

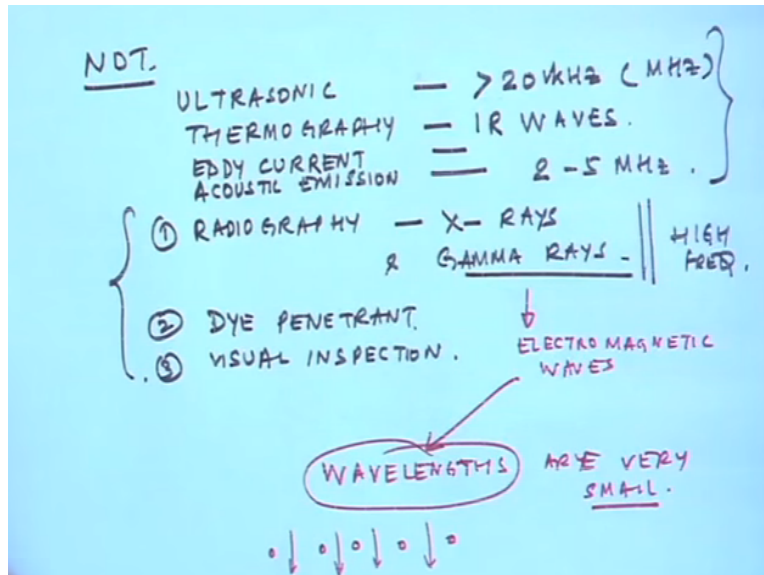
Machinery fault diagnosis and signal processing
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Module No # 08
Lecture No # 39
Radiography Dye Penetrant Test and Visual Inspection

This class is on the last lecture on the module of NDT techniques which are used in machinery condition monitoring and today I will be discussing about techniques of radiography dye, penetrant test and finally visual inspection which is also done and necessary for machinery condition wanted to know the status of a machine component in terms of whether cracks and defects have occurred, whether welds are there, whether the weld has been perfectly done extra.

So let us first look into what this radiography? Radiography is otherwise also known as the x-ray technique, so basically just to recap I mean we had in NDT also looked into

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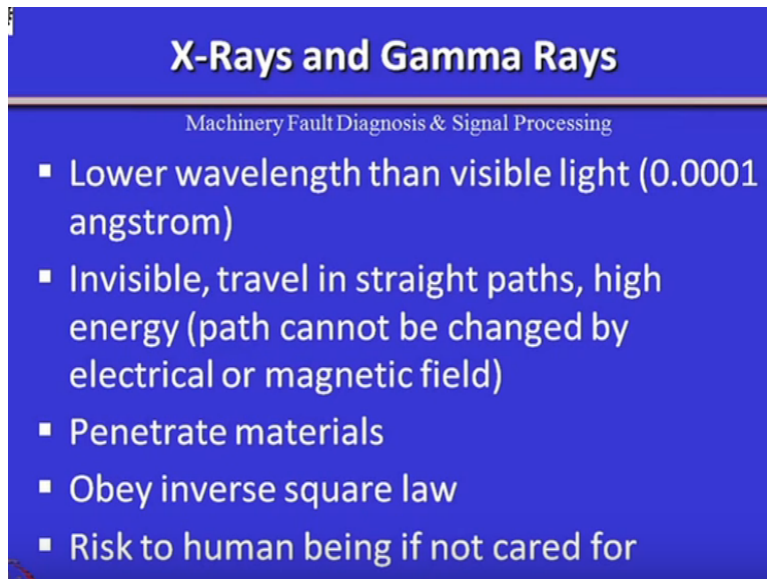


Ultrasonic thermography eddy current and then today we will be looking into radiography which is nothing but x-rays and gamma rays and then of course dye penetrant and visual inspection. This is all I want now, if I take look at the electromagnetic spectrum ultrasonic into thermography was mostly by IR waves ultrasonic by the wave beyond 20 kilohertz or in the megahertz means to be precise.

Of course there also acoustic emission also which is again the range of may be 2 to 5 megahertz and eddy current, of course it depends on the magnetic field but looking at the frequencies of ultrasonic thermo IR waves and acoustic commission, these waves X rays and gamma rays are very high frequency waves.

They are of course all electromagnetic waves however there wavelengths are very small compared to the wavelengths of IR waves ultrasonic and eddy acoustic emission. So because the wavelengths are small they are in fact smaller than the intra atomic distances. So they carry high energy or let us see what the characteristic is.

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X-Rays and Gamma Rays

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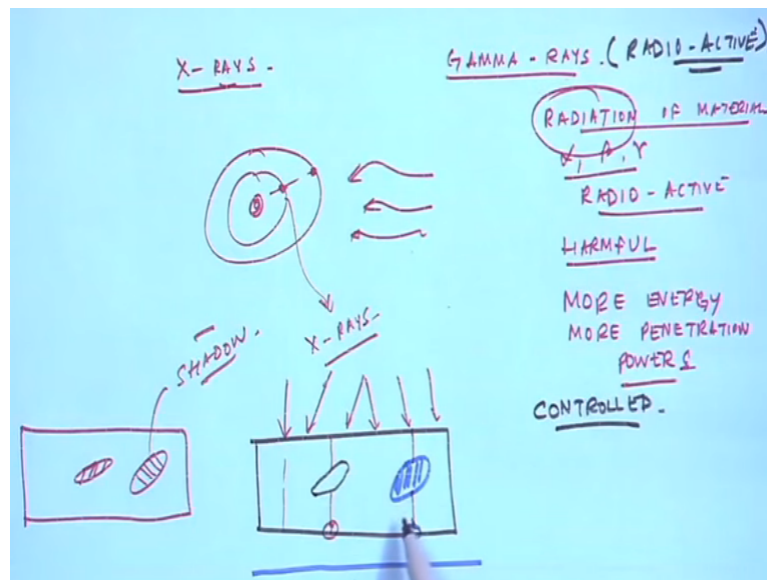
- Lower wavelength than visible light (0.0001 angstrom)
- Invisible, travel in straight paths, high energy (path cannot be changed by electrical or magnetic field)
- Penetrate materials
- Obey inverse square law
- Risk to human being if not cared for

So these characteristics of X rays and gamma rays are they have a much lower wavelength than the visible light as you know has an wavelength from 4,000 to 7,000 angstrom and infrared, somewhere between 9,000 to 14,000 angstrom. But compared to that they are on the other end of the spectrum where the wavelengths are very less and of course they travel in straight line.

They contain high energy and the best part is they cannot be reflected or changed by the presence of any electrical or magnetic field. However since they have such high energy in them they can penetrate metals materials and this penetration power of this wave X rays or gamma rays depends on the frequency of that particular waves and of course the material density also comes into play and their intensity of course obeys the inverse square law, like we have in the case of optics.

Like in the case of acoustic and they are highly dangerous because they can penetrate any materials. They can also endanger human beings who operate this equipment and they can enter and destroy the cells of the human body and then cause irreparable permanent damage, if the exposer of the human cells to these waves X rays are there for a longer time or at a shorter distance because of the inverse square law. So one has to be very careful while using x rays and gamma rays. I will come to how, what is the difference between x rays and gamma rays?

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So the way X rays are used suppose, an atom is there and there are electrons on the outer cells and if energy is applied to this atoms on a electrical field, these atoms in the case shell, this electrons in the case shell will down to a lower state and since this is a unstable stage or unstable orbit they will emit, pass back and they will emit certain waves which are essentially X rays. So one atom from material has to be bombarded with electrical energy.

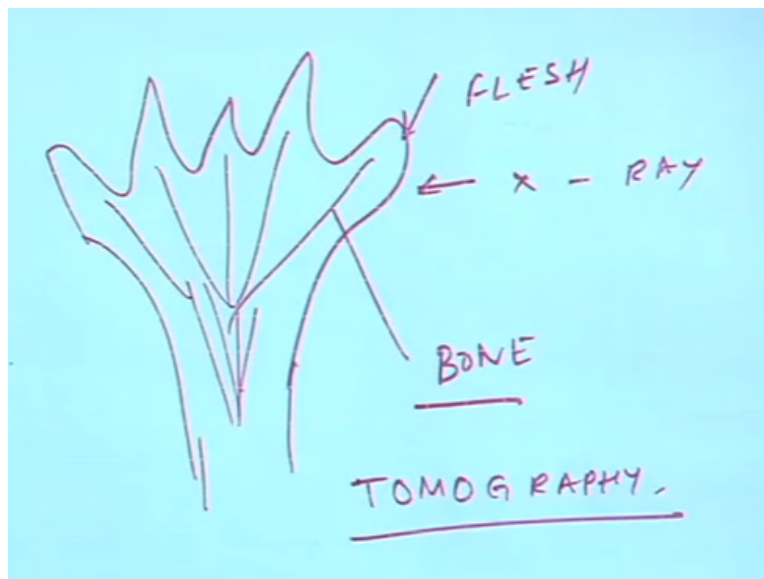
Then these X rays will be produced as opposed to gamma rays are something because of radiation of certain materials gamma rays in the alpha, beta, gamma rays. They are radioactive and of course small quantity of radioactive material can be used to produce these rays because of the nuclear radiation. They have harmful if not careful but they have more energy, more penetration power and if this waves are carefully controlled through proper optics electronic and focused to a particular spot, they can be used for many vision operation, cutting operations extra.

In fact you know you must have heard of the gamma rays used in surgery but they are radioactive that is the factor for which we have to be careful while using gamma rays for NDT though people use it because a small amount of nuclear material can be used to generate gamma rays and then they can be controlled and used for NDT testing because the key word be it X rays or gamma rays is that we use the energy of these waves to penetrate a material.

Now what happens like we had in the case of ultrasonic suppose, we have a material where there is a ward that is of different in city or we have a foreign particle of another density of a higher density. So if the X rays are incident on this material they are going to penetrate and because of the density difference. What happen the intensity of the X rays at this location will be different and this location.

So if we have some sort of an photographic plate if we and then we will draw this on the top view here. I will take an image as to the some image this is another image. So this is the shadow if we can say foreign particle or the ward present in the material and this is very handy. This is similar to the X rays which the doctors do for example.

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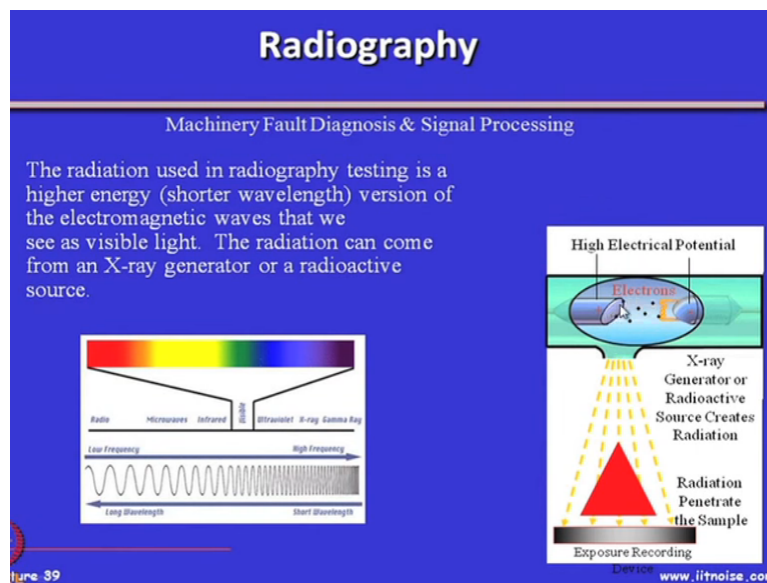
For the human hand and we can find out the bones by an X ray because this is the flesh and this is the so called bone. So there will be a density difference, so the penetration of these X rays depend on couple of things and that is the power of the X ray in terms of the distance from the X

ray, source to the material in terms of the time of exposure of this material to the X ray waves and then with this image can be formed on an X ray film or like photographic film.

Nowadays of course you know people are using computers, digital imaging to capture this X ray images and then of course other method, tomography where it you can have digital image captured through a computer of the X rays which are insert on a material. So to summarize it properties of X rays and gamma rays which makes them useful for using NDT.

Because they have low wavelength high frequency they can travel in straight paths. They have high energy, they can penetrate materials, obey the inverse square law and they are risk to the human being if not cared for. So this property of X ray is help us in using them for NDT techniques.

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So what is this radiography? The radiation used in radiography testing is a high energy shorter wavelength version of electromagnetic waves that we see as visible light. The radiation can come from an X ray generator or a radioactive source if I look at the electromagnetic spectrum here. This is our visible range, we know that is infrared ,microwaves and radio waves have little higher wavelengths.

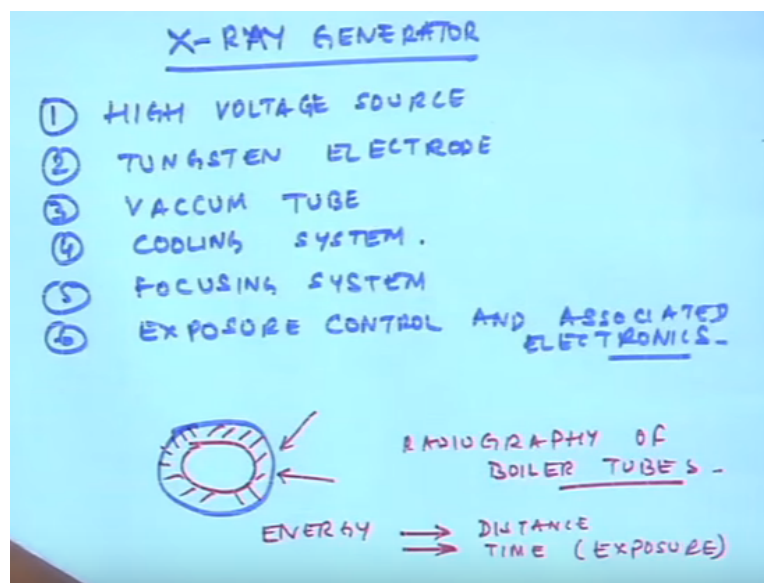
Of course there lower frequency as oppose to we have the UV rays which have higher frequency than the visible light, we have the X rays and the gamma rays. So the gamma rays shorter

wavelength more powerful X rays are little less powerful than the gamma rays and these are position in the electromagnetic spectrum remind you the speed of all the waves is same as the speed of electromagnetic waves and that is three into ten power eight meters per second.

Now how is this X rays generated okay so what we have here is an animation of this the two electrodes one as anode and cathode. So we generate a very high voltage imparts or high voltage or could be 1000 kilo volts of energy and then this is in terms of electron volts are a bit ten thousand hundred thousand volts. So because of symmetrical they will X rays will be generated and because we give such high energy to this electrode.

Here it gets heated up and usually tungsten is used as one of the alloys which generate the X rays. So there is tungsten metal element here but because of the high energy it gets heated up and for the generation is usually will get oxidized. So this chamber is actually a vacuum with a nice glass and then this electrode has to be cool. So there two important elements in an X ray generator one is the,

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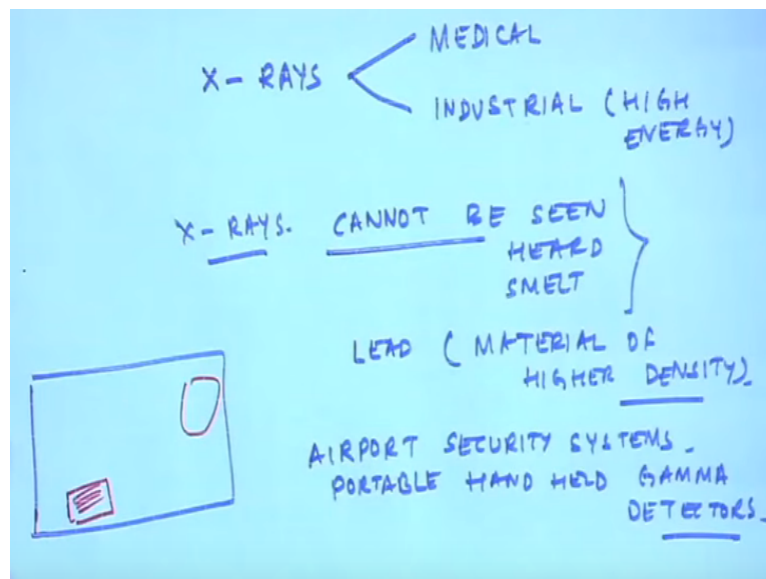
High voltage source other is the tungsten electrode then we have the vacuum tube then we have the cooling system. So you will have the focusing system and of course the exposure and exposure control, electronics control and associated electronics. So X ray generators need to have all this components and finally we have a material. How this X rays are exposed? So we will get an exposure recording it could be a film, digital image.

That is what though we have to bring in the component whose X ray is to done to a facility where X ray generators are there. But there are also portable X ray generators in the field which can be used to the incentive X rays. But I understand they are not very convenient and are not very user friendly and at since that I can take the X rays to the field but the component particularly in NDT.

Suppose we have a boiler tube, there is some scale formation. We can do the augmentation regarding the ultrasonic tumors but they can have X ray exposed to this. So radiography of boiler tubes is one application where X rays are done. Now because eventually everything depends on the energy, so that depends on two important factors distance and time.

By time I mean the exposure time but again suppose we have to be very careful while handling X rays and more careful while handling gamma rays. Because gamma rays are radioactive, so we have to have good amount of shielding. So that of course the human beings are not exposed to the industrial X rays. This X rays

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We have the medical X rays and the industrial X rays. See medical X rays are the X rays which we use in the hospitals. Suppose to find out a broken bone of a person whether the bones are intact whether there is a fracture that is what we use medical X rays where the energy of the X

rays are less. Because the density of the bones or human flesh is much less than the intensity of certain industrial materials like steel, aluminum, copper, extra.

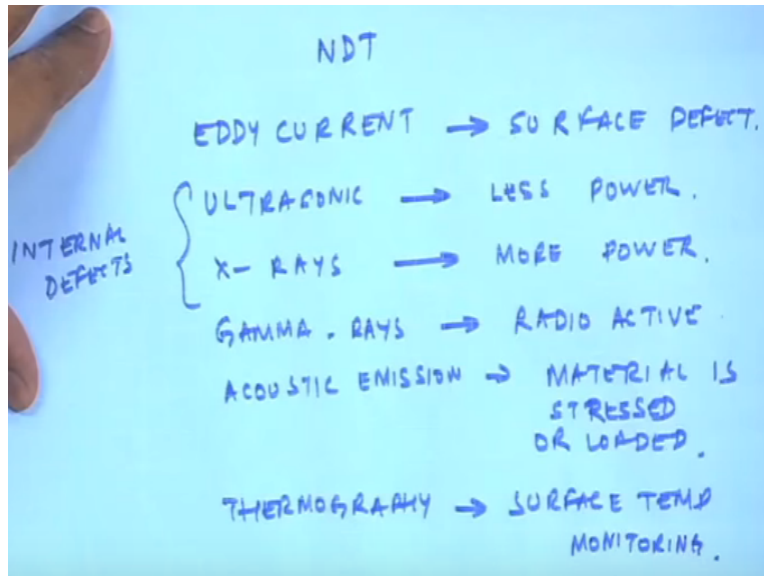
So these are of high energy, now you can imagine if this industrial X ray is exposed to a human being the cells may get damaged permanently. So one must be very careful even while doing the medical X rays. Those of you would have experienced medical X rays you would have seen how the operator takes care that he is not unknowingly exposed to X rays. Because another dangerous thing about X rays is they cannot be seen, heard, smelt.

So this is very dangerous X rays so not that a flash of light will go and then we have X ray, it is not that. So X rays cannot be seen, heard, smelt so this is the important parameter we have to keep in mind while handling X rays. You will not know whether an X ray has been generated standing in front of the equipment. So we have to be very careful now because the industrial X rays are of high energy.

We have to be careful and usually one particular thing that guard people use is lead or any material of a higher density, which can absorb the X rays. You would have seen X rays in the airport security systems. There are portable gamma detectors also portable hand held gamma detectors. They are radioactive, they have got security system for screening luggage's baggage's.

We use the X rays there and they are industrial X rays. So because the idea is there a density difference you can notice it. For example if in your suitcase there is a heavy metal or there is a soft liquid. So the patterns will be different in the X ray images and that is how people can identify objects which are hidden and not visible from the outside. That is something again is powerful unlike the eddy current.

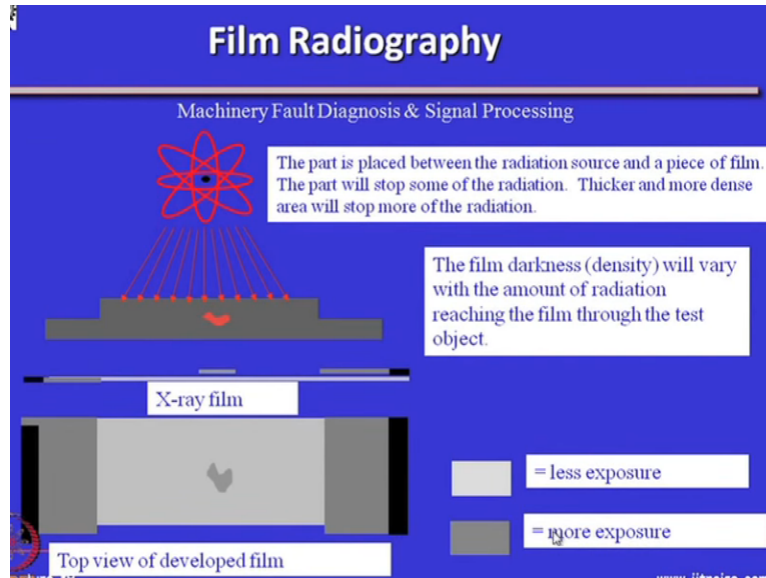
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Eddy current is for surface defect. Ultrasonic has less power than X rays. X rays there are both are can find out internal defects, more power and there above we have the gamma rays which are radioactive and of course acoustic emission is only when internal. Only when material is stressed or loaded. So just to give you a relative comparison of all the NDT techniques. Thermography is nothing but a surface temperature monitoring.

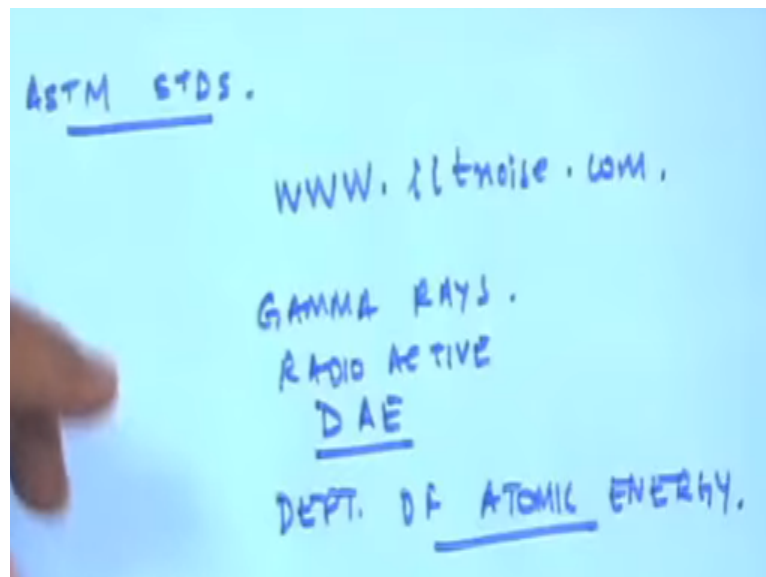
So now we can understand the relative application of different things, different NDT techniques which are used to know the status of machine components. It may not be an entire machinery but individual critical components. There physical condition, current condition can be known by using such techniques and we just talk about X rays.

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So what happens in this X rays is the part is in between the radiation source and a piece of film. The part will stop some of the radiation thicker and more dense area will stop more of radiation that is what is in the film radiation say. If I have a defect here and the film that is what it will look like? So this has been exposed less and more and so on and then we can have certain materials as guide plates. So there are in fact certain standard as to what are the calibration standards as well.

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Available for this X rays by many of this materials are available in my website IIT noise dot com, where we have in our laboratory many of the NDT technique instruments like thermal imaging camera, ultrasonic probe, acoustic emission system extra. Because to use gamma rays it

requires certification by the nuclear authorities gamma rays because of the radioactive material. We need on the department of atomic energy in our country whether we can store radioactive, what care has to be taken.

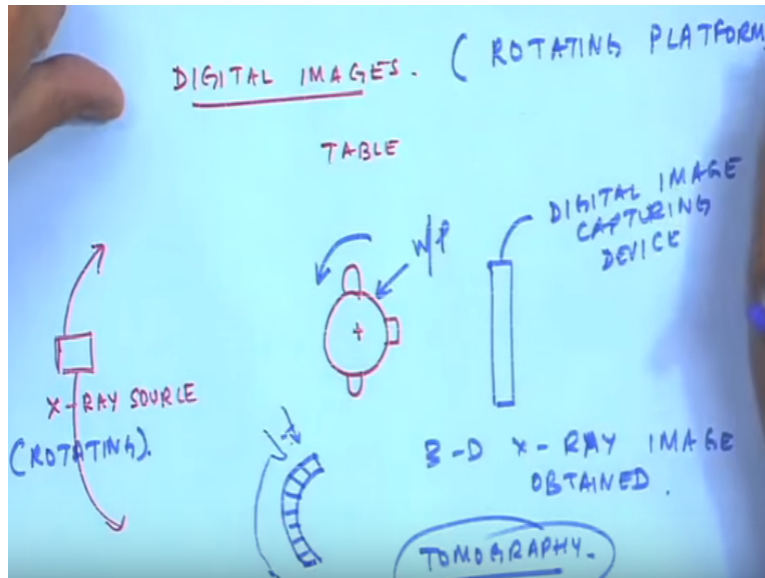
Because you know radioactive material after their usual life is over they have to be properly disposed off, so there are issues that I will not go into that because nuclear safety radiation is another issue one has to be careful about while using these materials. But never the less, we have to follow this strict federal regulatory requirement which are there for safe handling of such materials disposing such materials using their operation and so on.

So then let us focus into X rays which are mostly used in industrial systems to find out defects. So the film darkness density will vary with the amount of radiation reaching the film through the test object. So this is less exposure, that is more exposure. This top view of the developed film, this is very similar to the X rays many of you would have done at the hospitals where you had an X rays done to say got a film and this film is nothing but again it is a process like an any ordinary photographic film.

But this is again done in a dark room where in all the developing is done and then the film is washed, the chemicals are washed off, the photograph is dried and then of course the doctor puts it against the light and sees where are the denser particle, whether the dense particle being bone in this case there is a crack extra.

So this kind of things can be done similarly in the film radiography which is used in the industry. We can have a similar set up where in the component under test is brought down to this level location here and then we have an X ray film but nowadays because of the digital image processing instead of film we have

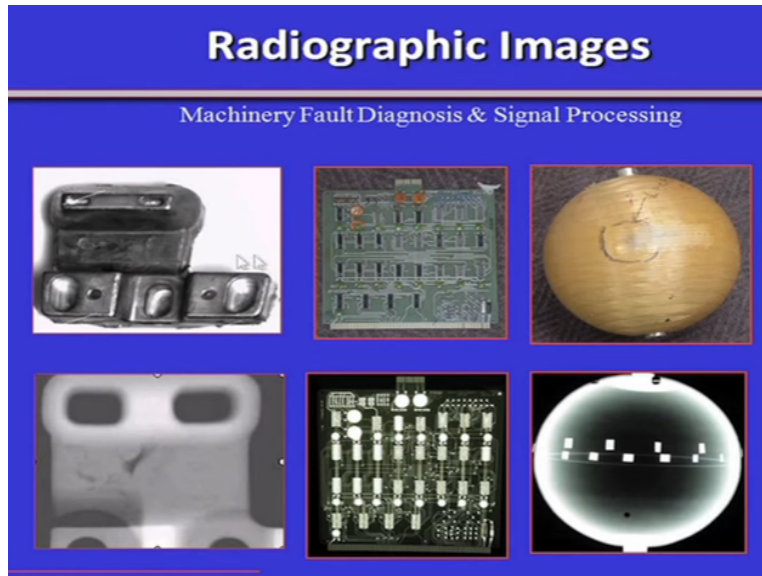
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Digital images and there are devices or the table where in either you can have the device or you can have the X ray source. You can either have the X ray source move around in an circular arc around the body or we can turn the body and you can appropriately have an digital image capturing device. So three D X ray image can be obtained and this is what involve the tomography and many of you would have done that enteral X rays.

If we this is here the jaw and then here your teeth would have seen one of the jaws. You can see the X rays move by computer control and then you can get the entire image of all your teeth in one go rather exposing it individually. So this kind of modern techniques where in this work piece or material is put on a platform and rotating platform is used or rotating X ray source. So depending on the convenience this kind of operations are possible. So end of the day we will get three D X ray for the image for the material under test.

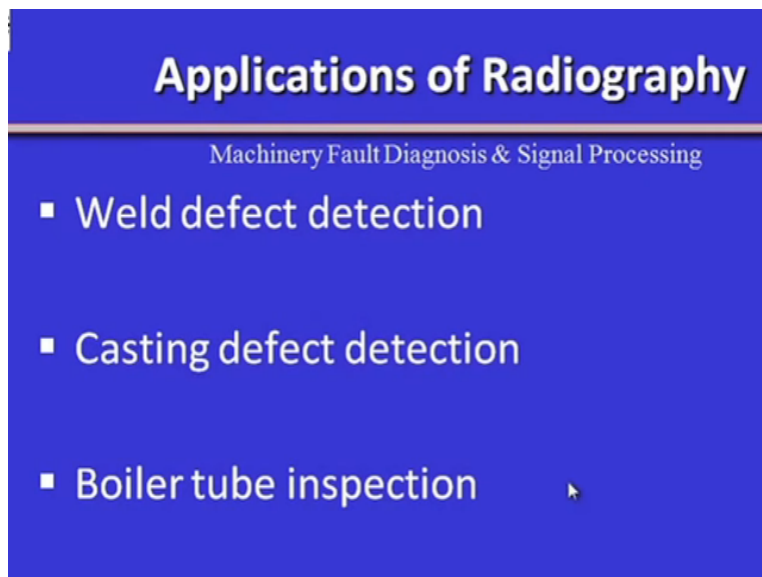
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So these are some of the radiographic images of certain components. You can see there are different machine components and few internal metal systems whether you can notice the density difference. You can see from the back side these are the black IC chips full of material denser material.

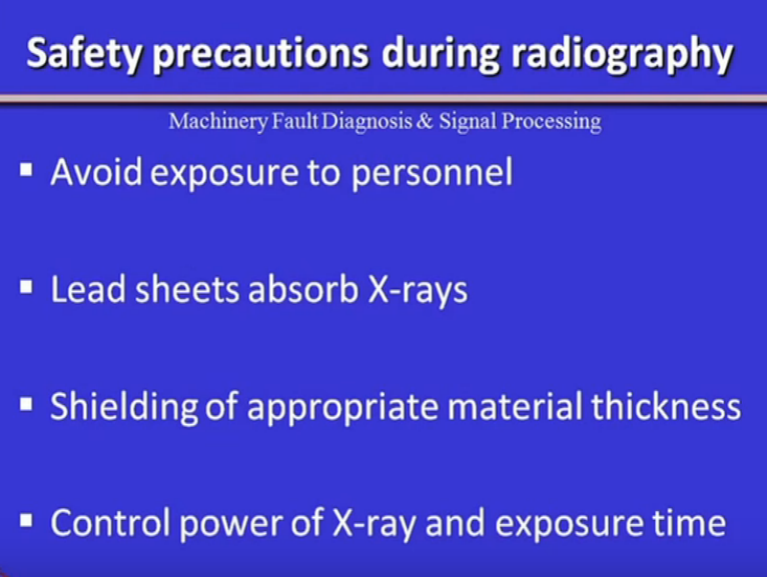
So this denser material appears here as white object similar here denser real object has white object here, there again. So these are how the radiographic image X ray image is of machine components help us understand whether or what is there inside a material.

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So applications of radiography because industrial applications is defined at the weld defect detection, casting defect detection, boiler tube inspection and the industrial security system. So we use industrial X rays for screening baggage's to find out the density extra. Of course this X ray system sometimes, they are harmful to human being. So here we be careful about how much exposure time we give to the particular component and then what is the distance of the X ray source to the component which have been tested.

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Safety precautions during radiography

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- Avoid exposure to personnel
- Lead sheets absorb X-rays
- Shielding of appropriate material thickness
- Control power of X-ray and exposure time

So some of the safety precaution which we have to take in during radiography. I mean on top of if that is gamma ray radiography or gamma ray testing we have to be more careful about the nuclear radioactivity associated with such gamma rays. However in the radiography because as I was telling you X rays cannot be seen, heard, smelled. They have to be careful that the exposure to personnel has avoided.

Lead sheets which are thick, high density absorb X rays. So you would have seen there are lead suits which are worn by operators so that they are not exposed. Shielding of appropriate material thickness I have written the word here appropriate because that depends on the exposure time, depends on the density of the material because then we can decide on the thickness. Because there is also a component known as penetration depth.

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$$I = I_0 e^{-\mu x}$$

PENETRATION DEPTH.

HAND BOOKS.

FOR DIFFERENT MATERIALS.

This follows an exponential curve because intensity and this depends on material property at any distance x . The intensity of X ray is given by this and this is the penetration depth for different materials. We can find out whether in a half age material is good enough or an one age material is good enough to stop the penetration of the X rays. So these are available in handbooks for different materials penetration depth for different materials.

Usually out of experience the operators know that if I have component surrounded by a material of particular thickness and then the X rays are appropriately absorbed and then nothing is going to go wrong. So there has to be always an option to control the power of the X ray and the exposure time by power. You can control the voltage to the electrode for emitting X ray and how much of exposure time is given.

Those of you who would have gone for medical X ray. Now there is a button guy press and there is a light which will glow and then once the X ray exposure is over the light will go off, so that gives you know may be its may be two second or five seconds depending on one second depending the power and exposure time and the technicians. The X ray operators they know for a human X ray how much is the time to be given and of course same is to for a industrial X ray.

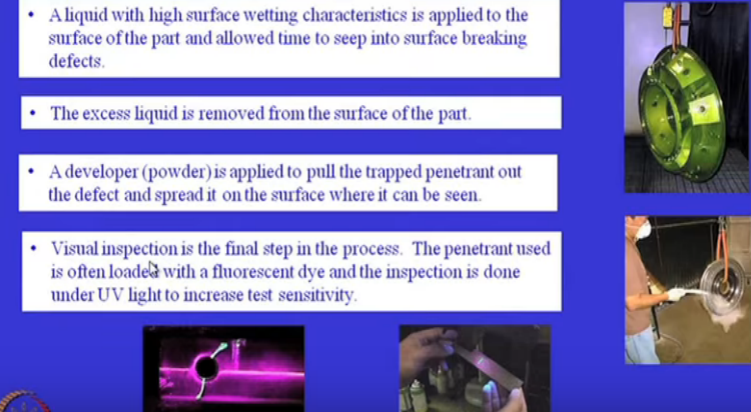
We will also have to control the exposure time and the power of course with the careful one node which is to be one has to be careful about is whether the exposure is so high that the lot of heat is being generated. So there are X ray system where it require intense cooling of the cathode tube.

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Liquid Penetrant Inspection

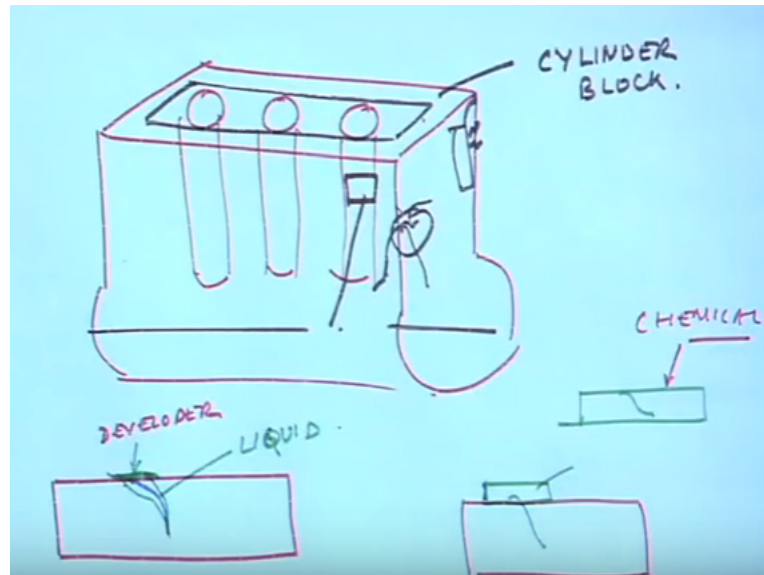
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- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull 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.



Now I will come to another technique which is used as NDT technique that is the liquid penetrant inspection. So this is altogether different than radioagraphy, but this are also used particularly when we have lot of casting, for example engine cylinder block.

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The engine cylinder blocks are usually cast it look something like this, these are the three cylinder engine. Then these are actually holes and this where your cylinder sting are there. The sting and then the connecting rod and the crank extra and these blocks are actually cast and then there are water jackets casted here and if there is a crack on this casting on the top and because there will be gas pressures at high pressures then forces things with time will leak out.

So we have to avoid such surface cracks or cracks which are very fine which cannot be perhaps seen by our naked eyes. So that is where a liquid penetrant inspection is done usually to find out such cracks. So liquid with high surface wetting characteristics is applied to the surface of the part and allowed to seep into surface breaking defects.

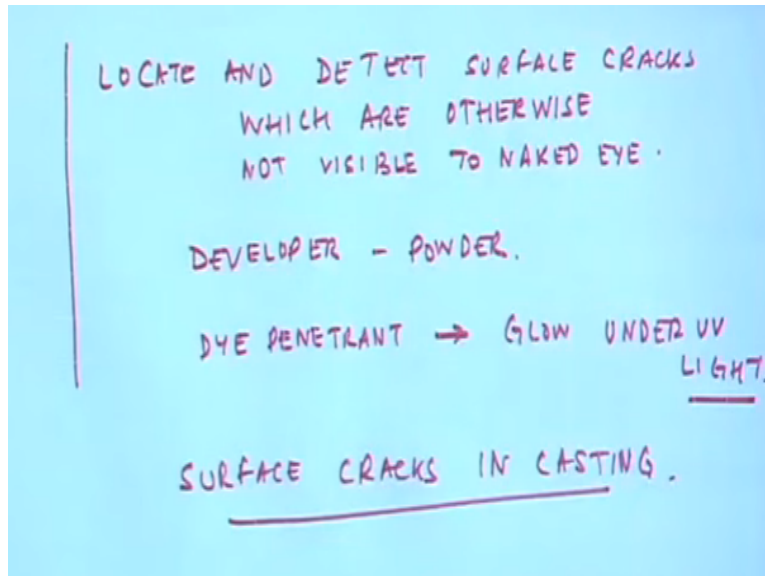
So if a liquid is there it will seep in and then it will come up the surface and then we can know the defects and then the process was this excess liquid is removed from the surface of the part by developer and then actually a developer is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen. So basically if I was to think of a material where is the crack, where is thin line crack like this.

So I will put a liquid, green one is the liquid here and then this liquid is going to come out to the surface. So I can put a developer this is my liquid so this comes on to the surface which can be picked up by a developer a good example would be you know, if there was a crack and then you pour some blue ink on to it and if I roll piece of blackboard chalk. So the chalk would get the mark of that liquid there.

So this is kind of the principle of liquid penetrant inspection only thing is that sometimes I can have this developer as chemical sometimes. This developer can be seen through some other things like a 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. So this is the penetrant has dye which glows under UV light.

So we pour, rub the surface with such penetrants and wherever and then clean it and wherever there is a crack. This penetrant is going to seep in and then it will come on to the surface and we can see it as a glow under UV light. So very easily you get you can see the crack surface is can be seen this is where we are putting a powder based developer, this fluorescent type developer which is being used to find out the defects in the system. So dye penetrant is a very easy and quick method to look at surface cracks.

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Locate and detect surface cracks which are otherwise not visible to naked eyes. So this developer can be a powder and the dye penetrant can be made to glow under UV light. So this are dye penetrant and this are usually done to find our surface cracks in casting. All kind of surface cracks can be detected by such UV lights. So why do we use.

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Why liquid penetrant

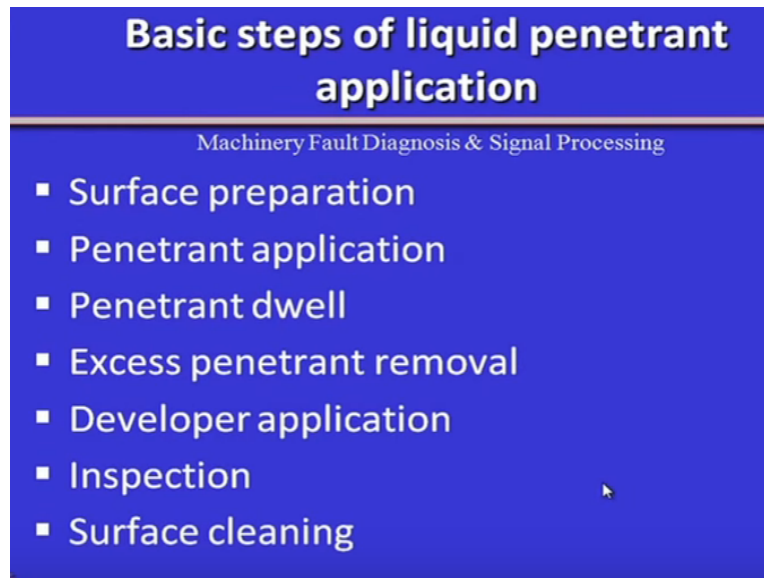
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- Improves detection of minor surface cracks by increasing their visibility (size)
- Provides a contrast against the background

Liquid penetrant because it improves the detection of minor surface cracks by increasing their visibility and size. It provides a contrast against the background usually the background of a material is very dull I mean imagine, we have a very dark black component machine very dull and if there is a surface crack on it may not be visible to naked eyes.

So if we do this dye penetrant apply dye penetrant on this surface cracks and then either have a developer which is a powder or whether we have a glowing dye penetrant. This on this dull black surface will glow and so it provides a contrast against the background and then we can detect the surface crack.

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So some of the basic steps which have to be followed while applying the liquid penetrant is, we have to prepare the surface as if there are no rough surfaces to feel. We have to nicely clean it degrease it and then penetrant is applied to dwell for sometime. So that it naturally seeps into the crack or avoid which are there on the surface and then the excess penetrant is removed by just cleaning and wiping it off on a piece of cloth and then developer is applied.

Once we applied the developer, this dye which has doubt of the crack will form an impression on the developer and this developer can then be expected then the surface can be cleaned. Nowadays there are high resolution camera but the problem is unless there is contrast with the background we may not be possible for us to detect the surface defects and so many places particularly in production.

What production plants where series of components are being casted and going to for example in engine plant? I know of an engine plant where they were doing this engine block which came out of that plant was being sprayed by a dye and then it was wiped off and then the entire cylinder block was exposed to UV lights and the by a quick I mean somebody with an UV light actually

moves around and sees and wherever he sees a glow he knows that there is a crack and that is how quick testing of cracks is done.

Because imagine if we bought an engine there is minute crack which goes undetected, I can understand the consequence. Once you bought a new car and your cylinder block leaks out the charge or the lubricating oil or the cooler. What a mess it would be and now we manufacture you know guarantee that nothing would go wrong with your car for hundred thousand kilometer. So to take that in your account one has to be careful that such cracks do not seep in because of obvious many reason.

May be because of a thermal difference while casting because of some material in homogeneity. This crack has happened every cylinder block because you know once you know how is a engine manufacture once cylinder blocks comes into place they put in all the different component the piston, cylinder, liners and you know the valves extra.

But before the very basic casting itself had to be checked and this can be very easily done through a liquid dye penetrant test that is you know you expose you coat or spray with the dye penetrant and then see it under a UV light and that is what you can do. Innovations can be done to liquid dye penetrant test because nowadays we have high resolution digital cameras and that is why we can have an totally vision base systems.

So of course that that will bring us to the next line of our NDT technique and if the last technique of NDT which we are be discussing today is just the plain visual inspection and whether we can take the help of imaging systems, optical systems to have a better image or better viewing of a machinery component or inspect a material and machinery component. So factors

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Factors influencing Penetrant dwell time

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- The surface tension of the penetrant.
- The contact angle of the penetrant.
- The dynamic shear viscosity of the penetrant, which can vary with the diameter of the capillary. The viscosity of a penetrant in microcapillary flaws is higher than its viscosity in bulk, which slows the infiltration of the tight flaws.
- The atmospheric pressure at the flaw opening.
- The capillary pressure at the flaw opening.
- The pressure of the gas trapped in the flaw by the penetrant.
- The radius of the flaw or the distance between the flaw walls.
- The density or specific gravity of the penetrant.
- Microstructural properties of the penetrant.

Influencing penetrant dwell time, is the surface tension of the penetrant. The contact angle of the penetrant. The dynamic shear viscosity of the penetrant which can vary with the diameter of the capillary the viscosity of a penetrant in micro capillary flaws is higher than its viscosity in bulk which slows the infiltration of the tight flaws. The atmospheric pressure at the flaw opening. The capillary pressure at the flaw opening.

The pressure of the gas trapped in the flaw by the penetrant. The radius of the flaw or the distance between the flaw walls. The density or specific gravity of the penetrant. Micro structural properties of the penetrant. So we have to be careful about these things which we influence penetrant dwell time.

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Materials commonly tested by LPI

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- Metals
- Plastics
- Rubbers
- Ceramics
- Glass

Some of the materials which are commonly tested by LPI unlike the eddy current or the ultrasonic eddy current where it has to be a magnetic material. Ultrasonic, it could be any material commonly tested by liquid penetrant inspection are any kind of a metals, plastics, rubbers, ceramics, glass.

There is no end to it provided your liquid penetrant can actually seep into the cracks and it can let it to dwell and then ooze out. So that if there is a glow if there is dye that penetrant it can glow under UV light or I can apply a developer, so that this liquid is going to get leave a impression on the developer.

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Common flaws detected by LPI

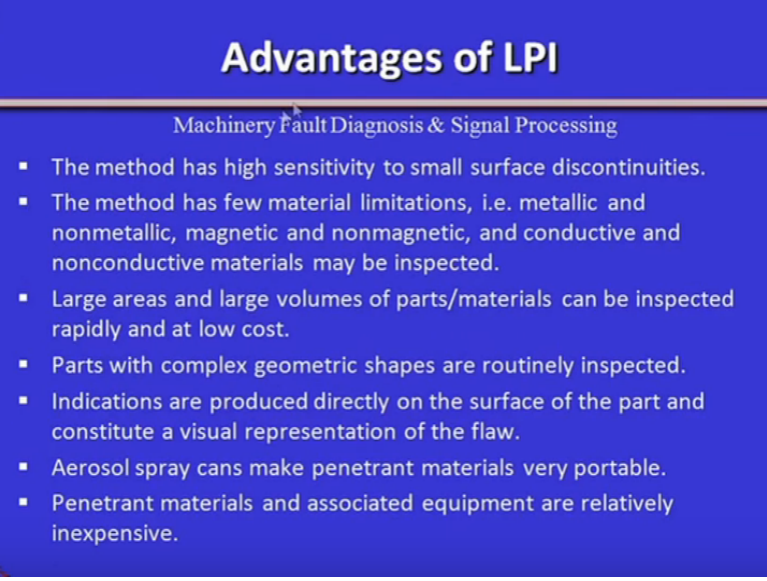
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- Fatigue cracks
- Quench cracks
- Grinding cracks
- Overload and impact fractures
- Porosity
- Laps
- Seams
- Pin holes in welds

Some of the common flaws detected by LPI or liquid penetrant inspection are the fatigue cracks, the quenching cracks during heated, grinding cracks, overload and impact failures, porosity, laps seams, pin holes in welds. These are some things very small but when detect carefully with ultrasonic radiation current.

Because there resolution here are so fine that we may be in a noise floor of the ultrasonic or an eddy current system. So this kind of test are very minute, thin hairline kind of cracks in the surface can be very easily detected by LPI.

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Advantages of LPI

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- The method has high sensitivity to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

So advantages of LPI is, the method has high sensitivity to small surface discontinuities, which was not there in the case of the eddy current or the ultrasonic. The method has few material limitation example metallic, non metallic, magnetic and non magnetic, conductive and non conductive may be inspected.

Large areas and large volumes of parts materials can be inspected rapidly at low cost. Parts with complex geometric shapes are routinely inspected. Indicators are produced directly on the surface of the part and constitute a visual representation of the flaw. Aerosol spray cans make penetrant materials very portable penetrant materials and associated equipment are relatively inexpensive.

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Disadvantages of LPI

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- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous surface can be inspected.
- Precleaning is critical since contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapor blasting must be removed prior to LPI.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required.

So some of disadvantages of LPI, only surface breaking defects can be detected. Only materials with a relatively non porous surface can be inspected. Pre cleaning is critical since components can mask defects. Metal smearing from machining grinding and grit or vapor blasting must be removed prior to LPI.

The inspector must have direct access to the surface being inspected. Surface finish and roughness can affect inspection sensitivity. Multiple process operations must be performed and controlled. Post cleaning of acceptable parts or materials is required. Chemical handling and proper disposal is required.

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Fluorescent penetrant

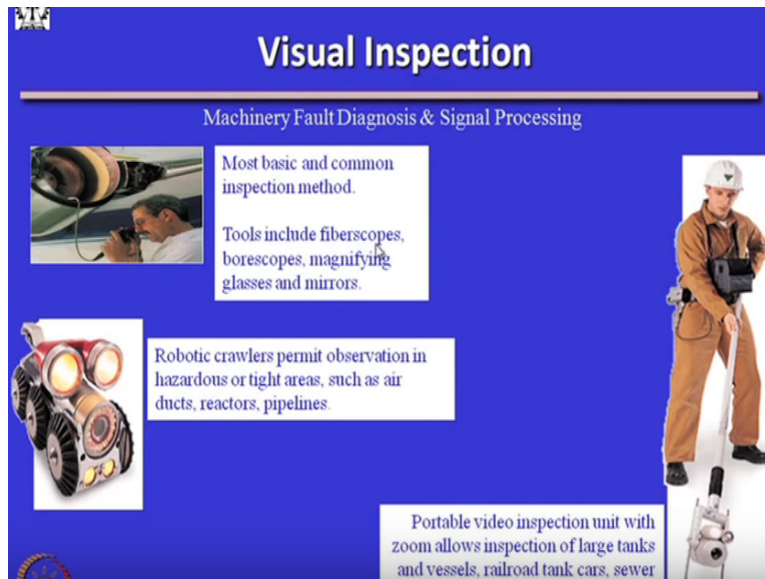
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Fluorescent penetrant indication

I have this one of the image of fluorescent penetrant on a metal rod.

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Now I will come to the last technique of visual inspection. What essentially it does is, we can have borescopes, fiberscopes, magnifying glasses and mirrors to see component which are not visible to us from the outside. So we can have an cameras built in like we are going to do a pipeline inspection. We want to do a cylinder internal dimension checking like similar to doctors putting in a camera in a tube and doing a surgery.

With this kind of visual inspection aided by cameras, magnifying glasses and mirrors and of course now we have also portable cameras, video cameras which can be put in robots. So and then inspect the places where humanly it is not possible somebody to go in for example inside a pipeline which is conveying crude oil or some sort of a liquid we would like to inspect the internals. So we can move in a camera robotic control cameras.

So these are what people also use for NDT visual inspection and techniques. So with this I would like to bring to an end the module on NDT and we will we basically looked in the four lectures on NDT techniques acoustic emission, ultrasonic, thermography, eddy current, acoustic emission, of course now radiography as well thank you.