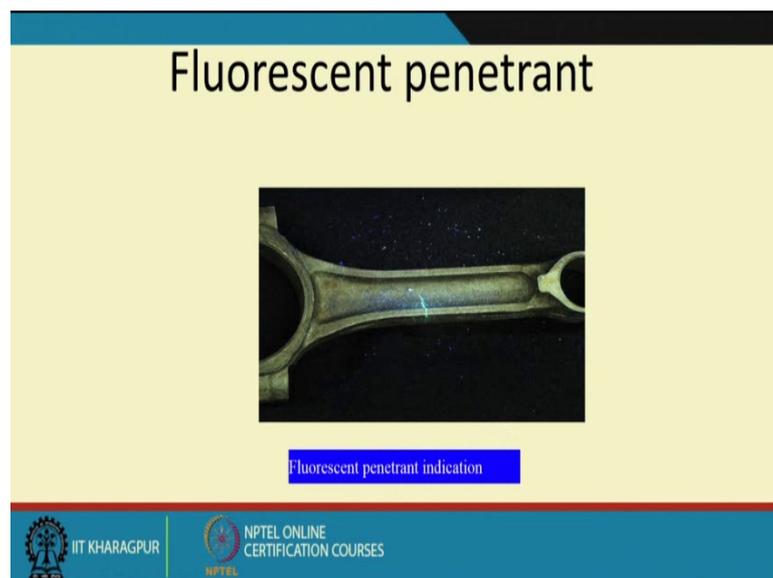


Machinery Fault Diagnosis and Signal Processing
Prof. A. R. Mohanty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 53
Radiography, Dye Penetrant Tests

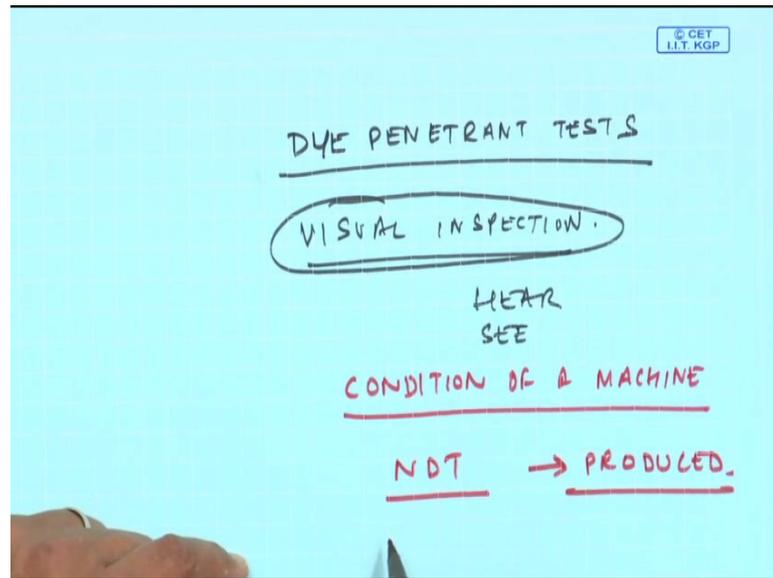
Yeah, in this lecture, we are going to discuss another couple of techniques, which are used in NDT and that is radiography and dye penetrant tests. So, again let me tell you, you know radiography and dye penetrant tests. These are not online tests and there are of course, radiography another word is the X-ray, it is very expensive also. So, this is not done real time though there are portable X-ray units and so on so forth.

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So, before we going to radiography, I will talk about this dye penetrant tests.

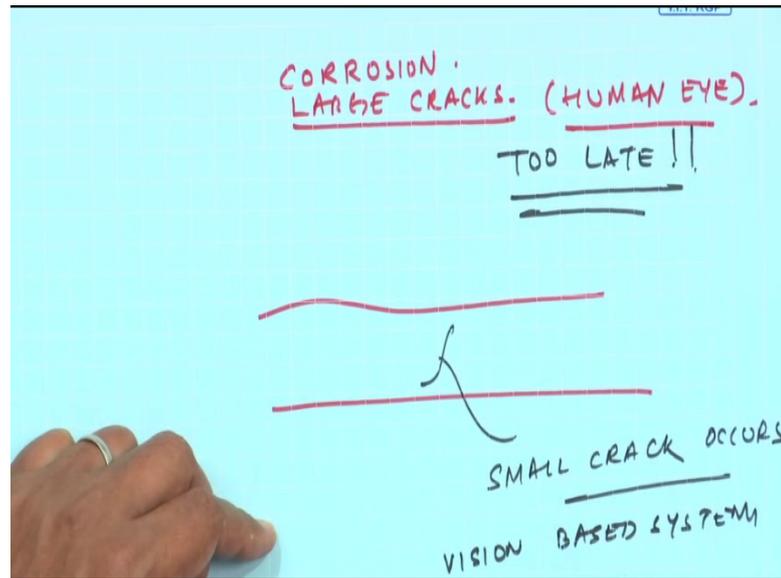
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So, these are they come under class of visual inspection well, when I am tell you even as a condition monitoring engineer or maintenance in engineer nothing must escape our sensory system b a two, what we hear, what we see, may be what we feel and so on ok, what we smell ok. So, human being is a very good system in terms of sensing because of the sensitive human organs.

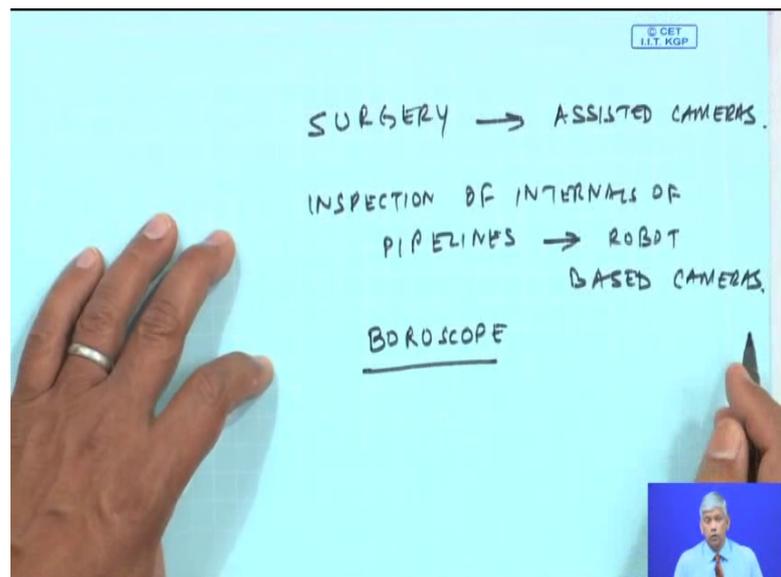
But so visual inspection also is a good tool for knowing the condition of a machine of course, when we talked about CBM, I did mention that to know the condition of a machine, the machine has to be living or running or operating, but in such cases when you talk about certain NDT test testing techniques, the machine has been produced and then we do a quality inspection or machine is in its in the shop floor we inspect ok.

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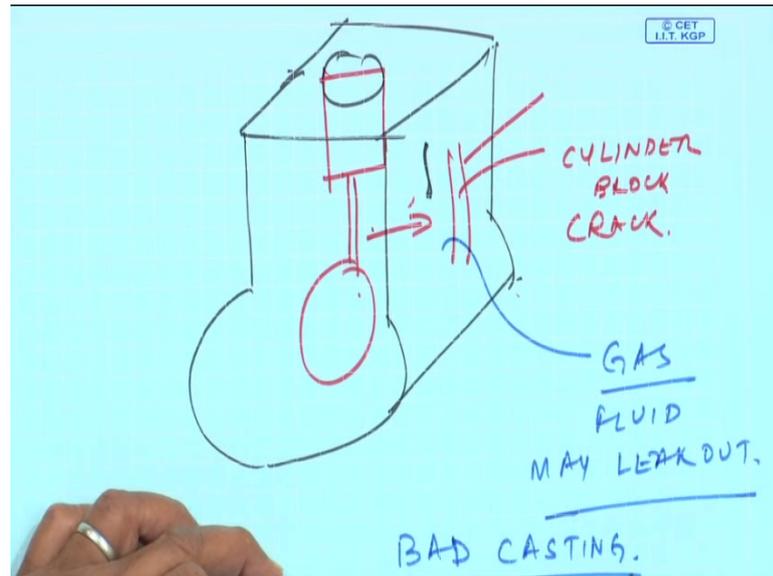
So, visual inspection can help us for inspecting corrosion large cracks. So, large; when I say large cracks, you know the cracks are pretty big. So, that human eye can human eye can see them, but let me tell you, it is already too late ok. So, when on the surface very small crack occurs technique vision based systems can be used vision bases systems could be camera based or could be which in because our naked eye we cannot see such micro cracks.

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You know you would have heard of doctors doing surgery using assisted by cameras inspection of internals of pipelines by robot based cameras or what we have also what it known as Boroscope surgery, we have endoscopes, etcetera, but in many mechanical production facilities you will see for example, a cylinder block which has been casted ok.

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This is a cylinder block a single cylinder block.

Suppose the crack has occurred. So, what is going to happen see when a piston or the connecting rod which is moving inside this and then move under pressure and so on. So, this is lot of gas pressure and then of course, there are water jackets and so on. So, a crack if it occurs because of exposure to high temperatures and then high pressures the gas or the fluid may leak out.

So, this could be because of a bad casting. So, one has to be careful to ensure that the quality of casting is good. So, to detection of such micro cracks is not possible by naked eyes. So, rather people use a fluorescent penetrant or a dye like you see in this figure here. This is a connecting rod, maybe after forging it has been machined and then you will see that if we put a dye on the surface because of the surface tension and the crack the material is dyes going to the deposited here on the surface.

And under a fluorescent light this is going to glow so very easily under a fluorescent light. So, basically you have this material the component speed with a dye and then you

see under a fluorescent light. So, any surface cracks which is here there will start to glow. So, this is a very quick way of inspecting rather than waiting for putting it in a machine and then and measuring the vibration because of this crack, it is already too late. So, right in the production stage of components and maybe after a major over all and maintenance people also you know do such checks you know and so on ok.

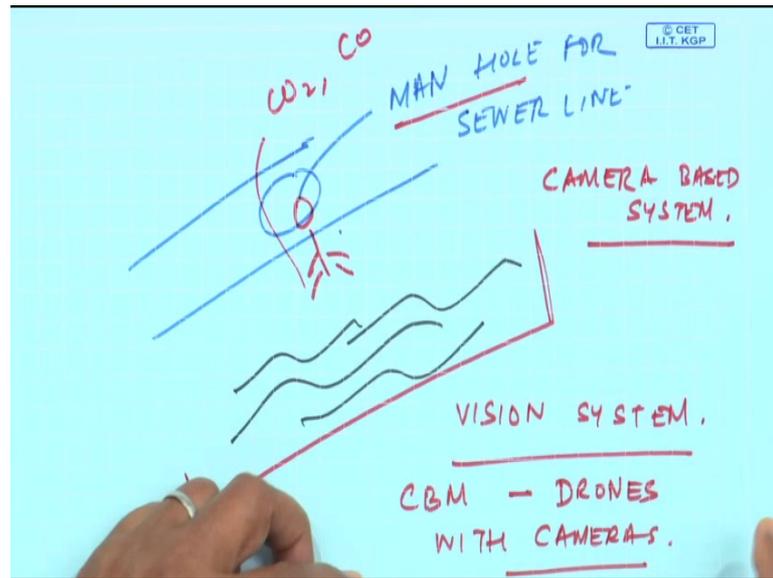
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The slide is titled "Visual Inspection" and features a yellow background with a blue header and footer. It contains four main sections:

- Top Left:** A close-up image of a person using a borescope to inspect a pipe. Text: "Most basic and common inspection method." Below it: "Tools include fiberscopes, borescopes, magnifying glasses and mirrors."
- Bottom Left:** An image of a red and black robotic crawler. Text: "Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines."
- Right Side:** An image of a person in a brown uniform and white helmet using a portable video inspection unit. Text: "Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines."
- Bottom:** Logos for IIT KHARAGPUR and NPTEL ONLINE CERTIFICATION COURSES. A small inset video of a speaker is visible in the bottom right corner.

So, some of the other techniques of visual inspection I have just go back this slide here see the most common visual inspection tools include other than or naked eye is this Fiberscopes, Borescopes magnifying glasses and mirrors and you would heard of robotic crawlers permit observation in hazardous or tight areas such as air ducts reactors pipelines, portable video inspection units with zoom allows inspection of large tanks and vessels rail road tank cars sewer lines.

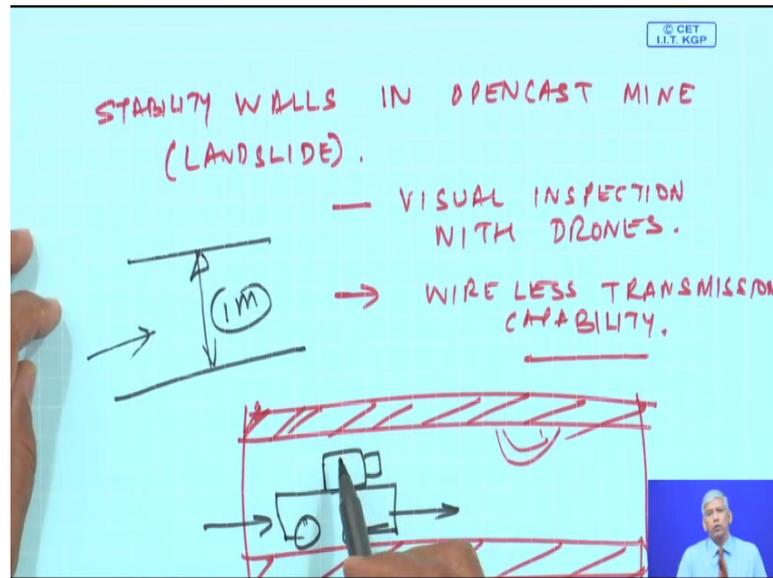
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You would have seen you would have heard many a times you know accidents happen, when the crew goes into the man hole for sewer line and there is a there is a big drain where there is here sewage. So, with the give out lot of poisonous gasses may be CO₂ CO. So, if any crew goes in, they have to of course, go with good you know breathing protection, but in such a cases, if I put vision based system camera based system.

So, nowadays vision based system are becoming very popular even an CBM because of the drone technology drones with cameras people are monitoring you know you know walls in opencast mine whether they are stable stability of walls landslides have occurred or not ok.

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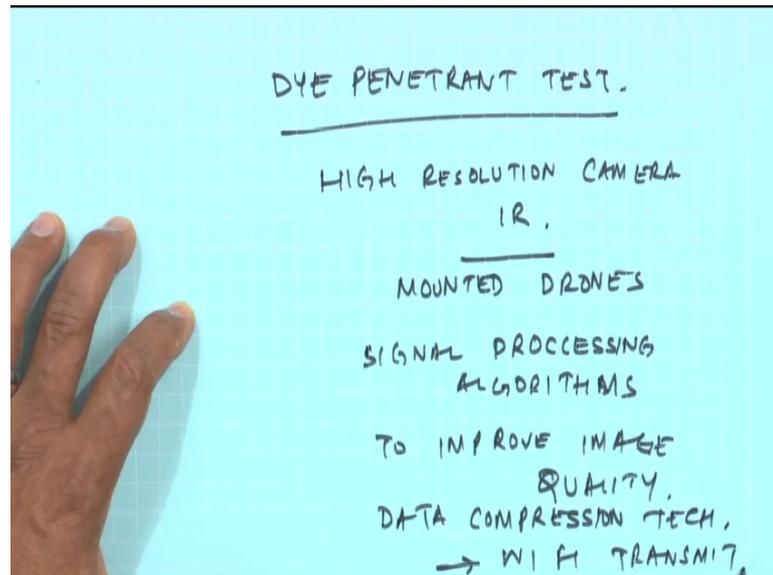


These are going visual inspection with drones having wireless transmission capability and the future this is going to very popular with less human intervention all this things can be done.

So, now coming back when these are not popular, people today when in industry, they use robotic based a large oil pipeline whether any obstruction as occurred etcetera. So, we can have a camera based system ok, on a moving crawler, I can they can move self powered or they can with drag and so, I remember some of some of my friends you know, you know 20 years ago, when they joined as engineers when large pipelines where being welded you now the diameter of maybe 1 meter and so on.

They used to literally crawl with their helmets with their lights and on to inspect the weld call it from the inside, but technology today has changed. Now we have ultrasonics, we have X-rays and so on. So, visual inspection has given. .

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Ah so, your dye penetrant tests is another way to very quickly check in a auction facility whether a crack surface cracked has occurred or not sometimes where liquid with an high surface tell you the entire process here.

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Liquid Penetrant Inspection

- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

The slide includes three small images: a green spherical part being inspected, a person applying a substance to a part, and a part being inspected under UV light.

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A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into the surface breaking defects ok. So, the excess liquid is then removed you wipe it and a developer is applied and spread on the surface where it can be seen and visual inspection is the final step the penetrant is used is often loaded with an

UV dye and the inspection is subjected only UV light. So, very easily you can see, you put the liquid remove the axis liquid put a developer and then spread it on the surface and seat under a light, but you will see this process itself is very time consuming nevertheless in the industry people do it, we cannot take it for granted the product has failed because there is a surface cracked.

But today with the high resolution cameras available high resolution cameras even looking under infrared and mounted on drones and development of you know signal processing algorithms to improve image quality and data compression techniques techniques used to reduce the quantity of data and then of course, Wi-Fi0 to transmit. So, you see in CBM, you know we started with an you know may be a stethoscope where people sense the vibration and that was the technology people used in the forties and today.

Ah about 78 years we have come up to a technology where sitting in a location maybe in IIT, Kharagpur, we can the remotely monitoring gas turbine in Alaska or a pipeline in Alaska. So, this is all very very easy and possible today ok.

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Radiography

The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.

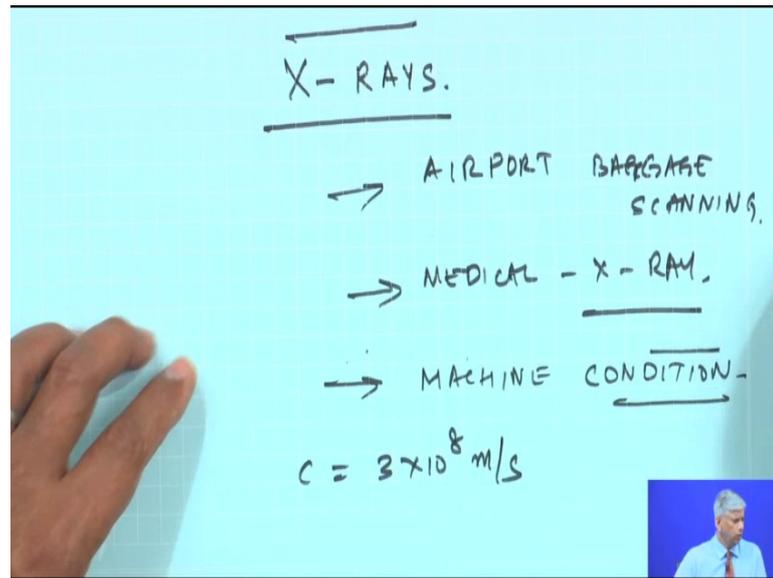
The diagram illustrates the process of X-ray generation. At the top, a box labeled 'High Electrical Potential' shows 'Electrons' being accelerated. Below this, 'X-ray Generator or Radioactive Source Creates Radiation' is shown as a red cone of radiation. This radiation 'Penetrates Sample' and is captured by an 'Exposure Recording Device'.

The electromagnetic spectrum diagram shows 'Radio', 'Microwaves', 'Infrared', 'Visible', 'Ultraviolet', 'X-ray', and 'Gamma Ray' from left to right. Below the spectrum, it indicates 'Low Frequency' and 'Long Wavelength' on the left, and 'High Frequency' and 'Short Wavelength' on the right.

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Now, another technique which I will talk about is radiography or sometimes we know as X-rays ok.

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All of you must be familiar with the X-rays in the you know airport baggage scanning scanning or medical X-ray when a have a broken bone I hope nobody has that.

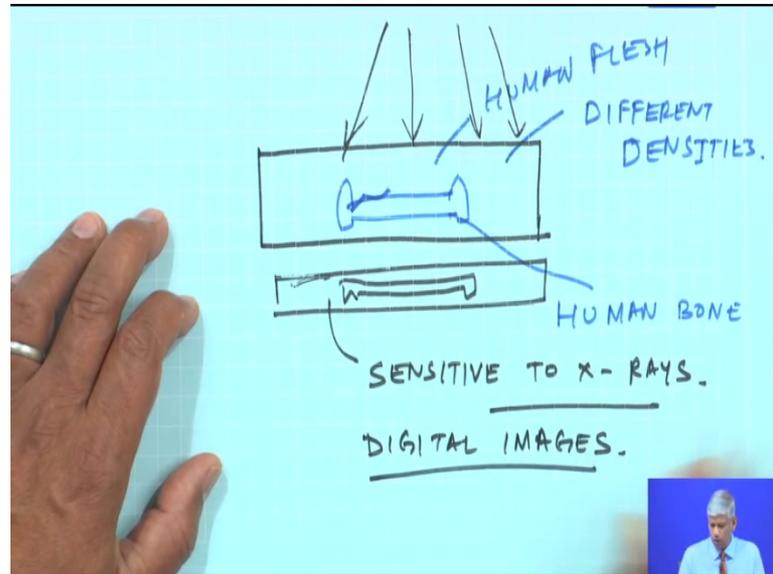
So, doctor tells you to get an X-ray done. So, similar also will used for the machine condition, what is there, what is happened, but mind you I must tell you that this X-rays, always look at the electromagnetic spectrum, they are all part of the electromagnetic spectrum, the speed of sound C is 3 and 10 to the power 8 meters per second, we are familiar with the infrared signals which is used in thermography radio waves as compared to microwaves.

But then we have as you increase the frequency the energy content in this rays are very very high. So, you would have seen gamma rays used for you know surgery, etcetera, you can penetrate deep into materials X-ray intensity can be increased. So, that they will penetrate with the human flesh and noticed the difference intensity when they come across the boom and we just saw, how ultraviolet lights are used visible light of course, in the wavelengths from four thousand to seven thousand angstroms. So, we can decide on the wavelength and frequency and this is this X-ray which we one has to be careful the radiation can come from an X-ray generator or a radioactive source.

So, this X-ray is can be used to penetrate into materials and that is why it is helpful to find out if a for in object has talk, for example, I create a high electric potential between and cathode and anode, either I can have an X-ray generator very very high voltage and

this will create this X-rays which will fall on a surface and the energy such that it will penetrate this sample.

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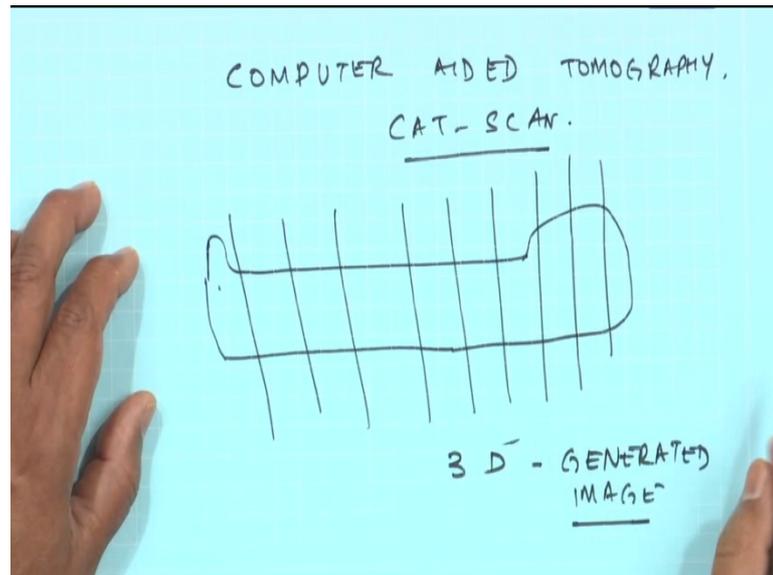


Now if the sample or the test device, has defect or a for in protrusion, they are all of different densities densities you would have heard of you know a may be a this is a human flesh and may be this is a human bone, I am not drawing the whole human being here. Now for the sake of discussion human bone must be my drawing because I have not drawn the entire person here.

So, if I put this X-rays and then I have some sort of an image plane where in this film is sensitive to X-rays, I can get an image of the bone. So, you can detect and that is what is used for your detection of gold in bag which is a being smuggled in the airport X-ray scanners. So, because of the density difference they can say there is some heavy metal you know gold has a high very high density comparative to a normal clothes or whatever you have put in a suitcase. So, that is how this is use this.

Similar concept is used to find out whether there is a formal element whether there is a crack. So, this is what this is used and of course, nowadays this film is being replaced with the digital images digital images and you would have heard of clad scan that is nothing but computer aided tomography clad scan of a human being you buy X-ray you know you can get the entire image.

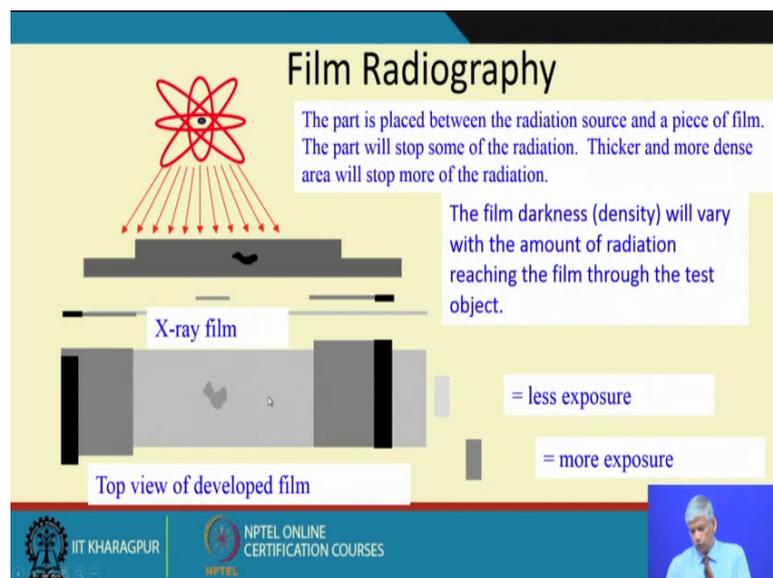
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Of course, with the again with you can monitor it you know a human being of course, this is how are human being.

You can you know do a scan mode of the X-rays and then get scanned images of the surfaces and you can have a three d generated rate or in a generated image, and they can be all digital also.

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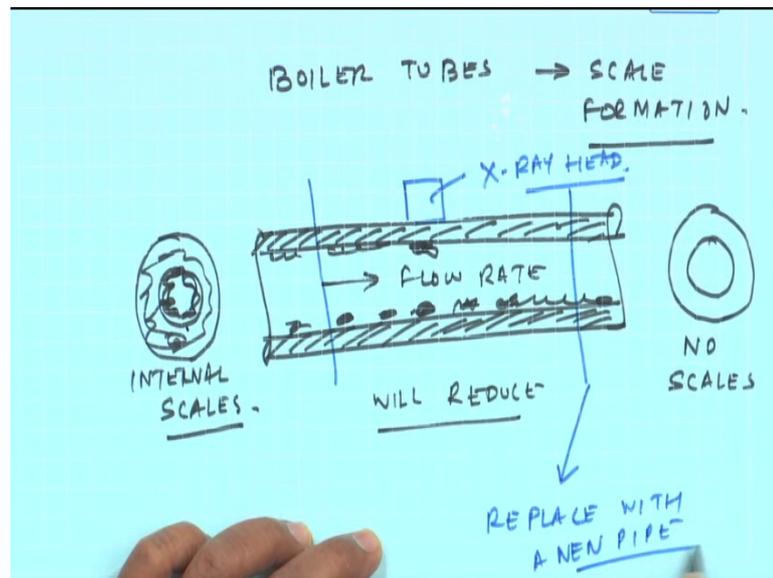


So, in the film radiography; so, what happens part is placed between the radiation source and a piece of film ok. So, this is my part and there is a X-ray film and there will be two

amount of exposure because of the density. So, less exposure and a thicker and more dense area will stop more of the radiations. So, what is just with the reverse?

So, the film darkness will vary the amount of radiation reaching the film through the test objects. So, more exposure and less exposure top view of the develop film. So, of course, this in an industrial scenario is very time consuming and nevertheless particularly in boiler tubes.

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There is lot of scale formation as you know ok. So, this is my tube of course, nowadays a portable X-ray generators are there which you can correct this side.

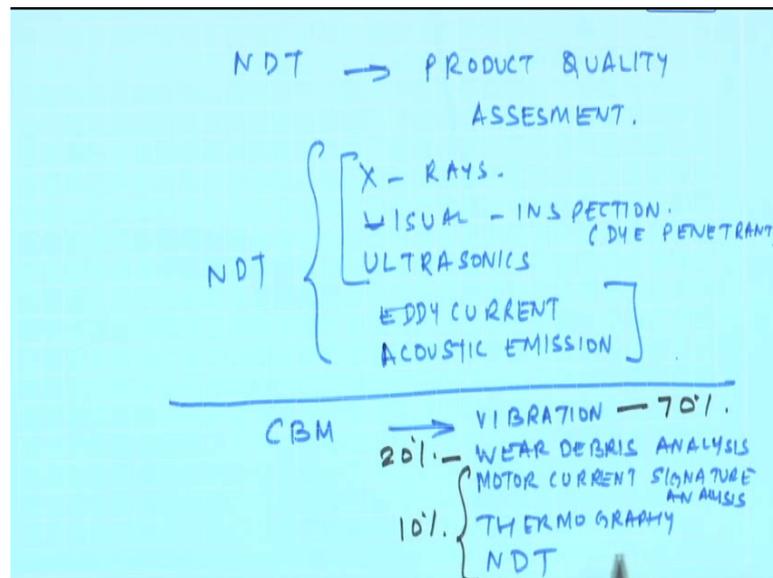
But all this process are expensive and a require return technician. So, X-ray head ok. Now imagine if certain scales have formed deposits are there. In fact, the deposits will be there and that throughout and if you look at the X-ray images on a section, it can clearly see such formation these are all solid.

So, these are original tube was this no scales and internal scales. So, because of this internal scales what happened the area is reduced. So, the flow rate will reduce. So, periodically you know you can do because see limitedly in such a steam power plant. The boiler tubes would not vibrate other than it is a flow induced vibration because of turbulence at different story altogether and the vibration is very in significant on top of it.

It is definitely not convenient or not desirable to measure the vibrations you know boiler tube when the boiler is in operation.

So the how would you know the quality of the boiler tube how good it is? So, when the boiler is shut down because there will be many such tubes you can do X-ray of the critical units in a few sample points and see such scale formations are there. So, then it is a time may maybe to cut this pipe out and replace with a new pipe. .

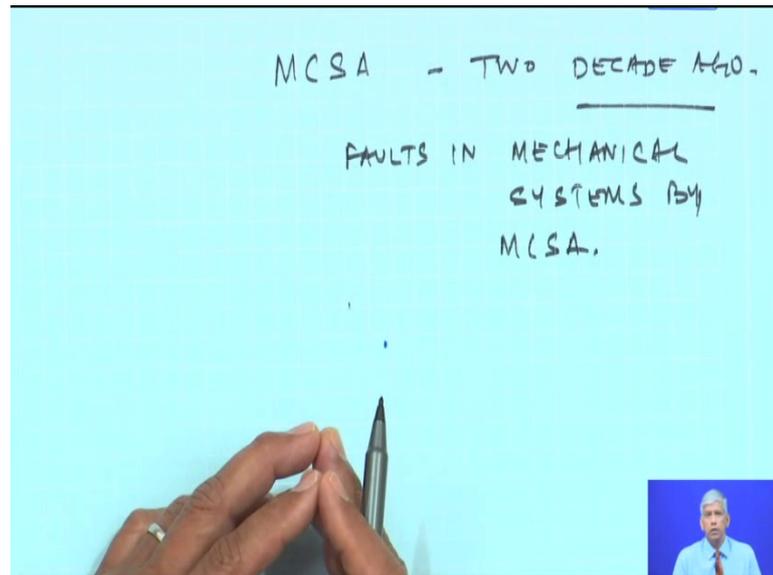
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So, there are lot of engineering applications of NDT techniques for product quality assessment like we have seen X-rays of course, the visual inspection and earlier, we are discussed about ultrasonics as well and then in the next class, we are going to discuss about eddy current and also we will see about your.

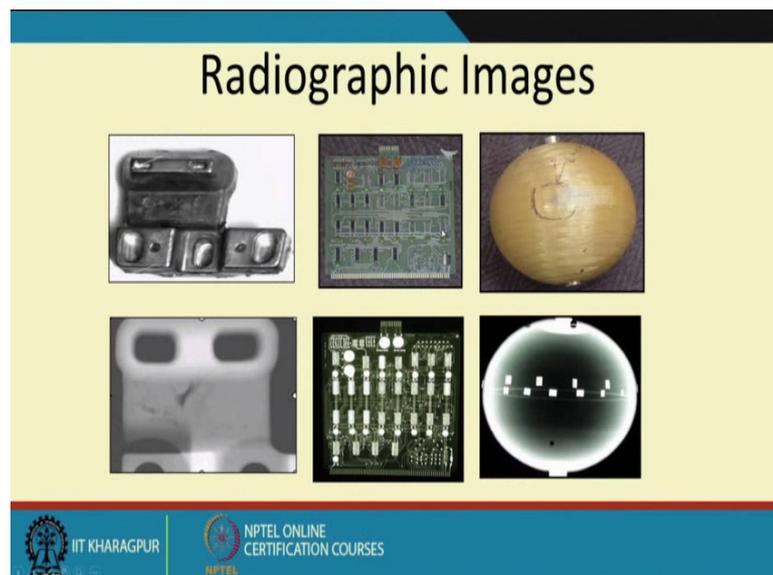
Of course in a this could be dye penetrant and then we will talk about acoustic emission. So, again, I just to recap when I talked about CBM, I did mention about vibration were debris analysis and then talk out about motor current signature analysis thermography and then all this NDT techniques. So, today again vibration is the most prevalent technique 70 percent wear debris analysis 20 percent and these are actually the remaining 20 percent throughout the world and I must tell you because of our search at IIT, Kharagpur on motor current.

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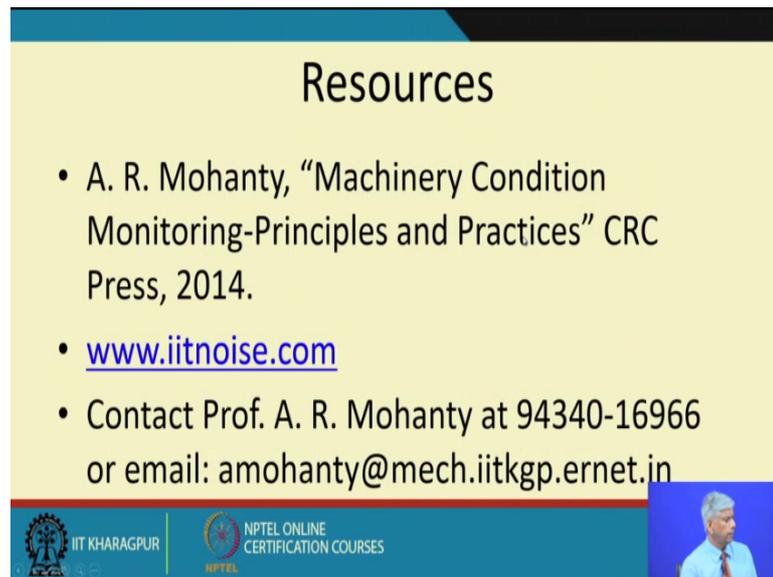
Signature analysis close to two decade ago, I will proudly say that we are the first in the world to come up with this me is a technique to find out faults in mechanical systems by MCSA and now we are patent on it and you can go to my website to know the details. So, MCSA is a technique which is fast coming up because of its convenience and we will see later on some of the case studies where this has been applied ok.

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These are some of the radiographic images in closer; I will show you can very easily detect the defects and such places ok.

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Resources

- A. R. Mohanty, “Machinery Condition Monitoring-Principles and Practices” CRC Press, 2014.
- www.iitnoise.com
- Contact Prof. A. R. Mohanty at 94340-16966 or email: amohanty@mech.iitkgp.ernet.in

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Thank you.