Lec 29: Dead-End and Continuous Filtration

Hello everybody. Welcome to this massive open online course on solid fluid operations. As we are talking about the filtration process in the previous lecture we have given some fundamental or basic principles of filtration. What are the different types of filtration process? What are the basic components of the filtration process? And based on that material characteristics and also pore size, what are the different types of membranes are available for the filtration? And what are the different configuration of the filtration that we have discussed also? We have discussed about the governing equation of the filtration that operation based on that driving force of pressure. So here in this lecture, again we will try to understand the dead end and continuous filtration process where you will see that some special type of equipments are being used to segregate or separate the particulate materials from the slurry. Specially you will see that those who are muddy water specially for the waste water treatment or in simple water treatment process in the basic operation in the beginning of that separation of the particulate materials from the water.

So there actually this filtration process is important and for that special type of equipment that I told it is generally as a name it is called plate and frame filter press. And this equipment has been used continuous operation in the industry as well as for the testing of that filtration efficiency in laboratory scale also in different institute they are using in chemical engineering department as a laboratory component. So here we will try to understand that filtration process by membrane where a special things is that based on that driving force of pressure drop how that filtration can be obtained. So before going to that as we have already talked about that operational modes of filtration by membrane are generally two operational modes for that membranes can be used.

These are like dead end filtration. Here in this case the membrane permeate passes through it all the particles are retained in the membrane. Whereas another type of mode it is called that cross flow filtration where the feed flows tangentially to the membrane and permeate passes through only a fraction is converted through membrane and also it will be coming to that permeate product. So in this case we are having these two operational mode. You will see that plate and frame filter phase is one type special design of that equipment for that separation process based on this dead end operational mode.

So in this case you will see that in the picture in the slide it is shown that here that plate and frame filter phase. You will see that here already we have discussed that this type of plate and frame filter phase there will be some plate and there will be a frame and in the frame with that plate supported there will be a cloth attached with that and cloth will be used as a membrane and whenever the subsequent such plate and frame with cloth will be attached and pressed by that certain pressure. You will see that solid particles will be retained on that cloth surfaces whereas through the pores of that cloth that means membrane the water or that means the except solid particles will be coming out and it will be separated. So this is the basic mechanism of that plate and frame filter phase by which you can separate that solid particles. Whereas whenever that under pressure that solid particles would be retained on that cloth there will be a formation of cake by depositing that solid particles.

So that cake itself will be working as a porous media where that some other solid particles of fine particles can be retained on that cake and continuously depositing that particles on that cake and then thickness of that cake will be increased and also resistance of that membrane will be keep on increasing there. So in this way you can get that separation of the particulate material from the slurry just by compressing that plate and frame along with that filter cloth there. So here it is seen that one plate and frame filter phase where you will see that subsequent n number of or series of plate and frame with that cloth attachment is procured in this equipment and separately you can see also these are plate and here also some frame it will be there and in that frame there will be cloth will be attached to that like this here see that cloth that will be as a membrane it will be attached. So what is the basic function of that here under this pressure you will see that this plate and frame with cloth it will be coming to each other and there will be a fresh and based on which you will see that the feed materials whenever it will be passed through that only solid materials will be retained on that cloth whereas that clean except the solid particles will be coming out through this that is shown in yellow color whereas the feed made feed slurry is shown in the green color like this. So here you will see that the separation how it is being happened here and this blue portion is basically the filter gate.

So in this way you can separate this solid particles from the slurry. So we can say that the slurry separated into its base liquid and the materials which will be under pressure to be separated and then it will be dried and then assessed for that how much solid materials it is actually filtered there. Once the slurry is fully loaded in the chamber you will see that a hydraulic pump applies to compress that plates which expels the excess fluid and forms a dry cake on the plate. That dry cake will be discarded after that operation. As the cake builds up on the plate surface the fine particulates are removed from the process fluid there.

So in this way this plate and frame filter press works. Now to assess this plate and frame filter press for separation of that particulate material from the slurry you have to have some governing equation or what will be the general membrane equation by which you can assess that filter process. So the general membrane equation for determining that permeation rate for the pressure driven processes can be written by this equation number 1 here where J will be is equal to delta P divided by mu into R m plus R c.

Here the Equation

$$J = \frac{\Delta P}{\mu(R_m + R_c)}$$

Here J is called membrane flux that is expressed as volumetric flow rate per unit area and delta P is basically the pressure difference applied across the membrane and this pressure difference is basically the contribution of that filter cake as well as that filter medium pressure. So these two components of that pressure will be contributing this total pressure of delta P that already we have discussed in the previous lecture and then R m is the resistance of the membrane and R c is the resistance of the deposited particles layer which is called as a cake.

So we can say that resistance of the cake here okay and it is called cake resistance and mu is the viscosity of the liquid and the one important point that you have to remember here that for micro filtration and ultra filtration membranes where feed flows laminarly through tortuous channels through deposited cake. So through that deposited cake you will see that fluid will be flowing as like that channel flow like that because there will be a tortuous path as a channel through that cake that means the void you can say that channel void you can say. So through that channels that liquid will be flowing as a laminar flow. So the overall pressure drop at any time that will be contributed by the pressure drop over medium and cake. So that is why you can write here delta P will be equal to P a minus P b here total pressure which is coming as P a minus P dash

Here the Equation

$$\begin{aligned} \Delta P &= P_a - P_b \\ &= (P_a - P') + (P' - P_b) \\ &= \quad \Delta P_c \quad + \quad \Delta P_m \end{aligned}$$

what is P a here it is shown in the picture that P a is here this one side of this membrane and another side of this membrane as P b.

So here P a minus P b that will be your total pressure and this P a minus P b can be contributed as P a minus P dash P dash is basically that interface between that cake and the medium. So that P dash so we if we subtract that P a minus P dash that will give you the delta P c that is cake pressure drop or pressure drop due to the cake deposition and then P dash minus P b is basically that delta P m this is pressure drop that is contributed by the filter medium that is by membrane. So here it is shown in the picture how it is working there. So in this case we can have this P a the inlet pressure P b is the outlet pressure P dash is the pressure at the boundary between cake and medium and also delta P is the overall pressure drop delta P c is the pressure drop over cake delta P m is the pressure drop over medium. Here in this picture it is shown that there will be certain distance d L of that cake based on which you can assess what will be the pressure drop upon this d L distance and total distance of the cake is given even total distance of this total filter and cake it is given by L c and L respectively.

And here you will see that what is the filtrate is coming at what rate that filtrate would be coming that would be considered as a Q as a flux also. Now in the filtration flow resistance increases with time as the filter medium becomes clogged or that filter cake will be builds up. So whenever filter cakes will be build up with respect to time there also you can say that resistance will be increased. So as time passes during filtration either the flow rate diminishes or the pressure drop rises. So in that case whenever cake will be deposited with respect to time their pressure also keep on increasing with respect to time.

So in this case we can have two types of things either increasing the flow rate with respect to time or increasing the pressure drop with respect to time or you can operate at a constant flow rate or you can operate this filtration process at constant pressure. So there are two types of filtration can be done by this plate and frame filter pressure. One is called constant pressure filtration where pressure will remain constant whereas flow rate allowed to fall with respect to time and constant rate filtration that is the flow rate will remain constant whereas pressure drop progressively increased with respect to time. So these are the two you can say way that you can operate or you can execute this filtration process here by this plate and frame filter pressure. Now whenever that cake will be deposited or particles will be deposited and forming a layer of cake they are that cake pressure how you can calculate as already we have discussed earlier in the lecture that pressure drop over cake by Kozeny-Carman equation you can predict or you can calculate.

So that is given here in equation number 3. So dpc by dl that will be equal to 4.17 mu u into 1 minus epsilon whole square into sp by vp whole square divided by epsilon cube or you can calculate by this equation number 4

Here the Equation

$$\frac{dP_c}{dL} = \frac{4.17\mu u(1-\varepsilon)^2 (s_p / v_p)^2}{\varepsilon^3}$$

Or here dpc by dl that will be the 150 mu u into 1 minus epsilon whole square divided by phi s dp square into epsilon cube

Here the Equation

$$\frac{dP_c}{dL} = \frac{150\mu u(1-\varepsilon)^2}{(\Phi_s d_p)^2 \varepsilon^3}$$

where dpc by dl is basically the pressure gradient over cake at thickness l and mu is the viscosity of the filtrate and u is the linear velocity of filtrate based on that filter area. This is linear velocity or superficial velocity and sp is the surface of single particle and vp is the volume of single particle and epsilon is the porosity of the cake and phi s is the sphericity of the particles. So based on this equation number either 3 or 4 you will be able to calculate what will be the pressure drop over cake by this Kozeny-Carman equation.

Then you have to calculate what will be the linear velocity u which is given by this equation here 5. This is basically dv by dt that will be equal to u into a from which you can calculate u will be equal to dv by dt by A

Here the Equation

$$u = \frac{dV / dt}{A}$$

where v is called volume of filtrate which is collected at the time t and volume of solids in the layer which is deposited that will be equal to dv that will be equal to A into dl into 1 minus epsilon.

Here the Equation

$$dV = AdL(1-\varepsilon)$$

What is epsilon? Epsilon is basically the void fraction that means how much liquid or void except solid out of total volume it is called void fraction and the mass that is dm in the layer which is deposited that can be calculated by equation number 7 where dm will be equal to a into dl

Here the Equation

$$dm = AdL(1-\varepsilon)\rho_p$$

this is the total volume in that particular strip of length and 1 minus epsilon that will be volume fraction of solids. So it will be volume of solid into density of the solid then it will give you the mass of the solid. So mass of the solid in the layer that will be equal to a dl into 1 minus epsilon into rho p.

Therefore, from that equation number 3 of that Kozeny-Carman equation you will be able to calculate what will be the pressure drop after substitution of all values of u, dv and dm like this. So after substitution of that value of u, dv and dm from equation number 5 to 7 into equation number 3 that is earlier equation number 3 is basically here it is a Kozeny-Carman equation. So in this equation if you substitute this u, dm you will be able to calculate what will be the dPc by equation number 8.

Here the Equation

$$dP_c = \frac{k_1 \mu u (s_p / v_p)^2 (1-\varepsilon)}{\rho_p A \varepsilon^3} dm$$

Then if suppose mc is the total mass of solids in the cake from equation number 10 here equation number 10 here after integration we can have like this if mc is the total mass of solids in the cake then from equation number 10 after integration of this equation number

9 we can have this delta Pc by A by mu u mc that will be equal to k1 Sp by v p whole square into 1 minus epsilon by rho p epsilon cube.

Here the Equation

Where you will see that k1 is basically a constant value from this equation number 3 from Kozeny-Carman equation and here once you get this equation number 10 from this equation number 9 then we can define here delta Pc by A divided by mu u into mc as denoted by alpha this will be called as the specific cake resistance.
Here the Equation

$$\Delta P_c = \frac{k_1 \mu u (s_p / v_p)^2 (1-\varepsilon) m_c}{\rho_p A \varepsilon^3}$$

$$(s_p / v_p)^2 = \left(6/(\Phi_s d_p)\right)^2$$

Or

$$\frac{\Delta P_c A}{\mu u m_c} = \frac{k_1 (s_p / v_p)^2 (1-\varepsilon)}{\rho_p \varepsilon^3}$$

This is basically the pressure drop ratio that pressure force by the viscous force and then it will be considered as delta Pc by A delta Pc A divided by mu u mc.

Here the Equation

$$\frac{\Delta P_c A}{\mu u m_c} = \alpha$$

So we can substitute this value of this component in the left side of this equation 10 as alpha so we can write that alpha will be is equal to k1 Sv by v p whole square into 1 minus epsilon by rho p epsilon cube by equation number 13. Also you can substitute this Sp by v p that will be equal to 6 by phi s dp whole square

Here the Equation

$$(s_p / v_p)^2 = \left(6/(\Phi_s d_p)\right)^2$$

which is obtained just after substitution of that single particle surface area by volume of single particle into whole square then it will be is equal to So after substitution of this you can get what will be the alpha value what is alpha?

Here the Equation

$$\alpha = \frac{k_1 (s_p / v_p)^2 (1-\varepsilon)}{\rho_p \varepsilon^3}$$

Alpha is basically the specific cake resistance that means here whenever pressure will be developed by depositing the solid particles as a layer you will see that the pressure drop over that viscous effect and inertia effect of mass deposition that means what extent of that pressure effect will be there on the membrane process that will be regarded as the specific cake resistance. What is the resistance it will come by this cake pressure drop per unit mass of cake. So that is called specific cake resistance.

So here one important point that whatever cake will be depositing on the membrane surfaces particles deposition that cake will be represented as a incompressible that means that cake will not be compressed further. So in that case it will be regarded as a incompressible cake that means here the volume of that cake will not be changing with respect to mass of the cake will not be changing with respect to time or with respect to length also there after a certain time. So in that case for incompressible cake specific cake resistance is independent of pressure drop and position in the cake there. So that is why it is called as incompressible cake. And filter medium resistance they are also another important component here that is regarded as or defined as a Rm which is actually expressed by that P dash minus Pb divided by Mu u that means Delta Pm by Mu u here. Here the Equation

$$R_m = \frac{P' - P_b}{\mu u} = \frac{\Delta P_m}{\mu u} \qquad [1/\text{m}]$$

So as defined already Delta Pm that means pressure contributed by the membrane medium. So that is Delta Pm which is coming as P dash minus Pb as shown in the picture here. And then Delta Pm by Mu u we can define it as medium resistance. So from equation number 12 and 14 after substitution of Delta Pc that means cake resistance pressure drop and you can say that cake pressure drop. So and also that pressure drop of that filter medium from equation number 14 then we can express that equation number here total pressure like here this is the total pressure this equation number 2 we can represent after substitution of Delta Pc, Delta Pm then we can get Delta P will be equal to Delta Pc plus Delta Pm that will be Mu u into Mc alpha by a plus Rm.

Here the Equation

$$\Delta P = \Delta P_c + \Delta P_m = \mu u \left(\frac{m_c \alpha}{A} + R_m \right)$$

Where alpha is already defined earlier that is specific cake resistance and the total mass of the cake can then be defined by Mc will be equal to V into C.

Here the Equation

$$m_c = Vc$$

So here C will be equal to mass of particle that is deposited in the filter per unit volume of filtrate. So in this way that C will be defined. So Mc will be equal to what mass of cake that will be V into C. What is C? C is the mass of particle deposited in the filter per unit volume of filter.

So in that way it will be defined. So we can say that C can be estimated by this equation here C will be equal to Cf divided by 1 minus Mf by Mc minus 1 into Cs by Rho

Here the Equation

$$c = \frac{c_F}{1-[(m_F/m_c)-1]c_s/\rho}$$

where Mf is basically the mass of wet cake and Mc is the mass of dry cake and Cf is the concentration of solids in the slurry in kg per meter cube of liquid fed to the filter and Cs is the concentration of slurry that is basically a Cf that means mass means concentration of feed solution and also Rho is the density of the liquid. So from this you can easily calculate what will be the total mass of the cake. So what we have observed here that that what the total pressure for the total pressure you have to know what will be the cake pressure or pressure drop by cake deposition then pressure drop by filter media. So summation of those can be represented by this equation number 15 where it will be in terms of specific cake resistance and the filter medium resistance.

So from this equation number 15 we can further calculate here. Now the substituting the value of U from equation number 7 and Mc from equation number 16 here equation number 16 Mc is equal to Vc and the velocity is from equation number 5 here. If we substitute that this is equation number 5 instead of 7. Then we can say that dT by dV that will be equal to Mu divided by A into delta P into alpha Cv by A plus Rm.

Here the Equation

$$\frac{dt}{dV} = \frac{\mu}{A(\Delta P)}\left(\frac{\alpha c V}{A} + R_m\right)$$

So in equation number 15 we can substitute from equation number 15 here it will be from equation number 15 then you can have this equation number 17 here.

So it will be here t by V after integration we can have this T by V will be equal to Mu C alpha by 2 A square delta P into V plus Mu Rm by A into delta P.

Here the Equation

$$\frac{t}{V} = \left(\frac{\mu c \alpha}{2A^2 \Delta P} \right) V + \frac{\mu R_m}{A \Delta P}$$

I think you understand it after integration what will be the equation will be stand and then here we can represent this we can represent this t by V that will be aV plus b here.

Here the Equation

$$\frac{t}{V} = aV + b$$

Here a is basically this one represented as ahere this will be a and this one will be as b. So here this is basically a straight line equation t by V that will be aV plus b where A is the you can say that slope of that straight line equation and b is the intercept. So here in this case you have to remember that you have to integrate this equation number 17 with the boundary condition as given in equation number 18 where at time T V will be equal to 0 and delta P will be equal to delta Pm.

Here the Equation

$$\text{BC: } t = 0,\ V = 0 \text{ and } \Delta P = \Delta P_m$$

So based on that we are having this equation number 18 after integration and then after simplification or considering that this coefficient as a and this coefficient as b.

Here the Equation

$$a = \frac{\mu c \alpha}{2A^2 \Delta P};\ b = \frac{\mu R_m}{A \Delta P}$$

So it will be a straight line equation that is equation number 19 and from this straight line equation you will be able to calculate what will be the slope and intercept and this slope and intercept will be estimated based on the experimental data where the volume of that filtrate will be increasing with respect to time or changing that volume of filtrate with respect to time and then how change of volume with respect to time from data t by V versus V and then from that you can fit it as a straight line. So from that straight line you would be able to calculate what will be the slope as a and what will be the intercept as b once slope A that will basically will be equals to mu C alpha by 2 A square delta P that means here and also b will be here intercept like this. So from this slope and intercept you will be able to calculate what will be the specific cake resistance for a constant pressure and what will be the you know filter medium resistance for a constant pressure. So in this way you will be able to calculate the cake resistance and the filter medium resistance.

Now what is that determination process of that cake resistance and medium resistance that already I have discussed here. So still just you see that first of all you have to do the experiment at constant pressure and get the data t by V versus V that means you will be collecting that filtrate at constant pressure during that operation and you will see that keep on increasing volume with respect to time you will get different data and you will calculate t by V then you plot this t by V versus V here and then data will be coming like this as a straight line and then fit this straight line with least error by least square method that is called fitting best fitting method and based on that you will be able to calculate what will be the slope here and what would the intercept here and from this values of slope as A and intercept as B you will be able to calculate what will be the specific cake resistance alpha and what will be the filter cake medium resistance filter medium resistance that can be calculated by these equations. Let us do an example here based on this theory. So it is said that one problem in a constant pressure cake filtration with an incompressible cake layer volume of the filtrate V is measured as a function of time the plot of t by V versus V results in a straight line with an intercept of 10 to the power 4 second per meter cube area of the filter is 0.05 meter square viscosity of the filtrate is given 10 to the power this is minus 3 Pascal second and the overall pressure drop across the filter is 200 kPa what is the value of filter medium resistance here what is the unit of filter medium resistance this will come 1 by meter.

So in this case we are having different data of volume versus time and also we are having that intercept and also we are having that area of the filter and based on which you have to calculate what will be the filter medium resistance of one constant overall pressure drop across the filter of around 200 kPa. So in this case B that is intercept is defined by this equation here given mu Rm by A delta P here intercept is given 10 to the power 4 and mu is given 10 to the power minus 3 and Rm is given here or Rm is to be found out from your problem and here A is given to you whereas delta P the pressure drop is given to you this is in I think kPa so you have multiply 1000 here and then Rm after calculation from this equation you will get Rm value is equal to 10 to the power 11 1 per meter per meter inverse. So I think this problem you can understand how to calculate the filter medium resistance once that intercept and slope. And then another problem here it is said that an aqua suspension forms filter cakes with a specific cake resistance of 4 into 10 to the power 11 meter per kg and what filter area would be required to produce 40 liter of clear filtrate from a 20 gram per liter suspension in 10 minutes. If the operating pressure is 50 kPa take the viscosity of the filter to be 0.

001 Newton second per meter square and assume that the membrane resistance will be negligible. So in this case the basic governing equation for that it is t by V that will be equal to mu C alpha by 2 A square delta P V plus mu Rm by A delta P. So in this case since it is said that the membrane resistance to be negligible so this part will be 0. So remaining part is t by V that will be equal to mu C alpha by 2 A square delta P into V. So from this A will be is equal to like this here as shown in the picture what is the A value.

So after substitution of all variables given in the problem here mu is given C is also given alpha is also given and then t time also given delta P pressure also given. So after substitution of all values and also V value also it is given volume of that you know filtered collected. So after calculation it will be coming as 0.46 meter square. So this area will be required to filtrate that 40 liter of clear filtrate from 20 gram per liter suspension in 10 minutes under operating pressure of 50 kilo Pascal.

Then another important point here that you have to remember so all whatever we have discussed to find out that filter medium resistance and cake resistance also what is the you can say that operational mode whether it will be constant rate filtration or constant pressure filtration. So till now we have discussed that it will be constant pressure filtration. Now suppose if you operate filtration process in such a way that there will be a constant flow rate whereas pressure will be increasing. So in that case you will see that specific cake resistance will be changing with respect to pressure. So if that pressure will increasing with respect to time then cake resistance specific cake resistance also will be changing with respect to pressure.

Now how it will be changed that we do not know. So in that case one correlation can be developed to find out or to predict that specific cake resistance with respect to pressure. So here that relationship of specific cake resistance with the change of pressure can be expressed by this equation number 21 here. So alpha is equal to alpha 0 delta P whole to the power S.

Here the Equation

$$\alpha = \alpha_0 (\Delta P)^s$$

Here alpha 0 is basically an empirical constant. This is an empirical equation correlation you can say like Y is equal to A into X to the power B like this.

Here alpha is equal to alpha 0 into delta P to the power S. Alpha 0 is the empirical constants and S is also a constant but it is called as compressibility coefficient of cake here. So we can say that we can develop an empirical correlations for the specific cake resistance in terms of pressure change with respect to time. Now for that you need some experimental data. You have to have the experimental data of specific cake resistance and also corresponding pressure drop.

Then only after fitting this equation of 21 with those data you will be able to calculate what will be the alpha 0 and S. Suppose from your experimental observation you are having different values of alpha and delta P. At different delta P you are having this alpha value. Suppose here there will be n number of datas. Maybe 10, 1500 datas of delta P and their corresponding specific cake resistance.

After that what you have to do to find out that alpha 0 and S you have to take a logarithm on both sides. Then you will get ln alpha that will be equal to what? ln alpha 0 plus S into ln delta P. Here also you can say that ln alpha can be represented as Y and here it will be as you know it is regarding the sum m or n you can say it will be or C you can say it will be C and plus S into here ln delta P as suppose X. So, Y will be is equal to C plus S X. So, C is the constant this is intercept and S is the slope of this line.

What is that line that you have to plot? You have to plot like this what will be the ln delta P in X axis and Y axis it will be what? ln alpha then you will get as a straight line here like this. So, again from this straight line what will be the slope that will give you the S value that means compressibility coefficient of cake and slope you will get it will be giving you as a C that means here ln alpha 0. So this ln alpha 0 you can calculate after taking that antilog of C that means from slope from intercept. So, from this way you can calculate from the experimental data of delta P and alpha what will be the value of alpha 0 and S. Next coming to the another important operation that is called continuous filtration or rotary drum filtration.

So, we have discussed that plate and frame filter phase by which you can separate that particulate materials from the slurry. Another equipment it is called that continuous filtration it is actually rotary drum filtration. What is that rotary drum filtration? You will see that here filter cloth is on the surface of a rotating drum. So, a filter cloth will be attached to a drum which will be rotating a certain filtration maybe one third of the drum it will be submerged it will be submerged one third of that drum it will be submerged in the slurry at any given time. Then you have to produce a vacuum so that the liquid will be sucked from that slurry through that media of filter or you can say that membrane or filter cloth which is attached to the drum surface.

Then continuous cake removal with the knife or scraper which is attached here to segregate or separate that particles which is deposited on the surface of the filter cloth which is attached on the surface of the drum. And this is happened only after that if vacuum is created and because of that vacuum the liquid will be flowing through that filter medium instead of passing that you know solid materials through the filter media. So, this is the basic mechanism of that rotary drum filter. Here it is basically rotating some parts or one third of that you know or some fraction you can say one third of the drum it will be submerged in the slurry that whenever that submerging portion of the drum that is filter cloth will be coming tasks with that slurry and parallelly vacuum whenever it will be sucked that liquid from that slurry only solid particles will be retaining on the surface of the cloth. So, this is the mechanism so this is also one type of separation mechanism of particulate material this is actually this operation is done continuously here.

So, this also you have to assess by governing equation of filter medium. So, what is that rotary drum filter operate at constant pressure here also it will be operate at a constant vacuum pressure and therefore that equation 18 earlier that whatever given can be used and the sum modification here it will be done. So, let us consider a single rotation of the drum and denote the time of one revolution to be here tr. First of all here what is the equation number 18 this is the equation number 18 here.

Here the Equation

$$\frac{t}{V}=\left(\frac{\mu c\alpha}{2A^2\Delta P}\right)V+\frac{\mu R_m}{A\Delta P}$$

So, this equation to be used again to assess this filtration by this rotary drum.

So, in this case since the drum is rotating at a certain flow rate. So, let us consider a single rotation of the drum and denote the time for one revolution to be tr. And let the fraction of the drum surface that is in contact with the suspension be denoted as fs. fs is the fraction that is known which is submerged that is generally one third let it be in general it will be fs. This means that in any one revolution the actual filtration time will be what is that fraction of this what is the one revolution time is tr.

So, since only fraction fs is coming in contact with that solution then the one revolution the actual filtration will be is equal to fs into tr.

Here the Equation

$$t=f_s t_r$$

Therefore, the filtration volume produced in one revolution will be given by this here given by like this. In this case we are just considering here t by V because this is equation number 18 after that we are just simply rearranging it as like this equation number here and then substituting t time of filtration that actual filtration time that will be equal to tthat will be fs into tr that we told here. So, after substitution of this t it is coming equation number 22 like this. Mu C alpha by 2 a square delta P V square plus mu RM by a delta P V that will fs into tr. Here the Equations

$$\left(\frac{\mu c\alpha}{2A^2\Delta P}\right)V^2+\frac{\mu R_m}{A\Delta P}V=t$$

$$\left(\frac{\mu c\alpha}{2A^2\Delta P}\right)V^2+\frac{\mu R_m}{A\Delta P}V=f_s t_r$$

Here also here that cake will be deposited or particles will be deposited as a layer which is called cake there will be specific cake resistance also the filter medium resistance will be there. After that you have to define suppose if drum speed in revolutions per second to be N that means 1 by trand the filtrate flow rate to be QF that means V by tr. So, in that case we can write then t will be equal to fsinto trthat will be equal to fs by N

Here the Equation

$$t = f_s t_r = \frac{f_s}{N}$$

because tr is equal to 1 by N. Hence, we can have after substitution of this tvalue as and also rearranging it we can express this equation after substitution of t value there and then again rearranging we can have this final equation of 24 here. So, mu C alpha by 2 a square delta P to QF square plus mu R MC by a delta P into QF into N.
Here the Equation

$$\left(\frac{\mu c \alpha}{2A^2 \Delta P}\right) Q_f^2 + \frac{\mu R_{mc}}{A \Delta P} Q_f N = f_s N$$

Here it is simply V will be equal to QF into TR. V will be is equal to QF into TR. So, this value is substitute here instead of V. So, after that we are having this equation number 24. So, in this case RMC the resistance of the membrane plus the resistance of the residual cake that left after the cake cutting step. So, here RMC to be considered here instead of RM only that is that plate and frame filter fresh.

Then if RMC small relative to the resistance of the cake that is formed during that that some portion of a drum will be submerged there and for solid cake production rate then it will be reduced to like this. The equation 24 it will be reduced to equation number 25

Here the Equation

$$Q_f = \left(\frac{2A^2 \Delta P f_s N}{\mu c \alpha}\right)^{1/2}$$

where RMC to be considered as very small compared to the resistance of the cake formed. So, from this equation number 25 we can have that increasing the drum speed that is N that will increase the filtrate flow rate. That means here if you are increasing the speed of the drum you can separate more slurry there. That means here if more filtrate output will be there with respect to increase of drum speed.

Another important point that we told that some fraction of that surface area of that drum will be submerged. So, in that case if suppose submerged area is AS and if A only is the total filter area then we can say that fs will be is equal to AS by A

Here the Equation

$$f_s = \frac{A_s}{A}$$

and then the mass flow rate of solid cake production after substitution of this FS value here in equation number 25 we can get m dot C that is mass flow rate of solid cake production that will C into QF. C is equal to C already given in equation number earlier that here how to calculate the CF I think in equation number here in this case 16A let it be 16A equation number 16A it is given C how to calculate and after substitution of C and also QF then you can get this value C into V by tr or it will be equal to 2C A square delta P fs N by mu alpha whole to the power 0.5.

Here the Equation

$$\dot{m}_c = cQ_f = c\left(\frac{V}{t_r}\right) = \left(\frac{2cA^2 \Delta P f_s N}{\mu\alpha}\right)^{1/2}$$

So, as equation number 27. So, from this equation number 27 will be able to calculate what will be the mass flow rate of solid cake production once that concentration of slurry area of the filter total area of the filter fraction of that filter which is submerged total pressure drop and speed of the drum also viscosity of the liquid as well as that what is the specific cake resistance. Let us do an example here based on this theory it is said that a rotary drum filter operating at 2 rpm which filters 1000 liters per minute operating under the same vacuum pressure and neglecting the resistance of the filter trough at what speed must be rotary filter be operated to give a filtration rate of 2000 liters per minute. So, interesting here that initially this rotary drum filter operate at 2 rpm whereas filters flow rate is there 1000 liters per minute. Now, you have to change the speed of rotary drum. So, what will be that rotational speed of rotary drum to get that double filtration rate that is 2000 liters per minute.

So, how can it be solved here we know that Qf will be is equal to 2 a square delta P fsn by mu C alpha whole to the power half as given in equation number as given in equation number I think 25 yes. So, from this equation number 25 we can then write here Qf will be is equal to K into n to the power half where K is a constant which is defined from this equation itself that K will be equal to 2 a square delta P f s by mu C alpha. That means other than this n to the power half what about remaining portion of this equation number 25 that is actually denoted by K. Now, at the first condition it is said that the flow rate is 1000 liter per minute and rotational speed is what is that it is 2 rpm or we can write here that equation as 1 as 1000 should be is equal to K n to the power half and the second case the flow rate will be 2000 then it can be written as K into n dash to the power half where K will remain same for both the cases because this surface area pressure drop even that fractional submerged area viscosity of the fluid concentration and filter cake resistance it will be constant it will not change. So, in that case we can write these two equation as per to case as given in the problem.

Now, dividing this equation number 2 by equation number 1 then you can have n dash to be equal to 8 rpm. So, that means to get the double filtration rate you have to increase the flow rate of this rotational drum by 8 rpm whereas it was earlier only 2 rpm. So, to get the double filtration rate you have to increase four times of that rotational speed of that drum. So, I think you understood this problem here. So, what we have discussed in this lecture that what is the plate and frame filter fresh how does it work and what is the governing equation and what are the basic components of that governing equation and also plate and frame filter fresh after separation of that particles and during that operation you will have some cake deposition and also some resistance because of this cake and as well as filter media and these two resistance will give you the total pressure drop and then plate and frame filter fresh will be operated in the two modes one will be constant rate another will be constant pressure drop.

How to calculate that for , specific cake resistance what is that specific cake resistance how to calculate that specific cake resistance how to calculate that filter medium resistance and based on that experimental data how to assess that , filter medium resistance and cake resistance and how to estimate that you can I think understand and also if you change the pressure drop how that specific cake resistance will be changing with respect to pressure drop and how that , relation of that specific cake resistance with that , change of pressure drop and that relation can be , assessed by making a correlation from the experimental data and then once that experimental data of that specific cake resistance and filter medium or that total pressure drop then from that , plot of that cake resistance and pressure drop, you will be able to calculate what will be the that slope and intercept from which you will be able to calculate what will be the , empirical constants and also what is the compressibility factor of that cake. So I think you have understood that how to calculate the specific cake resistance from the filtrate which is collected with respect to time and from that equation number 18 that we have discussed that V with respect to time how it is changing during that experiment and if you collect the data and if you plot that V by t versus V then you will be able to get that straight line formation there based on that straight line equation you will be able to calculate what will be the slope and intercept from which you will be able to calculate what will be the filter medium resistance and the specific cake resistance respectively. Also this constant rate filtration can be done in a rotational drum system where in the surface of that rotational drum it is attached some filter clock and with respect to time whenever that filter will be rotating with respect to certain speed at a constant pressure it will be vacuum pressure maybe. So in that case, how specific cake resistance and the filter medium resistance can be calculated based on rotational speed that also can be done and also I think you understood here.

If you have any other doubt in this lecture you can contact with me by this email. In the next lecture we will try to discuss more about particulate material separation by other mechanism it is called reverse osmosis. Here also some iron or some other salt solution or you can say that different very fine particles how to separated especially for dissolved salt how to separate by this membrane process that will be discussed. So thank you for your kind attention and have a nice day. .