Technical Textiles
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Lecture – 13
Filter Fabrics

Hello, everyone, so our new topic for today is filter fabrics. So today we will discuss the details of the production, their application, the materials use, and basically, we will start with the theories of filtration.

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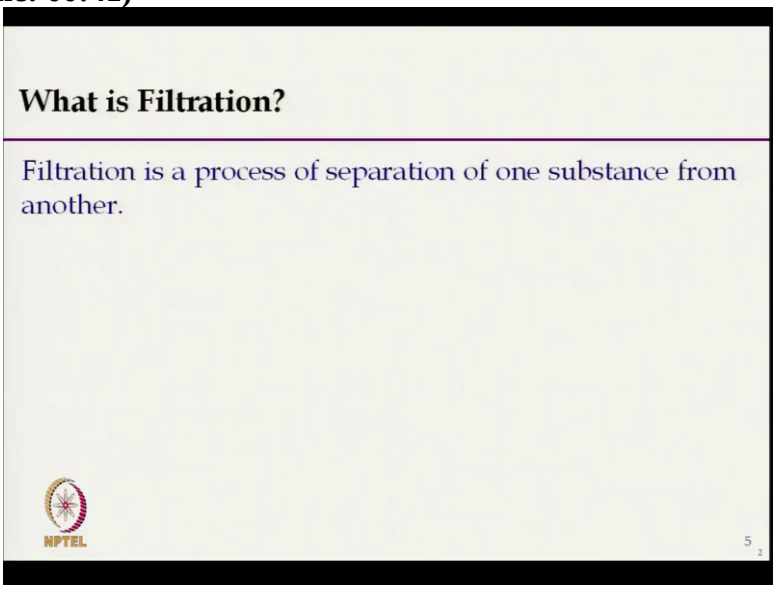

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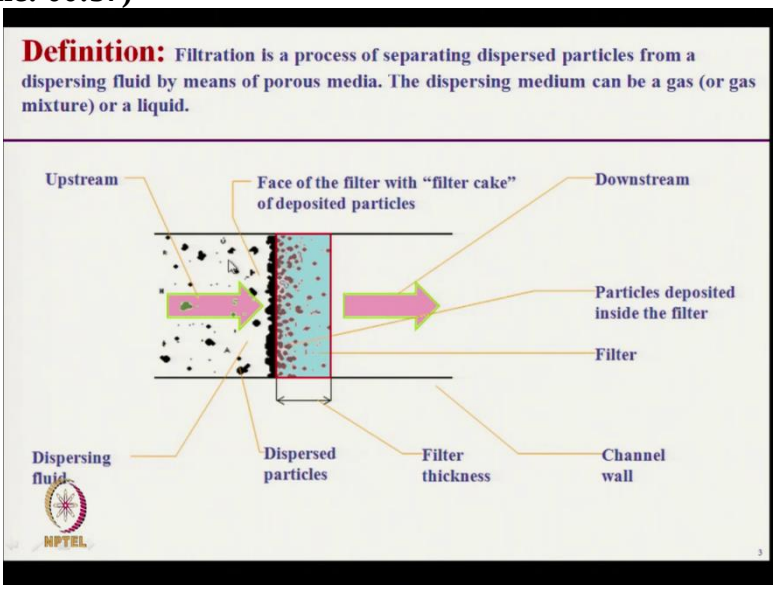

So what is filtration? So, it is a process of separating one substance from another. So that is basically the term filtration we mean in general. Now by definition, if we see it is a process of separating dispersed particles from a dispersing fluid medium by means of a porous media.

The dispersing medium can be liquid, or it can be gas or mixture of gases. So, here from the diagram we can see the particles, which need to be separated from the dispersing medium.

This dispersing medium may be fluid, may be liquid, or may be gas and particles are small solid particles and this is done by one filter medium. So, in our case at present, we will discuss the textile filter medium. So, here textile filter medium is there. And here it is a thickness of the material thickness of filter and it is a great importance, we will discuss, particularly for depth filtration and in the upstream side the dust and the fluid are fed to the filter fabric and all these dust particles are arrested by this filter fabric and clean air is coming out.

So, depending on the filtration efficiency, the number or quantity of this dust particles are arrested and the direction the side where from where the dusty fluids are entering into the filter fabric is known as upstream side and other side is downstream side and the particles can deposit outside the surface of the filter medium, that is a filter fabric and it may form filter cake or it can be deposited inside the structure.

But in most of the cases, both this cake formation and the depth deposition of the dust particles take place. So, this is the channel wall lower wall and upper wall through which the dusty fluids pass and the pressure at the upstream side is higher than the pressure in the downstream side and this difference is known as pressure drop. So, we will discuss all these parameters.

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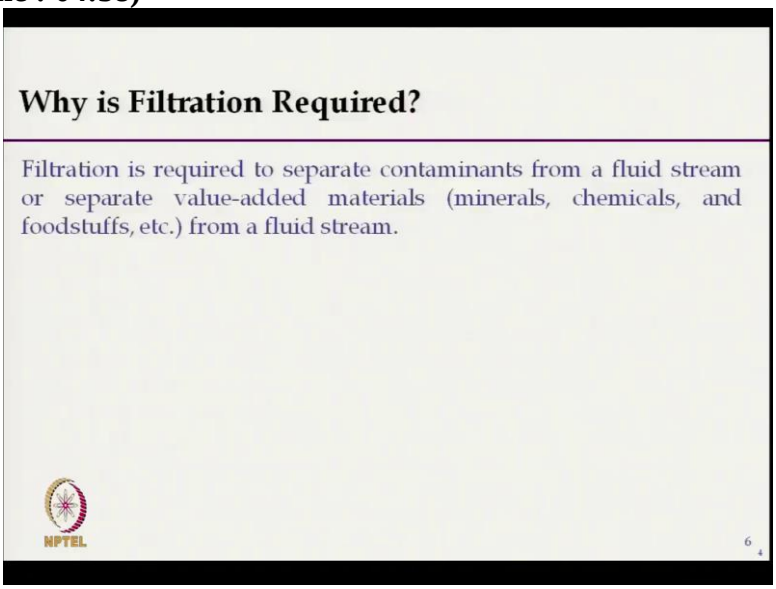

So, why do you need filtration? It is required to separate the contaminants from fluid stream or separate value-added materials like minerals, chemicals and foodstuff from fluid stream. So, it has 2 requirements basically, if we want clear fluid, may be liquid or may be gas free from any dust particle any particle then we need filtration or on the other hand, if we require to remove or take out the useful minerals or chemicals from a fluid system, fluid mixture then we separate the fluid and take the minerals, chemicals or foodstuffs. So, either we can use the fluid, or we can use the mixed filtrate particle.

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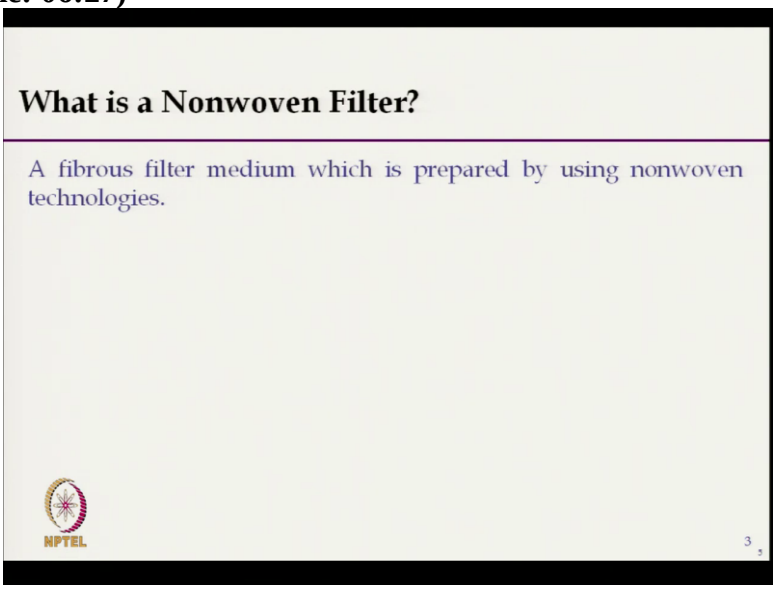

So, in general if you see in as far as textile filters are concerned, in majority of the cases we use nonwoven filter because of the obvious advantages its porous, it has got higher thickness. So, that the particles can be deposited inside the structure and also due to high porosity, the pressure drop is less, which in turn, reduce the energy cost.

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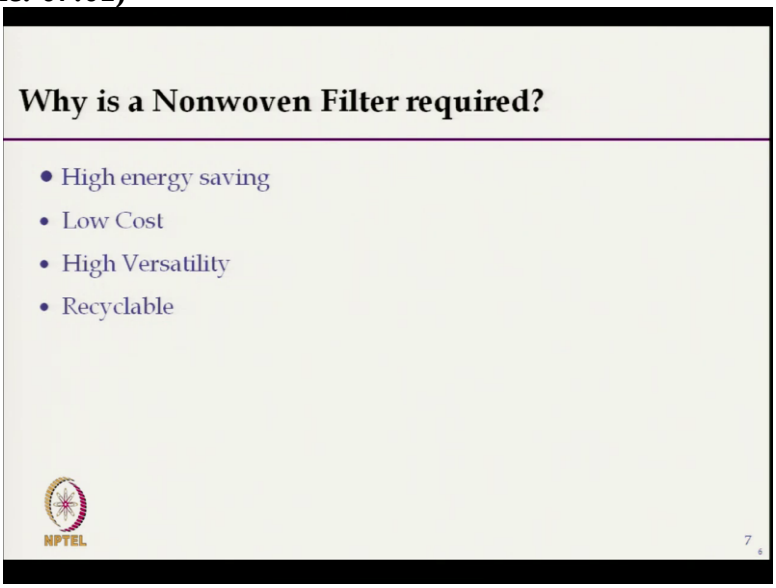

So, high energy saving, because due to lower pressure drop, so, energy saving is high. So required energy will be less. Let us see, why due to nonwoven we can save energy.

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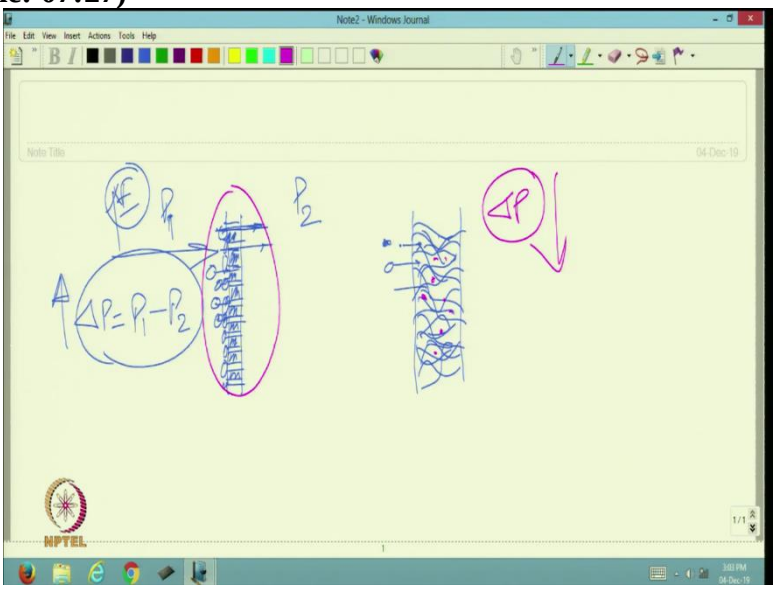

Suppose this is woven fabric, woven fabric has got specific dimension and the pores, proper structure of pores. Now, any particle so these are the say pores, and these are the solid portions. This is the solid portion, defined pores are there. Now, any particle which is smaller than this pore size will easily pass through the pore. But if the particle is larger in size, then it will immediately block the pores once the pores are blocked by dust particles, so flow of air will not be easy.

So, pressure in upstream side and pressure in downstream side will be different and the difference in pressure that is pressure drop will be very high. So, to flow the air, at this higher pressure drop, we need higher energy, higher energy is required. So, but if we use nonwoven fabrics, which are much open in structure and the fibres are aligned randomly and the particles smaller, even a smaller particle or larger particle, they can penetrate inside the structure and these particles will be trapped.

These particles will be trapped inside the structure without blocking the pores. So, delta P, the pressure drop here will be much lower than in case of woven fabric. So, we can save energy if we use the nonwoven fabric. So, it has been observed that nonwoven fabric reduces the energy cost as far as cost of production is concerned per unit length. Nonwoven is cheaper then woven fabric, it is versatile in nature means; we can use nonwoven filter in many applications.

Be it wet filter, dry filtration, microfiltration many applicants and pores filters and so many applications we can use nonwoven fabric, whereas in case of woven fabric, a particular woven fabric can be used in a particular application. So, it is limited applications are there and nonwoven can be recycled, because it is a made of fibre, we can melt and again convert the molten polymer to the fibre and nonwoven fabric.

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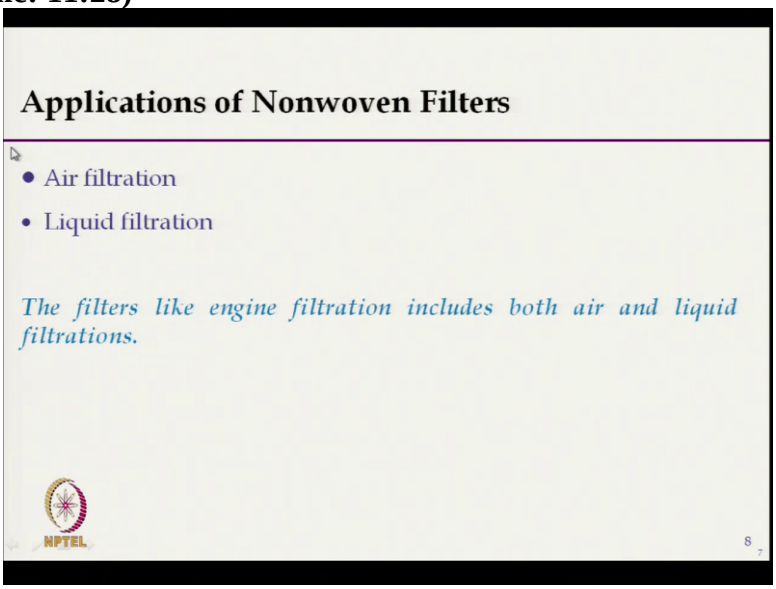

So, the nonwovens can be used in both air filtration or liquid filtration and the filters like engine filter they include both liquid and air filtration. So, where air and liquid filtrations are required together at a time. So, definitely we have to go for nonwoven filter, otherwise nonwoven is widely used for air filtration as well as liquid filtration.

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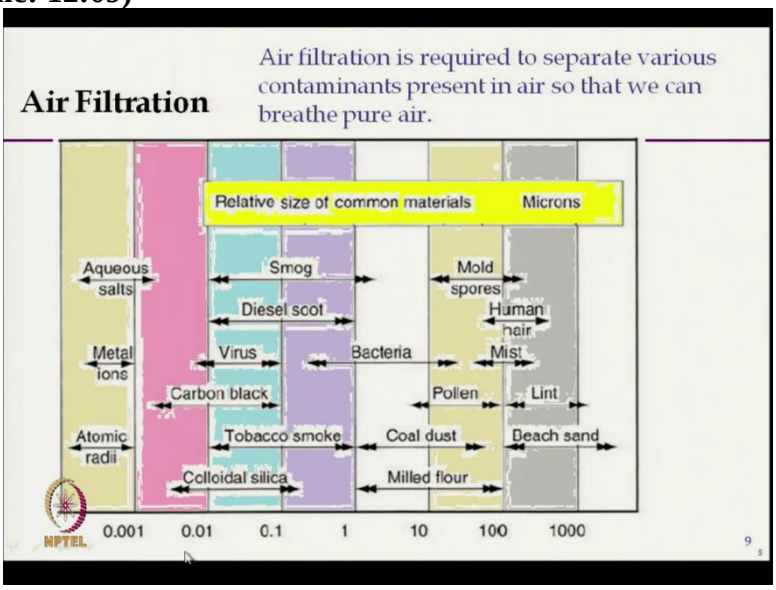

Now, filtration means the removal of particles. So, to design proper filter fabric we must first know the range of particle size, then only we can separate these particles from the air or

water. So, this is the particles which are present in the air and which needs to be separated. We see the like smog; the particle size is from 0.01 to 1 micron. Carbon black it is from 0.001 to say 0.1 micron like these bacteria within the range of say 1-micron range, it can go up to 10 microns. Similarly, human hair, mist, lint, pollen so, these are the different particles which we need to separate from the air to purify. To get the pure air.

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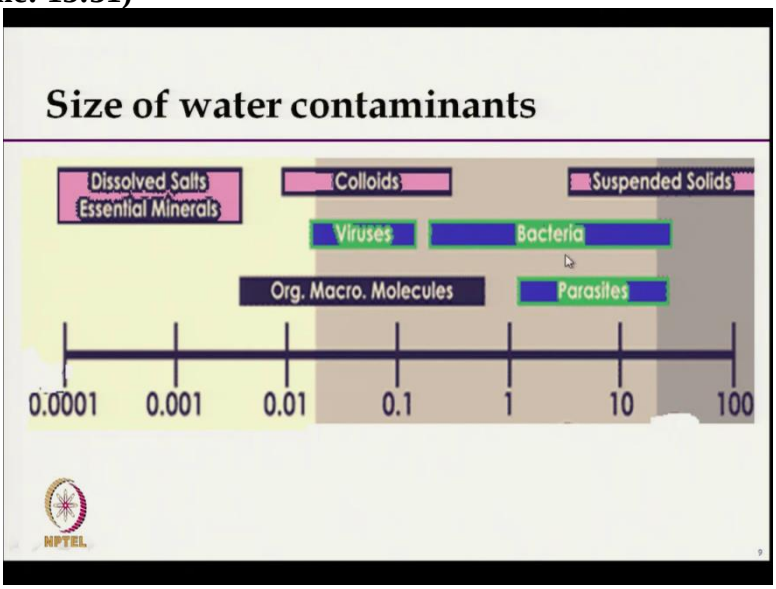

As far as water contaminants are concerned the similar dimensions are there like bacteria, virus. Virus it is ranging from point .01 to 1 micron. Bacteria is around 1 micron, parasite. So, these are the different particles. So, what are the applications of liquid filtration?

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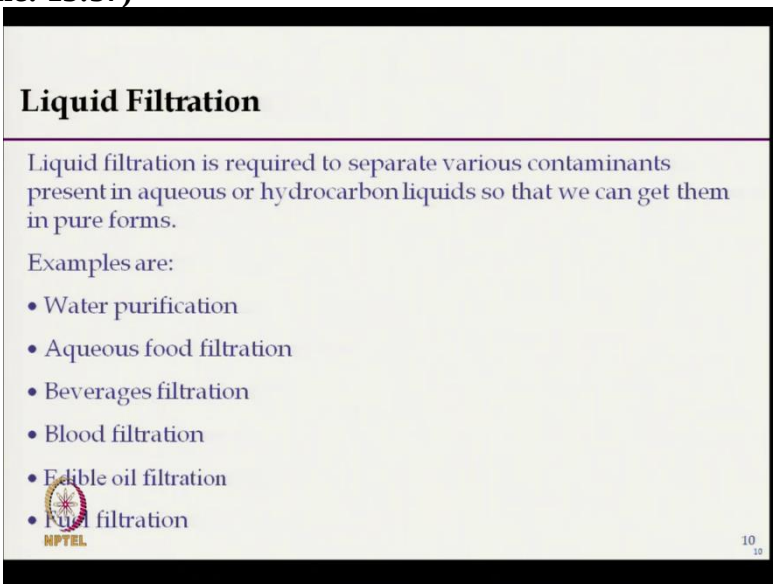

So, liquid filtration is required to separate various contaminants present in aqueous or hydrocarbon. So, aqua solution we will get different contaminants or if we want to filter the hydrocarbon, so, this liquid so that we can get them in pure form. So, the examples are water

purification. So, in water purification, we have to separate all the contaminant present in the water acquires food filtration, beverages filtration, blood filtration, edible oil filtration and fuel filtration these are the most common applications of the liquid filters.

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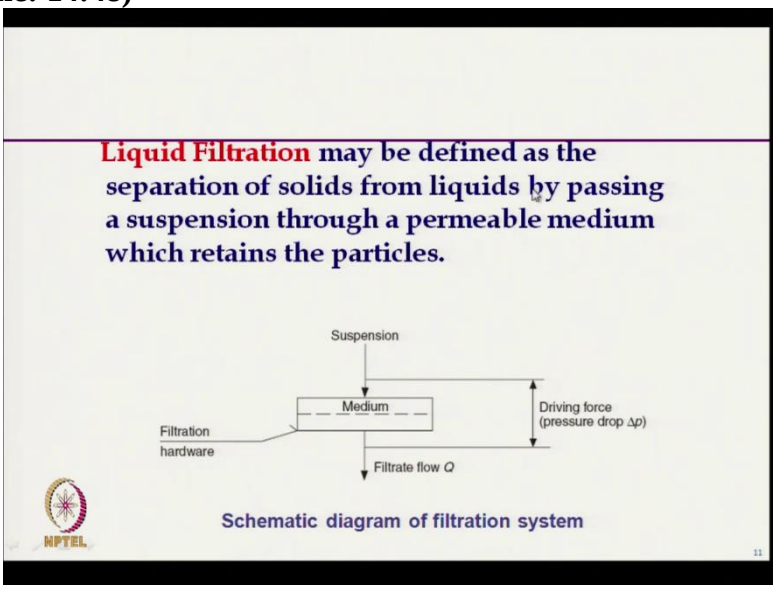

So, liquid filtration may be defined as the separation of solid from liquid, like air filtration is separation of solid from air stream. So, it is a separation of solids from liquids by passing a suspension through a permeable medium which retains the particle. So like air filtration, we need a permeable medium here, it is a textile filter fabric and through that fabric, only liquid can flow, and the other particles present in the solution will be retained.

So here it is a suspension of liquid and the particles. The suspension is flown through the filter medium and the filtrate flows and this is the driving force that means it is a pressure drop. So, this is high when the pores are being blocked.

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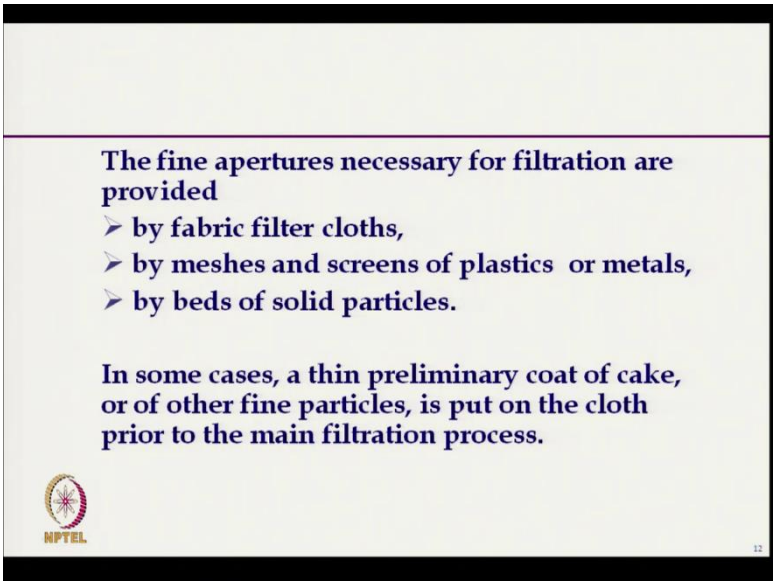

The fine apertures necessary for filtration are provided. This is provided by the either by filter cloth so, for liquid filtration we can use filter cloth, or we can use meshes or screens of plastic or minerals or some time we use beds of solid particles like sand beds we can use to filter the cloth sorry, filter the liquid. In some case, thin permeable coat of cakes are provided on the surface of the cloth it is put on the cloth prior to main filtration process. So, this is actually required to enhance the filters efficiency of the fabric.

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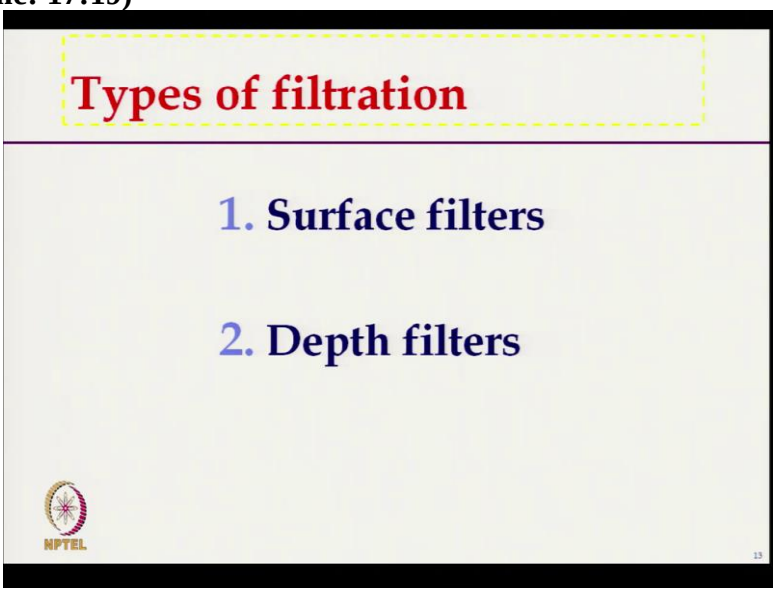

Now, we will discuss the types of filtration. So, broadly if we see the filtration can be divided into 2 types, one is surface filtration, and another is depth filtration. As the term says, the surface filtration is actually takes place at the surface of the fabric that is the upstream surface of the filter fabric.

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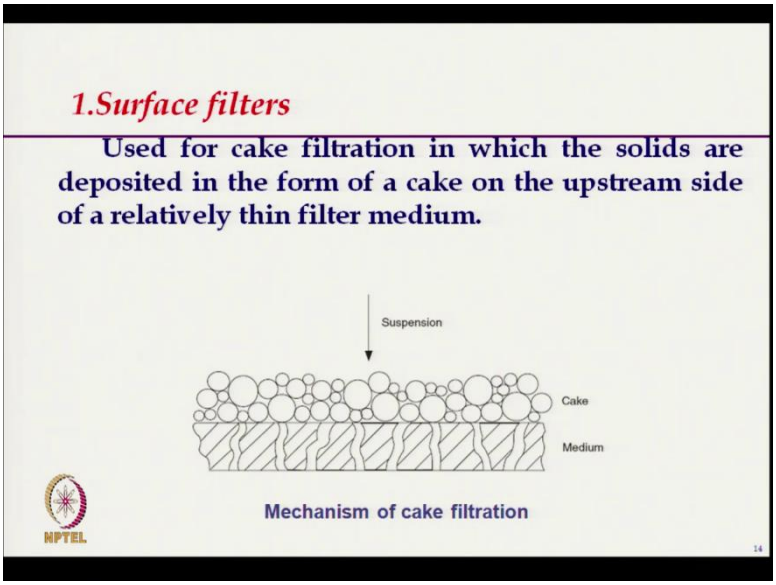

Now, from this diagram, it is clear that the particles are accumulated on the surface of the fabric. So, use of cake filtration in which the solids are deposited in the form of cake on the upstream side of relatively thin filter medium. Now, here, we normally use the woven fabric when you use the woven fabric, this type of surface filtration takes place. So, woven fabric or a very thin, spun bonded nonwoven fabric. They are used for this surface filtration. Let us see what happens during the surface filtration.

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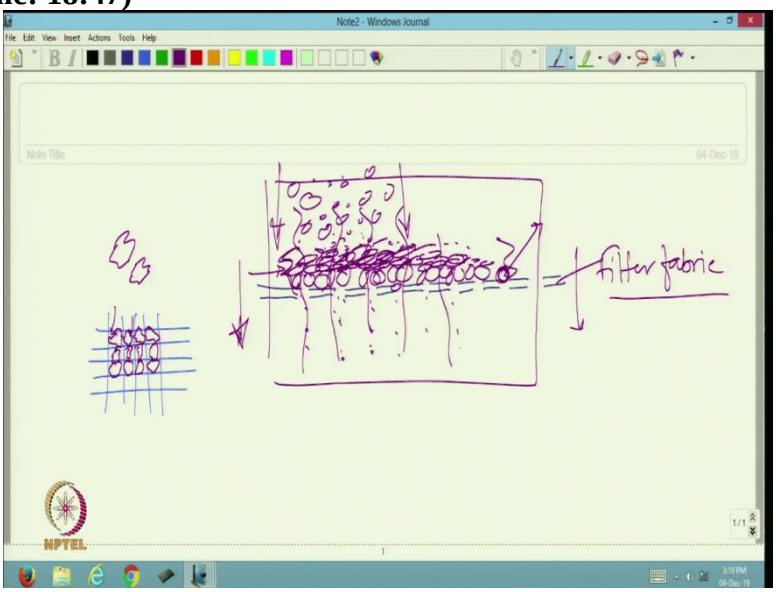

Suppose this is the fabric with holes, thin woven fabric or the spun bonded fabric. Now, dust particles they are a mixture of particles of different size very fine. Once the particle with the fluid passes through the fabric medium during this flow what happen initially, the smaller particles will pass through filter medium, this is filter fabric, but the larger particles will not be able to pass through this.

So, they will be stopped and this will form a layer although there will be chances where they can block the total pore entirely, but the chances of this type of situation is very rare because the dimension of the pores and dimension of particles are not exactly the same. Like if we take example of woven fabric, this is woven fabric the dimensions are say square dimensions of pores are square, but if we take one particle dust particle with uneven dimension, so, they will be stopped I am drawing the top view.

So, they will be stopped, but they will not be able to block the pores totally, 100% blockage will not be there. So, here the air can pass, there will be air permeability, it will remain still be permeable. So, like this way these larger particles will be arrested. This is one layer. Now still we will find the small particles are passing through this gradually there will be another layer over that.

So, this is another layer of larger or relatively smaller particles also mixture of, because by the time the opening became smaller but what happened here the formation of cakes with largest particle closer to the surface and gradually this cake will start as extra filter medium, that is called cake filtration and the porosity of this cake will still remain. So, the air can pass through this, but the particles even smaller particles will not be able to pass. So, this total phenomenon is known as surface filtration. So, in this way the surface filters work.

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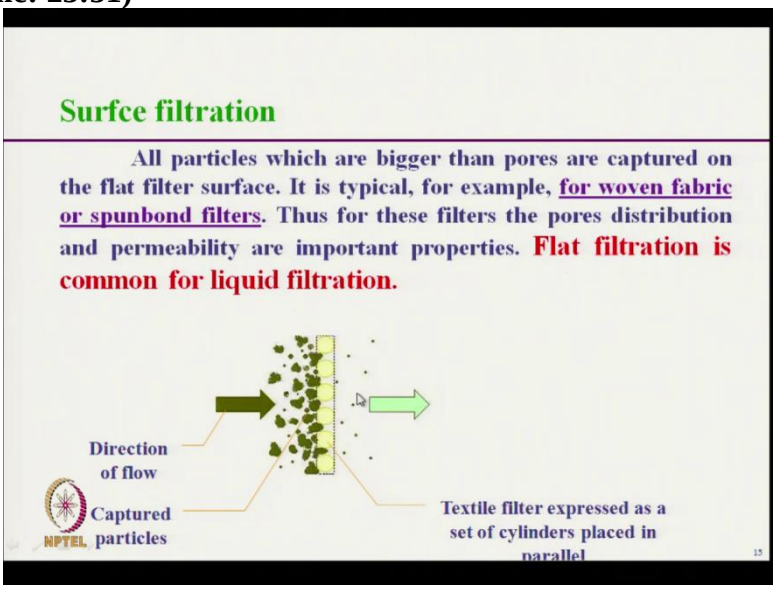

So, this is the diagram which shows that initially the smaller particles are flowing through the filter medium and gradually the filter cake formation is there and after a certain time the filters and efficiency becomes very high with proper flow of fluid and the pressure drop does

not increase too much. So, all particles which are bigger than pores are captured on the flat filter surface. So, the surface filter, another requirement is that the filter surface must be flat.

It is typical for example, for woven fabric or spunbond fabric. Spunbond and woven fabric we have smooth surface thus for these filters the pore distribution and permeability are important properties. So, for pore distribution, we must know like as I have mentioned that for woven fabric pores are defined and for spunbond filter fabric, we can also measure the pore distribution. So, flat filtration is common for mainly liquid filtration.

So, another important issue here is that the flow rate of the fluid should not be very high and also there should not be any disturbance in or turbulence in the flow, otherwise that turbulence may disturb the formation of cake. So, proper stable cake formations should be there for surface filtration.

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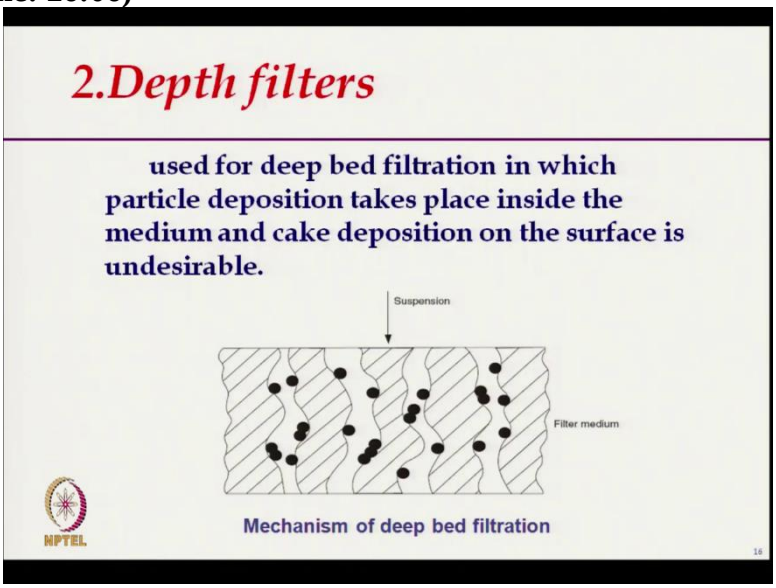

The second characteristic, second type of filter is it is the depth filtration. So here what we have discussed that is surface filters and which happens on the surface of the thin filter medium.

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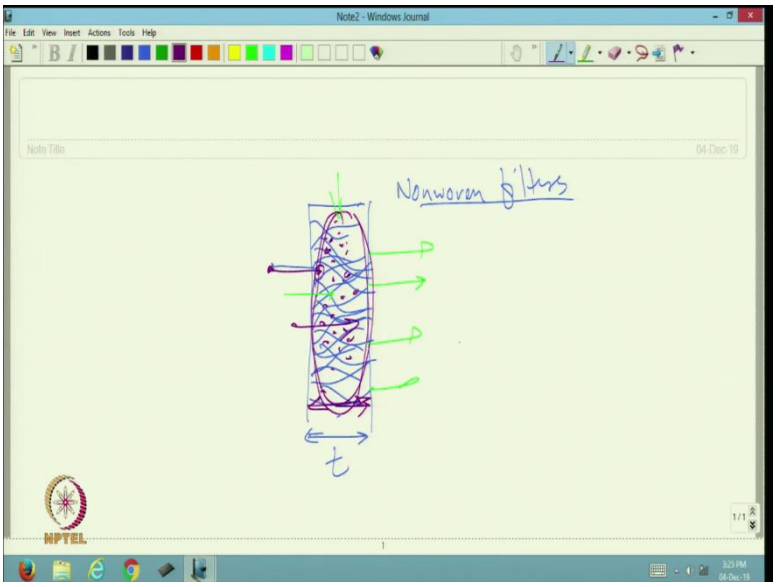

But for depth filter we need thicker fabric. This is the thickness; we need thicker fabric and that is why nonwoven filters are used for depth filtration. Another characteristics of nonwovens are the pores are not defined these are randomly oriented and random dimension. The particles even a very small particle, it can penetrate easily inside the structure. So, this is particle the particle it is penetrating inside the structure, but this particle will get trapped inside the structure.

This entrapment, to explain, due to various mechanisms that I will discuss. There are different mechanisms by which these particles get trapped inside the structure within the depth of this is the depth of the filter. So, as these particles are trapped and separated from the stream in the inside the depth of the filter medium, that is why this type of filtration is known as depth filtration. Here, the advantage is that the pores are not blocked immediately. It is very gradual process and that takes longer time. So, for nonwoven filters, if we use the depth filtration technique, so the life of the filter is long.

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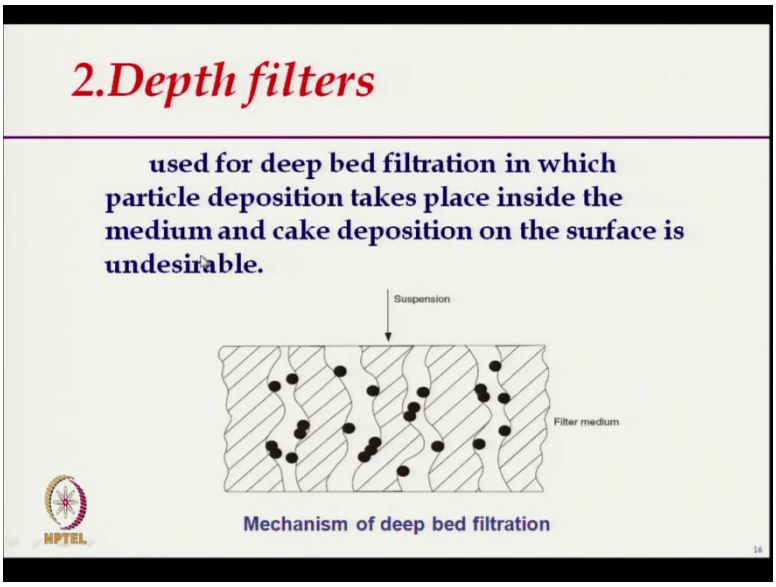

So, use for deep bed filtration in which particles, the particle deposition takes place inside the medium and cake deposition on the surface is undesirable. So, here in this case, cake deposition is not required.

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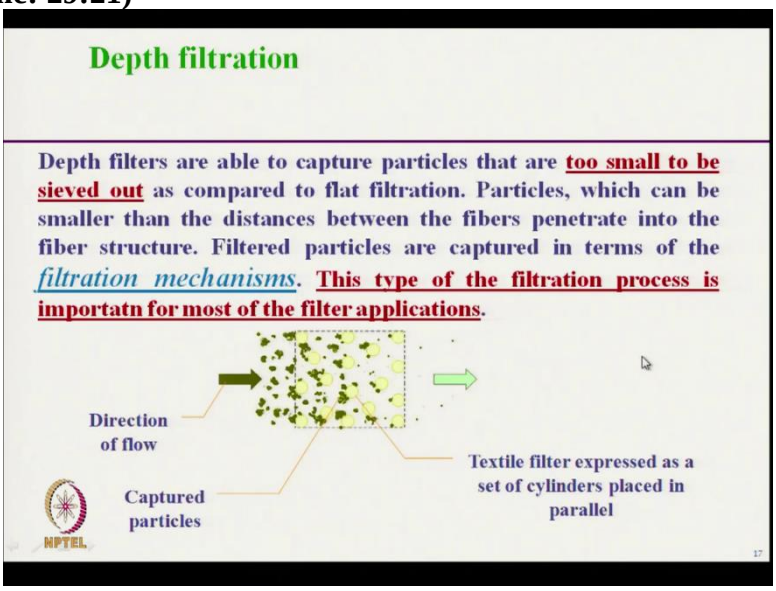

We can see the depth filters are able to capture particles that are too small to be received out. So, in the cake filtration initially, in surface filtration initially the smaller particles are that they pass through the filter medium. But, in depth filtration very very small size of particles are filtered, particles which can be smaller than the distance between the fibres. So, that is the distance between the fibres means the pore size much lower than the pore diameter, the particles can be captured.

So, this capture mechanisms are different they are captured by different mechanism depending on the size of particle, velocity of the stream. So, that I will discuss in detail, this type of filtration process is important for most of the filtration application. So, surface filtration is important, but the application is limited, but depth filtration is actually you can use in wide application areas.

So, this is the direction of flow and particles are captured inside the structure of the filter medium and some of the particles we can see it is coming out. But that can also be arrested. If we change the mechanism, we use if we change the air velocity or if we change the type of fibre that capture efficiency we can change or filtration efficiency we can change.

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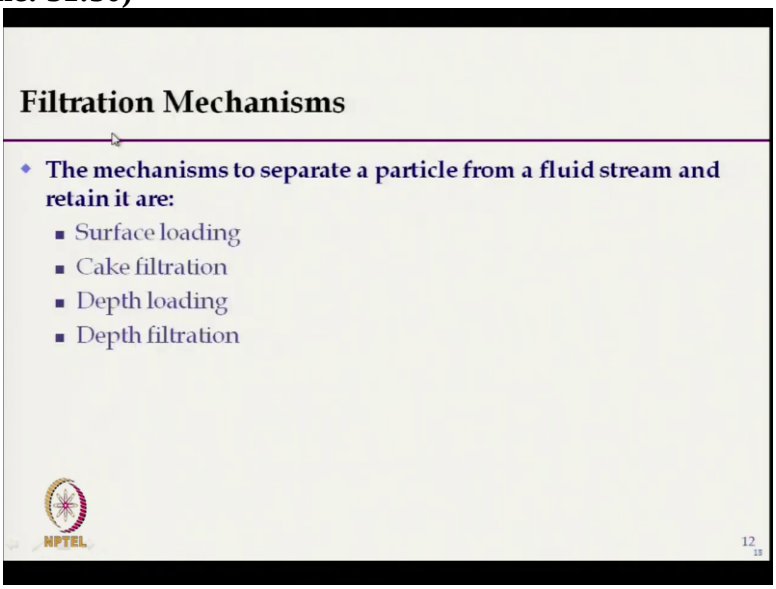

So, filtration mechanisms are so, surface filtration and depth filtration. There are of 2 types and surface filtration, the mechanism follows this surface loading and cake filtration. So, as I have already mentioned, surface loading means the particles the larger particles will be loaded initially on the surface and the cake will form gradually and the cake will actually cake will act as extra filter medium. Now, let us see suppose we are trying to use the filter mesh made of monofilament.

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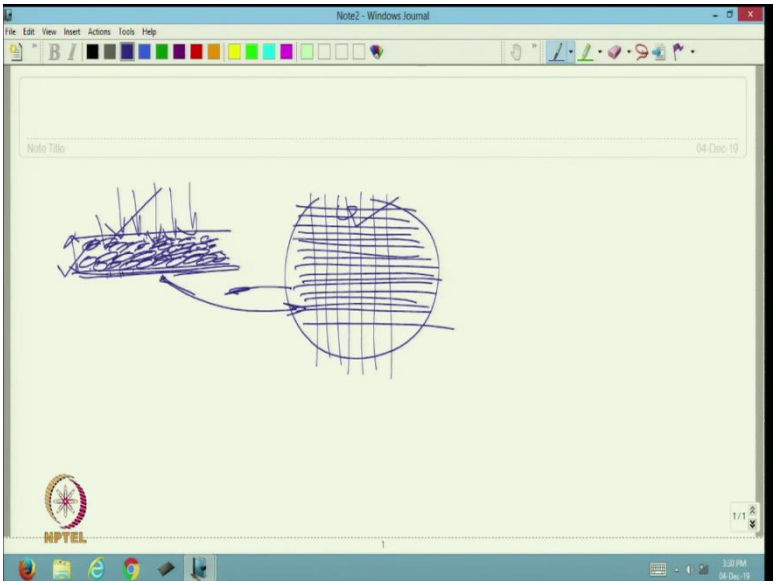

Nylon monofilament filter mesh we are using, ok. These are the filter mesh here the, it has got certain size initially, and I am drawing the side view, initially there will be surface load with the larger particles and gradually there will be cake formation with a certain thickness of the cake. This is the cake and this is the fabric, filter fabric and cake formation and finally, this cake will act as actual filter and this fabric that mesh will act as a support of the cake. So, this is called cake filtration process.

So, cake filtration takes place and very thin mesh first surface loading will be there then there will be cake filtration on the other end, if we see the depth filtration, depth filtration also has got 2 stages. First, there will be depth loading and then depth filtration.

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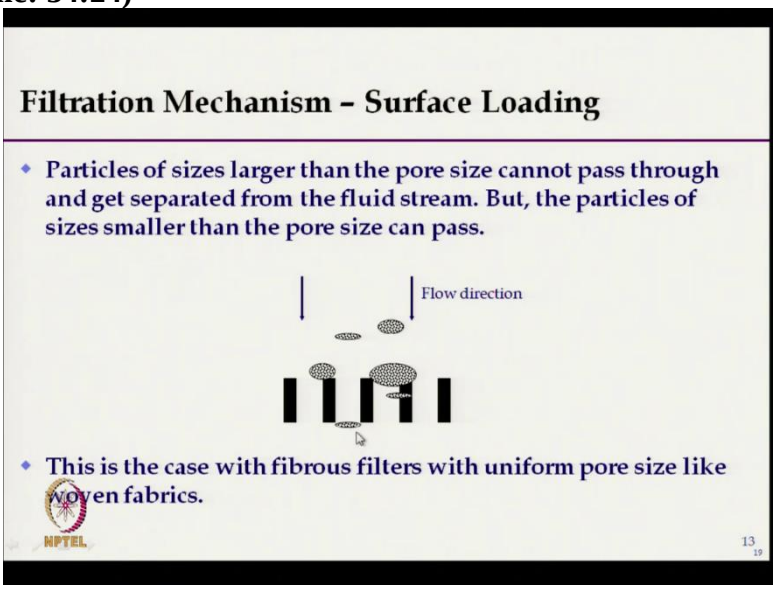

So, this is the surface loading, the smaller particles are actually passing through the pores and larger particles are arrested here and gradually there will be surface loading thus the surface will be loaded with the particles.

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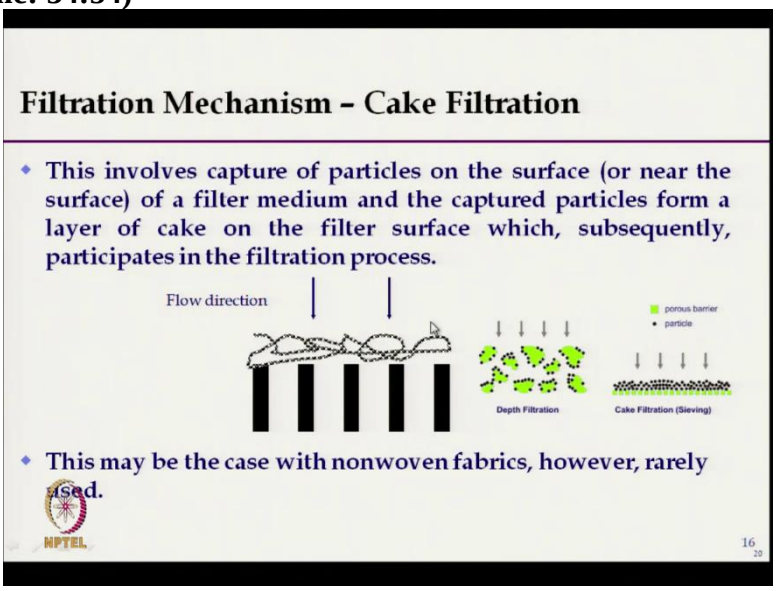

May be smaller medium even gradually the all the particles will be loaded on the surface and this will form one cake surface cake and here this surface cake will act as additional filter medium.

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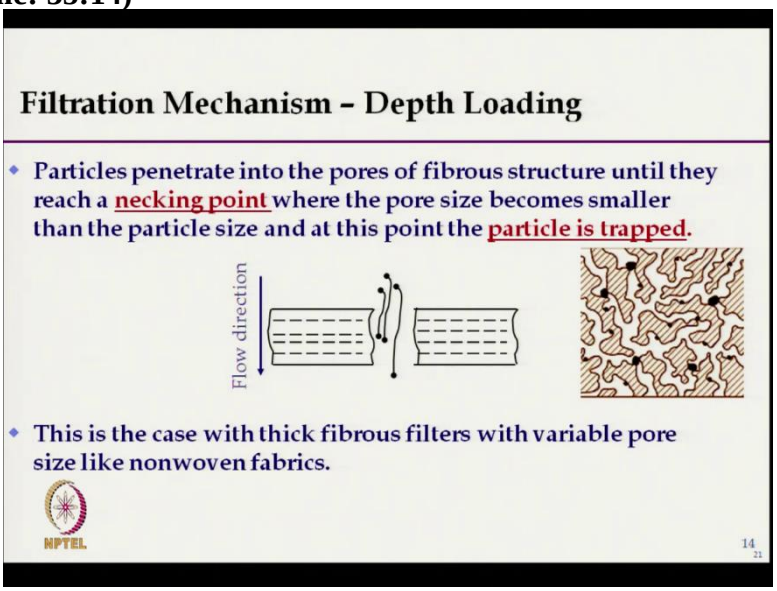

But if we see the depth filtration, in depth filtration there will be depth loading. So, in any nonwoven filter medium, we cannot expect that the pores are straight in nature.

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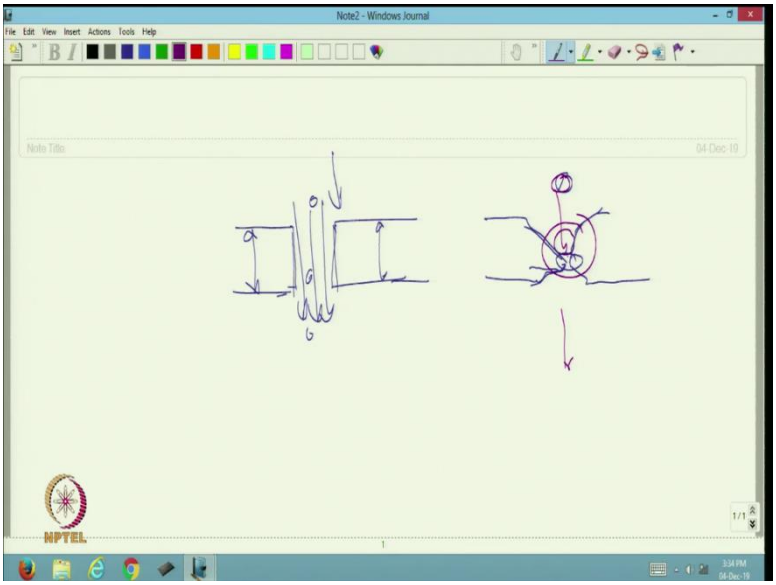

Now, we cannot expect this type of pore in any nonwoven fabric where the pores are straight or defined and the particles are passing through. So, in this type this type only can happen in case of woven fabric and spunbond fabric and nonwoven fabric with high thickness definitely there will be a point where the pores are becoming narrow this is called necking point. So, in this place once the particle is moving the particle will get trapped at the necking point. And we will get separated from the air stream.

So, first there will be a necking point and there at this point the particle will get trapped. So, necking where the pore size becomes smaller than the particle size and at this point particle is trapped, so, these are the different necking points where particles are being trapped and this is only possible in case of thick fibrous filter medium. So, fibrous filter medium the main advantage is that the dimension of filter, dimension of pores are not uniform there are variable pores. And this can be, it is possible only in case of nonwoven fabrics.

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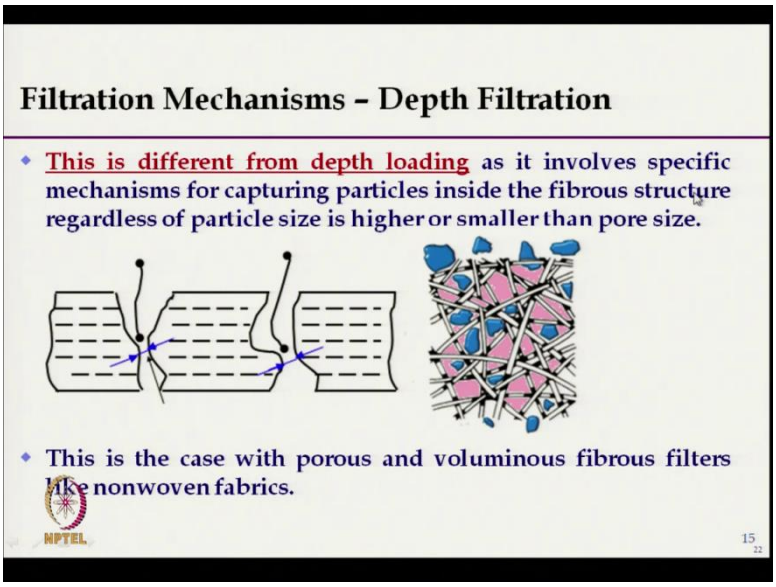

And depth filtration means, at the necking point the depth loading is there and after that, once they are getting trapped, they will get separated. So, this is different from depth loading. So, depth filtration is different from depth loading as it involves specific mechanism. Now, we have to understand the difference between depth loading and depth filtration. So, what we have discussed earlier, this is called, at the necking point, it is depth loading.

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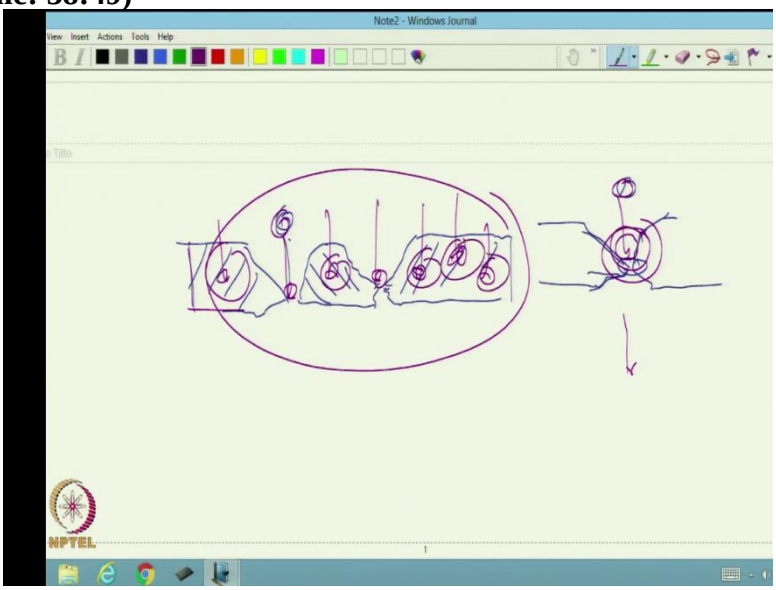

So, if we see so, this is the nonwoven fabric, the particle will be trapped at this point. Similarly, there will be different places where particles will get trapped. So, this is depth loading. So, at different points inside the structure of the nonwoven fabric, the particles will get trapped, but this is entirely different from depth filtration. So, loading is there which is totally physical in nature. But the depth filtration involves specific mechanism depending on

the size and the velocity, the capture mechanisms are there different capture mechanisms are there, which is actually known as the depth filtration.

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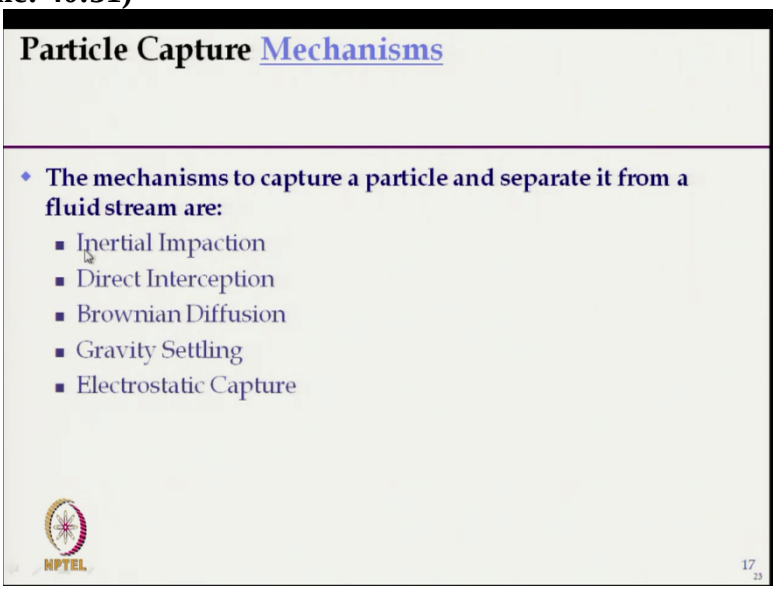

So, what are the capture mechanisms in case of depth filtration, So, what are the capture mechanisms? In case of depth filtration, there are mainly 5 different capture mechanisms. So, through which particles are being captured during the passage through a thick, porous medium thick nonwoven filter medium, these mechanisms are inertial impaction, direct interception, Brownian diffusion, gravity settling and electrostatic capture. So, these are the different capture mechanism. I will discuss one by one in detail.

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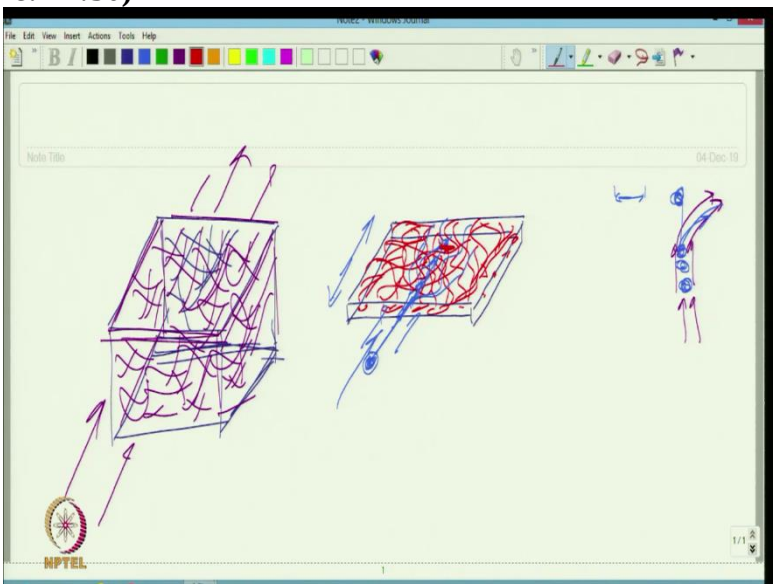

Now, let us see one nonwoven fabric this a nonwoven fabric, say a unit of nonwoven fabric. Now here if you see the fibres are these are the fibres randomly and we can see it says this is say a needle punched nonwoven. So, one unit cell of little pass nonwoven now if we take

slice of one portion top side. So, air is flowing from this direction and coming out from this direction, particles are flowing from this direction.

So, let me draw a small thin slice of single fibre layer, a slice of single fibre layer. Now, so these are the fibres, red colour I am drawing fibres. These are the fibres randomly oriented, having different pore structures, these are the fibres different fibres. Now, a particle which is say shown by this blue color, one particle is moving, this is a particle, it is trying to move through this thickness, this is the thickness of the fabric.

This particle when it is moving at very high speed with the along with the air it penetrated in this smaller size particle it and this particle size is smaller than the distance between average distance between the fibre. So, this small particle that has penetrated inside it is trying to flow through the along with the air. Now, air will try to take its own path depending on the space available, where there is opening space air will try to take that path, but this particle as it is relatively larger in size, this will not follow the air path.

So, suppose this is particle and this is air is moving, it is moving with air. So, air is moving, suddenly air is taking this start. But the particle once it is moving at high speed, this has got certain inertia, this will not bend with the air this will try to move straight in the path, this will follow its own path due to its inertia. So, as it is not the following the air path, why air has taken a different path? Because there was some obstruction, obstruction of what obstruction of fibre.

So, suppose at this point there is a fibre present. So, air was obstructed, and it has flown in other direction, but, the particle the particle did not follow that path, it has actually collided with the fibre surface and it has lost its energy and got settled at that point. So, this is this mechanism is known as inertial impaction. So, it has impacted due to its inertia.

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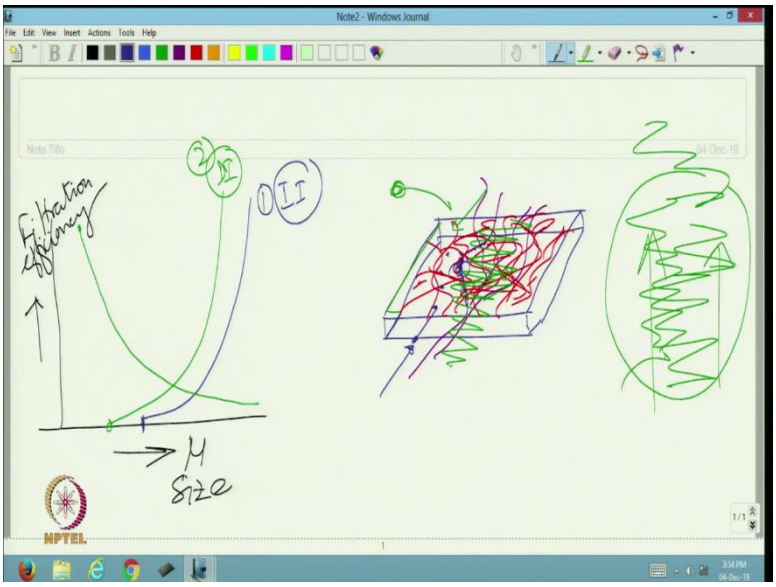

So, this inertial impaction if we try to plot this is particle size micron, this is filtration efficiency. So, the inertial impaction takes place at certain particle size, if the particle size is less, this inertia will also be less. So, inertia will not be. So, this inertial impaction this technique will not be this mechanism will not be followed there. And as we keep on increasing the particle size this inertial impaction will be more and more and the chances of particle getting captured will be more.

So, that is why, so, for certain size so, this will be typically this type of filters. This is the inertial impaction one. So, inertial impaction. Next technique is called direct interception. So, again, let me draw once again. So, again I am drawing one thin slice of fabric. These are the fibres. Now, when the fibres are aligned in random direction and air loaded with a little bit smaller size particle. So, in this at present the particles are smaller in size.

And air is say moving through the material through the filter media at different directions as depending on the available space, as the particles are smaller than earlier one smaller size these particles will have less inertia. So, they will try to bend along with the air. So, these particles will not move in straight path, like earlier case, here the particles will follow the bent path along with the air, but during this bent path, suppose this is a particle, one particle this particle is moving along with this air.

So, during this longer path, there will be one place where the distance between 2 fibres are less than this diameter or the size of this particle. And at that necking point this particle will get captured. So that is called direct interception it will get intercepted directly on the, that

making point that point. So direct interception. So direct interception takes place only in case of smaller particles smaller than the inertial impaction.

But the probability of getting this type of particles capture will increase with the increase in size of the particles. So, again for inertial, so direct interception, it will start at the little bit early the at lower particle size, but with the increase in size the chances of the particle getting captured will increase. That is called direct interception, second. Third one is Brownian diffusion. What is Brownian motion?

So, Brownian diffusion takes place due to Brownian motion of the particle and when it is diffused from one surface to another surface during that movement. So, Brownian diffusion is that when the particle moves in random Brownian motion at different direction randomly it moves, but it can only happen in case of very fine particles. If the particle size is very fine, then the chances of Brownian motion will be high and as the particle size increases the Brownian motion will get reduced.

So, suppose this is a very small particle, this particle moves in this fashion during its path and due to this random path, there will be a particular point where this particle will strike the fibre surface and get settled on the fibre surface. And this Brownian motion the chances of Brownian motion reduces with the increase in velocity of air stream. So, Brownian diffusion can only take place where we have very low air velocity and the size of particles are very small.

So, at very smaller size particles at this point, the efficiency will be high but as we keep on increasing the size so, the effect of Brownian diffusion will be less. There are other techniques, other mechanisms that gravity settling means the heavier particles due to its mass, due to its weight, it will get separated from the air stream and will get settled. And electrostatic capture means if you charge the fibre or if you charge the filter medium.

So any particle which is charged in opposite charge by opposite charge, this will get attracted and settled on the fibre surface or filter medium. So, these are the different filters and mechanisms. In next class, I will discuss in detail of all these mechanisms and what are their applications. Till then thank you.