, in the main sources for the main sources of the failure in due to the poor assembly includes ambiguity in instructions like, for assembly assembling is done in particular way. So, proper procedure has to be developed for assembling purpose.

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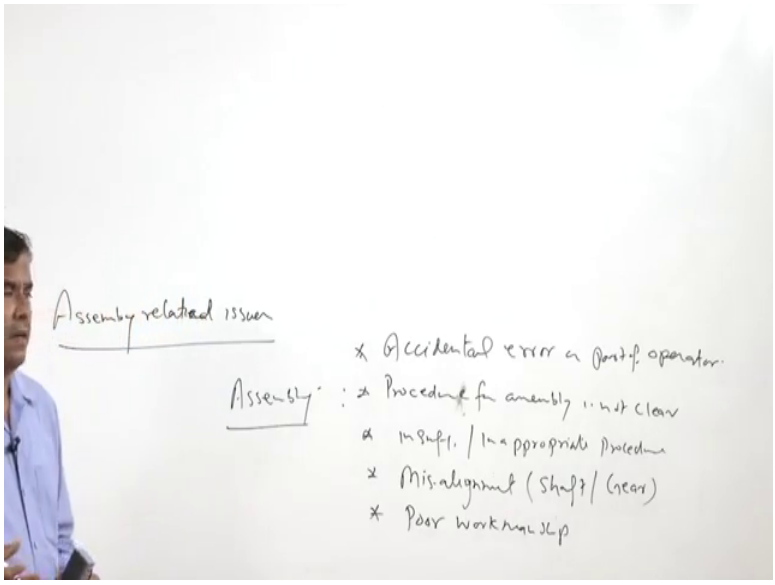

So, if the procedure for assembly procedure for assembly is not clear this is one then it can lead to the number of things to the judgement of the person who is assembling the things.

Ah the second one if the procedure assembly procedure is not clear or the procedure insufficient procedure means whatever the procedure has been developed is not enough or not proper insufficient or in appropriate in appropriate procedure of assembly. Then also it can lead to the failure then another point is related with the misalignment.

Because especially when the two components are having the relative movement with respect to each other or if the two components are joined together in such a way that the alignment is crucial for transfer of the load from one side to another and if that is not

maintained then it can lead to the unbalanced application of the forces and their stresses and that can lead to the failure of the components.

So, mis-alignment especially in the shafts and gears this kind of the fail the mis-alignment becomes the main source of the failure and then poor workmanship if the operator who is do assembling the different component if he is not doing the things carefully.

So, poor workmanship sometimes accidentally also like workman is careful, but accidentally if he is missing something to be placed in proper place then those accidental errors also sometimes accidental errors on part of the operator or the person who is assemble as assembling things can also lead to the ah.

So, this is placed as a inadvertent errors not the intentionally carried out also more efforts need to be put in like well thought out procedure for the assembly is developed and then if the procedure proper procedure has been developed it must be made clear like who will be doing? What will be done by whom? How it will be done? When it will be done like that.

So, well procedure well thought out procedure has to be spelt out or has to be mentioned clearly and mis-alignment has to be avoided especially when the relative movement exist between the two or more components and poor workmanship is to be avoided through the proper training and awareness programme of the operators. So, that they can be more motivated towards the work and they follow the instructions given for the assembly.

Ah. So, these are some of the general points which are observed whenever observed is reasons for the failure due to the poor assembly this is one of the cases wherein we can see the failure of the failure of the engine took place due to the inadvertent error on the part of the operator. So, in this case what had happen like?

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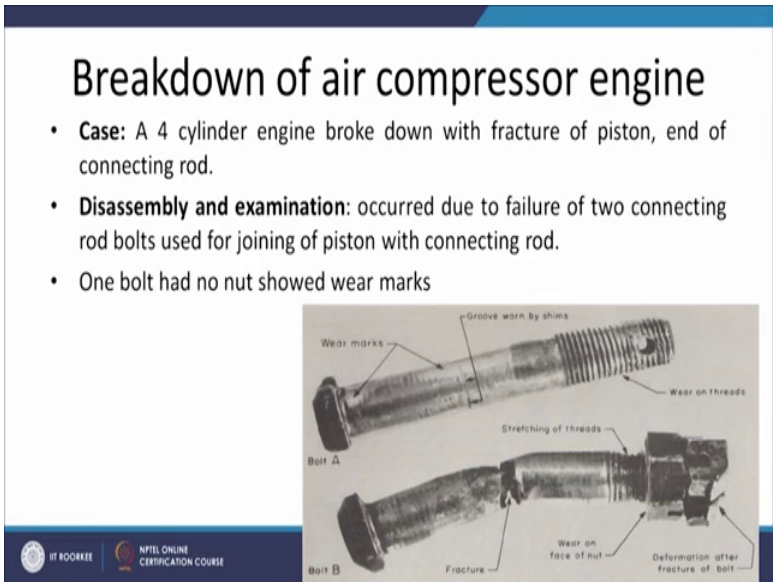

The breakdown of the air compressor engine which was full which was made from the four cylinder engine this engine actually broke down with the fracture of the piston on the connecting rod and side and the disassembly when the system was opened it was found system was opened for examination it was found that that the failure occurred of the two connecting rod bolts used for the joining of the piston and connecting rods.

So, the basically the failure occurred in the nut and bolt which were used for joining the connecting rod with the piston and 1 bolt had 1 bolt did not show any mark of the wear like here we can see these were the 2 nut bolts which were used for assembling the piston to the connecting rod and when the system was opened for examination it was found that one of the bolt had the wear marks on the on it surface while another was fractured. So, it was observed that the 2 2 nuts were present in one of the bolt while another bolt was free from an inert this is what also it can be seen

So, since the bolt a did not had any nut so it was free during the operation and that is why there was a lot of relative movement between the between this bolt and the connect and the piston which caused lot of wear marks on the surface of the bolt. While in other case since this was free so it was not taking much of the load while another was which was having the 2 nuts the which was having the 2 nuts say this was the only one which was carrying the load and since it was this was sharing the load say this was taking the load of the system completely.

And another one not sharing the load that is why it fractured under the it fractured this what we can see and this also lead to the stretching of the thread and some of the crushing of the threads on onto the bolt and the this and also can be seen that it was damaged.

So, here it was found that this actually nut was inadvertently tightened in the same one another and other one was the bolt was left another bolt was left without nut and that is why it was free to move. So, this is the kind of error which occur in which occurs inadvertently not knowingly.

So, this is one of the example where we can see inadvertent error on the part of the operator takes place likewise there can be number of situations where failure occurs due to the improper procedures we know that in cars the wheel when the wheel is assembled the tightening of the nuts is done in very particular sequence and if the sequence is not mentioned properly sequence is not followed then we may find that the nuts may get loosened and subsequently the wheel may come out during the running of car itself.

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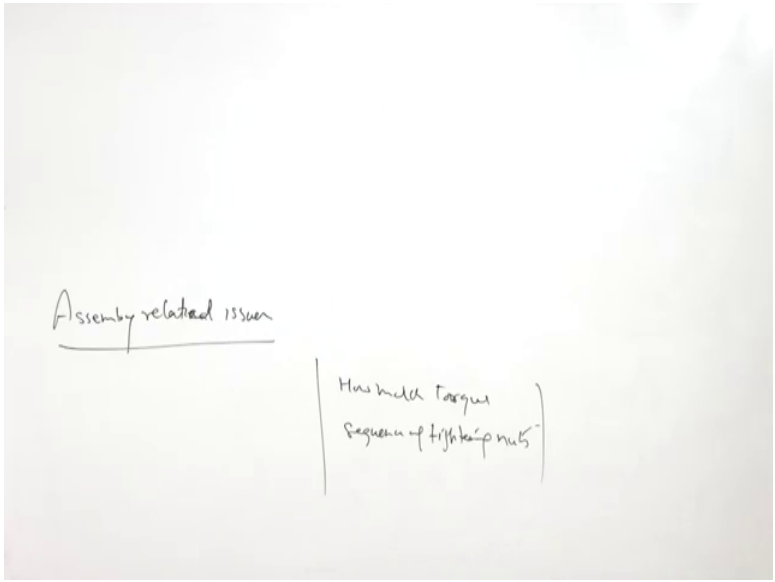

So, it is important that how much how much torque will be applied for patterning purpose and what will be the sequence of tightening sequence of tightening of the nuts in case of the cars and likewise the different sequences must be maintained whenever the assembly is prepared. This is another example where the failure of the gear occurred due to the misalignment.

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And in this particular case what we can see here mis-alignment will be leading to the increased contact in one side and another and the noncontact in another side of the gear.

So, the gear is having like two sides this is one and this is another side, this is the width of the gear. So, mis-alignment will be leading to the increased stresses and the increased load in one side of the gear which will be causing the higher rate of the wear in one side as compared to the another.

This also can be seen from the temperature rise it is expected the temperature rise in the two sides of the gear is not temperature difference in the two sides of the gear are not much and if it exists that is also used as an indicator, indicator of the possibility of the misalignment.

So, mis-alignment will be leading to the non uniform distribution of the stresses along the width of the gear and which will be causing the increased wear rate in one side as compared another side and that in turn will be leading to the increased wear rate in one side. So, similarly lot of there can be lot of examples for where failure occurs due to the misalignments in case of the shaft couplings.

When the 2 shafts are coupled using the couplings and if they are not properly aligned they will be causing lot of stresses during the operation and that can lead to the failure of coupling or the failure of shafts subsequently. So, proper assembly procedure has to be

developed and that is to be followed for avoiding any failure due to the improper assembly.

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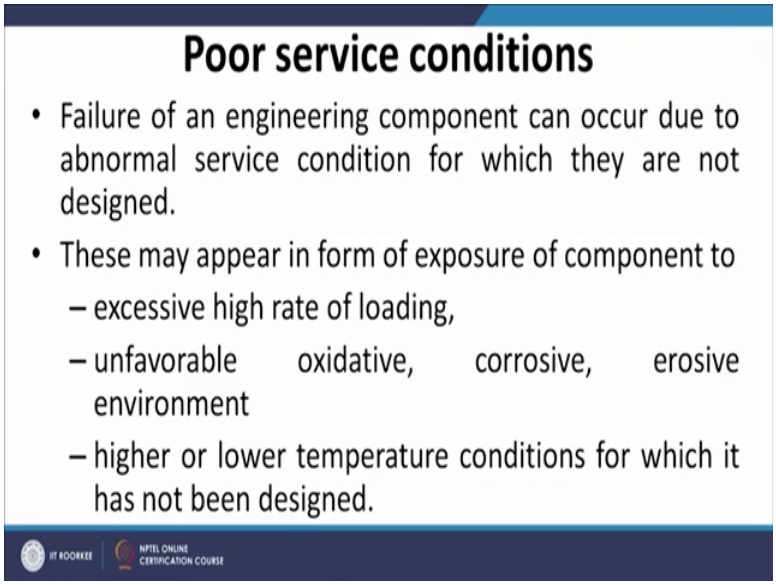

Now, the next is that poor service conditions we know that whenever a component is designed that is designed for a particular set of the service conditions.

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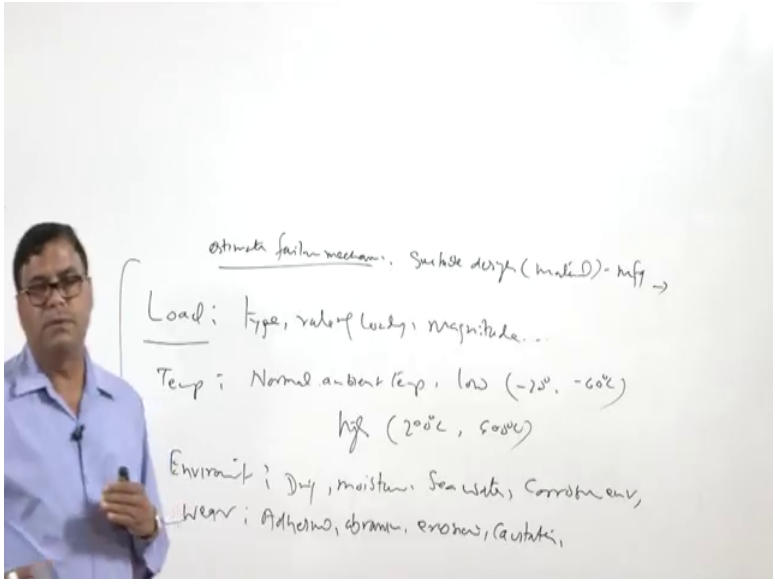

These service conditions include lots of variables which may be in terms of the load for which component is being designed like the type of load, rate of loading, Magnitude of the load that is the maximum load that can operate onto the that can be applied during the

service onto the components. So magnitude of the load and likewise many load related parameters.

Similarly the temperature it will be the normal ambient temperature, normal ambient temperature it will be the low temperature there will be limit like say minus 20 degree centigrade or minus 60 degree centigrade for which component is to be designed

Ah similarly there can be high temperature conditions it is 200 degree centigrade or 600 degree centigrade as per the application and accordingly the component will be designed suitable material will be selected it will be heat treated accordingly. So, that it can perform the required the condition required service and then apart from the temperature there can be environment environment which may be like in form of like in dry environment, or it is the moist environment moisture environment, or it may be like sea water it is to be designed for sea water, or it may be corrosive environment like the Hydrochloric acid or NaCl, like in case of the sea water or the liquid metal like number components are used in contact with the liquid metal like zinc, and magnesium etcetera.

So, the resistance of the component has to be checked again those environments and then accordingly it has to be used. And if it is kind of a special conditions then like wear for which kind of wear it will be subject like adhesive, abrasive, or erosive, cavitation wear etcetera. So, these are some of the examples for which these are the some of the service related things for which component will be design.

So, what we do basically we estimate the failure mechanism and based on this we select the suitable design criteria, suitable material is selected and then it is manufactured and after manufacturing we put the component into use. So, each component which is designed for a particular set of service conditions must be used in those conditions only. If the component is not used for those service conditions then it can lead to the undesirable unexpected performance even in premature failure of the component.

So, what we can see here if the component is exposed to the service conditions for which it has not been designed and fabricated then it will lead to the premature failure of the component.

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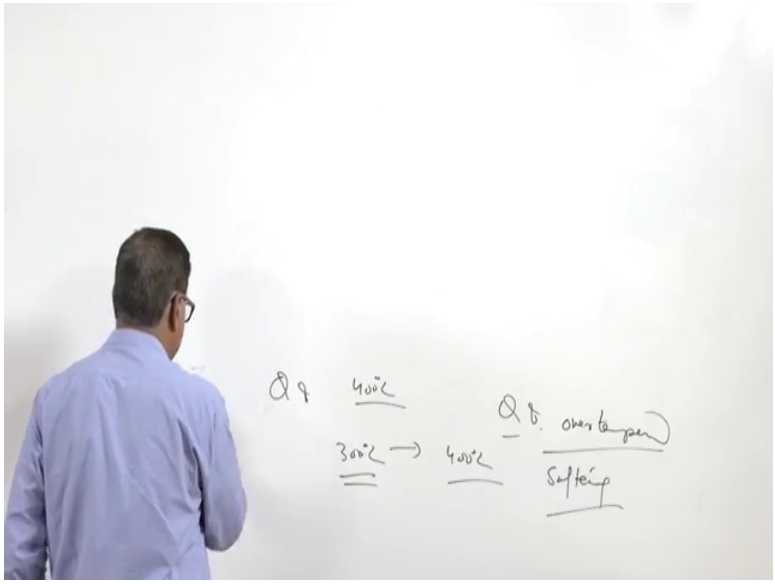

One of the simplest example for this can be like this. One Q and T still quenched in temporary steel which was quenched and then tempered at 400 degree centigrade for one particular application where service temperature is say 300 degree centigrade.

But if the same one increased with the performance if the same one is used for the 400 degree centigrade then there will be possibility that whatever the steel which was quenched during the exposure at 400 degree centigrade it will it will be over tempered. Over tempering will do simple things it will cause the softening, loss of strength, lot of loss of mechanical properties. So, they are ability to take the load will be reduced

So, if the steel has been quenched and tempered at particular condition then it should be used for the temperatures below those tempering temperatures. So, otherwise it will be over tempered.

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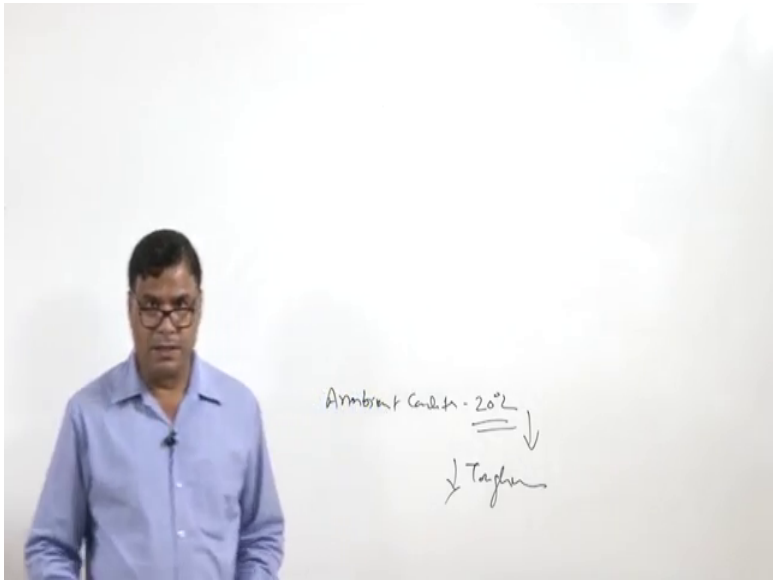

Likewise if a steel weld join like say the mild steel weld joined which is normally designed for say normal. Ambient condition conditions of the temperature like say up to minus 20 degree centigrade and if it is exposed for the temperature conditions even for the lower then it will lead to the significant drop of the toughness at low temperature and the component may not be able to survive under those conditions.

So, it is important that the component is used for the conditions for which it has been designed if it is exposed to some other set of the conditions then this will simply cause the premature failure of the component. So, some of the conditions here which has been mentioned like which if we considered as the poor service conditions means the failure of engine components can occur due to the abnormal service conditions for which it has not been designed.

And these abnormal conditions may appear in form of like abnormal high rate of the loading. We know that the normally the if the component has been designed using the tensile parameters tensile test as tensile properties like say yield strength, and ultimate strength which are conducted under the very lower strain rate conditions like this. So, strain rate conditions are say very low may be like say 0.1 or 1 mm per minute.

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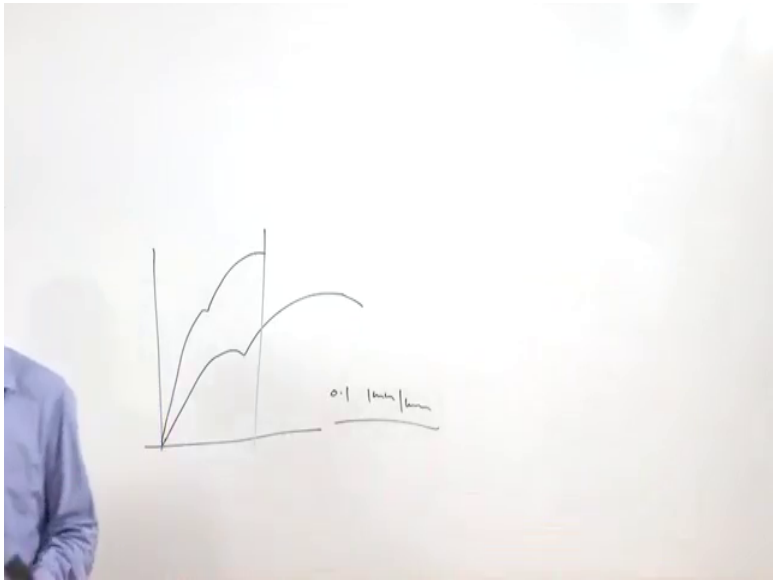

And, but if it is so that is showing the behaviour under these conditions, but if it is exposed for like say 10 mm per minute or 100 mm per minute strain load conditions then it will be showing the different kind of behaviour, it will be showing much higher strength, but reduced ductility. So, the behaviour of the material changes with the rate of the loading it tends to behave more like brittle material as compared to the more ductile material at high rate of the loading.

So, since the behaviour of the material changes with the rate of loading it may lead to the premature failure under the unfavourable high rate of loading conditions. Similarly unfavourable oxidative wear unfavourable corrosion conditions and erosive environment so, these are the service conditions. If the component is exposed for these conditions for which it has not been designed then it will be leading to the premature failure.

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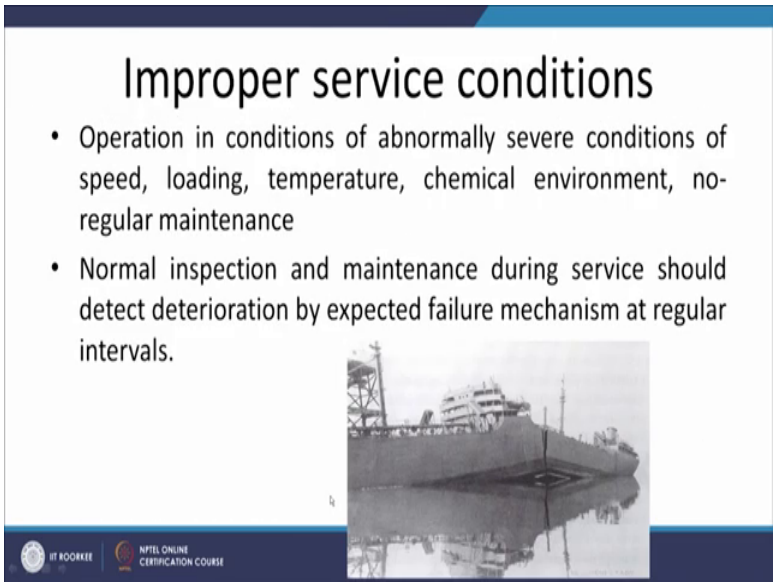

Similarly, the high and low temperature conditions for which it has not been designed can also lead to the failure of the component. This one typical example where one ship which was made of the medium carbon steel which did not have much low temperature toughness when it heat the iceberg under the low temperature conditions.

So, because of the low temperature conditions it had lost its toughness and heating with the iceberg lead to the lead to the fracture of the ship from the middle in the two parts. So, that fracture was primarily caused by the failure of the bits which were used for the joining of the ship.

So, the change in temperature conditions also can lead to the failure of the component. So, the operation in the conditions of the abnormally severe in respect of the speed, loading, temperature, chemical environment, and absence of the regular maintenance this can lead to the failure of the component premature failure of the components

So, normal inspection and maintenance during the service therefore, must detect what is the tendency of the component to fail by a particular mechanism. So, during the inspection its required that we are in position to check whether it can fail by a particular estimated mechanism or not and if can fail then we need to do the suitable repair and the maintenance and if it is not then it is allowed for the regular service.

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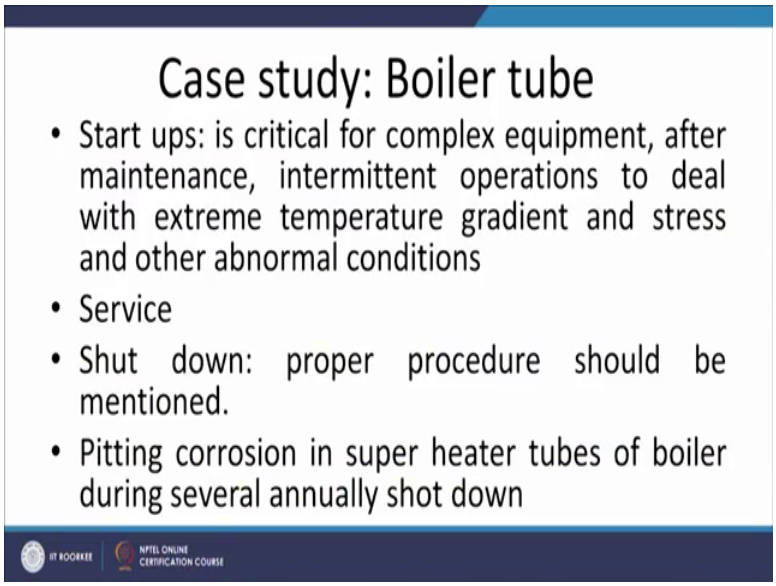

Now there is one case study where during the service itself the boiler tubes during the service exposure of the boiler tubes lead to the failure of the tubes prematurely. So, we know that start-up of the any new system is important and normally in the new when the component is new it is subjected to the somewhat lower stress conditions, lower service conditions, as compared to the normal service conditions.

So, we know we can see a start-up is critical for the complex components and intermittent after the maintenance intermittent operations to deal with the extreme temperature gradient and other abnormal conditions. So, the thing is when the component is new it is exposed for the reduced load, reduced temperature, reduced aggressive environmental conditions in initially stage of the service. So, that the component can really get used to for those conditions and especially in the initially stage and once it is placed in the service then it needs regular maintenance ah, but for the regular maintenance we need to take the shutdown and proper shutdown procedures need to be followed.

So, in one of the situations what had happened like the boiler tube boiler having lot of re-heater and super heater tubes. So, one of the super heater tubes showed the leakage during the trial test after the regular shutdown maintenance. So, the pitting corrosion in the super heater tubes the case study is related with the pitting corrosion in super-heated tubes of the boiler during the several annual shutdown when it was taken place.

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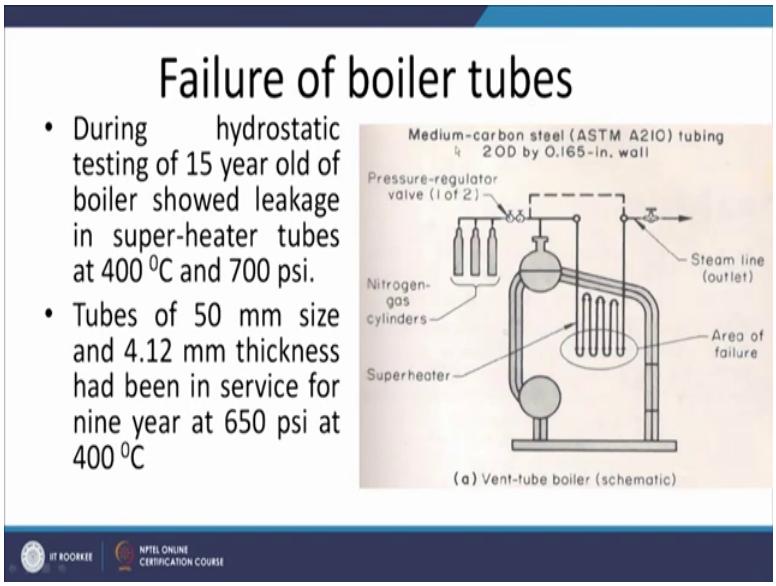

So, actually the boiler for the details if you go the boiler tube failure the failure of the boiler tube here. So, these are the super heater tubes and these started leaking during the trail run, and the trial run was conducted after the maintenance during the hydrostatic testing of 15 year old boiler showed the leakage in the super heater tubes and the tubes were operating at 400 degree centigrade and 700 psi.

So, the tubes of the 50 mm diameter and 4.12 mm thickness had been in service for past 9 years at this was so expected life was this one 15 years, but during the service after the during the service of the 9 years it had worked successfully at 650 psi and 400 degree centigrade. So, after the maintenance it was in trial run at 400 degree centigrade and 700 psi.

So, what it was made of medium carbon steel was used for making the super heater tubes which was having the wall thickness of 0.165 inch that was about like say 4.12 mm and 5 mm or 50 mm size the of the tube diameter. And this was the arrangement and for regular maintenance of the system and will shut down used to be taken and during that the maintenance was carried out.

And what had happened actually in this case the regular maintenance annually was carried out for the 9 years and during the maintenance period they use to open it up and then they will clean it up properly and then thereafter then after the regular maintenance

so they will put it on the trial run and then after the successful [train/trail] run trial run it used to be operated for the normal operation.

So, the tube say in this zone started leaking and it was found that so after since the leakage in the super heater tube started.

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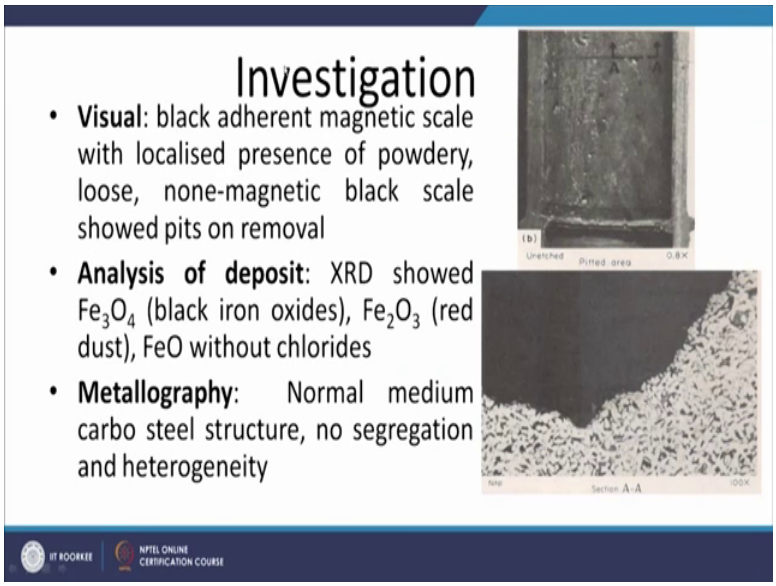

So, they wanted to investigate what lead to the failure of the premature failure of the super heater tubes. So, the tubes over cut and it was found through the visual inspection that black at adherent magnetic scale with the localised presence of powdery loose. So, both type of the black and both types of the oxides were found black adherent magnetic scale with the localised presence of the powdery loose and non-magnetic black scale.

So, the powders of both magnetic and non-magnetic type one was adherent and another was loose this was found on the internal surface of the tube. Analysis of these oxides by XRD showed that Fe3O4 black iron oxide powder and Fe Fe2O3 the red dust like the powdery form and in the iron oxide without chloride.

So, this was important to important for the inference that there was no effect of the chlorides which is normally added in water for the softening purpose and the metallography of the super heated tubes also showed that carbon steel carbon steel is the carbon steel has the normal structure of the ferrite and pearlite and there is no segregation and heterogeneity.

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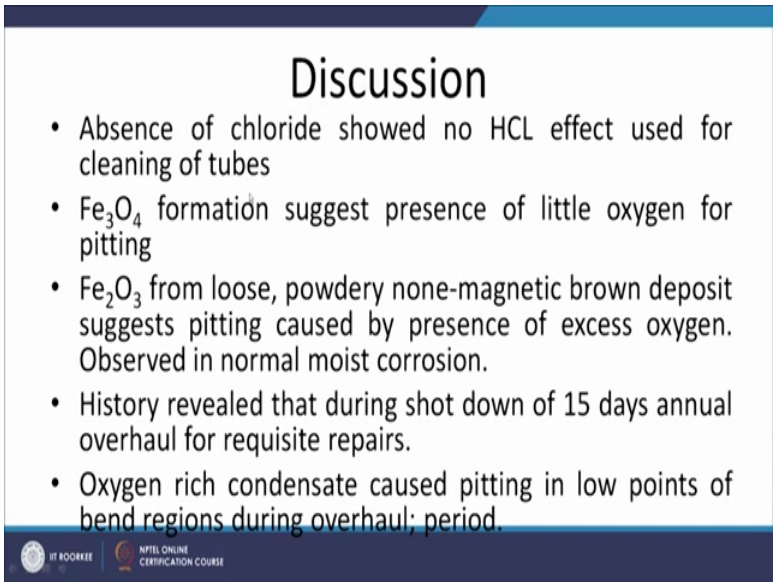

So, after this analysis it was observed that absence of the chloride showed that no HCL effect used to used for cleaning of the tubes because the HCL was being used for cleaning of the tubes and remove the dust and the rust Fe3O4 formations suggest represents of the oxygen is limited for the pitting and Fe2O3 formed the loose, powdery none-magnetic brown deposit suggest the pitting caused by the presence of the excess oxygen and which was observed in normal moist corrosion pits which were there.

And history revealed that during the shutdown 15 days annual overhaul for requisite repair was carried out and during this shutdown period itself the oxygen rich condensate cased the pitting in the lower points in the bend region during the overhaul period.

So, this was the reason like during the shutdown the oxygen used to get dissolved with the water which was getting segregated at the bottom of this tubes and this was the main reason behind the pitting at the lower bends of the super heater tubes the which were located here and that is why under the presser during the trial it is started leakage leaking from these locations.

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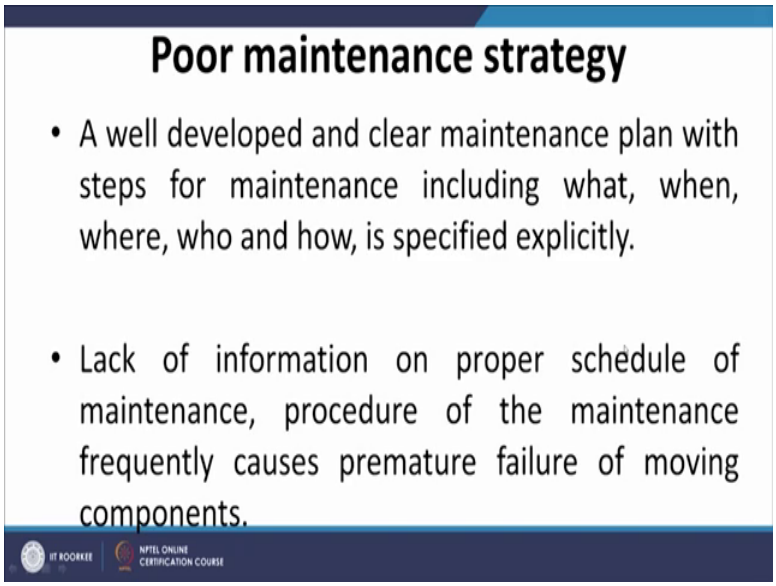

Now, the last point is about the poor maintenance strategy it is important that the clear and well thought out maintenance plan is developed and it should be clearly mention that what will be done for during the maintenance and when it will be carried out and or it will be done who will be doing and how the maintenance will performed everything needs to be specified very clearly.

And if the things are not mentioned clearly so any lack of the information on proper schedule of maintenance, procedure of the maintenance, it can lead to the premature, failure of the components especially the moving components where the lubrication is important for reducing the friction and reducing the wear of the components.

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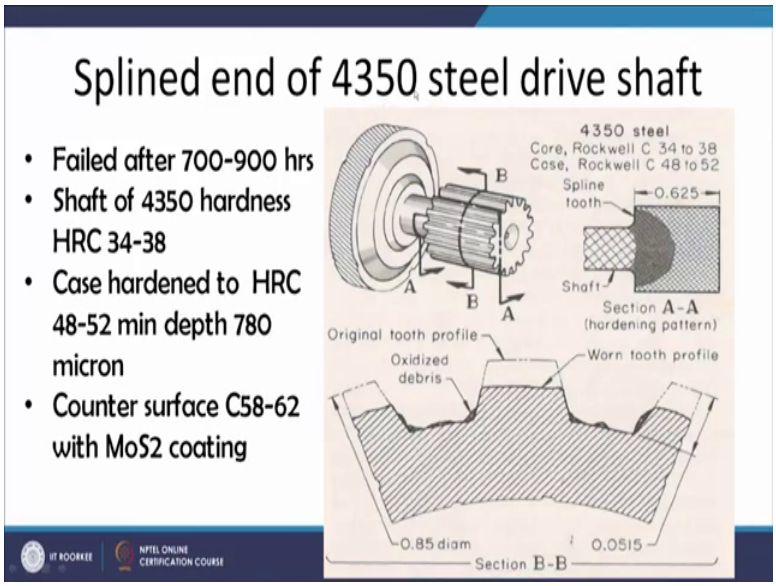

So, this is one typical example where in splined end of drive shaft 4350 steel drive shaft field prematurely and this shaft field after 700 to 900 hours of the service under the shaft which was made of the 4350 steel at the hardness of the 34 to 38 HRC and this was casehardened to the HRC to this level of the hardness after the casehardening for 48 to 50 minute and the depth of the hardening was 780 micrometre and the counter surface against to which the shaft was used at the hardness of the 58 to 60 HRC and this was coated with the the counter surface was coated with the molybdenum sulphide this is the solid lubricant coating.

And the splined shaft you can see here this is the splined end shaft and this the this splined actually failed due to the wear and this was investigated the cross section of the splined shaft showed showed the presence of the number of oxide particles at the bottom and did and the this lead to the modification of the tooth profile the tooth original profile was like this, but after the service it warned out significantly and it lost this much amount of the material from all the tooths.

So, it was indicating it was indicating basically the presence of the wear and lot of it was indicating the loss of the material occurred due to the wear and the presence of the oxidized debris also suggested the removal of the material by wear.

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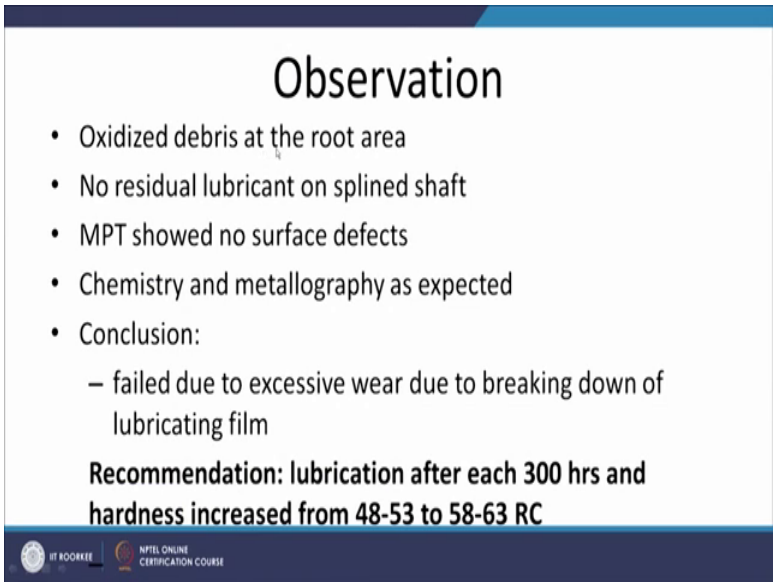

So, observation suggested that oxidized debris at the root area there was no residual lubricant on the spline shaft, magnitude particle showed the no surface defects, chemistry and metallography of the spline shaft showed the results as per the expected and specified one and so it was concluded that failure occurred due to the excessive wear due to the breaking down of the lubricants since the lubricant was not found on the surface of the tooth it was found that actually lubricant was absent or it was not maintained properly during the maintenance.

So, the recommendation was that lubrication after each 300 hours and it is also important that hardness is increased from 48 to 53 HRC to the 58 to 53 HRC. So, once if this was implemented thereafter no premature failure of the splined shaft was observed

So, now I will conclude this presentation in this presentation I have talked about the 3 aspects related with the fundamental sources of the failure one was improper assembling procedure second one was the improper maintenance and the third one was the improper service conditions. So, if the component is exposed for the unfavourable conditions then it can lead to the improper premature failure.

Thank you for your attention.