Failure Analysis & Prevention

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Lecture - 01
Introduction: Need and Scope of Failure Analysis and Prevention

Hello, I welcome you all in this presentation related with the subject failure analysis and prevention in the previous presentation, we have talked about the importance of the failure analysis and in this one, we will try to see the different aspects related with the failure analysis like when to consider a component has failed and what are what has been the major failures in the history of the civilization which has led to the death of the so many people.

So, we will be starting with the many engineering disasters these engineering disasters has led to the significant loss of the life and the property and which happened primarily due to the few reasons, for example, like an engineering failure leading to the engineering disaster might happen due to the like say the design flaws in the component which is failing or the material failures like the material which has been used for fabrication of those components were not fit for those, the service conditions and applications or insufficient knowledge is the kind of service conditions which will actually happened during the service were are not properly forecast and therefore, it resulted in the deficient design and maybe under estimation.

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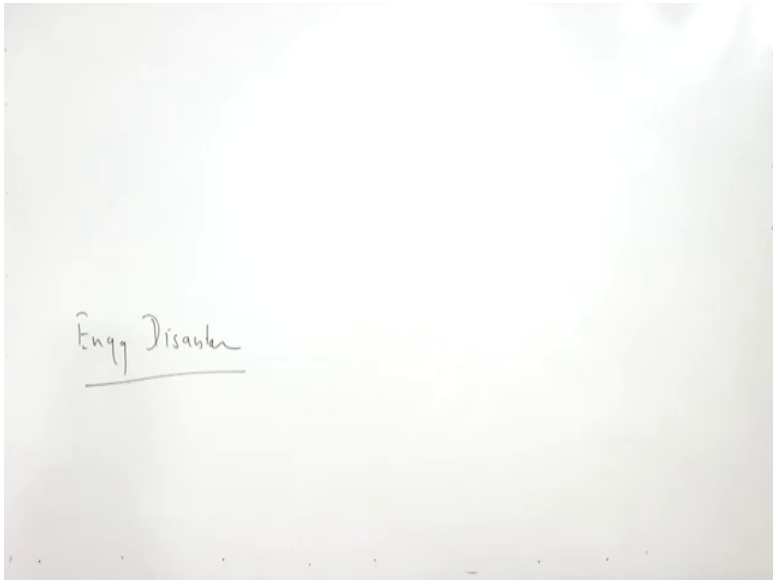

Under estimations related to the service conditions are the severity of the server conditions also might lead to the engineering failures and maybe a due to the carelessness and negligence of the those which are involved in design or the fabrication of the components or those which are there in service and maintenance of the components their negligence and carelessness can also lead to the engineering failures and which can appear in form of the big engineering disasters.

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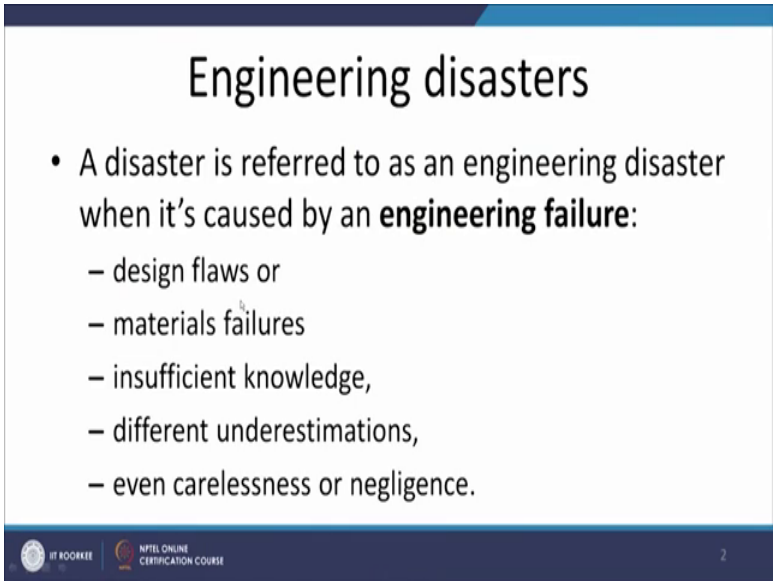

And these engineering disasters, we will see if there have been few very big engineering disasters in form of like say a titanic ship failure.

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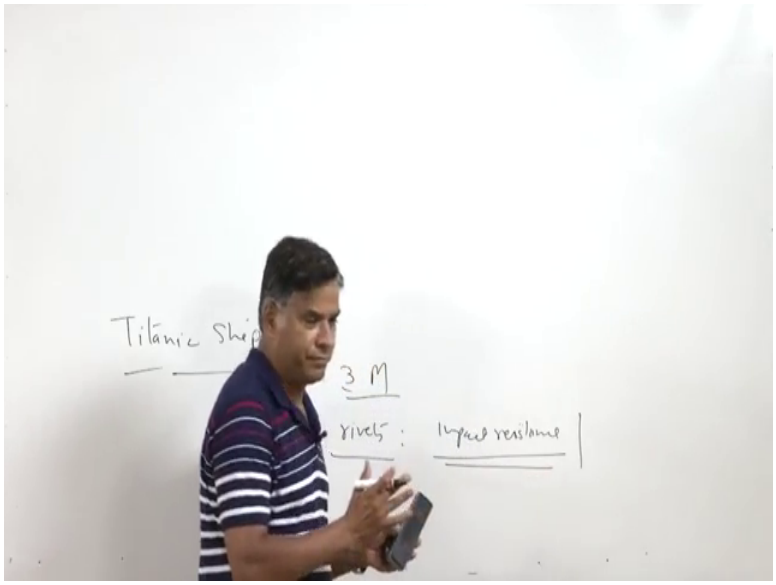

This was one in this titanic shik ship failure. This failure occurred as you can see in a 1912.

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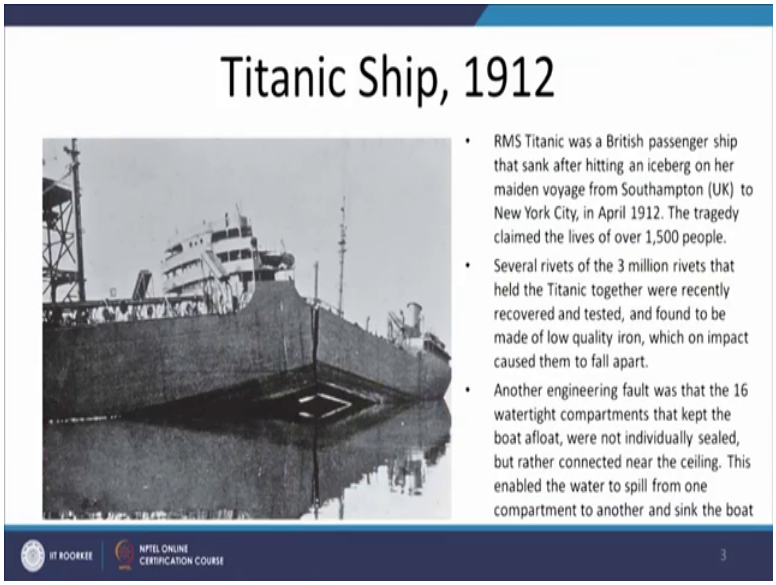

This af failure of the ship a lead to the a loss of the life of more than 1500 people and this failure primarily occurred due to the failure of the rivets this had more than 300 million

rivets to join the different plates of the shape and in this ship these rivets which were there, it was found that their impact resistance was very poor.

And when the ship hit the iceberg; that impact led to the fracture of the rivets and that fracture led to the separation of the different plates and that finally, lead to the sinking of the ship. So, if you see the details of this titanic was a British passenger ship that sank after the heating and iceberg and this happened in April 1912 and led to the loss of more than 1500 loss of the life of more than 1500 people and as we can see the several rivets of the 300 million; 3 million rivets that help titanic together were recently recovered.

And tested was the cause which was found for the failure of the ship was the poor impact resistance of the of those are rivets are due to the low quality iron which was used and another problem which was observed in design of the titanic ship was that there were sixteen water tight compartment which was separated all which was separated from each other, but all of them were connected near the ceiling and this enabled the water to spill from one compartment to the another and finally, lead to the sinking of the boat.

So, this was the big failure engineering failure or engineering disaster which primarily happened due to the poor impact resistance of the rivets as well as poor design of the ship where in there was sixteen different compartments all were in interconnected at the ceiling. So, when the water filling started, then this led to the failing of the water from one compartment to another in sequence and finally, the sinking of the ship had happened which led to the loss of a life of more than 1500 people.

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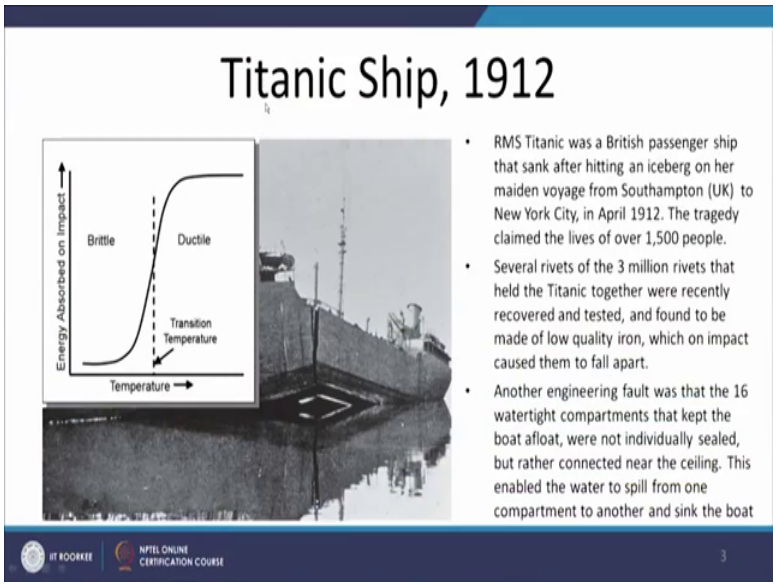

Then there is another case, this is what has been explained with the help of this diagram where in like a the iron under the low temperature conditions loses its the toughness and this particular temperature at which loss of toughness is observed is called ductile to brittle transition temperature and here, we can see the toughness as we know we measure in terms of the energy absorbed and energy absorbed reduces with the reduction in temperature for most of the steel this temperature is about minus 20 to minus 30 degree centigrade almost of the mild steel in structural steels.

While for alloy steels especially by adding nickel and other elements are this can be reduced further. So, that there is no significant loss or loss of the toughness. So, basically the when the material is subjected to the high temperature conditions like room temperature and above it has a fairly good ductility and it becomes brittle when it is exposed to the low temperature conditions.

So, basically the iron rivets which were used them had a low toughness under the low temperature conditions especially when it hit the iceberg and that lead to the fracture of the rivets and which led to separation of the ship also another big disaster engineering disaster was the Saint Francis dam.

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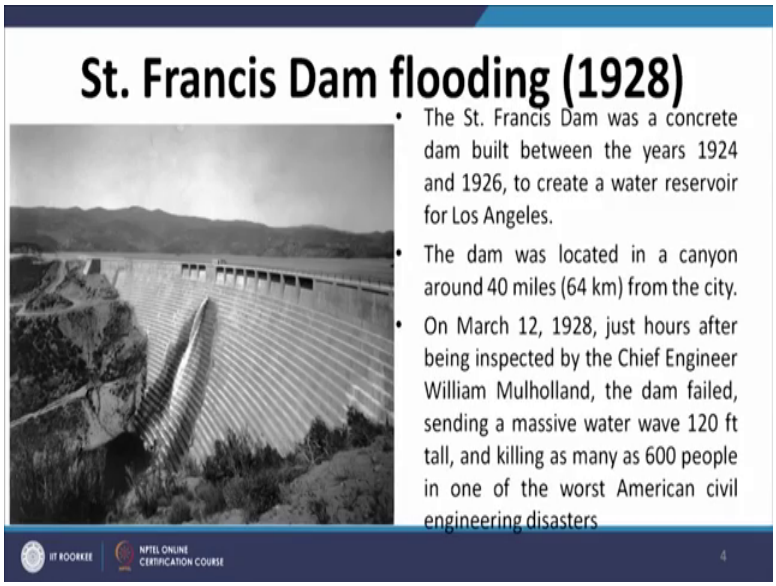

This dam was constructed in 1926 to supply the water to the Los Angeles city and this was very close to the Los Angeles about 60 miles from 40 miles from the Los Angeles into it. There is a famous Canva Canyon hills where it was constructed and this figure shows the dam constructed on the canon canyon hills which was about 40 miles from the Los Angeles it is about 20-15 kilometer from the Las Vegas and on March 12, 1928.

Just after few hours of the inspection by the relevant engineers the dam failed and that resulted in very high water waves and killing as many as 1600 people this has been one of the worst disasters in the American Civil Engineering disasters history. So, this is the kind of the residual and the left out structures were there the structure which was like this before the failure of the dam and after that all this is structure was damaged.

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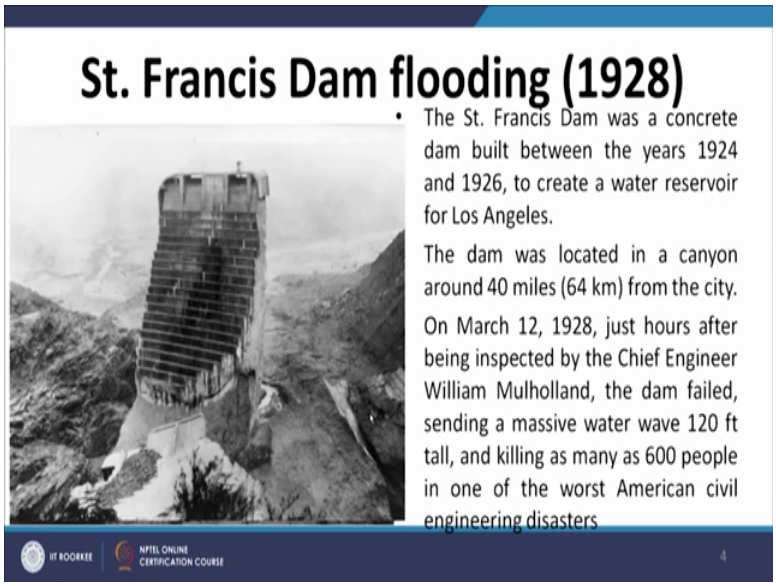

And this was the left outer structure after the disaster and the whole of the water led to the high water waves send that led to the killing of the many people.

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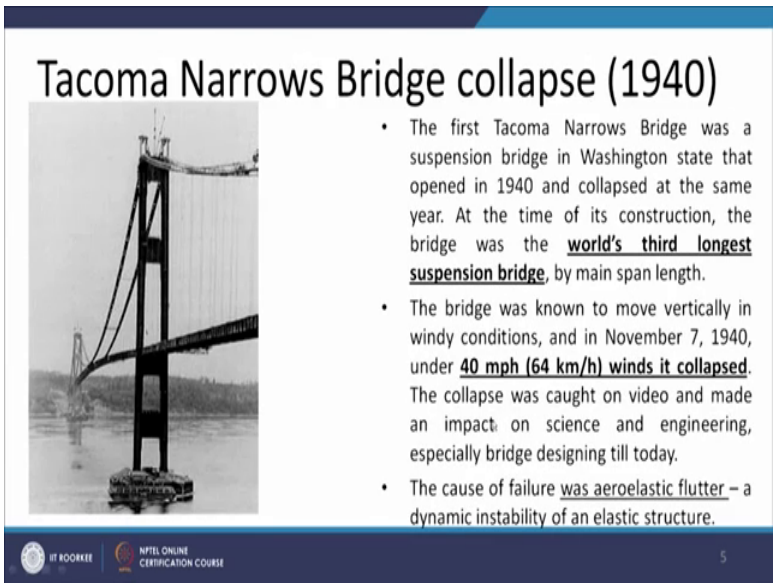

And then there is another accident which happened again in USA around 1940. This is called Tacoma narrow bridge collapse, all this was the third world's third longest suspension bridge in terms of the span length and that bridge used to flutter under the influence of the air. So, under the conditions on the of the wind velocity of 40 mile per hour this was fluttering to such an extent that it collapsed and this collapse was caught in

the camera also and the main cause of the failure was the aero elastic flutter that is a dynamic instability of an elastic structure.

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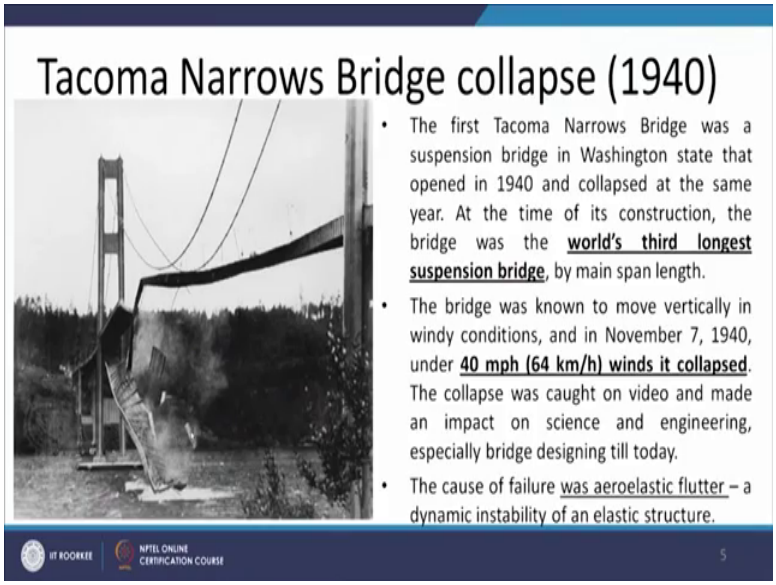

So, this flutter was recorded in camera and what was seen in this form here. Now this led to the collapse of the bridge.

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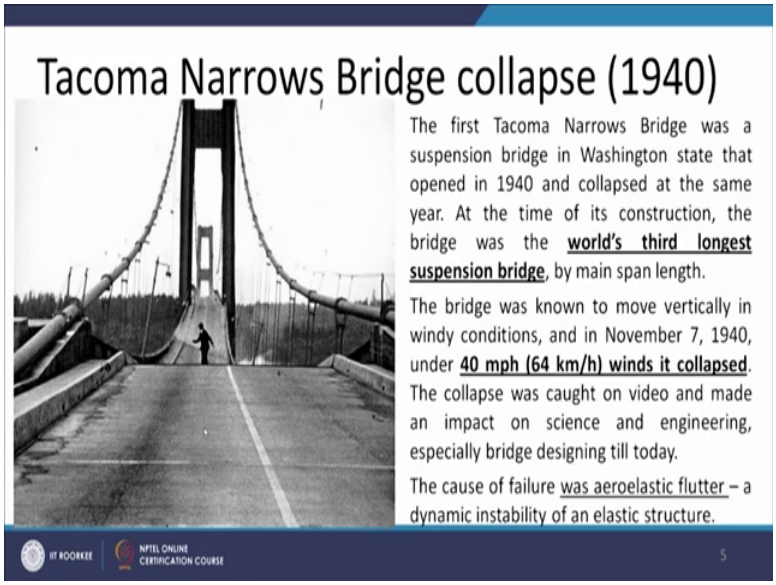

So, these are the flutter we can easily see under the influence of the air or the wind, it was fluttering up and down and this under the extreme conditions led to the collapse of the bridge.

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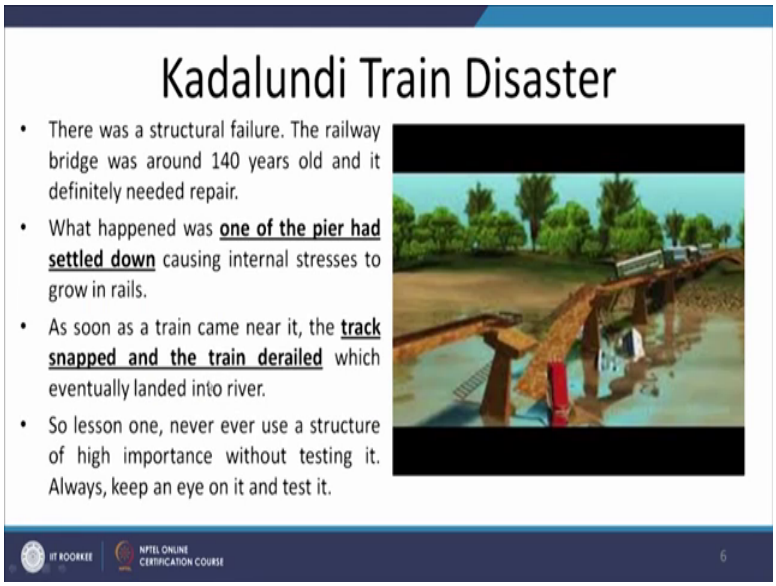

Then there are three more disasters which took which are here in India, one is a Kadalundi train disaster here the when the train was passing over the river bridge on the river had a number of piers.

So, one of the pier had settled down causing the internal stresses in the rails. So, when the train was passing the track snapped the track railway track snapped and the train was derailed which eventually landed into the river and. So, in this case basically the testing was not the carried out and the than the pier one of the pier at settled which caused a lot of stress internal stresses to the track especially when the train was passing through the air that train was got derailed.

And it landed eventually into the river. So, it is important that never use a structure of high importance without testing and always keep an eye on its integrity and safety and it needs to be tested first before being used then the Bhopal disaster was another big disaster which had happened in the Indian history.

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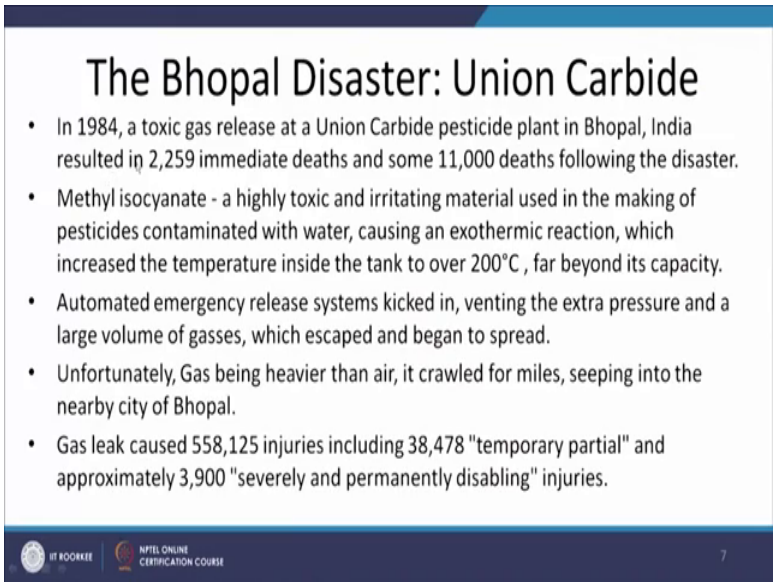

And the it happened in a nineteen eighty four where in toxic gas released at the union carbide pesticide plant in the Bhopal that resulted in death of more than 2259 people immediately and as a whole even after that also as a whole as about 11,000 people died as a result of this disaster.

And in this case what had happened like the methyl isocyanate which is highly toxic an irritant material this got contaminated with water which resulted in exothermic reaction and exothermic reaction increase the generated heat and which in turn increases the temperature inside the tank over 1200 degree or 200 degree centigrade which was much beyond its capacity and because of this increased temperature conditions automated emergency release system kicked in venting the extra pressure and large volume of the poisonous gases were released and that those gases is spread all around the nearby area.

The another problem was that had the gas been lighter one, it would have reduced the extent of adverse effect it had. So, say, but the gas was heavier than air. So, it settled down at the lower levels and that affected the people more badly and that led to the loss of more life. So, that gives a gas leak called caused more than 5 lakhs injuries including 38,000 temporal temporary and partial injuries and permanent disabilities of more than 3900 people. So, this was one of the biggest disaster of the Indian history that let that was also because of the some technical issues related with the production.

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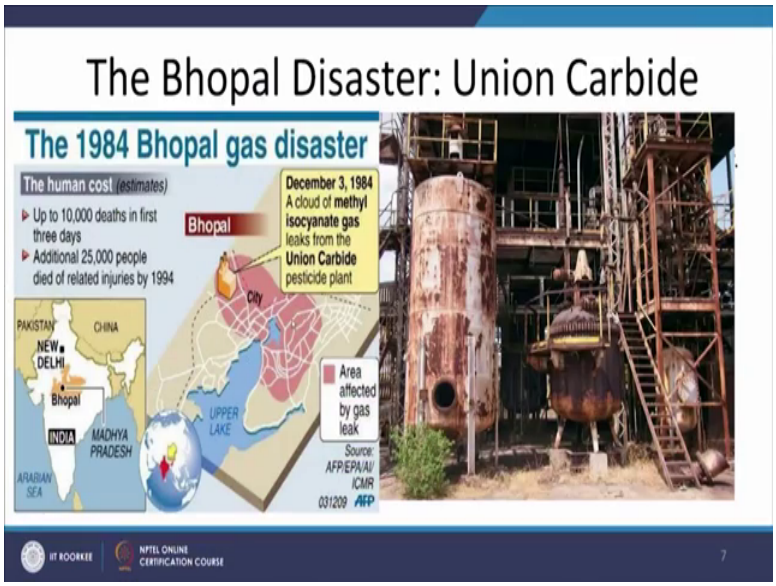

And these, just is schematically shows the union carbide plant where this disaster took place under the kind of the effect which it had and where the plant was located.

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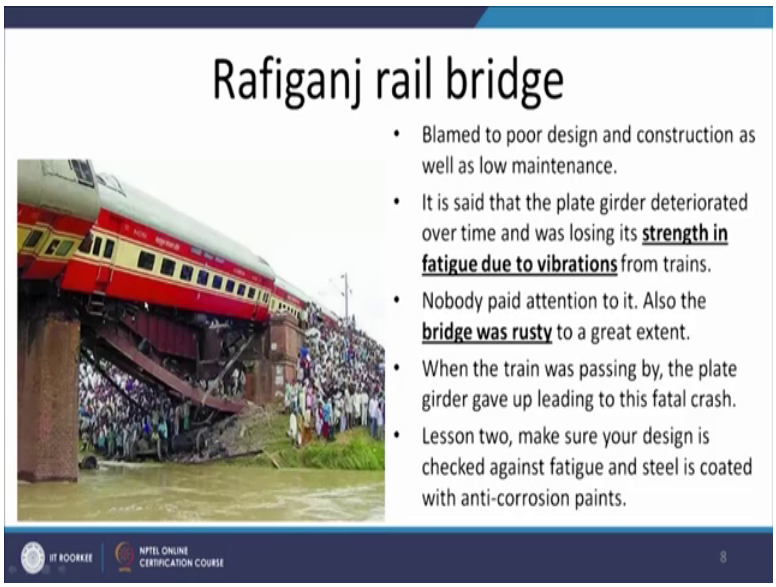

Then there is one example of the Rafiganj role rail bridge here also it was the failure was blamed to the poor design and construction and the low maintenance conditions and it is said that the plate girder decorated over a period of time.

Which like to the last of their strength fatigue due to the vibrations from the train and in the, and this was left unattended and over a period of the service this bridge was also

rusted which are internal to reduce the strength. So, when the train was passing the plate of the girder gave up leading to the fatal crash and because of this it was learnt because of this after this accident it was learned that make sure that you are design is checked against the fatigue and steel is coated for the corrosion.

So, for the Rafiganj roll rail bridge accident two causes were identified mainly one was the corrosion of the steel plate girders and another one was the fatigue. So, due to the vibrations the fatigue the crack or nucleated and fatigue reduce the strength and means load carrying capacity and which eventually under the loading conditions led to the catastrophic failure.

So, it is important that anti corrosion paints are made and the designs are checked for the fatigue loading conditions. So, these were the some of the failures which happened internationally and nationally and these underline the need of a looking into the technical aspects to see in which way what should be done in order to avoid the recurrence of the such kind of failures because whenever such kind of failures occur there will be leading to the huge loss of the life property reliability and very adversely affect the public as a whole.

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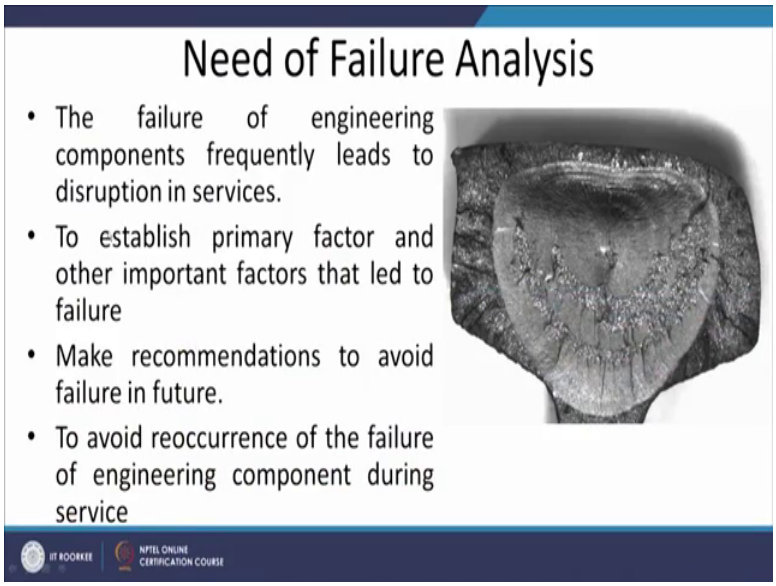

So, failure of the engineering components frequently leads to the description to the services and therefore, it is important that the primary factors causing the failure are

established and so that in light of the causes suitable recommendations can be made so that their failures or their recurrence can be avoided.

So, to avoid the recurrence re occurrence of the failure of the engineering component during the service suitable recommendations must be made ye. So, I; now we will try to understand that for the failure analysis what we need to do and when to consider that the product has failed or not; so, for this purpose as I have said the failure analysis is a systematic approach of the investigation primarily to identify the fundamental causes or the primary causes of the failure. So, that the corrective action can be taken, but for investigation in which direction investigation should be for that purpose we need to understand the two important thing to see in which way we should move for the failure analysis.

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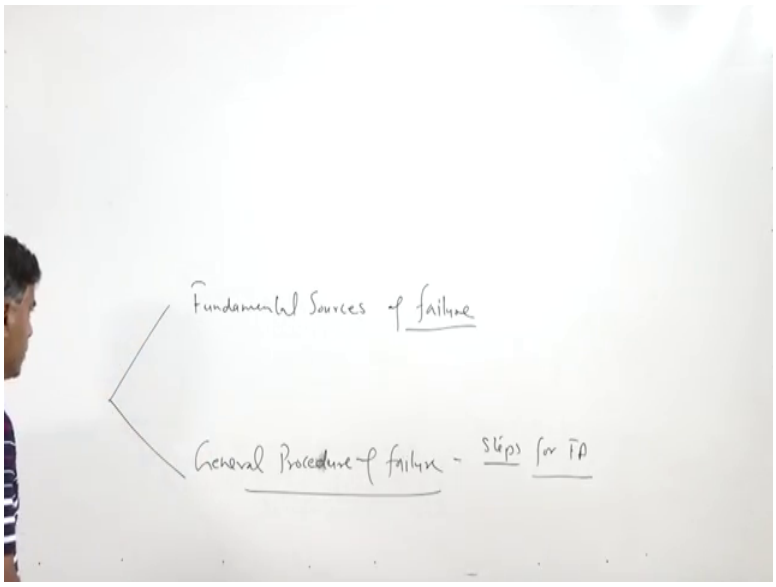

One is we need to understand systematically what are the fundamental sources of the failure all these will provide us the clues the directions which should be looked into to explore the possibility of the failure that these sources might have contributed towards the failures. So, fundamental sources of failure this is one thing.

So, we need to understand systematically; what are the various sources which can cause the failure of the component. So, this is one thing and another is what is the general procedure for the failure analysis general procedure of failure analysis there is there is few general things which needs to be which need to be seen in the failure analysis and

that sequence is to be followed, but not necessarily, it always that that sequence will be followed as per the finding of the one stage we will decide that in which direction we need to move for the investigation. So, general procedure of the analysis its basically about the general steps which are used for the failure analysis since there can be a series of the fundamental causes which fundamental sources which can cause the failure of the component.

So, all these need to be understood systematically. So, this is what is needed to have the proper failure analysis when to consider that a component has failed for that purpose we need to see the three conditions which are considered as the situations when we can say that a component has failed.

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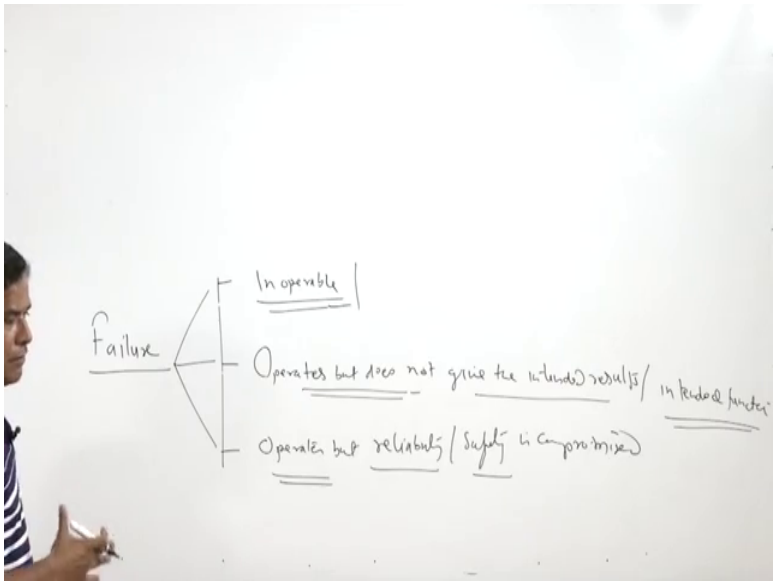

So, failure when to consider that a component has failed their three situations one is that the component is in operable. The second is the component or the product operates product operates, but does not does not give the intended results or we can say intended function is not being performed by the product. So, it operates, but the desired results are being not given and the third is the component operates, but reliability safety is compromised. So, we would not too we would not like to use the component when the come this compromised. So, these are the three situations like we switch on the fan switch, but the fan does not run.

So, that is one or we use a pen, pen is being used so, but it is not writing. So, that is the inoperable situation, we switch on the car, but car is not starting that is the in operation and the second are we are switch on we have switched on the turning (Refer Time: 21:00) (Refer Time: 21:02) machine, but machine is not operating.

The second case is we switch on the fan, but the fan rotates at very low speed and it does not give the air that is expected or we switch on the (Refer Time: 21:17) machine machining is being done that is fine, but it does not give the required surface finish it does not give the required dimensions. So, that is another case the system operates, but it does not give the desired results or does not perform the intended function like cutting tool is cutting the material, but it is it is giving the surface which is too rough for any use third situation is where the component operates, but the reliability is compromised.

So, if it is leading to the risk to the life of the proper life and the property then of course, the components need not to be used in that case even if it operates ah, but reliability and the safety is compromised then also we will consider that no components need to be looked into and it should be investigated to see what has led to the failure of the component.

So, these are the three situations where which are very generic in nature and it can be applicable for any kind of the failure of the any kind of mechanical components. So, the component does not operate or its inoperable it operates, but does not give the desired results or does not perform the intended function or it operates, but the reliability and the safety is badly compromised.

So, these are the three situations when we can say that the component has failed.

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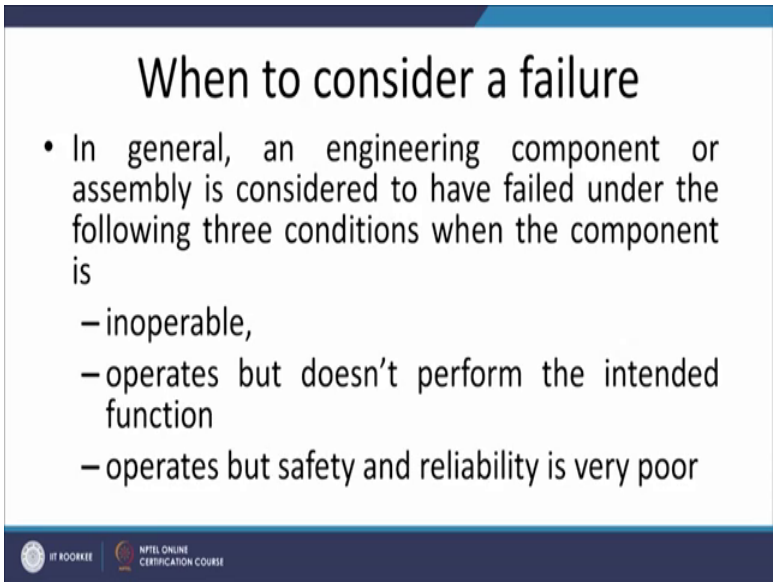

So, this is what has been explained in the presentation also like the component is inoperable operates, but does not perform the intended function and operates, but the reliability and the safety is poor or that is compromised.

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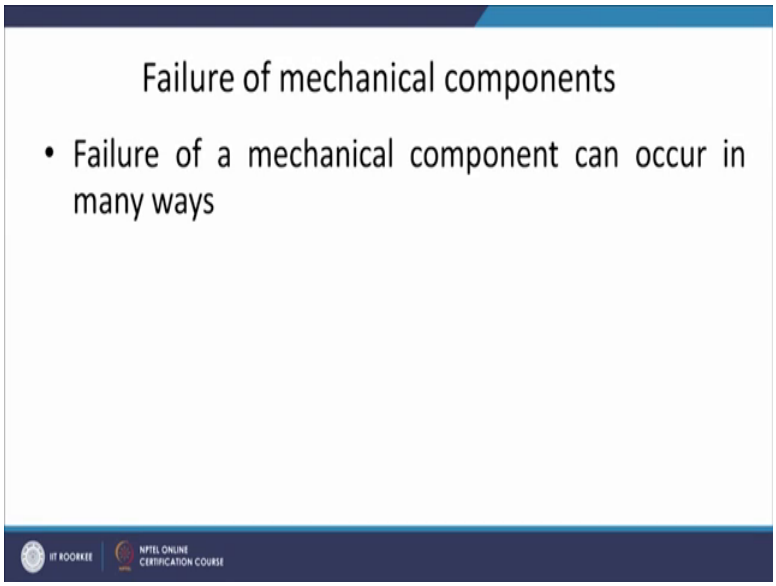

So, what are the different ways by which the failure of the mechanical component or the metallic components, take place.

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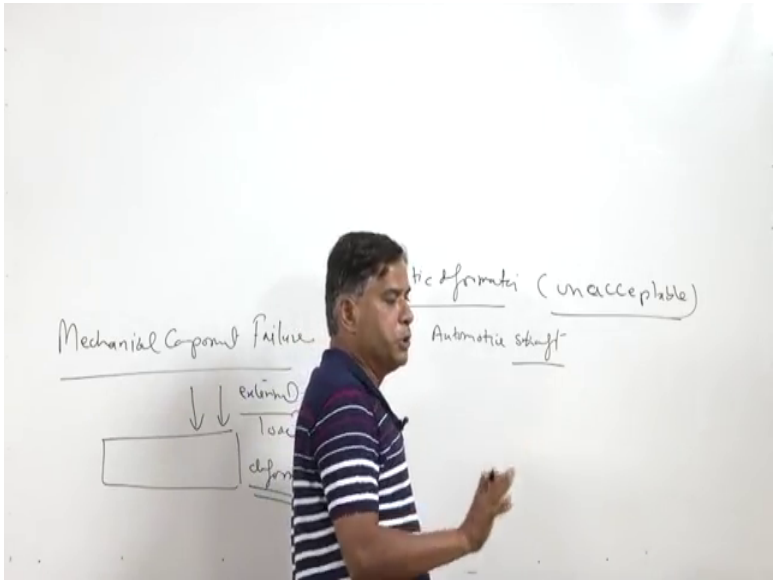

So, the mechanical components failure they are four broad categories by which the mechanical components can fail the number one here like the material what is the meaning of mechanical component that there is a component made of the normally made of the metal.

Ah it can be made of the wood and the plastics and other things also, but it is subjected to the external load for given function. So, some loading is there and the component has to work under the given loading conditions. So, under the loading conditions if it deforms elastically deforms elastically beyond the limit, then will say that the component has failed elastically component does not work I will ask is because the deformation elastic deformation is beyond the limit.

So, we can say un acceptable the elastic deformation un acceptable elastic deformation. This is the typical case where like what we consider automotive shafts what we want that elastic deformation of shaft is very less if it is more than it will adversely affect the opening and closing of the walls due to the improper position of the cam which is used for operation of the opening and closing of the walls.

So, similarly for other applications where elastic deformation is leading to the misplacement or miss positioning of the components then it will be leading to the improper functioning of the machine systems and leading which internally leading to the in malfunctioning or improper operation of the system as a whole. So, if the component

deforms elastically beyond acceptable limit then we consider that the component has failed or it does not work.

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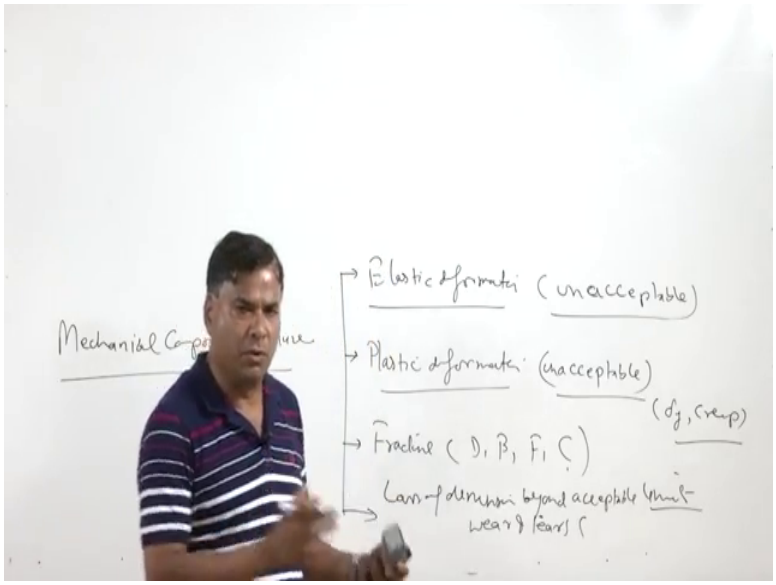

The second is the plastic deformation when the when the, differ under the influence of the external loads during the service.

If the component deforms plastically means the experience is a permanent change in dimensions shape then that will be leading to the plastic deformation. So, we can say un acceptable un acceptable plastic deformation beyond the limit meri marginal plastic deformation is ok, but if there are certain limits and the conditions of for a smooth functioning of the component if the dimensions go beyond those limits then will say that component has failed by the plastic deformation third is that complete fracture under the external load conditions if the loading goes beyond the limit, then component can fail like that in ductile fracture brittle fracture under the fatigue conditions creep conditions. So, there can be different things. So, there can be like say the ductile fracture brittle fatigue or the creep.

So, these are the different ways by which failure of the component can take place. So, here like the here the stresses has to be more than the yield strength limit or the deformation beyond this acceptable limit can also happen due to the creep. So, here this is called a stress rupture where separation or the fracture occurs in the fatigue, it is catastrophic in nature this brittle fracture is also catastrophic and we get the some

indications in case of the ductile fractures that no, yes component has started deform after some time it will fail.

So, this is the third category by which the mechanical the failure of the mechanical component can take place the fourth one is where the loss of dimensions beyond acceptable limits acceptable limits like, this primarily happened due to the wear and tear which can be like adhesion aberration corrosion erosion extra are the mechanisms which are working on to the mechanical component and that is leading to the loss of dimensions and sometimes, we will find that no that the dimensions of the component has lost so much that the dimensions have reduced and they are not able to take the load or the service conditions anymore and that will be leading to the failure of the component.

So, these are the four ways by which failure of the mechanical component normally occur elastic deformation plastic deformation and the separation or the fracture and the loss of the dimensions beyond acceptable limit due to the wear tear etcetera now.

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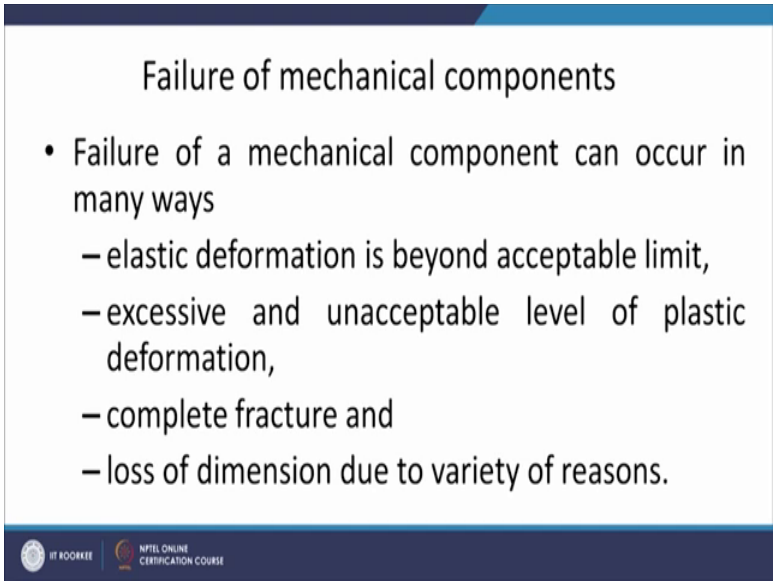

So, this is what we can see in the presentation elastic deformation is beyond acceptable limit excessive and un acceptable level of the plastic deformation complete fracture and the loss of dimensions due to variety of reasons which are primarily related like adhesion abrasion erosion corrosion etcetera.

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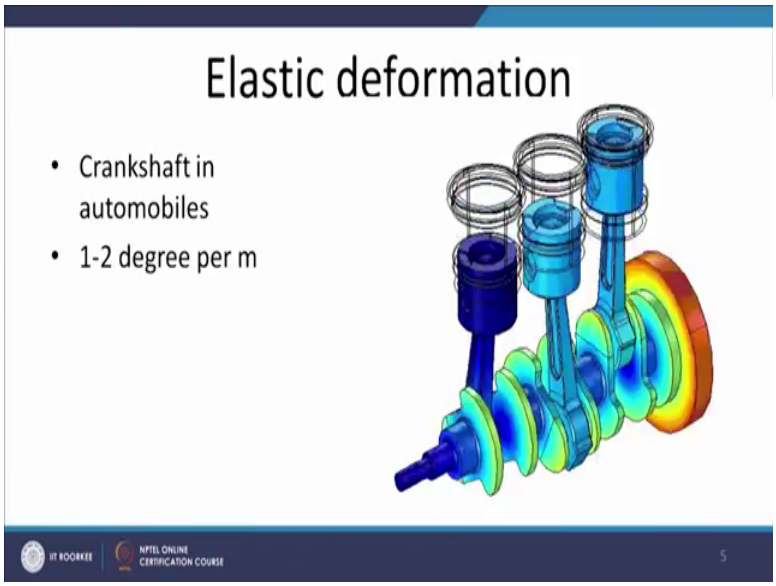

Now, we will see this is the typical case of the elastic deformation where during the operation the torque is transmitted from the engine to the through the crankshaft to the eventually to the wheels of the automobile and here the due to the transmission of the torque elastic deformation of the shaft will be taking place and if this elastic deformation is beyond the acceptable limit.

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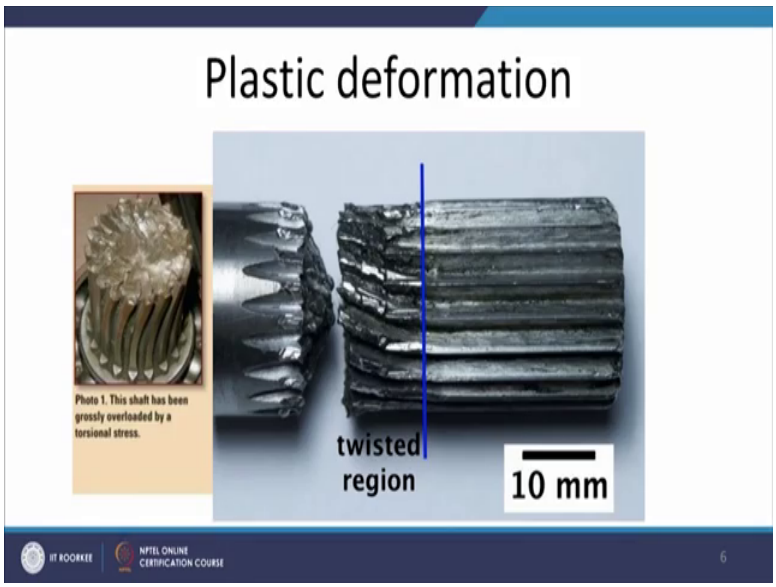

Ah then it will be leading to the malfunctioning of the walls and that will adversely affect the functioning of the automobile or engine or another is a plastic deformation where due

to the excessive loading when the stresses go beyond acceptable beyond the yield strength level, then it will lead to the this what we can see here it will lead to the deformation.

So, here these gear teeth have been subjected to the teeth on the shaft have been subjected to the greater than the elastic strength and that has led to the ah, sorry, plastic yield strength that has led to the plastic deformation and this and similar kind of the deformation we can see here where the gear teeth's have been subjected to the plastic deformation and here.

That twisting in particular direction is showing that it has been subjected to the torsional kind of the loading this.

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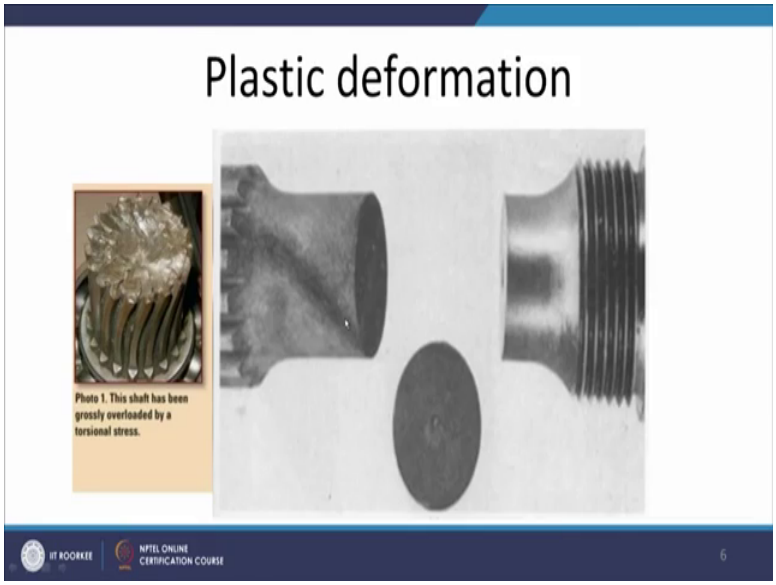

We can see here also like this by spiral feature indicates that other component as deformed plastically under the torque conditions or the twisting load conditions, then another failure is where the creep takes place the creep is a phenomena like this is.

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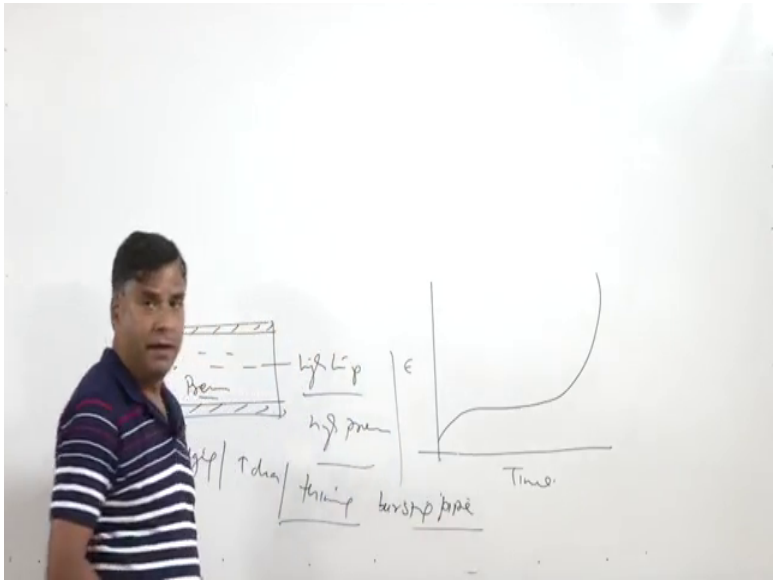

The tube having some wall thickness or like say in case of the boilers na and here we have a high temperature and high pressure. So, under the creep conditions means the metal will be experiencing the stresses due to the pressure and high temperature also. So, under the cost and the pressure conditions also when the component is subjected to the subjected to the high temperature as a function of time we find that there is a continuous plastic deformation.

So, initially there is elastic deformation and then it is subjected to the plastic deformation like this. So, strain being experienced by the pipe will keep on increasing as a function of time and as a result of this there may be localized bulging or increase in diameter or increase in thinning of the pipes. So, all these things will be leading to the eventually the busting of the pipes. So, this is why this is what I can be seen here in this tubes due to the continuous creep and the thinning of the walls that will be leading to the fracture.

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And the suppression this is a, the structure condition and the due to the overloading or its due to the overloading.

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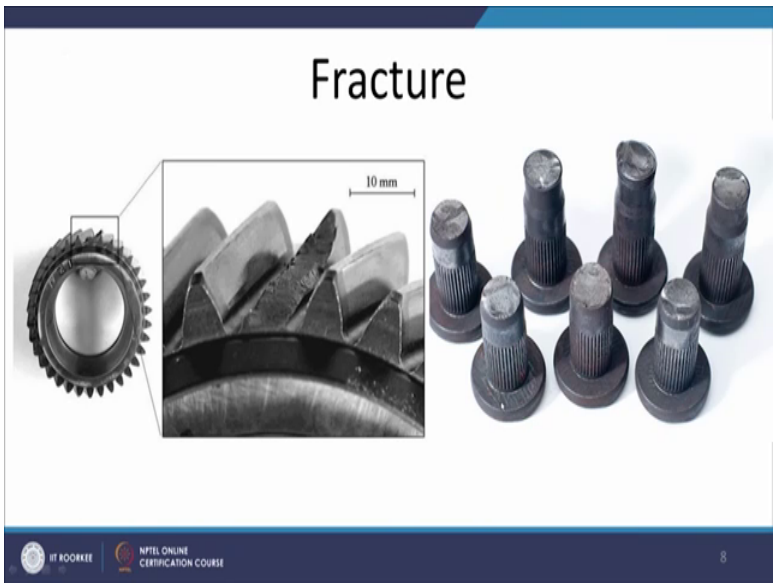

You can say these are the gear shift the gear is subjected to the overloading and the fracture of the teeth can take place, this kind of fracture of course, in normally it is a fatigue in nature where crack will first nucleate and then it will grow gradually during the service and ultimately to lead into the suppression or catastrophic of failure of the gear teeth's; so, now this is the kind of wear where loss of dimensions take place.

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So, this wear can be there in different forms in the case of gas turbines like the high temperature in case of a gas turbine they will be working under the high temperature conditions and if the hard particles are striking to the surface of the turbine blades, then they will be causing the erosion similarly in hydro turbines if the silt is coming along with the water then it will be causing the loss of the material from the turbine blades and the erosion of the material from the surface and that will lead into the loss of the material as well as loss of shape of the turbine blades and the guidelines.

So, this kind of ah; so, this is an example of the loss of the failure of the components due to the wear in the earlier case we have seen the failure of the component like the gear due to the fracture and here in one of the case what we have seen the failure of the tubes due to the creep and the failure of the shaft due to the plastic deformation where change in size and shape takes place due to the excessive loading beyond the yield strength limit this is the case of the elastic deformation if the crack the shafts are subjected to the greater if the elastic strength of the material is poor and the current shafts are not properly designed using suitable material of the required rigidity, then it will be leading to the alligator elastic deformation.

So, if you have to analyze these four fundamental forces four ways by which failure of the mechanical component can take place then we need to see what kind of the physical evidence is we need to collect and what we should look into so that the potential causes

of the failure can be explored. So, now, we need to see what are the fundamental causes that will lead to the failure of the mechanical components of this we can categorized in four groups.

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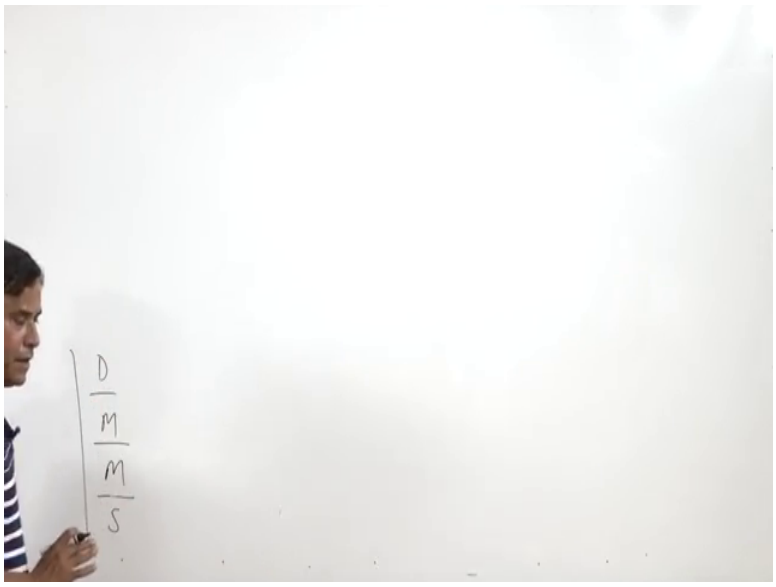

One is the design second is the material third is the service sorry third is the manufacturing and forth is the service conditions for which these are exposed, I will talk in detail about these fundamental causes at the factors which can lead to the failure of the mechanical components.

So, here I will summarize this presentation. In this presentation, I have talked about the few big engineering disasters which I have taken place internationally as well as in India and when we consider that act as a component has failed and what are the fundamental causes which lead to the a failure of the component.

Thank you for your attention.