NPTEL

NPTEL ONLINE COURSE

NPTEL Online Certification Course (NOC)

NPTEL

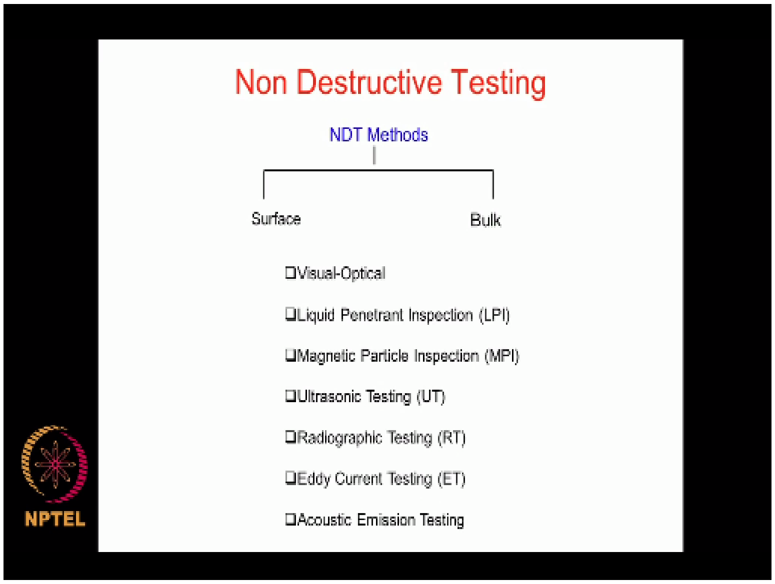
Theory and Practice of Non Destructive Testing

Dr. Ranjit Bauri
Dept. of Metallurgical & Materials Engineering
IIT Madras, Chennai 600 036

PENETRANT TESTING – PART 1

Hello and welcome back to this lecture series on non-destructive testing which is being offered under NPTEL online certification 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.

(Refer Slide Time: 01:01)

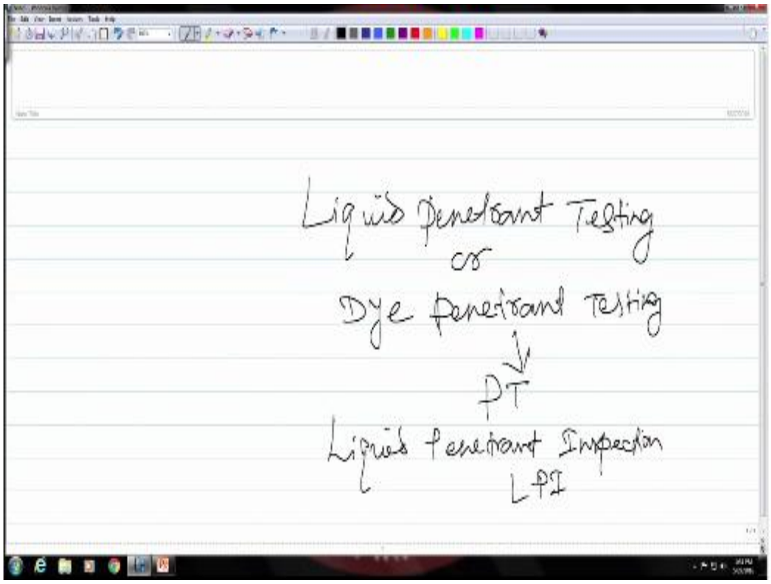


So, we have discussed the first one, visual optical in the last lecture and as I said, if you want to see and inspect what lies beneath, then you need to use one of these NDT methods, which are listed here. Some of these will come under the category of surface NDT method and some of these will fall under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

And there are certain techniques, for example ultrasonic, which 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 NDT methods one at a time and then first learn about the basic principle behind the technique 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.

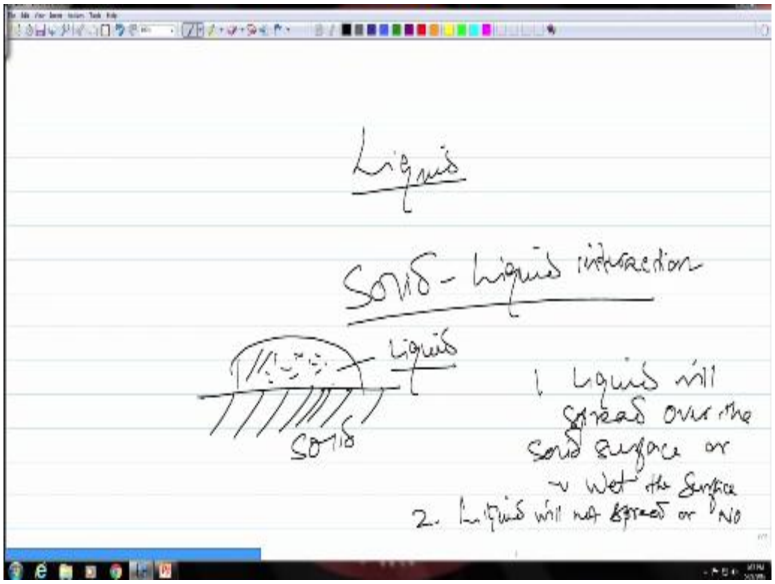
So, I will pick one by one and then we will discuss in more details. So, in the today's lecture we are going to pick up the first topic in this list, which is on liquid penetrant testing. So, this will be our first lecture as far as the NDT methods are concerned.

(Refer Slide Time: 02:50)



So, this will be on liquid penetrant testing or sometimes people 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 penetrant inspection or LPI in short. So, these are the names of the same technique which is the liquid penetrant testing or penetrant testing. 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 so on.

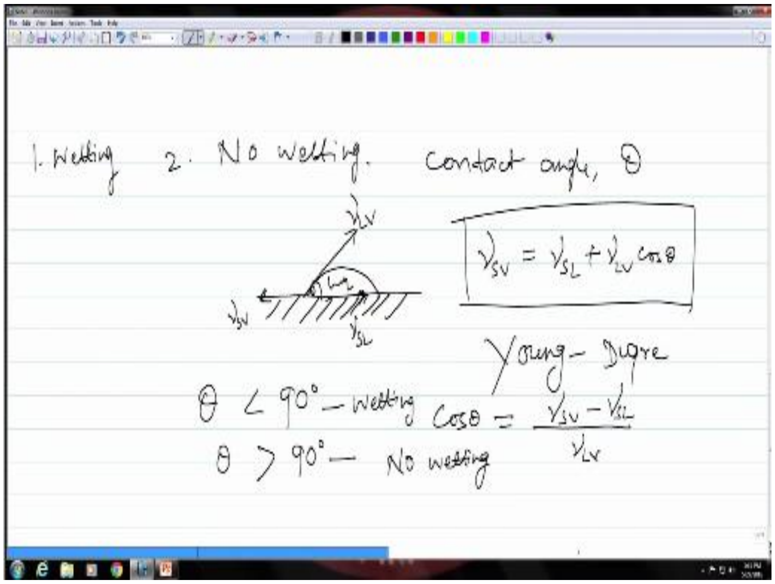
(Refer Slide Time: 04:19)



So, you have a liquid and you need to inspect a component, a solid surface. 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 this liquid does or how this liquid interacts with the solid surface.

So, that means you need to talk about solid liquid interaction. That means, let us say if I have a solid surface and then I put a liquid over this. 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 wet the solid surface and the second possibility will be, the liquid will not spread or it will not wet. So, there will be no wetting.

(Refer Slide Time: 06:49)



So, two cases; one is, wetting and the second is, no wetting. So, whether the liquid will wet the solid surface or not that would depend on a parameter, which is known as contact angle. Let us call this as θ. So, let us say, this is my solid surface and over this I have liquid droplet, like this. So, as I said, whether wetting will happen or not, this will depend on the surface energies and 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 $\gamma_{liquid\ vapour}$.

So, this is the surface tension of the liquid. Then, you have this particular interface over here. 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, which is the interface between the solid and the vapor. So, you have $\gamma_{solid\ vapour}$ and this is the angle which is known as the contact angle. Now, if you take the balance of forces γ_{SV} is being balanced by $\gamma_{SL} + \gamma_{LV}\ cos\theta$, i.e.,

$$\gamma_{SV} = \gamma_{SL} + \gamma_{LV}\ cos\theta$$

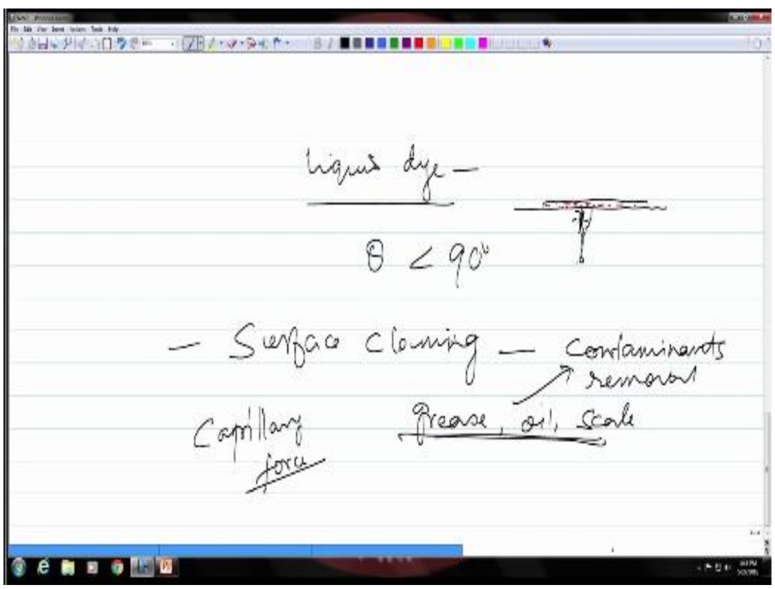
So, this is the well known Young's equation or Young Dupre equation, which talks about contact angle between a solid surface and liquid. And depending on this, you can derive the contact angle from this equation as,

$$cos\theta = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$$

Now, depending on whether $\theta < 90°$ or $\theta > 90°$, the liquid will either spread or not spread. So, if $\theta < 90°$, then the liquid will wet the solid surface and if $\theta > 90°$, the liquid will not spread or will not wet the solid surface.

So, this is the parameter, contact angle, θ, which decides whether a liquid will spread over a solid surface or whether it will not. Now, how does this connect to liquid penetrant testing, let us go ahead and see that.

(Refer Slide Time: 10:53)



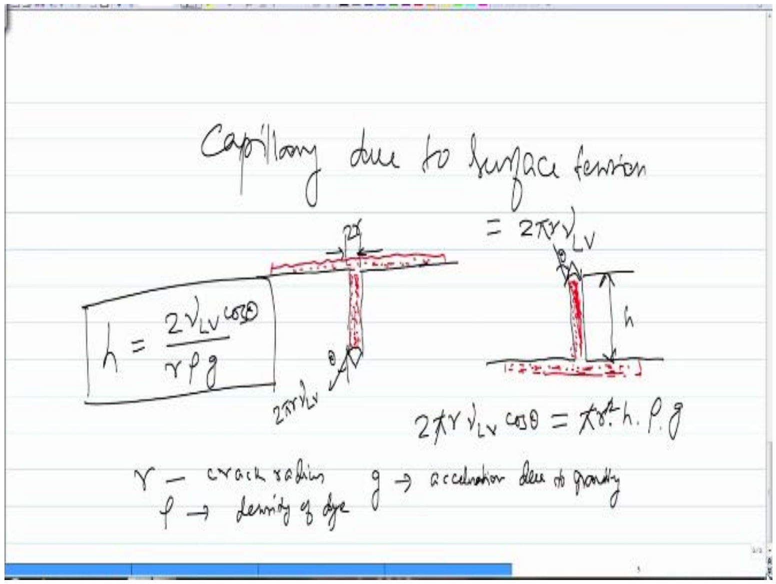
So, as I said, you use a liquid dye which is generally a color dye, most of the time a red color, is used and you take this liquid dye and then you spread it. You apply it on the solid surface. So, for this dye to be spread over the solid surface of the component that you are examining, this contact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

So, you need to clean the surface of all the contaminants and remove them. So, these contaminants could be anything like grease, oil or scale which might have formed on the surface. 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 will spread over the solid surface.

So, depending on whether you have a solid surface with defect or without defect, this liquid will spread over the surface. Now, let us say, you have some kind of discontinuity. Let us say a crack or some other discontinuity over here, on the surface. So, this crack has a crack surface. So, here you have a surface on both the sides of the crack, so that means you have a surface energy involved over there.

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. So, that means if you spread a liquid on a solid surface and if that surface has some kind of small opening or fissure, 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.

(Refer Slide Time: 14:49)



So, the capillary force due to surface tension γ_{LV} for a crack. So, let us say, this is a solid surface and I have an opening, a discontinuity. So, let us say the crack size is r. So, crack radius is r. So, this diameter is $2r$. This 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. Now, you can apply the liquid either through top and if the liquid is spread, if the solid surface is wetted 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.

So, this is the capillary force, $2\pi r\gamma_{LV}$, 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. 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, $2\pi r\gamma_{LV}$.

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,

$$2\pi r\gamma_{LV} cos\theta$$

which is supporting the liquid head or the weight of the liquid. So, the weight of the liquid is,

$$2\pi r\gamma_{LV} cos\theta = \pi r^2 h\rho g$$

given the crack size as r or the radius of the crack as r and let us say, this height or this depth is h. So, this is the volume, $\pi r^2 h$, then the density, ρ, multiplied by the gravity, g.

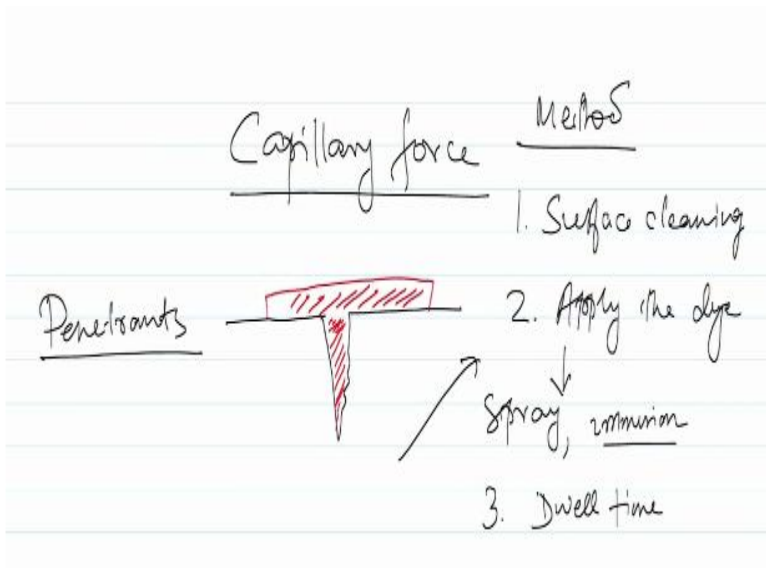
So, r is the crack size, ρ is the density of the dye or density of the liquid and g is acceleration due to gravity or gravity and h is the depth of penetration. So, from here, you would be able to derive that, up to what depth the liquid can penetrate, depending on the size of the crack and the density of the dye.

So, if you see from here, this will be your h. So, h is equal to,

$$h = \frac{2\gamma_{LV} cos\theta}{r\rho g}$$

So, as you could see, it primarily depends on the properties of the liquid dye that is the surface tension of the liquid γ_{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. So, this gives you an idea that for a particular crack size or a particular dye, what could be the depth up to which you can go and inspect. So, this is the basis for this particular method of dye penetrant testing.

(Refer Slide Time: 21:22)



So, the basis for this is the capillary force which develops due to the surface tension. 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. So, now as you have seen, you have applied this dye. As I said, it is generally red in color and it has gone inside the crack. 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. So, the whole surface will be covered by this red color dye and if there is any discontinuity, any flaw or defect, this dye will be sucked inside by the capillary force.

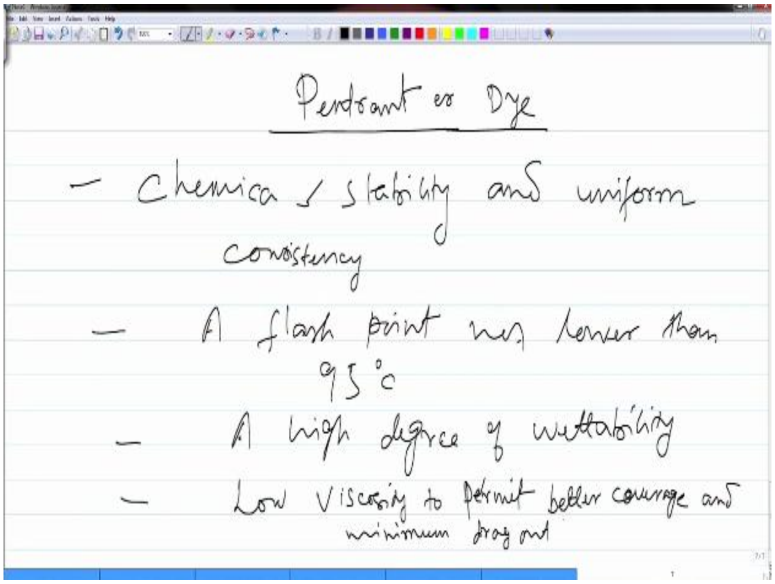
So, now that we have understood the basic principle, we can go to the method and see how exactly it is done. So, the first step is surface cleaning or surface preparation. This is to ensure that your surface is clean and the contact angle is less than 90 degree, so that the liquid dye can spread over the surface. Second, you apply the dye.

So, this is what is being shown in the diagram. So, you take this dye and it goes inside. So, in this case, you could either apply it through spray, or it is also possible to apply by immersing it in a tank, which contains the dye. So, either way depending on the size of the part or the convenience of the examiner both the method can be used.

Now, the next thing is, you need to allow some dwell time, because this liquid dye will have a certain viscosity, although it does not come into that equation, which we just now talked about. But, 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 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, what kind of defect size you are expecting in the part? So, this dwell time will ensure that you have enough time for the liquid to go inside the flaws. Now, this liquid will be now spread over the solid surface. But before that, let us see what kinds of pentrants are used and what properties this pentrants should have?

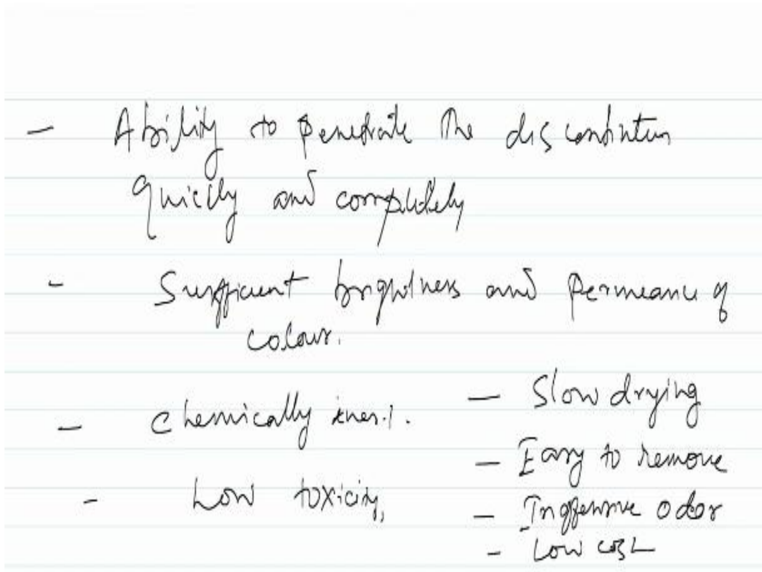
(Refer Slide Time: 26:00)



So, the first characteristics or property of this liquid is that, it should be chemically stable 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. Then, it should have a flash point, which should not be lower than 95 degree Celsius. So, it is close to 100 degrees that means it is not a flammable liquid. You should be able to handle it properly without the hazards of fire and all that.

And it should provide a high degree of wettability. As I told before, this wettability is the first requirement for this dye penetrant testing. So, you should have a liquid which will provide a higher degree of wettability, provided your surface is 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 in terms of the dwell time. And it will also provide you a minimum drag out.

(Refer Slide Time: 28:45)



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 and permeance of color. Next, it should be chemically inert. It should not react with the surface that you are examining. It should not be toxic. It should not evaporate quickly.

So, it should have slow drying property. Then, it should be easy to remove and it should not have any offensive smell. So, it should be, as far as possible, odour less and for the sake of economics, it should be low cost. So, these are the primary requirements for a liquid to be used as a penetrant in this method. 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. So, I will stop here today. Thank you for your attention.

IIT Madras Production

Funded by

Department of Higher Education

Ministry of Human Resource Development

Government of India

www.nptel.ac.in