**Fundamentals Of Particle And Fluid Solid Processing**
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**Lecture – 29**
**Sedimentation (Contd.)**

Hello everyone, welcome back to the another class of Fundamentals of Particle and Fluid Solid Processing. So, in the last class we started the discussion on the continuous operation of the settling phenomena. So, we will be carrying on that concept that the separation of solids from fluids that is the sedimentation for continuous operation.

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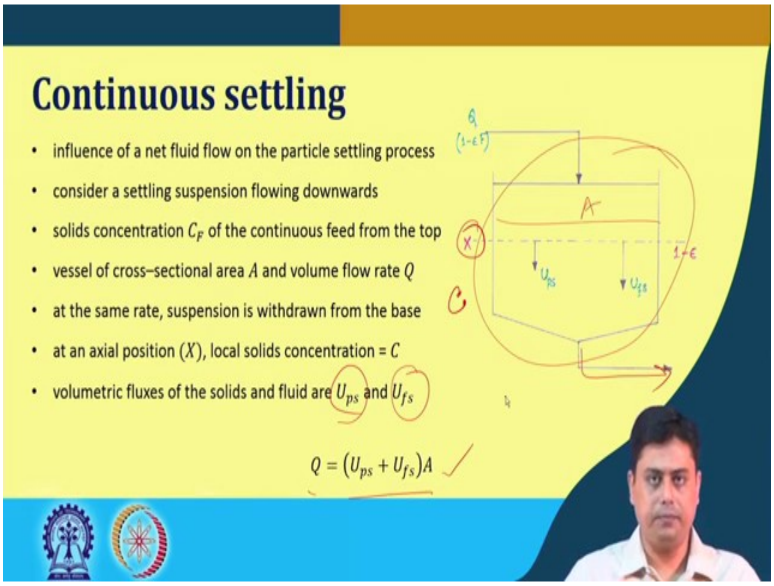


Now, in continuous operation as we mentioned that, we will be understanding that what is the influence of a net fluid flow on the particle settling process and for that if we consider sedimented sedimentation vessel like this that we have, that is feed coming in from the top and it is being continuously withdrawn from the bottom. Now if the solid phase concentration is $C_F$ that is coming from the top, the vessel cross sectional area is A and at the same rate if it is withdrawn from here than at any axial position from the top let us say X.

And if the local solids concentration is C, then the volumetric flasks of solids and fluid are $U_{ps}$ and $U_{fs}$ if these are the values we consider then by continuity, this Q is basically this total volumetric flux of particle and solids multiplied by the cross sectional area at any plane this would satisfy.

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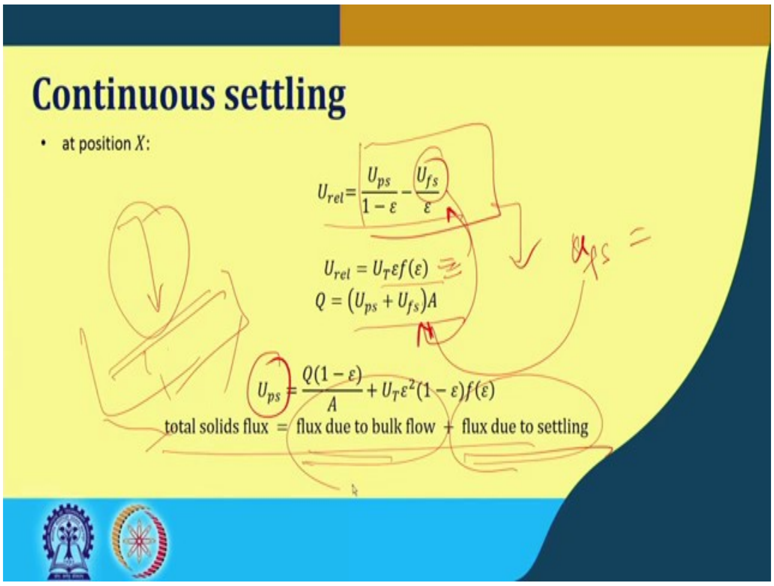


Now, we have seen that at position X the relative velocity of the particle and the fluid are or is this one that the superficial flux divided by its corresponding volume fraction.

$$U_{rel} = \frac{U_{ps}}{1-\varepsilon} - \frac{U_{fs}}{\varepsilon}$$

And again we knew that this relative velocity is

$$U_{rel} = U_T \varepsilon f(\varepsilon)$$

we also knew now by continuity that this should satisfy.

$$Q = (U_{ps} + U_{fs}) A$$

So, in the last class what I mentioned that, if we now replace this $U_{fs}$ from

$$U_{rel} = \frac{U_{ps}}{1-\varepsilon} - \frac{U_{fs}}{\varepsilon}$$

here in this expression of Q, $U_{rel} = U_T \varepsilon f(\varepsilon)$ is equals to this parameter this expression and then if we find an expression for $U_{fs}$ we replace this $U_{fs}$ in this expression for the overall Q.

So, we find that $U_{ps}$ or the particle solid or the solids flux is the flux due to the bulk flow plus the flux due to settling till now this till this portion we covered in the last class.

$$U_{ps} = \frac{Q(1-\varepsilon)}{A} + U_T \varepsilon^2 (1-\varepsilon) f(\varepsilon)$$

Now the significance is that here it basically conserves the concentration of the particles or the solid flux. Now here this is the total flux is equals to flux that is coming by the bulk solids that is the flow rate in that tank and the flux due to settling at any plane.

*total solids flux = flux due ¿ bulk flow + flux due ¿ settling*

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So, how this basically linked or how we use our batch settling data or batch selling knowledge in this continuous operation? Now in batch settling flux we observed that that was something like this curve this is the batch settling curve ok. Now we have a net flow in the system which is the bulk flow. This bulk flow has a slope $Q/A$ because the x axis is the concentration and y axis is the solids volumetric flux.

So, this slope of $Q/A$ represents the bulk flow the relation between the feed the concentration of the solids with its volumetric flux with a slope of $Q/A$ for the bulk flow. So, which means for the batch settling process or the batch operation, we have a batch settling flux now we have the bulk flow ok. Here we can see that this is nothing, but this the batch settling flux and this is the flux due to the bulk flow. So, addition of these two would give us the continuous settling flux.

So, if I add or if we add this line or the data of this line plus this line, this curve and plot it on the same graph, we would be having this relation or this curve that is here, which is the continuous total downward flux. This process we have considered for the downward flow, everything is flowing downward or a settling in a downward flow with that assumptions we derived this part.

So, basically what happens? In the continuous settling cases the continuous total downward flux is the summation of the bulk flow plus the batch settling flux ok. Now this graphs has immense importance how that is? Because here we can find out several information. For example, so, here the x axis is our the concentration ok. The feed the any concentrations here we the feed or the other concentrations we will see.

Now, say we know the feed concentration here because we started with the assumption that that this feed has a solids concentration of $C_F$ ok. So, that is in the bulk at the top when it has not entered the liquid pool or the fluid pool ok. So, this curves concentration or intersecting the bulk flow represents this feed concentration ok. Now at any point we have seen that this concentration should be equal to the any portion or any axial position inside that sedimentation tank. Which means if we see if we drag this line and try to intersect with the y axis, it basically intersect this continuous total downward flux at a certain concentration.

Now, this concentration is nothing, but the concentration of the bulk of the solutions or the downward settling velocity the solid flux concentration. So; that means, the portion we had we had bulk flow and then at a certain plane we are estimating that what is the concentration. Now by continuity we have seen the total flux has to be same at any plane if the particles and the solids are incompressible. Under that scenario by material balance from this graph, we can find that for a particular feed concentration the line it intersects here it is basically that corresponding $U_{ps}$, but the point where it intersect this total flux keeps this concentration of the downward settling particles.

Now, this would be always lesser than the feed concentration. This $C_B$ would always be lesser than the feed concentration. The reason is that the concentration multiplied by the velocity is basically the flux ok. Now this flux is maintained by continuity at any plane ok.

Now the point is that this downward settling velocity is always higher. So, the concentration has to be lower in order to maintain the same flux and that is why this $C_B$ would be always lesser than $C_F$ in such scenario ok.

$$\text{always } C_B < C_F: \qquad concentration \times velocity = flux$$

Now, this is the downward flow the total flow was happening the in a downward motion.

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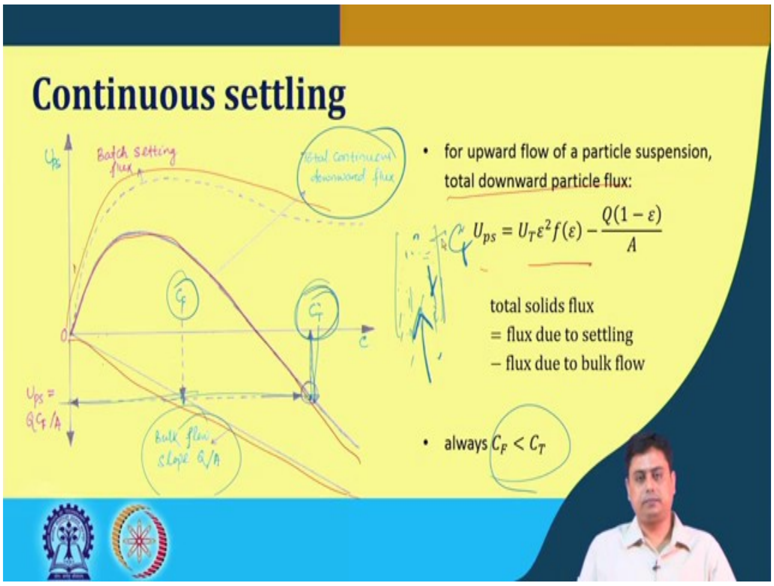


The similar analysis we can do for the upward motion as well or the upward flow of particle suspension when there is the bulk flow at from the bottom, but the particles are sedimenting downward. So, the by similar analysis we can see that the total downward particle flux for an upward flow of particle suspension is the flux due to settling minus the flux due to the bulk flow.

In the previous case, it was the summation of all these two component. But when there is upward motion of the bulk flow there we can have the total solids flux is equals to the flux due to settling minus the plus due to the bulk flow. That means, if we go back to this graph once again, we have we will have this as a batch settling flux this is the nature we have seen. Now the bulk flow is having a downward motion with a slope of $Q/A$ which is minus $Q/A$. Summation of these two data points at particular C B will be the resultant will be this thicker line.

Now, this is the total continuous downward flux.

$$U_{ps}=U_T\varepsilon^2 f(\varepsilon)-\frac{Q(1-\varepsilon)}{A}$$

So, which means the scenario is something like that that the bulk motion is a flow is something like this the particles are sedimenting. So, in that case here if our initial concentration initial feed concentration is known ok. So, we can have its $U_{ps}$ that is the point where it intersects with the slope $Q/A$ this line $Q/A$ line and if we go on intersecting this total downward flux, we have a point where it gives the concentration of the solids at the top portion.

So, which means here the T is mentioned we will see that later we mention this T as the top portion and earlier we mentioned as B as the bottom portion because here the things the things are settling. So, we consider the concentrations at the bottom of this vessel and here the net flow the bulk flow is upward, the particles are setting downward ok. So, the concentration of the particle at the top portion is $C_T$ that is what we can get from this result; that at any plane x from the top of the vessel, we can have its concentration from such data point or from such graph.

Now, remember this graph is for the upward flow of particle suspension, the bulk flow or the bulk flow is happening from bottom to the top of the bed or the vessel. So, in that case as I said the total solid flux is the flux due to settling minus the bulk flow or the flux due to the bulk flow.

$$total\,solids\,flux=flux\,due\,¿\,settling-flux\,due\,¿\,bulk\,flow$$

In other case when there was downward motion the total solid flux was the flux due to settling plus the flux you to bulk flow. From both this cases if we know the feed concentration we can determine that what would be the concentration at any axial position or any axial plane from a distance from the top of the bed or the inlet.

Now, in this case the concentration would be always greater than this feed concentration. Because of the same logic that the concentration multiplied by the velocity is the flux. Now here in the upward motion the velocity of this upward particle flow is the settling velocity of this particle is always lesser than the feed velocity. So, the concentration is higher in order to maintain the fixed flux at any plane.

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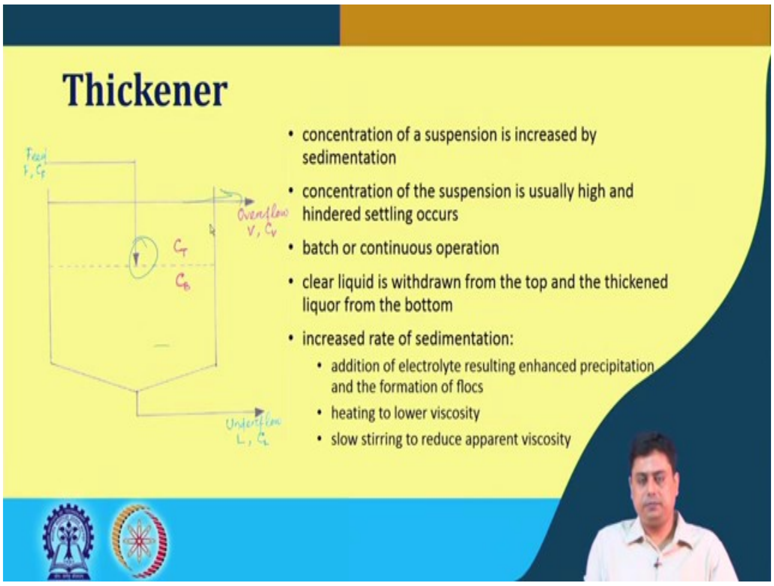


So, if we have understood this concept, these concepts basically applied to a sedimentation equipment called the thickener ok.

It works on this principle that we have a vessel of certain cross section, where the feed is being injected at a position which is intermediate between the top of top surface of the bed and the bottom of the bed, somewhere certain distance from the top of the bed. So, in this case or in this equipment then; that means, there will see that there are two zones basically before that let us clarify certain terms in thickener. Now what happens here when the feed is there a continuous it can operate in continuous or batch operation, but say let us say there is already some suspension.

So, some particles has settled which is being pulled out from the bottom of the bed. And the clarified liquid or the cleared liquid is being taken away from the overflow. So, here the concentration of suspension is increased by sedimentation and the concentration of suspension is usually high and hindered settling occurs in thickener. So, that is why we have seen or to have the design of this thickener we need those prior knowledges of multiple settling or multiple particle settling or settling in the overflow or the under flow condition.

Now, the clear liquid is drawn from the top and the thickened liquor is taken from the bottom. Now to enhance the rate of sedimentation practically several things are done for example, electrolytes are added to enhance the precipitation in colloidal particles or fine particles. So, that and also it helps in formation of flocs or the flocculation phenomena can happen which enhances the sedimentation rate. Sometimes this thickener the whole thing is heated so, that the liquid phase or the fluid phase in particularly this happens in the liquid cases. So, there the viscosity of the liquid lowers or it to reduce the viscosity ok.

And by doing that what happens that the larger particles are allowed to go or grow bigger and bigger and what happens? This finer particle gets soluble in that fluid mat. With the expense of this solubility with increased temperature of the system and lowering the viscosity in such a way this sedimentation rate can be enhanced. It also enhanced by the introduction of stirring mechanism inside the vessel. So, slow stirring actually reduces the apparent viscosity of the whole suspension and as it reduces, it also helps in the phenomena that I had just mentioned that. So, as the viscosity goes lower larger particles or the sedimentation rate increases the larger particles get bigger and bigger and the smaller particles are gets soluble in while doing the heating phenomena sometimes ok.

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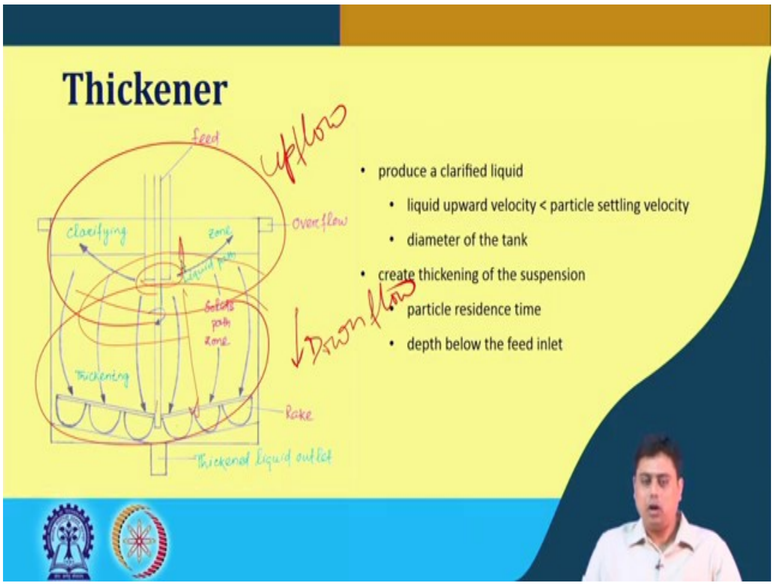


So, the point is that the objective of having a thickener; that means, is to produce clarified liquid as much as it possible so, that less amount of particles are thrown or taken from the overflow. So, a typical thickener looks like this kind of a scenario that we have a feed nozzle through which feed comes and it does not actually dropped exactly at the top surface from the top surface after a certain distance it is introduced with as less turbulence as possible in a in a manner. So, that it does not create that much turbulence. Because if it happens then the weight formation and all the other stuffs happens so, the particles basically do not get settled.

So, once that is introduced to this through these sections then what happens the particle settles in this thickener just say there are two motions or the two sections we will we has been we have observed. One is that there is the downward motion that is the solids flow path or the path that it typically follows that it typically comes down and it also basically focused towards the center of this vessel, which is at the bottom is of conical in nature not exactly flat or rectangular as its shown in 2 D.

So, it has a conical bottom and this is a stirrer which slowly rotates and these are the rakes which basically scraps those sedimented particles which are taken have it for taken out with a certain outlet from this bottom this thickened liquid is withdrawn. And the liquid path is something like this that is given in this arrows that it goes upward, the clarified liquid goes upward which is withdrawn from the overflow. This stream at the bottom we call under flow and this at the top where the clarified liquid is withdrawn we call the overflow.

And then this. So, to produce this clarified liquid the diameter of the vessel is of the main concern. So, the design parameter one of the design parameters of thickener to produce this clarified liquid is the diameter to decide on the diameter of the tank because in this section this liquid upward velocity has to be lesser than the particle settling velocity. The other objective of using thickener is to create the thickening of the suspension as much as possible and that depends on the particle residence time, which is influenced by the depth of the feed inlet that we have from the top and this height of the vessel as well or the respective measure of the feed inlet or the depth below the feed inlet and where the position of this feed inlet.

. So, these two are the main criteria of having this thickener designed properly. So, that means, if we try to summarize here the information that has been discussed till now is that the thickener is an equipment for sedimentation, there are several ways to enhance the rate of sedimentation in practical cases. For design of sedimentation which has a twofold objective one is to produce as clarified as possible liquid and to create the thickening of the suspension. To produce the clarified liquid we have to specifically concentrate on the diameter of the tank because the liquid upward velocity because here clearly now in a thickener we have two zones. One zone is this a flow zone if we see this is this is the up flow zone and this zone is the down flow zone.

Now, interestingly prior to introduction of thickener we have covered these two parts separately that when or what will happen when the particles are settling in down flow motion and particles are settling when there is a up flow motion of the liquid or the suspension. And that is the necessity because we are actually focusing now on the thickener part which has these two zones that below the feed depth we have the downward or the down flow zone and above the feed depth we have the up flow zone. How to measure the concentration above the feed level at a certain axial plane? We have seen that in a flow discussion. Below the feed depth there is the downward net downward motion how to find out a concentration at any plane any vertical plane, we have seen that when we discussed about the net solid flux in a downward motion of the suspension.

So, these two knowledges or these two sections is basically integrated in this thickener design ok. So, we will be seeing now that what is the critical load of a signal and how do we decide on that or when a thickener is under loaded or overloaded and how a thickener concentrations we can determine at any plane in a thickener, when all the other information are given or basically how to use these graphs. This is the downward flow and this is the up flow graph now these two are combined there in thickener because we have now two zones in thickener. So, we will be continuing with this discussion in the next class and we will see that how to extract the data from those graphs. So, until then.

Thank you for your attention.