Introduction to Mineral Processing
Prof. Arun Kumar Majumder
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture - 51
Gravity Concentration (Contd.)

Hello welcome, so in the last lecture we are talking about the jigging and we are discussing about jigging under the screen and jigging where we use some ragging material also. Now, when we have feed particles larger than the apertures of the supporting screen, that is; all your particles all your feed particles are coarser than your screen aperture size so; that means, no particle is going to pass through your jigs aperture.

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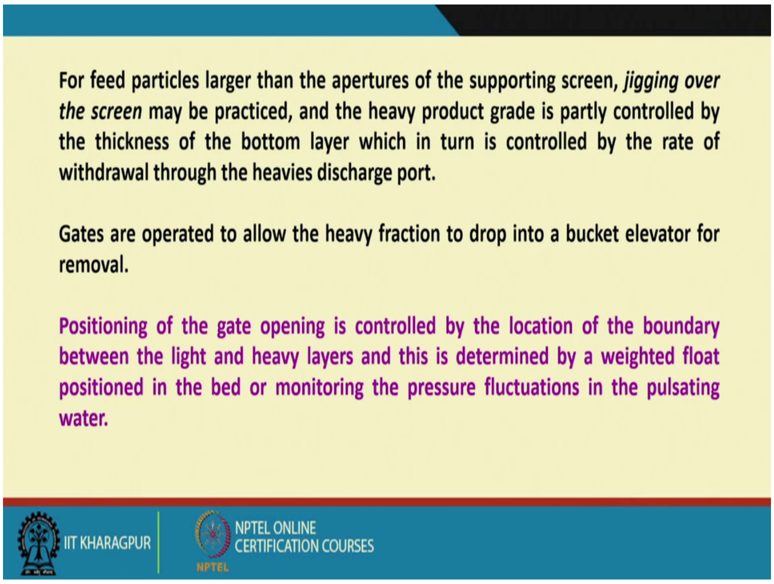

So, that is called the jigging over the screen; that is you are trying to separate out all the particles on top of the screen. So, jig that screen is only a support platform for your particle to hold. So, it is called the jigging over the screen. And in that case jigging over the screen may be practice that is when you are feed particles are larger than the apertures, and the heavy product grade is partly controlled by the thickness of the bottom layer which in turn is controlled by the rate of withdrawal through the heavies discharge port that is what I will explain that; you have got in now your stratified bed formation.

So, now, you have to have some means to collect them separately, that is your from the each layer that is I have got a stratified layer, now I must slice through a particular portion of that and that is the most difficult thing that is to predict that, where I should have a separation between my say your float fraction and sink fraction, because everything is in one particle bed.

So, once you are sure about that, then you can have some kind of your slicing up the bed, and then on top of that you are you are say bed you can take out the float and underneath that you have the sink material you have to take out the sink material that is your heavier fraction, but these are the design features. Now, to do that; what to do; now we has gates, that is how you are basically trying to slice it, we call it gates.

Gates are operated to allow the heavy fraction to drop into a bucket elevator for removal that is you have a gate and then that transfers to the heavier fraction to a bucket elevator and then the bucket elevator is basically they have to transfer your heavier fraction to a particular storage space or may be to another unit operation for further cleaning. Now, what is the critical part here; that is the positioning of the gate opening, that is how how long you will open the gate, that is you have got a gate; suppose this is the mechanism is like that, that is you have a stratified bed of particles like that and they are you have got a gate.

So, you want to open it. So, what will happen; when you are opening it the bottom most part will try to go down, but you have to close the gate before the lighter particles they try to enter the gate. So, that is the timing that is positioning of the gate, that is where you will position; how far and the gate opening. Positioning of the gate opening is controlled by the location of the boundary between the light and heavy layers.

So, where is the layer; where is the separating layer? I have got heavies, I have got lights, where is the separating layer; that is what we have to you have predict it. So, that is a an that is a job of an experienced engineer, who is experienced enough to operate your jigging your operation in your thought processing your material. And this is determined by a weighted float positioned in the bed or monitoring the pressure fluctuations in the pulsating water.

So, what happens; when you are this is little bit difficult to understand, because what happens; when you are having mixture of particle bed, which is resting on the your jig screen. Now, you are trying to fluidize the bed; that is we call it fluidized bed expansion. So, what happens the; when the water fast it is having interaction with the bottom most layer of particles. Although, the entire load of that that is your mass of the total particle bed remains constant, but because if your total amount of material is fixed, but when the fluid is trying to displace it it is displacing a particle layer at the bottom, which are having much your lesser density it average bulk density you will say; then the particles when they are stratified with the only the habeas particles are at the bottom habeas tend coarse particles are at the bottom.

So, that if I say that, if I am only considering that. So, that bulk density of that your bottom most layer is much higher than, when it is in mixed form. So, that is why there will be a pressure fluctuation in the pulsating water; that means how much of pressure you need for that your pulse. So, if I am monitoring that; so when it is getting much more resistance so; that means, the initial layers of the particle bed is concentrated with a heavier fraction, but that is also you have to have some kind of your modeling that is your correlation to be develop based on that.

And sometimes you are having some weighted float gate, that is called you are the gate opening that is you has looking at you are seeing that what is your product quality? And if you are monitoring the product quality based on that, say suppose you are finding that more lighter fractions are getting say contaminating your say heavier fraction so; that means, you are get positioning get positioning has to be lower term, because just imagine I have got a layer of this and your lighter particle is up to that, but my gate is positioned here. So, what will happen; these lighter materials also will come with your heavier fraction. So, if I monitoring that quality of my heavier fraction I know that I have to lower it down this is how it is being done.

But you need lot of understanding of a how a jig works to say perfect the operation.

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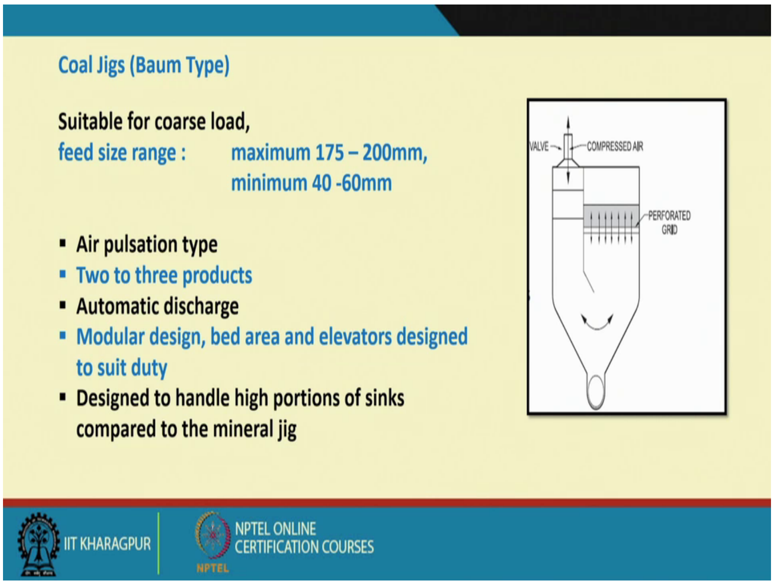

Now, this is what I have already shown, but this is a very popular design for coal processing this is known as Baum jig. So, it is suitable for coarse load, that is feed size range up to maximum 175 to 200 millimeter, minimum 40 to 60 millimeter, because what will happen; if it is fine at than 40 millimeter, your jig aperture may be around say 30 millimeter.

So, if I have particles less than your 30 millimeter they will pass through this. So, you have it is the mandatory that all the particles should rest on the your screen bed, because screen is there only at the support. So, you have to control the particle size, what you are feeding? And you also see that, it operates only it accepts only a relatively coarse are particles. And, how you are pulsing this; that is by compressed here; that is with the compress that is called air pulsation type jig; and it can have 2 to 3 products that; I can have your if I know that ok; if I have a height of your stratified bed is 1 meter, I know up to 0.2 meter from the top is my clean coal.

So, you take out that; and I know that 0.2 to 0.5 meter depth, it is having moderately mixture of your coal and your shell. So, that I take out to call it middling and the bottom one, I know they are more relative mode concentrated with the relatively heavier fractions, so that we say tales. And then so we are eventually having three products or may be what we can do; that is the float, whatever we have taken out that may have also some amount of your heavier particles.

So, that we send it to another jig compartment of this type or another jigging operation and there I can have a clean coal and I can have another fraction, which is also having significant amount of carbonaceous part, but that may not be utilized for a specific for a specific purpose, it may utilize for some kind of or some other purposes, but the prize of that clean coal may be much higher than that coal what we are using it for some other purposes. And that is why it is called the middling; that means, it is just a you are basically your middling means it does not confirm to the final quality, but it has got certain amount of coal, which is having some value for some particular use, but it will face you little much lesser money than your clean coal.

Then the discharges are automatic here, then it is the modular design bed area and elevators design to suit duty that is ; so those things are now shown here, that is mainly we are talking about how the products are been collected and your handled. Designed to handle high portions of sinks compared to the mineral jig; that means, if I have a; relatively higher percentage of sink material, so these this is design to do that, because we have got, so much of say volume available here and then the your sink material they go down and we can collect through that. So, that is these are the typical features of a particular jig we cannot go into that those details.

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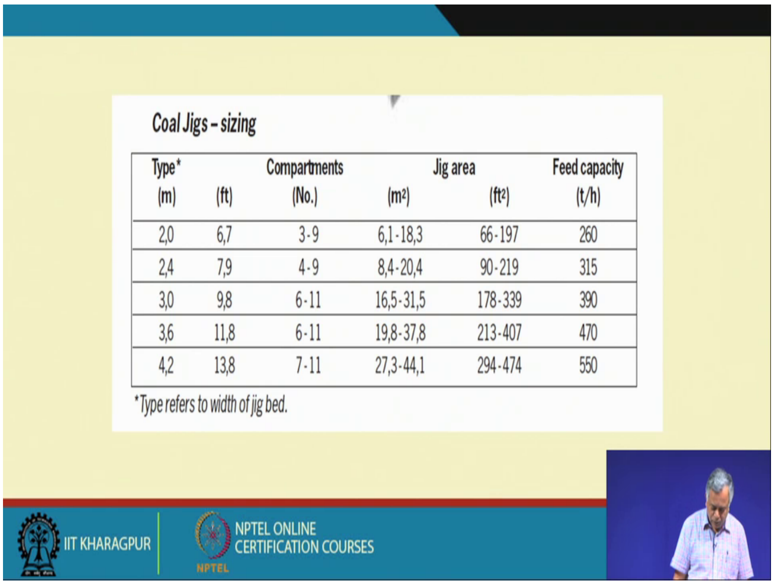

Type* (m)	(ft)	Compartments (No.)	Jig area (m²)	(ft²)	Feed capacity (t/h)
2,0	6,7	3-9	6,1-18,3	66-197	260
2,4	7,9	4-9	8,4-20,4	90-219	315
3,0	9,8	6-11	16,5-31,5	178-339	390
3,6	11,8	6-11	19,8-37,8	213-407	470
4,2	13,8	7-11	27,3-44,1	294-474	550

*Type refers to width of jig bed.

Now, to give you an idea, that how big the jigs could be; I am giving this example from whatever dimensions I got it for say coal washing purposes the jigs are used. And you see that the dimensions could be from 2 meter that is it could be a 2 meter long to your 4.2 meter long. And the I am not talking about the, what is the width of this, because I am specifying the meter square that is the area jigging area, how big is the jigging area you have.

It could be from 6.1 meter square to 44.1 meter square area jigging area. And the feed that is a your tonnage capacity, it can have from 260 turns per hour to 550 turns per hour. So, these actually refers that is your how much; how much is the say capacity of the a jig can have, sorry; here this is this is what is showing that is the your say width of the jig bed not the length, because length you can increase, because length depends on that how much of residents time of the particles should be given.

So, that is the width of the jig bed and this is the; your jig area; that means; now we can calculate that what is the length of that. And, so you see that they are a very relatively very high capacity jig that is available and this is a photograph I have taken it from open source to show you that how a feldspar jig looks like.

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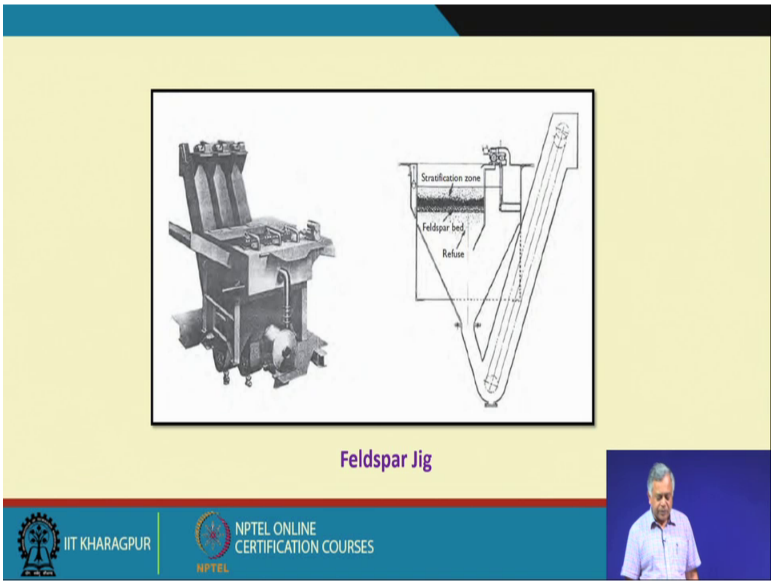

So, this is what basically the feldspar jig like your ragging material being used. So, the refuse material, that is a sink material; which is coming through that and you can have a your some kind of a bucket elevator to say transfer them from this portion, this portion to your to a separate launder. And the your overflow you are already getting through the overflow air that is some kind of your discharge mechanism.

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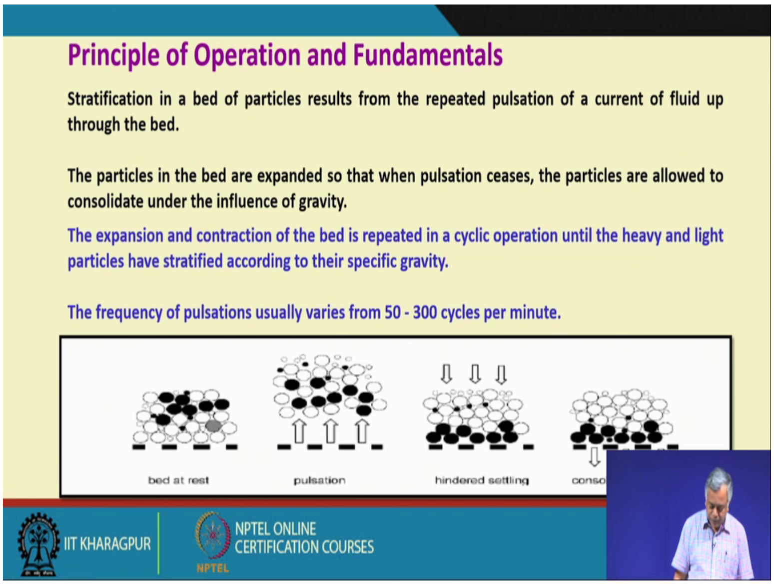

Now, if you look closely at the principle of operation of jig. So, what exactly we are trying to do; that is by doing that, in terms of your bed of fluid mechanical literature. If we try to look at it will be much better understood. So, when the particles sorry are at rest, suppose the black dark colored particles are my heavier particles and light color particles are the lighter materials. So, they are in a mixed rate. Now, what is happening; when you are having a pulsation stroke that they are being lifted up.

So, essentially in terms of chemical engineering literature it is called the fluidization. Fluidization means increase of the void spaces or increase of the bed sizes or bed expansion. So, when you were trying to do it; the relatively lighter particles will be moving relatively much higher height and then the heavier particle, because their mass is more. So they are; so the dark colored particles are here and your lighter particles are much further they have traveled further than the your heavier particles.

So, during the suction stroke because the mass of the; of a same size particle the heavier particles will have will be having more mass and they have traveled a lesser distance in the upward direction. So, they will report to the jig aperture very fast in a faster rate than the or the jig your screen bed, it is faster then the your lighter particles, but what will happen to the fine heavy particles.

So, fine heavy particles again the similar mechanism, what we have explained; I have explained it that what is the ragging material is doing. So, you see here that the coarse light particles, when they are getting your say trying to raised on the your top of the heavier particles coarse heavy particles; so because of their sizes are bigger. So, they will have some kind of your void spatial in between the particles and these dark colored heavy light you have small heavy particles, because of their mass that is your highers your mass, they will try to trickle through this spaces and that is called the consolidated trickling in terms of mineral processing literature. I would say this is one kind of diffusion through the coarse. Now, let us see that what is written here; that is stratification in a bed of particles.

So, this process we call it stratification, so in a bed of particles results from the repeated pulsation of a current of fluid up through the bed; that means you are you are trying to stratify the bed based on their density difference that is rearrangement of the particle mixture having two density classes, that I want to rearrange them based on their density difference. So, the heavier particles should be reporting at the at the bottom and the bottom of the bed and the lighter particles should be on top of that.

So, this is what is being done by this pulsation stroke; because you are trying to expand the bed wider, that is you are giving more void spaces, more free path for the particles to reorient themselves bases on their own mass. The particles in the bed are expanded, so that when pulsation ceases, the particles are allowed to consolidate under the influence of gravity this is; what is the phenomena. The expansion and contraction of the bed is repeated, because in one cycle this is the complete pulsation and suction we call it one cycle. The one cycle may not be sufficient enough for the particles to reorient them self based on their mass I would say is based on their mass.

So, you have to do it repeatedly or sometime. So, that they are segregated in a form, which we wanted to have. So, the expansion and contraction of the bed is repeated in a cyclic operation, until the heavy and light particles have stratified according to their specific gravity, but how many cycles we need? That the frequency of pulsation usually varies from 50 to 300 cycles per minute. So, depends on what is the size range you are going to track and what is the density different between your wanted that is your heavy and light particles; that means, here you can again apply the your criteria for concentration criteria that is what we discussed at the beginning of the gravity concentration your say lecture.

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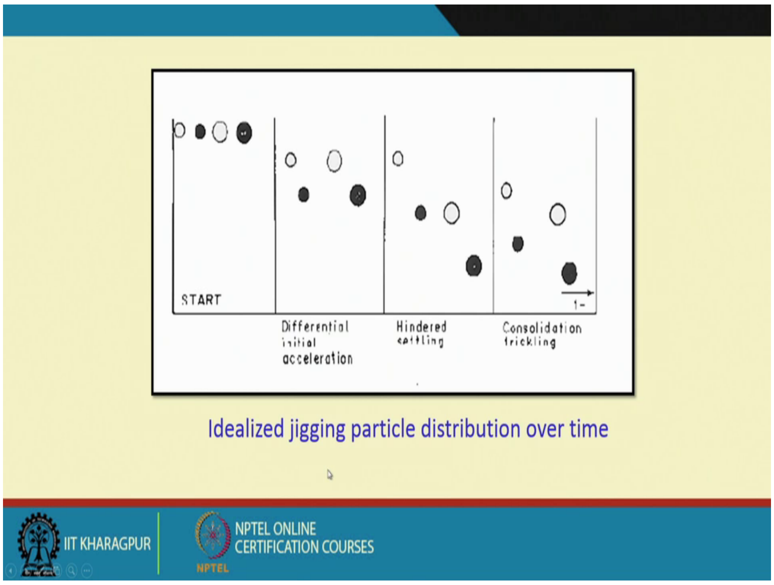

So, this idealized jigging particle distribution over time, that is in the start they are all there that is at the same height same position, then differential initial acceleration; because here one thing is very interesting that the settling velocity we are talking about, but the your settling time is so less, because you are doing it repeatedly you are suppose you are having a 300 cycles per minute; that means, the particles may not given appropriate time to reach their terminal setting velocity.

So, we are trying to apply here the differences in their accelerating velocity, accelerating settling velocity not the terminals settling velocity which we had discussed earlier. So, that is why I written; that the differential initial acceleration, then in this is the hindered setting mode, because the particles are crowded, you have so many particles and this is the consolidation trickling that is what we have already discussed.

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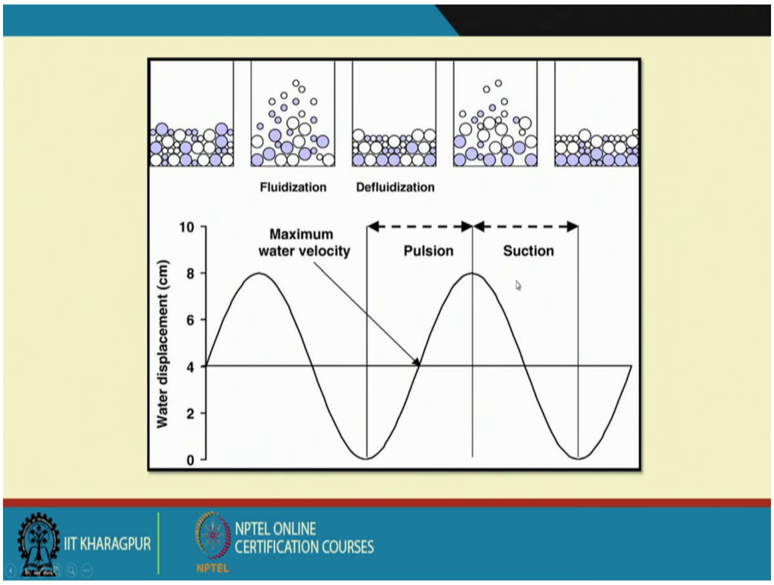

This is again with that similar type of thing I wanted to show you that, how this pulsation and suction stroke look like. So, that is your like is your sinusoidal motion in many time. So, this is the pulsion stroke that is from here, you are having this pulsion stroke pulsion such pulsion stroke and this is the your suction.

So, this complete one that is you are lifting, because you are you are pressing the fluid now the entire fluid layer they are trying to go up. So, that is the pulsion and or say pulsation. And when you are withdrawing it, so entire fluid will try to go down like this manner; so that is the suction stroke, so this is the complete cycle. So, that is from here to here this is the complete cycle. So, how much time it takes to complete this that is called the cycling time so, where the water velocity will be maximum here at, if the water would be having the maximum velocity at the bed.

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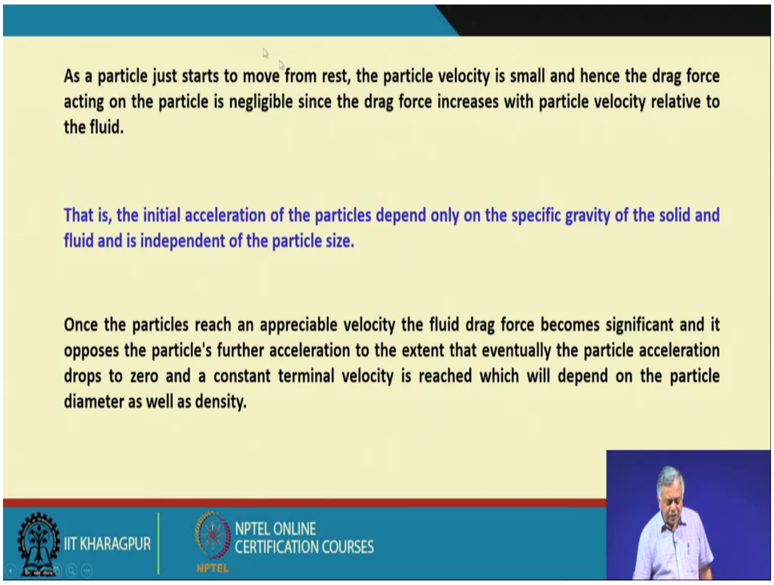

So, as a particle just starts to move from rest, I am trying to explain you a bit more. The particle velocity is small, so that is as the particles just starts to move from rest that is what we are trying to lift them. The particle velocity is small and hence the drag force acting on the particle is negligible. Since, the drag force increases with particle velocity related to the fluid I have already discussed it in the movement of solids lecture series. That is the initial acceleration of the particles that depends only on the specific gravity of the solid and fluid and is independent of the particle size.

The very interesting thing that is; how we are trying to minimize the effect of differences between the particle sizes, because what we trying to say that; as a particle just starts to move from rest, the particle velocity is small and hence the drag force acting on the particle, if the velocity is small so; that means, it has not displace much of the water. So, naturally you are drag will be less, that is what we are trying to say here. So, the initial acceleration of the particles, that is m d v by d t that is your d v by d t. So, that m will depend only on the specific gravity of the solid and fluid, because the your drag; drag is depended on how much of surface area of particles you are having in contact with the water.

So, here what will happen; that you are drag is less because particle is not moving much faster. So, it depends on; so initial acceleration will be more will be dependent on the; your particle density and the fluid density. So, that is based on the; it is independent of the particles size. So, once the particles reach an appreciable velocity, the fluid drag force becomes significant, that is initially; when the particle tries to move up that initial velocity is less and when the initial velocity is less, so the fluid drag is less, because it is not expressing much of the fluid.

And when there is no displacement not much displacement of the fluid, the relative your share between the your particle your particle your surface and the fluid layer is less, but and in that case so your movement will depend that is at what rate it will travel that will be more controlled by the density differences than the size, but once a particles reach an appreciable velocity, the fluid drag force becomes significant and it opposes the particles further acceleration to the extent that eventually the particle acceleration drops to 0 and a constant terminal velocity is reached which will depend on the particle diameter as well as density. This is the concept of terminal setting velocity.

So, during the accelerating motion initial stages particles size does not have much role, particle density has got the major role to play, but after some time when you starts the accelerating further. So, the drag force will come into picture and you start having the effect of both size and density. So, that is why; that is the basis that is if I know how to control the pulsation and suction strokes frequency and their amplitude.

So, if we know that how to exploit this, that is you are only the initial accelerating velocity term, that is your; that is time how much requires, that is before it reaches the terminals setting velocity condition. So, if I try to do the separation within that time period in between the terminals setting velocity and the accelerating, that is when it is addressed and before reaching the terminal setting velocity condition. What we have shown in that your initial gravity concentration lecture with two plots that even for a coarse are particles this differences is around one fraction of a second 0.4 or 0.5 of a second.

So, when I have a 300 cycles per minute so; that means, every second we have got 5 cycles. So, one cycle is taking 0.2 of a second and so 0.2 of a second and then you are half of that is suction and half of that is pulsation. So, when the particle is having your say upward velocity accelerating velocity that is in the half of that.

So, we are giving around 0.1 second times. So, that is much closer to my initial accelerating velocity. So, we are not giving the particles to reach the terminal setting velocity condition. So, in that case you are trying to minimize the effect of particles sizes you were trying to promote the separation between the density, but when you are having a reduce cycle probably you are reaching to that zone.

So, where you will have 50 cycles per minute, where we will have 300 cycles per minute that depends on what are the particles sizes and what are the particle density ranges you are trying to treat and then other features also are very important that I would discuss with some kind of your equations.

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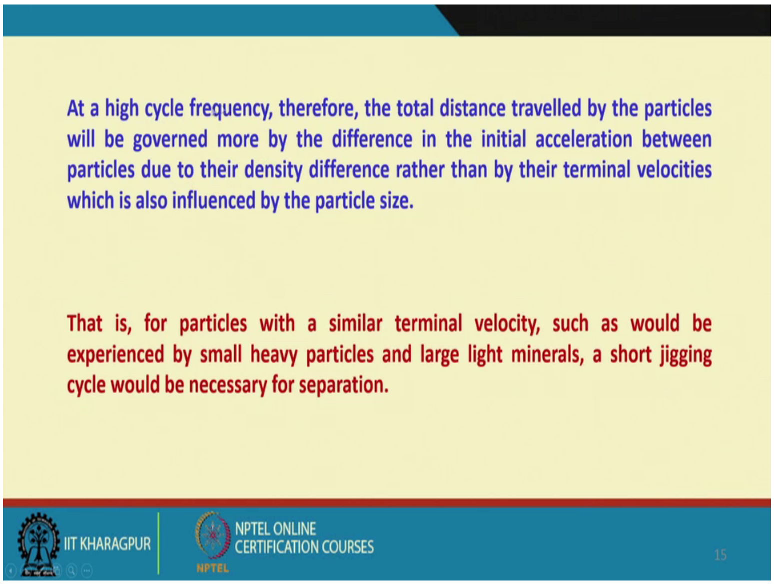

At a high cycle frequency, that is therefore, the total distance travel by the particles will be governed more by the difference in the initial acceleration between particles due to their density difference, that is what I have already explained you; that is at a high cycle frequency that is when you are at 300 cycles per minute, this is basically you are trying to promote the initial acceleration based mostly on the density difference.

Rather than by the terminal velocities, which is also influenced by the particle size; that means, you want to minimize the effect of the particles size differences that is for particles with the similar terminal velocity, such as would be experienced by small heavy particles are large light minerals, a short jigging cycle would be necessary for separation. So that means, what it is telling that; if I have your particles of equal terminal setting velocity, because of the say suppose I have got light particle, but they are much larger and you have got a heavy particle, but they are relative finer. So, they can be both your equal setting velocity.

Now, if I am not controlling this what will happen that equal setting velocity particle will travel together and will report in the same stream. So, I am not able to separate this two particles based on the density, but if I have a short jigging cycle, that means; if I give if I am operating within that you are up to 0.4; second that is if we are much closer to your 0 to your 0.1 or 0.2 seconds you are if you remember that curve, then we are trying to promote the separation mostly based on the density. So, that is the requirement that you need a short jigging cycle or separation this is very very important to understand based on my setting velocity your concept.

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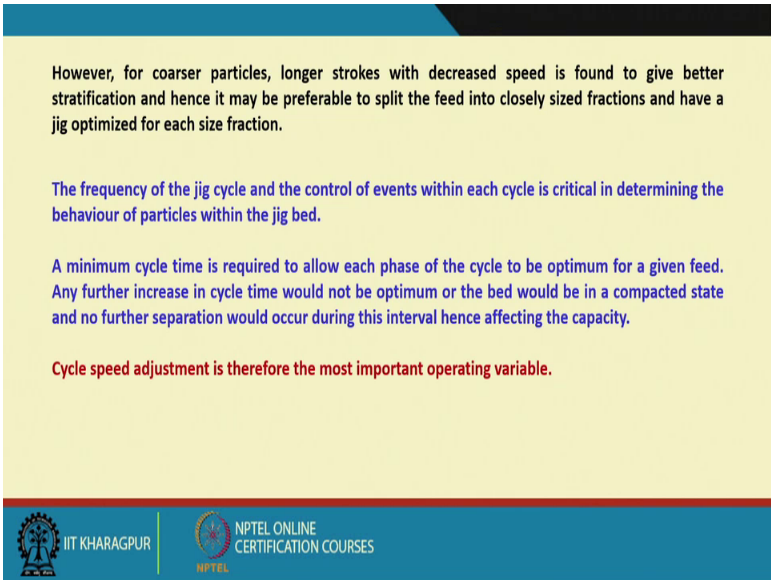

However; for coarser particles longer strokes that is your, what should be the stroke; that is if you remember that your that cycle. So, one is frequency another one is a stroke. So, longer strokes with decrease speed is found to give greater stratification hence and hence it may be preferable to spilt the feed into closely sized fractions and have a jig optimized for each size fraction, that is; now if I ask you to process from 100 millimeter to 0.5 millimeter sizes of material say suppose it is coal, should I feed it into one jig or should I have a discrete sizes in between and then we try to separate them into a different chamber given jogging chambers.

So, that is what it is being told that it better that we have a discrete particle size ranges and then we can select the separate jigs and try to try to separate the try to clean the coal in different compartments. The frequency of the jig cycle and the control of events within each cycle each critical, what are those events; that is jig cycle control of events means is the pulsation and the suction stroke, how they should be designed; and what is the at your stroke length is critical in determining the behavior of particles within the jig bed a minimum cycle time is required to allow each phase of the cycle to be optimum for a given feed.

So, if you are not allowing that time the particle will not have time to reorient themselves based on their own density then what will happen; then your entire effort is going into vague, because they are not yet say get stratified based on their densities. Any further increase in cycle time would not be optimum or the bed would be in compacted state and no further separation would occur during this interval hence affecting the capacity, because too much of compaction, if the bed is already compacted, if the bed is already filled that you have already got the stratification done, then if you still continue that there is it is just a wastage of your energy and you will you are basically increasing the resident time which is not require.

So, your capacity will be reduced. Cycle speed adjustment is therefore, the most important operating variable. And I will try to show you that how they are related in the next lecture till then.

Thank you very much.