Failure Analysis and Prevention
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Lecture - 21
General Procedure of Failure Analysis: NDT for Failure Analysis

Hello I welcome you all in this presentation related with the subject failure analysis and prevention. And we are talking about the general practice and procedures for the failure analysis. And in this connection we have already talked about the 2 points, one was like the collection of the background information of the failed component and the second one was the preliminary examination of the failed component, and after this we have got the failed component we need to study the failed component with regard to the presence of discontinuities or the stresses which have been experienced by the component during the service.

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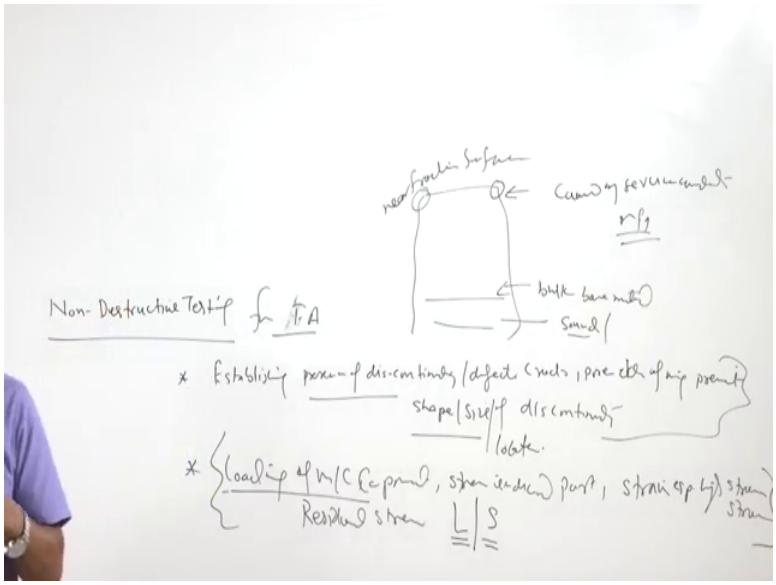

So, for that purpose we need to perform the non-destructive testing. So, non-destructive testing, so non-destructive testing for failure analysis. So, what is the kind of a role of the NDT in failure analysis? So, you know the primary purpose of conducting the NDT on the failed component is a to basically identify the presence of discontinuities in the component if they are there.

So, establishing establishing presence of discontinuities, defects, cracks, pores etcetera if they are present if any present in the present where. So, this presence is to be identified especially with regard to the certain locations like; I it may be near fracture surfaces or in the bulk base metal itself.

So, there will be the, and this will be done for the 2 different purposes. the NDT of the bulk material will help us to see whether the material is sound or not or if it is having the inherited discontinuity due to the use of imperfect base metal itself. Or if the discontinuities are present or defects are present like cracks, and other things are present near the fracture surface then it may indicate that either these have been caused by the service conditions or these were presented due to the various regions related with the improper manufacturing.

Ah. So, once these are identified identification and establishment of these discontinuities is done, basically with regard to the shape and the size of a discontinuities ah. So, the main aim is a to relate the possible contribution of these discontinuities with the failure or fracture.

So, if the discontinuities are there of the large size at the critical location then they of course, can be considered as a major possible contributor towards the failure, but that will be established only through the fracture mechanics analysis of the entire situation in light of the size and shape and the location of these discontinuities in the main component which has failed.

So, it provides the basis for the failure analysis due to the presence of the discontinuities if they are established through the NDT. So, this is one of the aspects and another one is to do the analysis with regard to the approximate loading of the machine component, or the stress induced in a particular part it also indicates the kind of the strain especially in especially in the high strain areas.

So, these are some of the things apart from that it can also help us to see if there is any presence of the residual stresses in the component and if they have contributed towards the failure. So, these are the 2 types of the things which can be done through the use of NDT in connection with the failure analysis. So, establishing the presence of discontinuities and then investigating their role towards the failure. And the second one is like the kind of the load which has acted on to the machine or a particular component

kind of stresses which have been is induced or what is the effect of the service conditions in terms of the load on to the strain which has been induced or the kind of residual stresses where which were there which were present.

So, apart from the design load if we are able to establish this through the NDT; that the component has been subjected to the certain kind of the load and certain kind of the stresses which you are beyond the acceptable level for that particular component beyond the allowable level of the stresses for that component.

So, this can be used as a possible way to relate with the failure. So, and it can also indicate the possibility of the accidental load or the abnormal load under which the failure has taken place with respect to the design load or the expected load. So, these are the 2 main objectives of conducting the NDT of the failed and one we are able to identify and establish the size, shape and the type of discontinuity is it is location, where they are present and then efforts will be made to relate them with the failure.

So, and the second one is to identify that it will help to estimate the kind of the load stresses strain which have been induced as a result of the loading during the service. So, that can be related with the possibility of the normal load or abnormal load accidental load so likewise.

So, now how it is conducted? So for establishing the defects and the discontinuities.

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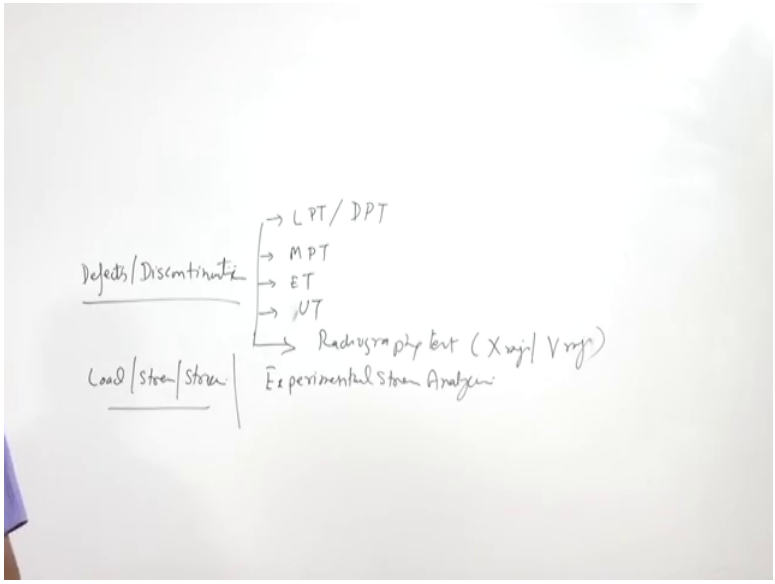

In the failed component, we have one category of the methods and for establishing the load stresses strain we have another category of the method. So, this falls under the experimental stress analysis. And a for determining or establishing the defects and discontinuities in the failed component we have the another category of the methods. So, we will be talking about these methods in detail.

So, there are 4 5 common methods of the establishing the discontinuities and defects in the failed component ah, like liquid penetrant test this is also known as DPT dye penetrant test this is one. Second is the magnetic particle test, third is et current test, 4th is ultrasonic test, and the fifth is like radio graphy test wherein we have like X ray or the gamma ray testing of the metals.

So, each type of the test of for certain advantages and disadvantages over the others so, we will take up each type of the test one by one sequentially. So, like say the first is liquid penetrant test.

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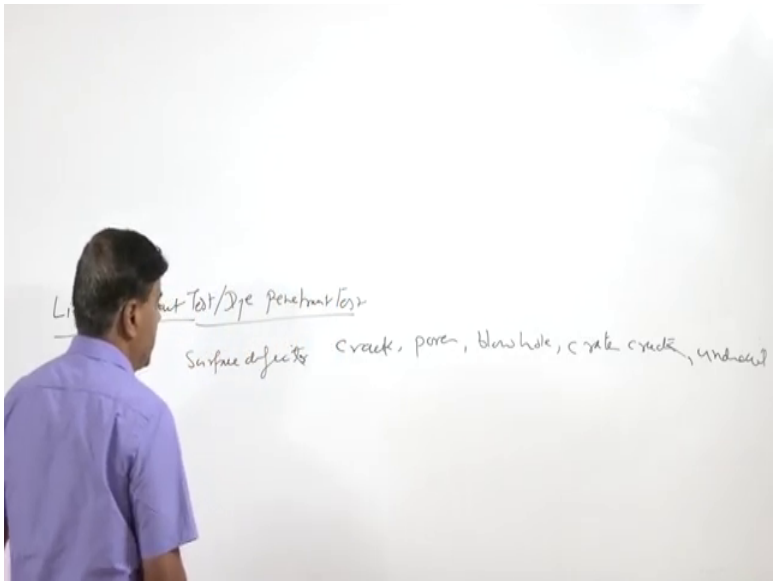

This is also known as dye penetrant test. This test is primarily used for the surface defects, which may be in form of the like cracks, pores which are open or the blow holes are like in weld joints, crater cracks, crater cracks or undercuts all these things can be easily established with the help of the dye penetrant test. So, this is primarily for the surface cracks. So, very fine pores and the cracks etcetera can be easily identified and established with regard to their size and location where they are present.

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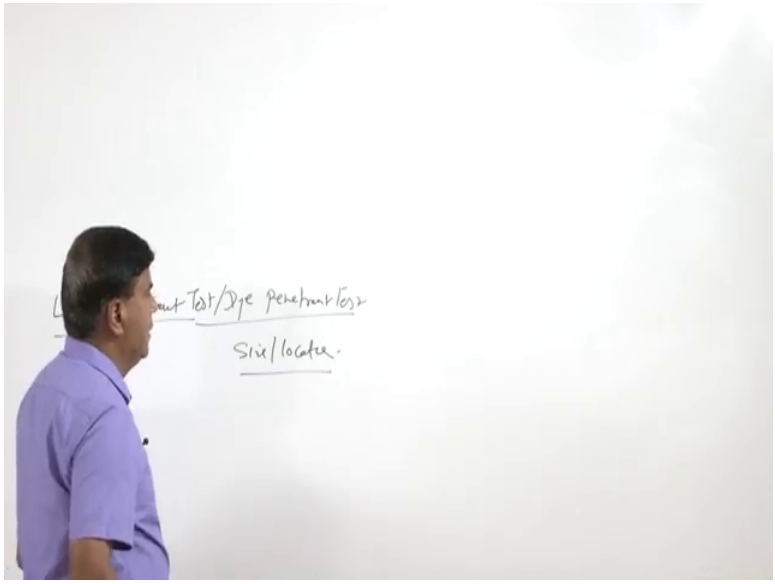

So, in this set test what we do basically like say if this is the component and it is having some kind of crack like this.

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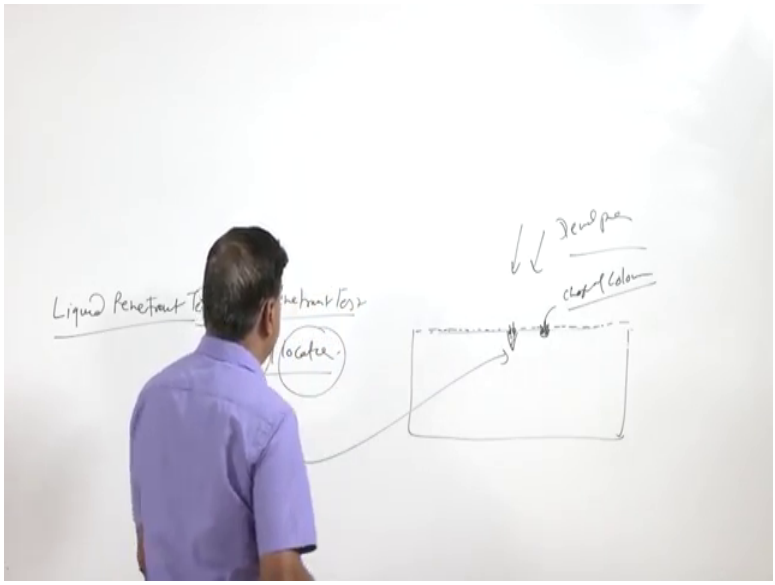

So, first of all the surface to be inspected of the failed component is cleaned. And after the cleaning we apply the dye over the surface. So, dye is basically thin liquid metal with the color so kerosene kind of thing can be used for this purpose with the color. So, whenever it is a spread over the surface so, thin liquid by the capillary action seeped into or gets filled into those fine pores or cracks and once this is given sometime after

spraying the this one is cleaned. So, after cleaning all these things are basically removed from the surface. And thereafter we apply developer, so developer is sprayed is spread over the surface. So, when the developer is applied developer or the chalk powder is spread over like the chalk powder n is one of the form of applying the developer.

So, since the dye has already been cleaned from the surface so all those regions where from it has been completely removed. The developer or chalk powder will not have any change of it is color, but wherever there is a pore or there is a crack at that location the developer will absorb the liquid dye which has seeped into these locations of the cracks and the pores.

So, and these areas your there will be change of colour. So, the location where the change of color in the developer is taking place or the location where or the length up to which this change in color is taking place these 2 things will be indicating the size and the location. So, the distance up to which there is a change in color that will be indicating. The size of the discontinuities similarly where the change in color is taking place that will be indicating the location where such kind of the discontinuity is present.

So, this kind of method can be used on any kind of the material whether it is a magnetic, non-magnetic, metallic, non-metallic, electrical conducting, non-electrical conducting etcetera.

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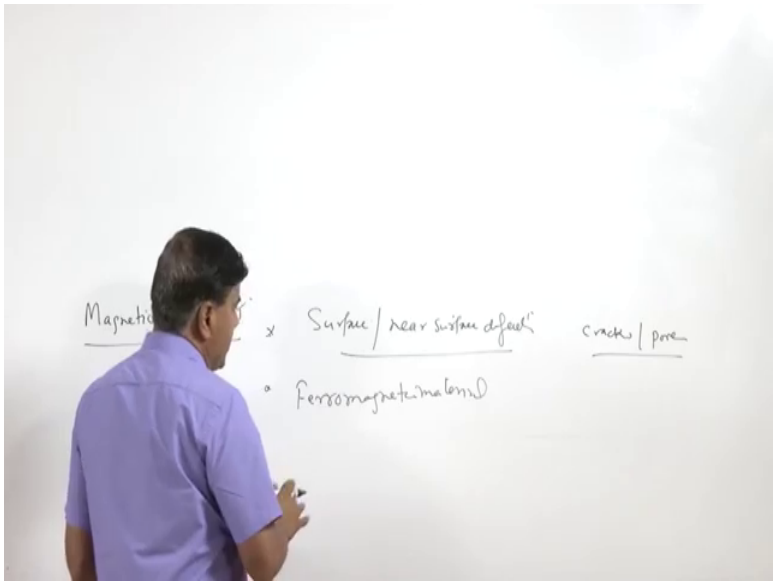

The next method is the magnetic magnetic particle test. this test is basically used for the surface and near surface defects mostly these may be in the form of the, like say mostly these may be in the form of like cracks or pores etcetera ah, but, but very the deep surface defects cannot be established and identified through the magnetic particle test this is one thing, second mostly the ferromagnetic materials. So, the discontinuities and the defect in ferromagnetic materials can be evaluated or assessed by this method.

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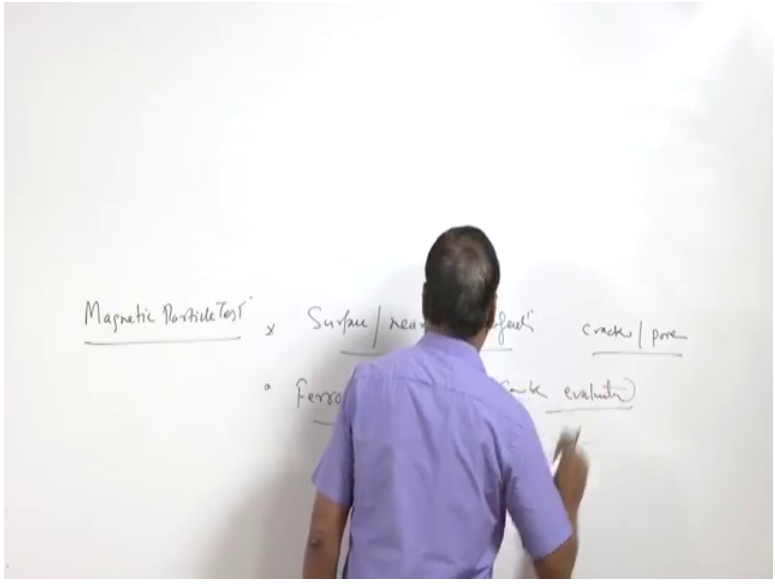

For non-magnetic materials and the poorly magnetic materials it cannot be applied with and therefore, mainly this one is applied for in the ferromagnetic materials.

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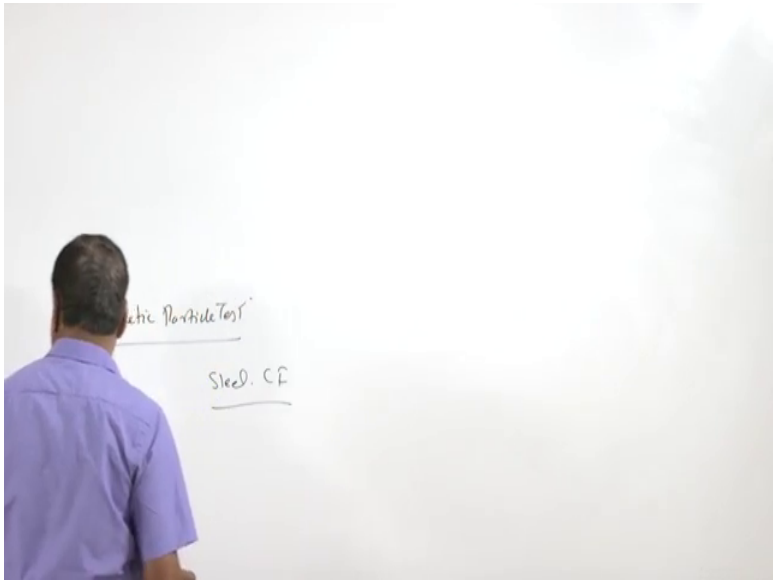

So, mostly for like say the steels the cast iron kind of the components their discontinuities can be easily checked through the this magnetic particle test. To understand this test we need to see the certain basics of the magnetism.

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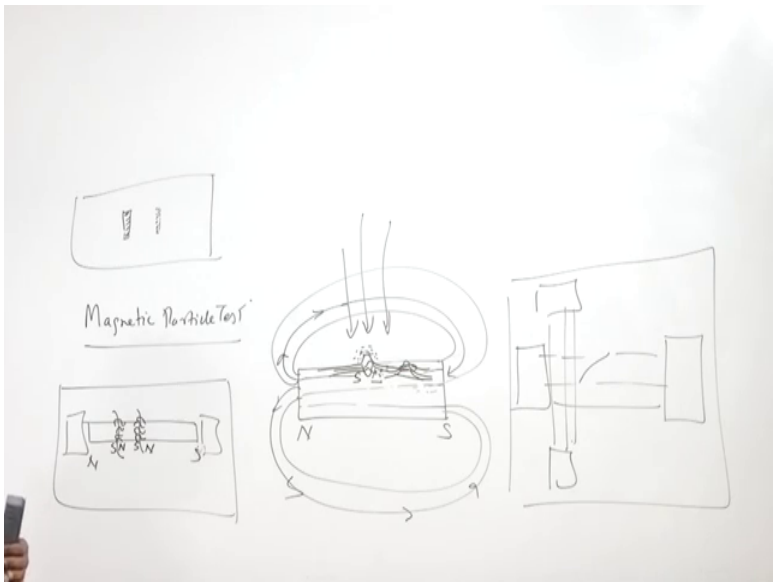

Where we know that in mag each magnet there is a north pole and there is a south pole.

So, the magnetic lines of the forces take exit from the north pole and they enter through the south pole. So, this is what will be happening at both the ends. Suppose in this

component if we find any discontinuity in form of the crack. So, these magnetic lines of the forces will be passing through the component like this, right ?

So, since this is n and if there is any discontinuity then the location wherever there is a defect and discontinuity the leakage of the magnetic flux will start. And there we will find that 2 additional poles like here you now we will have the north and here we will have the South Pole. So, here these magnetic lines will taking exit and they will be entering like this they will be taking exit and then they will be entering like this.

So, there will be basically the leakage of the magnetic flux from the location where there are discontinuities. So, if there is a discontinuity in just a surface region subsurface region then there will be very weak leakage of the magnetic flux or means very poor disturbance in the flow of the magnetic lines; and therefore, when the defect and the discontinuity is exposed to the surface these N S poles will clearly be their identified and the lot of leakage of the magnetic flux will be taking place. And at this location when the magnetic particle is sprayed in powder form means magnetic material in powder form is spread, they spread then they get a pile up around the area where there is a discontinuity.

So, if this is the like component, so entire component is magnetized there can be number of ways to magnetize it and what we will see the most common method is a like use of the electromagnetic forces electromagnetics magnetism, where the flow of current is used it to magnetize the component who which is to be checked we can use the permanent magnets ah. So, whenever any component is magnetized it will remain there for some time. So, demagnetization of the component is also important. So, like say the magnetic lines of the forces will be moving like this.

So, if the defect and discontinuities are parallel to the lines of the magnetic forces, then it will be difficult detect the presence of discontinuities. So, detection becomes easier when the orientation of the defects and discontinuities is perpendicular to the lines of the magnetic forces.

So, not just one direction of the magnetizing is required, but we may require the magnetization in the different directions, say for this particular component if if if there is a discontinuity here then magnetization from this direction will be leading to the as some poor or the weak kind of the detection. and similarly if the magnetization is done through

this way it will also lead to the poor detection because it is not really perpendicular discontinuities are not really perpendicular.

So, we trying the magnetization through the in the different directions, that we find the situation where the discontinuity is about perpendicular to the lines of the magnetic flux and once this happens like this is the case. So, here when it is magnetized of course, when it will be magnetized will have like say this is an S and this is N. So, if there is a discontinuity what we will have N here we will have S N here we will have. So, N S N S like this. So, here there will be more effective leakage of the magnetic lines of the forces. And in this area when the magnetic part particle is sprinkled or spread over the component will find that the particle will get piled up in this particular area more so it will get segregated like this.

So, the extent of the segregation and the area over which it has been segregated the length over which it has segregated these will be the suggest, these will be indicating the presence of the defects and discontinuities at that particular location of that particular length.

So, when the discontinuities are open through the surface the leakage will be more strong. So, the piling up of the magnitude particle will also very strong. And that will be leading to the very effective and severe segregation of the powder particles as compared to the case when the defect is is below the surface.

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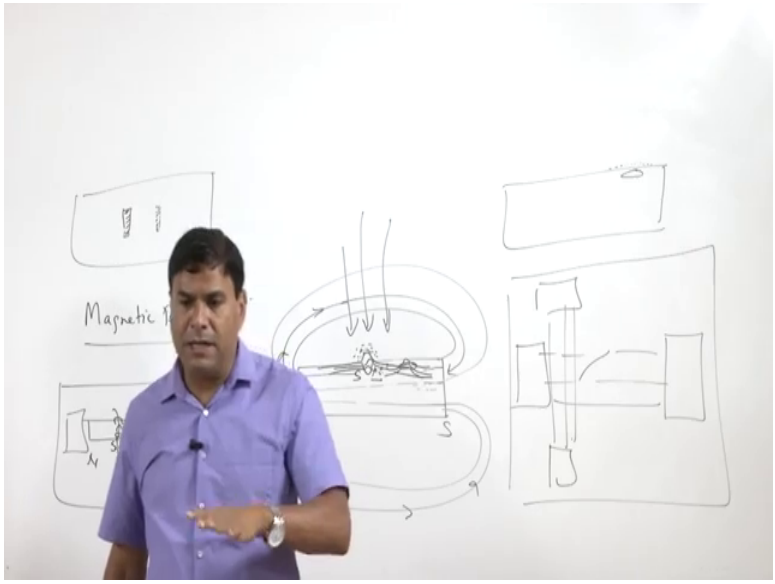

So, when the defect is below the surface like this then very poor piling up of the powder particles will be taking place. So, that will be indicating the location and the extent up to which the location of the discontinuity and the shape of the discontinuity under the surface.

So, we very weak piling up of the powder particle will be taking place when the discontinuities are detected below the surface or when the discontinuities occur below the surface in case of the magnetic particle tests. So, very fine cracks very closed cracks can easily be detected by the magnetic particle tests as compared to the dye penetrant test. If the part crack is very closer than dye may not be able to get into the crack zone inside the crack and that will be leading to the poor detection of the cracks in case of the dye penetrant test.

But such kind of the detection will be easy means the detection of the fine cracks will be easier when the magnetic particle test is used then there is like the ultrasonic test.

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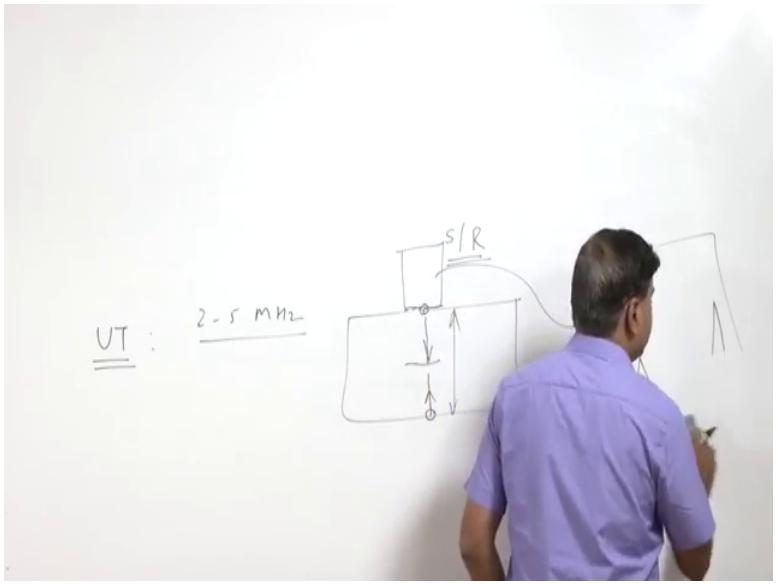

Ultrasonic test this is used for basically the sub surface defects and the discontinuities.

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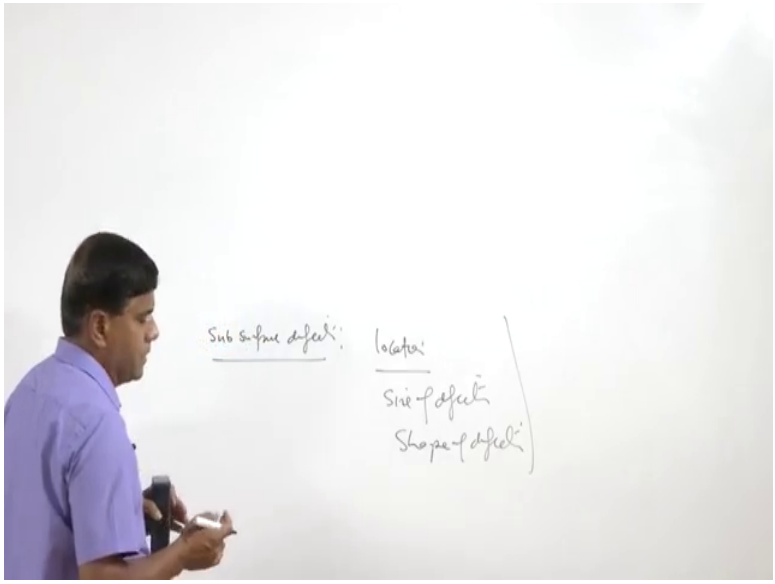

So, it can help to identify the location where the defect is present and the size of the defect. In addition to this it also helps us to see the shape of the defect in the subsurface zone.

So, you ultrasonic test is very convenient and very useful test in establishing the kind of the discontinuities, the size of the discontinuity, shape of this discontinuities and where they are present. So, this method is this method is applicable for the variety of the materials and the different range of the thicknesses. it works on the use of the ultrasonic waves like 2 to the 5 megahertz and it works on this 2 principles.

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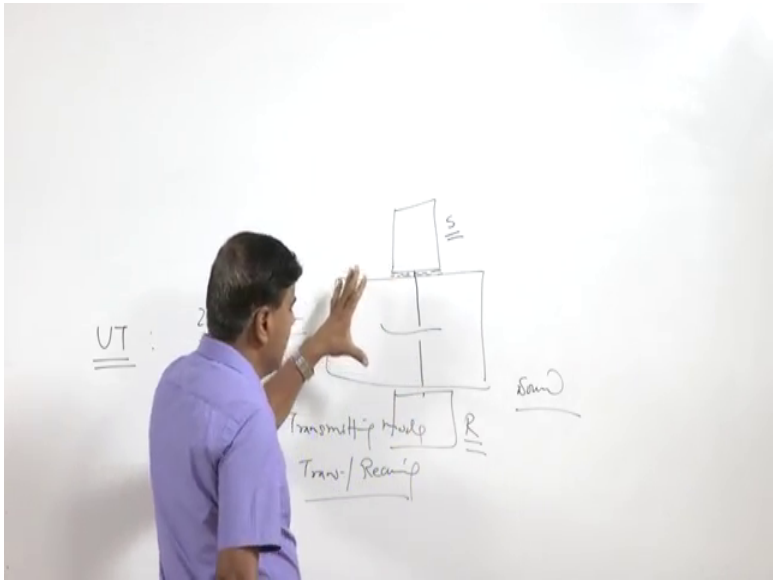

One is like when the ultrasonic waves are directed with the help of the source, they will be reflected the principle is simple when the the the source and in between we use the coupler so that it can really transmit the vibrations into the component. So, whenever there is a change of medium in the path of the waves the waves are reflected back.

So, like this is one where when the vibrations are directed on to the component they will be reflected back first from this and then a part of this will be transmitted through the thickness. So, there are 2 variants one is the transmitting mode transmitting mode and so means there are 2 ways one is where the transmission and the receiving both are done using the same probe..

So, in one case where the transmitting is done in this case in this case basically there is a one source probe and another and we have the receiving probe. So, it will be receiving the ultrasonic vibrations to see if it is reaching from it it is sent from one side to the another one. So, if the material is sound then the wave will be able to reach up to the end and this will suggest that material is sound.

But if there is a discontinuity then the waves will not be able to reach up to the end. In this in case of the transmitting mode and there is another, but there is another problem, the problem is that the 2 probes the sending and the source and the receiving probes should be aligned properly otherwise all the otherwise will not be receiving these vibrations. and there is another kind of the mode where the sending and the receiving

probes both are roles are performed by the same probe and in that case we use the principle of the reflection of the ultrasonic vibrations.

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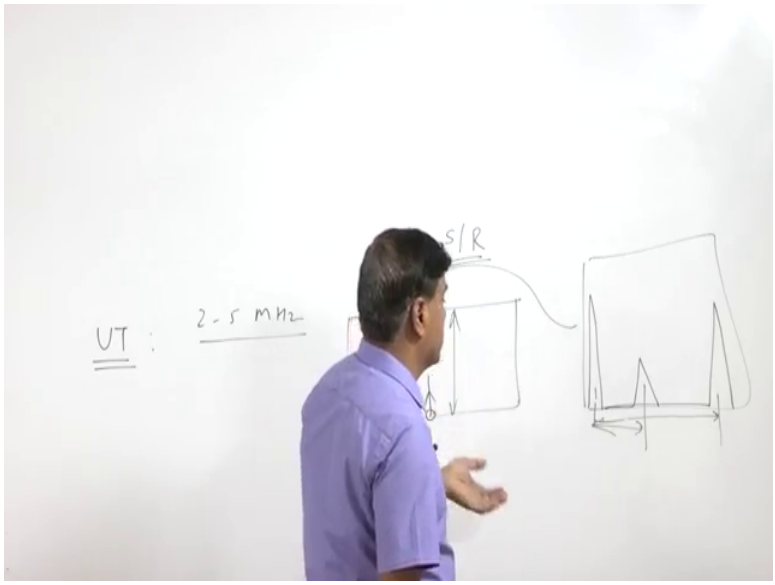

So, in that case like say this is the probe which is working as a both source and the receiving receiver of the ultrasonic vibration. So, here the vibrations are transmitted in the component and then through the coupler the first wave will be reflecting back and then it it will reach to the other end and then it will be reflecting back.

So, sending and the reflecting back both will be happening and this one is recorded and seen under the oscilloscope. So, what we see the first wave which is reflected will be a strong peak corresponding corresponding to the first reflection of the ultrasonic vibration. And if it is a reflecting from the other and to the vibrations which are being reflected from the other end they will reflect as a another peak on the other side of the oscilloscope. So, this distance now can be calibrated to see that what is the distance between the 2 peaks in the in the system.

Now, if there is any discontinuity then what we will be seeing like discontinuities here, then it will show us the another additional peak. Additional peak will indicate where the discontinuity is present means, what is the depth at which the discontinuity is present in the case of the ultrasonic testing.

So, the presence of the intermediate peaks will be suggesting the location, where such kind of the discontinuities are there in the material. Nowadays there are a very advanced versions of the ultrasonic tests where we can see the 2-dimensional images of the discontinuities with the size shape and location where they are present.

Now, the another test is the radiography test.

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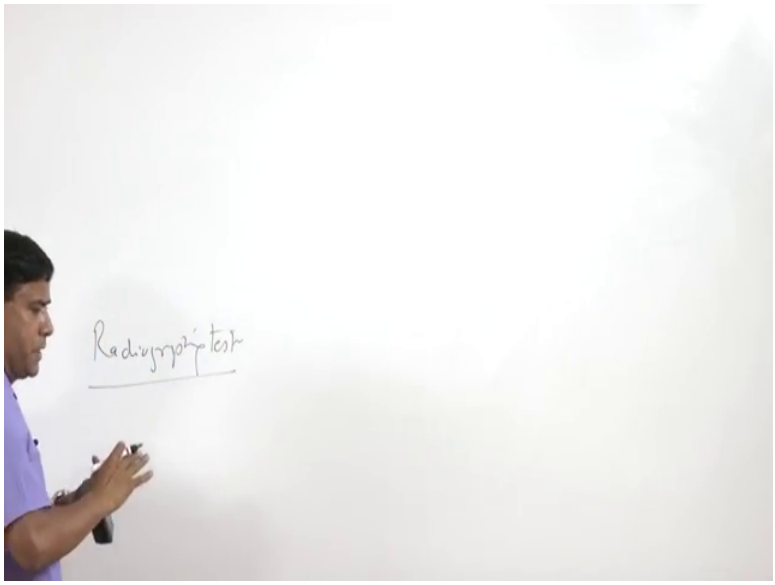

Ah radiography test helps us to see this is normally done for like say X rays is one method.

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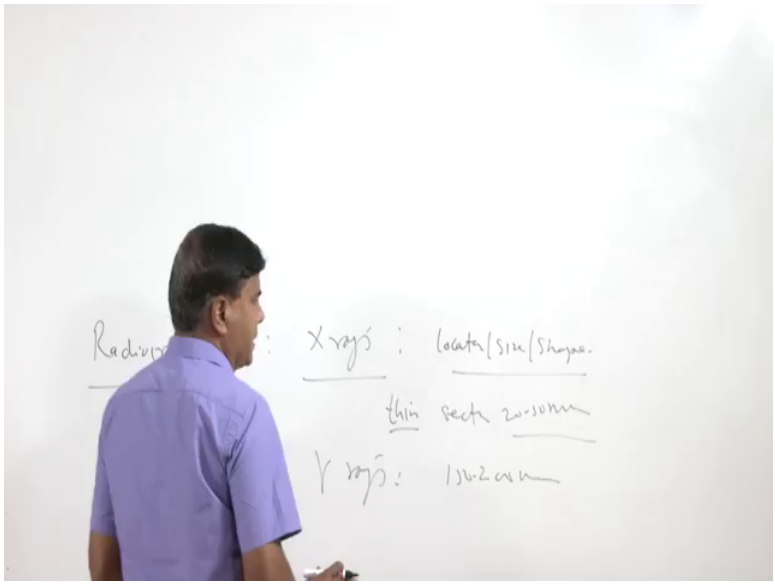

X ray's helps us to see the location, size and the shape of the discontinuities and this is applied for comparatively thin sections like say 20 to 50 mm. And for the thicker sections the gamma rays are used maybe like say 150 to 2 100 mm thickness the gamma rays are used. And it works on the simple principle that the low-density metals allow the travel of these rays easily as compared to the high-density materials.

So, say I will take up one simple example here.

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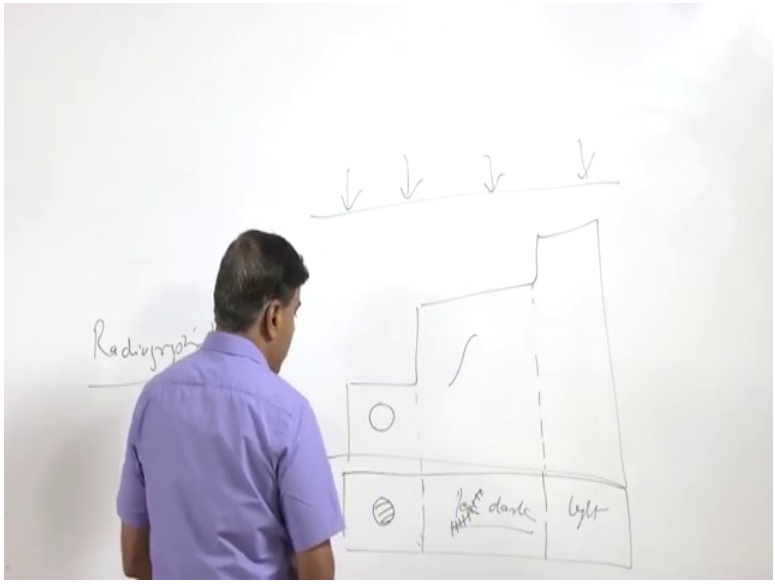

Ah this is the component subjected to the, these radiographic rays. So, here mostly we have the air and this is the portion where material will be passing through the X rays. So, this portion this up to this it will be very dense in terms of very dark. Indicating that most of the X rays have passed through this on only a few ones have been absorbed or a by this in the journey during the travel from the, this portion of the metal. in this section there is more distance to be traveled through the metal. So, most of them will be absorbed and they will be weakened. So, this will be somewhat less dark. And this one will be like say most of the rays will be absorbed. So, here it will be very light one.

In this sequence as and when we come across a particular kind of the defect like this pore, then in this location what we will be seeing this is the area where gracefully we observed and this is the area zone where no rays will be observed. So, this location will be looking like the dark one ah.

Similarly, if here there is a crack then in this location will be seeing one dark line like this, indicating the possibility of the defect in the component. So, to have the exact location of the discontinuity in x ray and gamma rays normally the that the the the radiographs are developed from the 2 directions perpendicular to each other. So, that low their location of the discontinuities can be identified.

Ah now I will summarize this presentation. in this presentation basically i have talked about the need or the importance of the NDT in failure analysis. NDT helps to identify the presence of defects and discontinuities in the failed component. And then efforts can be made to relate the, these discontinuities with the possibility of the failure through the use of the fracture mechanics approach. And also, there is a stress analysis technique which helps to determine the load the stresses and the strain which has been experienced by the component during the service.

Thank you for your attention.