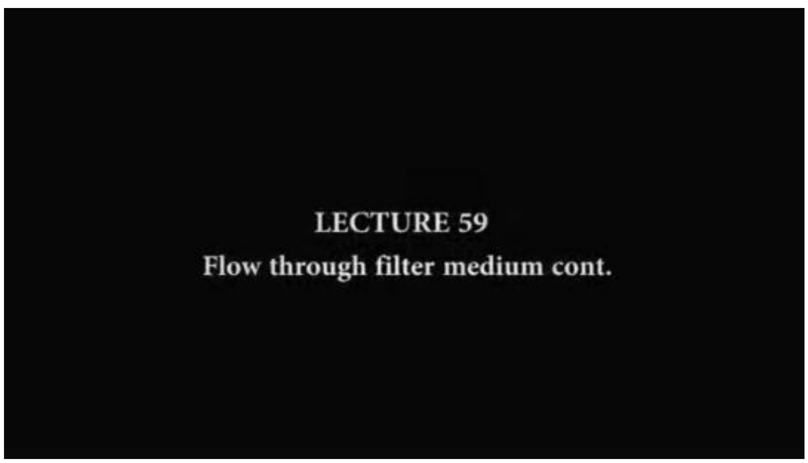
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

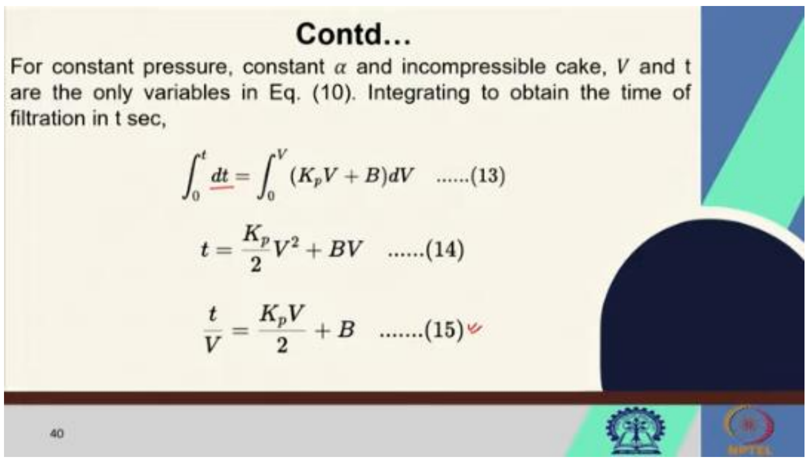
Lecture59

LECTURE 59 : Flow through filter medium cont.

Welcome, friends. So, in the week of 12, we have been discussing the flow through a filter medium. In the previous classes, what we actually discussed was the basic filtration equations and how the filtration equations look for a constant pressure filtration. We were interested in the time requirement for this constant pressure filtration process. And what we learned was that during that process, we have to consider the resistance provided by the filter medium and also the

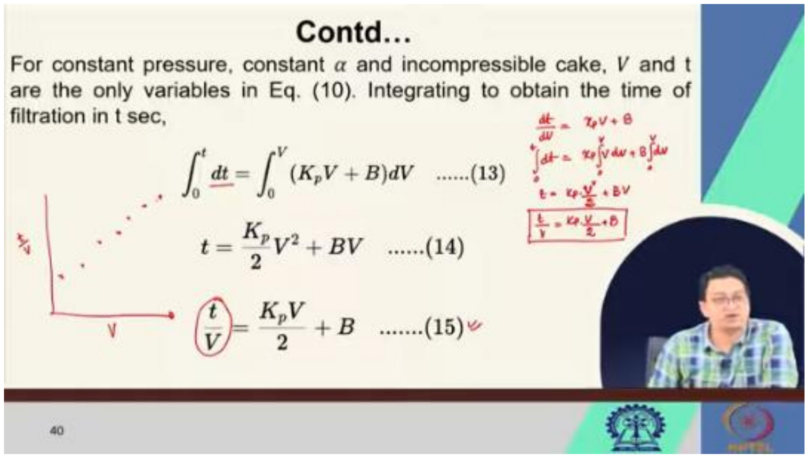


filter cake. So, we have considered the resistance of both of them and eventually, we have developed the basic filtration equation in terms of the flow rate, filtration rate, and also the pressure drop. So, if you recall, we have derived this part in the previous class. We will start a little bit from the back so that we can have a better understanding of where we are standing. So, what we had was that if you

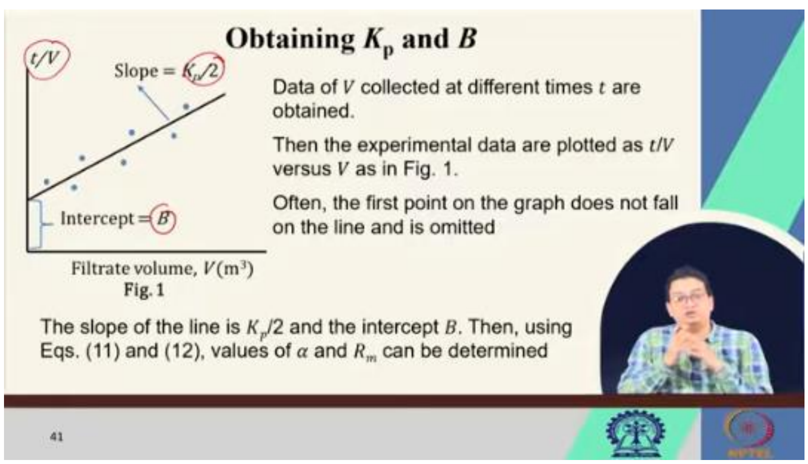


we have already derived. So, dt / dv was equal to k_P v plus b, where k_P and b are the constants. Now, what did we do? We integrated both sides: k_P v dv plus 0 to T, 0 to V, L_o to V, and we finally have T equals to K_P multiplied by V squared by 2 plus B V. So, T by V equals to K_P

V by 2 plus B. So, that is what we have. We had our final form of the equation. Now, as I said in the last class, if we plot t by v versus v, that means on the x-axis if we have—if you plot on the x-axis—we have v, which means the volume of filtrate. Here, on the y-axis, we have t by v. So, we will get this kind of graph, okay. So, these are the actual points over here. So, at corresponding V, we will be getting t by V. So, what we will do is we will add a trend line. If you do it in Excel, we can

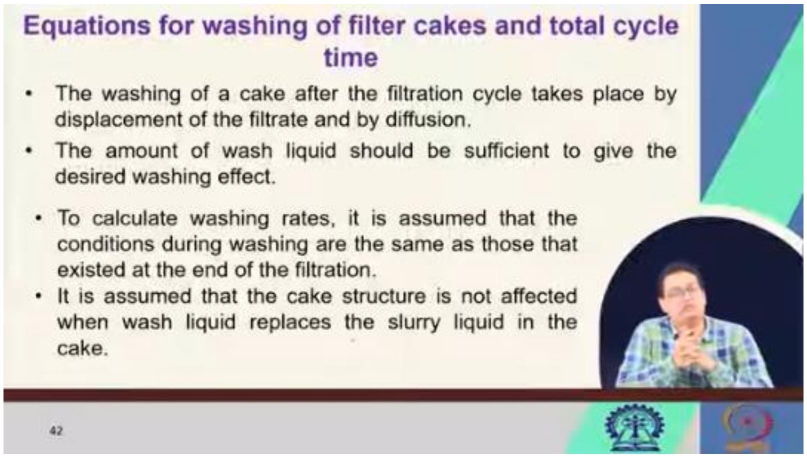


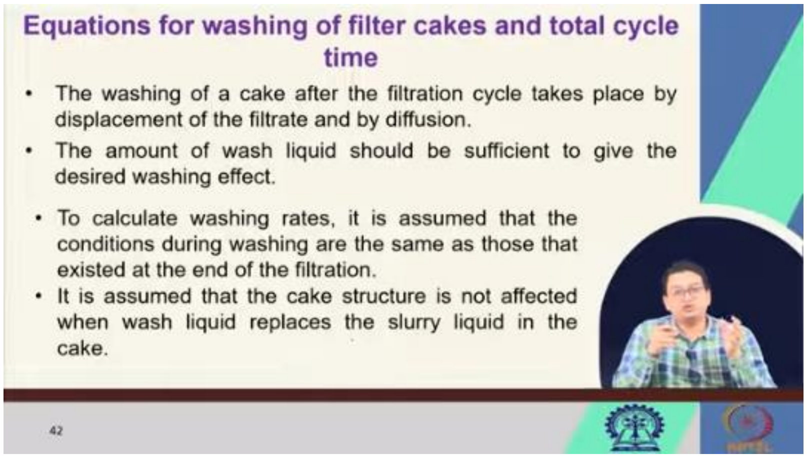
add a trend line, or we can do it by hand on graph paper. So, the slope of this one is K_p by 2, and this one is the intercept B, okay. And from there, we can obtain the values of alpha and Rm, okay. So, that is what I was saying: filtered volume on the x-axis, y-axis t by v—we will get this kind of points, and we will add a trend line. The slope will be K_p by 2, and the intercept is B, okay. Now, experimentally, what we do during constant pressure filtration is, during the filtration process, we collect the volume of filtrate over time.



Let's say you start from 0. After 60 seconds, 120 seconds, 240 seconds, then 360 seconds, we keep on collecting the V value. So, V is basically nothing but the accumulated volume of the filtrate, and then we plot it, okay. So, the experimental data we collect from there, we obtain the requirement of the alpha value and R_m value. It can be determined in a graphical approach. We will see later how to do it, all right. So, this is the way of obtaining K_p value and B value, okay.

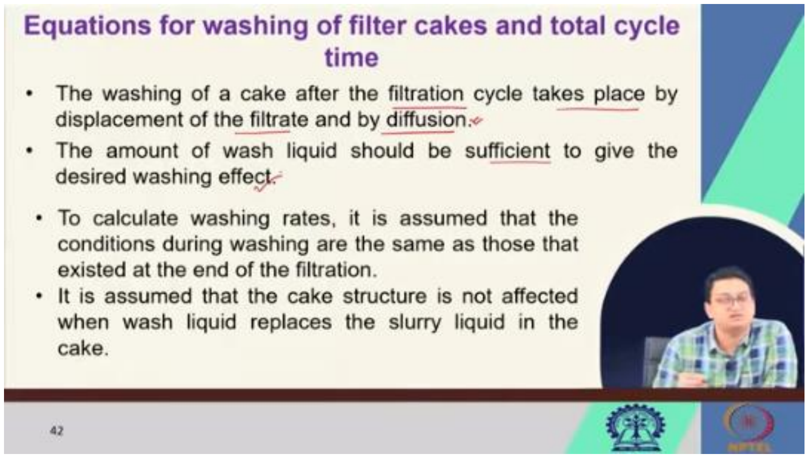
Now, coming to the washing part, once the filtration process is over, we have to go for the washing. Why is the washing done? Washing is done to remove the impurities if present in the cake or any kind of soluble solids that can be entrapped between within the cake material. So, that can be very useful. So during this process, the cake is actually washed with some washing fluids.





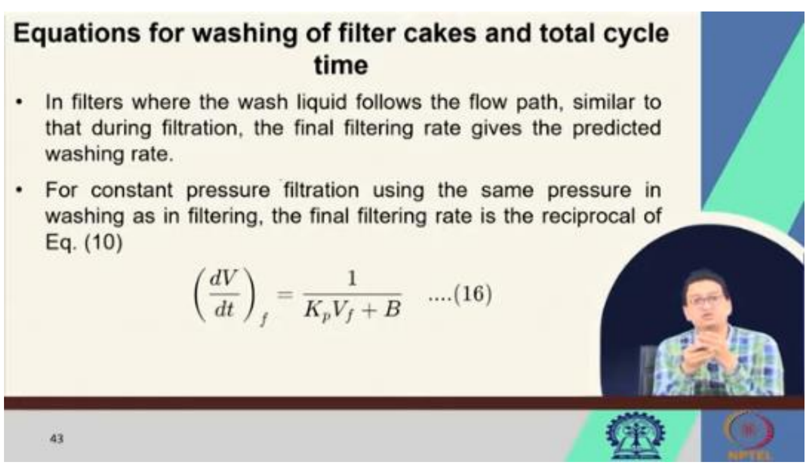
Now, in some cases, cakes are very useful, the filtered cake. Let us say, if you talk about the sugarcane juice filtration, the filtered cake is actually used as a fertilizer. But at the same time, if there is any kind of entrapped liquids or any entrapped solids within the filtered cake, it has to be removed by some way, and we follow the washing process. The washing of the cake after the filtration cycle takes place by displacement of filtrate and by diffusion process. So, the filter is displaced, and we push the washing fluid, and the diffusion

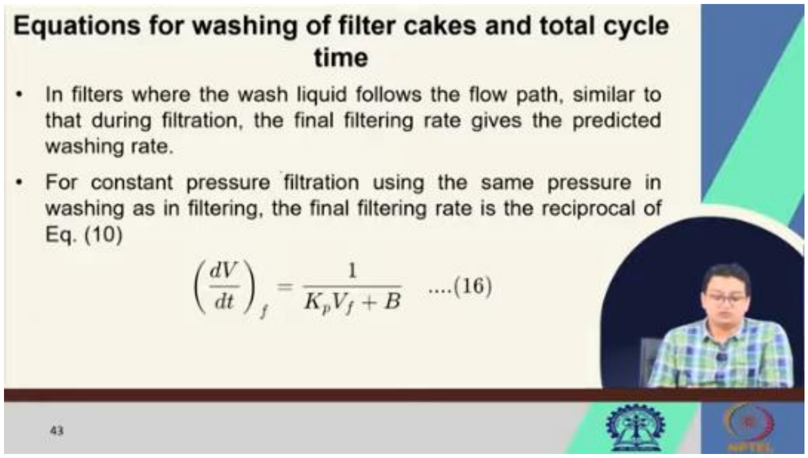
process takes place to wash the filtered cake, okay? The amount of wash liquid should be sufficient to give the desired washing effect. So, this is pretty much clear, okay. So, we keep on continuing washing the material, okay. Now, to calculate the washing rate, what is the assumption? How can you calculate the washing rate?



All the conditions that were there previously during the filtration process remain the same. So, that means the conditions during washing are the same as those during the previous filtration process. Now, it is also assumed that the cake structure is not affected when wash liquid replaces the slurry liquid in the cake. So, the cake structure should not be affected. So, it has to be incompressible; it should not be compressible, and the overall cake structure should not be

destroyed by the pressure of the washing fluid. What may happen during the washing? Channeling of the cakes. Ok, there could be some breakage of the cake material, ok, or some fracturing of the material. So, that will actually hamper the overall washing part, ok. So, now, how to calculate the washing time, ok. So, now, how do you calculate



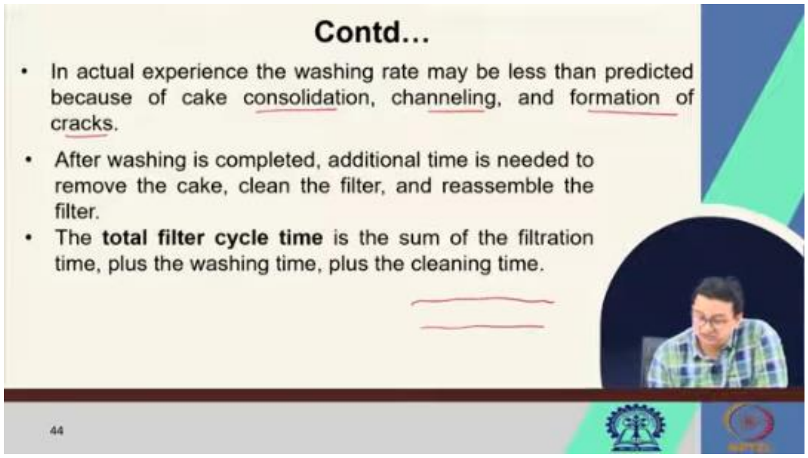


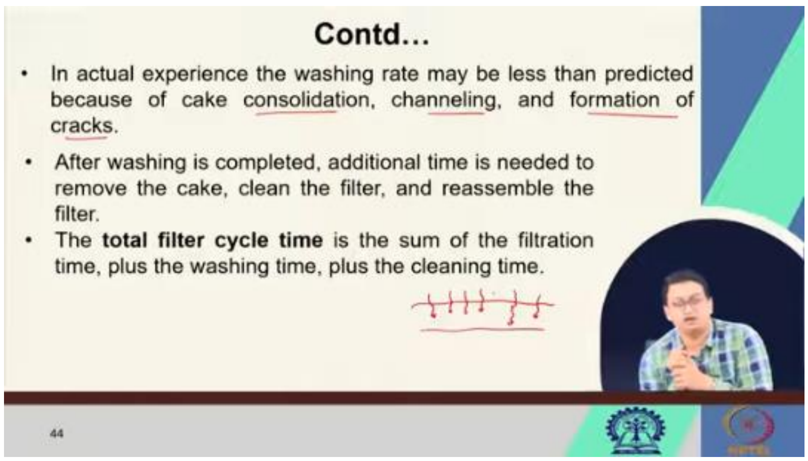
the total washing time, ok. So, it comes after the filtration, ok. Now, in filters where the wash liquid follows the flow path similar to that during filtration, the final filtering rate gives the predicted washing rate, ok. So, it has to follow the previous assumption we made earlier. For constant pressure filtration, using the same pressure in washing as in filtering.

The final filtering rate is the reciprocal of equation 10. So, if you go back to equation 10. So, as I just now discussed, we had dT by dV equals to K_p multiplied by V plus B. So, this is nothing but it is a reciprocal of this one, that is the final filtering rate. So, dV by T. So, that is our equation for the washing part. Now, as I was mentioning, during washing, what can happen is that the actual timing may be less than the predicted one.

What we are actually estimating using our mathematical expression could be less than the actual one when we measure practically because of the cake consolidation, channeling, and formation of the cracks, ok? So, in the cake consolidation, the you know, cake becomes very hard; it is a consolidated material. So, the washing fluid or washing liquid does not go that way or penetrate the filter cake as expected, ok? The channeling, what happens during the channeling process?

So, if you have, let us say, a cake formed like that, ok. It will only flow through a certain path, ok. It is not actually that the washing fluids are uniformly distributed throughout the filter cake. So, it is very expected that it should be uniformly distributed over the filter cake so that our washing takes place very efficiently. But because of the channeling effect, the liquid only follows a certain path.



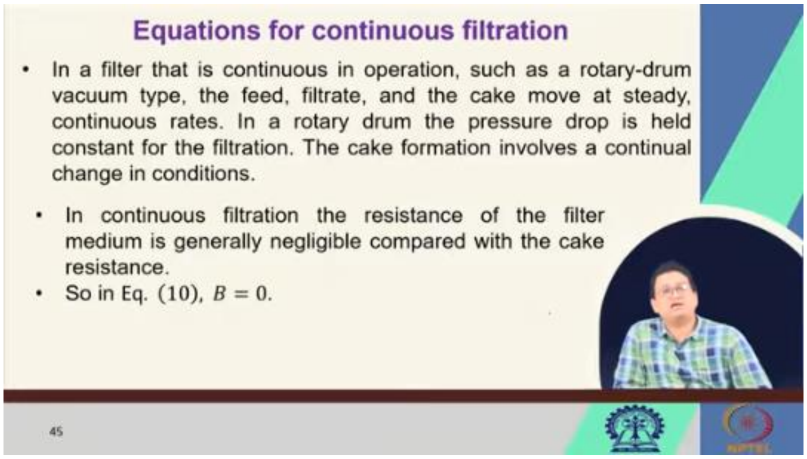


So, the washing it is not that much of effective. Formation of crack that means if it is any any part of the filter cake are having some cracks. So, the liquid movement will be within the structure will be very much restricted and it will be ah the washing would be very difficult in that cases ok. So, after washing is completed, additional time is needed to remove the cake, clean filter and reassemble the you know filter.

Now, see as I said that during this process if anything occurs this kind of problem ok. So, the washing rate could be much more lesser ok. So, that the total time rate I mean time required will be much more higher because it is not very efficient. Now, once the washing is completed, the additional time is provided to scrap away the all the cakes that has been deposited and we clean the filter and then again we put it back everything. So, therefore, you now you can imagine.

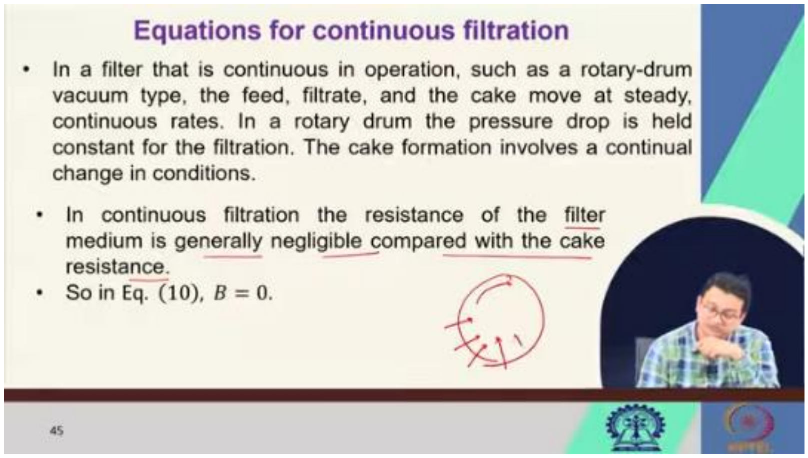
So, we had a filtration process overall, then we have a washing process. So, total filter cycle time what we call the filter cycle time it is the sum of all together that means, the filtration time plus washing time plus cleaning time. So, it starts from very beginning to the complete process of the till the process of cleaning. So, that means, the filtration time is somewhat you know some fraction of the total filter cycle time ok that is very obvious from here ok.

Now, what we will do is we will look at the continuous filtration. So, what is continuous filtration? That means filtration is occurring at a continuous rate, ok. So, in this continuous operation, as we discussed, like in rotary drum-type vacuum filters, ok.



So, in that case, the feed, filtered, and the cake move at a steady and continuous rate. That means the formation of the cake and its movement will be in a very continuous state, and it is very steady, ok. Now, here it is said that in a rotary drum, the pressure drop is held constant for the filtration, and the cake formation involves continual changes in the conditions. In continuous filtration, the resistance of the filter medium is generally negligible compared with the cake resistance. Now, why?

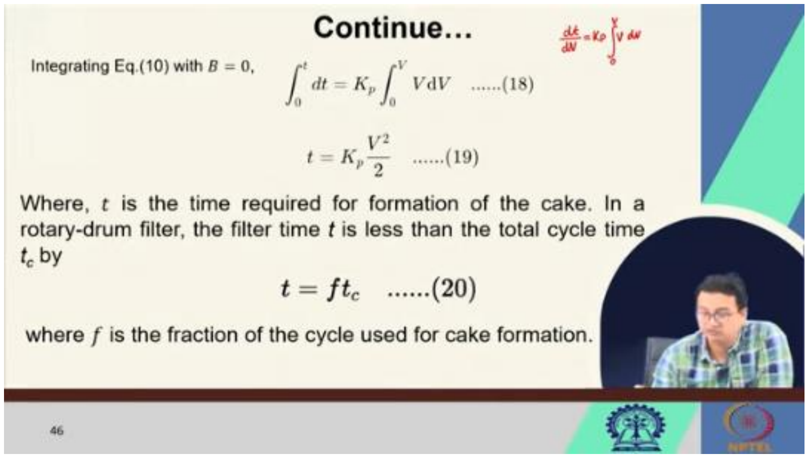
Now, imagine this is the case: suppose you have a rotary drum, ok. So, it is continuously rotating and sucking inside all the slurries, ok. That means here we have, on the surface, a filter medium put over here. Now, while the liquid is being sucked, the solids get deposited on the filter medium, ok.



Now, it is a continuous process. So, over the period there will be a build up of the significant amount of filter cake. So, when the significant amount of filter cake is actually formed of course, there will be some doctor's blade or knife that will actually you know scrap away some of the cake, but what here I am trying to say is that resistance provide provided by the that much of significant amount of filter is much more higher compared to the you know filter medium on.

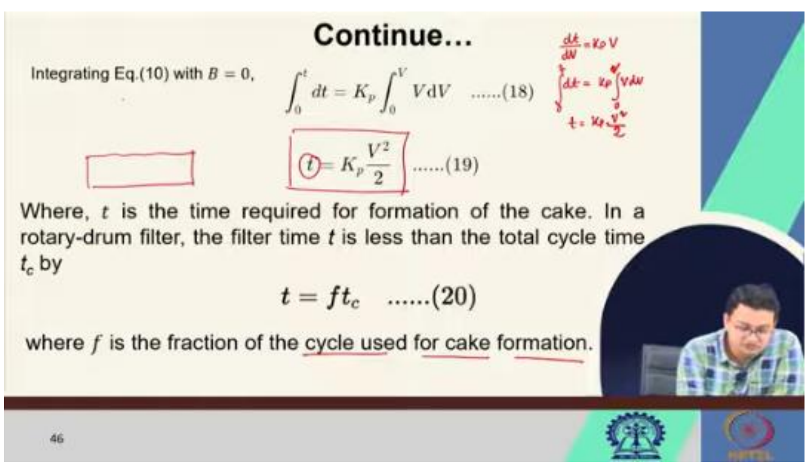
So, filter medium is a very you know thin you know permeable membrane or it could be a wet cloth or any other kind of filter medium ok. So, that resistance is not that much compared to the cake resistance because the process is continuous and over the period there is a significant amount of build up of deposits. So, that means, what we can say? So, you remember the second term that is we had the B, we had the B is we you remember mu R m in related to this part, the resistance part. So, this part can be neglected and we can consider B equals to 0 for the continuous filtration.

So, what will be left with? We will be left with only the K_p part. So, then what we will be having? So, dt equals to dt / dv equals to k_p o to v v dv. So, b equals to 0 ok.



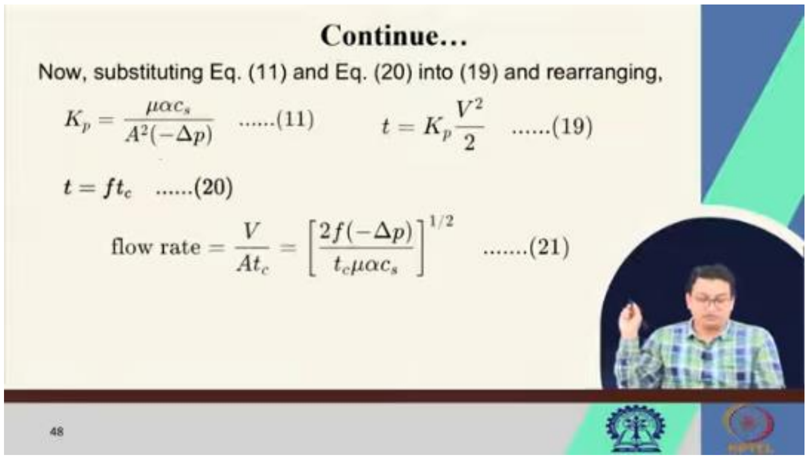
Now, we integrate 0 to t k_p sorry I will do it. d T / d v K $_p$ multiplied by v. So, we will integrate it over here v d v and it is from 0 to 2, 0 to v. So, therefore, we will be having K_p multiplied by v square by 2 ok. where T is the time required for the formation of cake ok. So, this part here is the T is the time required for formation of cake. Now, the T can be expressed as a f multiplied by T_c where T_c is the total filtration cycle ok and f is the fraction of the cycle

used for the cake formation. Now, what happens in the when the rotary drum actually rotates the part of it actually is submerged in the slurry. So, if you look at we will draw the picture let us say we have a slurry over here. So, the drum is like that ok. So, when it rotates and we have a suction inside.



So, this part is actually submerged in the slurry that means, this part will have effective cake formation. liquid will go inside the filtrate will go inside. So, probably it is could be not in between 20 to 40 percent submergence submergence ok. That means, this F can be also considered that because since 20 to 40 percent is submerged. So, this f is actually 0.2

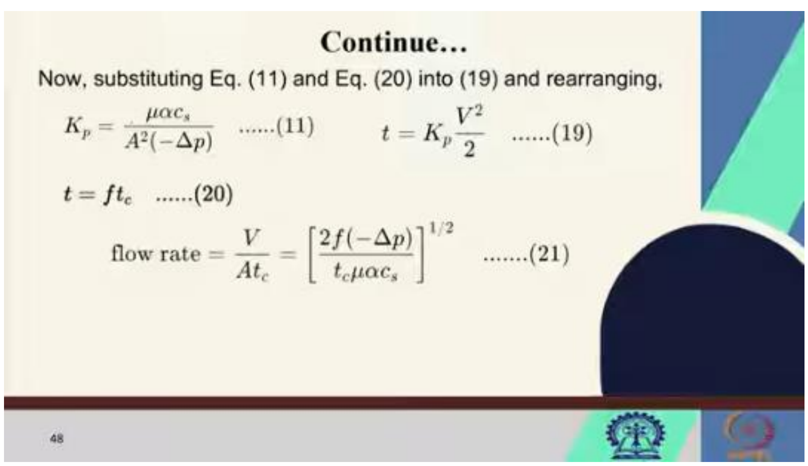
to 0.4 that because this much of fraction of time in the whole cycle it is actually used for the formation of the cake, OK. In reality, that is what happens. So, now what will we do? We will actually try to calculate the flow rate in this case. So, how can we calculate the flow rate? So, we will use this information.



So, what is K_p equal to? Mu alpha C_s divided by a square minus delta p. So, this is K_p. This one time is f multiplied by T_c. So, T_c is the total filter cycle or filtration cycle. T is the time required for cake formation. Okay. All right.

f is the Fraction of time for cake formation, and what else we have, sorry. v equals to K_p v b equals to 0. So, T equals to K_p v squared by 2. So, that is the one we have.

So, here T equals to k_p v square by 2. Now, what we are interested? You know flow rate. So, what is flow rate? Flow rate is

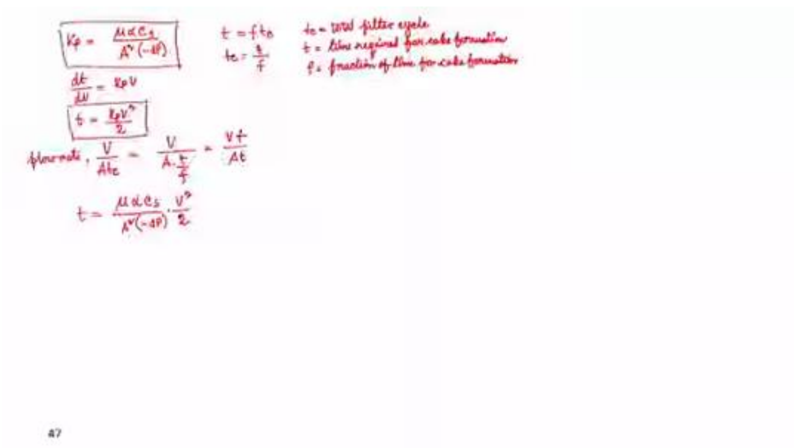


V by A T_c. So, in this case we are considering the complete filtration cycle ok. So, V by A meter cube by meter square meter per unit time ok. So, what we can write? So, let us do it

V by A T_c. So, this T_c is nothing but T by f right. So, A multiplied by T by f. So, we will have

V f by A t. ok. So, now, now what we will do? So, we have to now you see we have this information over here t equals to K v v square by 2 and we have this one ok. So, let us do it.

So, what will we do? So, we have K_p. So, K_p we will put mu alpha C_s s square. Delta p multiplied by v square by 2, ok. So, T equals to K_p mu alpha C_s A square delta p multiplied by v square by 2. So, now, here.



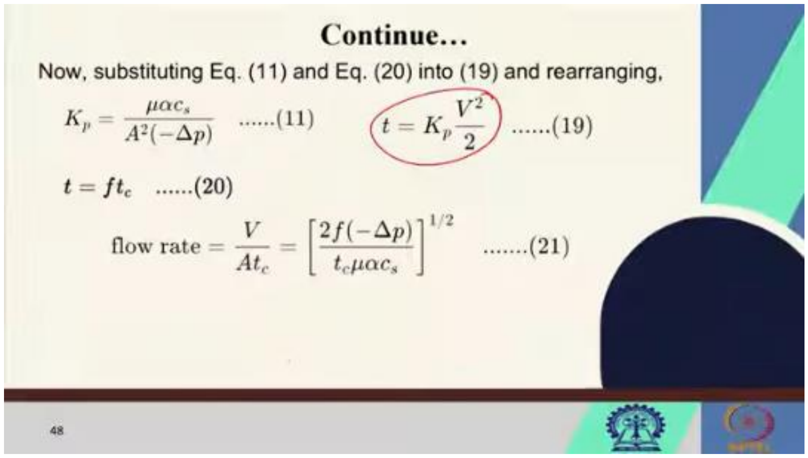
So, A T C A T by A V f by T. So, this T, I will be putting over here. That means, V by A T_C equals to V f by A. Now, mu alpha C_s V square by 2. Now, what does it give? Let us see A, A gets cancelled. So, we have v f on top A p 2 multiplied by 2 mu alpha C_s v square.

So, again v, v gets cancelled. So, v by A Tc equals to 2f A T_c. Mu alpha C_s v. Now, what will we do? So, we will take v in this side.

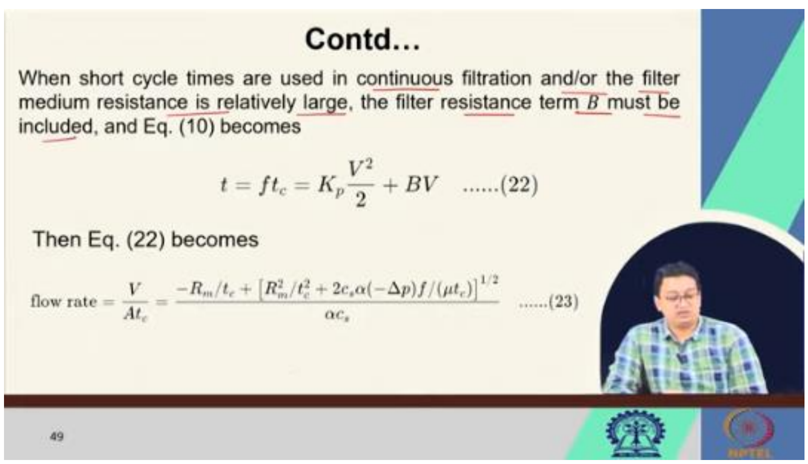
So, you will have v square a, and it will come to the denominator a square. We will multiply the denominator with another T_c. So, we will have T_c square. So, on the top, we will have 2f minus f p. Here also, we have Tc because in the denominator of the left side, we have multiplied T_c. So, here T_c mu alpha C_s V. That means this gives V by A T_c.

So, this is the flow rate equals to 2f minus V divided by T_c mu alpha C_s multiplied by V to the power half. So, the flow rate in this case can be calculated using this expression: 2 multiplied by f multiplied by minus delta P. So, this is basically the pressure drop. If the pressure drop value is given, we will be using the magnitude of that, ok. Then, divided by T_c mu alpha C_s divided by V. So, same thing Sorry, V will go on the top.

This V will not be here because V we have taken on the top. That is fine. So, 2f multiplied by minus delta P T_c mu alpha C_s. So, 2f minus delta P T_c mu alpha C_s. So, this is the flow rate in this case.



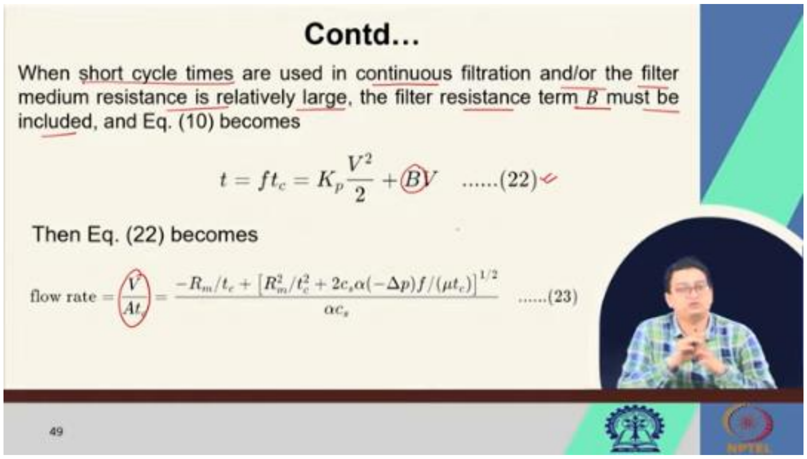
Now, coming to the next. So, when short cycle times are used in continuous filtration or the filter medium resistance is relatively large in practical cases, the filter resistance term B must be included; it cannot be encoded. It cannot be ignored. Why? Because it is said that short cycle times are used.



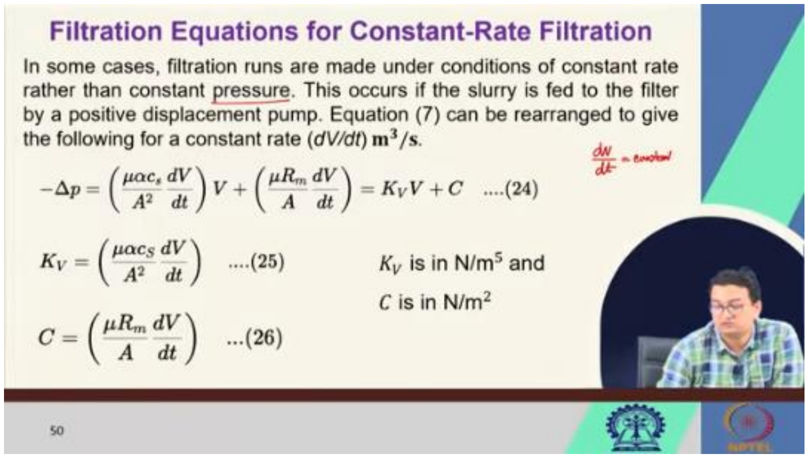
Short cycle times mean the deposition of the filter cake and the thickness of it is relatively small compared to if you keep on doing it for a longer time period. So, that means this B value actually plays an important role in that case. So, the resistance of the filter medium may be on par with the resistance of the filter cake that is being deposited on the surface of the filter medium. So, in that case, what we have to do is T equals to f T_c equals to K_p v square by 2 multiplied by B v.

Then, if you rearrange all those things, then flow rate V by A T_c becomes minus R_m by T_c plus we have inside the parenthesis R_m square by Tc square plus 2 C_s alpha multiplied by minus delta P f by mu T_c. to the power half divided by alpha C_s. So, the flow rate in that case for the short cycle time we have to use this expression in the short cycle. So, for the long cycle, flow rate is 2 f multiplied by minus delta p divided by T_c mu alpha C_s to the power half and here, in this case, the flow rate would be V by A Tc minus R_m by T_c multiplied by R_m square by T_c square plus 2 C_s

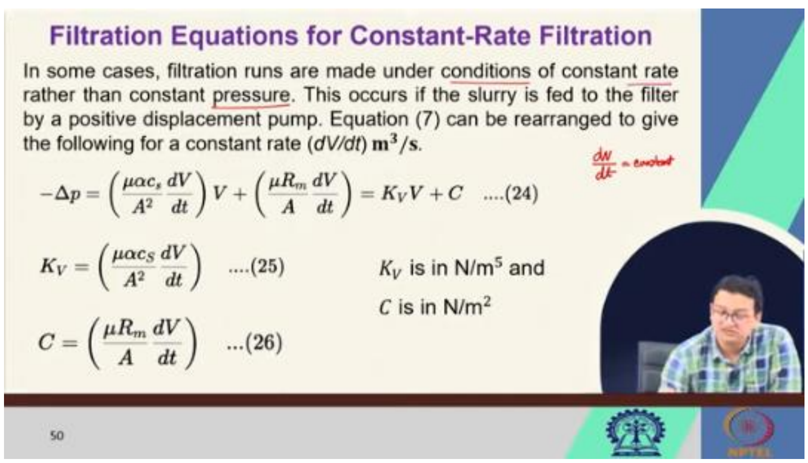
Alpha multiplied by minus delta P f. So, this is the whole thing about now, so in the constant pressure and constant rate, these actually mean two things. Now, there could also be variable pressure and variable rate, but that part is beyond our scope within this time period, ok. So, that part we will not be discussing, ok. So, now, in the constant rate filtration, what would be the final form of the equation, ok. So, in the constant rate rather than constant pressure.



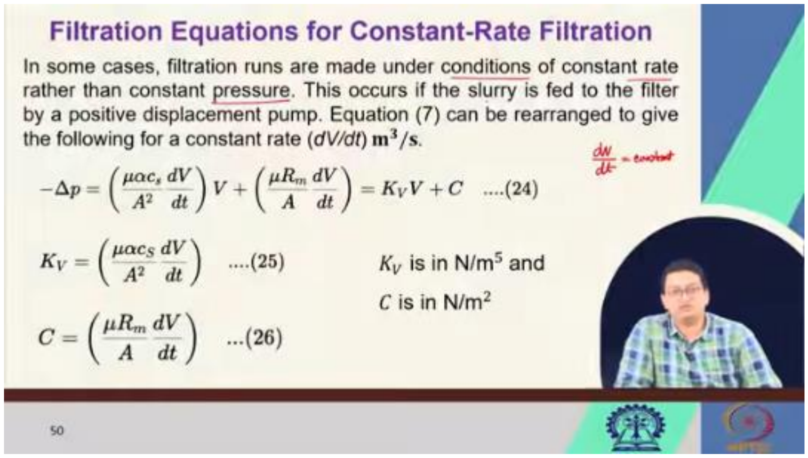
So, what we have in the constant rate means dv / dt we will be having constant. So, in the earlier cases, so far we have talked about the constant pressure, ok. So, whatever we have taken into account, the constant pressure filtration and then the washing cycle, then also we are having over here the flow rate, ok, in equations for the continuous filtration. So, one is we had in the batch process and one is for the continuous. Now, we are coming to the, you know, rate is the constant.



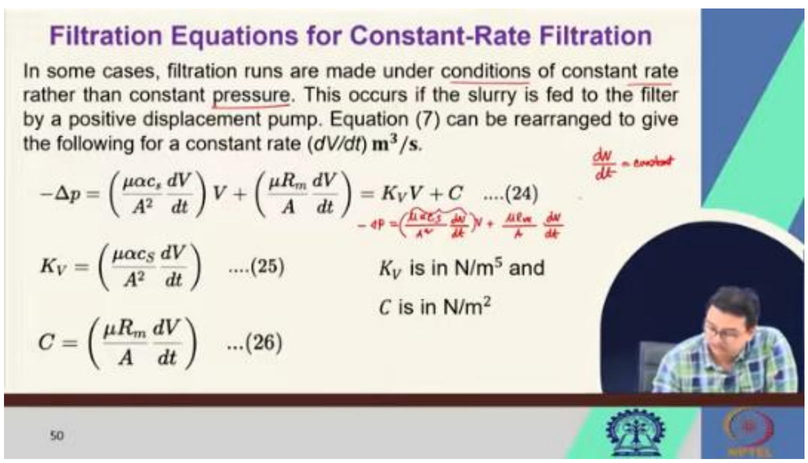
So, constant rate filtration. So, filtration runs are made under conditions of constant rate rather than constant pressure. This occurs if the slurry is fed to the filter by a positive displacement pump. That means you have to supply a huge amount of slurry using a positive displacement pump. Then, equation 7 can be further modified, ok.



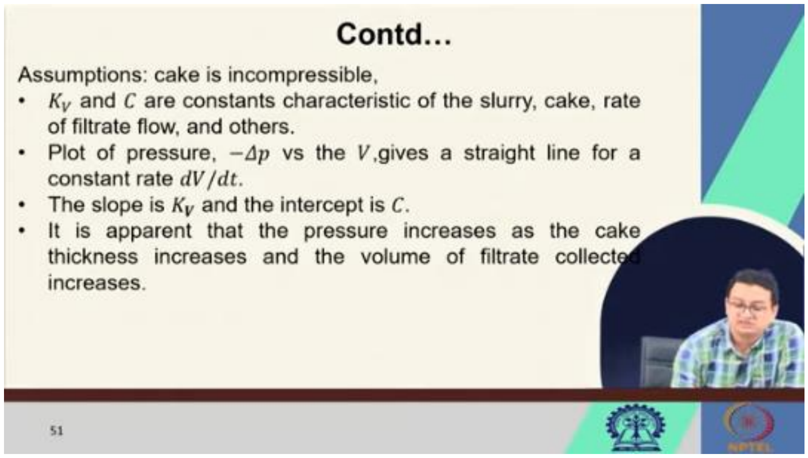
So, equation 7 we can go back, but we still can remember what is the equation 7 looks like, ok. So, here I will just quickly derive it. So, now the thing is you remember we have done we have taken dv dt on the left side dv / dt multiplied by 1 by A in that case we will take the delta p the left side. So, delta p if you rearrange you will be having this one mu alpha C_s by A square dv / dt multiplied by v ok.



So, this is nothing but the k you know k v part over here because we are talking about the constant rate plus mu Rm divided by A dv / dt and this is also considered as A K v ok. So, K v mu alpha S A square dv / dt. So, you remember for the Kp we had a mu alpha C_s A square divided by minus delta p ok. here the dv / dt is the kv is the constant it has the unit of Newton per meter to the power 5 ok.



This part is considered another constant this is C mu R_m mu R_m multiplied by divided by A dv / dt it is actually considered as A C. So, these are actually two units. So, C is the unit is the Pascal Newton per meter square. Because it is somewhat different than the constant pressure filtration. Now what are the assumptions? Assumptions again the cake is incompressible.



KV and C are the constant characteristics of the slurry. The cake rate of the filtrate flow and others also remain as they are. OK. So, the KV and C are actually characteristics of all those parameters and remain as they are, OK. Now, if you look over here, if you plot this one versus V, OK, the pressure drop with the V, the volume of the filtrate, we will get

the slope and the intercept. So, the nature is mx plus c, OK. That means the plot of pressure minus delta p versus V gives a straight line for a constant rate dv/dt. The slope is KV and the intercept is C. It is also apparent that the pressure increases as the cake thickness increases and the volume of filtrate collected increases. So, this is very apparent. This is already discussed. So, what we have actually looked at in this part? We have looked at the washing cycle, OK, how to

calculate the total filtration cycle and from there how we can calculate the time required for the cake formation for the continuous filtration process, not for the batch formation process, as it happens in continuous filtration for the rotary drum type filtration. Now, we have looked at in this part about the constant rate filtration. Rate means the volumetric flow rate remains constant, and what we have seen is that this is the final expression in this case: minus delta p equals KV multiplied by V plus C, all right. So, today we will stop here. In the next class, we will continue from here.

Thank you.