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Theory and Practice of Non Destructive Testing

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PENETRANT TESTING – PART 1

Hello and welcome back to this lecture series on non-destructive testing which is being offered under NPTEL online certificate course so in the last lecture we discussed one of the topics which was on visual optical method and as I told you can do few things by using this technique but it has its own limitation in the sense you would be able to do only certain external inspection tunnel surface of the component and if you want to visualize something which is below the surface or which lies underneath then you need to use one of these NDT methods that we have listed as you could see in the first slide okay.

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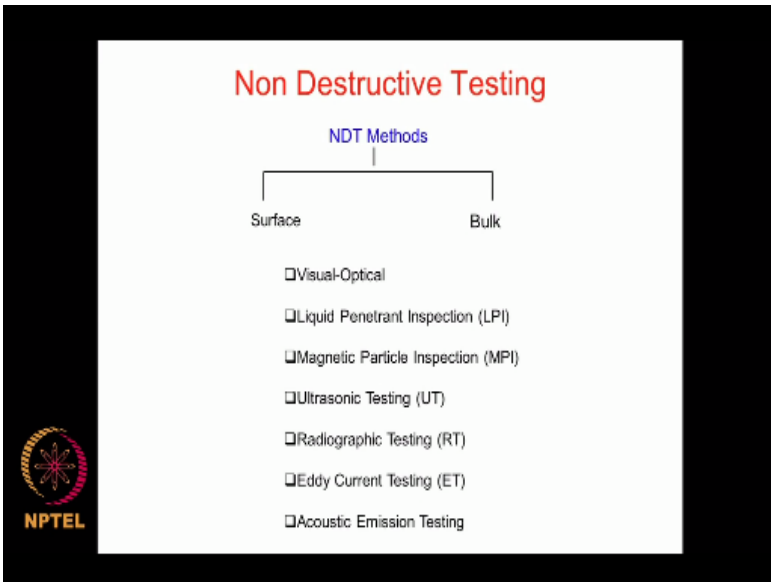

So we have discussed this one as I said the first one visual optical in the last lecture and as I said if you want to see and inspect what lies beneath then you need to use one of these NDT methods which are listed here some of these will come under the category of surface energy method and some of these will fall under the category of bulk or volume and NDT methods techniques like liquid penetrant inspection magnetic particle inspection and eddy current testing they will come under the surface method and methods like ultrasonic testing and radiographic testing they will fall under the bulk category.

And there are certain techniques like for example ultrasonic which can do both I mean it can do both surface NDT as well as bulk NDT so what we are going to do in this series of lectures is to take each of these techniques each of these in NDT methods one at a time and then first learn about the basic principle behind the technique as I would have said before also and then go on to learn about the method itself as to how the method is done how the process is applied and what are the process parameters and so on okay.

So in pick one by one and then we will discuss in more details so in the today's lecture we are going to pick up the first topic in this list which is on liquid penetrant testing okay so this will be our first lecture as far as the entity methods are concerned.

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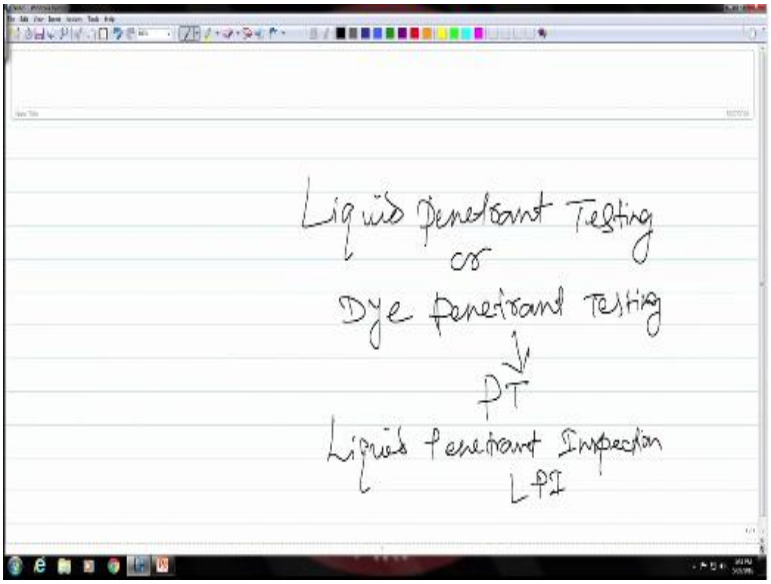

So this will be on liquid penetrant testing or sometimes it will also call it as a dye penetrant testing because a liquid dye is used and in short sometime they also prefer to call it as simply PT which stands for penetrant testing there is one more name to it which is liquid the liquid penetrant inspection or LPI in short okay so these are the names of the same technique which is the liquid penetrant testing or penitent testing okay so as I said we will first learn about the basic principle behind this we will see on what scientific principle this particular technique is based on and then once we learn that we will go on to see the method and then see what are the process parameters how it is done and soon.

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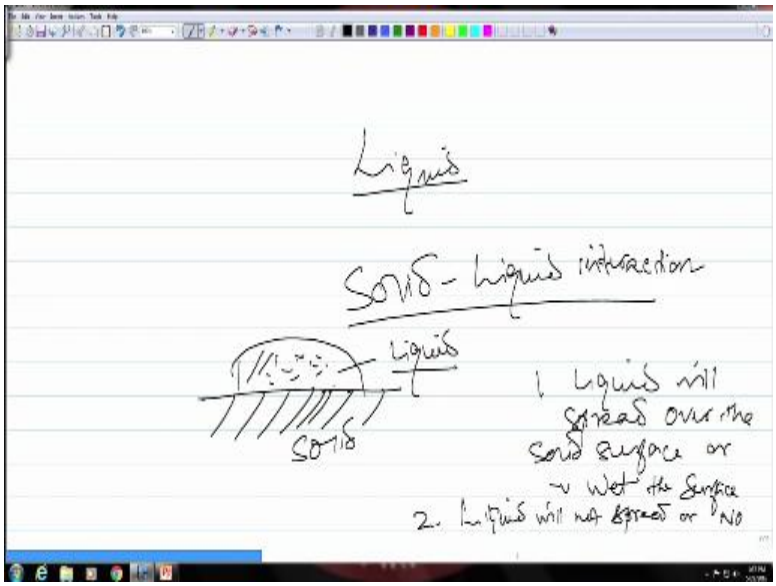

So as I said all you have here you have a liquid and you need to inspect a component so you have a solid surface okay so you apply this liquid on the solid surface and then allow it to spread over it and then if you have defects or flaws you can inspect it depending on what his liquid doe show these liquid interacts with the solid surface.

So that means you need to talk about solid liquid the interaction that means let us say if I have a solid surface okay and then I put a liquid over this okay now depending on the interaction or the surface energies two things can happen one is the liquid will spread over the solid surface or in other words the liquid will wait the solid surface okay and the second possibility will be the liquid will not speared or it will not wet so there will be no waiting.

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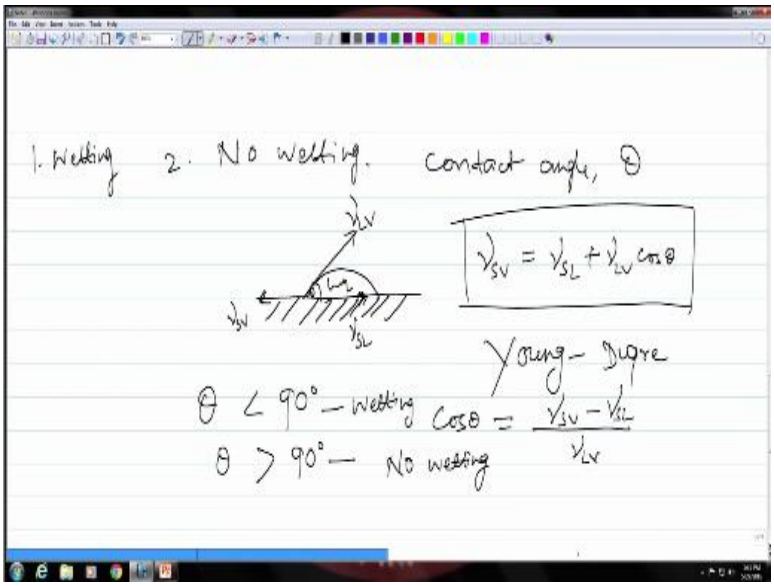

So two case one is waiting and the second is no waiting okay so whether the liquid will wait the solid surface or not that would depend on parameter which is know contact angle let us call this as θ okay so let us say this is my soiled surface and over this I have liquid drop let like this okay so has I said whether waiting will happen or not this will depend on the surface energies which will finally come back to this contact angle so this is the surface energy between the liquid and the vapor so if you call the surface energy is γ so this will be γ liquid vapor okay.

So this is the surface tension of the liquid then you have this particular interface over here oaky so this is your solid liquid interface so here you have γ_{SL} which stands for solid liquid and then over here you have one more interface one more surface and one more surface energy which is the interface between the solid and the vapor so you here you have γ solid vapor okay and this angle that I talked about which is known as the contact angle okay now if you take the balance of forces what you have here you have this γ_{SV} is being balanced by $\gamma_{SL} + \gamma_{LV} \cos\theta$ okay.

So this is the well know young's equation or young Duper equation which talks about contact angle between a solid surface and liquid and depending on this so you can derive the contact angle from this equation as okay now depending on whether θ is less than 90 degree or θ is more

than 90 degree the liquid will either spread or not spread so θ is less than 90 degree than the liquid will wet the soil surface okay and if θ is more than 90 degree the liquid will not spread or will not wet the soil surface okay.

So this is the parameter contact angle θ which decides whether a liquid will spread over a solid surface or whether it will not okay now out of this connect to liquid penitent testing let us go head and see that.

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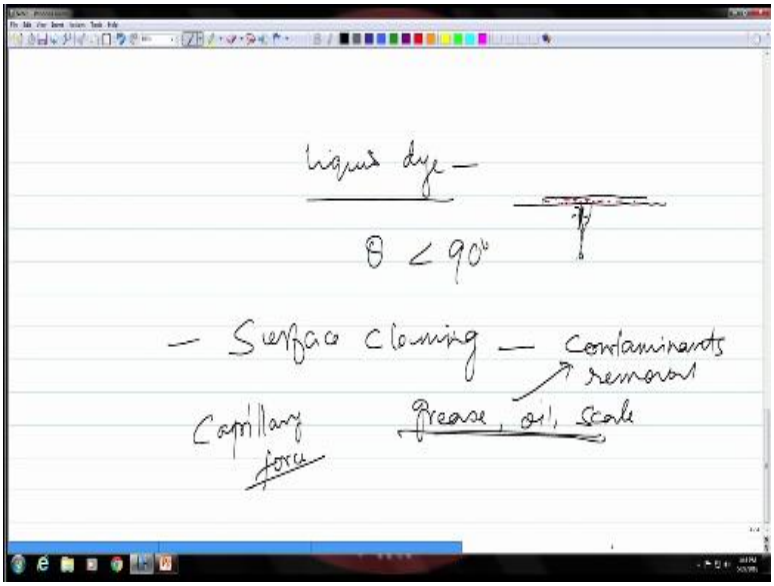

So as I said use a liquid dye which is generally a color dye most of the time a red color is used and you take this liquid dye and then you spread it you apply it on the solid surface for this dye to be spread over the soil surface of the component that you are examining this contact angle θ between the component being the surface of the component being examined and this liquid dye solid should be less than 90 degree okay and for that to happen the surface would be clean so that is why the first set in this particular method is surface cleaning.

So you need to clean the surface of all the contaminants and remove them so this contaminants could be anything like grease oil or scale which might have formed on the surface okay so all

these will tend to increase the contact angle so first you need to clean all this so that you can have a clean surface and the contact angle will be less than 90 degree so this will ensure that the liquid dye that you are applying on the surface we will spread over the solid surface okay.

So now once that happens once the liquid spreads over the surface now depending on whether you have a solid surface with defect or without defect this liquid first of all as I said will spread over the surface now let us say you have some kind of discontinuity it is a crack or some other discontinuity over here okay on the surface so this crack has a crack surface so here you have a surface on both the sides of the crack you have a surface so that means you have a surface energy involved over there okay.

So because of that this liquid will be drawn inside this so the force which draws a liquid inside an opening or any fissure on a solid surface is known as the capillary force which develops due to the surface tension of the liquid okay so that means if you spread a liquid on a solid surface and if that surface has some kind of opening some kind of small opening or feature then a capillary force will develop because of the surface tension of the liquid and that capillary force will draw the liquid inside that discontinuity or that opening okay. So the capillary force due to surface tension γ_{LB}.

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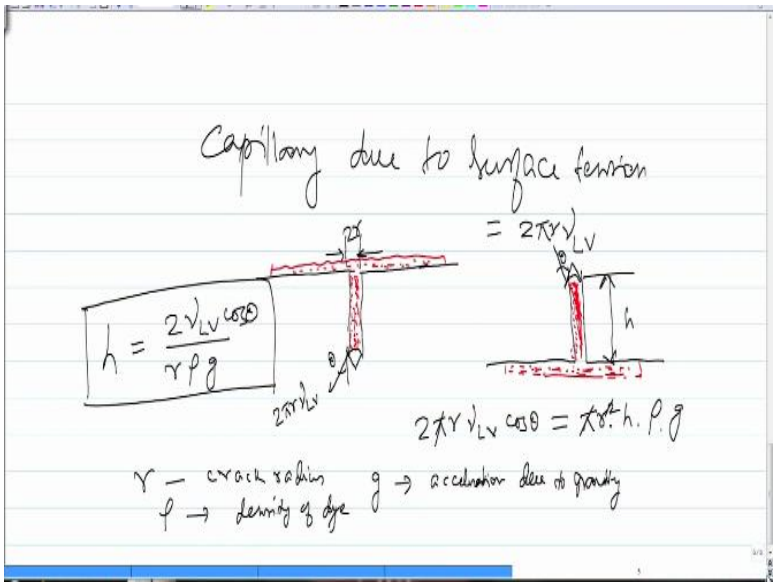

If you want to see it for a crack so let us say this is a solid surface and I have an opening a discontinuity let us say this is a crack okay and we will give a size to this crack so let us say the crack size is are so crack radius is r so this diameter is 2r okay so a crack of size r or radius R these capillary force due to the surface tension would be 2 $\pi r\gamma_{LV}$ where in γ_{LV} is the surface tension of the liquid okay now you can apply the liquid either through top like this okay and if the liquid is spread if the solid surface is betted by the liquid then due to this opening and the capillary force which develops this liquid will go inside the crack in this fashion and this will be the contact angle okay.

So this is the capillary which is drawing the liquid inside in certain cases the dye is also applied from bottom that means you take the component and immerse it in a tank which contains the dye okay so this is your solid surface and then you are immersing it into a tank which contains the dye so in this case the liquid will penetrate from bottom so it will go up but again this is the same capillary force which is driving this liquid inside the crack so there again you have this contact angle θ so this is the capillary 2 $\pi r\gamma_{LV}$ okay.

So what you have inside this crack is a liquid head so that means the weight of the liquid is being supported by this capillary force so if you take the component of the capillary force along this axis vertically then this is the component which is supporting the liquid head or the weight of the liquid so the weight of the liquid is given the crack size as r or the radius of the crack as our and let us say this height or this depth is H so this is the volume then the density multiplied by the gravity g okay.

So r is the crack sighs ρ is the density of the dye or density of the liquid and g is acceleration due to gravity or gravity okay and H is the depth of penetration so from here you would be able to derive that up to what depth the liquid can penetrate depending on the size of the crack and the density of the die okay so if you see from here this will be your H.

So H is equal to okay so as you could see it primarily depends on the properties of the liquid dye that is the surface tension of the liquid gamma lv and the density of the liquid and apart from that it also depends inversely with the crack size, so if you have a larger crack the penetration depth will be lower and vice versa okay so this gives you an idea that for a particular crack size a particular die what could be the depth up to which you can go and inspect okay. So this is the basis for this particular method of dye penetrant testing okay.

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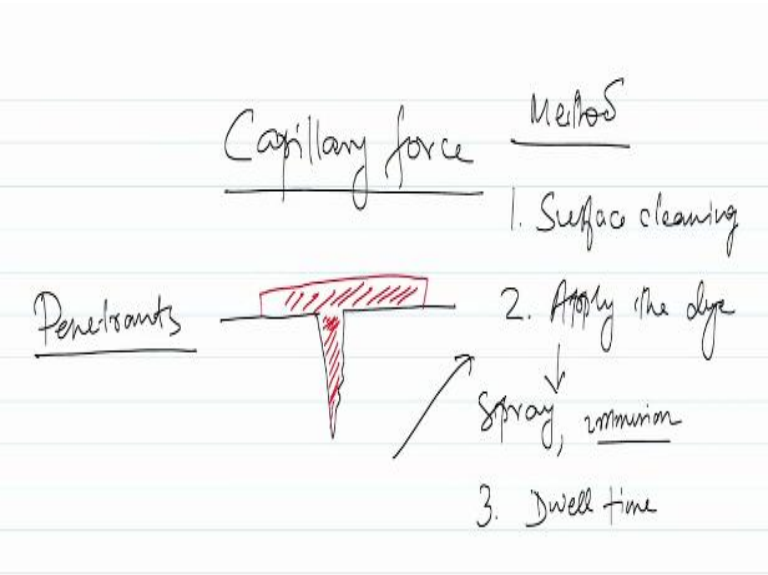

So the basis for this is the capillary force which develops due to the surface tensor okay now the question is how to use this to make visible indications of the crack that you might have on a component that you are examining okay so now as you have seen so let us magnify a bit so you have applied this dye as I said it is general red in color and it has gone inside, inside the crack okay and it is all over the place because what you do in this case you have a spray can which contains the dye and you spray it over the surface okay so the whole surface will be covered by this dye red color dye and if there is any discontinuity any flaw or defect this dye will be sucked inside by the capillary force okay.

So if you see the method as such now that we have understood the basic principle we can go to the method and see how exactly it is done so the first step as I told is surface cleaning or surface preparation okay this is to ensure that your surface is clean and the contact angle is less than 90 degree so that the liquid dye can spread over nicely over this over the surface second you apply the dye okay.

So this is what is being shown in the diagram so you take this dye and it goes inside okay so in this case as I have mentioned before also you could either apply it through spray so you can have

a small spray can and you can spray it or it is also possible to apply by immersing it in a tank which contains the dye okay so either way depending on the size of the part or the convenience of the examiner both the method can be used okay.

Now the next thing is you need to allow some dwell time because this liquid I will have a certain viscosity although it does not come into that equation which we just now talked about but this viscosity because due to the viscosity it will take some time for the liquid to go inside the crack if there are discontinuities and crack on the surface so you need to allow certain time so that the liquid dye can go inside the flaws and defects.

And this dwell time as to how much time you should allow that depends on know what kind of part you have what is the size of that part and what kind of defects and what kind of size you are expecting in the what kind of defect size you are expecting in the part ok so this ad well time will ensure that you have enough time for the liquid to go inside the floss okay now as I said this liquid will be now spread over the solid surface so the whole surface the liquid will be all over the surface, okay. But before that let us see what kind of penitents are used and what properties this penitent should have okay.

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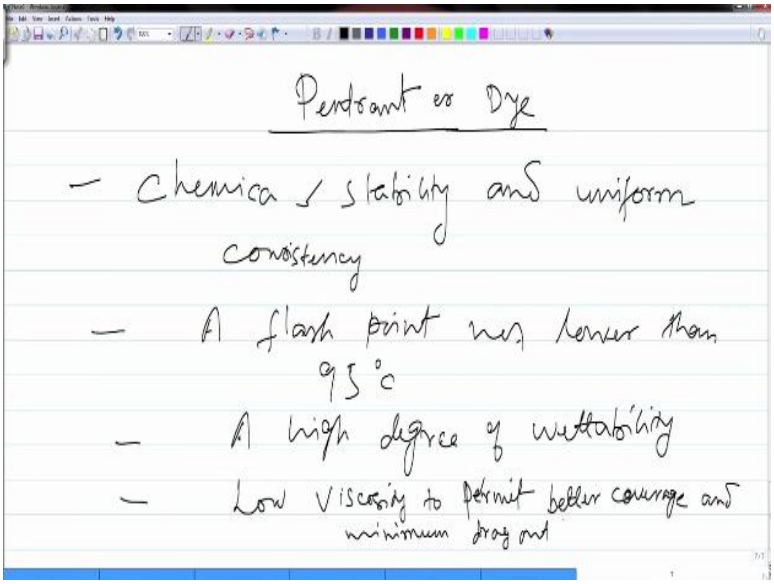

So the first characteristics or property of this liquid is that it should be chemically stable okay chemical stability and it should also have uniform physical consistency that means it is not have one density in one part and some other density in the other parts okay then it should have a flash point we should not be lower than 95 degree Celsius so it is close to 100 degree that means it it is not be a flammable liquid you should be able to handle it properly without the hazards of you know fire and all that.

And it should provide a high degree of weight abilities as I told before this weight ability is the first requirement for this dye penetrant testing so you should have a liquid which will provide a higher degree of variability provided your surfaces clean and it should also have low viscosity so that you do not really have to allow a very long dwell time so this will permit better coverage and also save some time as I told in terms of the dwell time. And it will also provide you a minimum drag out.

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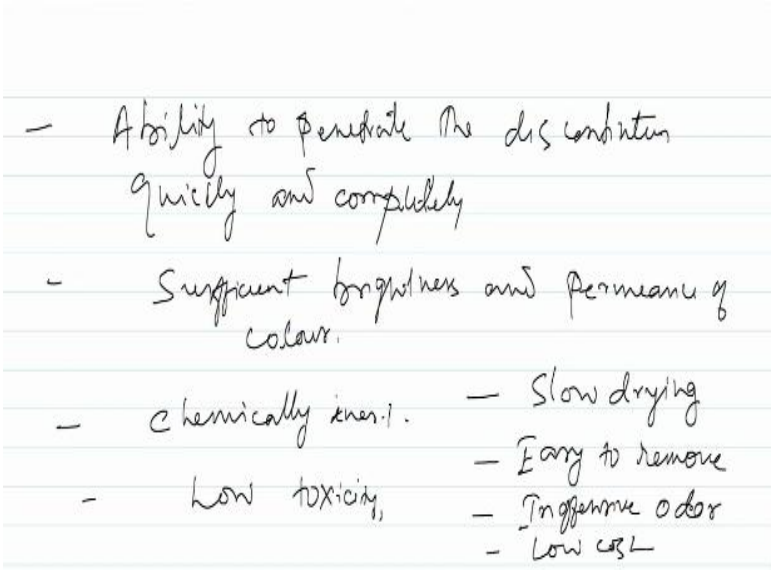

Then it should also be able to penetrate the discontinuity quickly and completely then it should have sufficient brightness so that you get that contrast for the visual inspection at the end of the process you have to inspect it so we should have sufficient bright net brightness so that you can

get that contrast for the inspection and permeance or color next it should be chemically inert it is not react with the surface that you are examining it should also it should not be toxic it has not evaporate quickly.

So it should have slow drying property then it should be easy to remove and it to not have any offensive smell so it should be as far as possible order less and for the sake of economics it should be low cost and so these are the primary requirements for a liquid to be used as a penitent in this method okay so I think in this class I will stop here today and in the next class we will see the other steps of this method and then finally we will see how the defects and discontinuities are made visible and you get feasible indications by this particular process okay so I will stop here today thank you for your attention.

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