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Indian Institute of Technology Delhi

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National Programme on
Technology Enhanced Learning

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Video Course on
Advanced Textile Printing Technology

by

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IIT Delhi

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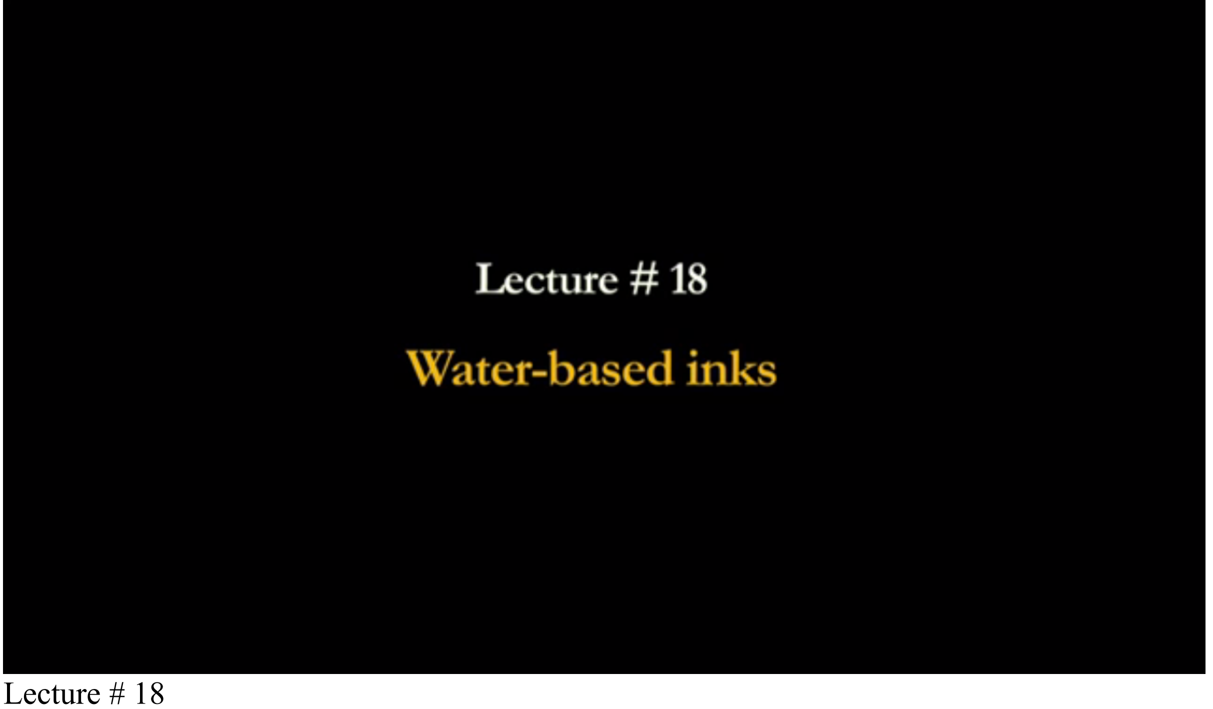

Lecture # 18
Water-based inks

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So we continue from where we had left.

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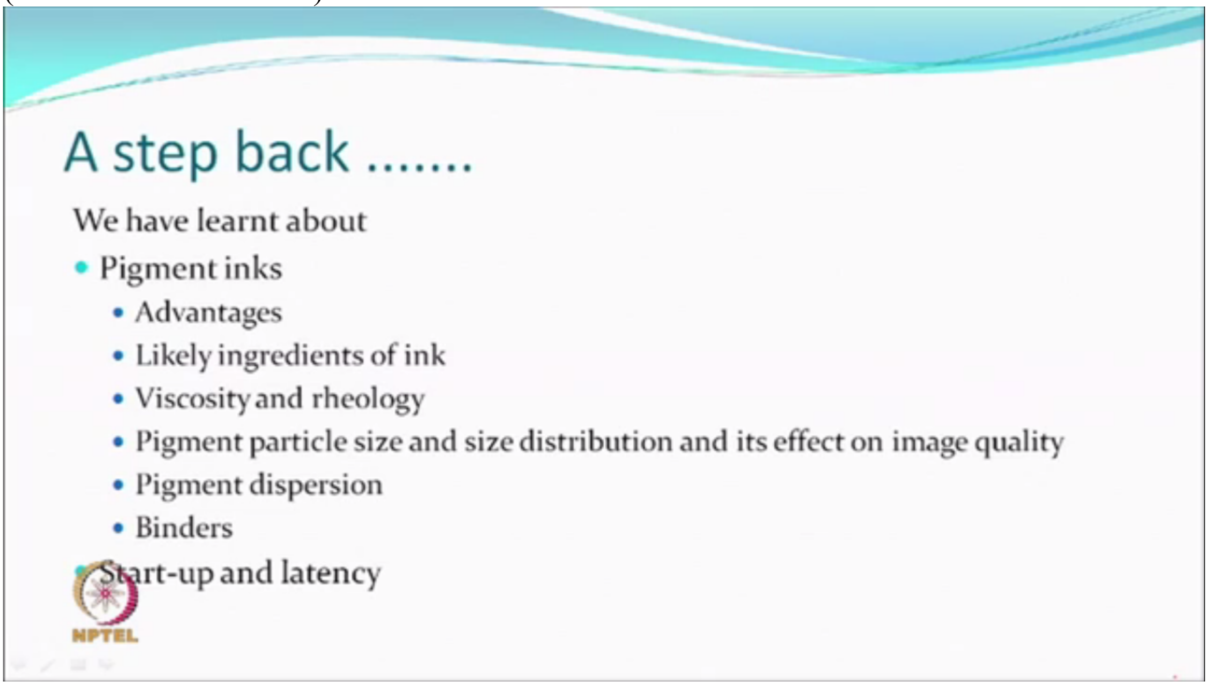

What we had done was the pigment inks and learned about their advantages, likely ingredients, viscosity, rheology, the binders that you may have to add, pigment size, size distribution, dispersions and some points about start-up of the printing process, some can be delay or latency which happens that how many times you have to jet before right quality of print comes. So that's what we learned. We'll go a little further.

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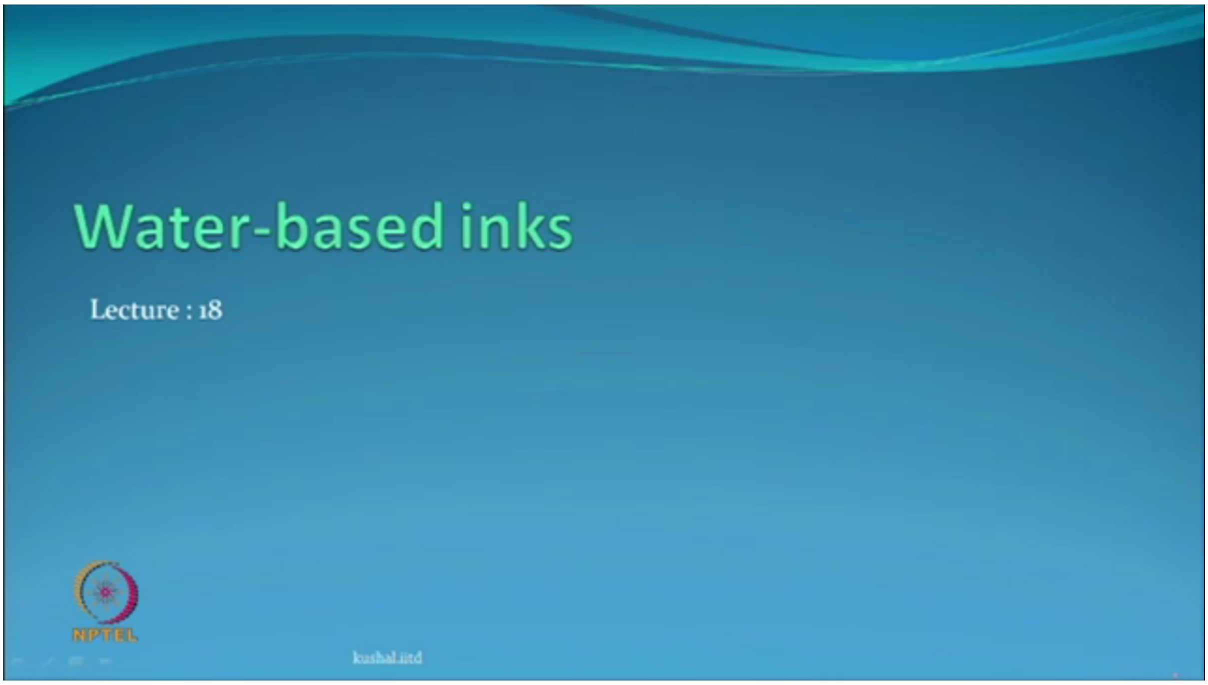

We are looking at in some way in general water-based inks. The pigment dispersion also is in a water. So the other dyes which are used for making inks generally are obviously water-based for textile.

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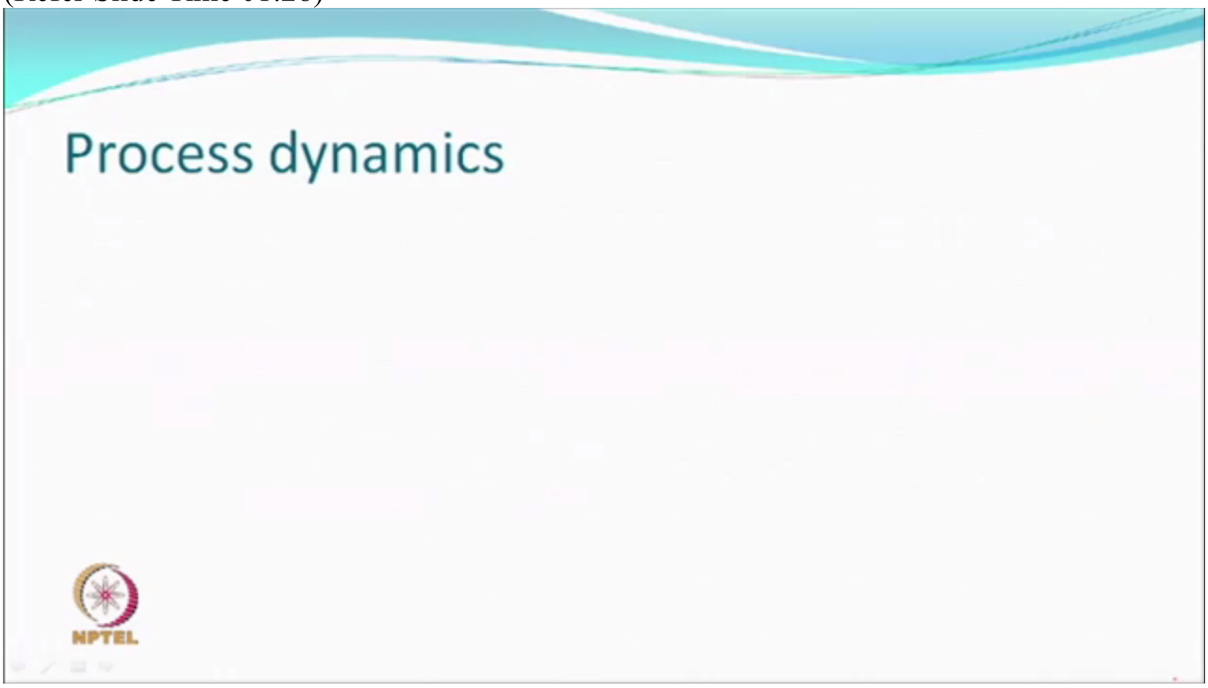

So the process dynamic means that there is an ink which is there in a reservoir. It is going to be jetted out at a certain frequency, and how do we ensure that right amount of droplet size and right amount of speed concentrations are actually jetted? That is basically a dynamics and which is controlled in some sense by what are the ingredients? How do they change their surface tension? How do they change their viscosity?

We had earlier said that we are dealing with a low viscosity system, but still in a short time, when the time sometimes could be very short, we are looking at million microseconds in which everything happens. So, therefore, even small changes are also quite important.

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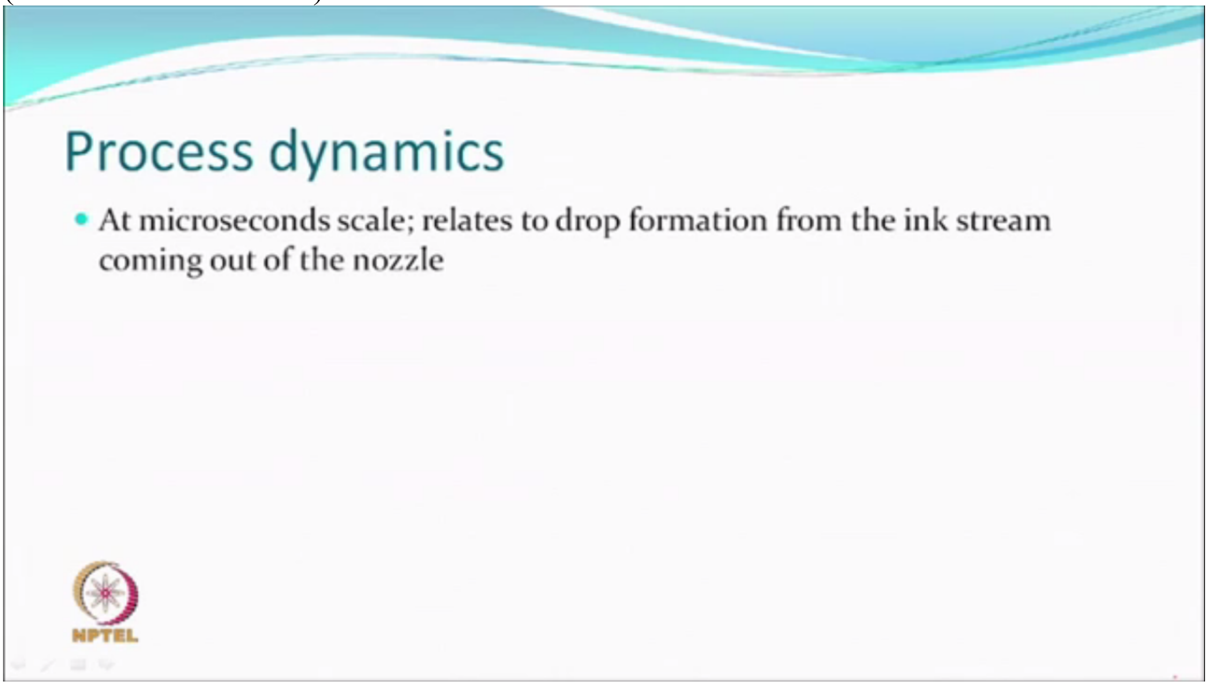

So a few things can happen at a microsecond scale, which means the drop formation itself and the stream, which comes out of the nozzle. So these are the kind of things will happen at a microsecond. That means before you think, things are over.

At the millisecond level, once the drop forms a dot on the fabric surface, so the spreading and penetration is also quite fast and rapid as long as your fabric has been prepared very well. So it is not that it takes, you're not looking at something which, which drops and looks like a drop. It is a small drop so which happens, which helps also because if more colors are being printed and the spreading keeps on taking place, one is never sure as to where it will end. So all this must finish penetration etc., in milliseconds.

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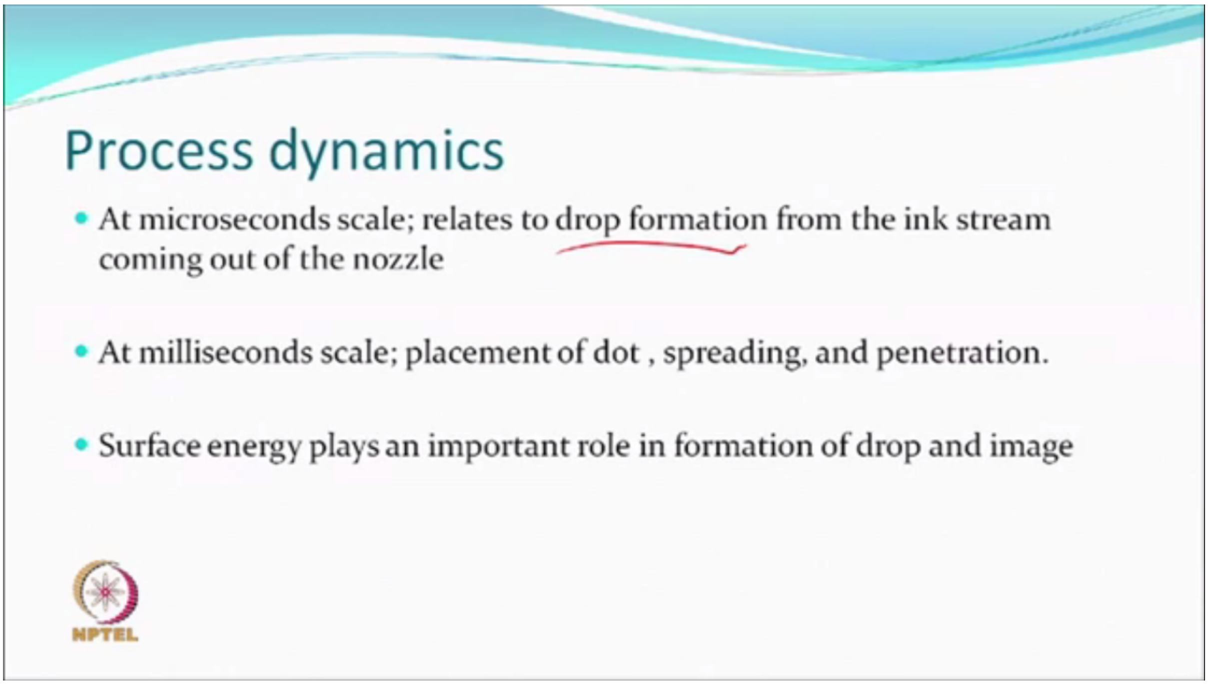

The surface energy, surface energy of the solution itself, which is related to surface tension and that can be changed by adding surface active agents or any other solvent that you add, like you dilute something. Viscosity changes, we understand, but if you add instead of the same solvent another solvent, then the energy also changes other than the viscosity can play a role in formation of a drop and an image.

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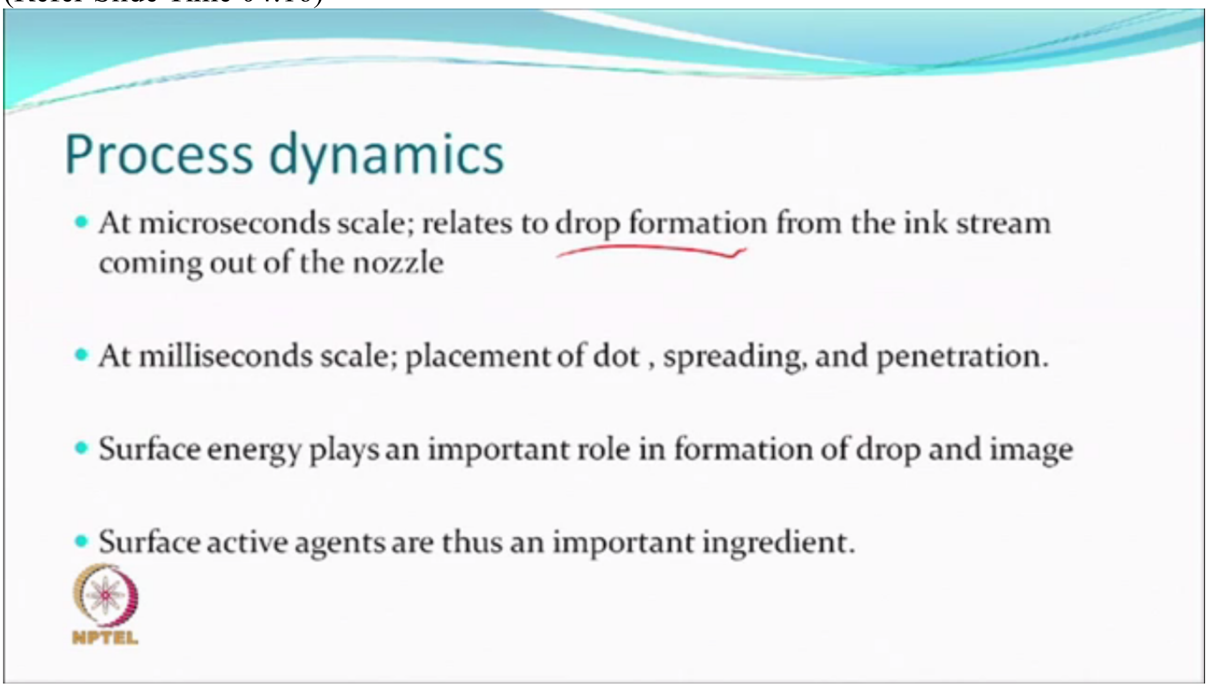

So whenever you add anything called a surface active agent, they obviously are there too in the case of let's say disperse dye to disperse, in the case of pigment to disperse, but in the case of water soluble dyes, so they would be acting to change the surface tension of the liquid and which will have wetting issues, good or bad, but they will definitely change that.

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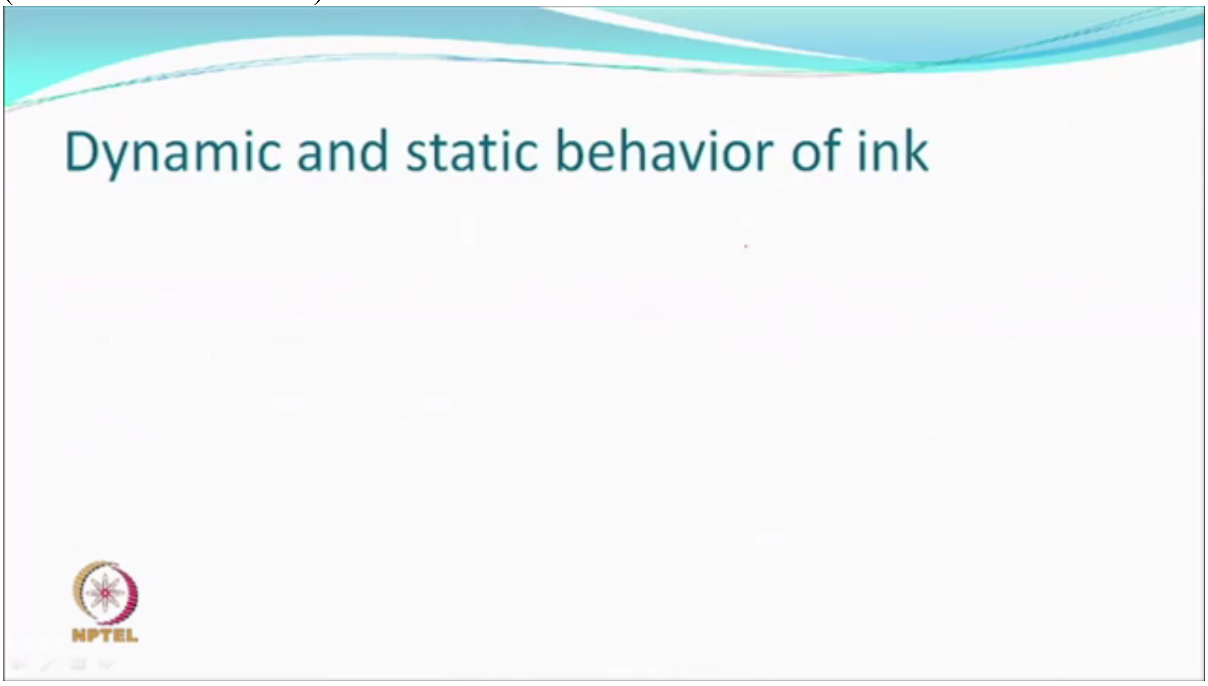

So the ink, obviously, has as we say the dynamic behavior and static behavior and this is because of various things that you add there. So what we call is that you can tune the behavior by selecting a suitable organic solvent. If it is a water-based system, water will evaporate. No issues. After the drop has been put on the fabric, it evaporates. No problem.

But when you are not printing, let's say one of the colors is not being used in that design so much or machine had been stationary, so there is a drying of the ink at the edges or the nozzle. That can become a particle, a solid material and so it can cause some issues. So organic solvents are used. So organic solvents when you add or you add anything, so the evaporation rate can be changed.

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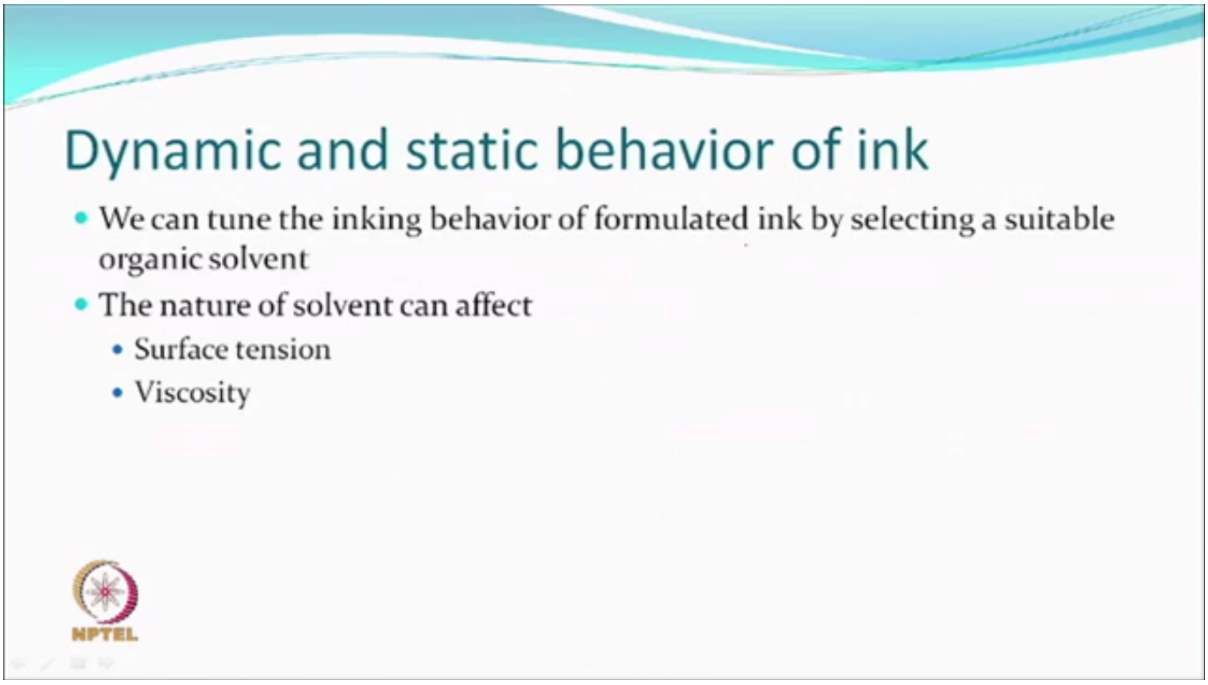

So the nature of solvent can affect the surface tension and viscosity.

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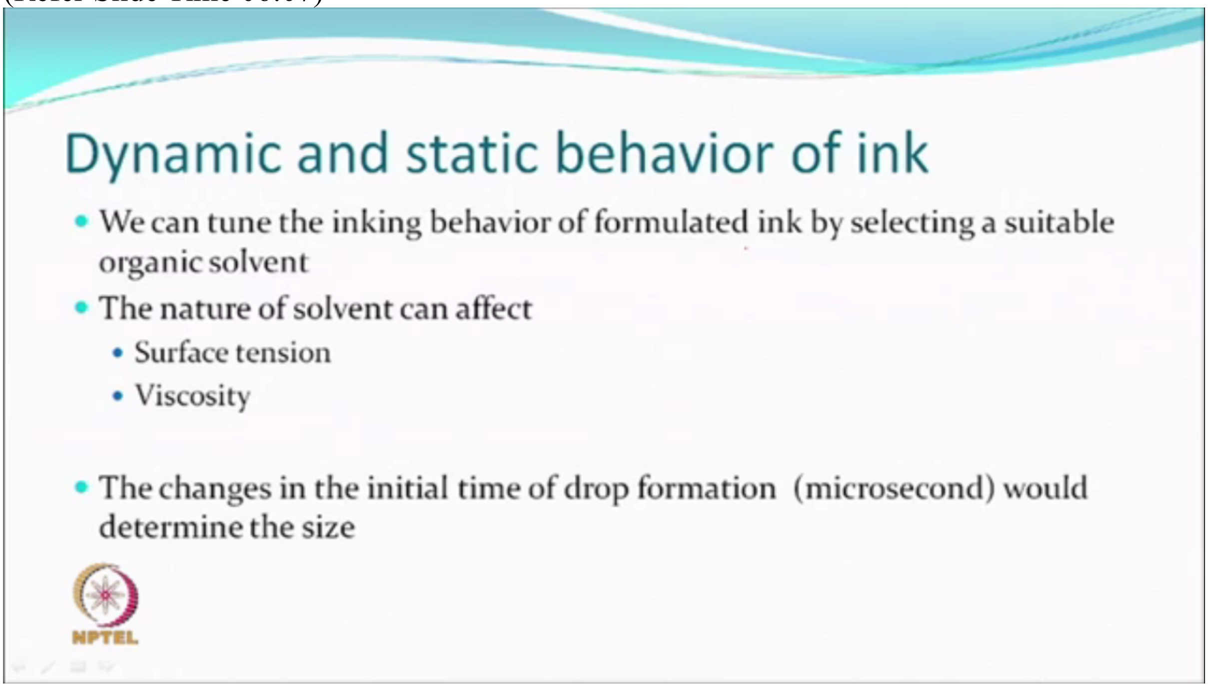

So in the initial stages of the drop formation, if these changes take place, they also determine the size. See, how fast it has come. It is not necessarily that let’s say certain amount of liquid has been displaced that it will become one drop. It may get into or divide into many drops depending upon these properties, like the same water when you spray at a faster rate, it sprays into an atomized smaller, smaller droplets.

That means how fast you work and if instead of water, if you had a thick viscous liquid, you might find it does not break into smaller part because the viscosity doesn't allow them to get separated also. So these things at -- because happening in a very short time, a small change also is important and therefore this is a specialized area of making an ink.

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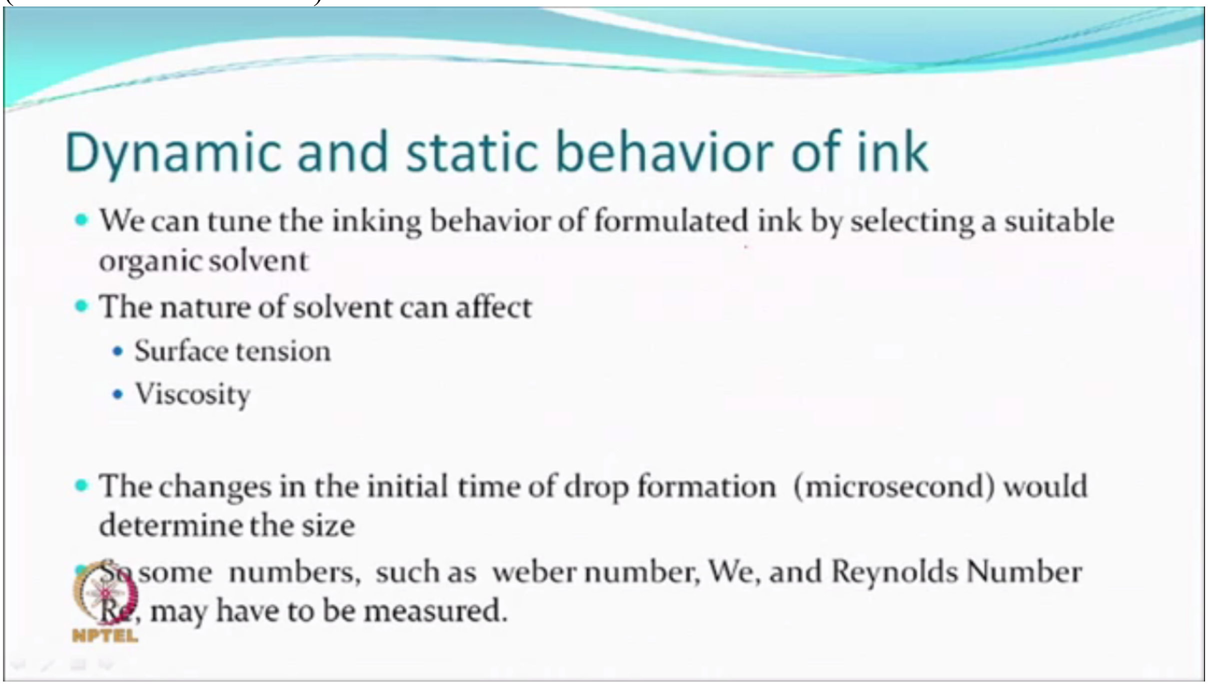

And sometimes some numbers people like to measure of this so-called dispersion or a liquid ink that you make a Weber number, W_e, or a Reynolds Number may be measured, monitored at different times. When you make the ink, these numbers may be having some values. After two months of storage, these numbers may not be the same. If it is not, then somebody will have to do think about it. That's the stability part of it.

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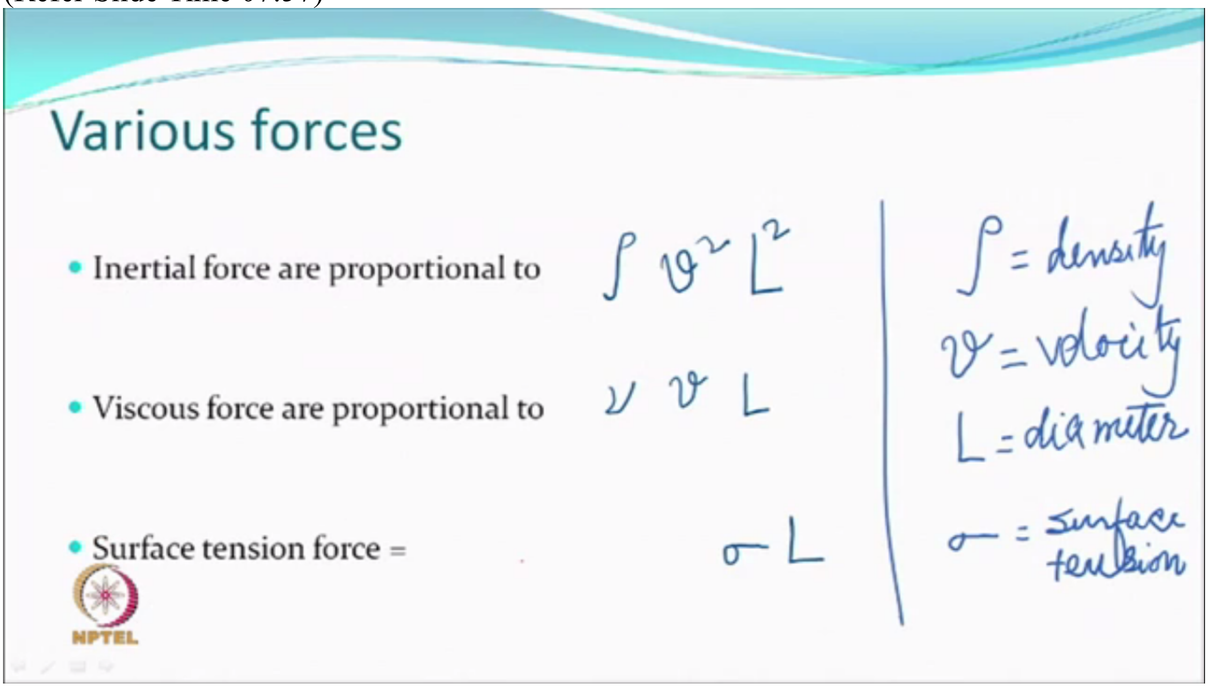

So these numbers are related to various forces. One of the force which we call is an inertial force that because of inertia you have to put pressure, like you have an actuator, which is pushing it. What are the dimensions? What is the resistance offered? All those things. So there is a (inaudible 08:19) what force are you going to be throwing out. These are related to the density of the liquid, the velocity at which the mass is being ejected and L in generally may be related to length or we can say the diameter of a drop also could be related to that.

So one is that you have the nozzle and diameter of a nozzle. Other is because of that also plus the forces that you apply, which are like the inertial forces, are going to be governed by some of these numbers. So, velocity, obviously, is to the square the power 2. The diameter also is like this and therefore the force that is generated or to be generated will be always higher.

The viscous forces are proportional to the viscosity and the velocity and the dia. Surface tension forces are to the surface tension, which is the interfacial tension, the air versus the liquid interface, and of course what is the length, diameter and so on and so forth. So they are generally everything like surface tension wants to make the drop rounder and one, the inertial forces would like to spray. So they will be acting against each other.

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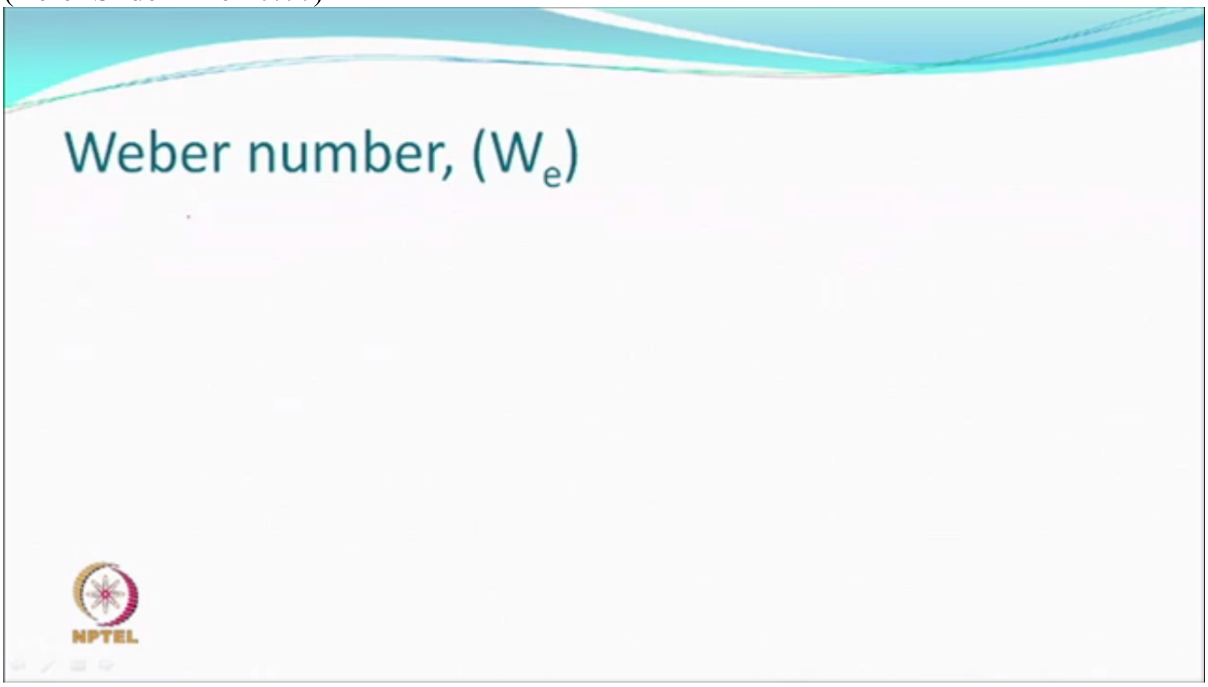

So this Weber number, it characterizes the atomizing quality of the spray and therefore the size of the droplet. It's a dimensionless number. So the units are chosen of all these in such a manner that you just get a number. So, roughly speaking, it's a ratio between the inertial forces and stabilizing forces, which are cohesive forces, like the surface tension itself. If surface tension is high, then it is difficult to separate. Right?

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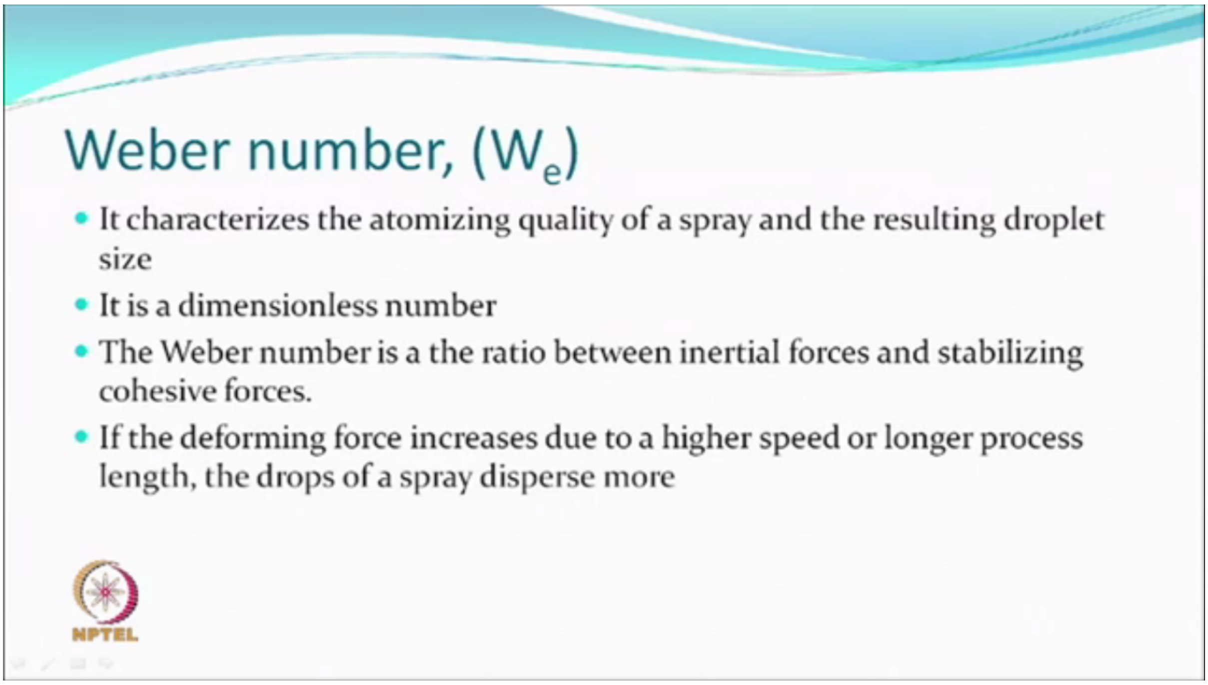

If the deforming force increases, that means you have high pressure, high frequency of the actuator. You can get a higher speed. The drops can get dispersed more. The spray will become dispersed. The droplet will disperse as it comes out of the nozzle.

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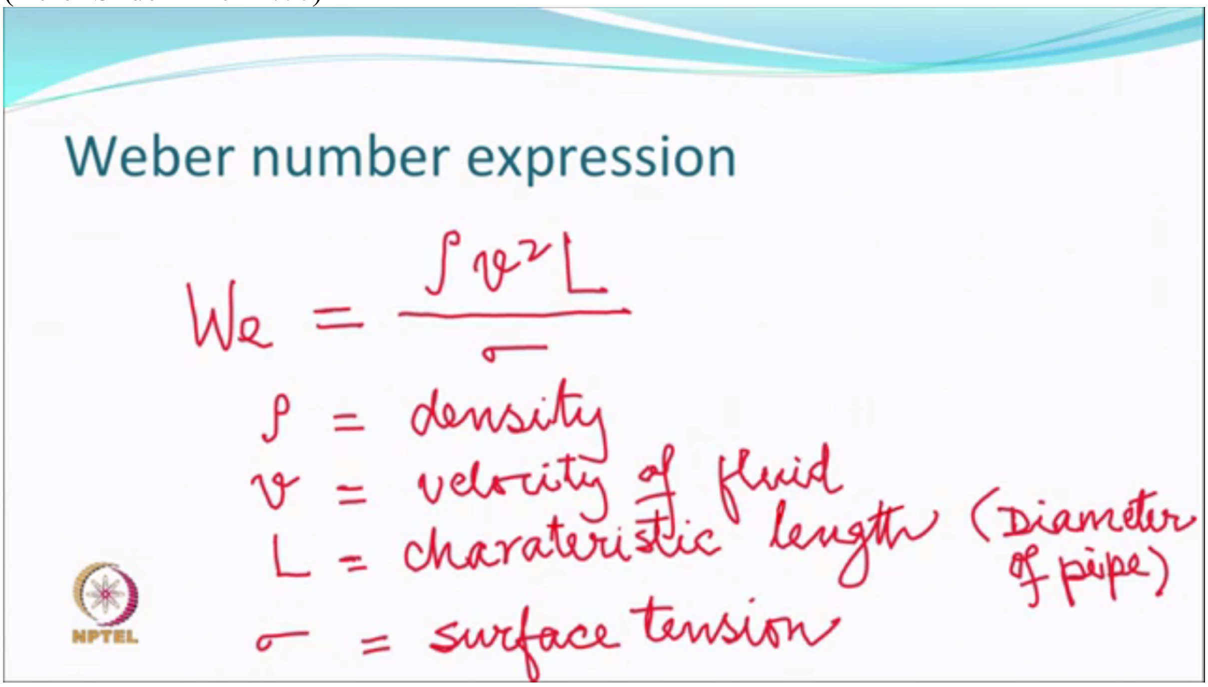

So the Weber number expression is something like this related to the density, the velocity, the dimension and also the surface tension.

The other is a Reynolds number, which is something again to do with the velocity. So this is inertial forces versus viscous forces. So it's a ratio approximately of the inertial forces and viscous forces.

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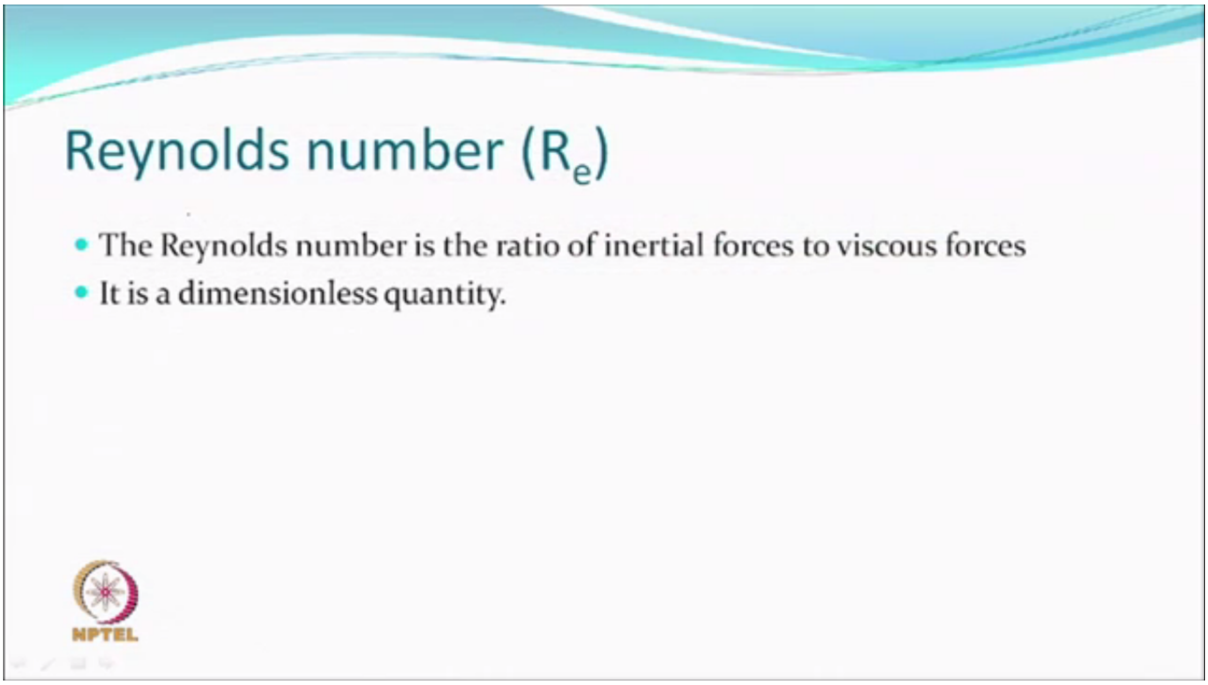

It's also a dimensionless quantity. Reynolds number if it is small, then it means that the viscous forces are dominant, and the flow will be laminar. On the other hand, if this is large, that means inertial forces dominate over the viscous forces and the flow will be turbulent.

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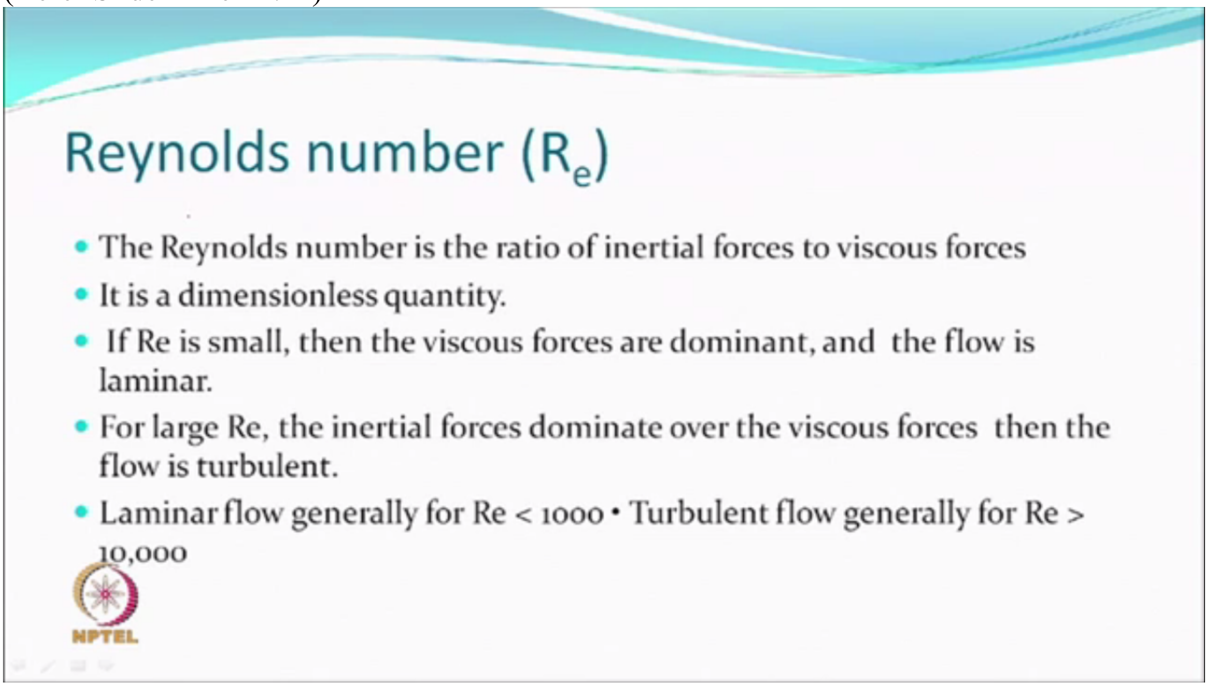

In general, if the Reynolds number is less than 1,000, one can think of the flow like a laminar, laminar flow and turbulent in case this is more than 10,000. So in between there is a gray area. It was not really a fixed line below this, above this, but definitely because it will relate with viscosities as well.

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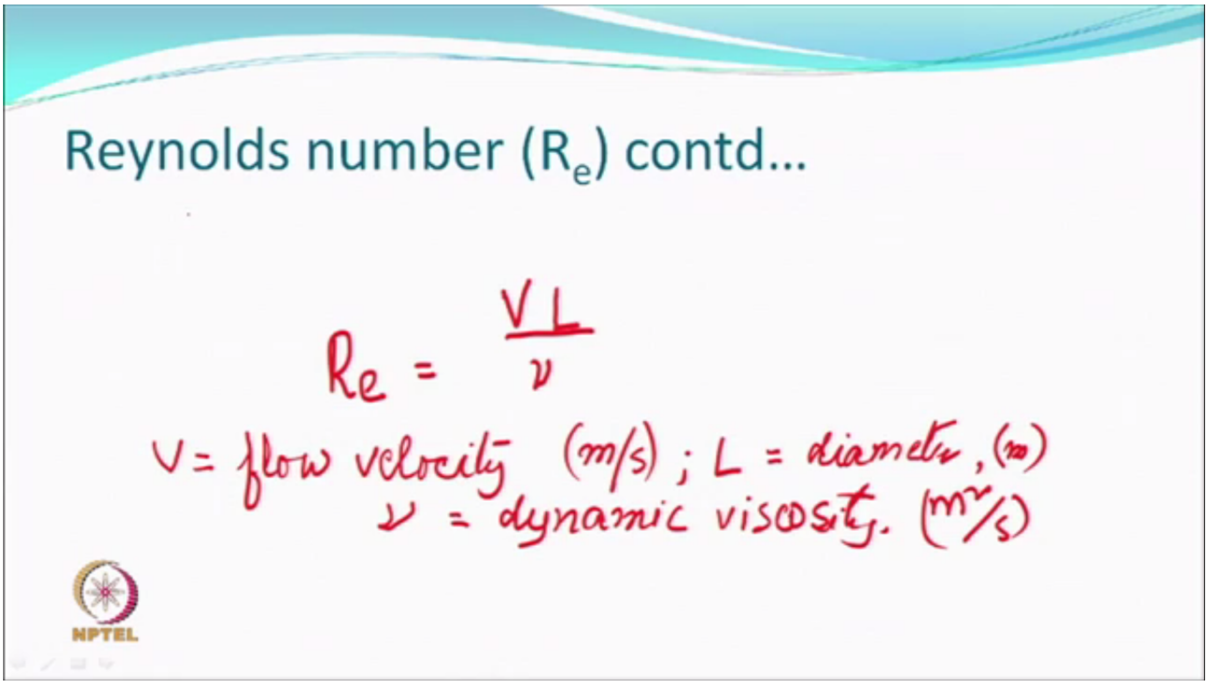

So this also is related to velocity, the diameter and viscosity. So higher is the viscosity, lower is the Reynolds number. So the thicker fluids will generally have a tendency to move in a parallel Newtonian flow type of things. The lesser is the viscosity will flow in a rapid manner. So if anything that you add to your ink changes any of these values, then the drop size, the stability of the drop, for example, when trigger has taken place, the liquid has gone out, something has become a drop or drops, then what happens to the meniscus? Does it keep dripping or it goes back? So all that has something to do with the surface tension.

So this is what in some sense determines the reliability of printing or jetting. So start-up, which is that is you start the machine and everything should come to the force, would also depend on the water-based inks, which are generally more have this issue and so reliability has to be increased.

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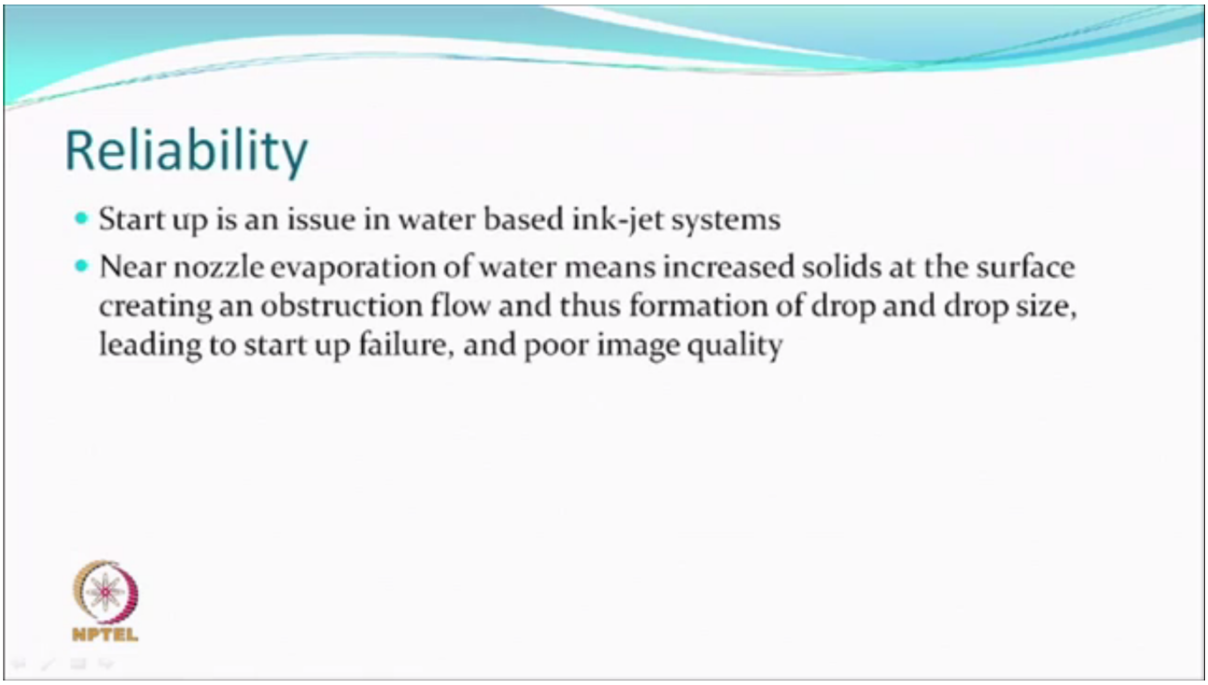

And for this, and this happens because there is a near nozzle evaporation of water, which means solids at these surfaces are going to be deposited, and so it will cause an obstruction of flow, formation of a drop and drop size leading to a start up failure, and then, of course, poor image quality. So all they are related.

So if you have a start up issue, that means ink is drying up at the nozzle. Other than, of course, you can have precipitation, coagulation of the dispersion breaking, that's a separate story, then things will be very different.

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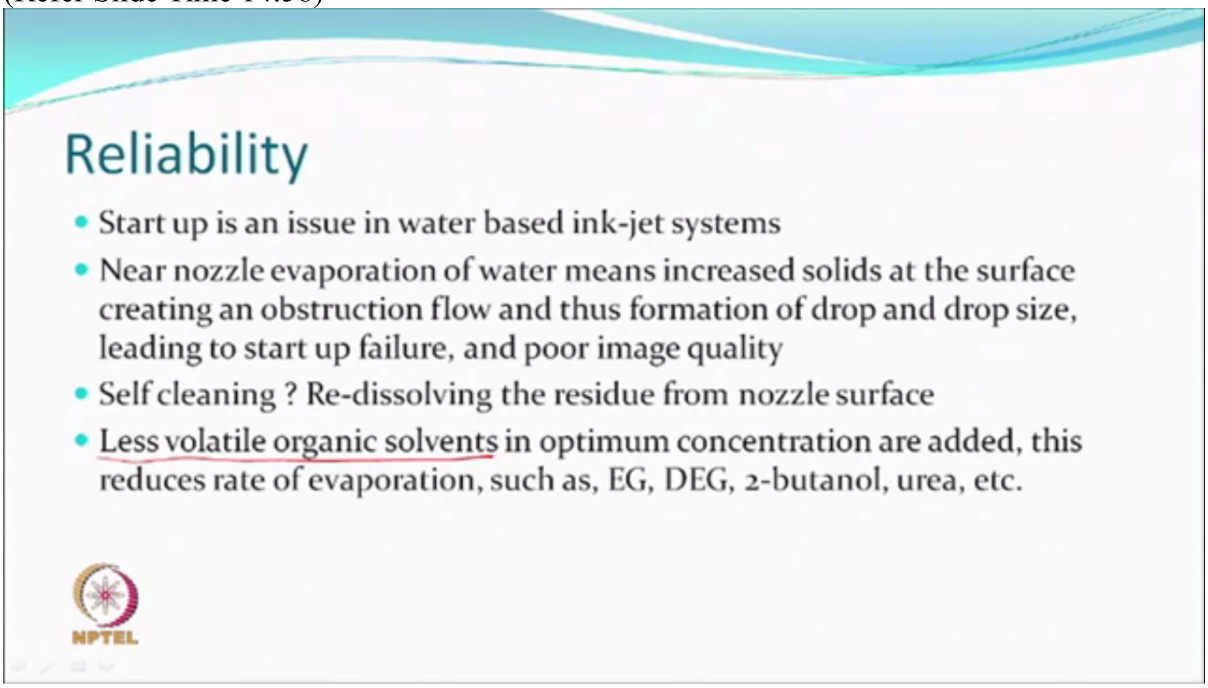

So something called a self-cleaning, self-cleaning means re-dissolving of the residues from the nozzle surface by itself and how will it happen? It would happen if you add some solvents, which help it to get into the solution form.

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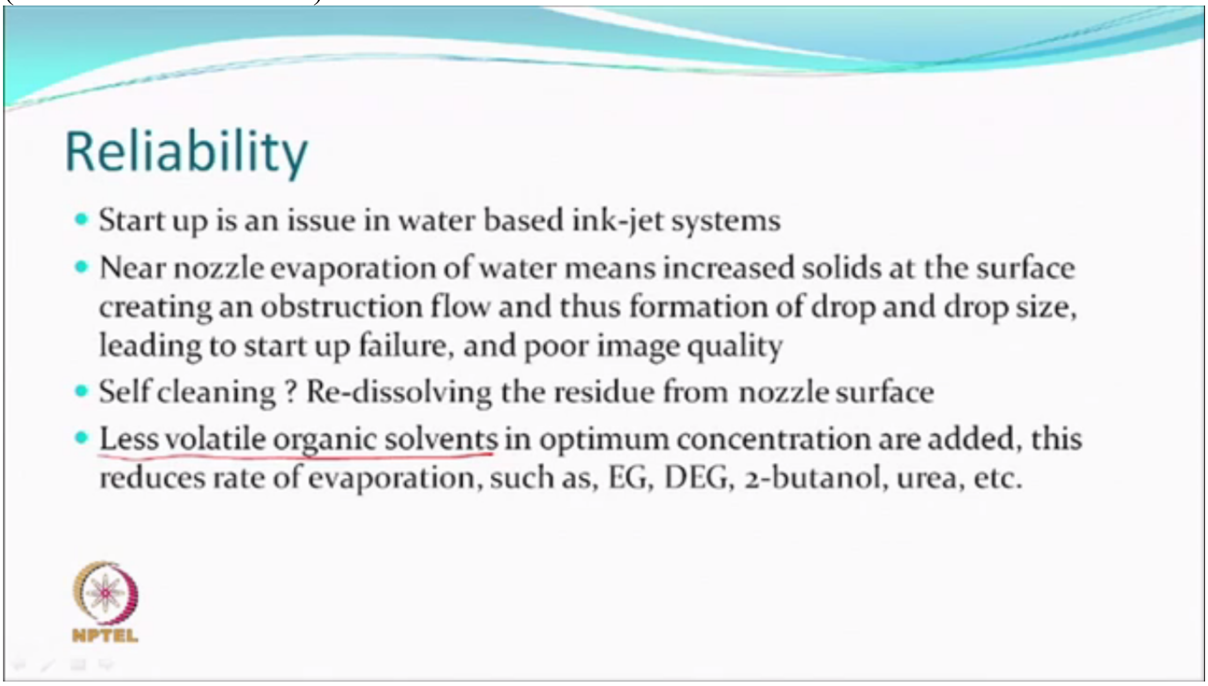

So less volatile organic solvents, we are looking, comparing with obviously water, at some concentrations can reduce the rate of evaporation. Some examples even ethylene glycol, diethylene glycol, butanol. So in some sense they are water soluble. They are hydrophilic. They're not hydrophobic, but because of their larger molecule, they don't obviously evaporate at first and they obviously reduce the evaporation rate of water as well. Other than that, they may actually act as solubilizing agent also.

So the additives, so the solvents are additives. Surface-active agents are additives, other than biocides and so on and so forth that you may like to think.

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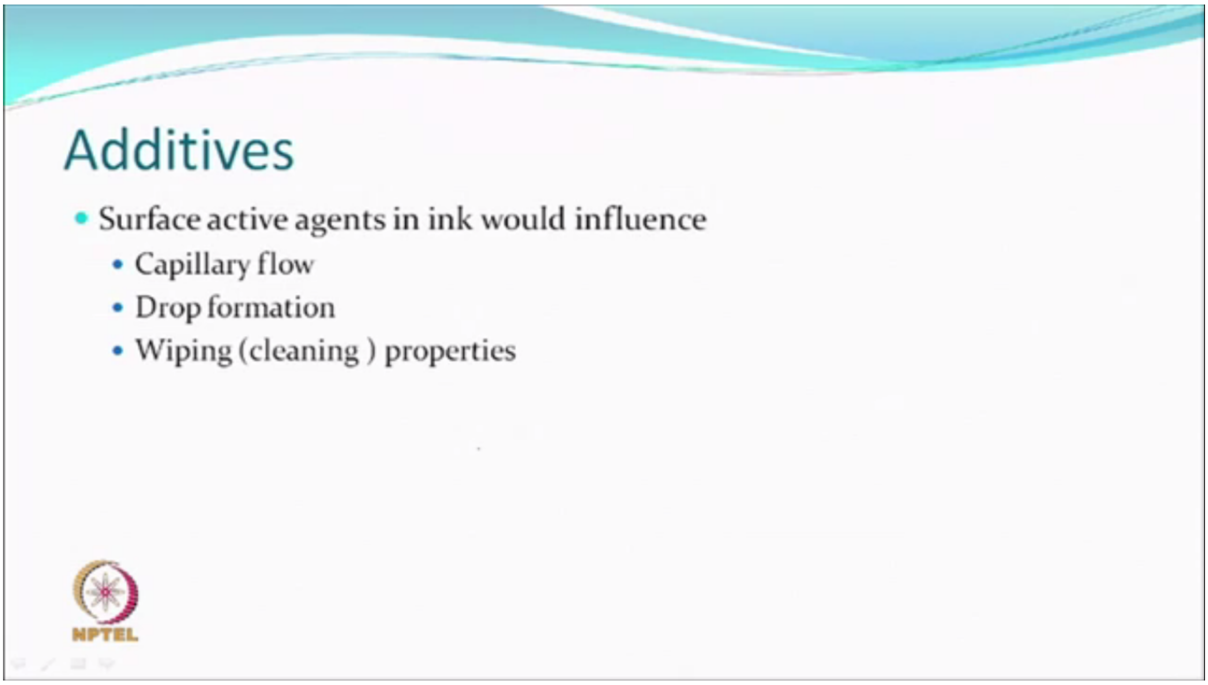

The surface active agents would influence the flow through the capillary, drop formation, wiping or cleaning properties. So people would add that as you know that the surface active agents reduce the surface tension as well.

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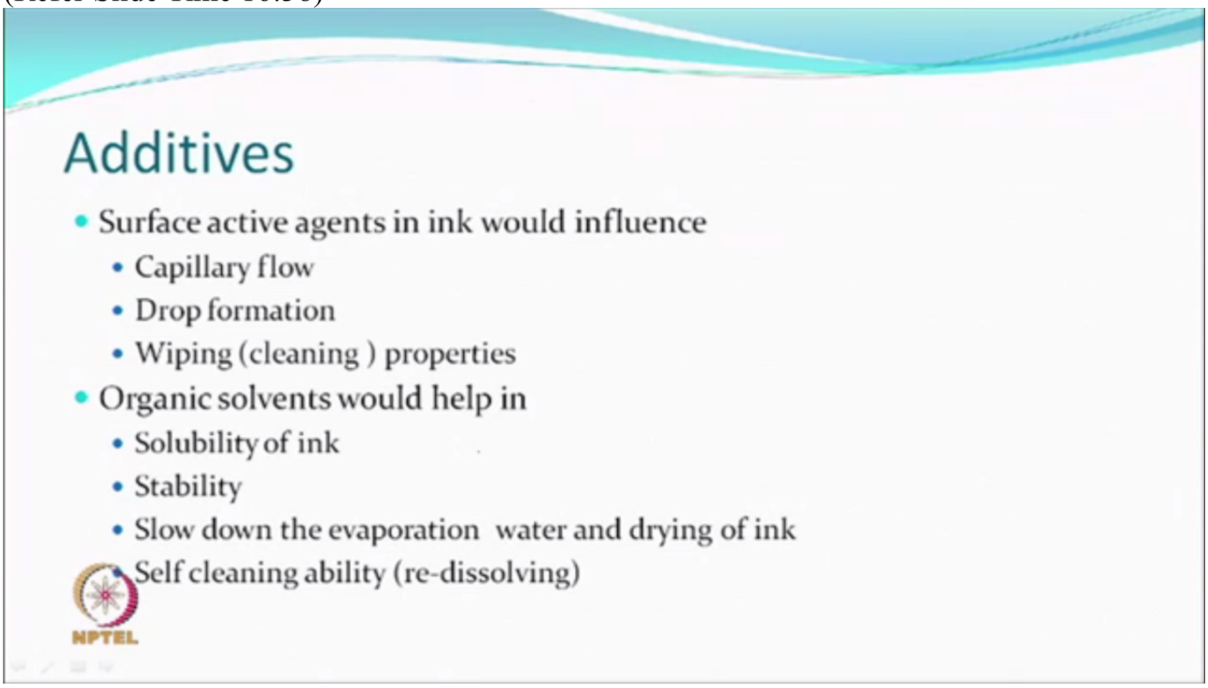

So the organic solvents would help to solubilize the ink and thus increase the stability in general and may give a self-cleaning ability.

So we look at the disperse inks. Disperse inks are similar to pigment except that they do have some solubility and they can dye as dyes or print as dyes.

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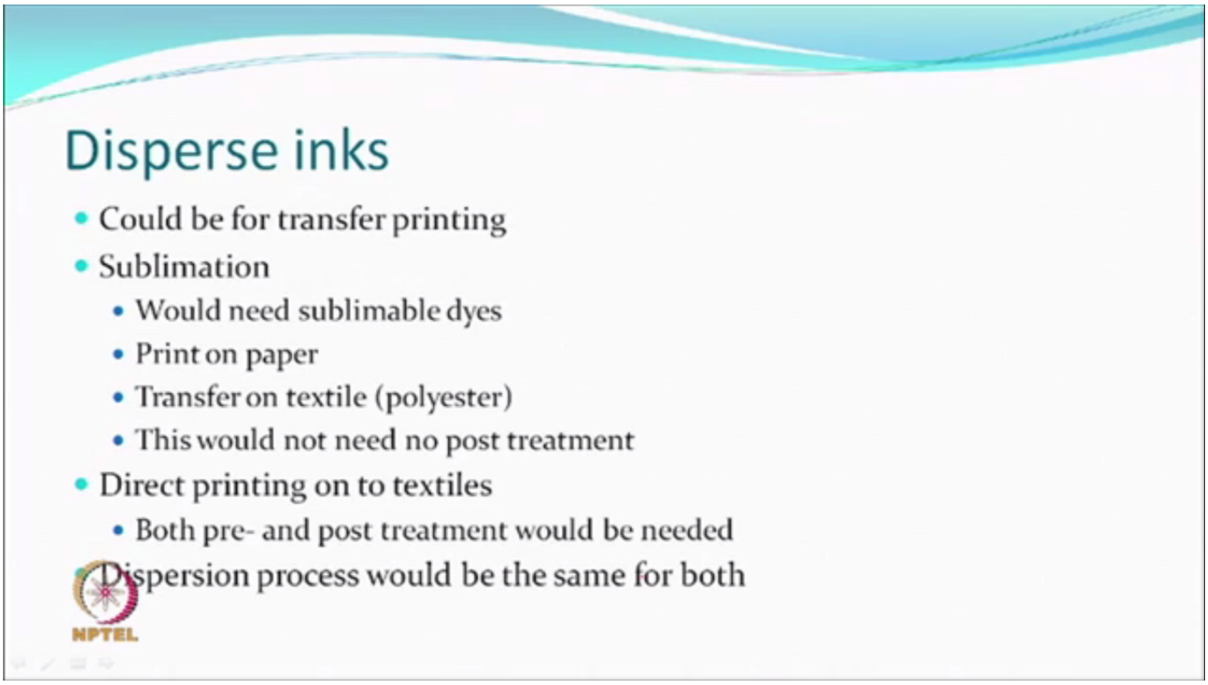

So these disperse dye inks as you've learned from the other day visitor could be used for transfer printing. So you have inks for transfer printing. So digitally it can be printed. So they will have the sublimation type of dyes and print on paper, transfer on textiles. You see when we talked about transfer printing earlier, the printing could be done with sublimable dyes by any method, roller, rotary or anything else. But now the inkjet is becoming as popular for this purpose as well.

So other is a direct printing onto textiles. So in case you are doing only sublimation, then the pre, at least the post-treatment is not so much required, but when you do the direct printing onto textiles, both pre-treatment and post-treatment would be needed. As far as the process of dispersion is concerned, it is same for both type of inks.

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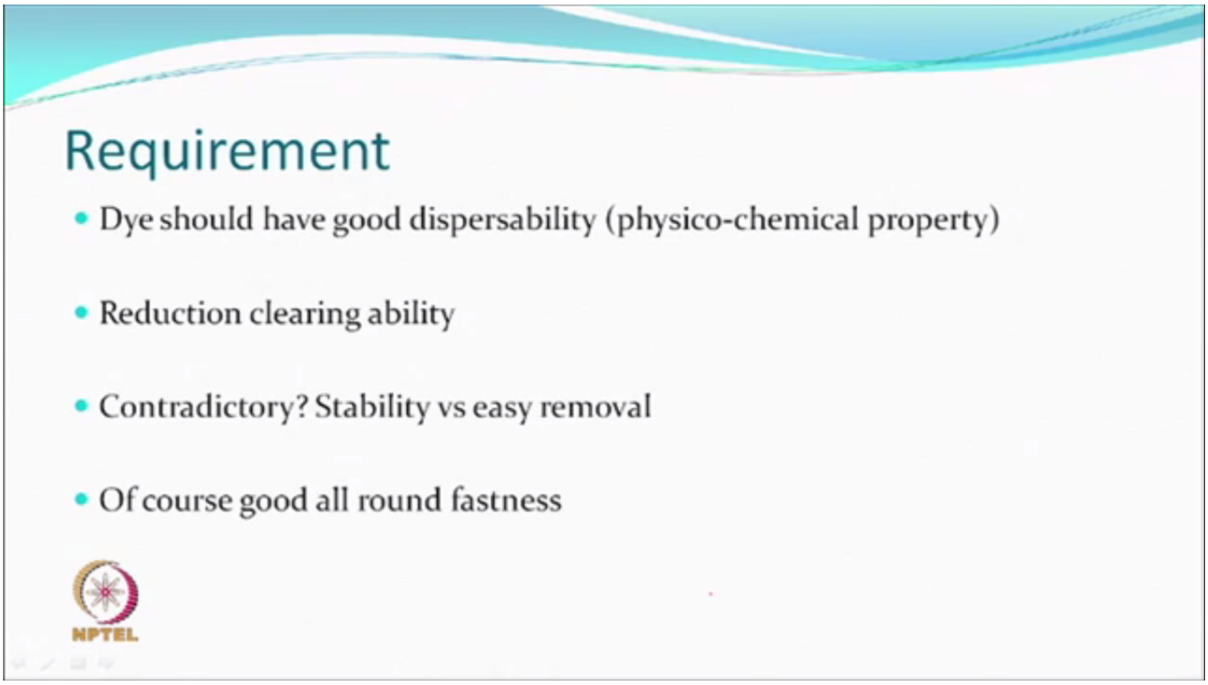

So from the ink point of view in the disperse dye inks, you are looking at good dispersability. So dispersability means physico-chemical. The chemistry is responsible, which would mean the HLB value matching up with the surface active agent. Physical means that how much sighs you have reduced to the particles. If you reduce the size quite a lot, auto-dispersing also takes place, but if you reduce too much, then particle surface energy becomes so high that they have a tendency to aggregate also and so the surface active agents will be making sure that they don't aggregate. They remain as small. Otherwise, again, choking will take place.

Then there is a requirement of reduction clearing. Remember every time we do STHP dying with dispersed dye of polyester after dyeing and washing, it is assumed that some amount of particles get deposited on the surface, and so they are removed by reduction clearing processes. So in some sense you're saying that stability versus easy removal.

Stability means it should remain as it is, wherever it is. Easy removal means that you should be able to remove. So they appear to be contradictory in some sense. The size will have to be adjusted in such a manner. The chemistry means solubility will have to be looked at, but in any case that is what would be the requirement, and of course good all-round fastness will be required. If it goes as a dye inside, obviously, it's okay, but something which remains on the surface would have a problem. Light fastness, obviously, is the chemistry, which, of course, (inaudible 20:31).

The contradiction or let's say the challenge comes is that you are looking at a particular type of a shade or a dye, color, and on top of that, you want light fastness also. So, therefore, selection of dye will be an important aspect in this.

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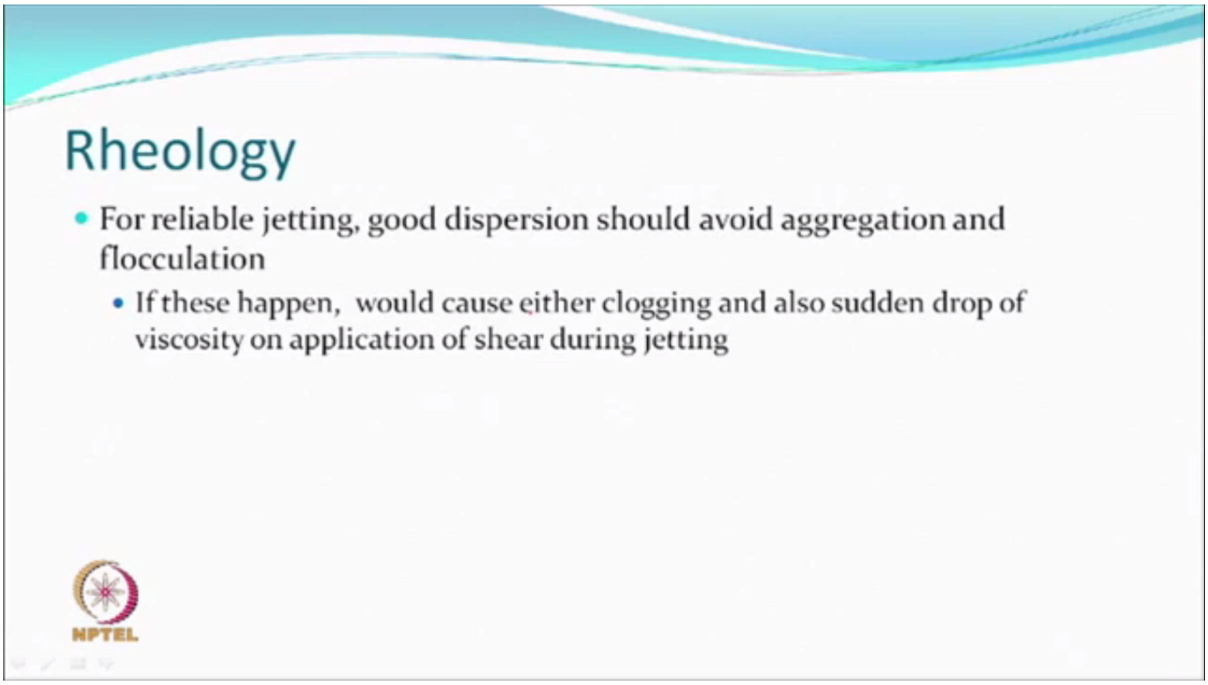

For reliable jetting, the rheology, what happens when you put shear would be important. Good dispersion definitely so there's no aggregation or a flocculation takes place. If these things happen, then obviously clogging will happen. Sudden drop of viscosity may be seen particularly in the shear condition.

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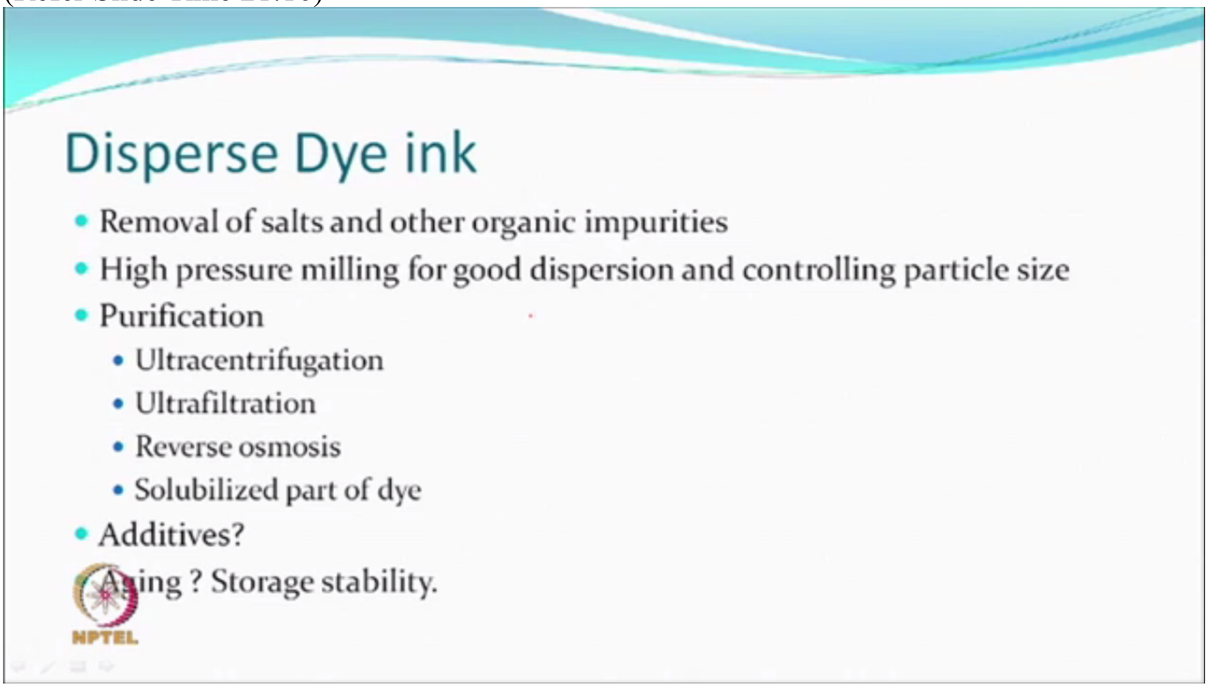

So disperse dye ink, so they are more pure compared to the, the one which are used for dyeing or printing. So anything like a salt, organic impurities must be removed. In the normal dyeing, you actually add them before selling. You may be adding certain things, but here you were looking at it should be as pure as possible. Then it is not water soluble and therefore you will be doing lot of milling to reduce and control the particle size.

So that's an important part, and then remove everything else. Keep the particles on one side. Anything called as solubilized dye, maybe use ultra filtration, reverse osmosis. So you're going to be using all these techniques. Therefore, you are increasing the cost and then, of course, at the end you will be adding some additives as we said because you are also interested in the storage stability because dyes may have to be stored for months and years before they are actually used, and this also is tested.

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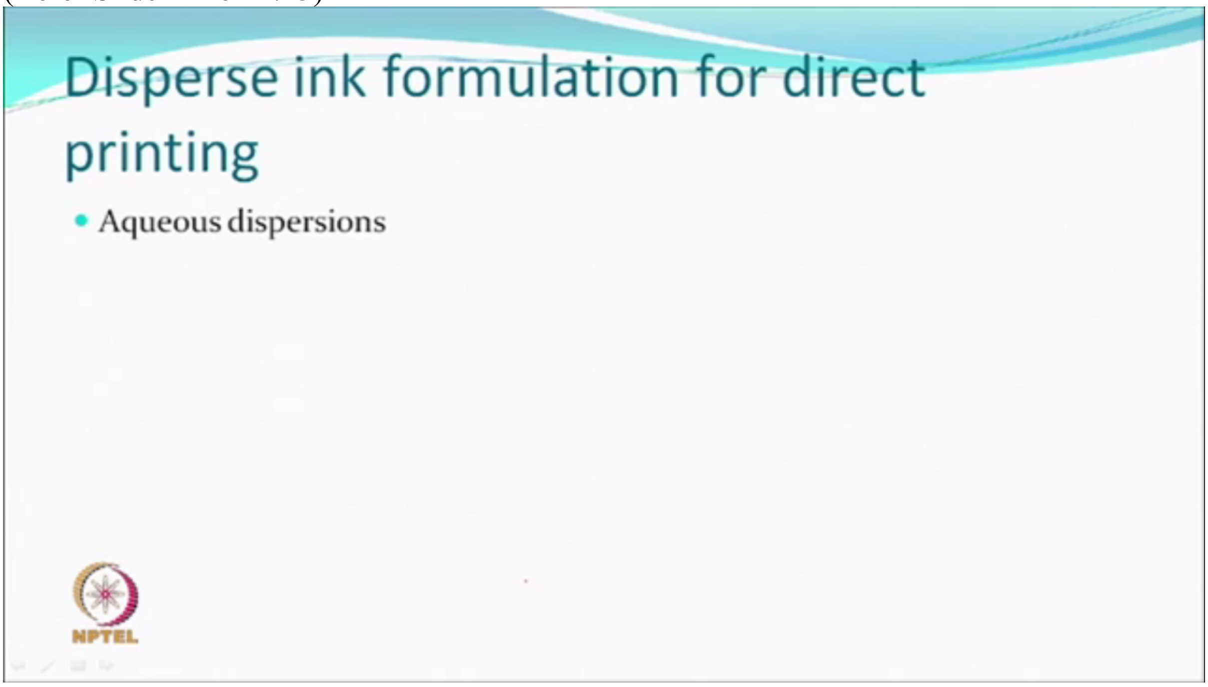

So these are the formulation. Obviously, it is an aqueous formulation means is a dispersion.

Wetting of the dye particle is facilitated so that dye remains, particle remains wetted, the satisfied, and doesn't go, want to go anywhere else.

Similar to pigment dispersion process, approximately 20% of solids and rest everything else, so that is how we look at that means you can have more solids also. More solids means more other agents to stabilize. That will mean the viscosity can also increase. So you have to control the viscosity not go very high.

Particle size, obviously, has to be very small. So there is 0.1 to 0.25 micron type of particle size, which is definitely much less than the size of a fiber or a fiber diameter.

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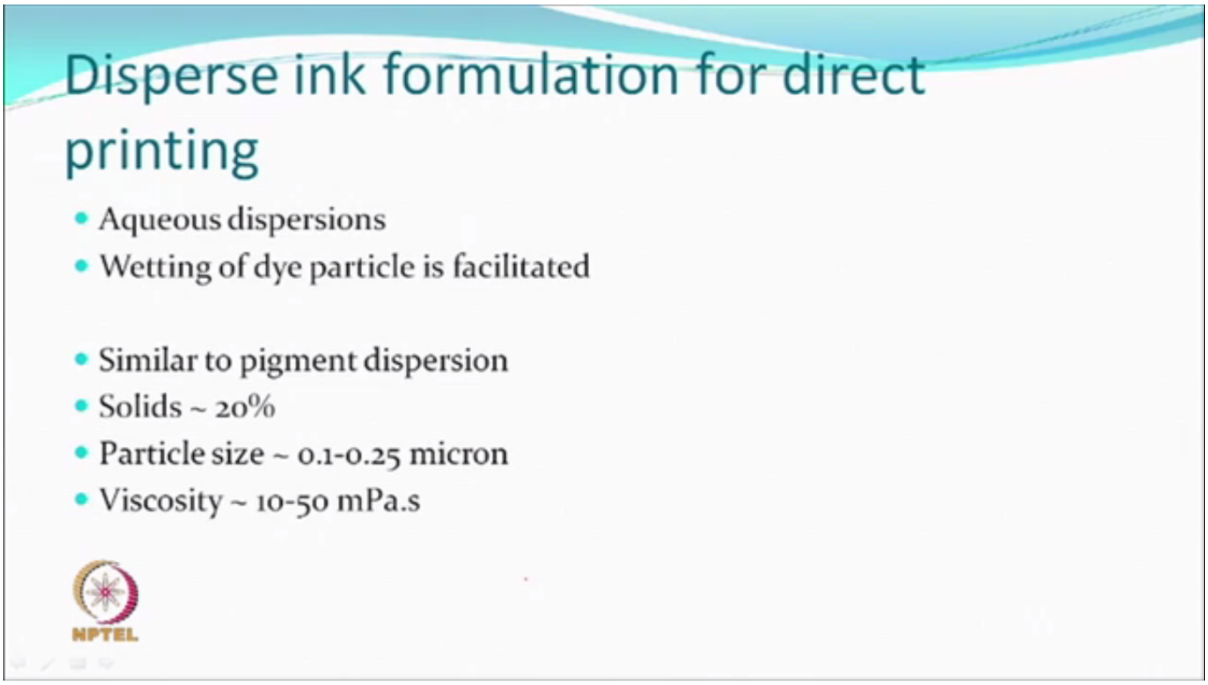

Viscosity is in the range of 20 to 50 milli Pascal second of the ink.

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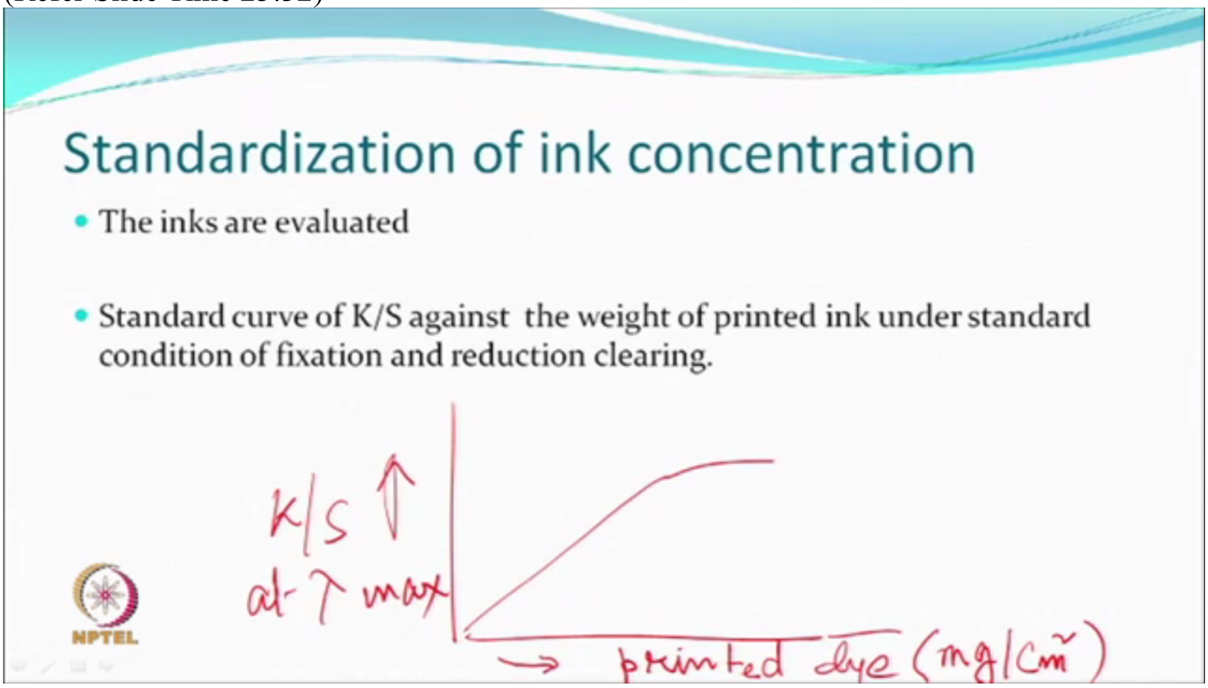

The standardization also whether it's a 20%, 22%, 25%, 15%, 30% whatever other than thing people would like to also know the same shade which should come. So one is that I have made the process, but when you say you are standardizing at the end of the whole thing, you measure the K/S value of the printed area under the condition of fixation and reduction.

So after let's say you have kept it for 180 degrees high pressure steam, high temperature steam, how much it has gone down? The same color, if goes too much down, obviously, it will appear lighter. After reduction clearing whatever changes take place in surface will happen.

So when you try to optimize the concentration of a dye one has to know what processes are going to be followed or you have suggested, and whatever happens finally completely calibration curve will have to be formed by doing all these processes. If somebody dye manufacturer makes this, they suggest, they also suggest to use this process.

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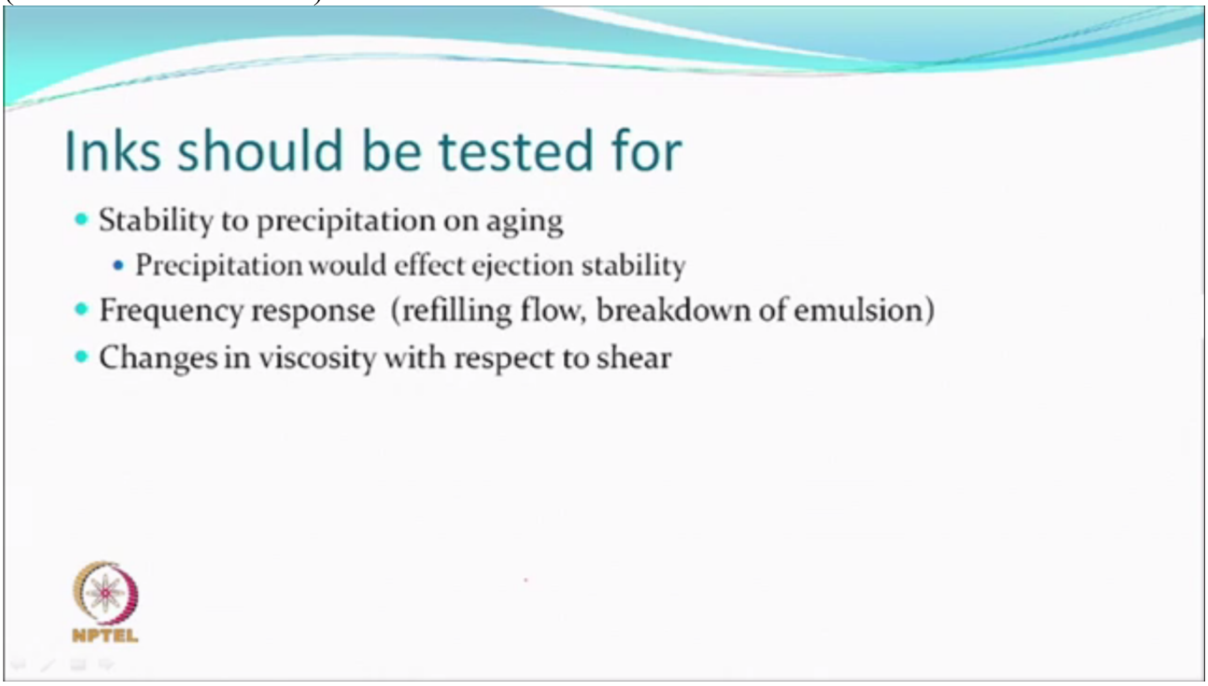

So these inks obviously will be tested for stability to precipitation on aging. So they'll be using tests.

Then frequency response. Now whether you have continuous jet printing or you have drop on demand, the frequency is different. So what it means is that when you talk about kilohertz, you understand what it means. So in such a small time, you are ejecting so fast. How does the liquid respond that when something goes out, something must come in and the same amount? If it does not that goes out more, comes less, then you have various kinds of issues. So it is tested and frequencies, the refilling flow, breakdown of emulsion, everything looked in a static condition right, but dynamic condition it may not be right.

Changes in viscosities will happen when you share. Those kind of properties may have to be tested to look it changes only this much, which is fine for us. If it changes too much, then it may start dripping.

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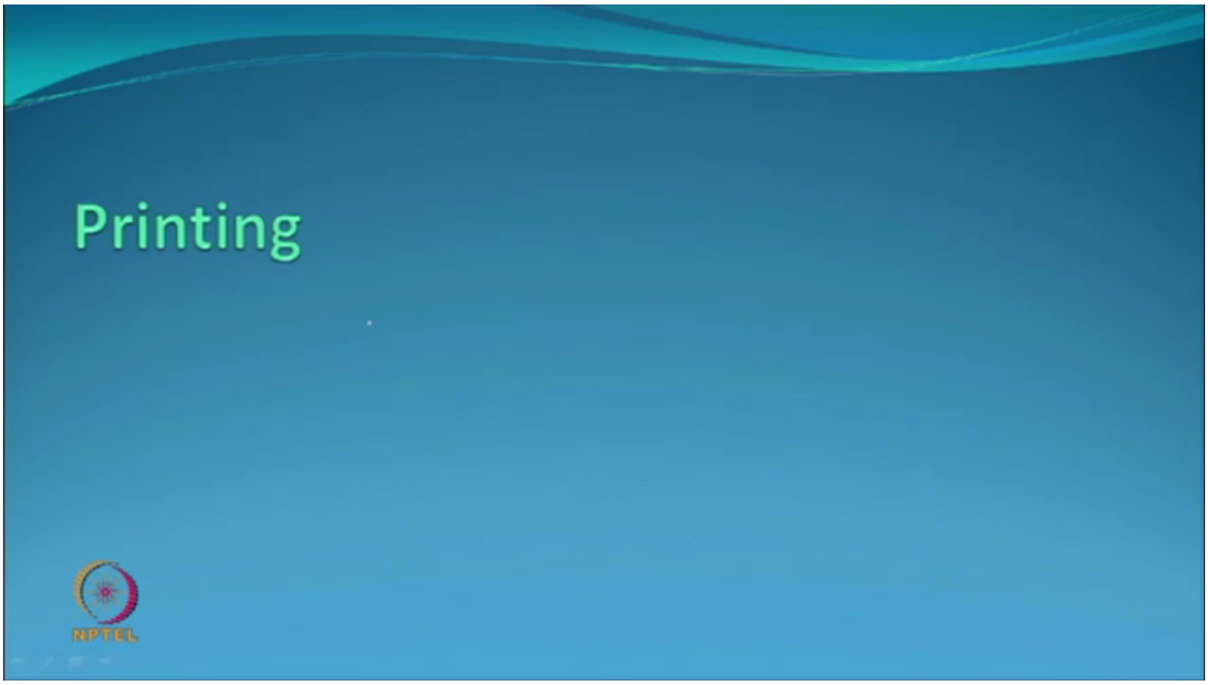

Then printing with the dispersed inks. So, obviously, dispersing, direct printing, substrate, polyester generally. Theoretically, you can print all the synthetic fibers, and there will be some affinity for this.

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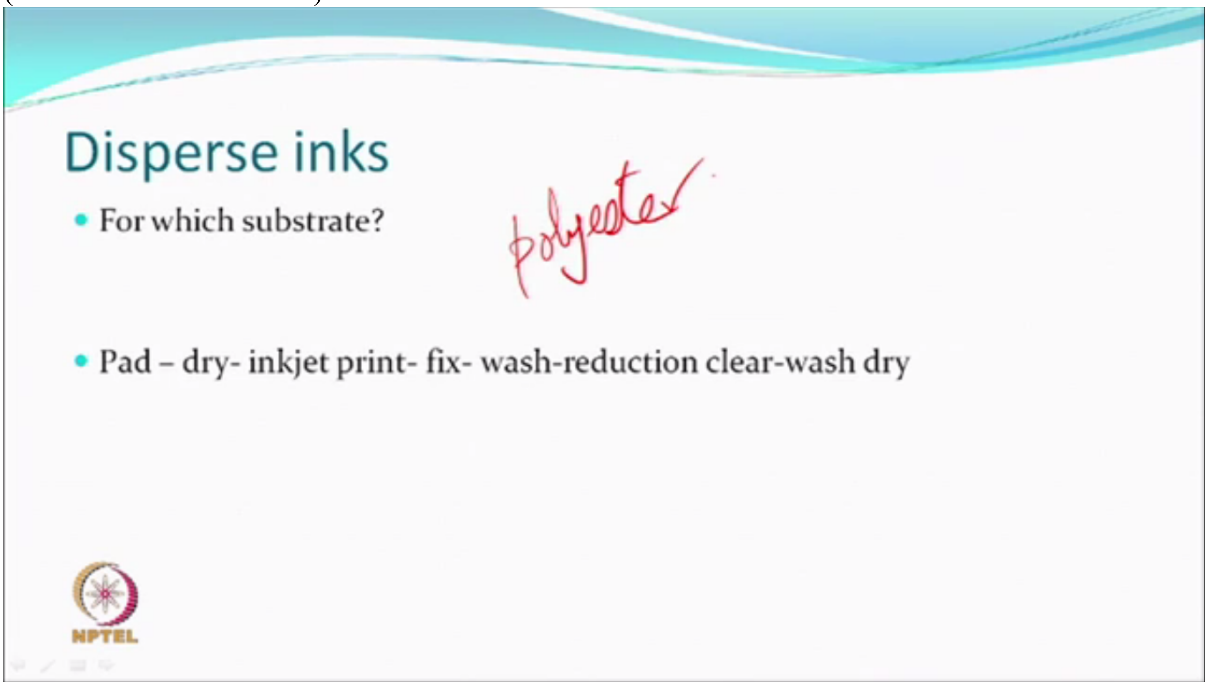

So pad - dry - inkjet print - fix - wash - reduction clear - wash and dry, so unlike the transfer printing, this process is a longer process and everything has to be done. But you'll still get good image, photographic quality image, all those things will be there.

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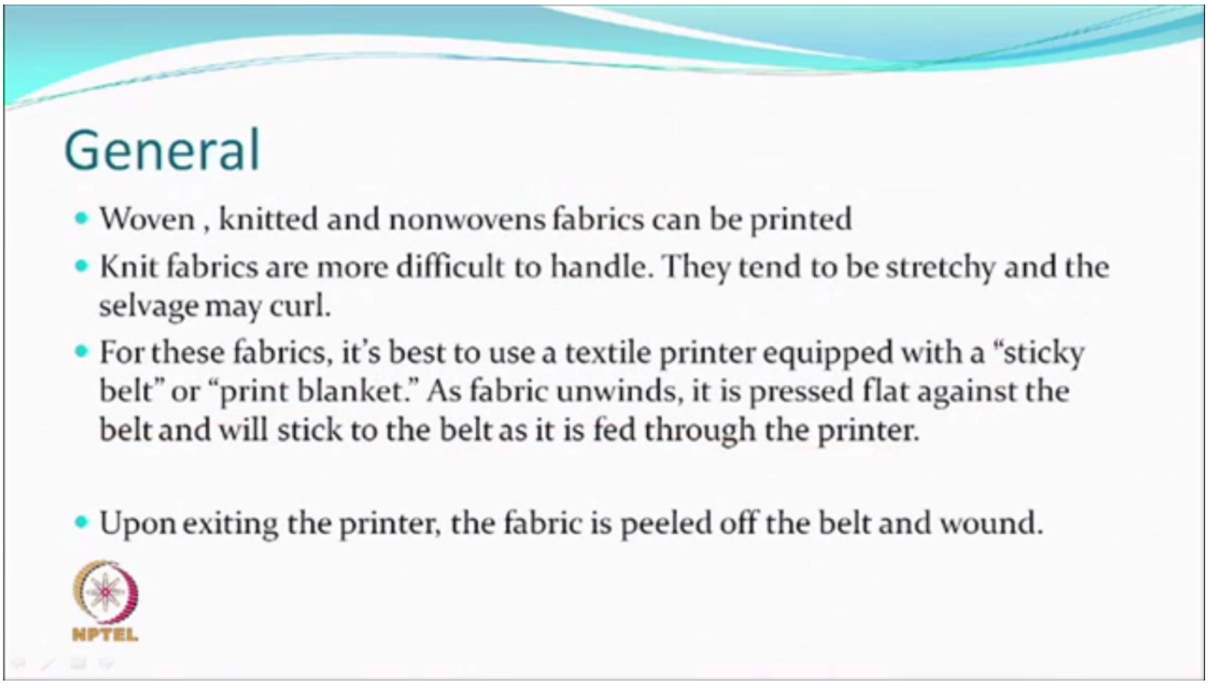

So, theoretically, all types of fabric: woven, knitted, nonwovens can be printed. Actually, sheets can be printed also.

Knitted fabrics invariably have stretchability and so one has to take extra care while printing. So one of the care is that you have a sticky surface. You paste the fabric before printing on a blanket or a belt, and so after printing you peel it off from the belt and wind.

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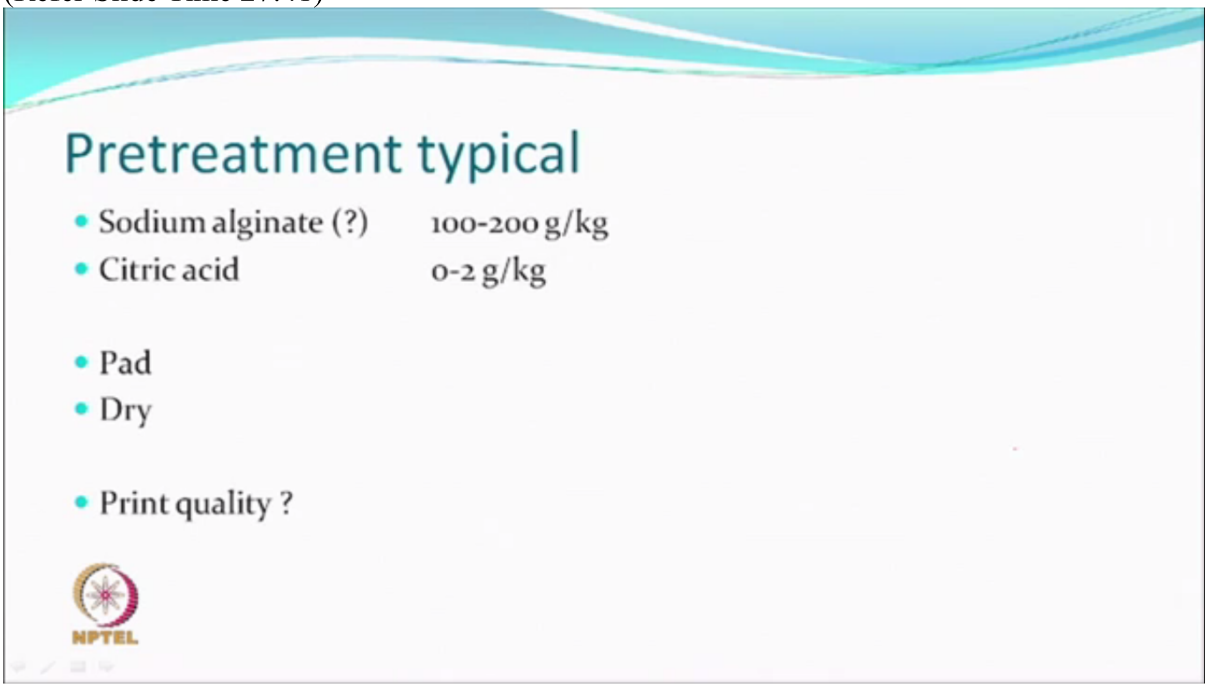

So typical pretreatment maybe some thickening agent, could be sodium alginate, doesn't have to be, but the only thing is the Sodium alginate is a hydrophilic material, obviously. Other treating agents also stable to a bit of an acid. If you remember, generally, disperse dyes have slightly acidic pH always. So you may add some acidic -- a citric acid or citric acid normally may be added simply because its evaporation is less.

So after this your pad, dry, and then we hope for the best that print quality is going to be taken care of.

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So the ink that is consumed obviously based on design weather how much are you covering, the 100% or 30%, 40%, but, generally, consumption is not very high. We hope that it is something close to 0.1 milligram per centimeter square kind of a consumption, which may be there, which is reasonable for the costing is based on this.

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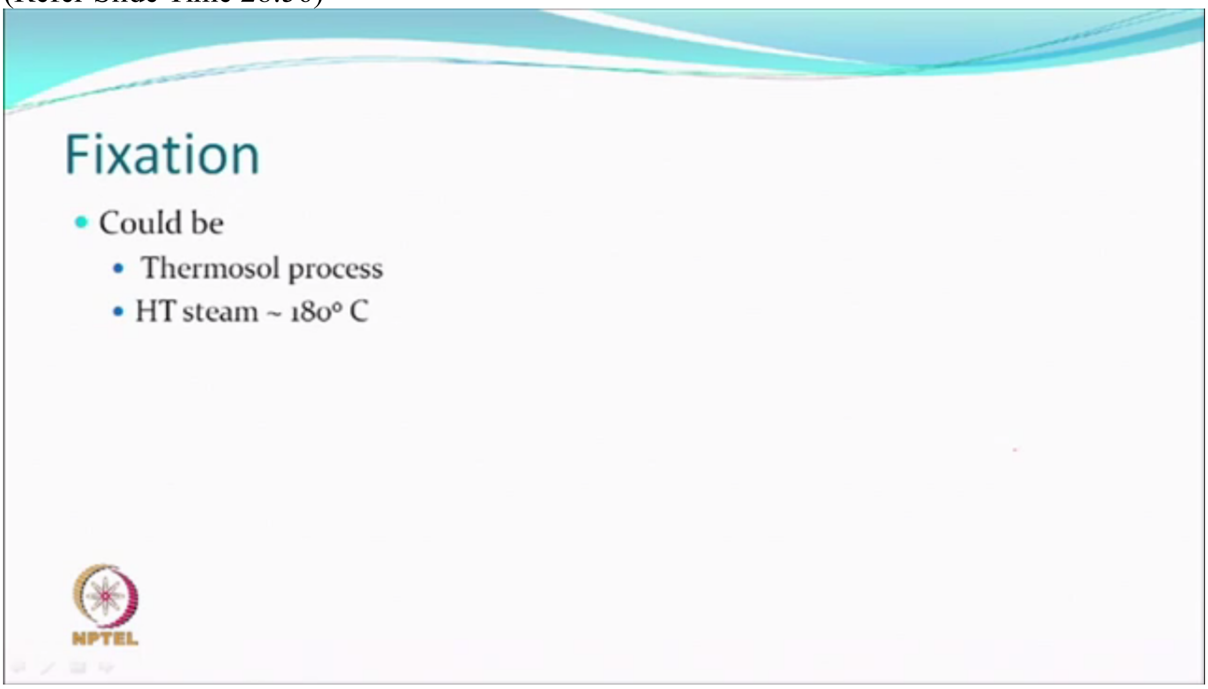

The fixation you can use the thermosol after printing directly, which is possible or high temperature steam. The way the polyester is fixed after printing and dyeing, this is the same process can be used there. So that's the fixation.

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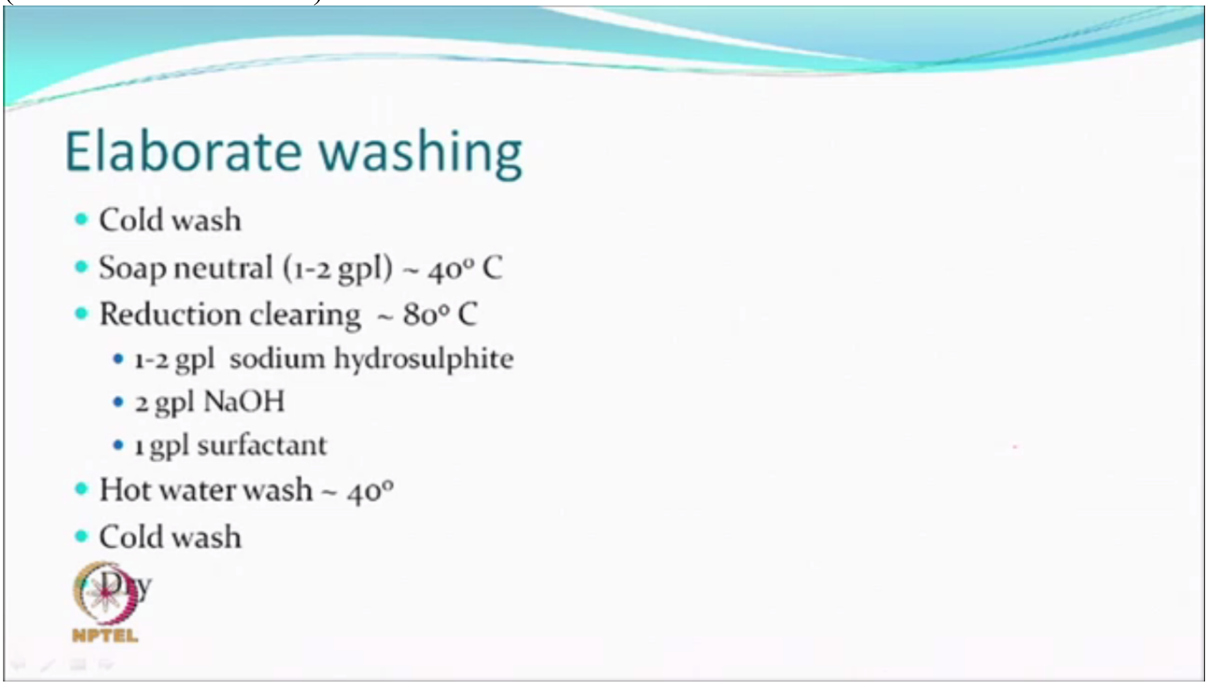

So the washing is elaborate in the sense that everything is being done including cold wash, and then a neutral soap. So these two are the initial processes, and then this is interesting process, which is reduction clearing. So the same sodium hydrosulphite and alkali is there in this reduction clearing bath, and then you wash it with little hot, then the cold and the dry. So that means even if it's a dispersed dye, a direct printing on (inaudible 29:53) you still be requiring a good amount of washing sequence.

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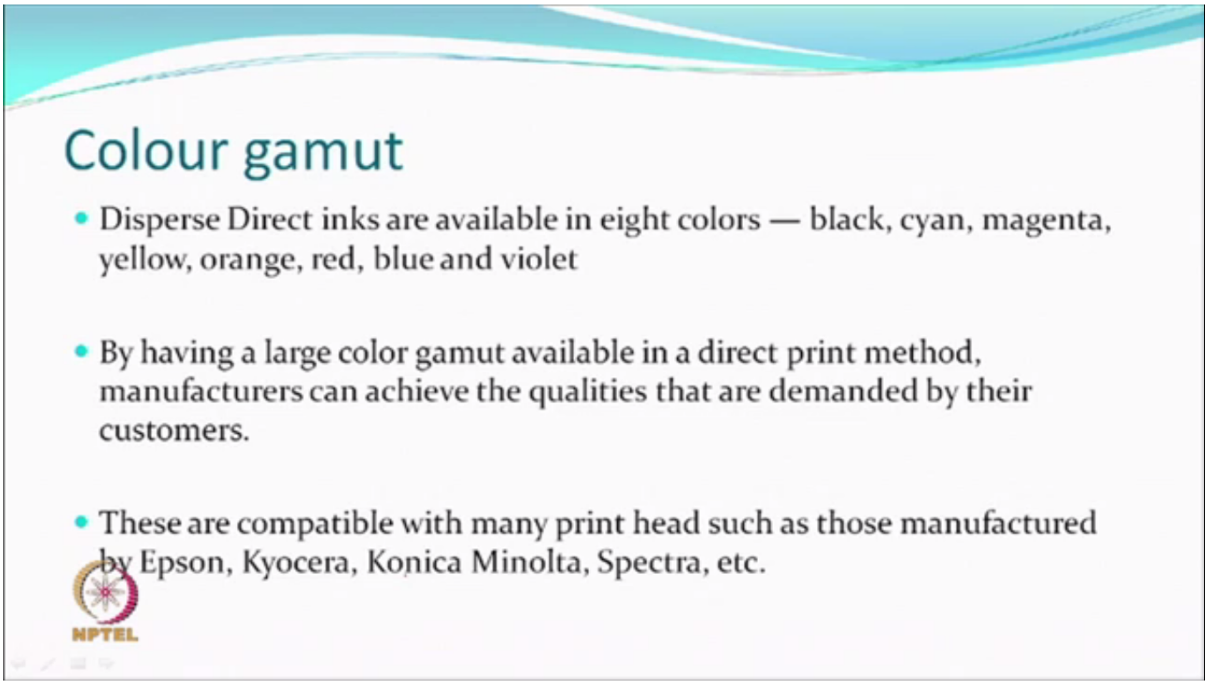

The disperse dye inks are could be available in not just the four, but eight color gamut, and by having a large gamut, the manufacturers can satisfy the demands of the customer, the real reproduction is happening. And this you can appreciate it if it is a designer color, four colors can do everything, but if it is a molecule and you are expecting the magenta is exactly the same magenta that it may not be.

It's a dispersed dye. You have added this. You have subtracted that from the molecule. In such a case they will say add something else so that the same color comes. The true reproduction of a display whatever is on computer or whatever you saw would mean something else need to be added.

And most of these disperse inks would be suitable for almost all kinds of printheads which are manufactured by different companies, and so that's a good thing that they can -- we don't really have to worry, but as I said in the beginning sometimes that manufactures of the printheads as well as those of the inks, they must collaborate. They must know what has been added in the ink. Whether the printhead would have any problem? It is not just that running for one day. You're running 24/7 and so the cost of the head is quite high. So this type of things working with that.

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So any application where polyester is being used (inaudible 31:41) the people have found apparel anyway. Home textile is a very popular type of thing where various kinds of designs can be printed. Personal things like swimwears, and if people are looking at digital printing could come, comes in handy. So polyester nylons are quite popular as far as swimwears are concerned. Shoes which is a product as such people could like to print anything on that. Umbrellas, automobile seat covers, some of these things are for the disperse ink are natural choice.

So apparel could be a thin type of fabric. Home textile could be a thicker GSM fabric. Sometimes people may want it should not be visible from the other side. People sometimes say, no, let it be visible from the other side. If it's a thin fabric, if it is visible, you don't really mind if that happens. So that's, again, the choice of the user.

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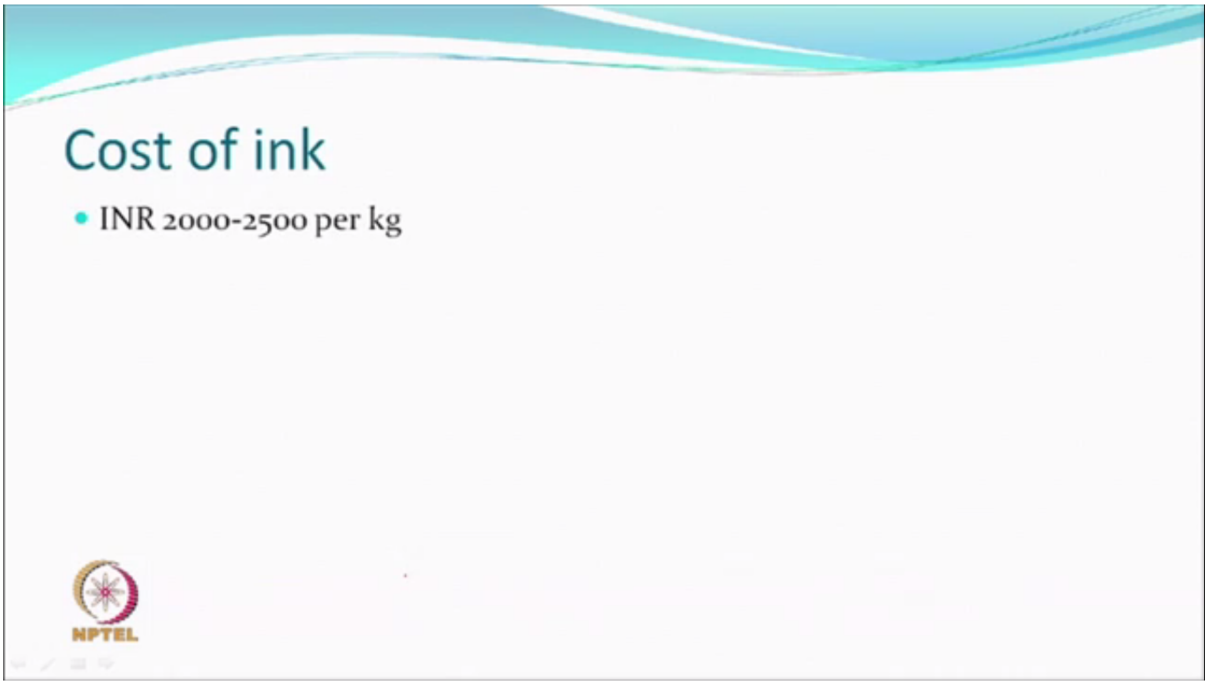

So the cost of such type of inks obviously have come down. Why have come down is because your solubilized wet dyes also will be in this kind of range, but they are solid, and this is liquid kind of thing. But this is now in some sense we can consider as an affordable cost because wastage is very, very less. And of course, if proper fixation takes place, then wastewater effluent issues are obviously less.

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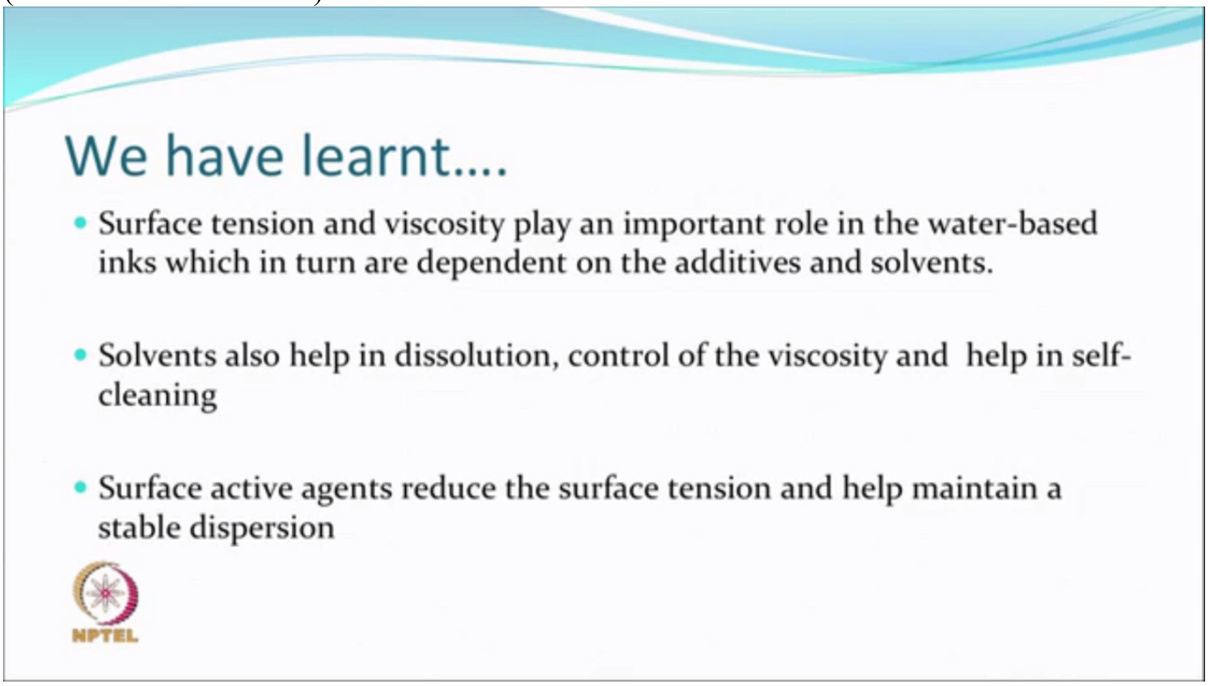

So that's what we've learnt that in the water-based ink, the surface tension and the viscosity play an important role and they are being governed by adding additive, solvents and other things.

The solvents, obviously, help in dissolution as well as maintaining viscosity and self-cleaning type of thing, while surface active agents not only reduced surface tension, but also maintain a stable dispersion of the dye.

So we stop here.

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