Introduction to Mineral Processing

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Lecture - 39
Classifier (Contd.)

So, we have made a comparison in the last class in between the gravitational classifiers and centrifugal classifiers we have shown that all the advantages mainly associated with the centrifugal classifiers, but still gravitational classifiers are in some specific cases they are in use and if you are working in older plants, maybe you have to handle the gravitational classifiers. So, let me spend some more time on explaining that how what are the different features and of these gravitational classifiers.

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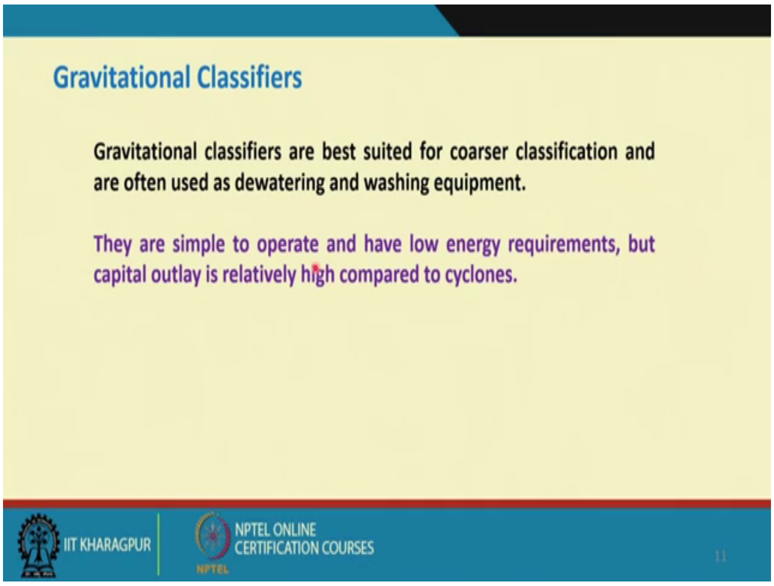

So, gravitational classifiers are based suited for a relatively coarser classification and are often used as dewatering and washing equipment.

So, many times we want to have a solid liquid separation; that means, I want to recycle back the water. So, there we want many times we use this gravitational not the classifier then it is becomes a settling tank and some washing equipment like I want to remove the clays from my code relatively coarser materials. So, they are also I use it the many a times the gravitational classifiers, what is the best thing about classification classifiers are they are very simple to operate and have low operational energetic comment, but capital outlay is relatively high compared to centrifugal classifiers, that is name is one is cyclones.

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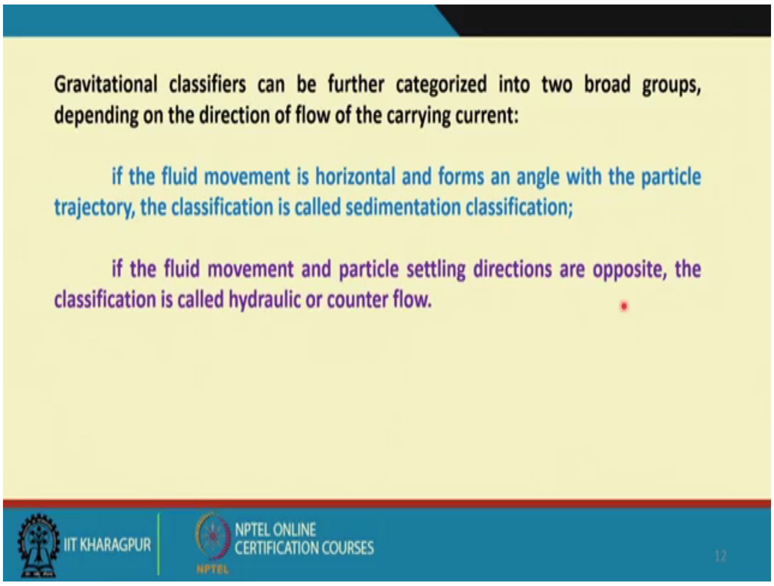

Gravitational classifiers again can be categorized into 2 broad groups, depending on the direction of the flow of the carrying current; what the meaning is that that I have tried to explain here, that is if the fluid movement is horizontal; that means, if the fluid movement is like this in horizontal and forms a angle with the particle trajectory that is your particle is moving suppose like this and air this is movement is like that. So, you are making an angle with this, the classification is called sedimentation classification; that means, fluid is moving like this and your particle is travelling into that your container or into that vessel like this.

So, that is called a sedimentation based classification, in another 1 if the fluid movement and particle settling directions are opposite and is particle is moving like this fluid is moving like this, the classification is called hydraulic or counter flow current based your classifier.

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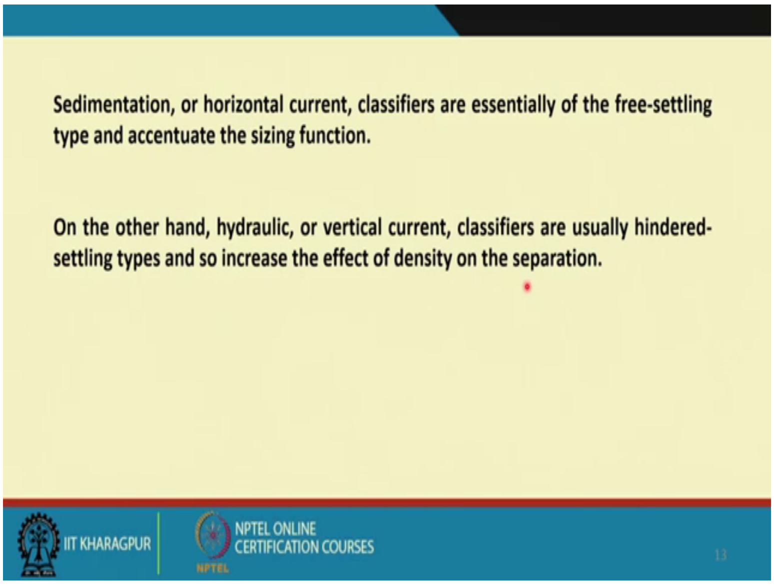

Sedimentation or horizontal current classifiers are essentially of the free settling type and accentuate the sizing function; that means, they use mostly the principle of free settling velocity; on the other hand hydraulic or vertical current classifiers you know the water is moving like this, so it is a vertical current it is not electrical current it is basically we say that is the your fluid movement in this direction; classifiers are usually hindered settling types. So, in this case we are using free settling principle, here we are using hindered settling based principle and so increase the effect of density on the separation we will try to explain it through some of the classifiers design I will show you.

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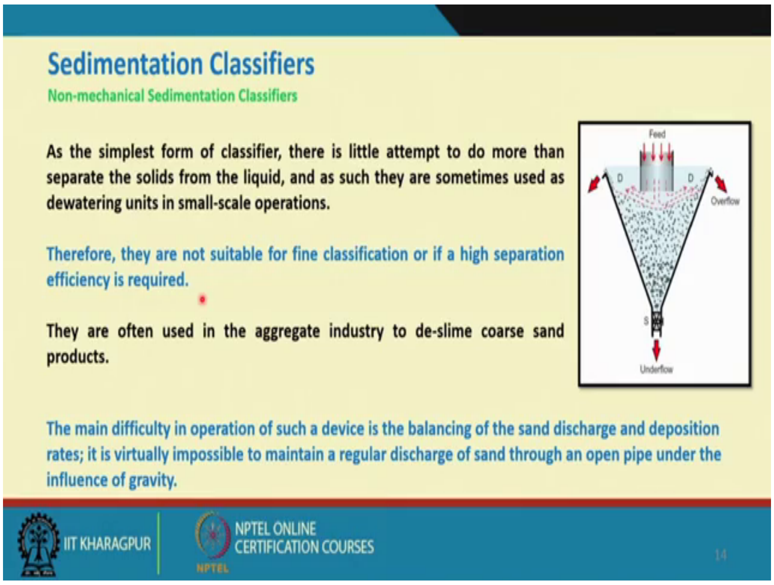

Say this is a picture or say sketch of a sedimentation classifier, I have taken up this image from de slime coarse processing book I kindly acknowledge that; so you look at here what happens you have a cone here with the vessel is conical shaped and your water and then your feed that is in the form of a slurry that is your mixture of your particle and your fluid medium that is water, what if you have to do you have a conical vessel like this and you are feeding it at some depth. So, what will happen the fluid will try to go out like this fluid will have a motion like this because; the vessel has got a certain volume.

So, if you keep pouring your slurry into that, so once the volume is filled up. So, then the water will start going out of the vessel and that we call it overflows stream. So, in that case what will happen now, but your fluid is having a your horizontal movement like this and your particles the relatively coarser particles, they will try to settle faster into that and because of that settling there will be some displaced fluid also. So, that will have the upward velocity of your displaced fluid.

Now the very fine particles whose settling velocity is less than the upward rising velocity of your water, so they will be also carried through this overflow water and now I am basically having a separation or a overflow consisting of very fine particles at your large quantity of water and this relatively coarser particles they start getting accumulated, here you have got a valve and you are basically opening this valve with certain time interval and then you are collecting the relatively coarse particles.

So, those are the simplest form of classifier that is little attempt to do more than separate the solids from the liquid, mostly we try to separate based on that because it is very difficult to separate your particles based on the sizes, but; however, when you are try to do this what is happening, you are relatively fine a very fine particles ultra fine particles they will be also going along with your overflow water. So, basically you see that these type of separation, this type of vessel we cannot have your size based separation accurately; but where we can use it we can have a solid liquid separation quite effectively although in your water if you have very ultrafine particles they may be also collected.

So, what is the nature of your solid particles that is very important, if you have ultrafine particles maybe your solid liquid separation will not be perfect. So, that is why so they are not suitable for fine classification or if a high separation efficiency is required; what is the meaning of that that is if I want to have a separation in between 20 micro micrometre and 10 micrometre particles probably I cannot do that, but say suppose I have particles mostly of a size of your around 40 micrometres or maybe 50 micrometres and their I have large pool of water and then I want to separate these 50 micrometres particles and your water that is I want to recover that water.

So, what we can do that is I can use this type of principle and my 50 micrometre particle will start settling and then once it is getting concentrated I can open this valve and I can take out my say particles and the I can get clean water through the overflow, but remember it if I have ultrafine particles, you may be collecting some of the ultrafine particles because of the displaced fluid in the upward direction, because of the settling of these relatively much coarser particles; they are often used in the aggregate industry to de slime coarse sand products that is what you can do that is in aggregate industry, exactly that is the principle we are using what I was mentioning that is if I have slimes like your clays and you have coarse sand.

So, what I want to do I want to separate this clays from the sand particle that is the washing. So, I can pour these sand and your clay particles along with water. So, what will happen the clay particles will also be removed or say collected through the overflow along with large volume of water and your coarse particles I can just separate it here. So, I can have a separation in between clays and your coarse sand product and that is called a de slimming stage.

The main difficulty in operation of such device is the balancing of the sand discharge and deposition rates; that is the problem is that is how do I control this valve. Now modern days you can have some your pneumatic valves or maybe you can have pressure gauges and they know when the pressure is build up of is more than a certain value, so you can automate this 1.

But the older persons they have that the odd that is your experience that is with the settling velocity principle you ca you have to operate this valve, that is you should know that when to open this valve; but if the discharge rate of these solid particles that is relatively coarser particles if they are not balanced with the rate at what you are feeding it, then the there will be accumulation of these particles and your separation may not be accurate and you may have a jamming of this type of classifiers.

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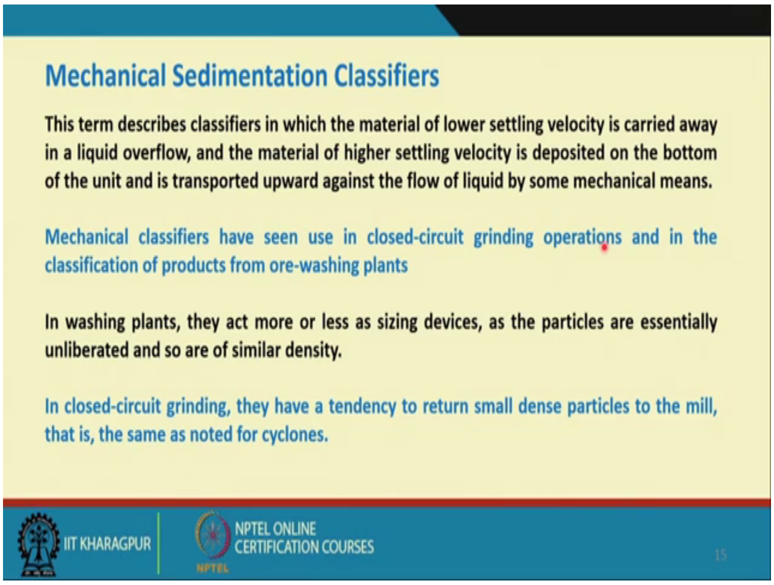

Then there are certain varieties of mechanical sedimentation classifiers, these term describes classifiers in which the material of a lower settling velocity is carried away in a liquid overflow, that is what I was saying that if I have lower settling velocity this will be carried in the overflow and the material of higher settling velocity is deposited on the bottom.

So, you are trying to collect your lower settling velocity through the overflow that is your water will try to overflow because you have a certain volume; but how do you collect the solid particles that is your relatively higher settling velocity particles, which has been deposited on the bottom of the unit. So, you should have some mechanical means to transport them and to take them out from the system.

So, when you are using some mechanical means for my product recovery, then we call it mechanical classifiers and these are more popular in certain industries mechanical, classifiers have seen use in closed circuit grinding operations and in the classification of products from ore washing plants and they are being used in some of the closed circuit grinding operations and in some cases for washing means, that is I want to clean the surfaces of my particle where the by very fine particles are adhered to the surfaces of those particles.

So, inversing plants they act more or less as sizing devices as the particles are essentially unelaborated and so are of similar density because, when you are doing it for relatively coarse sizes mostly the particles have not been ground yet to that size what is liberation size demands.

So, mostly the particles which are very ultrafine sizes and the relatively coarser particles you can assume that there up equals densities in many cases, but in case of closed circuit grinding they have a tendency to return small dense particles to the mill, that is the same as noted for cyclones. So, this thing we will discuss when we discuss about the cyclones that is your centrifugal classifiers.

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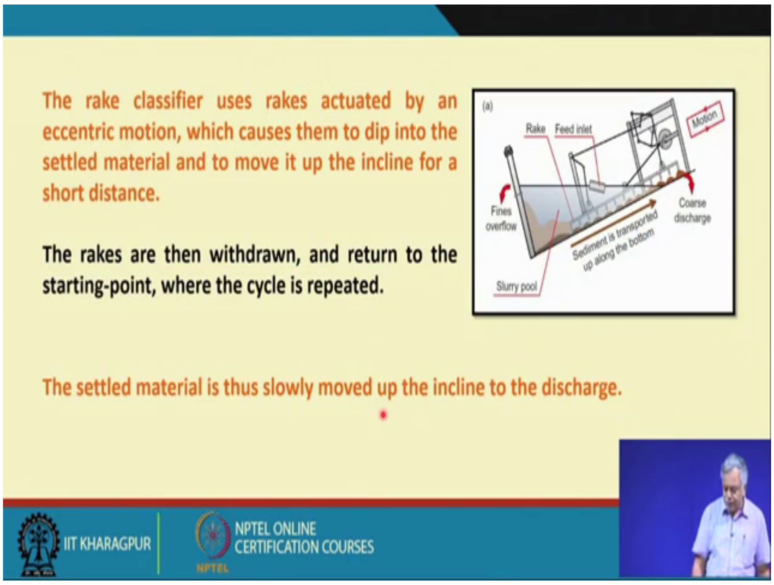

Now, let me show you again this image has been taken from de slime book, I kindly acknowledge that. So, here see what you do that is you have got a pull like this, that is you have created some space for my slurry to be pulled. So, in that case what happens now that is called a rake classifier.

So, the rake classifier uses rakes actuated by an eccentric motion which causes them to dip into the settled material and to move it up the incline for a short distance. So, what you are trying to do that is you have got a feed inlet, here what is your feed now it is your mixture of course I have fine particles along with large volume of water and this is called the pulled, so you are feeding it here gently.

So, what will happen the coarser particles will try to settle immediately at the bottom of this and relatively finer particles because you are pouring in continuously, so the it will start overflowing and the water will start overflowing along with that the relatively finer particles they will be also removed from this your say volume space and then you are basically collecting that is why it is said the fines overflow along with large volume of water and the relatively coarser particles which are basically settled here or trying to almost get settled here.

Now, you have to take them out, so here you have got a rake which is mechanically driven and that rake is basically you are transporting that material out from that system. So, that rake is basically a conveying system and it is try to collect them, it is trying to transport them. So, that they are discharged through this opening. So, this is called the sediment is transported up along the bottom. So, this is the slurry pool and this is the fine inlet these are the rakes. So, this is the fine overflow and this is the coarse discharge and these are the mechanical part of this that is how you are creating the motion and all this. So, what you are trying to do now you are continuous this is a continuous system.

So, we are continuously feeding the fines and coarse, the fines are getting carried away with the overflowing water, now the relatively coarser particles they are settling at a faster rate relatively faster rate than the finer particles and once they reach the bottom or about to reach the bottom there is a basically a raking system and which is basically transporting that material out from the system; that is you are getting a coarse discharge.

Now the travel here that is your rake how you have designed it because, the particle may try to slide back because if you have not taken them out properly and that rate at what you are taking it out that should be balanced that is the coarse particles at what rate you are taking them out and at what rate by files are reporting through the overflow that should be properly mass balanced with at what rate that your incorporating the feed. So, that mass balancing concept you should have and I should do this and this is a challenge that at what angle it should be and what should be the design of the rakes and all that.

So, the rakes are basically after that then the particles are withdrawn and returned to the starting point where the cycle is repeated, that is once they are carried then again rake comes back here and then you are doing the similar thing. So, this is how the settled material is slowly moved up the incline to the discharge.

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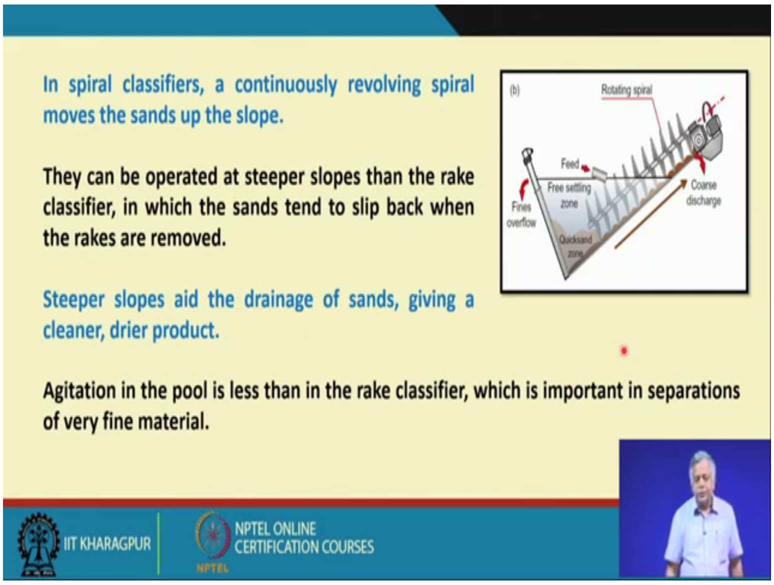

There is another variety of that is called the spiral classifier. So, in spiral classifiers instead of rake we are using a spiral. So, spiral actually is trying to transport your settled relatively coarser material which is settled; now when you are having spirals this gradient you can increase much than the rakes that is the mechanical aspect of that.

But the benefit for this that is your drainage of water that is your coarse particles are having much lesser quantity of moisture, than the coarse particle what was discharged through the rake classifiers and that is why it is becoming more popular in as a your mechanical classifier. So, they can be operated at steeper slopes than the rake classifier, in which the sands tend to slip back when the rakes are removed; that is in a rake is an intermittently you have to remove it and then again place it in between that my sand particles may be say returning back to the pool.

But in this case you do not have to withdraw it; it is a continuously it is basically transporting the material because of the spiralling action. Steeper slopes aid the drainage of sands giving a cleaner drier product agitation in the pool is less this is another aspect that is while transporting the material from the settled tank, the settled pool you should create lesser disturbance to these pool; otherwise what will happen some of this settled particles again may report to the your may be in suspension and they may be also carried along with your finer overflow stream. So, the challenge is that how do I minimize the agitation that is it should be at position as possible.

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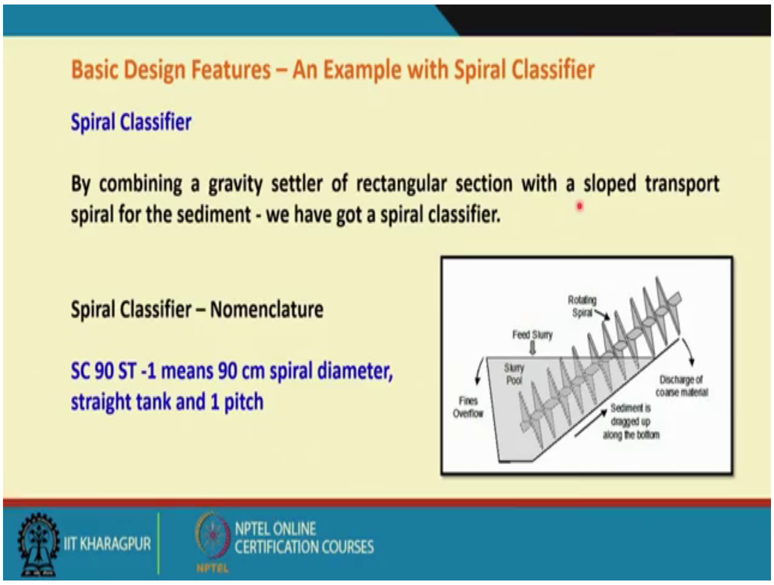

Now you will look at the basic design features of a spiral classifier what are the basic design features. Now by combining a gravity settler of rectangular section with a sloped transport spiral for the sediment we have got a spiral classifier, so it is apparently very simple design. So, spiral classifier the nomenclature normally we use like this that a SC 90 ST 1, what is the meaning of this? Normally the technical catalogues if you look at these spirals classifiers they are having this type of nomenclature, it means that the 90 centimetre is the spiral diameter, that 90 stands for that and ST is the straight tank that whether it is I have another slide, I will show you that what is the geometry of these pool that whether you have a straight tank or with some other thing and your 1 pitch is a 1 means is that 1 pitch.

So, is the spiral classifier 90 centimetres of spiral diameter and having your straight tank that is your pool and once is that it has got 1 pitch, you can have the say double pitch also.

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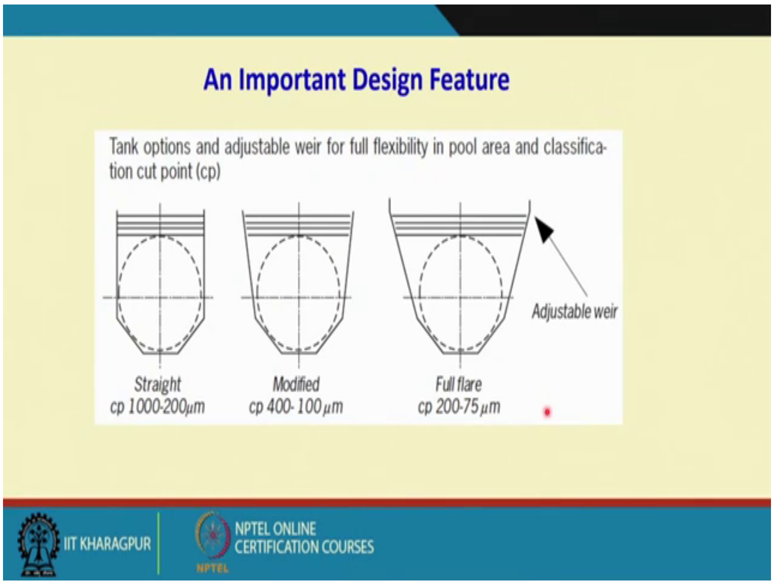

Now regarding that tank say that if this is an important design feature. So, what are the options you have the on the tank it can be straight tank like this, it can be have a modified your flare type of this design, you can have full flare like this. So, the strain tank this c p means is the cut point, that is at what size you can separate that is the d 50 sizes it is around 1000 to 200 micrometre, these are fall only for your quartz density particles. The modified 1 you can have from 400 to 100 micrometre; that means, you can have a finer size separation and when you have a pool player you can have very fine sizes separation that is from 200 to 75 micrometre.

So; that means, depending on the application you have to select your basically that tank design or the appropriate type of tanks.

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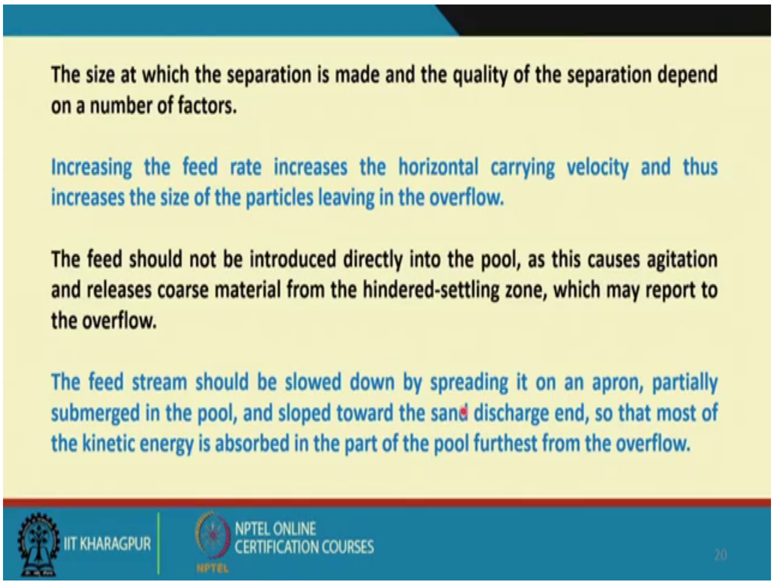

The size at which the separation is made and the quality of the separation depend on a number of factors what are those factors. Firstly, if we increase the feed rate it increases the horizontal carrying velocity because, you are feeding it at a very high rate because you are feeding the slurry.

So, the horizontal carrying velocity increases and thus increases the size of the particles living in the overflow, because when the velocity is more so that means we have created more disturbance and because of the disturbance some of the coarser particles will be also reported through the overflow; the feed should not be introduced directly into the pool, the slurry should not be directly injected to the pool otherwise it will create more agitation and releases coarse material from the hindered sending zone which may report to the overflow.

So, these 2 factors what do I try to say that, you have to take extreme precaution while designing it that is. So, that my pool remain poisoned the more agitation more coarser material will be a reporting through your finer size fraction through the overflow, the feed stream should be slowed down by spreading it on an apron feeder partially submerged in the pool and sloped toward the sand discharge end.

So, that most of the kinetic energy is absorbed in the part of the pool furthest from the overflow; that means, the particle which are already which are only having a tendency to be suspended or to be your verified nature that they do not want to remain settle, so they will be only collected through the overflow that is the simpler meaning of this sentence.

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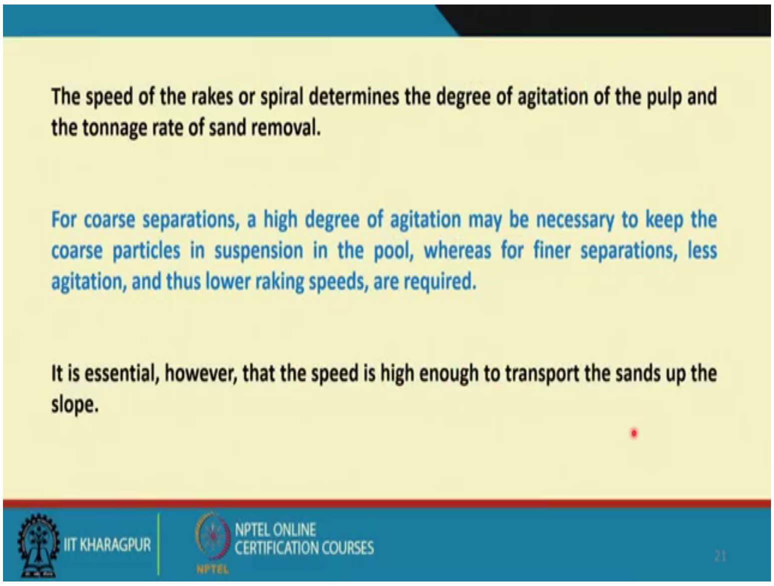

The speed of the rakes or spiral determines the degree of agitation of the pulp and the tonnage rate of sand removal. Now I want to make a quotient flow or I do not want to disturb the pool area, that is your I do not want to agitate the fluid in the fluid medium into the pool, for that I may have to run my rakes or you have spirals at a very slow speed, but the slow speed means your coarse are material removal rate will be less.

So, to make a balance your feed rate has to be lowered; that means, the capacity you have to compromise. So, you have to have a balance between your at what rate the spirals will be run or the what should be the raking speed and what is that capacity you want and what is that your efficiency you want, so you have to control this also. For coarse separations a high degree of agitation may be necessary to keep the coarse particles in suspension in the pool; that means, if I want to have a separation at a very coarser size, so I do not want them to be suspended to be settled so I need agitation.

So, you have to agitate the pool in that case whereas, for finer separations less agitation and the slower raking speeds are required; that means, when I need a separation at a relatively coarser size, I can have much faster speed of my rakes or spirals.

So, that I want to generate some agitation into the pool, so that they are not settle. So, that they are I will get high capacity also, but for finer fraction I have to reduce the speed, because I do not want to agitate my fluid medium. So, there I have to compromise with the lesser your capacity of my classifier.

So, it is essential; however, that the speed is high enough to transport the sands of the slope, because if you are not having a certain speed otherwise what will happen the sand particles may slide back. So, you are not carrying your sand particles. So, you need to have certain amount of speed also and that is the balancing factor you have to do.

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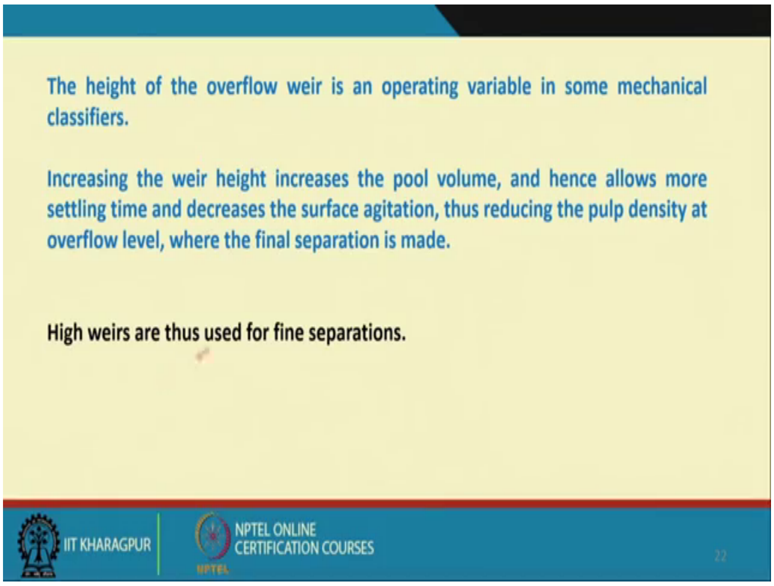

The height of the overflow where is an operating variable in some mechanical classifiers, the high definitely that is at what size of the if I need more finer particle to be at separation at much finer sizes, I have to increase the height because otherwise and if I can accept a little bit of course at your overflow then I can reduce the height. So, more height means lesser capacity and smaller height means more capacity, but at the expense of your quality.

So, increasing the weir height increases the pool volume and s allows more settling time and decreases the surface agitation, thus reducing the pulp density at overflow level where the final separation is made; that means, if you have more of this height so you will having more of water overflowing than the particles, because the particles will be travelling down that; high weirs are thus used for fine separation high weir means that, is your overflow weir that is the overflow mechanism how you were collecting dilution of the pulp.

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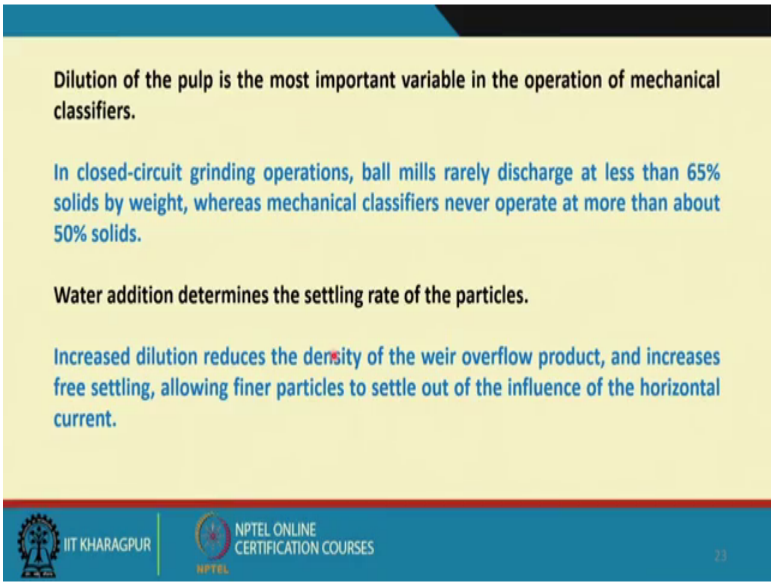

Is the most important variable in the operation of mechanical classifiers; that means, what is that maximum solid percentage in the feed I can have, that is very most important operating variable; in closed circuit grinding operations ball mills rarely discharged at less than 65 percent solids by weight; that means, what are the discharge we have we have got minimum 65 percent solids whereas, mechanical classifiers they were operate at more than about 50 percent solids that is by weight.

So, you have to dilute it so you have to add some water. So, the ball mill discharge you cannot directly feed it to a your mechanical classifier you have to add some water; whatever addition determine is the settling rate of the particles, because more dilute that means, the more free settling conditions you are giving.

So, less hindrance so the faster settling velocity you are having, increased dilutions reduces the density of the weir or flow product that is your overflow; how much of solid is there and increases free settling allowing finer particles to settle out of the influence of the horizontal current; that means, you are basically trying to give them an opportunity to settle based on their free sending conditions.

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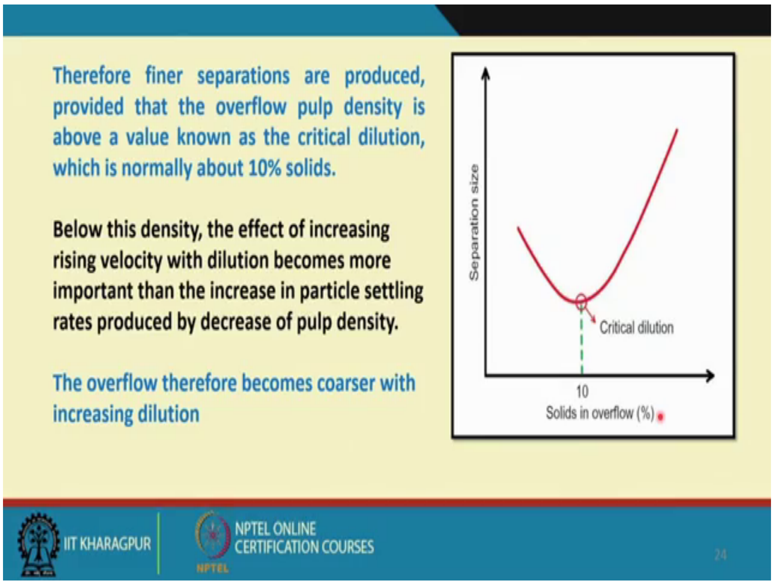

Now, what is that optimum dilution we can have or the critical dilution we can have. So, therefore, the finer separations are produced provided that the overflow pulp density is above a value known as the critical dilution, which is a normally about 10 percent solid by weight. What will happen if we operate beyond this limit now below this density the effect of increasing rising velocity with dilution becomes more important, that is your relatively coarser particles when it is trying to settle at a much faster rate because, if it is too dilute. So, it is truly your free settling condition then the displaced fluid velocity also increases.

So, in that case what will happen in that then the increase in particle settling rates produced by decrease of pulp density, so the overflow therefore, becomes coarser with increasing dilution. So, what will happen may be some particles which are supposed to be settled into a hindered sending condition, they will be now carried through your overflow weir. So, this is the this is again I have taken from the (Refer Slide Time: 31:35) book and this is what it is showing that if I have a more than your 10 percent you know that is the critical dilution of the your solids, in the your pulp density and if I have less than that again the separation size increases and if I have more than that it increases exponentially, almost exponentially the separation size; that means, you will end up with coarser sizes in the your separation.

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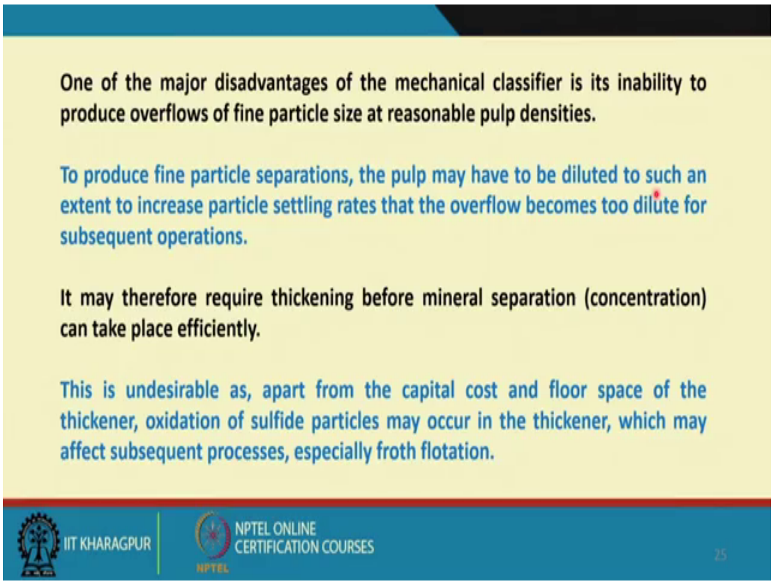

So, one of the major disadvantages of the mechanical classifier is it is inability to produce overflows of fine particle size at reasonable pulp densities, that is at a consistent pulp density; to produce fine particle separations the pulp may have to be diluted to such an extent to increase particle settling rates that the overflow becomes too dilute for subsequent operations, it may therefore require thickening before mineral separation.

So, what will happen if my pulp is too dilute that is your products, that is your say suppose your finer particles then I have to thicken it because, I have got much more per relative percentage of water. So, again I have to send it to a thickener and that will add cost that will occupy more space floor spaces.

So, this is what basically is the limitation of that because, if I want to deal with now trick those fine particles with more quantity of water then I have to again dewater them, so that I can have a thicken your say pulp. So, this is undesirable as apart from the capital cost and floor space of the thickener, many cases when you are using sulphide minerals that oxidation occurs in the thickener, which may affect subsequent processes especially froth flotation because, they are now exposed to more of these oxidized atmosphere.

So, when the layers are oxidized very difficult to separate them in a froth flotation process. So, these are the pros and cons of the mechanical classifiers. So, now look at that what are the applications of these spiral classifiers.

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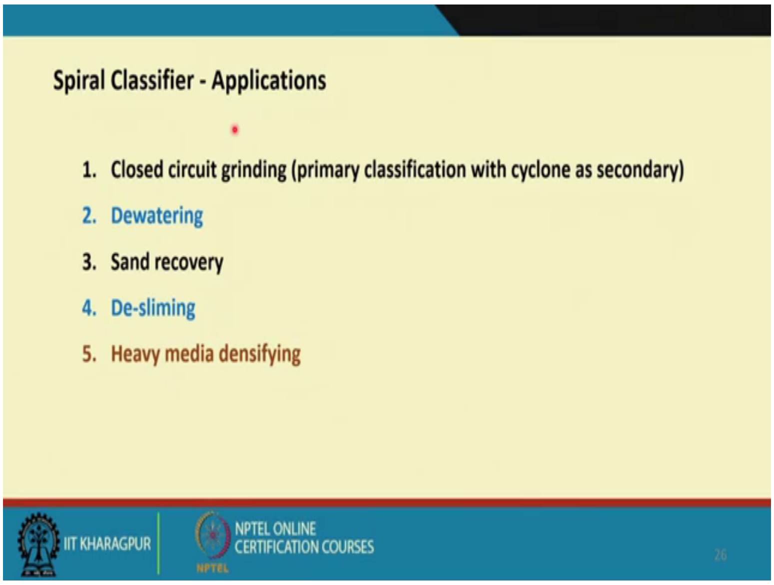

So, they have application in closed circuit grinding that is in primary classification with cyclone as secondary that is you can have a centrifugal separator after that. So, you are taking out you are removing majority of the coarser particles and then you have got relatively finer particles and you want have again a separation then you put it into a centrifugal separator.

We have already discussed about dewatering that is solid liquid separation sand recovery, that is I have your sand and clay material I can recover this sand de sliming that is your removal of clay materials again and heavy media densifying that is many times we use some magnetite particles for your say coal preparation processes which will not discuss in this course, but they are the magnetite particles you have got some very fine your.

So, maybe clay particles may be very fine coal particles, so you want to purify those you want to improve the quality or the grade of my magnetite, there we try to use it because, the ultrafine particles will be carried through the overflow water and your magnetite particle because of their higher density they will be settle and they are carried through the spirals.

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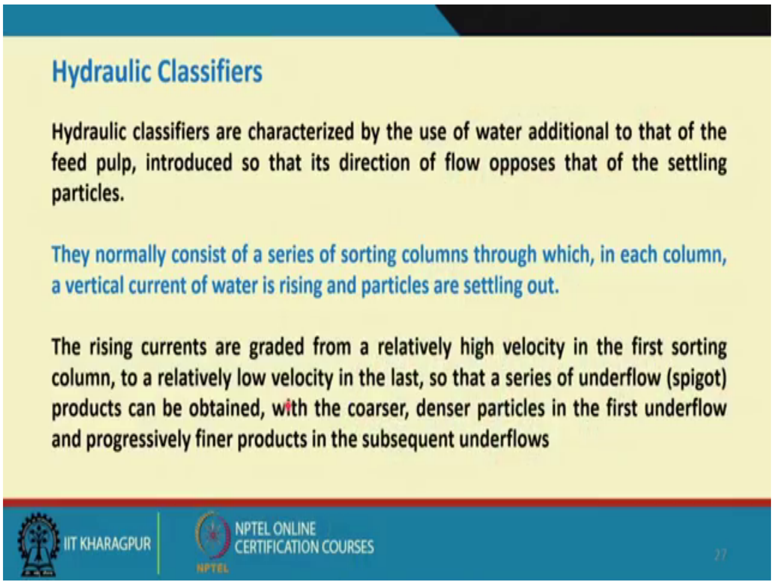

Now, there are another group of classifiers it is called hydraulic classifiers, the hydraulic classifiers are characterized by the use of water additional to that of the feed ball, introduced so that it is direction of flow opposes that of the settling particles.

So, what am I trying to do here now feed in the pulp in the form of pulp you are feeding, but as we mentioned that in a hydraulic classifier you are also adding water in a opposite direction of the particle movement; that means, particle is trying to settle in this and you are trying to have your upward velocity of your water, that is what the demonstration we have given a movement of solids in fluids lecture also and just, so the lecture what I had given on this topic in the very first lecture.

They normally consist of a series of sorting columns through which in each column a vertical current of water is rising and particles are settling out the rising currents are graded from a relatively high velocity in the first sort it column, that is say suppose I have got your sizes from 100 micrometre to 10 micrometre. So, I want to have a separation in between 100 to 80 micrometre 80 to 70 micrometre 80 to say 30.micrometre and below thirty micrometre. So, 100 to 80 micrometre particles they have a relatively higher settling velocity, so I need much more higher upward velocity of rising water, then what I will be doing it for the relatively finer material where we will be dealing with 30 to 10 micrometre particles how we do it? So, we do it progressively.

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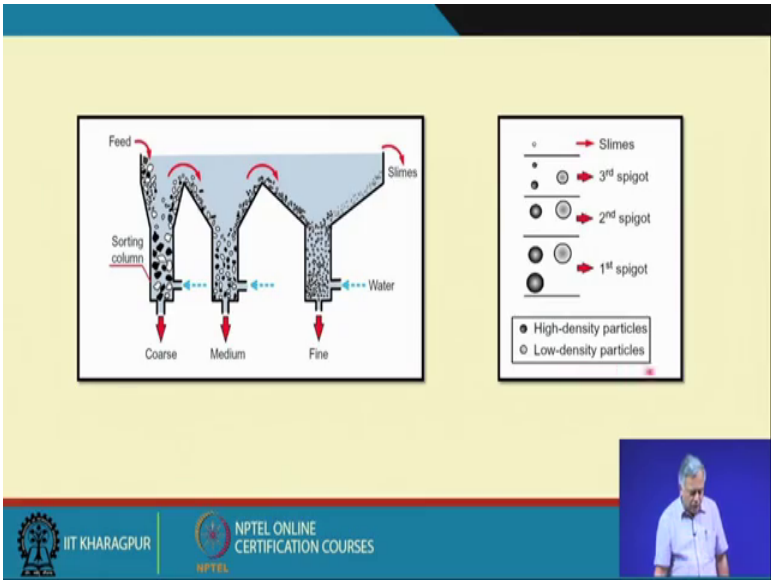

So, it is like that like you have got 3 sorting columns. So, you have got a mixture suppose your 100 micrometre to 10 micrometre particles and I want to have a discrete sized products. So, if I know the settling velocity of different discrete sizes, that is safe from 100 to 80 micrometre particles I know their certain velocity is say suppose just for discursion say suppose 5 millimetre per second. So, I will have my rising water velocity just your say actually around 4 millimetres per second. So, what will happen or maybe say just above the you have 4.5 millimetre per second.

So, 100 to eighty micrometre particle they have a set velocity of 5 millimetre per second, remaining particle they have a settling velocity much lesser than 4.5 millimetre per second. So, these particles will not be settled here and they will be transported to the next column. Now here we are left with 80 micron to 10 micrometre particles, now I want to have a separation from 80 to 30 micrometre and 30 to 10 micrometre; now 80 to 30 micrometre particles say suppose they are settling velocity is say 3 millimetre per second. So, if I have a rising velocity of water is around 2.5 millimetres per second, so those particles will be settled.

But these below 30 micrometre particles they are having much set lesser setting velocity than 2.5 millimetres per second. So, they will be transported to the next 1 like that and then what we are trying to do that is your relatively coarser particle I am trying to separate out here through some opening and this is the medium size particles and these are the fine size particles and that is how we can have a size separation as a similar to what we did in a your laboratory sieving operations, like these sorting columns we are trying to imitate what my sieves have done it.

But easier to say this, but the essential thing what I need to know that is what are the settling velocities of different particles and that is why I cautioned you that when you are using a settling velocity model, I must know the accuracy of that because any accuracy in your a pre predicted value will have in accuracy in the design of these and your separation will may not be precise.

So, this is what actually we can do it, even we you can also design this type of your sorting column if you know that what is the settling velocity of these particles.

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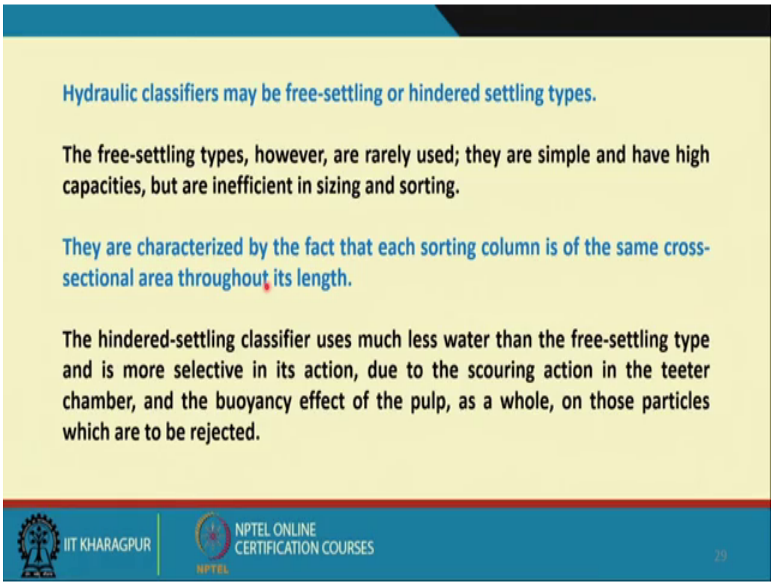

Hydraulic classifiers may be free settling or hindered setting type and then the free settling types; however, an rarely used they are simple and have high capacities, but an inefficient in sizing and sorting because you must have control on that. So, you want to promote the separation based on hindered setting mode; the in descending classifier a use much less water than the free settling type and is more selective in it is action, because you can control that you have a reduced rate of settling. So, I can have proper control of my upward velocity of my water. So, I can have selectivity in my separation thank you very much. Next week we will take up some other new topic till then.

Thank you.