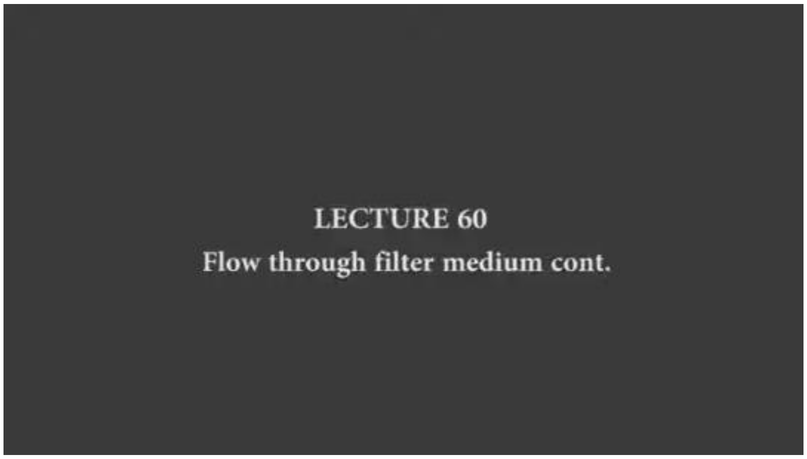
IMPACT OF FLOW OF FLUIDS IN FOOD PROCESSING AND PRESERVATION

Lecture60

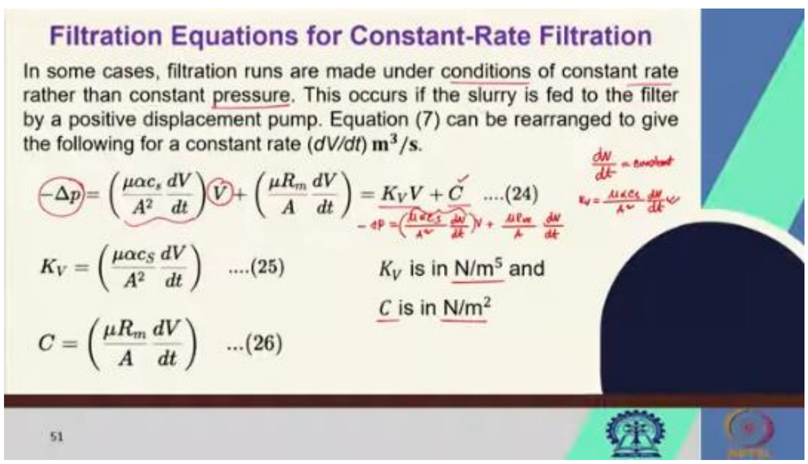
LECTURE 60 : Flow through filter medium cont.

Welcome, friends, to the last lecture of week 12 on flow through the filter medium. So, in the flow through the filter medium, in the previous class, what we have learned in the previous classes is that about the total time required for washing and how to calculate the time required for the formation of the cake for the continuous type filtration process. So, one example is the rotary vacuum drum type filtration process, and we have looked at the final expression. If you are having, you know, the

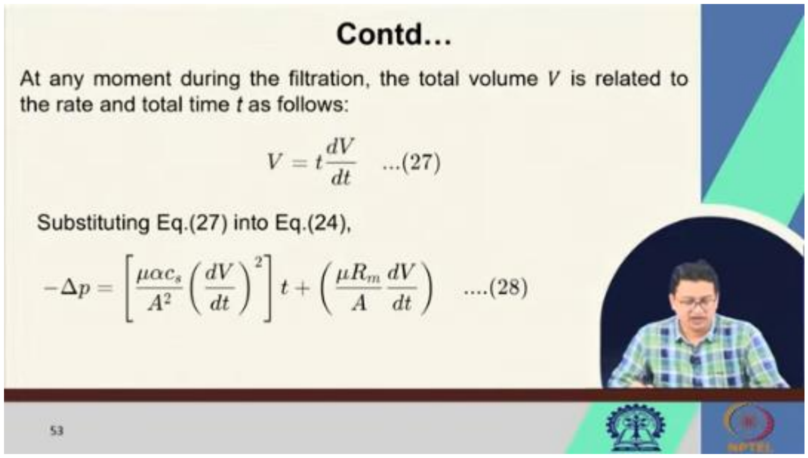


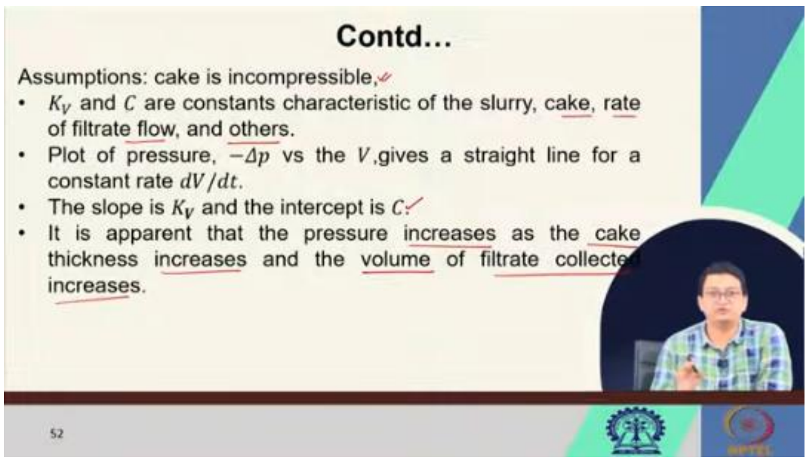
filtration occurs for a very long time, and if you have a short duration one, so for the longer one, if you have a long time of continuous filtration, so the amount of deposited solid or the cake on the filter medium is, you know, significantly high, so the resistance provided by that one is much larger than the filter medium, okay. So, we can ignore the resistance provided by the filter medium. So, this is for, you know, long-duration filtration. So, when you have the short duration one or the short duration one, we have to consider the second term, which is B. And, we have seen in that way when we will, you

know, look at the, you know, the volume of filtration or, you know, flow rate of both cases, the expression is kind of very different. Also, we started talking about or looking at how the constant rate filtration occurs. Constant rate means the dv by dt, the volumetric flow rate, remains constant. It is a quick recall that minus delta P equals to K v multiplied by v plus a constant term where K v is mu alpha C_s by a square multiplied by dv / dt and C equals to mu R_m by a multiplied by dv / dt. So, this is our expression. Now, this part also we have discussed how to obtain all those parameters, the K_p and the C value. So, we



Have to simply plot the pressure drop versus the volume of filtrate, and it will give us the straight line. The intercept will give us the C term, and the K b part is the slope. We will see how to do it for one of the examples. So, that is what we have discussed so far. Now, what we will do? So, we will look at the final expression of this one for the constant rate filtration. So, at any moment during the filtration process—sorry, at any moment during the filtration process—the total volume collected.

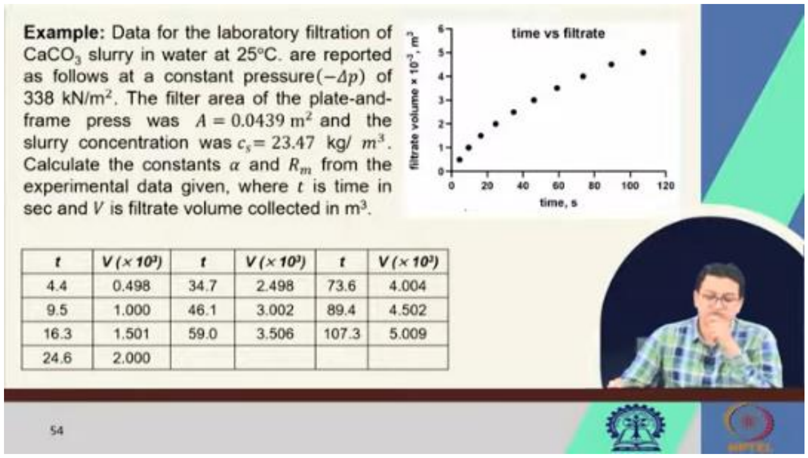


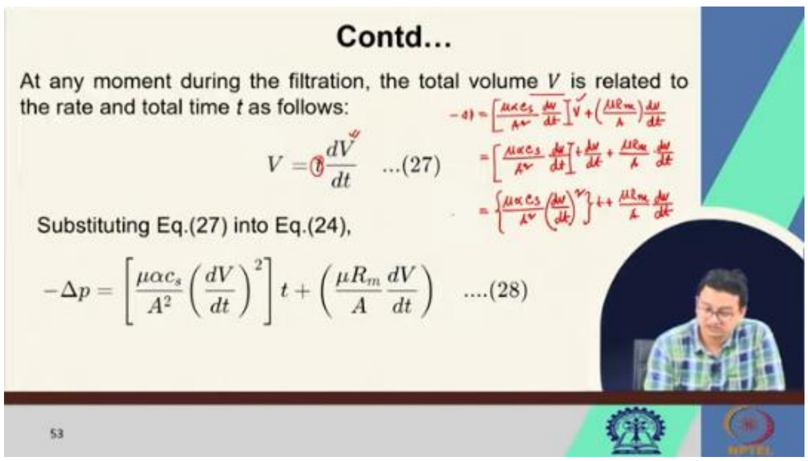


Total volume of filtrate collected, which is denoted by V, is related to the rate and total time, right. So, that means V can be written as dV / dt multiplied by t, okay. So, this is the volumetric flow rate over the time during that short span and multiplied by t. So, this is why because this is actually constant—dV / dt is constant. So, if you simply do it, replace this one. So, minus delta P equals to μ α C_s divided by A^2 we had dV/dt.

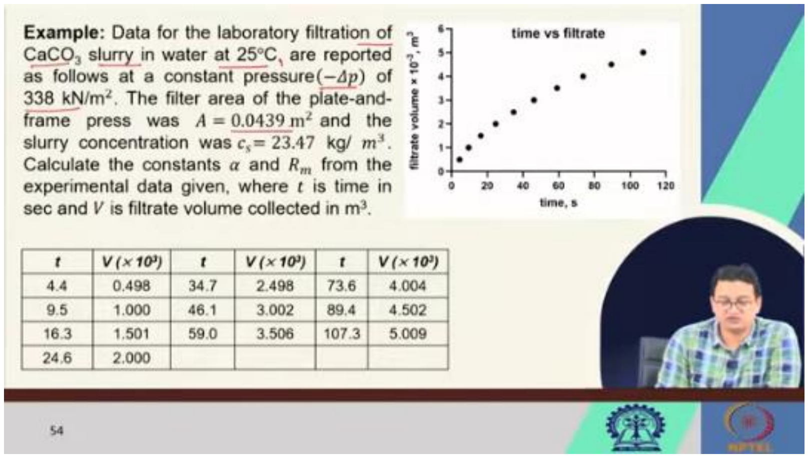
So, this part is Kv right multiplied by V plus μ Rm divided by A. So, that is what we had. Okay, multiple—yeah, so now what we will do—so V is nothing but t multiplied by dV/dt, so this one is μ α C_s divided by A^2 multiplied by dV / dt, so t dV / dt plus μ Rm by A dV / dt. So, this gives us μ α C_s^2 dV/dt^2 right t plus μ R_m by A dV / dt. So, this is our final expression.

We can calculate the values from here, all right. Now, we will look at a few examples so that we can have a better picture of how to calculate all the constants, all the parameters, and how to proceed with this one. So, we will go with the first example over here. So, the first example—let this be Example 1—it says that the data for the laboratory filtration of a calcium carbonate slurry in water at 25 degrees C are reported as follows at a constant





pressure. So, that means this one is minus delta p is fixed, OK. This value is given as 338 kilo Newton per meter square, 338 kilo Pascal. The filter area of the plate and frame press was 0.0439 meters square. That means the filter area for a given filtration equipment is given. The A value is given as 0.0439 meters square, OK.

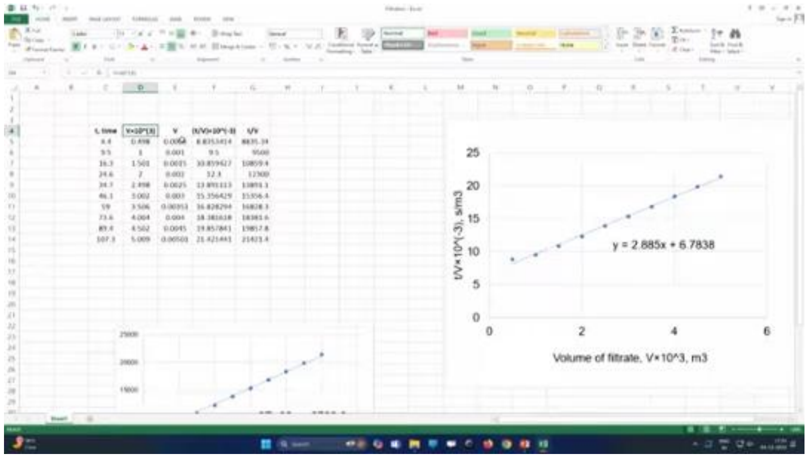


And the slurry concentration is given as C_s 23.47 kg per meter cube. Calculate the constants alpha and R_m from the experimental data given, where t is the time in seconds and v is the filtered volume collected in meter cube. Now, if you plot it on the x-axis, we have time here. You have filtered volume multiplied by 10 to the power minus 3 meters' cube, OK. If you do it so, ah, what we will have is this kind of nature, OK. The graph looks like this, so it is slowly increasing, OK. The time versus

filtrate ok So, if you recall in order to estimate the value of kp and b. So, this is the constant pressure 1. So, what we have to do? We have to get the form in terms of you know t by v ok. We can have k_p v by 2 plus b. That means, in that case if you plot this versus v. That means, volume of filter and t by v will have slope equals to kp by 2 and intercept equals to b ok and these are the experimental data are given t at you know 4.4 second 9.5 second 16.3 and so on till 107.3 seconds the volume of filtrate is given over here like 0.4981 1.5012 then at 34 points 7

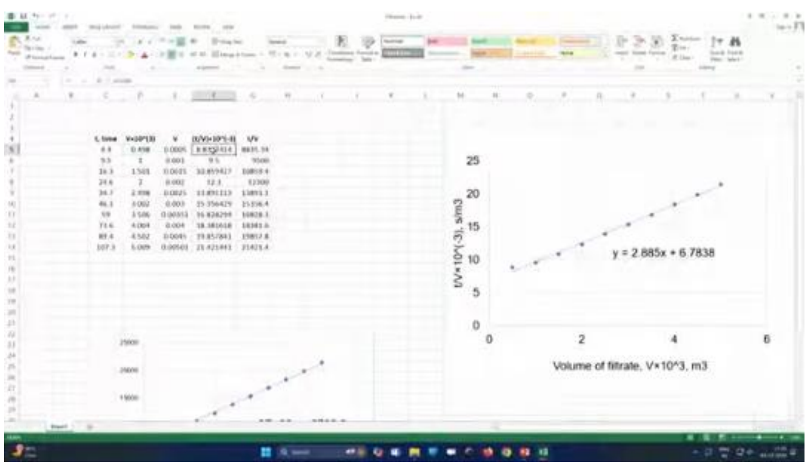
2.4983.002. So, these are all things ok. Now, what we will do you can do it in the pen and paper using the graph ok. We will here now take help of the excel all right ok. I hope you can see over here ok. So, these are all the data I have put in the excel.

So, here the t is the time to from 4.4 seconds to 107.3 seconds ok. So, here we have v into 10 to the power 3 as per the data is given 0.498, 1, 1.501, 2 and so on ok. we can do it in 2 ways ok. So, here we can have t by v that means, if you do t by v it has to be multiplied by 10 to the power minus 3 because it is v into 10



To the power 3, that means real V values are actually this one divided by 10 to the power 3. So, 0.0, it has taken 0.005 in the Excel. So, yeah, 0.498. If you have this kind of, you know, up to 4 to 6 decimal places, it will actually give us 0.005, and so on, you will get like this: 0.00501, something like that, OK? So, these are all the values here, t by v. So, the beauty of this one is it can take all the, you know, values in terms of 10 to the power minus 3, OK? Same for here. So, it can also take real data, actually, if you put in 10 to the power 3; otherwise, it will be like this, OK.

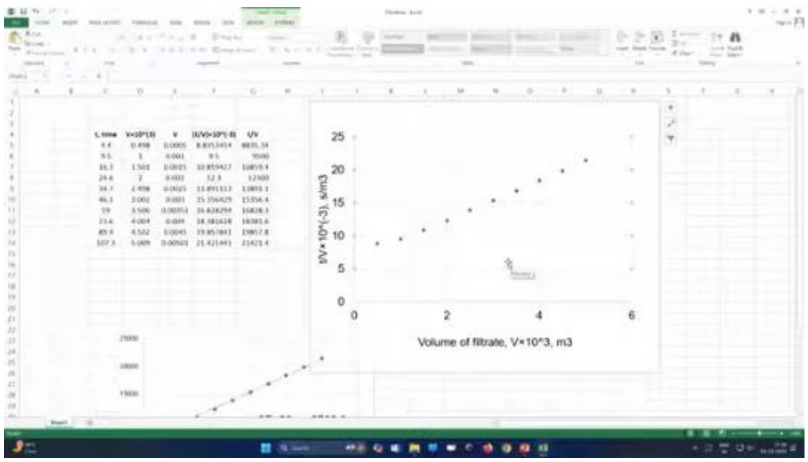
So, here, if you do t by v, t by v is nothing but if you look at it here, T divided by V is the C_5 by D_5, OK. So, this is the Excel cell operation. And this one will actually help you out with how to handle the experimental data like this, OK. Otherwise, we do it on the graph paper only. So, these are all the values over here.



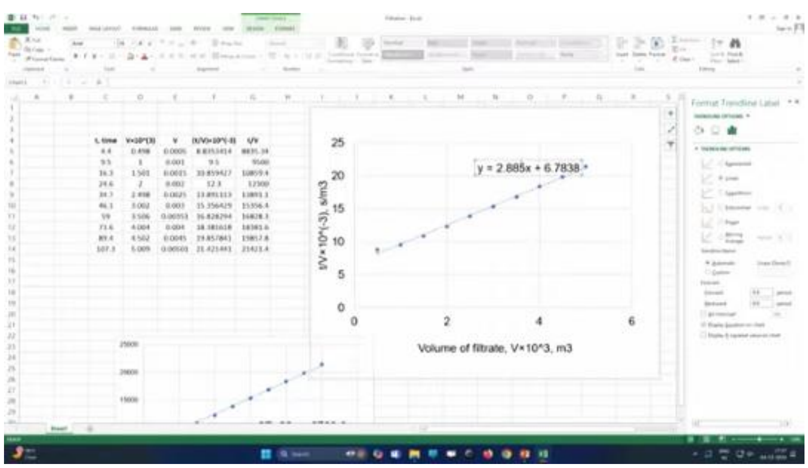
So, 8.835, 9.5, 10.85, and so on. Also, I have put only t by v, OK, with all those things. Now, if we plot them—I just want to show you—if you plot it, so here we have the volume of filtrate on the x-axis and on the y-axis, we have t by v to 10 to the power minus 3, the s per meter cube, OK. Now, we will get this kind of, you know, things.

So, this one I will just delete. So, this is actually a trend line. So, this is actually the real plot, the real data, and that is how it looks like. Volume of filtrate versus T by V. So, that is how the real data looks like. Now, you remember.

So, the intercept is the B part, and the slope is K_p by 2, right? Now, what will we do? We will take all this data, we draw a trend line, add a trend line. That means we will add a straight line and expand it and where it intersects, we will get the intercept from there.

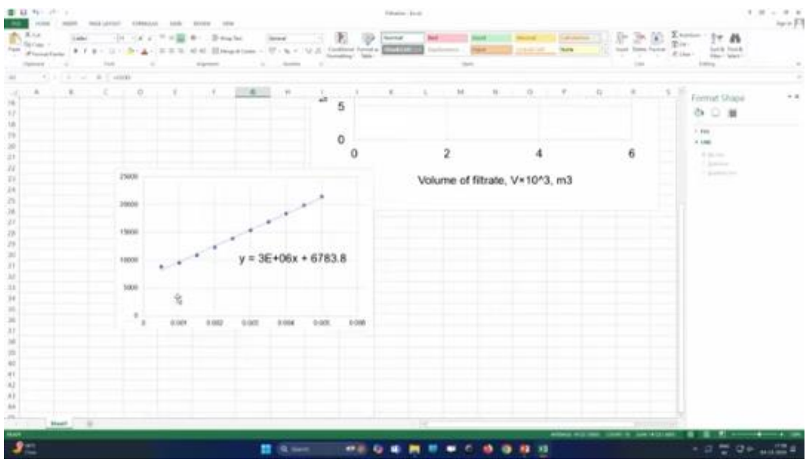


So, what will we do? We will display the equation on the chart. So, this is actually the equation given in the y = mx + c form, ok. So, this one, 2.885, is basically your slope, K_p by 2, ok, and here 6.7838 is the B. Now, since we have 10 to the power minus 3 on the y-axis and here it is 10 to the power 3, this one has to be multiplied by 10 to the power 6, ok.



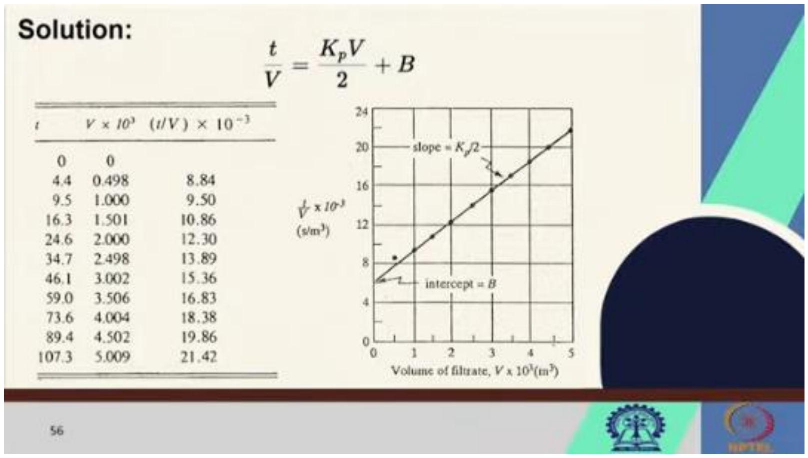
That means, the K_p by 2 equals to 2.885 multiplied by 10 to the power 6. So, Kp will be some 5.7 or 5.8 something like that. This one only since this is only intercept. So, multiplying this one with the 1000 will be enough because here you have the 10 to the power minus 3. So, 6 point it will give us 6 7 8 3.

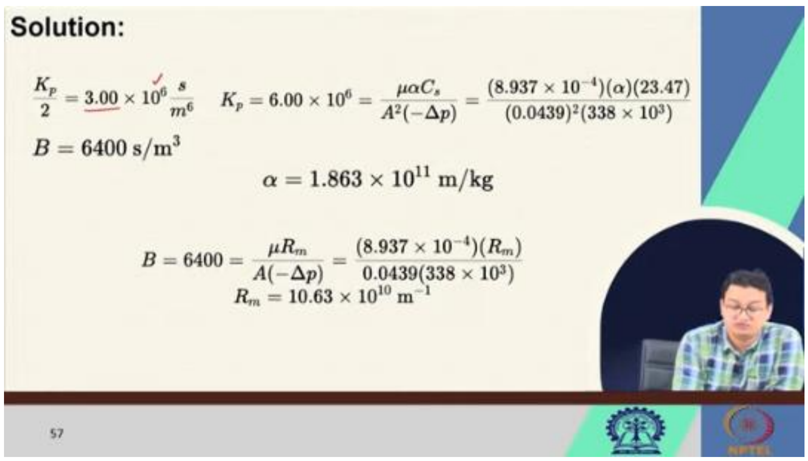
So, that is what if you do this for then these are the values you will get. Now, if we take that only v and only t by v ok. That means, we can also plot v and the t by v ok. So, values will be little bit different although they are actually coming very close. So, here therefore, we will have here v, v is all these values 0.0005, 0.001, 0.0015 here in the x, y we are having t by v. You can see over here and again I will just



delete it ok. So, these are the data raw data ok experimental data ok v and t by v and again with this one we will add the trend line display equation on the chart. So, you can see now it is actually showing the value ok. So, it is a k p by 2 is 3 into 10 to the power 6 ok 3 into 10 to the power 6 and here it is 6 7 8 3 or 6 7 8 4 the b value. ok kind of close if you look at over here 6.783 as i said multi it has to be multiplied by 1000 so it will give us 6783.8 here is the

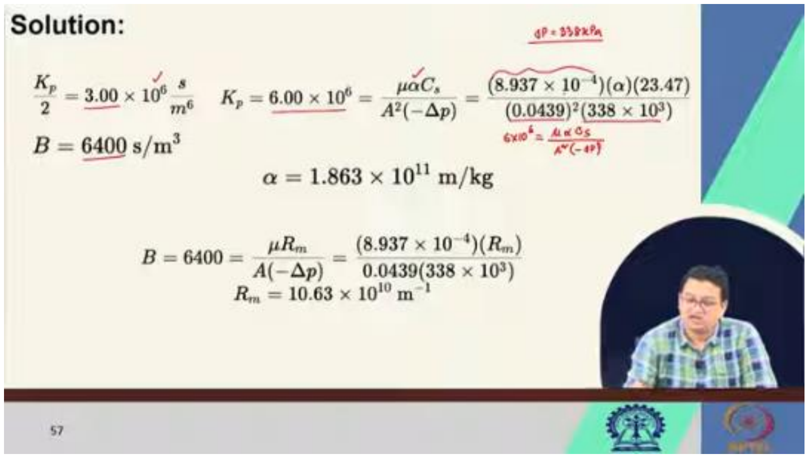
Same, this one is a little bit off, although they are very close. OK, so that is how you can get the value using Excel. OK, so that is how it looks like this. I have already explained to you. So, slope is K_P by 2—sorry, pen—K_p. Slope is K_p by 2, and here is the T by V multiplied by 10 to the power minus 3. And finally, if we do it that way, as I said, you remember that the K_p by 2 equals to 3 into 10 to the power 6. So, K_p equals to 6 into 10 to the power 6, OK. And here we will be having B value is 6400 S per meter cube, OK. How to calculate this?



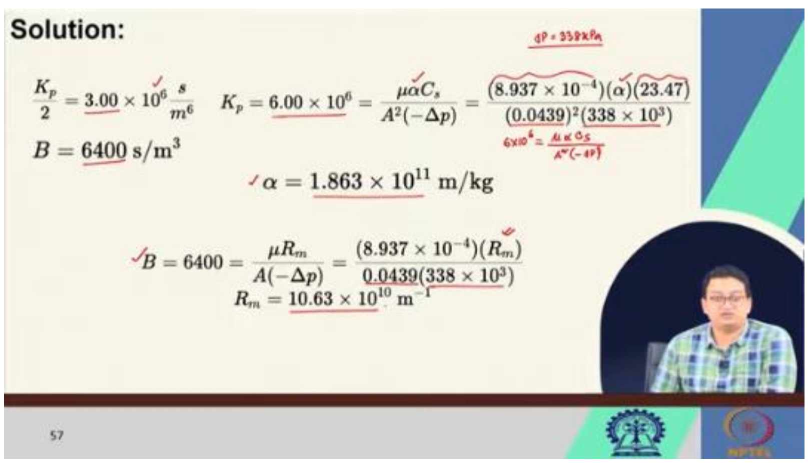


So, what is actually being asked? The specific cake resistance, that is the alpha value. So, alpha value means 6 into 10 to the power 6 equals to mu alpha C_s. C_s is the solid concentration in the slurry area divided by the square area of the filter and delta p. So, here the delta p is given as 338 kilo Pascal. If we plug in all these values—338 kilo Pascal—always remember, you have to be really careful about the units, OK.

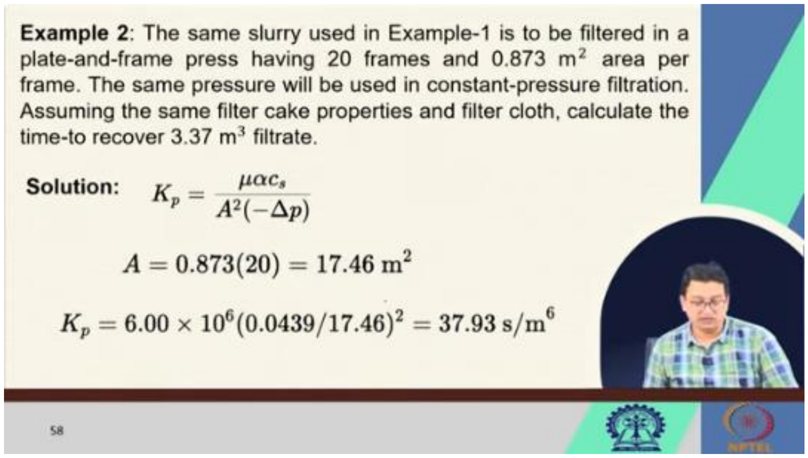
So, 338 multiplied by 10 to the power 3. Here, this is the area: 0.0439. Mu is given; the viscosity is 8.937 into 10 to the power minus 4. Usually, the filter viscosity is close to water, OK, at the same temperature. Alpha is unknown. The C_s is 23.47. The alpha value, therefore, we have 1.863 multiplied by 10 to the power 11 meter per kg. B is 6400.



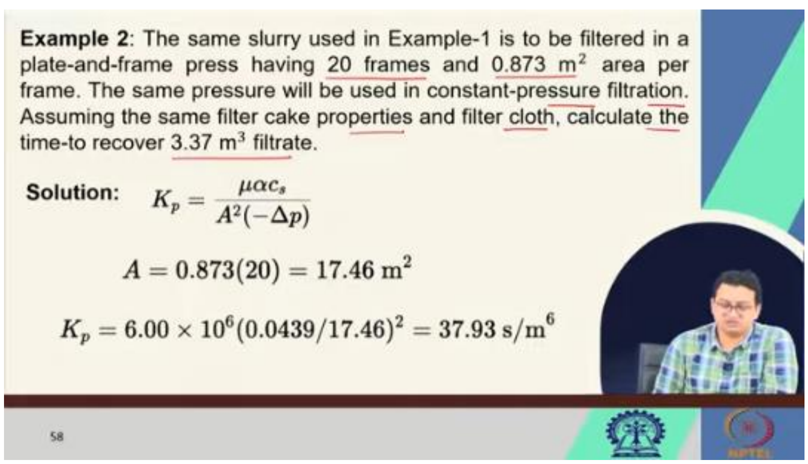
So, in the Excel sheet, we are getting something like 6383 or something like that. So, mu Rm divided by A multiplied by minus delta P. So, the mu value and R_m value are asked—the resistance provided by the resistance. The value of the filter medium A is 0.0439 multiplied by 338 multiplied by 10 to the power 3. So, finally, Rm is 10.63 into 10 to the. power 10 per meter. So, that completes this part. I hope you have understood.



Now, coming to the next part of this example. Now, the next part of the example states that the same slurry used in Example 1 is to be filtered in a plate-and-frame press. It has 20 frames, and each one has an area of 0.873 square meters. That means each frame is 0.873. So, you remember the plate-and-frame. So, frames are there to hold the plates, and the filters are actually provided onto the plate, all right.

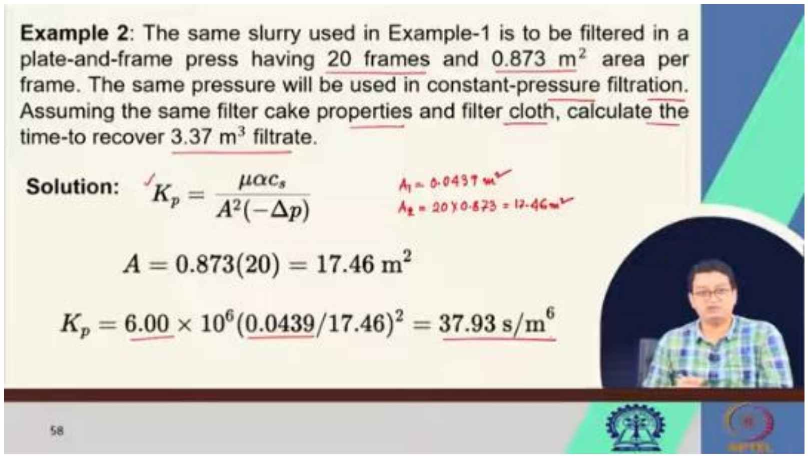


So, they are actually, you know, clamped together. There are 20 frames, which means the overall area has to be 20 multiplied by 0.873. If the same pressure is used in the constant-pressure filtration process, assuming the same filter cake properties and the filter. cloth, calculate the time to recover this much filtrate volume: 3.37 cubic meters of filtrate. So, very easy. So, K_p is mu alpha C_s divided by A squared minus delta P. So, now, the A has changed.

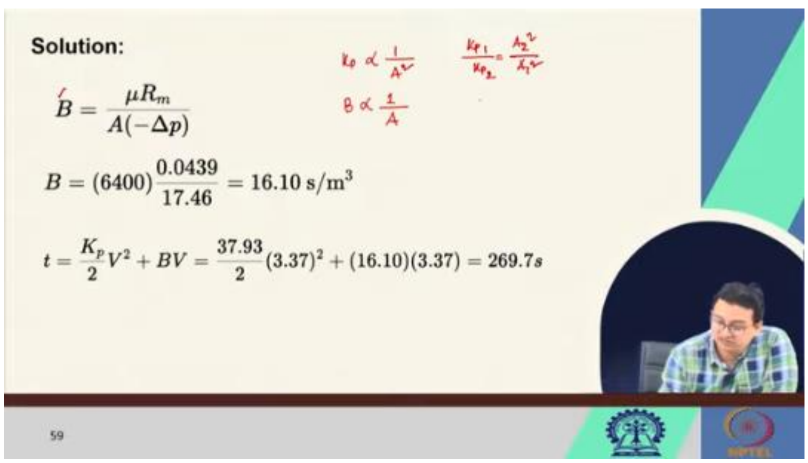


So, earlier a has a different value a value was how much 0.0439. So, 0.0439 earlier now A has become. So, maybe A_2, I can say A_2 is 20 multiplied by 0.873 that gives 17.46 meters square. Now, what we will simply do? So, other parts remain constant right.

So, mu alpha C h and this part is also constant ok. Now, K_p will be therefore, the 6 into 10 to the power 6 0.0439 divided by point 17.46 whole square. So, now, it is coming 37.93 all right. So, this is the current K_p value. Now, what would be the b value?



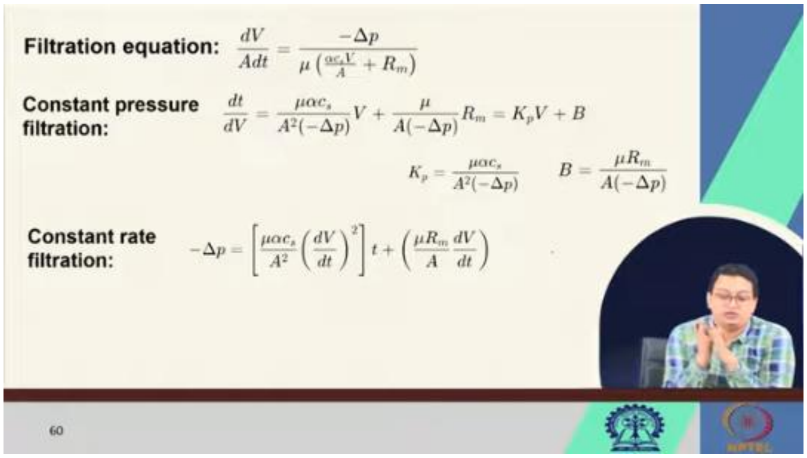
b value will be equals to mu R_m divided by a multiplied by minus delta P same thing. So, if you see the b is you know inversely proportional to the A K_p also inversely proportional to the A square ok. So, that means, you know Kp_1 by Kp_2 has to be you know A_2 square divided by A_1 square Similarly, so B_1 by B_2 it has to be A_1 like this ok. That means, then B_2 is we want to find out B_1 multiplied by A_1 divided by A_2.

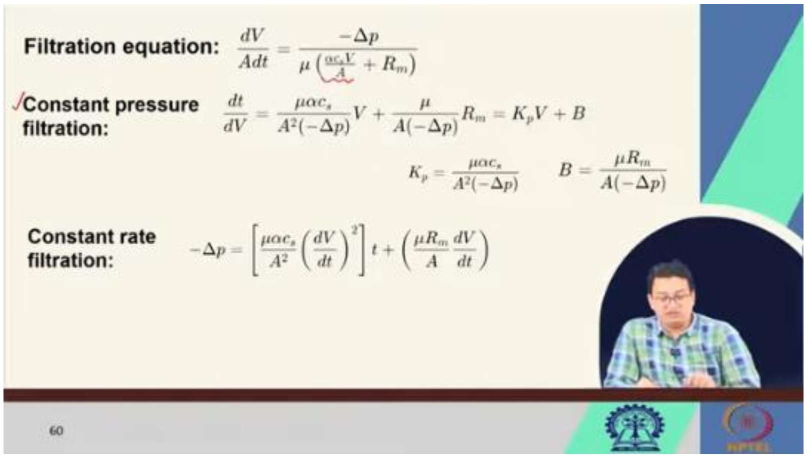


So, B_1 was 64000, sorry, 6400. Multiplied by 0.0439, divided by A_2, which is 12.46. So, you will get the new B value. So, that gives us the total time of filtration: K_p divided by 2 V squared plus B V. So, V is now given as 3.37, whole square multiplied by 37.93. Divided by 2, plus 16.10 multiplied by 3.37, that gives us 269.7 seconds, or you can convert it into minutes—probably a little more than four minutes, four and a half minutes or so. Okay, so that is our result now.

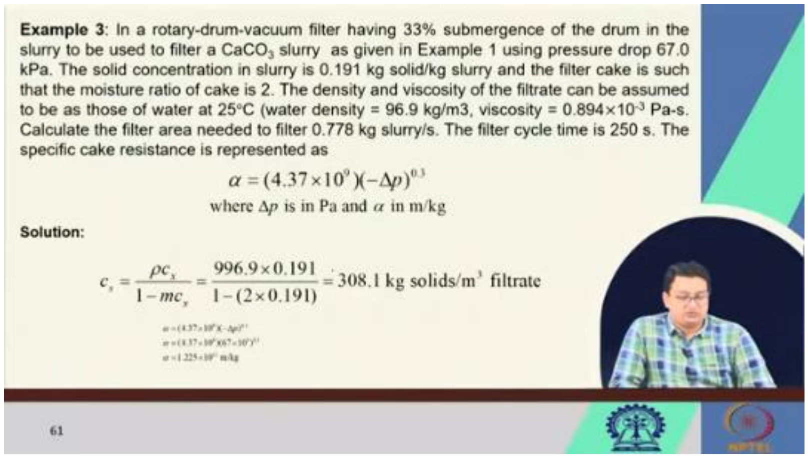
So, from this part of the lecture, we can have this idea that the basic filtration will be there, which is actually dv divided by A dt. So, this is actually our takeaway message, okay? Equals to minus delta P divided by mu alpha Cs v divided by A plus R_m, okay. So, it follows

Darcy's law. This is also equivalent resistance provided by the cake. For constant pressure filtration, we can have dT divided by dV equals to mu alpha C_s divided by S squared multiplied by minus delta P v plus mu divided by A multiplied by minus delta p R_m. So, you will be having K_p v plus B, where K_p is mu alpha C_s A squared divided by A squared minus delta p.





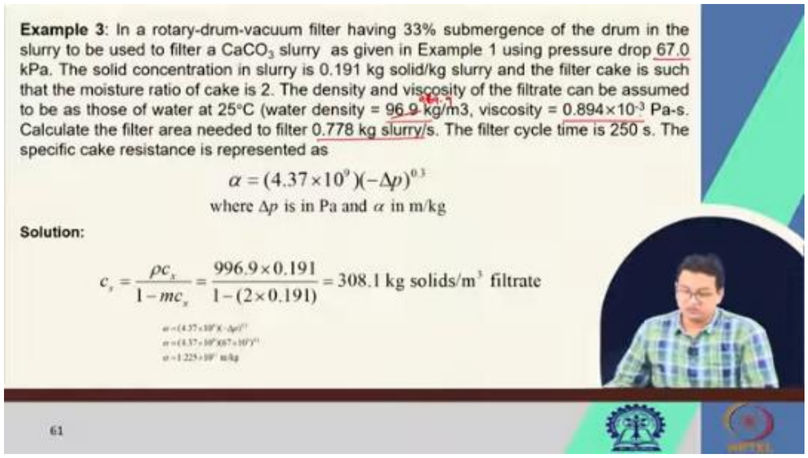
Here, B is mu R_m divided by A minus delta P. And for constant rate filtration, we have this expression. For constant pressure, we have delta P at the right side within the expression here, dT by dV. Over here, the left side for the constant rate, we have delta P at the left side, dV divided by dT over here. Now, coming to another problem, this is our final problem, and we will finish with these examples. So, what does it say? In a rotary drum vacuum filter having 33 percent submergence of the drum in the slurry to be used to filter. So, what it says? In a rotary drum vacuum filter having 33 percent submergence of the drum in the slurry to be used to filter



Calcium carbonate slurry, like what we have seen in Example 1. Now, the pressure drop has changed over here. It is 67. Kilopascal. What is the pressure drop? 67 kilo Pascal. The solid concentration in the slurry is 0.191 kg solid per kg slurry. And the filter cake is such that the moisture ratio of the cake is 2.

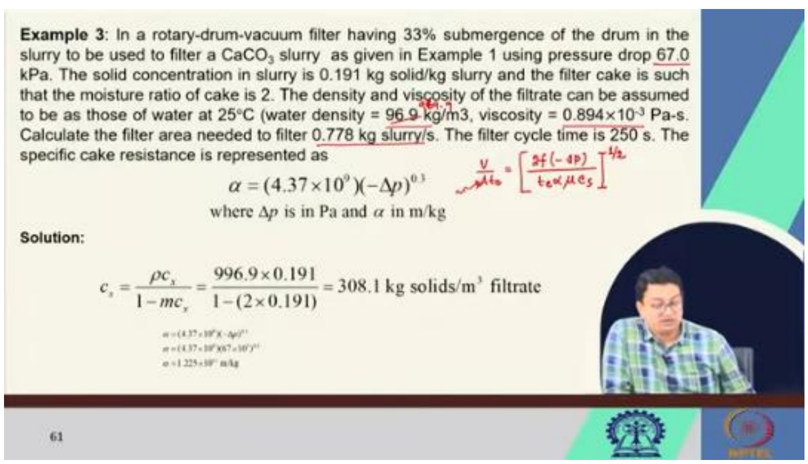
Now, the density and viscosity of the filtrate can be assumed to be the same as those of water. At 25 degrees Celsius, where—let us say—I have, sorry, this is actually a typo. So, this is 996.9 kg per meter cube, okay? But so this is actually 969.9 kg per meter cube. Viscosity is 0.894 times 10 to the power of minus 3 Pascal-second. Calculate the filter area needed to filter 0.778 kg of slurry per second, okay?

So, that is the one already given to us. Total filter cycle time is given as 250, okay? 250 seconds, that means the T_c, all right. Now, the specific cake resistance is expressed as alpha equals 4.37 multiplied by 10 to the power of 9 minus delta P to the. Power of 0.3, and these are the things, okay. What is actually calculated is the filter area, okay? Now, so you remember, when we are actually discussing the filtration cycle, so what we had was V by A T_c equals to 2f.



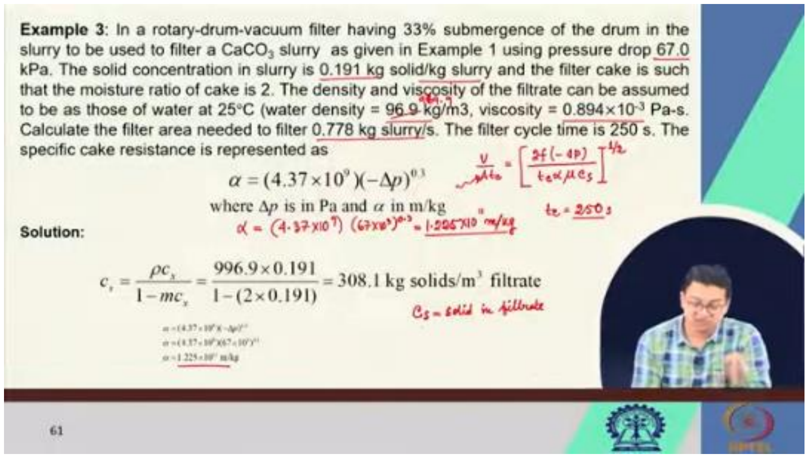
Minus delta T_c alpha mu C_s right to the power half. So, that is the one we have. Now, what is our interest? Our interest is this A. This A is our interest.

Now, see the delta alpha we can calculate using this one. So, alpha if we calculate, the alpha value is given over here: 4.37 into 10 to the power 9. So, delta P is 67, right? 67 kilo Pascal we have to convert it into pascal into 10 to the power 0.3. So, you will get the alpha value over here like this. I think it is there also in the next slide: 1.225 into 10 to the power 11 meter per kg.



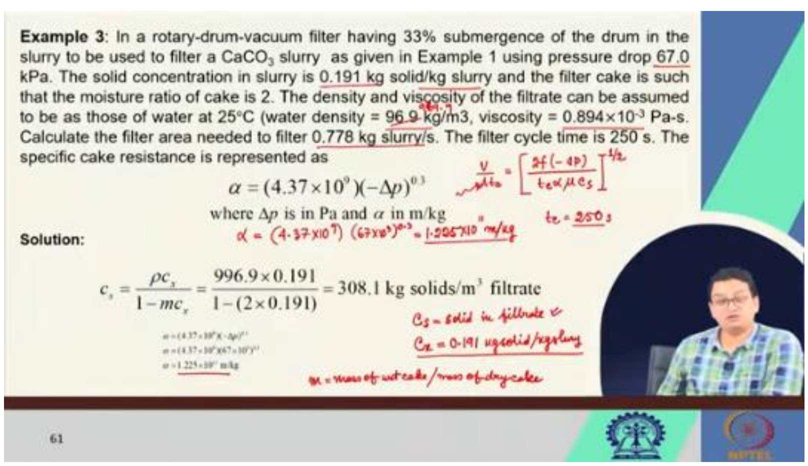
So, what else do we need? Alpha is here, then mu is given. What else? T_c is given. T_c is 250 seconds, right? C_s is also known. What is the C_s? C_s is over here. C_s is no, this is actually solids concentration in slurry, okay. So, C_s we have to calculate. So, what is C_s? C_s is solid in, you know, filtrate. That means kg of solid per meter cube of filtrate, solid concentration per unit volume of filtrate, okay.

So, that is the C_s. What is this? This is actually C_x. C_x is 1 point—no, sorry—0.191. kg solid in kg slurry. So, you remember, right? So, 1.191 kg solid per kg slurry.



So, that is C_x. Now, you remember, we have to calculate Cs—how C_s relates to C_x. C_s equals to rho multiplied by C_x divided by 1 minus m C_x, ok? If you recall, why we have considered this form—ideally, it has to be 1 minus x. Since there will be liquid along with the, you know, solid entrapped within the filter cake, that part we need to take care of. So, that is very important. That is why the M is multiplied, where M is the mass of wet cake. by mass of dry cake, ok.

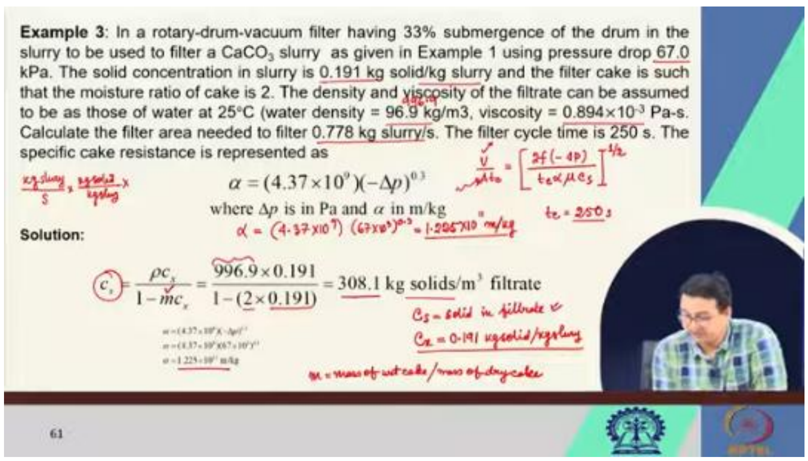
Also, this is called the moisture ratio of the cake. It is given as 2, ok. So, if I plug in all those values. So, this is 9—sorry, ah. So, this we have taken over here. 996.9 kg per meter cube—close to 1000 kg per meter cube, ok.



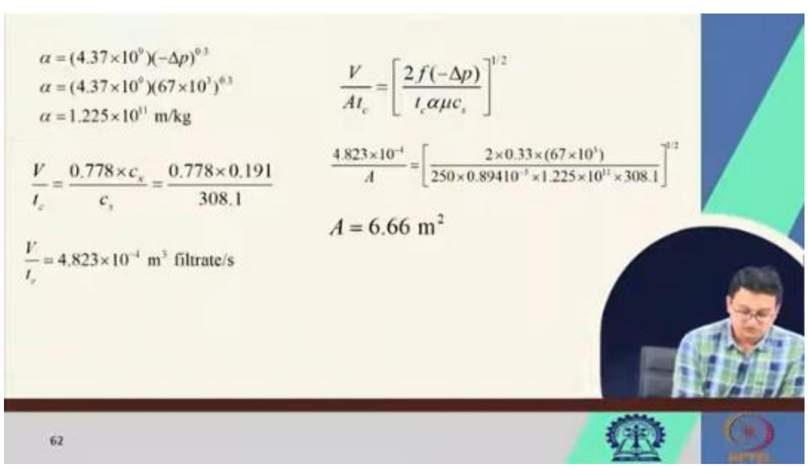
So, please correct this part, ok. So, rho is taken as 996.9, multiplied by C_x, which is given as 0.191, divided by 1 minus m C_x. So, m is 2, and this value gives 308.1 kg solids per meter cube of filtrate. Now, the question is, we have the solids per meter cube of filtrate, but how much V is there? Because if you see over here, it is V we are actually interested in, ok? V we are interested in, ok. How to do it? Now, V by T_c. So, see, we have A, this one, 308.1, ok. This is actually C_s. One thing is provided,

to calculate the filter, 0.778 kg slurry, ok. We have to convert it to the volume part. So, how can we do it? So, let us say if we have A kg slurry per second, ok. If we multiply this one with this one, kg solid

I will write it on this side; I am short of space. See, we have a kg slurry per second multiplied by C_x. We have kg solid divided by kg slurry. kg slurry, kg slurry gets cancelled. Now, what will we do? We will divide this by which one? The C_s part.

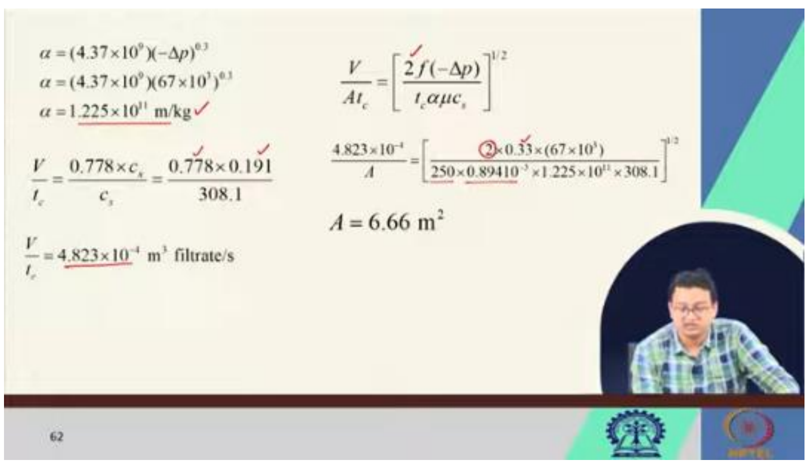


So, 1 by C_s. C_s means if you divide it, then we will have kg solid and meter cube of filtrate. Filtrate, right? That means kg solid, kg solid gas cancel, kg slurry, kg slurry gets canceled. We have meter cube per second, all right. That means if we do that, V by Tc, we can write it as 0.778 multiplied by C_x divided by C_s, okay? So, if you do this, all right. Alpha we can... So, if you do this, you will have 0.778 multiplied by 0.191 divided by 308.1, okay. So, this gives us 4.823.



Multiplied by 10 to the power minus 4 meters' cube filtrate per second. So, we have V by T_c, okay. Alpha value we We have already calculated. Now, what we will do: V by A T_c equals to 2 f multiplied by minus delta P T_c alpha mu C. We will put 2 over here, this one. Now, f, as I said in the question, it says 33 percent submergence. That means that fraction of time is equivalent to 0.3 t, which is

Required for the cake formation. So, that means we will do f is 0.33, delta P is 67 into 10 to the power 3 divided by 250 is total Filtration cycle. This one is 0.894 multiplied by 10 to the power minus 3 multiplied by 1.225 to 10 to the power 11 multiplied by 308.1. Finally, we will have A equals to 6.66 meter square, all right. We have taken a few examples in order to have a better understanding of how to use the experimental data for obtaining the Parameters during constant pressure filtration. We took help from Excel also, and we have calculated. We have also solved the



Problem. Another problem is how to calculate, you know, the filter area or, you know, from this concept, you can also, you know, do many other problem-solving tasks. So, I hope this has helped you a lot, OK? And with this, actually, I will end up here. So, this actually completes the flow through the filter medium. I hope you have enjoyed the class. Thank you so much.

$$\alpha = (4.37\times10^{9})(-\Delta p)^{0.3}$$

$$\alpha = (4.37\times10^{9})(67\times10^{3})^{0.3}$$

$$\alpha = 1.225\times10^{11}\ \text{m/kg}$$

$$\frac{V}{t_c} = \frac{0.778\times c_x}{c_s} = \frac{0.778\times 0.191}{308.1}$$

$$\frac{V}{t_c} = 4.823\times10^{-4}\ \text{m}^3\ \text{filtrate/s}$$

$$\frac{V}{At_c} = \left[\frac{2f(-\Delta p)}{t_c\alpha\mu c_s}\right]^{1/2}$$

$$\frac{4.823\times10^{-4}}{A} = \left[\frac{2\times0.33\times(67\times10^{3})}{250\times0.89\times10^{-3}\times1.225\times10^{11}\times308.1}\right]^{1/2}$$

$$\boxed{A = 6.66\ \text{m}^2}$$