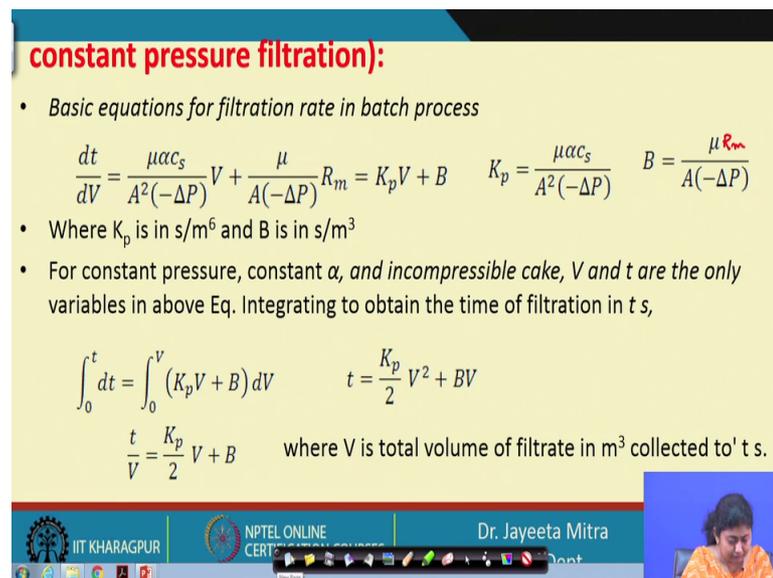**Fundamentals of Food Process Engineering**
Prof. Jayeeta Mitra
Department of Agricultural and Food Engineering
Indian Institute of Technology, Kharagpur

Lecture - 43
Mechanical Separation Techniques (Contd.)

Hello everyone. Welcome to NPTEL online certification course on Fundamentals of Food Process Engineering. We are discussing about Mechanical Separation Technique since the last 2 classes, and today also we will continue with the same topic. So, in the last class we have seen the filtration mechanism, the principle behind calculation of the pressure drop through the filter cake and the filter medium ok, and what are the important factors that going to affect the rate of filtration in a process ok. And, today we will see few more cases of filtration and also we will solve a few problems on that.

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So, let us start. First we will discuss now that constant pressure filtration. So, we have seen normally that the pressure may change because of the deposition of the cake on the filter medium. So, if you know the deposition increases so; obviously, the pressure drop will increase ok.

Now, if the pressure drop increase that will going to affect the rate of flow. So, 2 cases may occur, either the rate we want to make constant ok, or we want to make the pressure drop constant ok. So, both the cases what will be the method of analysing the parameter

of the cake and also the filter media that we will see.

So, first we will see the constant pressure filtration. In that, we will start from the basic equation of you know basic equation for rate of filtration that we have calculated that was our linear velocity. So, that that equation if you remember that was v that is equal to dV by dt divided by A that is equal to minus delta P, delta P includes both P c that is pressure drop through the cake, plus delta P f that is pressure drop through the medium divided by there was ok. So, there was mu into alpha c s into mu into alpha c s into V by A, plus there was mu into R m. This was the equation.

Now, what we did here is that we have reverse this equation. We have taken A this side ok. So, it has become A square here A square into delta P. So, this A and this A is coming with this delta P. So, we are getting A square into minus delta P into V plus mu into R m divided by A into delta P. So, we have reverse this equation in terms of dt by dV now, and have taken this A to the other side and finally, we got this equation that is dt by dV, that is equal to mu alpha c s by A square minus delta P into V plus mu into a mu divide by A into minus delta P R m ok. And this we have further simplified in the form of K p into V plus B.

Now, it has been interpreted as dV amount of filtrate has been passed through the filtration system in dt time through the cake as well as through the filter medium. A is the cross sectional area of the filter medium. Mu is the viscosity of the filtrate. Alpha is specific cake resistance of the cake that has been deposited; c s is the c s is kg of the solid present per meter cube of the filtrate. Capital V is the volume of filtrate that has been pass through in time t minus delta P is the total pressure drop across the flow line that is through the cake plus the filter media and R m is the resistance of the filter media.

Now, we can express this as K p into V plus B. So, K p will be mu into alpha c s by A square minus delta P. Similarly, B will be mu divided by A minus delta P. So, K p the unit of K p will be second per meter to the power 6 and the unit of B is second per meter cube. Now, for constant pressure, constant pressure constant alpha that is specific cake resistance we need to have constant and incompressible cake, because if it is compressible then; obviously, the pressure will not be constant. So, that is why we consider that incompressible cake. Capital V that is the volumetric slow, volume of the flow that has been taken place in time t. These are the only variable in this equation ok.

So, if we want to maintain the constant pressure. So, alpha we need to fix and incompressible cake we have to assume. Only thing V and t these are variable.

So, to integrate this equation to obtain the time of filtration in t second; so, if we take dt and the other side we take dV and we integrate. So, then we need to find that the time of filtration in t, t second. So, for from initial time t equal to 0 to t equal to t dt, that is equal to integration initially at the start when the no volume has been pass through to the final volume V K p into V plus B into dV. So, we are getting the expression as t equal to K p by 2 into V square plus BV. So, this is the time required for constant pressure filtration ok.

Now, we can also represent this in the form of t by V that is equal to K p by 2 V plus B. So, why we want to, you know, expressed in terms of that because in any experiment, when we want to find out that what will be the parameters of K p and V and we have the data only the different t and V different or different volume of the flow that has occurred at different time.

So, getting this kind of expression we can very well get a linear pattern ok. So, if I plot t by V with respect to V; so, we can very well get a linear equation in the form of mx plus c. So, from the slope and the intercept we can have the values of other parameter, that is required here ok. So, this I have already mentioned that the V is the total volume of filtrate that is collected in t second. So, V is in meter cube volume of the filtrate.

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So, then to calculate the time for constant pressure process; where alpha and R m is necessary. Data of the V collected at different time t these are obtained. So, with that I can plot t by V that is s per meter cube divided by V that is filtered volume in meter cube. So, then we can get one straight line, the slope will give us the value of K p by 2 and intercept will give the value of B. And since the K p by 2 and B these are related with alpha and R m, as we have seen in the in the previous equation. So, K p is equal to mu into alpha c s by A square minus delta P.

And B equal to mu into mu divided by A into minus delta P. So, delta P are constant we can get that. So, area is known to us so, then alpha value and here the R m value mu into R m divided by A into minus delta P. So, this way we can calculate now ok. So, this is how for the case of a constant pressure filtration we can calculate the time, and all other parameters like specific cake resistance and resistance due to filter medium.

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Now, coming to the next case that is constant rate filtration; so, when the filtration starts actually, there is a initial stage of filtration. What will happen that it frequently happen, that filter resistance is large relative to the resistance of the filter K. Filter medium resistance is large compared to the resistance of the filter K, because the cake is thin in the initial stage right. So, this condition the resistance offered to the flow is virtually constant, and filtration proceeds at the more or less constant rate.

So, initially when the deposition of the cake is not there, at the onset of this deposition,

that time the resistance offered by the filter media is high compared to the resistance of the cake and constant rate of filtration prevails. So, this can be seen as we have taken the same equation that is the related the related to that velocity in terms of dV by dt divided by A that is related with delta P, and mu alpha c s mu into alpha c s into dV by A plus mu into R m. So, that equation we have taken and in terms of pressure drop and V now we have plotted this.

So, what we are getting? We are getting that minus delta P equal to mu alpha c s by A square into dV by dt into V plus mu R m by A into dV by dt. This is equal to we can write it in terms of K V into V plus C; where K V is mu into alpha c s by A square into dV by dt, and C is equal to mu in to R m by A into dV by dt. So, K V the unit is in Newton per meter to the power 5, and C unit of C is Newton per meter square.

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So, for incompressible cake K V and C are constant characteristics of the slurry for incompressible cake. For incompressible cake K V and C are constant characteristics of the slurry and cake, rate of filtrate flow and so on. So, K V and C will be constant for the slurry for the cake and for the rate of filtrate.

Now, a plot of pressure that is delta P versus the total volume of filtrate collected that is V gives a straight line. So, in the previous case when we have plotted the constant pressure filtration, that time t by V was only the variable. So, t by V was plotted with V now since we are dealing with the constant rate filtration. So, pressure drop varies here

with the volume V. So, that we are plotting now to get a straight line ok.

So, for a for a constant rate since dV by dt will be fixed. So, the slope of the line as K V and the intercept is C ok. The pressure increases as the cake thickness increases, and the volume of the filtrate collected into this. So, with that the pressure will increase, and the equation can also be rearrange in terms of delta P and time t; as we have done for the delta P versus V, we can calculate delta P and t as variable. And any moment during the filtration, the total volume V is related to the rate and the total time t by the following equation.

So, V equal to t into dV by dt. So, rate of filtration into time, that will give us the total volume of the filtrate that has been pass through. And minus delta P into mu into alpha c s by A square into dV by dt whole square into t, just we have replace that V with this expression. And mu into R m by A into dV by dt. So now, delta P with respect to t we can plot ok. And here the specific cake resistance is not a constant.

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So, here we will solve one problem which is based on the constant pressure process. So, the data for a slurry in water. So, it is slurry in water at 298.2 Kelvin that is 25 degree Celsius. These are reported as follows at a constant pressure process; where the pressure was 338 kilo Newton per meter square. So, 338 kilo Pascal this was constant.

The filter area of the plate and frame press was a 0.0439 meter square, and the slurry

concentration was c s that is kg per meter cube, that was 23.74 kg per meter cube. Calculate the constant alpha and R m. So, specific cake resistance and filter media resistance; from the experimental data given where t is in time in second ok, in second and V which the filtrate volume collected in meter cube.

So, let see first what is the data given. So, here is the data so, we are getting as we have we have already know that for the constant, pressure process pressure is constant only the variable is time t and volume V collected at that time. So, these data we are having starting from 4.4 second to 107.3 second and V varies from 0.498 into 10 to the power minus 3-meter cube to up to 5.009 into 10 to the power minus 3 ok. So, this is the data, then what we need to do is for the solution?

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Solution:
First, the data are calculated as t/V and tabulated in Table.

The intercept is determined as $B = 6400$ s/m³ and the slope as $K_p/2 = 3.00 \times 10^6$ s/m⁶
Hence. $K_p = 6.00 \times 10^6$ s/m⁶
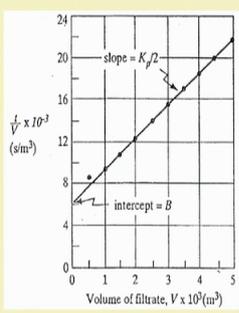
t	$V \times 10^3$	$(t/V) \times 10^{-3}$
0	0	
4.4	0.498	8.84
9.5	1.000	9.50
16.3	1.501	10.86
24.6	2.000	12.30
34.7	2.498	13.89
46.1	3.002	15.36
59.0	3.506	16.83
73.6	4.004	18.38
89.4	4.502	19.86
107.3	5.009	21.42

Plot t/V versus V

First, this is t, this is V, we need to have the data of t by V ok, because the equation for straight line if you want to make we need to plot t by V with respect to V. So, t by V we have calculated this is t by V into 10 to the minus 3, this is the data. Next is we need to plot this, t by V versus V. So, here in our x axis volume of the filtrate V into 10 cube that we have plotted.

And in the y axis we have plotted t by V into 10 to the power minus 3. So, this is t hat now we are getting a straight line. So, from that the intercept is calculated B, that is equal to 6400 second per meter cube. And the slope that is K p by 2 so, K P by 2 is 3.00 into 10 to the power 6 second per meter to the power 6. And K p we are getting 6 6.00 into 10 to

the power 6. Now, we have calculated that K p and B.
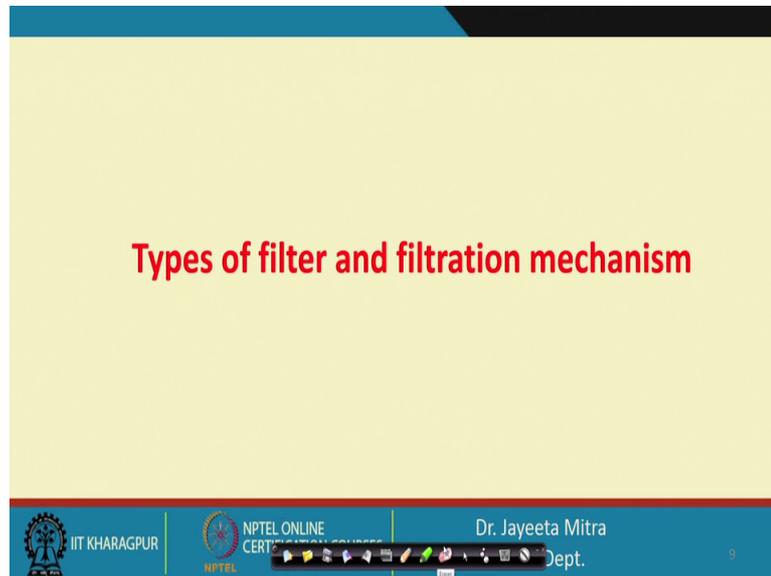
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Then what is the condition? Given that at 298.2 Kelvin the viscosity of the water we need to use. So, this we can get from chart if not given in equation. So, this is 8.937 into 10 to the power minus 4 Pascal second. So, we need to substitute this data, this is the value of mu, we need to substitute into this 2 equation. We know the expression of K p and B, K p is mu into alpha c s by s square into delta P, mu is this one that is the viscosity at a particular temperature at what temperature the flow is occurring; so, that we can take from the chart.

Alpha we need to find out specific cake resistance; c s is given, area given, delta P given which is constant. Here also this will be mu into R m by K minus delta P. So, mu is given A is given delta P given R m we need to find. So, we will put this data. So, K p is equal to 6 into 10 to the power 6 that is equal to mu alpha c s by A square minus delta P. So, mu is 8.937 into 10 to the power minus 4 Pascal second alpha into c s 23.74 kg per meter cube. By area is 0.0439 meter square so, this square and delta P is 338 into 10 10 to the power 3 this is given in kilo Pascal in the equation we are putting in Pascal so, this is.

Then next is alpha which is 1.863 into 10 to the power 11 meter per kg, that we are getting from this expression. After that we will put the value in the form of B, that is 6400 into mu into R m by A minus delta P. So, mu is given R m we need to calculate this is given. So, what is the value of R m now, R m is 10.63 into 10 to the power 10 per
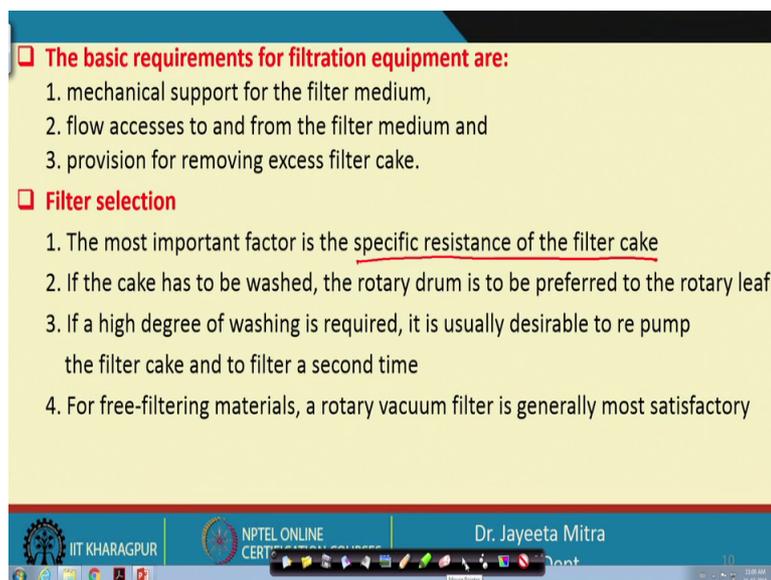
meter. So, from a constant pressure process now we are able to calculate the specific cake resistance, specific cake resistance and also the filter media resistance from the time and volumetric flow data.

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Now, next is types of filter and filtration mechanism.

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Now the basic requirement for filtration equipment are what are the things needed. First is the mechanical support for the filter media. Flow axis to and from the filter medium, and provision for removing the excess filter cake. And filter selection what will be the

basis of selecting the different kind of filter. The most important factor as we know is specific cake resistance, ok.

So, if the cake has to be washed, the rotary drum is to be preferred to the rotary leaf. So, rotary drum is better and if a high degree of washing is required. It is usually desirable to re pump the filter cake and to filter a second time. For free filtering materials rotary vacuum filter is generally most satisfactory.

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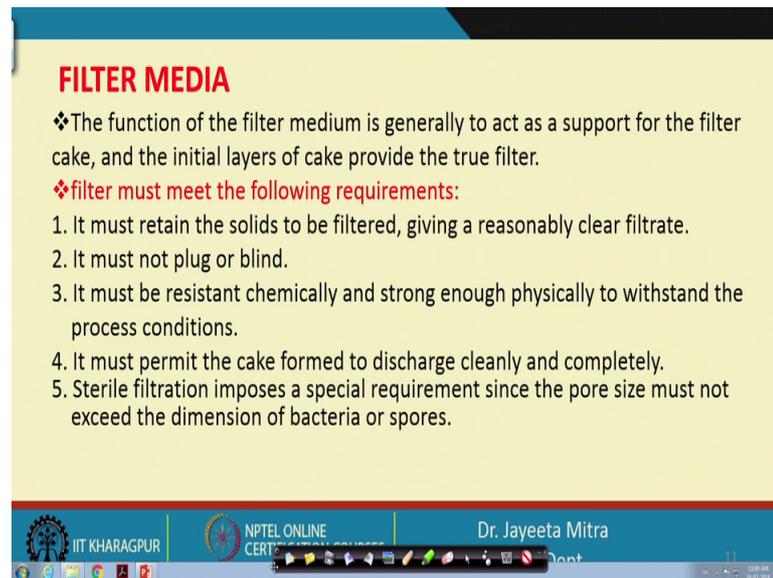
And filter media the function of the filter medium is generally to act as a support for the filter cake and the initial layer of the cake provide the 2 filter. So, filter must meet the following requirements, that is it must retain the solid to be filtered; giving a reasonably clear filtrate. It must not plug or blind that is the particle of the slurry should not clog the force of the filter medium.

It must be resistance chemically; that means, it should not react with the slurry which is coming on onto it and strong enough physically to withstand the process condition. It must permit the cake formed to discharge cleanly and completely, and sterile filtration imposes a special requirement since the pore size must not exceed the dimensions of bacteria or spore. So, these are the requirement.

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And what is filter aids? The object of the filter aid is to prevent the medium from becoming blocked and to form an open porous cake. So, reducing the resistance to flow of the filtrate ok because, if the resistance is increasing flow rate will decrease, that is why the particle must be inert insoluble incompressible and of regular shape.

Filter aid for example, the diatomaceous silica perlite wood cellulose or other inert porous solid are used as filter aids. And filter aid may subsequently be separated from the filter cake by dissolving away the solid or by burning out the filter aid; is solids have no value they and the filter aid are discharge together. So, because filter aids are getting mixed up with the solids or the deposition; so, both are discarded if it if they are not required if the solid cake is not required.

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So, filters are divided into 3 main groups. Cake filters clarifying filters and cross flow filters. The features if we look into the surface filters are used for cake filtration in which the solids are deposited in the form of a cake on the upstream side of relatively 10 filter medium. And K filter separate relatively large amount of the solid as a cake of crystal or sludge as illustrated. Now, the filter medium has a relatively low initial pressure drop in this particular cake filter case.

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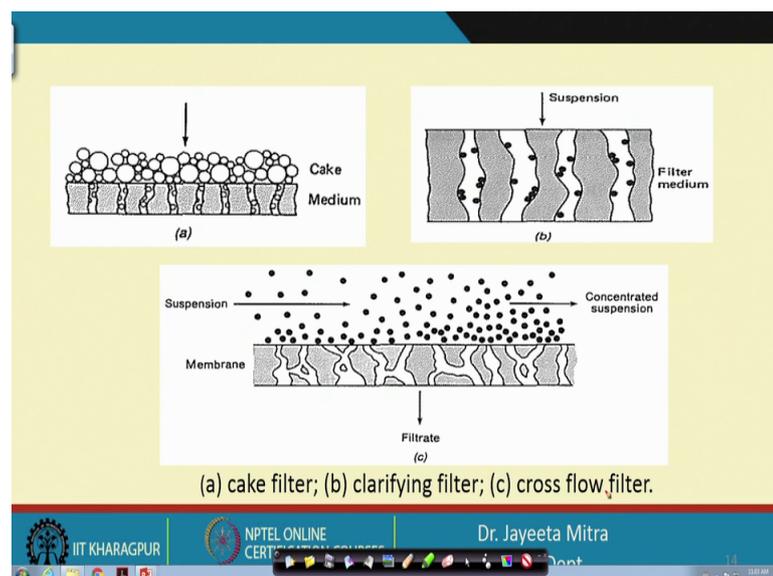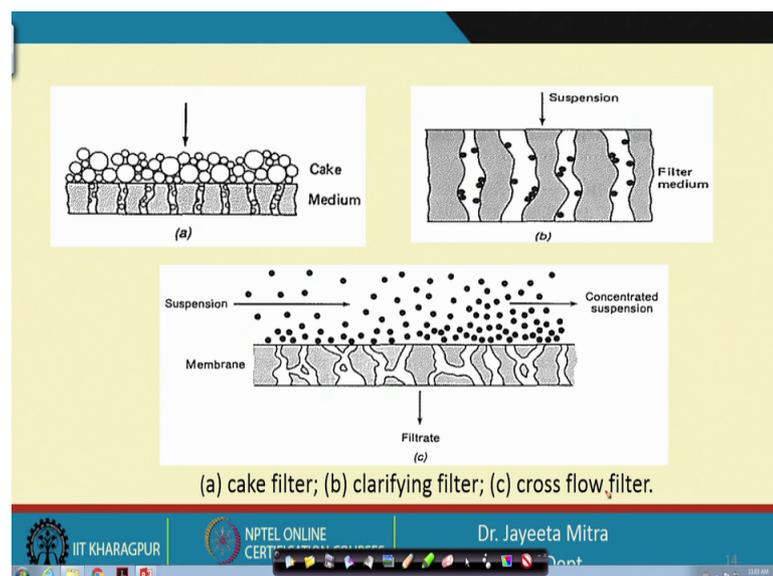
So, here we can see that the cake medium that is are pores are very small all the particle

will form a cake initially on the on the filter media. And the second case which is clarifying filter here the pores are generally big and small particles will come down through the floor easily, come down to the perforations of the filter medium very easily.

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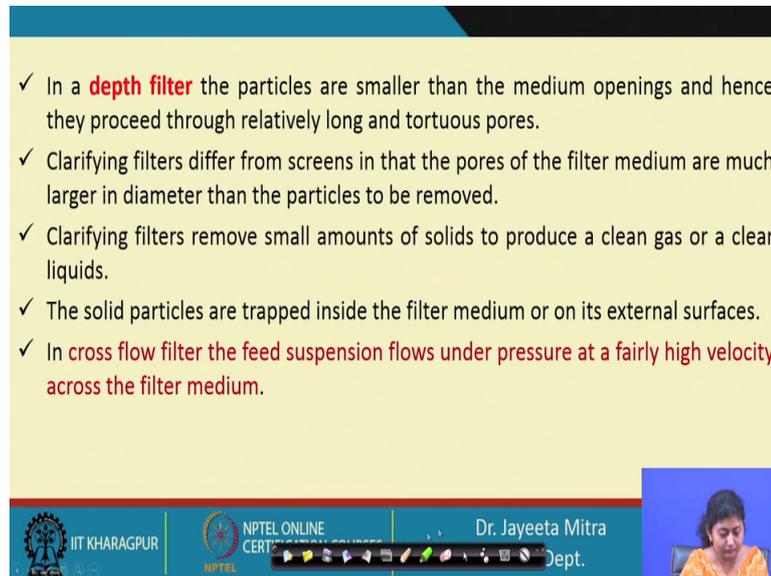
And third is the case of the cross flow filter; so, in our depth filter the particles are smaller than the medium opening, and hence they proceed to the relatively long and tortuous pore. So, that we have seen in the clarifying filter case. And they differ from the screen in that the pores of the filter medium are much larger in diameter than the particle to be removed. In case of screen we have seen that the particle which has pass through we assume that the diameter equivalent diameter of the particle is just like the just equivalent with the screen opening size ok. That is the equivalent diameter of the screen opening.

But here the particle are very much smaller than the size of the openings or the perforations. And, clarifying filters remove small amount of the solid to produce clean gas or clear liquid. The solid particles are trap inside the filter medium or on its external surfaces. In cross flow filter the feed suspension flows under pressure at a fairly high velocity across the filter medium. So, we will stop here and we will continue in the next class.

Thank you.