Fundamentals of Surface Engineering: Mechanisms, Processes and Characterizations

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Lecture-57
Surface Modification Techniques: Thickness and Soundness

Hello, I welcome you all in this presentation related with the subject details of surface engineering and you know that we have talked about the various aspects related with the fundamentals of the wear mechanism and then methods which are used to modify the surfaces for improving the surface properties and enhance the tribological life and after the modification of the surfaces of the substrate for enhancing the tribological life it is important that those modified surfaces are also characterized with regard to the various properties.

Such as the soundness depth of the modified layer the mechanical properties and metallurgical properties and their tribological properties. So, you know that we are now talking about the characterisation of the modified surfaces and the main purpose of this chapter is to find out the values of the various properties of the modified surfaces, so, that we can take suitable and well informed decisions about the suitability or applicability of the modified surfaces for the target application.

So, basically we decide how; based on the characterised values of the modified surfaces decision is taken whether modified surface is fit for given application or not.

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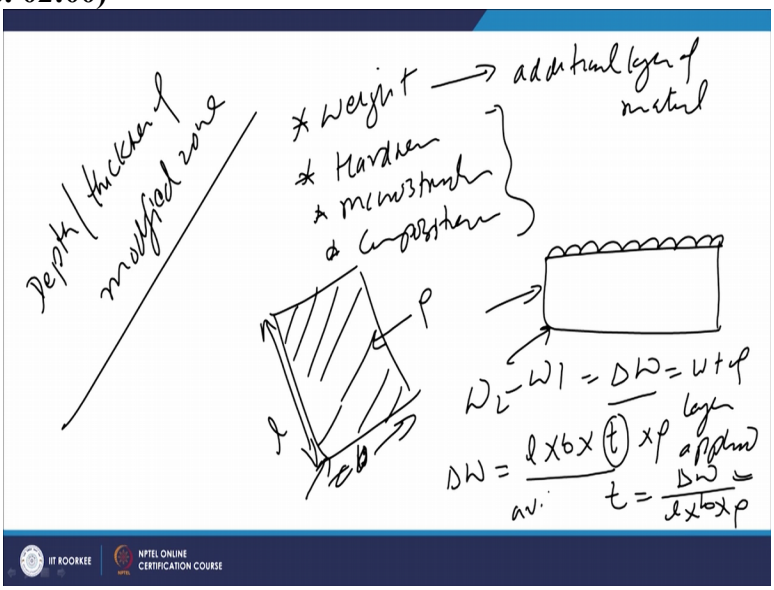

So, under this previous presentation we have talked about one method of the depth or thickness of the modified zone thickness of the modified zone. So, under this we can use the variety of the methods and we have one method we have talked that was about the weight method. And apart from that the other indirect methods are like hardness testing or the micro structural variations are the compositional variation. So, these are the indirect methods, these 3 are the indirect methods.

And in case of the weight method we have to take the weight of the sample before and after the development of the modified surfaces. And any increase in weight is attributed to the modified thickness of the modified layer. So, in those methods where additional layer is applied additional layer of the material is applied this weight method is found to be more effective like say on the surface of the substrate we apply a layer of the material.

So, we have to take the weight of the material before applying the layer of the material and after we have to take also the weight of the component or the substrate after applying the layer. And difference of these two is used to see; is a considered or is attributed to the weight of the layer applied weight of the material applied in form of layer. And now this weight is used for indirect calculation of the depth of the thickness of the modified zone.

And for that purpose basically we calculate if the if you see this modified zone in the top view and if this modified zone is in this; over this area then what will see width of this modified zone is B and the length of the modified zone is L density of the material which is applied is Rho, Rho into B into L into B into say average thickness about which we do not know. So, this is a value to be obtained and product of these 3 will be giving us the volume.

And multiplied by Rho, so this will give us the weight, so that it can be obtained from the delta W/l into b into Rho this will give us the average thickness of the layer which is applied on the surface of the substrate. This is one method there are other two methods which are used for measuring the thickness of the layer which is applied.

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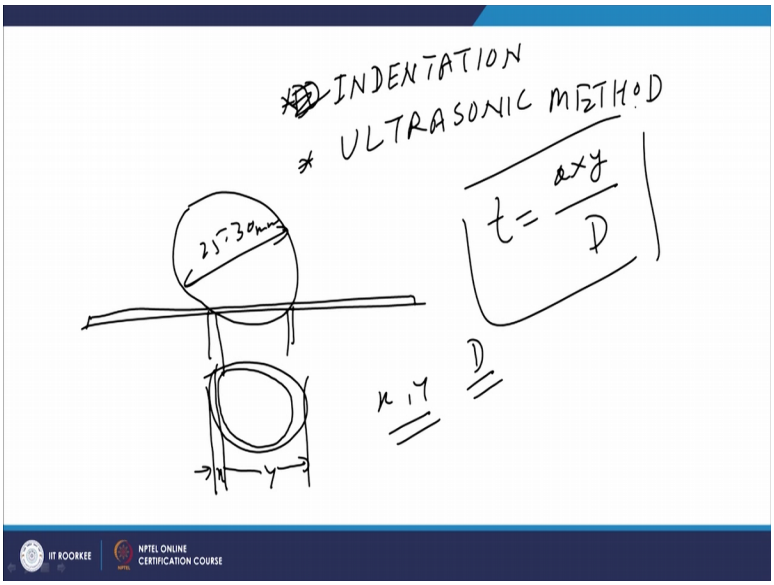

And these are like indentation method and the second one is the ultrasonic method. So, the principle of the indentation method is very simple like this is a substrate over which we have applied thin layer of the coating or layer of the material has been deposited. Then we apply in we develop one indentation using suitable ball on the surface of the on the modified surface.

In this case what we do like the ball of the large diameter like 25 to 30 mm ball and diameter is used to develop the segmentation and then the dimensional measurement of the indentation are used for calculating the thickness of this layer which is applied. So, if we see this is the surface indentation of the modified zone. And this is the indentation of the substrate like this.

And then we determine the values like y from one and this is the x this is the, another value. So, these two values of the x and y are used for calculating the thickness along with the diameter of the ball which is being used for developing the indentations of thickness of the coating which is the thickness of the layer which is applied in this indentation method is obtained from the x multiplied by y/d gives us the approximate value of the modified zones.

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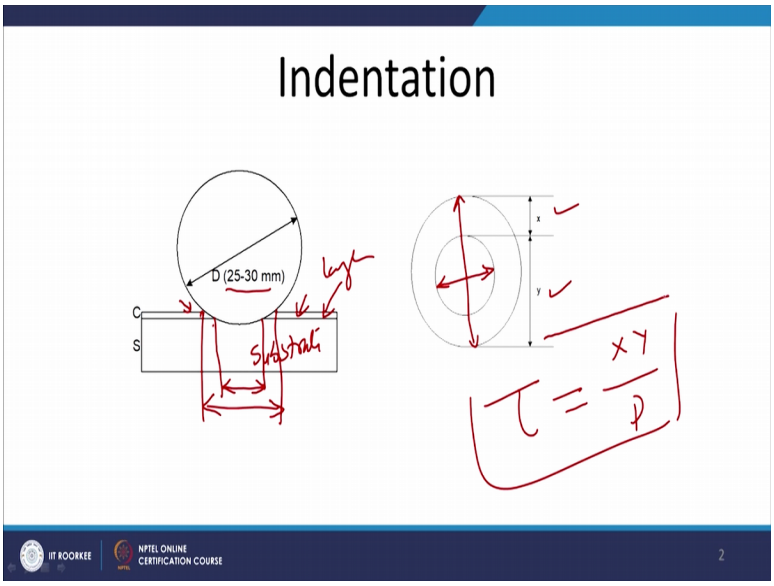

This is the method which we can see here in this case this is the substrate and this is the thin layer of the material which is applied a ball of the large diameter like 25 to 30 mm diameter is applied and suitable load is applied, so, indentation is made on to be surface. You know since the modified surface layer of the material which is applied at the surface of the substrate that will have the different properties than the substrate. So, accordingly the indentation may vary significantly.

In these two cases and then these dimensions are measured in terms of the diameter of the indentation at the surface of the modified layer and this is the diameter of the indentation at the substrate. So, this is the diameter of the indentation at the surface of the substrate and this is the diameter of the indentation at the surface of the modified layer. And once we are able to get these two values we can easily obtain the value of the y and x.

And this y and x are used to calculate the thickness of the modified layer which is obtained from x into y / d this is how it is obtained.

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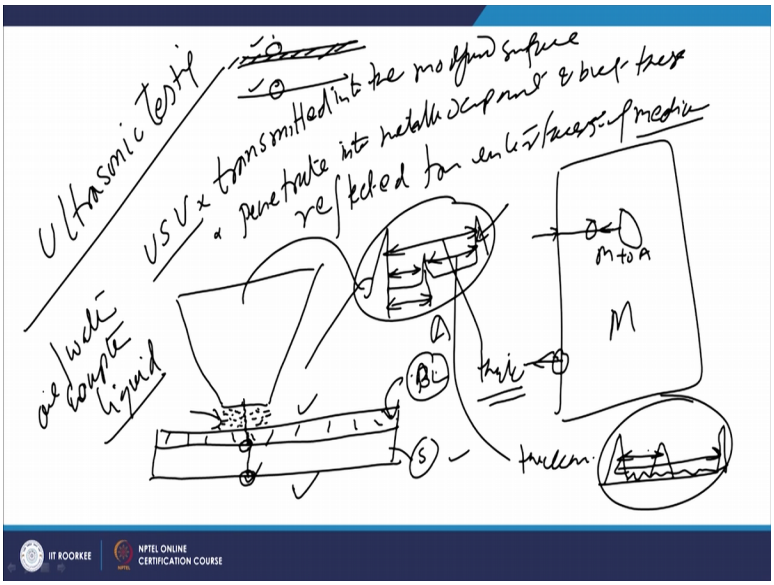

Now will see another method of the measuring the thickness this is called ultrasonic testing. In the case of ultrasonic testing ultrasonic vibrations are transmitted into the modified surface and it uses the typical property of a very unique property of these ultrasonic vibrations that these can penetrate into the metallic component. But these get reflected from the interfaces of mediums like, if there is a change in medium here we have air this is the metal this is the substrate.

So, as soon as the vibrations move from the air to metal it comes across one interface and these are reflected. Similarly if the vibrations are being transmitted and so this and these are translated into the metal as soon as these come across any defect then these will then there will be one interface will be formed and this interface will be between a metal to air. In this case the interface was between the air and the metal.

Whenever one change of the medium takes place one interface is formed and the vibrations are reflected from that interface. So, this is a unique characteristic of the ultrasonic vibrations is exploited in the thickness measurement. So, what we do like we use ultrasonic vibration probe which is applied on to the surface of the modified layer like this. This is the modifier which is applied of metals B and this is the metal S in form of substrate.

Then when the vibrations are applied these are applied on to the modified component through the use of the suitable liquid. So, that if there is a minimum loss of these vibrations and these get easily transferred to the component this is this; so, the vibrations are transmitted through the liquid which is mostly in form of oil or water this is called copular. It has to connect prop with the surface of the component of surface of the substrate of the modified surface.

When these vibrations reach to the surface they will be initially reflected. So, this reflected vibrations we can see on the oscilloscope in form of very strong peak like this. And then these will be transmitted through the modified layer and then they will be coming across one interface between these two metals which is in form of like say B and S. Again these are reflected and then final reflection will be coming from another side where there is a change in medium from the substrate metal to the air.

So, will be getting in this case these three peaks so the last peak is corresponding to the reflection of the vibrations coming from the bottom side surface of the substrate and air interface that the first and strong peak is coming from the air to the modified surface metal interface which is also a strong peak then there will be one weak peak reflection which will be coming from the; which will be coming from the modified.

The material which is applied from the interface of the coating and the substrate are the layer which is applied interface of the layer of the material which is applied and the substrate. So, the spacing between the two is used to characterize the thickness of the layer which is applied and the spacing between these two peaks is used to characterize that entire thickness right from the modified zone to the bottom of the substrate.

And the distance is used to characterize the thickness of the substrate, so in this case basically we are transmitting the ultrasonic vibrations at the surface. So, from the; when these are applied at the initial it will be reflected back from the surface itself. And the part of them will be transmitted in the metal and as soon as they come across to the lower interface again they will be reflected back. And if there is any defect or the interface then will be getting the third peak as well.

So, oscilloscope basically if there is no interface and there is just the one substrate layer vibrations will be reflected back from the top and then vibrations will be reflected back from the bottom. And these two will appear as a strong peak from the top and the bottom these are the two strong peak corresponding to the peaks from the top surface and the bottom surface and this distance will be indicating the thickness of the substrate.

But if we apply one coating like this then again one interface will inform that will be getting additional peak here and that will be indicating the thickness of the modified layer or the layer of the material which is applied on to the surface of the substrate.

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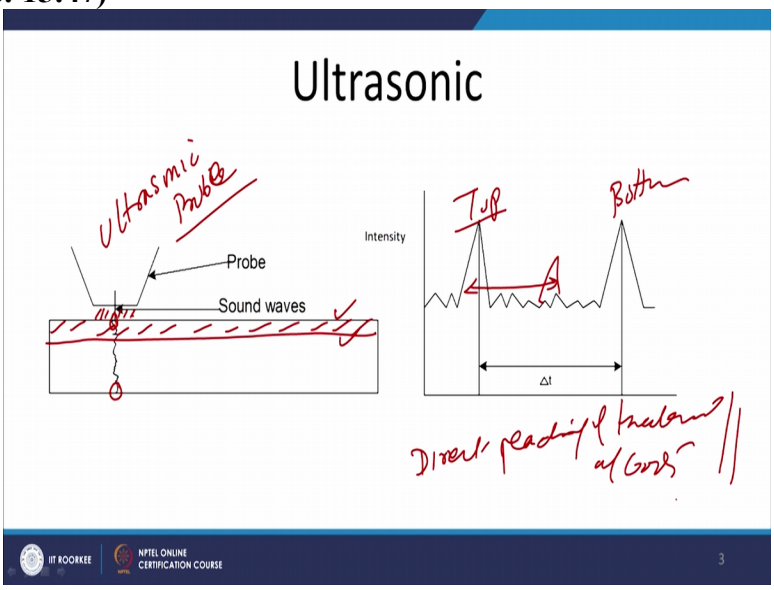

So, this is what we can see here in the next diagram like when the Ultrasonic vibration probe is applied to the surface of the component it will be applied to the coupler it will be transmitted vibrations will be transmitted so initially it will be reflected from the top surface. So, this is this peak is corresponding to the top surface and then another strong peak will be getting due to the reflection of these vibrations from the bottom surface.

So, this is corresponding to the bottom surface and if there is a layer of the material which is applied then we will be getting one additional peak from the in between and that will be suggesting the presence of the interlayer. So, the surface peak and the interfacial peak between the layer of the material applied and the substrate. So, that interface will be giving one additional peak in between especially when there is no other discontinuity.

And when there are discontinued we can get number of other peaks. So, basically ultrasonic vibration method gives us the direct reading of thickness of the coating or the modified layer which is applied.

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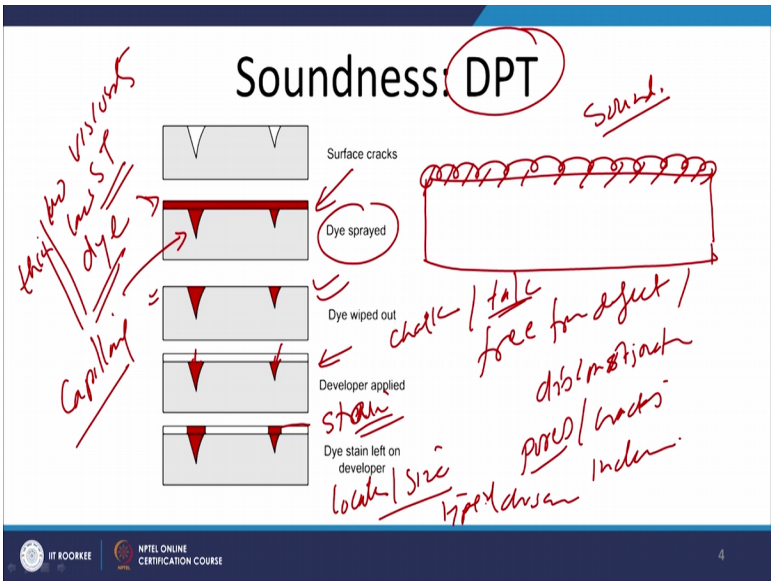

And now we will see; so after the thickness measurement and now we have to see that whatever the modification has been carried out at the surface of the substrate that modification is a perfect or a modified zones which is formed is a sound or not. Sound means whether it is free from defects and discontinuity or not in form of like say there maybe pores, there maybe cracks there may be inclusions defective modified surface will be leading to the increased tendencies for crack easy crack nucleation and there growth and premature fracture, higher metal removal rate, higher wear rate so this will not be leading to a good situation.

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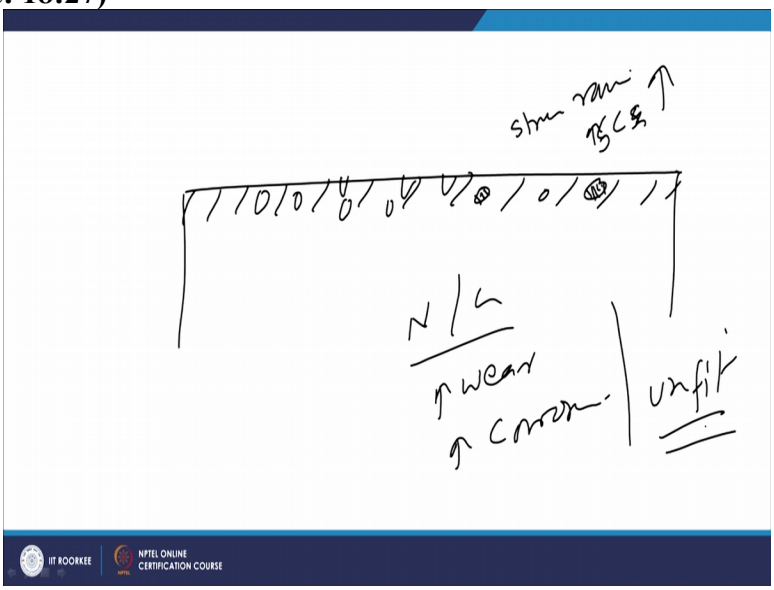

Because the defective modified layer, if there are like defects in form of cracks here and there pores in the modified zones or inclusions of the foreign material or impurities. Then will be acting as stress raisers. Increasing the stress concentration increasing stress concentration will be

simply leading to the easy nucleation and growth of crack increased wear, increased corrosion tendency of the material. So, in that case it may be unfit unsuitable for those applications. So, all the modified surfaces should be assessed.

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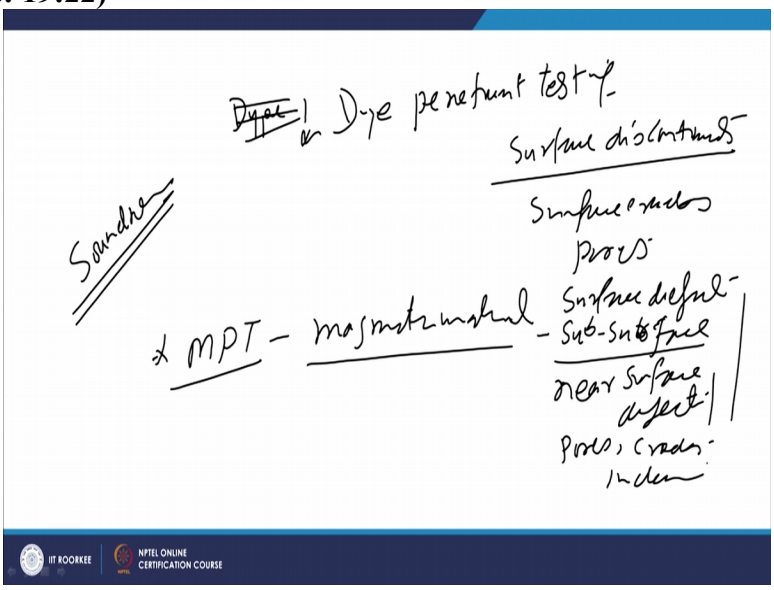

For their soundness, so integrity and soundness testing of the modified zones is performed using various methods and it includes like Dye Penetrant Testing. This is primarily used for assessing the surface discontinuities which may be there in form of surface cracks or open pores or the blowholes which are present at the surface. Then we have the magnetic particle test. Magnetic particle test is primarily used for magnetic materials.

To assess both surface defects and subsurface but these are not them very deep. So, we can say near surface defects can also be assessed by the magnetic particle test. This may be in form of like say poles are cracks or inclusions etcetera.

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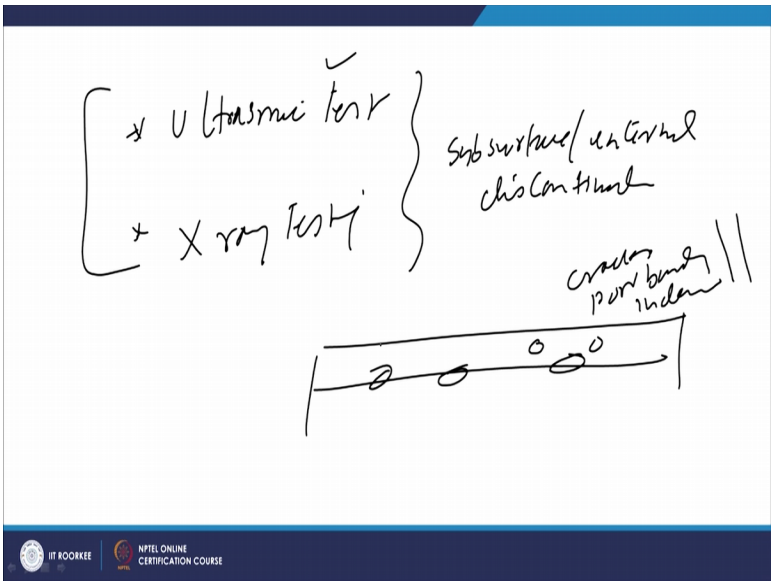

Then there are other methods like ultrasonic testing and x-ray testing. In case of; in other two methods we have seen they are primarily used for assessing the surface discontinuities. While these two methods are used for primarily used for assessing the subsurface or internal discontinuities. For example if the modified layer at the interface has some kind of the defects poor bonding and then all those cannot be detected very effectively.

Using the other two methods like DPT and MPT but this can be detected easily by the ultrasonic and X-ray testing. So, the defects which are present below the surface in form of cracks, poor bonding, and inclusions etcetera can be detected using the X-ray and ultrasonic testing methods. Now will see some basic principles associated with these processes.

In case of the Dye Penetrant Test if the surface having the discontinuities in that case we apply a very thin low viscosity low surface tension of liquid having the dye is spread over the surface. So, this is a spread in this form so that dye which is there within the pin low viscosity liquid being is spread over the surface. So, this minute and find discontinued is present at the surface will be sucking the liquid by the capillary action.

And once this liquid with the dye is spread over the surface after sometime it is wiped out, it is removed. So, this is the case when all the dyes present at the surface has been removed and the day with the liquid which has been served is left in the components. There after we apply one developer, developer may be in form of likes a chalk powder or talc powder.

So, that is spread over the surface so this will be as these developer will be observing the liquid and since the liquid is having the dye so it will be leaving behind the stains in the developer and wherever there is strains are present whatever is the extent of to which stains present that will be indicating the location of the size and type of the discontinued is present at the surface.

So, since the penetration of the thin liquid into the discontinuities is mandatory for assessment of the discontinuities in this method and that is why this method cannot detect a discontinuous which are present in the subsurface zone

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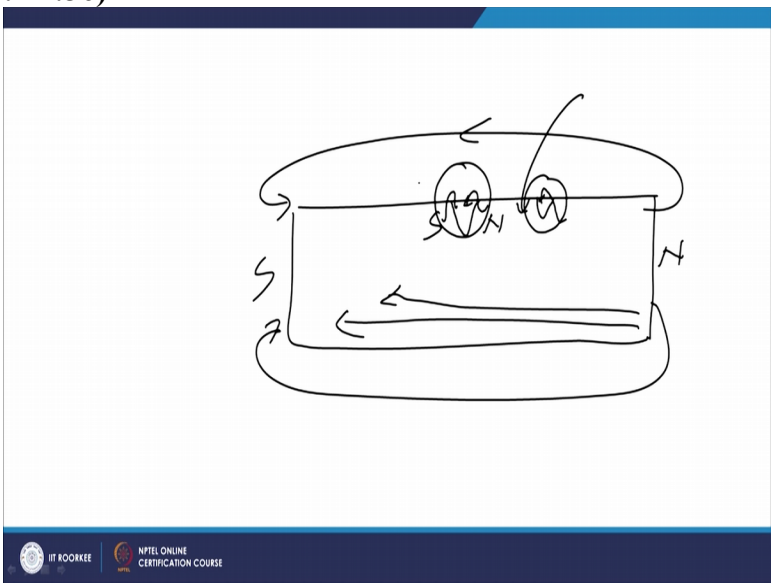

The magnetic particle test is the another method this test simply lies on the principle is based on the principle like all the magnetic materials having the north pole and south pole and magnetic lines moving from north to south like this. And if there is any discontinued then again it will be forming two poles and again we know that these lines of the magnetic flux will you moving more effectively through the metals.

But if there is open if there is a pores or if there is crack then again it will be forming the two poles and wherever the defects and discontinued is are present the leakage of the magnetic flux start from that area. And this leakage of the magnetic flux will be leading to the leakage of the magnetic flux will be leading to the formation of the additional the fields here. And this aspect is exploited to detect the location where were the discontinued is our present

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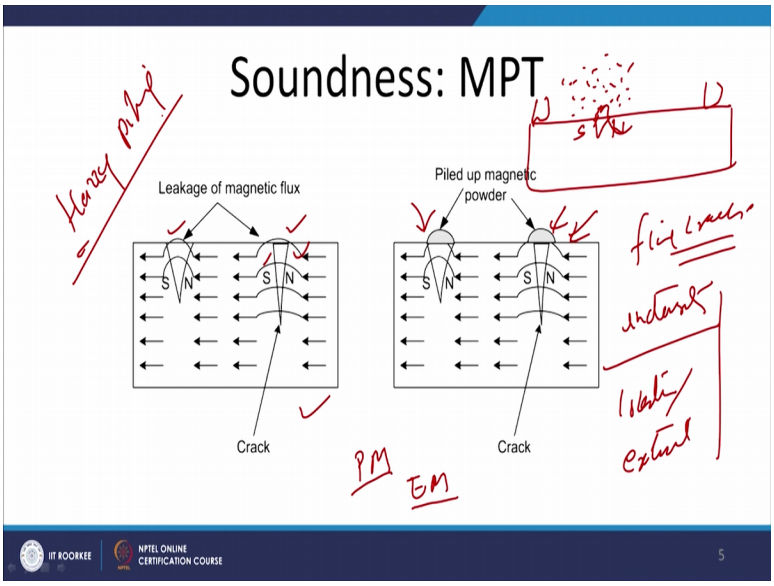

So, are considering this one in mind like say this is the component having the discontinuetity it is magnetized either using the permanent magnet or electro magnetics electro magnets. So, obviously the North and South poles will be formed and in this case whatever the locations are having the discontinuity is from there the leakage of the magnetic flux will start and Italy forming the two additional poles.

Now once the component to be checked component to become like this the component having discontinuity here so it will be magnetized using flow of current or using the permanent magnet. So, here will be having the two additional poles and there will be leakage of the magnetic flux. So, after the magnetization we sprinkle the magnetic powder particles. This is spread all over the surface of the substrate are the modified surface where there is a magnetic flux is magnetic particles that location

And they will get after magnetization of the components having defects when we sprinkle magnetic powder particles these will be getting piled up at the location where ever there is leakage of the magnetic flux. So, depending upon the intensity of the pile up location and the extent to which the pile up is taking place that will be indicating the location of the discontinue 30 size of the discontinuity.

And so this is how will be able to detect the find cracks present at the surface if the discontinuities are present below the surface in case of the magnetic particle test very easy piling of the Powder particles take place. So, very easy and a little bit piling up of the particle at

particular location of suggests that they discontinue are present near the surface layer is not at the surface players.

Now I will summarise this presentation here, in this presentation just have talked about the traditional methods of the thickness testing and two methods of the soundness testing is important to see that how is the soundness of the modified zones whether they are free from the defect and is correct or not other two methods of the soundness and integrity testing in the next generation. Thank you for your attention.