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Unit operations of Particulate Matter

Lec- 09
Continuous Filtration, Filtration Equipment (Part-01)

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Welcome to the 4th lecture of week 2 which is on continuous filtration as well as industrial equipment for filtration, so this series consist two lectures lecture 4 and lecture 5 in lecture 4 we will discuss continuous filtration and different equipments involved in filtration at industrial level and description of these equipment will be discussed in 5th lecture of week 2. So let us start with 4th lecture of week 2 which is on continuous filtration, now what is continuous? In lecture 1 2 and 3 we have discussed the batch filtration in batch filtration different steps.

Work involved and in each case once we remove the cake which is formed one we remove the cake which is formed under filter media after that only we can start second cycle, so continuous filtration is what continuous filtration we can define as continuous removal of the cake because we would not allow cake to deposit for loner time and therefore once the cake formation is enhanced or is increased the filtration process stops, so in continuous filtration we do some arrangements. So that the cake which is form on the filter media that is that continuously removes.

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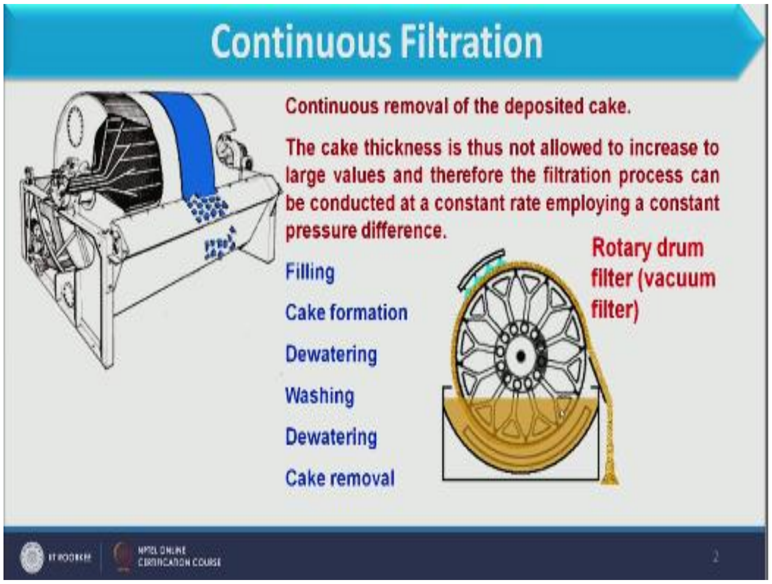

So in continuous filtration we go for continuous removal of the deposited cake the cake thickness is thus not allow to increase to large values and therefore the filtration process can be conducted at constant rate employing a constant pressure difference, now if you remember the batch process where we have define two phenomena first is the constant rate and second is the constant pressure, now pressure why we increase the pressure because after some time when the filtration is carried out.

After sometime the cake deposition cake is formed over the filter media and which offers resistance in the path of liquid to move and therefore we have to increase the pressure so if you remember the batch process there we have defined two phenomena first is constant rate and second is constant pressure, now in when we operate the system after some time cake is formed over the filter media for example this is the filter media cake formation appears over here and has the thickness of this cake increases.

This cake is basically this cake offers the resistance in the path of filtrate to move to cross this and the therefore after some time the filtrate which ahs to pass this it is volume should be it is volume is reduced after continuous operation and as this thickness of the cake increases, the volume which is collected as filtrate that should be that is decreased so that rate of filtration cannot be maintain so to maintain that rate of filtration we have to increase the pressure, so that it can be operated at constant rate.

However in continuous operation what is in continuous filtration what happens the cake is continuously removed, so cake cannot cake thickness cannot be increased and therefore the rate of filtration is not affected by the formation of cake and therefore at constant pressure we can maintain constant rate phenomena, now when we go for the batch filtration what are the difference steps if you remember the steps were filling that filling with the slurry then cake formation dewatering, washing.

Again dewatering and then cake removal all these steps apart from this there was another step which is was about apart from this there was another step which was about cleaning, dumping and reassembling of the system as cake is removed continuously there is no need for reassembling dumping etc. So all these steps which were involved in batch that can also be involved in continuous filtration and here we have rotary drum filter which is very common example of continuous filtration and which is operated at vacuum.

And in this diagram you see here we have the rotary drum filter which we has a specific diameter as well as length and it is operated at vacuum, now how it is operated that can be illustrated through this animation if you see this drum is continuously moved or continuously rotates some section of this drum is some merge into the slurry and if you see this some curved bar is there, so this curve bar is basically use for uniform mixing or homogenous solution of slurry homogenous slurry. Now as some section of this rotary drum is sub merge into the slurry and all these if you see in between lines.

These lines are connected with the vacuum pump, so this system is operated at the vacuum so once this system is some merge into this it sucks the water and during this sucking of the water sucking of the filtrate the cake formation occurs over here so when we go for the different step filling is basically submerging of this drum into this slurry then cake formation it means it sucks the filtrate and due to this cake formation occur then once it revolves one it leaves this slurry it comes in this section, if you see here we have complete formation of the cake here whatever water is available.

That is again taken by the these lines which are connected with the vacuum, so here we have the dewatering step once the dewatering process is completed we should go for the washing so here you see cake washing is done in here we have assembly to wash the cake and when the cake water is washed over here, again that water is sucked by these tubes and after washing again here we have the process of dewatering because whatever water is available in this cake that should be taking by these tubes.

And after that here we have the knife which is continuously taking this continuously removing this cake so once it will be again some merge into the slurry the cake formation starts, so it will be used as it enters as almost fresh drum, so you see all these steps are involved in batch process also and in rotary process also. So if all these cycles are covered in one rotation whatever steps involved in batch all these are involved in rotary drum or continuous filtration in single rotation, so when we compare continuous filtration as well as batch filtration.

One rotation of continuous filtration is equal to one cycle of batch, so in that way we can correlate batch filtration as well as continuous filtration.

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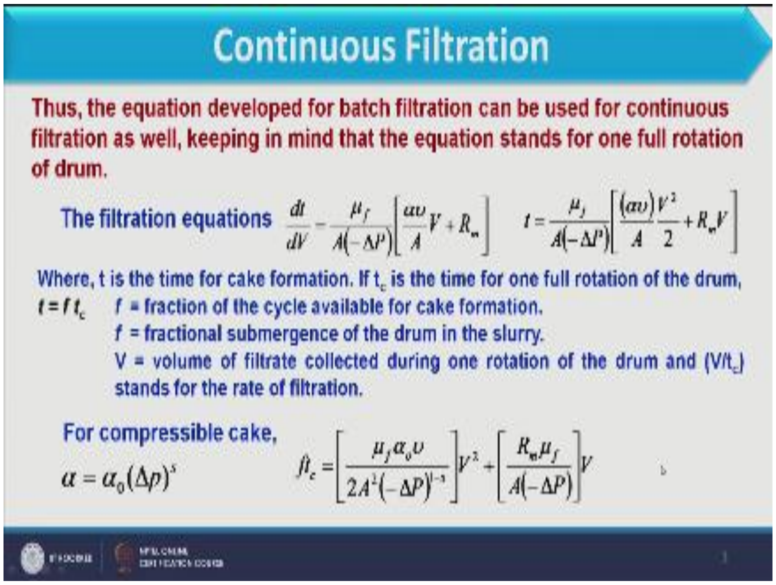

Thus the equation developed for batch filtration can be use for continuous filtration as well keeping in mind that equation is stands for 1 full rotation of the drum, so when whatever equation we have derived for batch that we can also use for the continuous filtration process but whatever filtrate we will obtain by this that will be the filtrate collected in single rotation for continuous filtration that all we have see, so the final filtration equation if you remember this we have derived in lecture 2 of week 2.

So time value from this when we integrate this we can get the time expression in terms of volume, where t is the time of cake formation and if you see here we have the volume we collected and when V volume to be collected that is the time of cake formation also, because here V is the volume of filtrate so in whatever time filtrate is collected in the same time cake formation is carried out.

So t is the time for cake formation and if t_c is the time for one full rotation of the drum then we can relate t with ft_c, t_c you remember t_c is the time for cake formation and that happens in one full rotation when we apply this particular equation, so time for, so if t_c is the time for one full rotation of the drum then we can co-relate t that is the time of cake formation is equal to fxt_c.

Now here what is f, f is basically the fraction of cycle available for cake formation and that is fractional submergence of the drum in the slurry.

So f how we can define the f is the section of the drum or surface of the drum submerge in the slurry that we can define as f, so usually it is considered as 20% of total surface is dipped into the slurry is submerge into the slurry so in that case f should be 0.2, and V is the volume of filtrate collected during one rotation of the drum and V/t_c stands for rate of filtration. So for compressible sludge using sphere co-relation we can have $ft_c == \mu_f \alpha_0 v/2A^2(-\Delta P)^{1-s}]V^2$.

And similarly another factor for media, filter media that is $[R_m \mu_f/A(-\Delta P)]V$ so this equation we can use for constant pressure and compressible cake in continuous filtration, so as the concept of constant rate and constant pressure is not applicable in this case this particular equation is used to calculate time or time required for full rotation for compressible cake.

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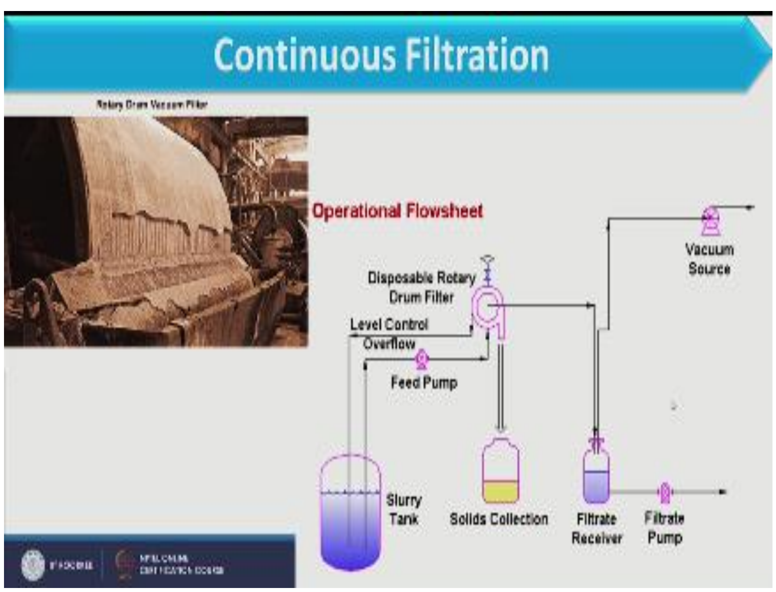

So if you see this particular slide here rotary drum vacuum filter is shown which we have just described, now if you see this figure here we have the knife which continuously removes the sludge or removes the cake which is formed over the drum which is shown over here, and after removing this the drum re-enters into the slurry tank, and here in this figure we describe the operational flow sheet because this is the continuous process.

So what happens rotary drum is associated with this slurry tank so through slurry tank feed enters into this, this position is merged into this and here we have the level control, level control is to ensure that some certain section of the drum should be submerged in the liquid, when liquid level enhances then this it is recycle back to the slurry, when liquid level enhances then this liquid is recycled back to the slurry tank.

So slurry is, drum is submerged up to here in the slurry tank the whole washing process is carried out whatever scarp is there that is whatever cake is there through knife it is collected into the solid collection tank and then the filtrate, how the filtrate is collected through the tube which we have just discussed those tubes are connected to the filtrate receiver and whole system is connected to the vacuum source, and then filtrate is taken out through pump for different use.
So here we have the complete flow sheet for continuous filtration.

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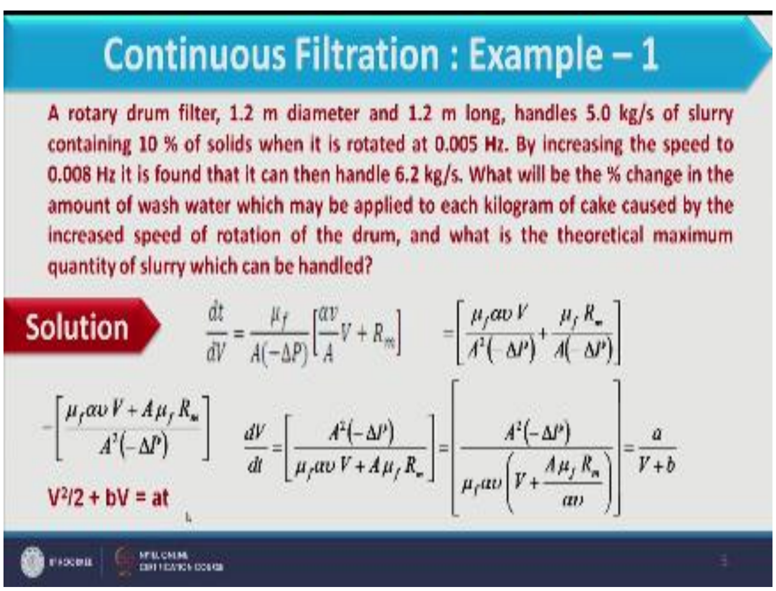

Now to demonstrate how the calculation of continuous filtration is carried out we have taken one example, and here rotary drum filter having diameter 1.2m and 1.2 length as well it handles 5 kg/sec of slurry containing 10% of solid when it is rotated at 0.005 Hz. By increasing the side by increasing the speed to 0.008 Hz it is found that it can then handle 6.2 kg/sec slurry, what we have to calculate is percent change in amount of wash water which may be applied to each kg of cake cost by increased speed of rotation of the drum.

And what is the theoretical maximum quantity of slurry which can be handled, so you see what we have to find is the amount of wash water so we have to first calculate the rate of washing and then amount of wash water we calculate for case 1 where rotation is 0.005 and for case 2 where rotation is 0.008 and then we compare these two amount to calculate the percent change. So here we have the solution for this problem, this is the final filtration equation for the single rotation after rearranging we can obtain this expression.

Further rearrangement gives this particular expression and so we can calculate dV/dt by rearranging this expression which is looking like this and then after solving this we can what we have done over here if you see $A^2(-\Delta P)/\alpha\mu_f$ V we have taken out so in $(V+A\mu_f R_m/\alpha v)$ so you consider if we consider this particular expression all parameters available in this is a constant which we have denoted as A.

V is there and all these parameter club into 1 and it gives a constant P so we can write whole expression that is dV/dt=A/V+b, and further integrating it, it gives V2/2+bV+at.

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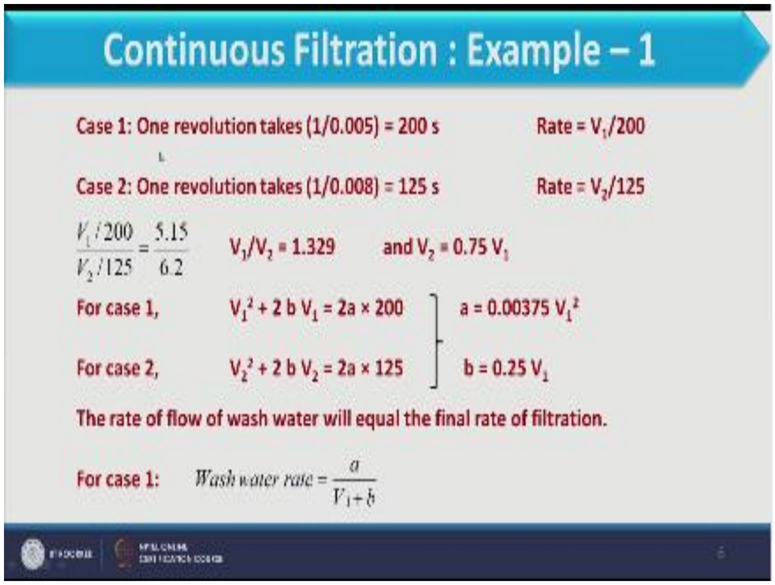

Now here for case 1, one revolution takes 005 Hz which is equal to 200 seconds and rate should be equal to $V_1/200$, how the rate is defined total volume collected divide by total time required. And similarly for case 2, one revolution takes 125 seconds and rate should be $V_2/125$, now from these two expressions we can relate V_1 and V_2 which is shown over here and V_1/V_2 we can define as 1.329 and further V_2 should be equal to $0.75V_1$.

Now in the previous slide we have derived the expression of volume and time and that expression was $V^2/2+bV+at$, now for case 1 $V_1^2+2b1+2ax200$ and similarly for case 2 it should be $V_2^2+2bV_2=2ax125$. Now putting the value of V_2 from this expression to here and then calculating of a and V, we can get a has $0.00375\ V_1{}^2$ $b = 0.25\ V_1$. Now the rate of flow of wash water will equal the final rate of filtration this we can consider, for case 1 wash water will = a/ V_1 + b, that you can see from the last slide the rate of the equation how we have defined and similarly putting V_1 we can calculate we can find the wash water rate for case 1.

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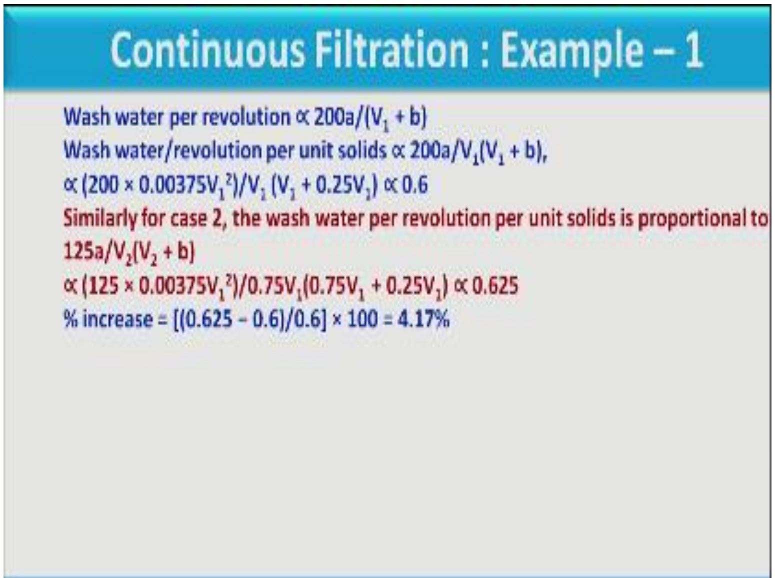

So wash water rate per revolution is proportional to 200 x rate of washing that is a/ V_1 + b, so wash water required per revolution. Similarly wash water per revolution per unit solid is proportional to 200 x a / V_1(V_1 + b), now here you can see we have defined per unit solid but we are considering volume over here because volume will be associated with the solid which is forming the cake. Therefore we can use this per unit volume, instead of per unit kg of solid.

So this is proportional to 200 x we can put the value of a which we have seen in the last slide and we can put the value of b also after solving this particular expression we can say that wash water per revolution per unit solid is proportional to 0.6 and similarly for case 2 the wash water per revolution, per unit solid is proportional to 125a/ V_2 (V_2 + b) and after putting the value of a and b over here this is proportional to 0.625. So 0.625 – 0.6/0.6 is 4.17% increment we have observed using the revolution of rotary drum.

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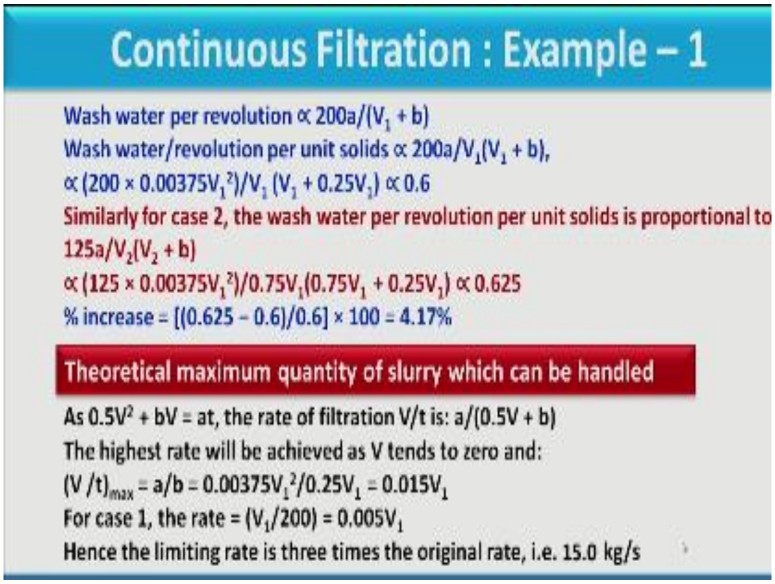

So here we have to calculate theoretical maximum quantity of slurry which can be handled, for this we should know the rate of filtration, if you remember this expression we have already derived from the previous slide and then rate of filtration from this equation we can calculate the V/t as a/0.5V +b. Now this rate of filtration is affected by this volume otherwise a and b are constant. So highest rate can be achieved when v are considering v as 0 and that comes as a/b = 0.00375 $V_{1\ 2}$, 0.25 V_1 and it gives 0.015 $V_{1.}$

On the other hand for case 1 the rate should be V_1 / 200 and this we have seen in the last slide which values comes as 0.0005 V_1. So when we compare these two the rate of filtration, and this is the highest rate of filtration, so when we compare these two we can say the highest rate if filtration is 3 times more than the present rate of filtration and therefore as well slurry heat can be handled at optimum condition or maximum slurry it can be handled is 3 times more than that is used for case 1. Therefore case 1it was 5 and now it should be 15, hence the maximum quantity or limiting rate is 3times the original rate, and therefore the maximum slurry that can be handled is 15 kg/sec.

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So that is all about the continuous process, now we will discuss, what are the different equipments available in industry for filtration? So first of all we will speak about classification of cake filters, 1st we have batch pressure filters, here we have plate and frame filters and pressure leaf filters. Batch vacuum consist vacuum leaf filters and further continuous pressure filter, if we speak, we will see rotary drum pressure filters in this category and continuous vacuum filters, we see rotary drum filters as well as this filter.

Along with this we have centrifugal filters which we can be operated for batch and continuous operation and under this category filtering centrifugal are found. So these are some of the classification of cake filters.

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Now here we have seen one condition that is under vacuum and second is at normal condition, so what is the advantage and dis advantage of vacuum filtration? Advantages are it is continuous operation because continuous removal of cake can be observed over here, which is not possible for the non vacuum process, producing relatively clean filtrates, convenient access to the cake for sampling, like we have continuous removal of cake, so if we have to take the sample for the cake that we can take very easily.

Easy control of operating parameters such as cake thickness, because we do not allow cake to form over the filter media for longer duration therefore continuously removed, so the operation becomes easy in this case, wide variety of materials of construction, along with this there are some disadvantages also. Higher residual moisture in the cake, because after once if the cake is continuously removed, so de watering is not carried out up to sufficient time in therefore the cake which we have obtained through this in comparison to the cake which we have obtained through normal or pressure condition or batch process.

Difficult to clean mainly as required for food grade applications and further high power consumption by the vacuum pump. So if you see vacuum operation continuously which consumes significant powered. Therefore as far as operational economy is consider, this is more expensive in comparison to batch. So here I am stopping this lecture we will discuss equipment of filtration which are used in industry in next lecture of this series. So that is all for now thank you.

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