Introduction to Mineral Processing
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Lecture - 38
Classifier

Hello everybody welcome to this. So, forth lecture of this week 7. So, in this week we have discussed about the movement of solids in fluids. We have discussed how to calculate the three settling velocities of spherical particles. I have discussed briefly about the complexities involved with the non spherical particles settling behaviour calculations and we have also discussed about hindered settling velocity related calculations.

Now, we will be talking about a new topic it is called Classifier. The classifier is basically when we use when the particle size becomes very fine when practically the size separation using industrial screens become technically difficult as well as economically not viable because as the fineness of the particles increases the surface area requirement becomes use. And in that case we try to separate the particles based on their sizes using this principle of movement of solids in fluid media.

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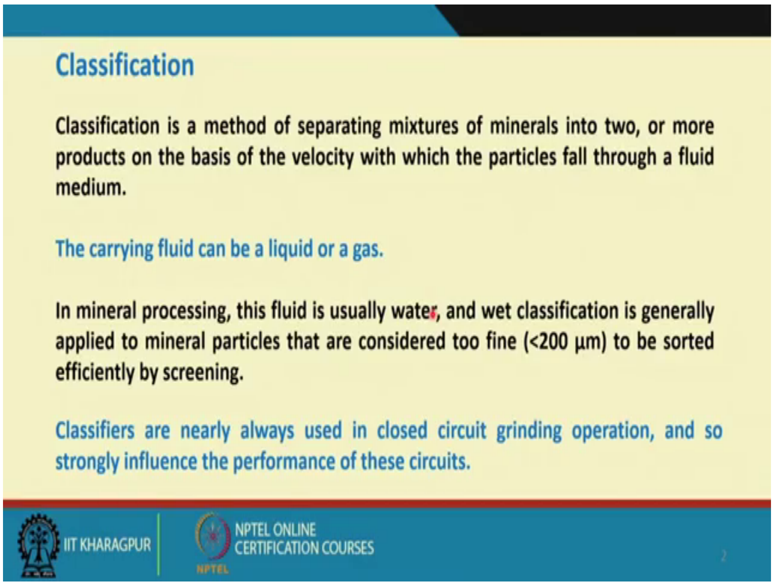

So, if you look at the definition the classification. So, classification is a method of separating mixtures of minerals into two or more products on the basis of the velocity with which the particles fall through a fluid medium. That means if I have say suppose to equal density particles one is 100 micrometer, another one is 40 micrometer and if we drop both the particles into a fluid medium, into a stagnant fluid medium. So, the settling velocity of 100 micrometer particles will be much faster or much higher than the 40 micrometers particles. So, if we give some time for them to travel through that fluid medium there will be a relative positional difference between these two particles so; that means, they are at different locations into the fluid column.

Now, if I have some means to separate them out from that two different locations I can have a separation between 40 micrometer and 100 micrometer particles. This carrying fluid can be liquid or a gas. Most of the cases in mineral processing we use water as a fluid medium because the wet classification is generally applied to mineral particles that are considered to fine that is less than 200 micrometer to be sorted efficiently by screening. Why we use water? Because my downstream processes that is after sizing further processing is being done most of the cases by water and in case of water, you have seen that if you remember the basic equation you need some fluid resistance to have some differences between the two particle classes differing in size or differing in density. So, the water can supply you that much of resistance.

The classifiers are nearly always used in closed circuit grinding operation. As I said that for very fine particles and very fine particles they are coming out from my grinding operations. So, what do we do? Suppose in a ball mill we want to grind everything below 40 micrometer. So, when the product is discharged we try to put it into classifier and we just take out the material which are finer than 40 micrometers, coarser than that that is any particle coarser than 40 micrometer we recycle it back to the grinding medium we call it recirculating load.

So, the performance of the classifier will also control the performance of my the ball mill operations and also that if my classifier does not do his work properly. So, my downstream processes where my equipments are basically selected assuming that it will treat 40 micrometer particles, but if my classifiers because of inefficiencies we are giving particles coarser than that or maybe much much finer than that then there will be inefficiency in my downstream processes also. So, that is why it is written here that is strongly influenced the performance of these circuits.

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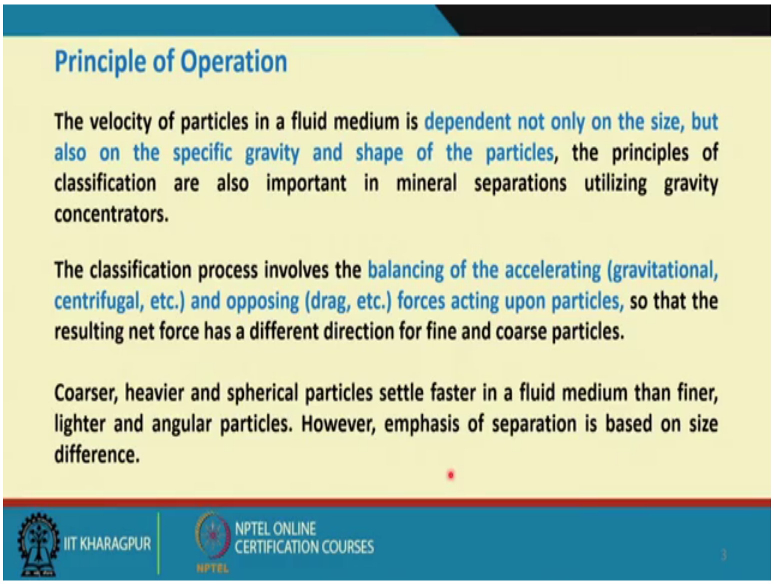

Principle of operation if you look at that is what I have already explained you. And if you go by these sentences that is what is written here there is the velocity of a particle; velocity of particles in a fluid medium is dependent not only on the size, but also on the specific gravity and shape of the particles. That is what we have discussed extensively during the lecture series on movement of solids in fluids.

The principles of classification are also important in mineral separations using gravity concentrators; that means, now in case of classifier we try to promote separation based on the sizes that is the difference in sizes. But it is almost impossible to neglect the effect of the density of the particles also. So, you have to consider the density of the particles whereas, the challenge is that is how do I minimize the effect of density and we try to promote separation based on size when we are talking about classifiers the classification process involves the balancing of the accelerating that is your gravitational, it could be centrifugal forces that is your downward forces and opposing that is your drag or maybe your buoyancy forces acting upon the particles. So, that the resulting net force has a different direction for fine and coarse particles. That means what we try to say here that is your force balances should be such adjusted that your relatively finer particles should have much lesser settling velocity in that fluid medium that is the water then my coarser part relatively coarser particles to have separations between those two sizes.

If we just use those equations we will find that that coarser heavier and spherical particles settle faster in a fluid medium than finer, lighter and angular particles. However, impasses of separation is based on size difference as I said in case of your classifier; how do we do it that is the challenge and that is what basically differentiates the different designs of these classifiers. We will discuss about that.

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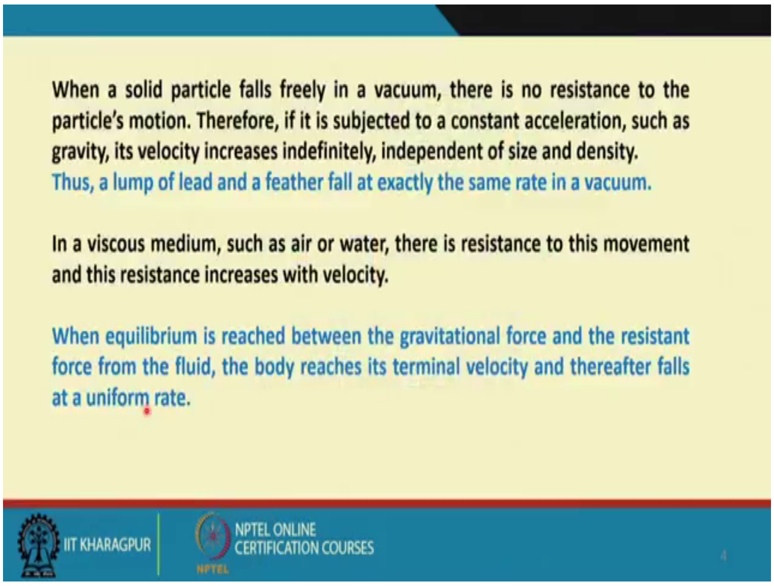

We all know that when a solid particle falls freely in a vacuum there is no resistance to the particles motion. Therefore, it is subjected to a constant acceleration such as gravity and its velocity increases indefinitely independent of size and density it is in vacuum please remember. So, that is why we have learned in our school days that a lump of lead and a feather fall at exactly the same rate in a vacuum. So, we cannot do this size separation in a vacuum. We need a fluid media where it will have it will exert some resistance to the motion of the particles

So, we need a viscous medium that is where we get some resistance. Such as air or water there is no resistance to this movement and their resistance increases with velocity. So, when equilibrium is reached between the gravitational force and a resistance force from the fluid the body reaches its terminal velocity and they are after false at a uniform rate. I do not think that I have to explain it again because we have dealt with this topic separately in moment of solids and fluids.

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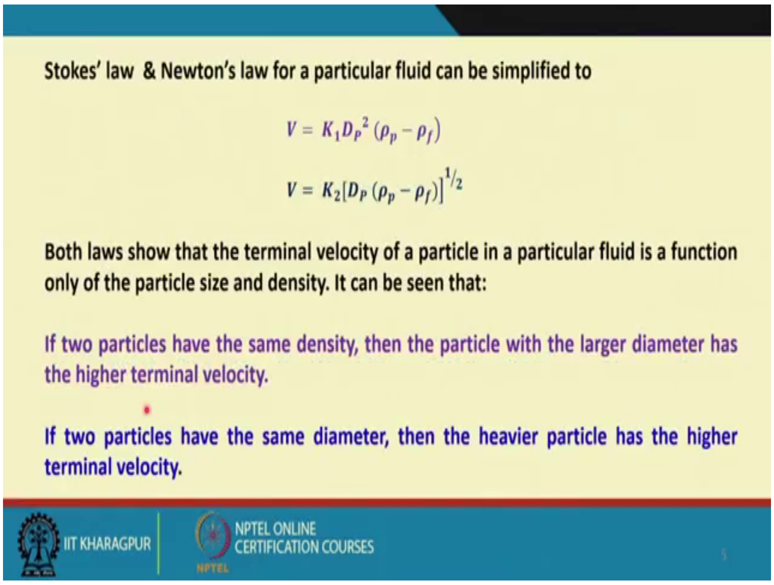

Now, let us see some interesting thing we do we apply Stoke's law and Newton's law. Suppose a particle size is D p and that particle density is denoted by rho p and the fluid density is denoted by rho f and K suppose this is a constant that is other terms I have taken it as constant. So, if we assume that this particle D p is following a your say Stoke's law then what is the equation we get that is we can write it in simplified term we have say taken all this mu term and eighteen mu and all this term into K 1.

So, we say V is equal to that is the velocity terminal settling velocity in (Refer Time: 11:24) region of a particle is K 1 D p square rho p minus rho f.And for Newtonian fluid for a Newtonian your (Refer Time: 11:36), that is your particle who follows the Newton's law that is when the Reynolds number is more than seven 50 we can write V is equal to K 2 into D p rho p minus rho f square root of that. So, both laws so that the terminal velocity of a particle in a particular fluid is a function only of the particle size and density. So, it can be seen that that is if two particles have the same density then the particle with the larger diameter has the higher terminal settling velocity.

Similarly, if the two particles have the same diameter then the heavier particle has the higher terminal velocity.

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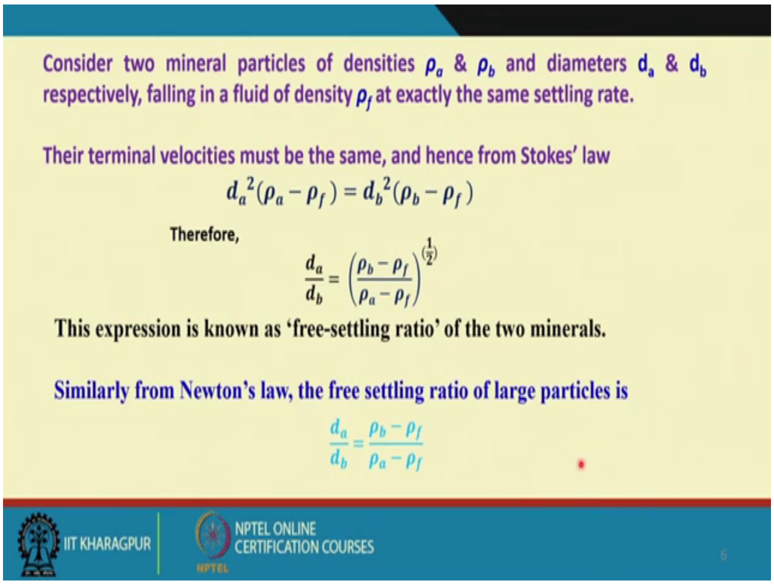

Now, you let us consider two mineral particles of densities rho a and rho b some of this is a mixture of two particle distinguished said two discreet two particles and having densities of rho a and rho b and their diameters are d a and d b small d a and small d b. They are falling in a fluid of density rho f had exactly the same settling rate because as I said that if two particles are having same density then the larger particle will fall faster than the smaller particle. If two particle size is same sizes are same then the heavier particle will fall faster. But say suppose I have got a 1 millimetre of a particle whose density is 2.65 and another one that is 2 millimetre size, but density may be 1.3. So, they can have same settling velocity just for example, I am saying. So, that is what in that case when the particles may be differing in size and density, but they may have identical terminal settling velocity.

And if we say if we assume that both these particles are following Stoke's law. So, in that case what we can write that is d a square rho a minus rho f is equal to d b square rho b minus rho f because those two constants are getting cancel out. So, we can write that d a by d b is equal to rho b minus rho f divided by rho a minus rho f to the power say square root of rho b minus rho f divided by rho a minus rho f. So, this expression is known as free setting ratio of the two minerals. That what is the free settling ratio of these two minerals I will put some number in the second slide and I will show you there what is the meaning of this.

The same condition suppose these two particles are having more Reynolds number that is they are following Newton's law, but they are having equal settling velocity into that fluid, in that case what is the presetting ratio. That is d a by d b is equal to rho b minus rho f divided by rho a minus rho f. So, that square root of is not there when you are following Newton's law.

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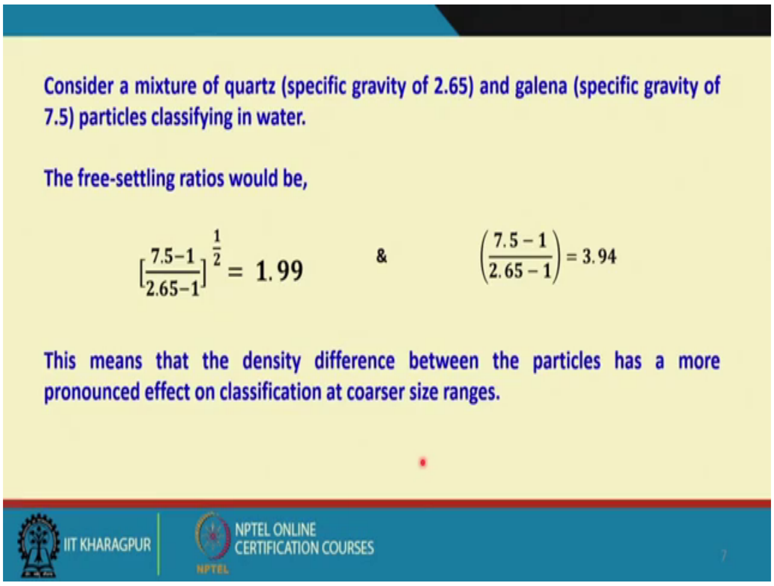

Now, let us put some numbers into that. Suppose now we have got a mixture of quartz particle whose specific gravity is 2.65 and galena that is p b s is a mineral for lead as a specific gravity of 7.5 particles classifying in water. I am not talking about the sizes I want to know they are free settling ratio. So, the free settling ratios for very fine particles so being Stoke's law would be that is rho b that is 7.5 minus rho f divided by rho a that is 2.65 minus 1 square root of that we get around 1.99. We can assume that is equal to 2.

So, what is the meaning of this? The meaning of this is that, a quartz particle having double the size of a galena particle will have the same settling velocity or identical settling velocity into a fluid medium where fluid is water. That means, if I want to separate a quartz particle of say suppose 20 micrometer and 10 micrometer galena particle using this principle relative settling velocity difference we cannot do it because a 20 micrometer of quartz and 10 micrometer of galena both of them are having equal settling velocity that is the meaning of this. That is for finer sizes.

Now, suppose I increase their sizes they are following the Newton's law. So, what is happening in that case that if they are bigger enough. So, it will become rho b minus rho f that is rho b is 7.5 minus rho f is 1 and rho a is 2.65 minus 1 that is a rho f we get around 3.94 that is 4. So, what is the meaning of this? Now, it may be your eighty millimetre of a quartz particle will be having identical settling velocity of a 20 millimetre of galena particle. So, it is 4 times.

So that means, I can have a size base separation between these two particles having density differences the tune up to 0.65 to 7.5 within a size range of 20 millimetre to your 80 millimetre of quartz particle. In that case it is only double the size, in this case it is four times. So, you have got more your say spread of the size data. Why it has happened and what is another implication of this? This means that the density difference between the particles has a more pronounced effect on classification at poor size ranges. That means, when the particles are relatively coarser sizes then the minimizing the effect of density is very difficult. But when the sizes are very small then the density effect is not that pronounced and we can have a separation into the finer size regions.

And this is the reason why for very size, very fine particles we try to use this principle that is they are relative motion in a fluid medium because we know that the density effect will not that be pronounced. But if we try to apply this for relatively coarser particle their density will start becoming very, playing some dominate roles.

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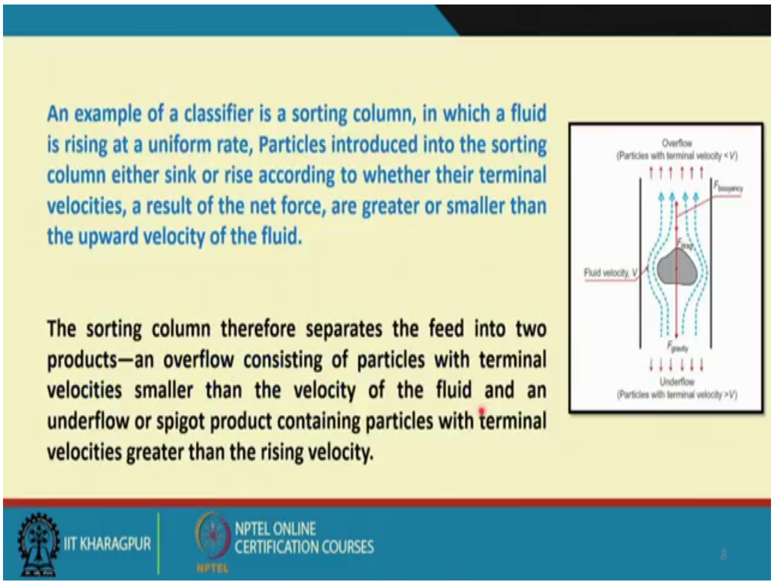

An example of a classifier and is how do I classify. I had already given this type of example in my movement of solids and fluids lecture still I would like to show you this. That is suppose this is a sorting column and this is the particle and I want to have, I want to have a rising velocity of water in such a way that I want in some cases the particles should be reported to the particles should be carried with the fluid and seem cause some cases I do not want the particle to be carried with the fluid I want them at the bottom. So, what I have to do?

That means, if I know the terminal settling velocity of this particle into the fluid medium I know now say suppose that settling velocity is around suppose for discussions like it is 10 millimetre per second. So, if my fluid velocity in the upward direction is more than 10 millimetre per second so that means, the particle will be carried to the top and if my fluid velocity is less than 10 millimetre per second then the particle will gradually be reported into the under flow and that is how we can separate.

Now, what do you have? Now, suppose we have two different particle classes, one is having 10 millimetre per second velocity downward velocity, another one is having 5 millimetre per second downward velocity. So, if my rising water velocity is within 5 to 10 millimetre per second; then what will happen? My 5 millimetre per second the velocity the particle who is having this will be reported to the overflow and your faster settling particle will be reported to the underflow. And that is how we can basically have a separation based on these principles.

However, in actual scenario we are not going to deal with a couple of particles we have to deal with large volume of particles. So, in that case how do we apply this? So that is a challenge to the design engineers. Although the basic principle remains same; but how do we apply it and that is where the machines are coming into pictures.

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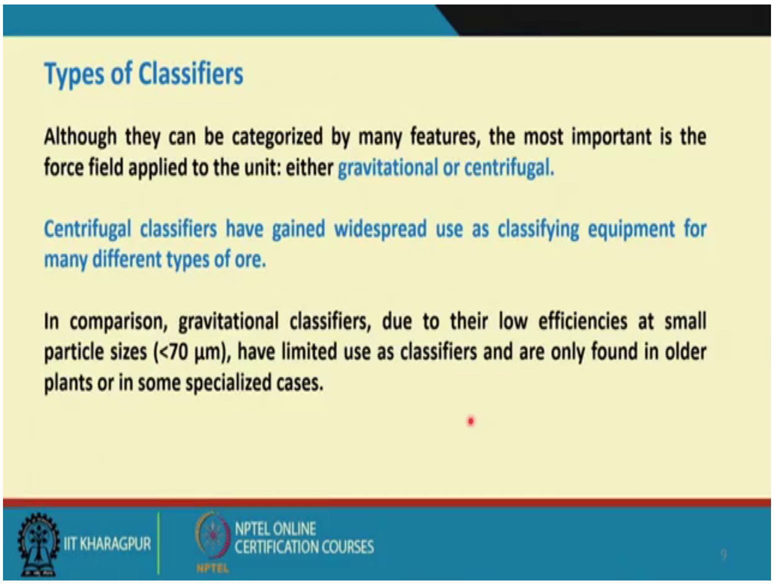

So, that is why we say that types of classifiers there are various types of machines available we call them their different classifiers and not every classifier can be used for every purposes. So, where we can use which classifier and why and these are the things we will discuss in brief.

So, the classifiers although they can be categorized by many features the most important is the force field applied to the unit that whether it is applying only normal gravitational force field or it is applying also the centrifugal force field. This talk this lecture we will confine it with only the gravitational force field based classifying systems we will have a separate lecture series on these centrifugal separators because it has gained widespread use as classifying equipment for many different types of ore, but before that let me discuss a bit more on gravitational classifier. So, gravitational classifiers they are not that efficient at small particle sizes less than 70 micrometer and I have limited use at classifiers and are only found in older plants or in some specialized cases.

Why it is not that efficient? Now, when you have your products coming from your milling circuit that is your may be ball mill or may be ag mill or may be sag mill. Eventually they have ground the mind ore. So, there you have got your huge density differences between the particles and their sizes are also different. So, it is very difficult to have a perfect separation what say to be efficient separation based on the size only because the density also plays a major role in that, but still we are using some of these gravitational classifiers in some of our old plants and some specific cases some specialized cases we are also using it.

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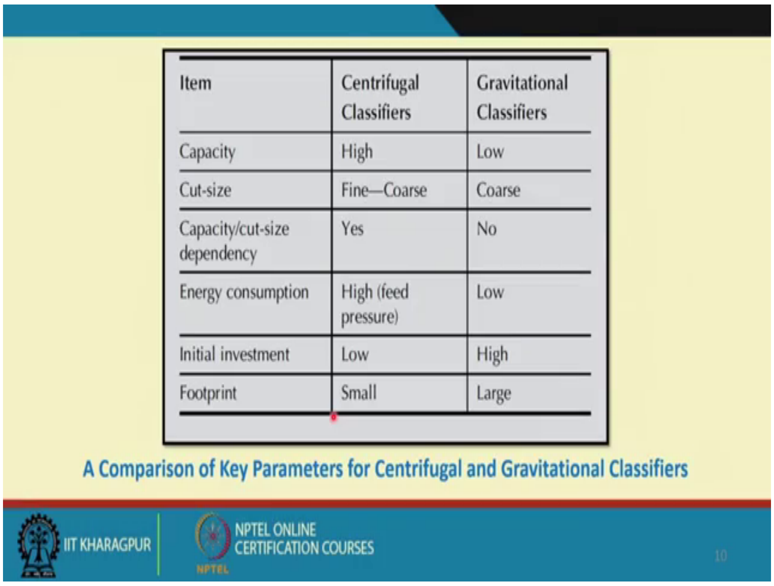

Item	Centrifugal Classifiers	Gravitational Classifiers
Capacity	High	Low
Cut-size	Fine—Coarse	Coarse
Capacity/cut-size dependency	Yes	No
Energy consumption	High (feed pressure)	Low
Initial investment	Low	High
Footprint	Small	Large

If you compare between the centrifugal classifiers and gravitational classifiers, why I am saying that gravitational classifiers they do not have much of the application in the modern plants the centrifugal classifier have replaced them. The reasons are if you look at the capacity comparison centrifugal classifier having much higher capacity than the and capacity means per unit volume of that your equipment space.

Car size that is a separation size that is the d 50 size, if you remember the particle size distribution we have discussed about your d 50 sizes even in the industrial screening lecture I have shown you how to calculate the d 50 sizes that is called the cut size. So, in a centrifugal classifier you can have the cut size even in the very fine size range to very coarse size range. Although in gravitational classifiers it is mainly coarse particles.

I will look at the capacity cut size dependency yes; that means, your in-centrifugal classifiers as you go down the your d 50 size your capacity you have to change, but gravitational classifiers because it is dealing with coarse particles capacity is not that related to the cut size. Energy consumption comparison here said for centrifugal classifiers you need a high feed pressure in gravitational classifier you need relatively low feed pressure. Initial investment for centrifugal classifiers much less than the gravitational classifiers. Footprint requirement for gravitational classifiers is smaller than much smaller than your gravitational classifiers.

So, you see that the capacity, the control range of the cut sizes, your cost of initial investment, your footprint they are all in favour of centrifugal classifiers and that is the main reason that why centrifugal classifiers are more popular these days than the gravitational classifiers. We will continue this lecture end to the next day.

Thank you very much.