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**Theory and Practice of
Non Destructive Testing**

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PENETRANT TESTING –PART 2

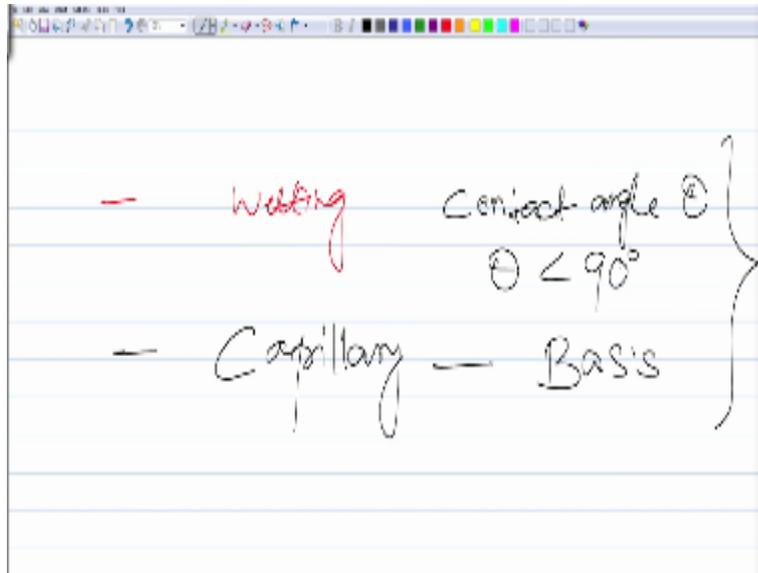
Hello, welcome back to this lecture series on NDT. This is the third lecture. In the last class we just started our first topic on NDT, which was on dye penetrant testing and in that we discussed about the basic principle of this particular method. And then, we saw, what is the basis for this particular technique. So, we will quickly take a recap of last class, what we did and then, we will proceed.

But before that, I should tell you that this penetrant testing is one of the earliest methods to be used as an NDT technique and it was perhaps used for the first time by the railways for inspecting their rails and wheels. So, what they used to do for inspecting their wheels, they used to take some kind of oil in a big tank in which they can immerse their wheels.

So, they will immerse the wheel in that tank which contains the oil and allow sometime to soak it and then after some time, they will take it out and after that they will apply chalk dust on the surface after soaking it in the oil. Chalk dust, either dry chalk dust or some kind of suspension of chalk dust, in some volatile liquid. So, this chalk dust, what it will do, if there is any crack or any such discontinuity, it will suck out or it will suck out the liquid from the cracks and it will make some kind of visible indications. So, in this form the railways used to apply this particular technique for inspecting their rails and wheels to find out any defect.

So, over the years it has been improvised and today we have it in the current form and that is what we have been talking about in the last class and in today's class also we are going to continue on that.

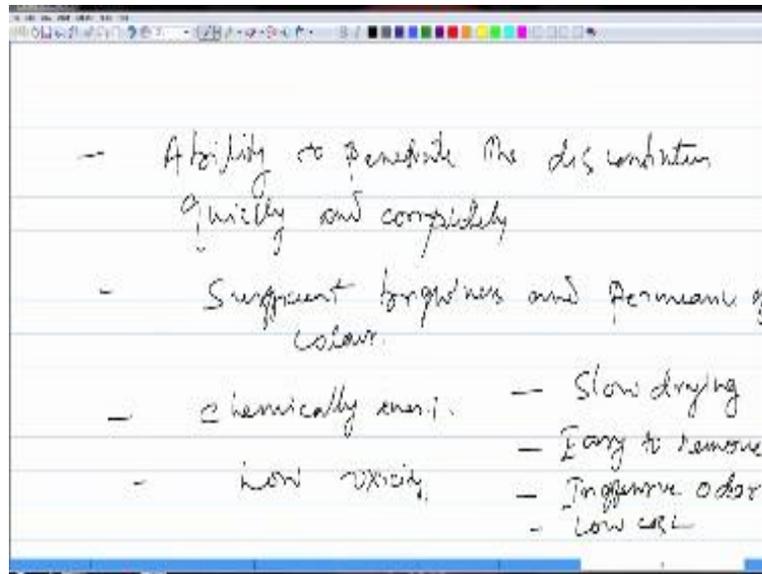
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So, let's take a quick recap as to what we learned in the last class. So, what I said for this particular method is that first you need to have wetting. So, you are having this liquid dye. You are applying on a solid surface, so it should spread over the surface and wet the surface. So, that is the first requirement and for this the main parameter which controls this is the contact angle θ and for wetting to happen, $\theta < 90^\circ$.

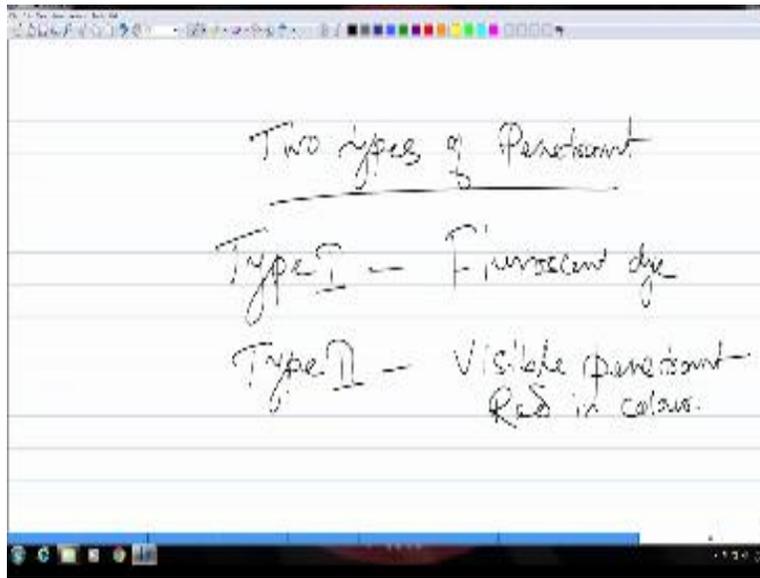
Now, the next thing we saw was the basis or the driving force behind penetrant testing is capillary, which is developed due to the surface energy or surface tension of the liquid. The capillary is the main driving force behind dye penetrant testing. So, let us continue on this and I have also talked about the kind of liquid which is used.

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That is the properties of the dye which can be used as a liquid penetrant in this case. So, these are the typical properties that you need in a dye for it to be used as a penetrant in dye penetrant testing.

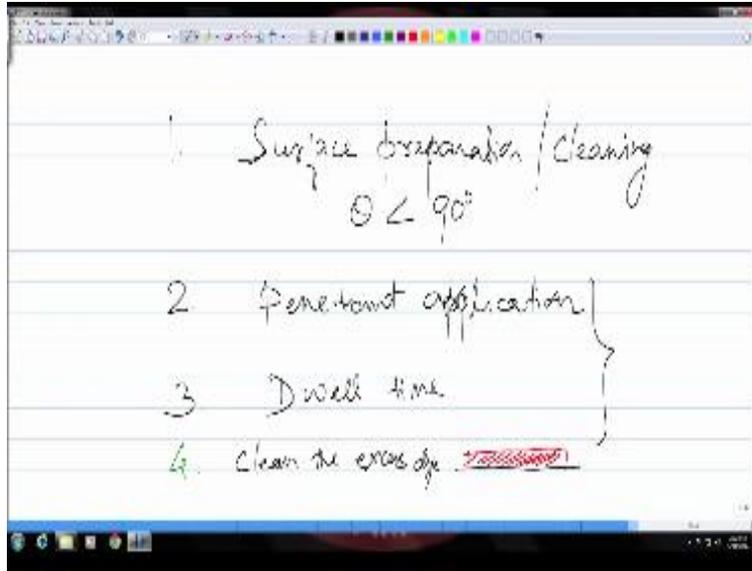
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So, continuing on that there are two types of dyes. The first one is type 1. These are just known as type 1 and type 2. Type 2 is the normal visible dye which is normally red in color and this is what most of the time we use and type 1 is sometime used based on the requirement. This is a fluorescent dye. So, sometime you may want to use a fluorescent dye but in that case you need to do the final inspection under UV light in a dark room.

This fluorescent dye will fluoresce and if there are any cracks or defects they will make visible indication and they will also glow because you are using a fluorescent dye. So, sometimes this kind of fluorescent dye is also used. So, these are the two different types of penetrant which are in use. As I said is the visible red colored. I now coming back to this method.

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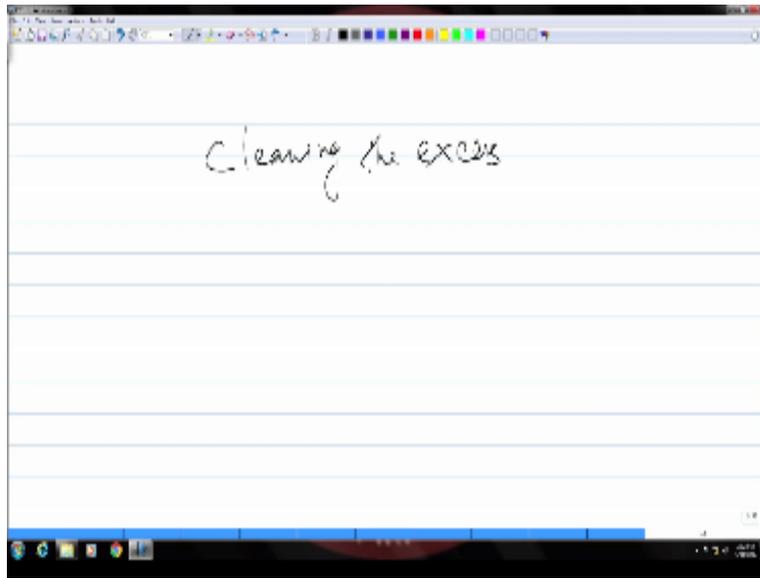


If you see the different step, the first one; is surface preparation or surface cleaning and this is to ensure that, $\theta < 90^\circ$, so you clean the surface, remove all the grease, oil, dust or any scale which might have found on the surface and keep it clean, so that it provides a contact angle which is less than 90 degree and in that case the liquid will nicely spread over the surface, second is; penetrant application. So, you apply the penetrant after the surface is cleaned.

And then third is; dwell time. So, you have to allow some time for the liquid to go inside the flaws, if there are any and this dwell time will depend on the part size or the kind of flaws you have, the size of the flaws and so on. So, you have to allow some time for the liquid to go inside the flaws.

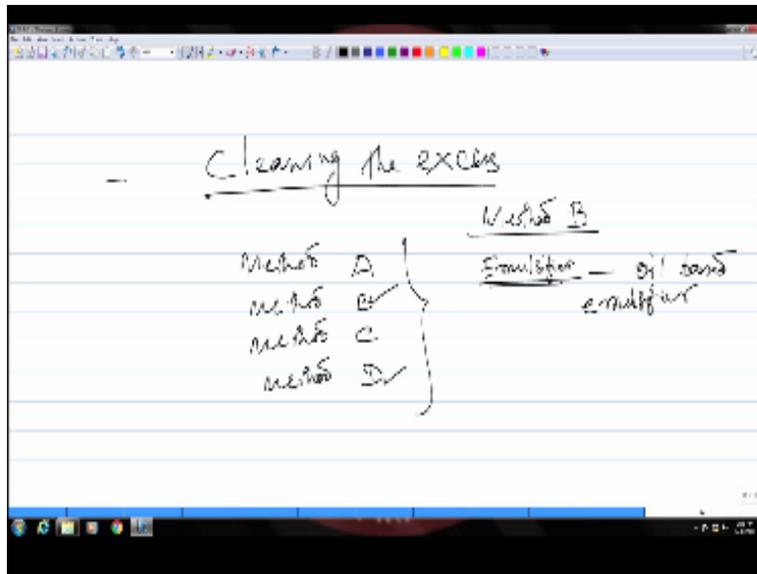
Now, once you have done this two, you have a part, the surface of which is completely covered by a red color liquid. So, this red dye is now all over the place and if there are flaws, it might have gone inside the flaws also. But now the surface will look red because the dye has spread over the surface. So, that means at this point you cannot start the inspection unless you clean the excess dye which is spread over the surface. That means the next step would be to clean the excess dye.

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And this may be bit tricky because you need to ensure that you clean the surface. In fact the surface should go back to the condition as it was in the beginning. But at the same time you need to ensure that if there are any flaws and if the liquid has gone inside those flaws. You have to be careful not to remove the liquid dye from the defects. So, that is why it could be tricky and you should do it carefully.

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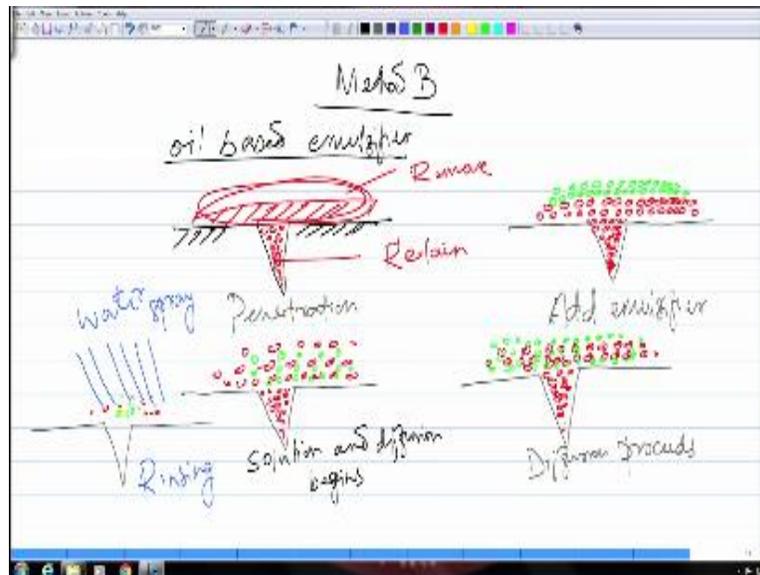
And that is why a particular process is recommended for this that you need to follow. A particular method to clean the excess dye and these methods are given some names like in terms of four letters, Method A, method B, method C and method D. So, these are the four methods of cleaning the excess dye and these methods are well established and you need to follow them. As I told you, this could be tricky and you need to take care, you need to do it carefully.

So, let us have a look what these methods are and how they are done. First, we will pick these two (Method B and Method D) because these involves a particular mechanism. So, in cleaning the dye if it is already not water washable and that could be the case many times that the dye itself is not water washable. So, you need to render this dye. You need to make this dye water washable, so that you could easily clean it by a water rinse.

So, you can rinse it with water. You can apply water spray carefully and you can clean the entire surface. So, the purpose of following this method B or method D is to make the dye water washable, so that it can be removed by washing. So, in that case you need to use an emulsifier which will emulsify the dye as it gets mixed with the dye and once it is emulsified then it can be easily removed by water, so it becomes water washable, once it is emulsified.

So, in case of method B, this is an oil-based emulsifier and let us see how does it work? When you apply this emulsifier on the surface, which is completely covered by the dye, so it works by a particular mechanism, so let us see that.

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So, this uses an oil-based emulsifier. So, let us say there is a crack like this and this is your solid surface. So, once you apply the dye, so it will spread over the surface and it will also go inside the crack due to the capillary force, as we have already discussed. So, you need to ensure that this particular part which is on the surface, this has to be removed and the dye which is inside the flaws that has to be retained and that is where you need to be careful.

So, this is in the beginning, where the entire surface is covered by the liquid dye and now we are taking the help of an emulsifier to make it water washable and then, you are going to clean it with the water spray. So, now we have applied this emulsifier also. So, these are the dye molecules. We will indicate them by red color and now you have used an oil-based emulsifier. So, we will indicate the molecules of the emulsifier by a different color.

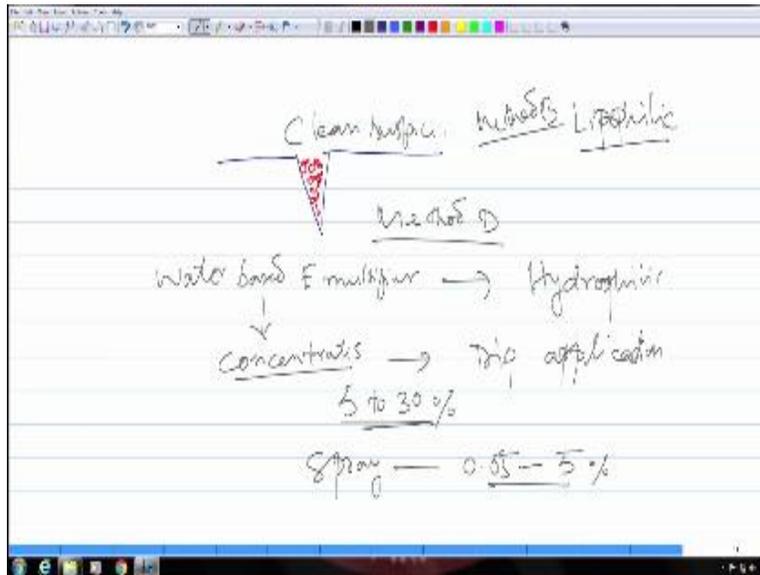
So, let us say this green color is the emulsifier. So, you have applied it on the surface. So, if you see the steps in this case. So, the first one is; dye penetration. The dye has penetrated inside the flaw. Then you add the emulsifier and then allow the emulsifier to act. So, let us see what happens after that. So, in case of an oil-based emulsifier, which is method B, the emulsifier is going to diffuse and get mixed with the dye. So, that means, in between these dye molecules now you have these emulsifier molecules also. So, they are diffusing into the dye molecules and getting mixed.

So, that means, once we apply that the solution of the emulsifier with the dye begins. The solution and diffusion begins at this step. So, this will continue further because finally you need to make this dye emulsify able. You have to emulsify it and then you can wash it by water. So, the diffusion will proceed as you allow some more time, so that means more and more emulsifier molecules will be mixed with the dye molecules.

But remember all that should happen on the surface but not inside the flaws, so you have more and more emulsifier molecules being mixed with the dye molecules. So, this will be called as diffusion process. And then, once there is enough mixing between this emulsifier and the dye, then the dye itself will be emulsified and then it becomes water washable. So, then next, you need to wash it with water so you can apply water spray and rinse it.

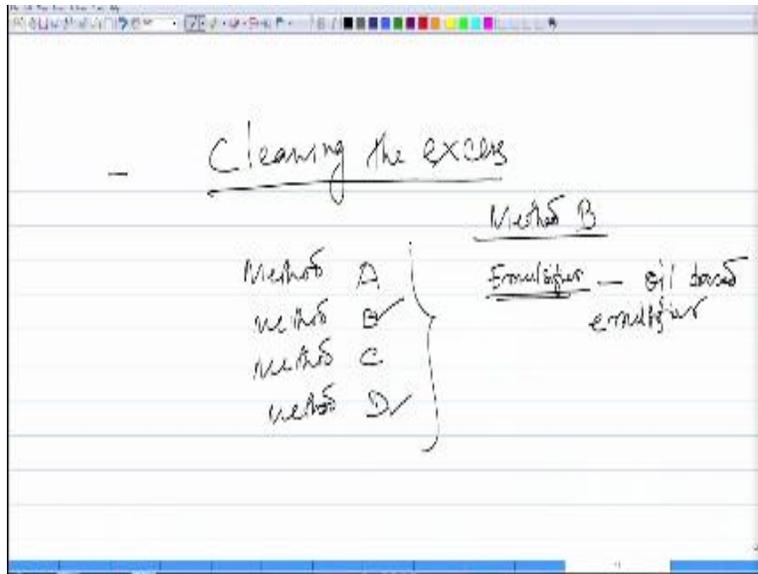
So, now that everything is mixed, you now rinse it with water. So, that you can do by using a water spray or a water gun because now the dye has become water soluble because it is emulsified. And once you do this, after this particular step of rinsing with water, your surface should look exactly how it was in the beginning.

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That means the surface would be free of any dye and it should look as clean as it was in the beginning but the dye would still be inside the flaws, otherwise your purpose is lost. That is why it could be tricky as I told. So this is how it should look like at the end of the cleaning process. So, the dye is there inside the flaws but the surface looks clean.

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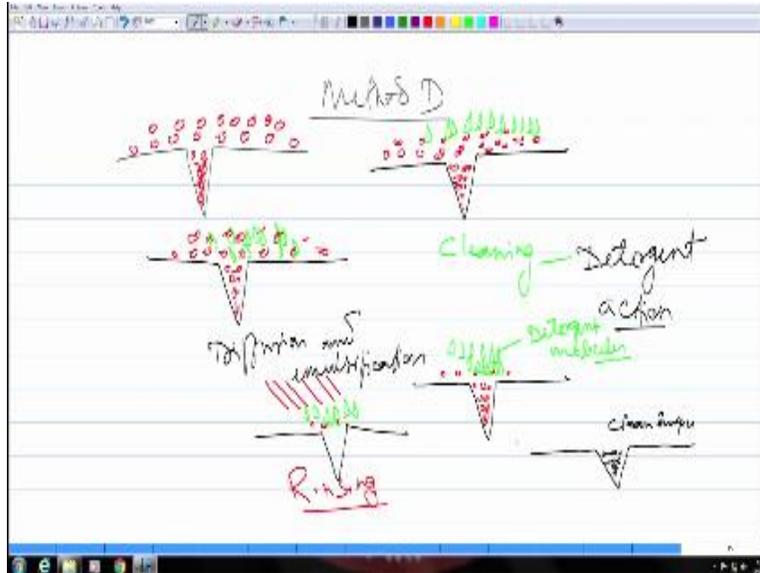


But before that let us talk about the other methods also. So, we just now talked about method B, wherein you use an oil-based emulsifier to emulsify that excess dye and clean it.

Now, let us have a look at the method D. So, in case of method D, the emulsifier that you have, is water-based. So, that means this can be called as a hydrophilic and in case of method B, we saw that it is oil-based so that is why that is called lipophilic. So, this water based emulsifier as a concentrate, so you need to dilute it, depending on how you are applying it. If you are applying it by dipping the part. So, the part which is covered by the excess dye, you can take it and dip it inside this emulsifier.

So, in that case you need to use 5 to 30% of this concentrate. So, you need to dilute it up to that extent and if you are using it by spray then you can take this in the range of 0.5 to 5%. So, this is how it is used and let us see once you use it what happens, like what we saw in case of method B.

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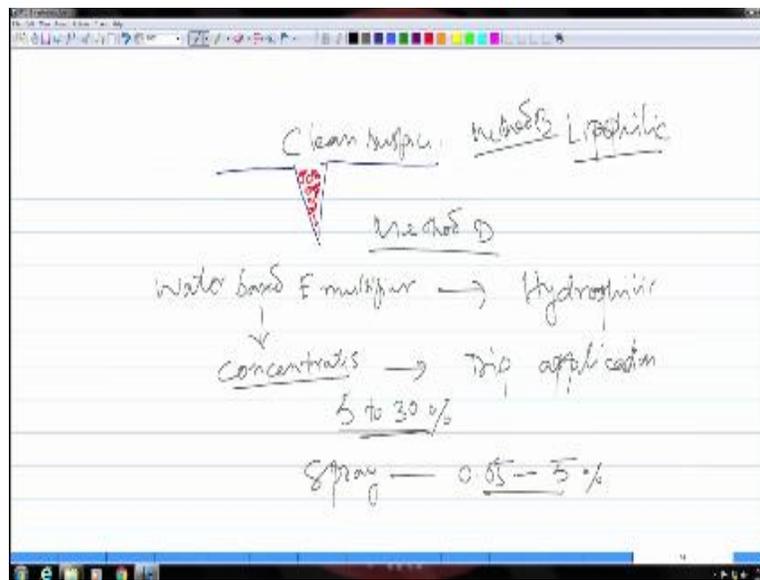
So, there again in the beginning, you have the surface covered entirely by the dye and it is there inside the defect also. Then, you apply the emulsifier so we will again indicate that with a different color. So, let us say these are the emulsifier molecules which now you have applied on the surface. So, here also the emulsification will begin. So, as you apply the emulsifier and allow some time or apply some more, then this emulsification will begin.

But in this case, this is not really like what you saw in case of method B, it was complete mixing between the dye and the emulsifier and then it becomes water washable after it is emulsified. But in this case the cleaning happens by a detergent like action. Like how a detergent remove dirt particles from a piece of cloth. So, here also the action is similar, because it is a water-based emulsifier. So, once you let this emulsification happen, then it will act like a detergent and clean the surface and remove the excess dye.

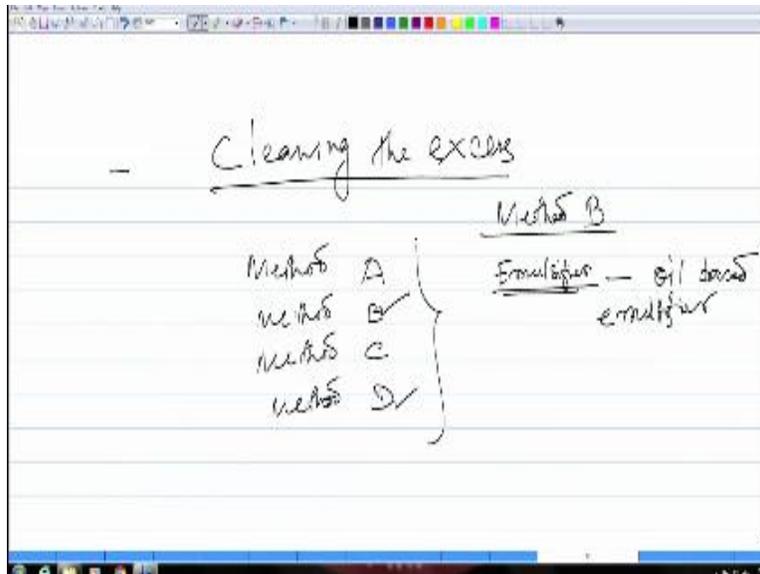
So, that means as you proceed, you will have layers of dye molecules on the surface, as these dye molecules are being removed by these detergent molecules. These are the emulsifier molecules, so this will act like a detergent kind of action. So, once this happens, then now you can use a water rinse to clean the entire surface like what we did in case of method B. So, this is suitable for using a water spray and then clean the surface.

So, there are few emulsifier and by them the dye is emulsified. So, now we can use a water rinsing to clean the surface. And at the end of it, like the previous case, again it should go back to the initial condition. So, you should have a clean surface. And your dye would remain only inside the flaws. So, you still have the dye inside the flaws, but the surface should be entirely clean, like how it was. So, these are the two methods wherein you need to use an external emulsifier to make the dye water washable and then using a water spray you can clean the surface. But there are other two methods also.

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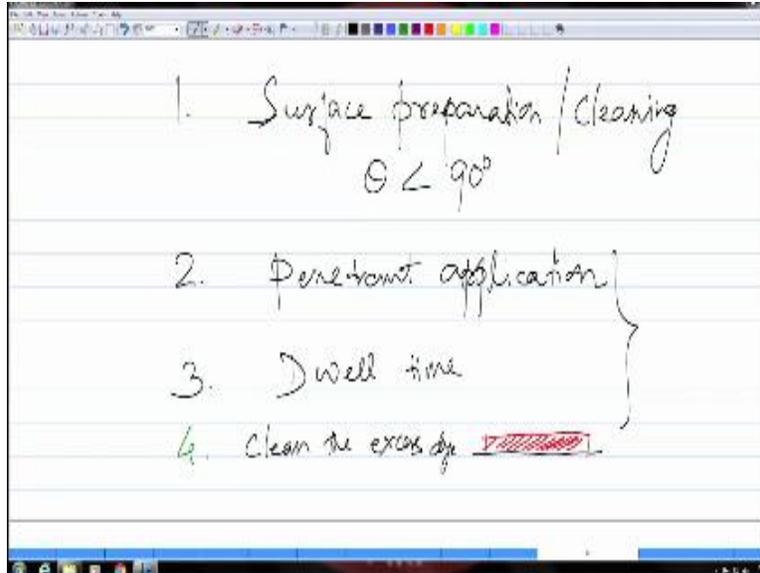
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So, this is method B and D but if you see, we have listed two other methods, which are method A and method C. Method A and method C are the simplest ones. In case of Method A, the dye itself is water washable that means this kind of dyes contain an inbuilt emulsifier. So, you can easily remove it by using water and method C is about using a solvent to remove the excess dye. If it is a small part, you can take it in a piece of cloth. Take the solvent on that and nicely rub it over the surface and clean.

If it is bigger part, you may want to use some other application process, for example, you can use a spray and things like that. And then again you clean it with a cloth or things like that. So, these are the different methods of cleaning the excess dye because before you start the inspection the surface should look like as it was in the beginning.

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So, this was the fourth step of the steps that we have in this process. So, for today I will stop here and then we will see after you clean the excess dye in the next class. We will see how these indication is made. I mean after this what is that you need to do to make visible indications of the flaws by sucking out this dye, which is inside the flaws. So, that is what we are going to do in the next class. For today, this is all I have. Thank you for your attention.

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