Introduction to Mineral Processing
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Lecture – 48
Gravity Concentration

Hello, welcome everybody. I would like to start a new topic which is also very important in mineral processing separation processes it is known as gravity concentration process. What is gravity concentration process? Now we know that the two particles may differ in the sizes or in the densities or may be in the sake. Now we have discussed about that if there is a difference in their sizes how we can separate them? If they are in relatively coarse size ranges that is you have difference between 50 millimeter and 40 millimeter, we can use a screen; if the differences in the range of 50 micrometer and 20 micrometer we can use a classifier like hydro cyclone.

Now, this topic where we try to separate particles based on their differences in the densities what is the govern what is the basic principle fundamental concept behind it? It is similar to that classifiers principle that is when we drop two particles or when we put two particles differing size, but if they are of equal density they in the coarse- size particle, they travel faster in a static fluid medium than the finer sizes; based on that we are separating it. Aimilarly if the two particles are having equal size identical size, but the different density, then the heavier particle will travel faster than the lighter particle into that fluid medium.

So, these are the techniques that is gravity concentration methods or the techniques we have got many equipment where we try to separate particles emphasizing on the differences in the density in the density. Why I am saying that emphasizing because in actual particles in actual minerals whatever is coming from my mind side, you have a size variation, you have a density variation both are varying, but here we try to minimize the effect of differences in the size and we want to promote the separation based on the density.

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Now, what is gravity concentration? This is one of my very favorite slides that is I say that it is an example from nature; even nature does the gravity concentration in a much much bigger scale than what we people are doing in my processing plant. This is one of the coastal area in the southern part of India and this is a picture taken by me at that place where you see that if you look at closely to this your particles you see that these particle classes are basically much darker than these particle classes; these are much your like golden color these are blackest.

These are nothing, but we call it beach placer minerals which contains high density minerals like ilmenite, sillimanite, zircon, rutile, monazite like that which are much heavier than the sand particles. Now what happens why the heavier particles or the that is why I have written it that these are dark colored dark colored and they are heavy particles; why they are away from my seashore or the sea and why they have travelled so, far a distance and why the sand particles relatively lighter particles they are here why they are here that is away from the sea and they are much closer to the see what happens. The reason is that is when the it is being transported by your see all this material they were in a mixed conditions.

So, they were transported by the sea waves and when the sea wave has touched the shore here. So, what is happening now when it goes back when the wave is coming towards you they will have more of kinetic energy and you will find that when it is going back it is having less of energy you will hardly find any waves because your ground that is your land what you have that absorbs that majority of that your kinetic energy. And so, when you have more of energy that is we call it in the form of a d s that is sea waves. So, all these particles were in suspension irrespective of the black and your golden color now what happens when the wave has hit this place.

So, immediately the heavier particle because of his higher settling velocity than the sand particles; they get settled there. And this lighter particles they were transported further by the back water that is what is a water that is going back to the against a sea which has got much lesser energy, but because of the flow along with the flow they are transported.

So, even if you look at that is you will find that the coarse heavies are here, fine heavies are here and then the coarse sands are here and the fine sands are there. So, that is also a classification come your separation between the densities that has happened and the nature is doing it. So, there is a very complicated phenomena I have tried it to simplify it to make you more interested in this topic this is example from nature.

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Even if you look at this classic book written by Agricola on metallica said to la metallica in 1556 which is more than 600 years old or which is more than say 500 is a 60 years old. So, you will find that there are some descriptions even for gravity concentration techniques that is earlier people when more than 500 years ago, they used to use this technique these are called we will discuss this what they are they are nothing, but a pan like a have a typical shape and then you are trying to your wash your material.

So, that you get some concentrated I think they were trying to get some gold out of some deposit and they try to concentrate that gold particles. So, these are even; so, gravity concentration is probably the oldest form of mineral processing that is the documentary evidences are here in this Agricolas classic book and, but still it is relevant for the modern mineral processing plants because of the or we could engineer much better for processing the particles even at the very finer sizes.

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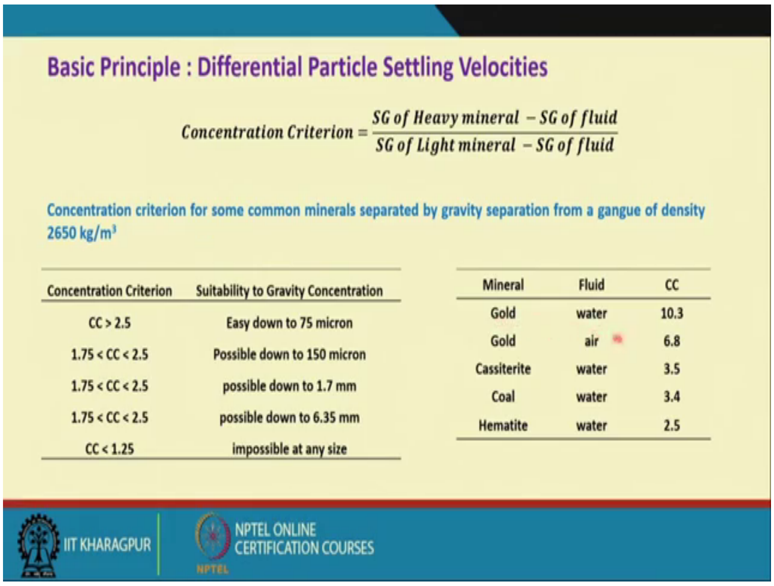

What is the basic principle here? That is your differential particles settling velocities. So, the same phenomena we use for classification also. So, here we use a term that is where my gravity concentration will technique will work or not? How do I decide it? So, in a very simple term we have we write it in this way there is concentration criteria that is equal to S G is the specific gravity of heavy mineral minus the specific gravity of the fluid divide by specific gravity of the light mineral minus specific gravity of fluid.

What is the meaning of this? Suppose the specific gravity of through of the heavy mineral is 7, fluid is by default most of the cases it is water. So, that is specific gravity is 1; so, it will be seven minus 1 that is 6 and suppose I have got a specific gravity of light mineral is 3 and that is 2 minus 1 that is 1.

So, my concentration criteria is 6; now when the concentration criteria is 6 this has got some similarity with this that is your heavier mineral will probably settle at a rate 6 times faster than my lighter mineral; why I said approximately that may not be always correct because what is the shape of your particle and other properties of the fluid will also determine.

But this is a criteria we normally use now there are some concentration criteria for some common minerals separated by gravity separation from a gang of density 2650 kg per meter cube; why 2650 kg per meter cube we have taken because it is the density of quartz particles. Most of the mind materials we have got the majority of the gang; as the silicate materials there is a naturally occurring minerals

So, we normally compare it; so, that is 2650 is the standard standard practice as because my most of mine minerals they have this. So, concentration criteria for some common minerals like say suppose gold. So gold if you do it that in a water medium; so, gold is specific gravity is 19. So, in that case what will happen? So, 19 minus 1 that is 18 divide by 2.65 minus 1 that is 1.65.

So, 18 divide by 2.65 probably you get a value 1.65 you may get a you should get a value of close to this 10.3. So, like that if it is in air it is 6.8. So, what it is showing that more the difference more the value of these concentration criteria the easier is the separation. So, the density of the fluid medium that is the specific gravity of fluid medium also plays a critical role. You see if the air as got a almost negligible specific gravity in relation to your gold particle.

So, they are the concentration criteria decreases to 6.8; similarly we can calculate it for cassiterite, coal and hematite and all this these are the values are given. There is also another your concentration criteria given in many textbooks that is if your concentration criteria is greater than 2.5; then the suitability of gravity concentration is easy; that means, it is easy to separate particles down to 75 micrometer size that is even up to 75 micrometer size; we can easily use a gravity concentrator to separate those two minerals that is separate that mineral from your silicate minerals that is if it is gangue density particle.

Remember it this criteria is based on these density; so, if your density of your light mineral is something else you have during formulate it, but you have to remember that what is the concentration criteria I need it is if it is greater than 2.5. So, up to 75 micrometer size it is easy and these are the general guidelines you should use it with caution.

Similarly if my concentration criteria is in between 1.75 and 2.5, you see that particle size increases that is up to 150 micrometer size; it is possible to separate them. Now if my say your concentration criteria is in between say your 1.75 that is for coal that is if it is your 1.75 to 2.5 it is possible down to 6.35 millimeter and if the concentration criteria is less than 1.25; it is impossible at any size.

So, your concentration criteria will be determine will determine that up to what size you can do it. So, as the concentration criteria is going down; your particle size increases; that means, you have a size restriction that is beyond a particular size if your concentration criteria is not high probably it is not possible or it is probably not advisable to use a gravity concentration technique.

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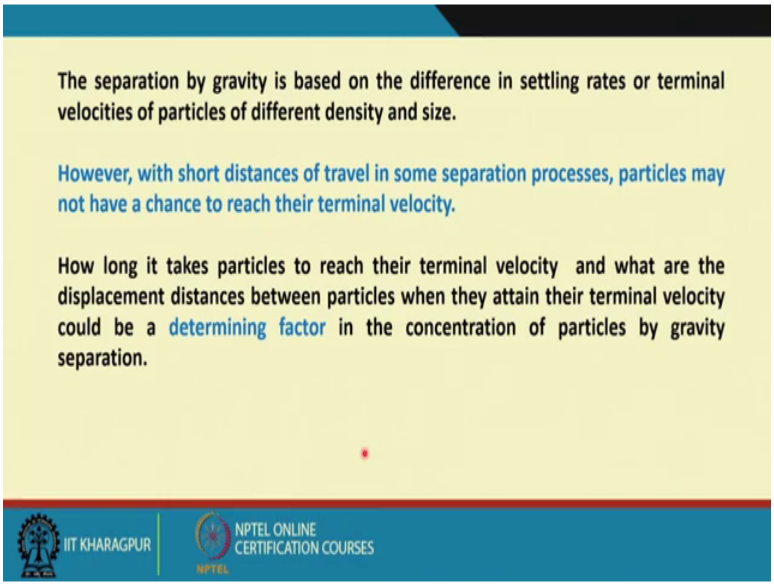

The separation by gravity is based on the differences in settling rates or terminal settling velocities or particles of different density and size. See the application of again the your the basic equations or the concepts of movement of solids in fluids; it is also applicable for the gravity concentration processes. So, it is basically based on the differences in their settling rates or the terminal settling velocities differences.

However with short distances of travel in some separation processes particles may not have a charge to reach their terminal velocity. So, what happens? If you remember that basic equation of motion of a particle into a fluid medium that m d v by d t is equal to m g minus that your term for c d your drag coefficient and buoyancy.

So, there we say that dv by dt is equal to 0 for our simplification of the calculations; what it is telling that in many separation processes that if the adequate time is not given for the particles to reach the terminal settling condition; that is when it has reached the steady state condition that is it is not accelerating further. Then particles may not have a chance to reach their terminal velocity and in some cases we are trying to use that accelerating velocity term also.

So, with short distances of travel in some separation processes; the particles may not have a chance to reach their terminal settling velocity conditions this is the caution. How long it takes particles to reach their terminal velocity that is; if I drop a particle into a fluid medium, how long it takes? That is up to what fraction of time it will still have accelerating velocity. And what are the displacement distances between particles when they attain their terminal velocity could be a determining factor in the concentration of particles by gravity separation in many instances.

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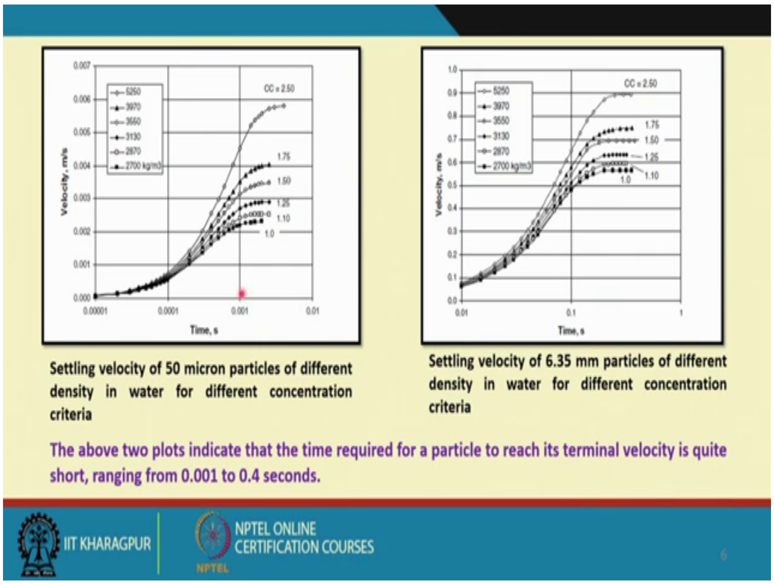

This graph this plot shown that settling velocity of 50 micron particles of different density in water for different concentration criteria; that is if we look at this that your this is the time axis and this is the velocity. And you see that when it becomes constant your velocity when the velocity terms call it becomes constant.

So; that means, that is the terminal settling velocity condition; you see that for different your density particles that is for different density particles this time is varying that is this one is 5250. So, it reaches the steady state condition almost at 0.001 second just more than that, but for a your this particle 2700 kg per meter cube; it may be slightly higher, but almost all the particles are very close to this region it is for in between 0.001 to 0.01 second.

Now what it is telling me that what is the retention time of your particle into the your separation vessel? Suppose your residence time is 10 minutes; then 0.001 second or maybe even 0.01 second, you can neglect it that in relation to 10 minutes 0.01 second is nothing because that is equal to 600 second and 0.01 second the very small fraction.

So, you do not have to worry about the accelerating velocity, but if your resonance time of the particle into your separating vessel is 1 second, then can you neglect 0.01 second? Maybe in that case also you can neglect it because of your simplification of your calculation, but if your total residence time is only 0.1 second probably you cannot neglect it.

So, where you will use the full equation or where you will can use the only the terminal settling velocity condition; that you can decide based on this. That is for a 50 micrometer particle, it reach it requires only 0.01 second or in between 0.001, 0.01 second for different density particles. If you look at the settling velocity of 6.35 millimeter particles much coarser than that of different density in water for different concentration criteria, you see that their time requirement for reaching the terminal settling velocity condition is much higher than the finer particles.

. So, the above two plots indicate that the time required for a particle to reaches terminal velocity is quite short ranging from 0.001 to 0.4 second, but what I would suggest you that look at the difference between these two; that is for smaller size particle finer particles, it requires less time to reach that than the your heavier particles. So, what is that residence time you are giving that is very important criteria to make you think that whether I can neglect the dv by dt term or not.

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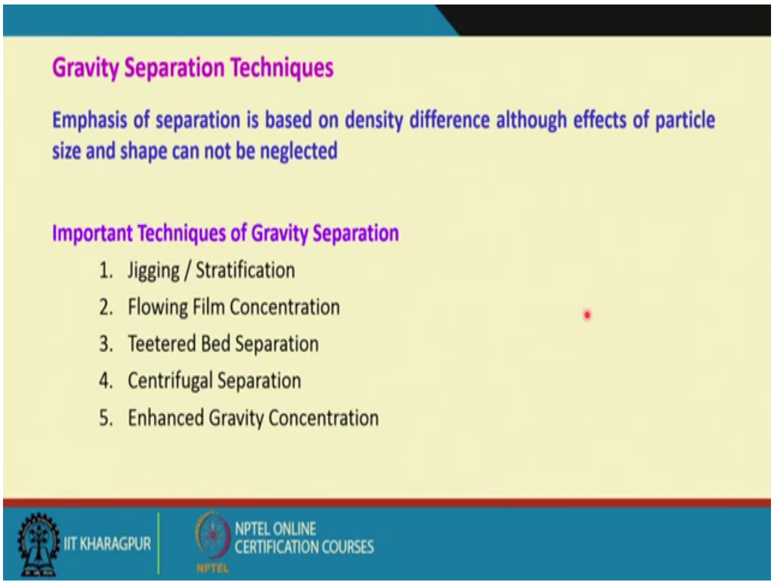

Now, let us see that what are the different gravity concentration techniques there? So, here as I said that emphasis of separation is based on density difference; although effects of particle size and shape cannot be neglected. So, do not presume that it is a density separator; so, it is separating based on only the differences in the in a densities. You have to consider that how much effect is there because of the differences in the sizes as well as in depth your shapes also.

So, we can group the different your gravitational technique; we have got many techniques. So, we have grouped them into five different categories; one is called jigging or stratification. So, although the terminal settling velocity differences that is the basic your principle of separation, but we want to promote my separation by adding some other forces or some other techniques to promote that separation process ok.

So, and that is the main differences between these five different processes and some cases we want to minimize the effect of differences in the size, we want to promote the separation based on their density differences. Sometimes we want to promote the separation by adding by incorporating some other forces or some other techniques and this is what we are basically the basis through which we are categorizing them into five different groups.

So, one is called jigging or stratification; another one is called flowing film concentration, third one is teetered bed concentration or separation, fourth one is centrifugal separation, fifth one is enhanced gravities concentration. I will try to because the course has to be completed within 30 hours. So, I may not be able to do justice on explaining all the techniques in detail, but I will emphasize on the most common techniques what is being what are being used in mineral processing plants in general and then I will briefly touch upon the other techniques.

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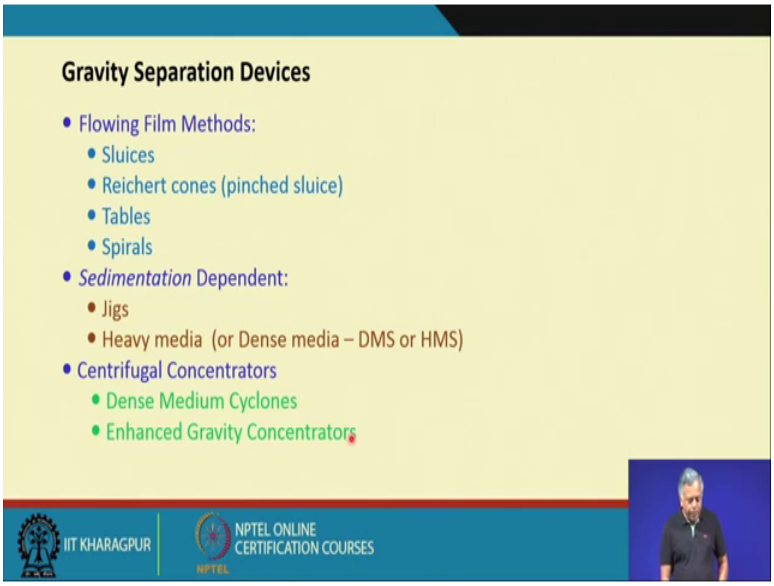

. So, if we look at the gravities separation devices based on these techniques. That is you can categorize the equipments have a level based on these techniques. So, flowing film methods; you have some of some of these equipment which is the basic principle is based on that I will explain you later on what is the flowing film technique.

One is sluices, other one is Reichert cones or pinched sluices we call it then tables spirals. Sedimentation dependent it could be jigs, it could be heavy media or dense media separation. Centrifugal concentrators that is your dense media cyclones or enhanced gravity cyclone enhanced gravity concentrators like that also we can the device wise the equipment wise I can group them and. Now what we will do we will try to explain them in one by one that what they are and how do they work?

Now, the most important the one of the ancient your technique is basically using your cerises that is what I have shown you in the from the Agricolas book.

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If you remember that there are some your pan type of thing that is this type of say technique this type of your boxes, we call it sluice boxes they are being used. Now what is this flowing film concentration? Here the flowing film concentration if we if I try to explain it, we need to understand a bit of your fluid flow related sciences. So, what happens when a fluid is flowing through a suppose your channel the channel could be like this.

So, when a fluid is flowing through this then it is a property of the fluid that the velocity at the bottom most layer that is close to the floor that is what is just in touch with the floor; there the velocity of this fluid is close to 0. And the fluid velocity increases as the height increases what I try to mean that if I feed a certain amount of fluid through this and the fluid will starts traveling through that.

And that fluid will be having some thickness say suppose your 10 centimeter or say your say 10 centimeter thickness; in that 10 centimeter thickness what I am saying that at the bottom the fluid may have almost 0 velocity. And as you go up the 10 centimeter thickness, the topmost layer or maybe just close to that topmost layer will be having the maximum velocity.

So, what is happening? When a fluid is flowing through a surface and if I have a channel like this if I have a bed like suppose fluid is flowing through this channel. So, the bottom most layer is almost not moving. And then gradually if I imagine that it is a your the entire depth of the fluid is basically a your accumulation of different layers of your fluid layers you have a different fluid layers.

So, each layer is having a different velocity and the velocity is consistently increasing as you go up. So, what will happen? Now suppose I have got the movement like this that is this suppose this is a fluid layer, this one is a fluid layer. So, it is moving like this and this is another fluid layer; so, that is moving like this faster. So, what will happen there will be some shear that is the friction between the two layers?

So, because of this shear if the shear is too intense; so, what will happen? There will be some eddies formed that is the flow will be turbulent. So, depending upon that how much is this here; that will dictate that whether the flow is called your equation flow, we call it laminar flow or whether the flow is turbulent. So, in this flowing film concentrators normally the fluid the average velocity of the fluid is very fast. A good example of this what I try to say that it is like a river, it is flowing and the river the bottom layer which is close to the bed of the floor of the river that layer is almost not moving and as we go up that different layers are having increasing velocities.

So, if I plot that your the velocity as a function of your depth that is height; it will having a velocity profile like this. So, in this case that difference is that in our flowing film concentrators our depth is very less depth of the flowing film we call it film it is within 4, 5 millimeters in contrary to what is the depth you normally encounter or you observe in a river it may be 4, 5 meters on an average here it is 4 to 5 millimeter, but the difference between the river flow and here the flow is that my flow is very fast.

So, because the flow is moving average velocity is very fast; so, the flow becomes turbulent. So, what will happen? Now say suppose if we incorporate some particles into that having equal size, but two different densities. Now because of their mass because the heavier fraction or the any particle based on its mass will inevitably try to go down that is it will try to settle. But because the flow is having a very high velocity; so, each layer is being seared and because of that there will be the eddies produced that we call it turbulent flow.

So, the turbulent eddies if that intensity is more than the downward velocity of the particle. So, it will try to back lift it and the particles will be in suspension and this property of the fluid we are using it to engineer this is your we call it flowing film concentrators for particle separation. Now how we can separate the two particles? Now if I can control this intensity of these eddies.

So, if I generate eddies in such a way that only my lighter particle wind mill suspension, but the heavier particle will settle there. So, my lighter particle will be transported a further distance and my heavier particle will get settled there. So, now, if I stop that or if I have a splitter; at the end of the discharge like here what is happening if my fluid is traveling that is in the form of slurry. So, my heavier particle they are at the bottom and my lighter particle add a your at a much higher depth at a much at close to the top.

So, now if you imagine that I have got a splitter and I am splitting the flow. Suppose within 5 millimeter if I have a splitter at 2 millimeter height. So, I will have an overflow I will have an underflow; so, under flow I will be having the heavier materials and overflow will be having a lighter materials the bit of complication. But my ancient people do you know this they did probably not aware of this fluid mechanical phenomena, but this phenomena you can use it if I have very your say you have huge density differences between the particles, you can easily use it to separate the heavies and lights.

We will continue this lecture and the next round of this your lecture series till then.

Thank you very much.