Introduction to Mineral Processing
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Lecture – 26
Grinding (Contd.)

Hello, welcome, so we are discussing about the grinding we have discussed about the ball mills and the critical speed, which is very important. And we have also discussed in the last lecture that what will happen if the if you run your mill at too high speed and too low speed, and what is that your say guiding tool that is your critical speed.

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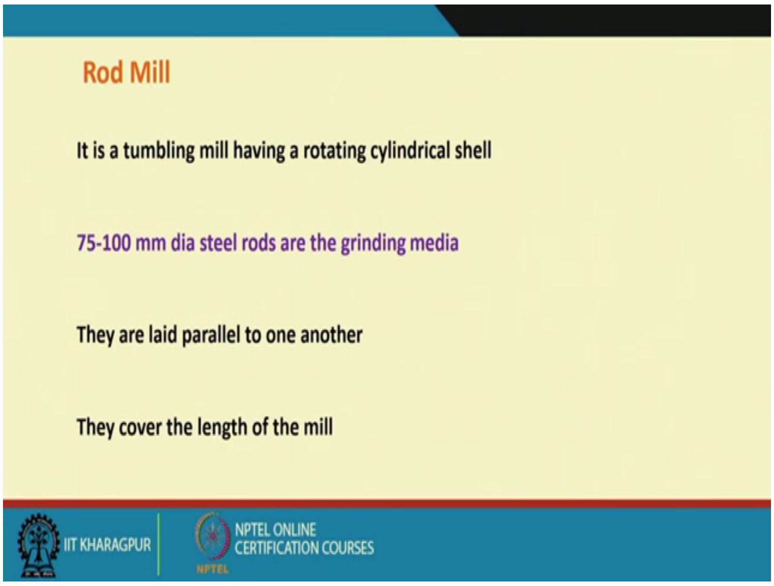

Now, here we have discussed about that is we mentioned that there is another kind of mill that is called the rod mill. So, here it is a tumbling mill having a rotating cylindrical shell, because the length has to be more than the diameter, because it is in place of your grinding balls as we use in ball mill, here we use rods. So, if the l by d ratio is not if equal, l is equal to d then the rods may not tumble like this, it may fall like this so that we do not want. So, 75 to 100 millimeter dia steel rods are the grinding media here means in place of the balls, they are laid parallel to one another, and they cover the length of the mill. So, entire length so the balls are there and when the tumble in between the particles they sit, and they get broken.

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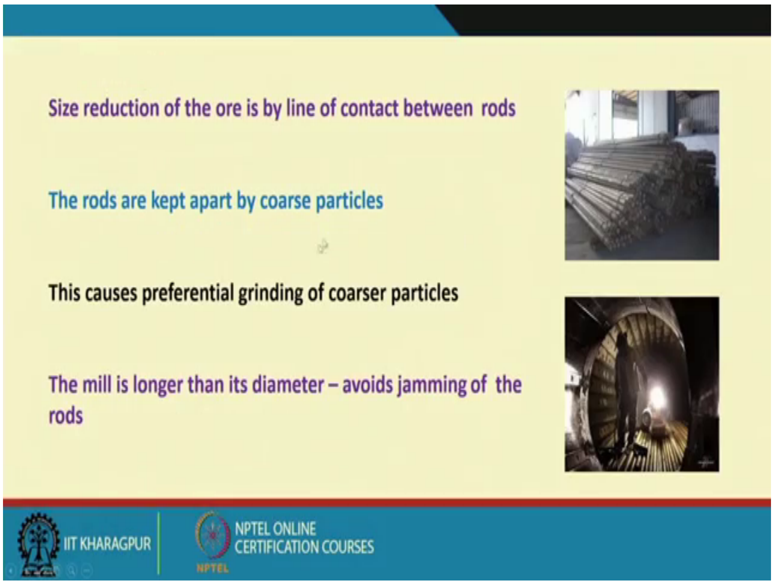

Now, this is the rod what we use normally this is the one of the images which shows that what kind of rods we use. And this is how a rod mill inside they look like. So, the size reduction of the ore is by line of contact between rods. So, what is happening, when you are using a ball, so the point of contact that is as there is a point of contact between the balls. And even when the ball is hitting the particle there is a less surface area of the ball which is being utilized for breaking the particle, but here in the case of ball mill you have got an impact also.

But here what is happening if you have two rods, so in between the particles are trapped, and then the entire surface area of the rod you are utilizing for your breakage of your material due to abrasion. So, the rods are kept apart by coarse particles because in between when you try to rotate it, so in between the coarse particles they sit inside and then the rods are basically they are set apart.

This causes preferential grinding of coarser particles that means, when I have your two rods like this if my coarser particle is here, so the finer a particle. So, if I have finer particle here, so when the ball when the rod rotates there will be a preferential breakage of the coarser particles then in relation to the finer particles. Because there will be hardly any abrasion between the finer particles and the rods because the coarser particle has to be broken first. So that is how we have a preferential grinding of coarser particles. The mill is longer than its diameter avoids jamming of the rods because otherwise there will there may be a jamming of the rods.

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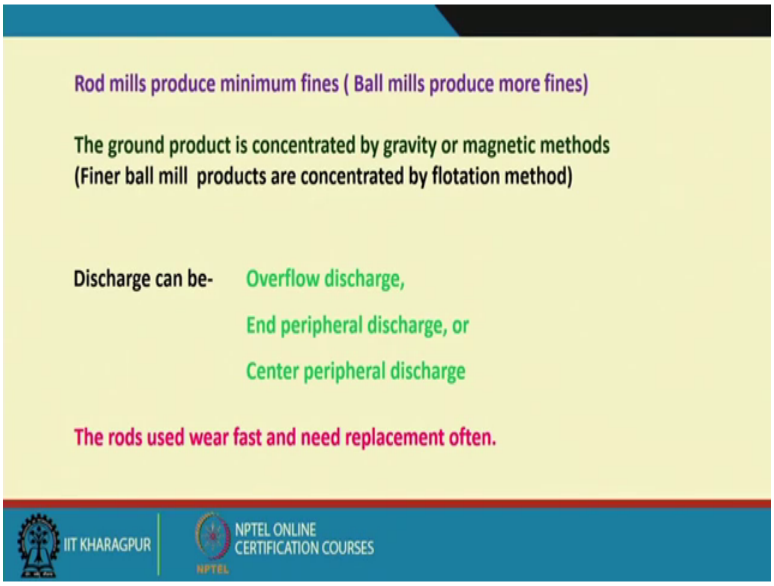

So, rod mills produce minimum fines, why now it tries it tries to break the relatively coarser particles at a faster rate than the finer particles, but in case of ball mills you do not have this type of preferential breakage options because of the mechanism what you are utilizing in a ball mill. So, the ball mill generally generate relatively more proportion of fines than in a rod mill; and in a rod mill product you have got your relatively your closest size range of materials.

The ground product because it generates relatively coarser particles, the ground product is concentrated by gravity or magnetic methods. So, that means, when my product from the rod mill, when my product from my grinding media they are decided to be separated, or they are planned to be separated by a gravity concentration technique that is by using their body forces. Or based on their magnetic property differences, so we try to use a rod mill because the gravity concentration process efficiency and the magnetic separators process efficiency drops drastically when the particle size becomes finer and finer, so that is why if we have a gravity circuit or a magnetic circuit. Then you know before that we try to break the particles by using try to grind the particles by using a rod mill but when we are aiming at very fine product and we try to process it or in the downstream processes, a process called froth flotation or maybe some other flotation.

So that is based on your surface chemistry based phenomena. So, there we need to generate much of larger surface area of the particles, so that I can exploit the or say surface property differences between my wanted and unwanted materials. So, the ball mills are preferred before flotation process, whereas the rod mills are preferred before gravity or magnetic methods.

The rod mill discharge can be overflow discharge, it can be end peripheral discharge or it can be center peripheral discharge. Although these are very important, but because of the paucity of the time or the limitation of the say time limitation of the course, I cannot explain you in detail, but the interested people they may look at any textbook that what is the overflow discharge. It is basically based on the discharge mechanism that is a product distance mechanism how you are trying to take out the material from your mill that is called based on that the different names are there.

The rods used wear fast and need replacement often, because better in the contact between because the rods are always in contact with the particle surfaces. And maybe if there is no particle inside in between the two rods the rod another rod will hit another rod and there will be aberration, there will be impact because of the rotational moment. So, they wear very fast and you have to replace these rods very, very often.

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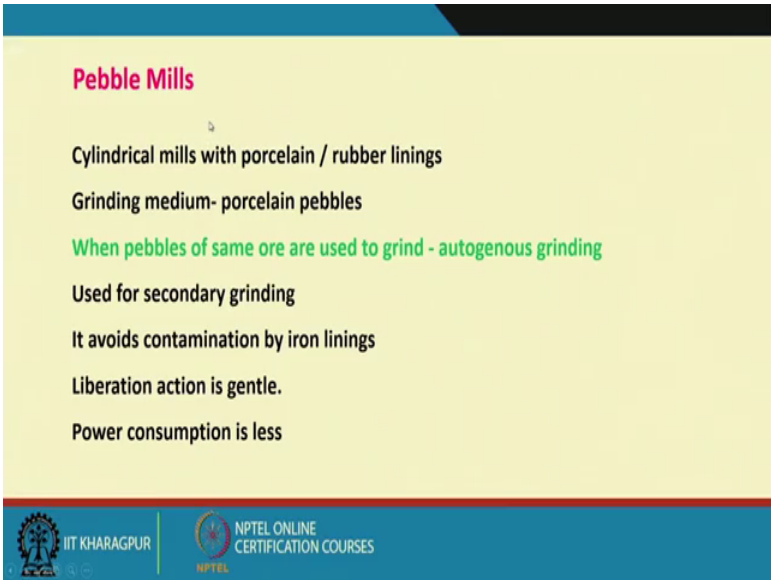

There are also pebble mills, which are basically the cylindrical mills with porcelain or rubber lining. So, we make it because to protect your mill surfaces from the wear.

Grinding medium they are porcelain pebbles, and when pebbles of same ore are used to grind it is called autogenous grinding that is what we have already discussed that bigger particles hitting relatively smaller particles two more to generate much more finer particles. So, we do not use any artificial medium in the form of balls or in the form of rods then we call it autogenous grinding.

Pebble means are generally used for secondary grinding that is for after primary grinding we try to use it. It avoids contamination by iron linings, because we are using pebbles either; they are basically the made of your porcelains, so they are not that prone to wear or maybe we are using the like in your autogenous grinding. So, you do not have much of the wear of the material surface or the ball we are is not there. So, it avoids contamination by iron linings. So, many a cases like if you are working for a pharmaceutical industry and you try to grind your material, so there you do not want any contamination because your industry does not allow you to do so. So, if I want to prevent that contamination, I have to use either a autogenous grinding mill or maybe a pebble mill or maybe you can use a ceramic liner also inside.

Here the liberation rate of deliberation action is gentle and power consumption is also less, because the mill volume is so basically you do not have artificial medium. So, when you are consuming the energy for rotating your grinding medium, so here that situation does not arise. And your per unit volume you can feed more amount of material for grinding, so your capacity per unit volume is much more higher than your the ball mill or rod mills, so that is why your power consumption per unit turned of material process it becomes lesser.

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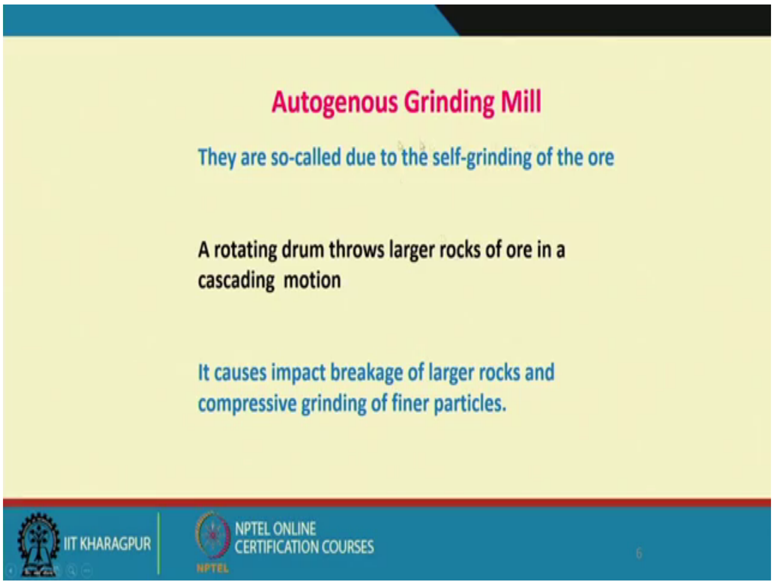

Then about the autogenous grinding mill that they are so-called due to the self grinding of the ore because it is another material, material of similar characteristic, but bigger than that it is hitting. And it is acting we are utilizing them as a grinding medium, so that is called a self-grinding of the ore that is why we call it auto generous grinding mill. A rotating drum throws larger rocks of ore in a cascading motion that is your when the mill rotates that is your drum type of your separate or say mill it rotates. So, it generates much of cascading action because of the larger rocks and then it tries to have a shear or say aberration and that is how the particle gets broken mostly and because of the impact also.

It causes impact breakage of larger rocks and compressive grinding of finer particles. So, when the larger rock falls into the top, so because of impact that larger rocks gets your much relatively finer sizes and with the repeated action the larger rocks ultimately goes out of the system as a finer material as a finer product. Even the larger rocks are when it is falling into the your finer particles that is because of impact or because of compression because it can have your one particle one bigger particle is here and in between and another bigger particle is there. And then in between you have got a relatively finer particle there may be a compressive force also, so it is called a compressive grinding also for finer materials.

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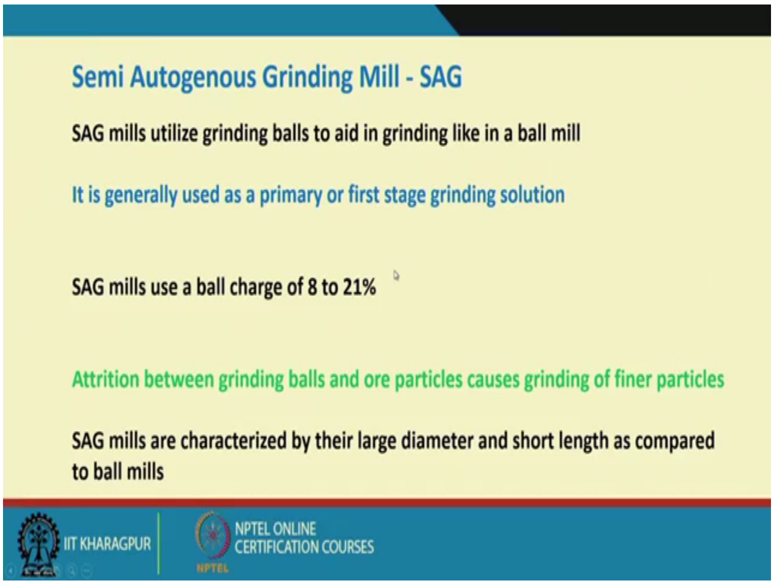

There is another type of mill, which are called semi autogenous grinding mill - SAG. So, the autogenous grinding we write it in an abbreviated manner SAG, and we call it here SAG that is called semi autogenous grinding mill. What is the semi autogenous grinding mill, the semi autogenous grinding mills utilize grinding balls to aid in grinding like in a ball mill, but it is not up to that percentage and a reduced quantity, it is a much reduced quantity then what do we use in a ball mill. So, what happens it is basically a combination of your ball milling action, and your autogenous grinding action, because many a times you see that your relatively larger particles may not have the sufficient strength to break your relatively finer particles. So, or maybe they are very brittle particles. So, by some couple of rotations they themselves get broken. So, then the relatively finer particles they start, they are not getting hit by bigger particles because already the bigger particles they have become much more finer particles.

So, in that case, you add some steel balls as you do it in ball mill and to aid this grinding process. So, to campaign said that said your limitations of your bigger particles. So, SAG mills civilized grinding balls to aid in grinding like in a ball mill, it is generally used as a primary or first stage grinding solution. SAG mills use a ball charge of 8 to 21 percent of the total mill charge. So, as a ball charge is around 8 to 21 percent and why there is a huge deviation, there is a difference between 8 to 21 percent because that depends on what is the material characteristic you try to feed or you try to break.

Attrition between grinding balls and ore particles causes grinding of finer particles that is a similar phenomena what we had observed in a ball mill that is called the attrition or because of the abrasion you know that is the bigger balls of higher density and very hard surfaces they when they are having a cascading action. So, they try to break my particles into finer sizes because of abrasion SAG mills are characterized by their large diameter they are very big mills. Why do you want a large diameter mills because when the diameter is more, so the point from where that there is a change that is your break point is basically at a much higher height than if you are using it at a lower diameter a smaller diameter your say mill.

So, what will happen if you do your break point is a much higher say if the distance between your toe and the break point is much higher, so the impact of the particle when it falls that is when it say goes away from its circular path and then it follows a parabolic path and hits the toe region. So, the impact will be more on the particles. So, if I have a very large diameter mill, so I can promote this impact breakage and even the cascading action will be much more prolonged. And when the mill is bigger diameter automatically that capacity of the mill increases and they are of short length as compared to ball mills. Why short length because of the impact and because of the abrasion, the particles are already broken, so I do not want to give the particles to be broken to a very fine sizes than what is wanted what is required.

So, if I have your smaller length, so the particle will go out from the system or the residence time of the particles inside my mill will be reduced. So, that is what is that basically that design say changes or the differences in their basic design from they are in between a ball mill and a your SAG mill semi autogenous grinding mill. So, as a large diameter relatively shorter length as compared to ball mills.

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The inside of the mill is lined with lifting plates. Why do you need the lifting plates, because I need to lift my material because otherwise it may the different materials they try to your say deviate from its circular trajectory and they may start falling back. So, I want to we need to use a lifter, so that the entire pulp that is your mixture of your or entire charge is being lifted. And inside the mill where it then falls off the plates on to the rest of the ore charge that is the mill is lined with lifting plates to lift the material inside the mill, where it then falls off the plates onto the rest of the ore charge, because this is what is like your mill liners. I will show you they a picture that how the mill liners look like otherwise they may slide back.

Because if I do not have a lifter and if the entire mass because it is a higher capacity mill, so if you are feeding a large quantity of feed material, water and your balls, and the intake charge when it is being lifted, so there may be some falling back action or part of this charge. So, we want to take them to the point of your break point. So, for that we have the lifters, we have to lift it.

SAG mills are primarily used at gold, copper and platinum mines with applications also in the lead, zinc, silver, aluminum and nickel industries. If you look at this you see that all the minerals whatever I have mentioned here their grades are very less in your feed material. So, when the grade is less, I have to process a large quantity of material per unit time to get my desired quantity of my metals. So, you need you require because when you are processing low grade ores, you need to process large volume of materials to get the desired amount of metal to be extracted from that. So, it demands that you need a very high capacity mill.

So, if you are using a ball mill, the majority of your ball, if your charge consists of occupy occupied by the balls. Now, you are having a reduced ball charges, so that I can process much more volume of material, but without compromising with the quality of my end product. So, what we have done you have increased the ball diameter and then because of that you are promoting the cascading and your impact that is you are cataracting action and your cell length of the mill is sorted in comparison to your ball mill and then the product gets discharged very fast. So, the residence time inside the mill is also less. So, this is for low grade ores.

And these are basically there are many other criteria also that is your what is the your grind ability index of that material, what is the work index of that and all this thing you have to take into consideration, but what just for your general knowledge purposes and this is what the interpretation I gave. So, gold, copper and platinum and with also with the lead, zinc, silver, aluminum and nickel industries and even the SAG mills are also used for many other minerals these days.

The largest SAG mill is 42 inch in diameter, it is a gigantic mill powered by a 38,000 horsepower motor, which draws around 28 megawatt your power. So, the largest SAG mill is 42 inch in diameter – huge, powered by a 38,000 horsepower motor, because you have to rotate the entire mass.

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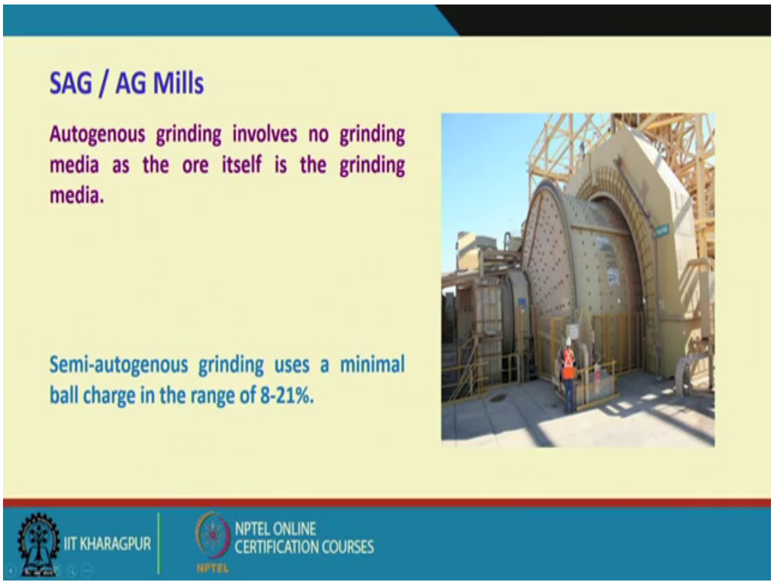

This is what actually looks like you see the diameter of this, this is a gentleman of average height of around 6 feet 2 inches and you see that how big the mills are. And now we think of the foundation it is required, the design constraints, the materials what you will be using all sorts of things are there, and the maintenance related issues and for all this as the mill have become gigantic, so there are requirement for sophisticated instrumentation for getting the information what is going on inside. So, many attempts are being made even there are some these days the image processing techniques are also being used for monitoring the say profile inside the liner or maybe even your lifters when they are getting worn out. So, these information is being sent to the control room and then you can take appropriate maintenance related decisions autogenous grinding involves no grinding media as the ore itself is the grinding medium that is the difference between AG and SAG mills. Semi autogenous grinding uses a minimal ball charge in the range of 8 to 21 percent.

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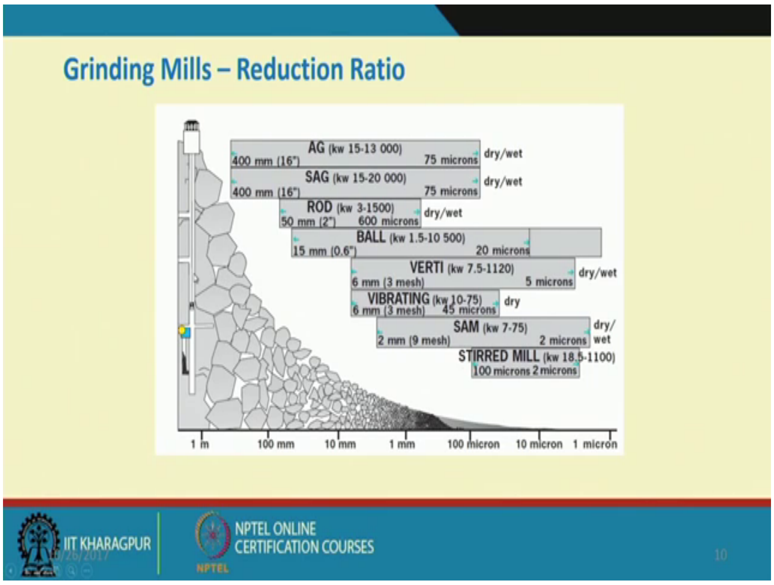

If I look at the grinding mills the reduction ratios, I hope you remember the what is the definition of reduction ratio that is what is the 80 percent passing size of your feet and now what is the 80 percent passing size of the product. So, the ratio in between them gives you ratio it is called the reduction ratio. Because why the reduction ratio is important, know I had given in one example for crusher circuit design that is i want to have a reduction ratio of 25 that means, I want to break my feed material to 1 by 25th of its current size. So, how many numbers of your say crushers we acquire.

So, here also say suppose I want to grind my say feed material from a 10 centimeter to below 10 micrometer. So, what is the reduction ratio the reduction ratio I have to calculate. So, 10 centimeter you have to convert it into micron, and then you have you can take that 10 micron and that ratio is a huge ratio. So, this will give you some rough idea that what are the different mills, how much power they consume and what is the reduction ratio they use. The AG mills they normally consume 15 to 13,000 kilowatt hour of power and at the reduction ratio is from 400 millimeter to 75 microns, it can be used as a dry or wet process. So, you can calculate that what is the reduction ratio.

So, the SAG may semi autogenous grinding mills it ranges from 15 to 20,000 kilowatt and again you can break even get a reduction ratio problem 400 millimeter to 75 micrometers. Rod mills consumes around 3 to 1500 kilowatt hour power, and it can give you a reduction ratio from 50 millimeter to 600 micrometers. If you look at ball mill it consumes a power of 1.5 to 10,500 and it can give you a reduction ratio from 15 millimeter to 20 micrometers. There are vertical mills, we have not discussed, it can give us from 6 millimeter to 5 microns. Vibrating mills we also had not discussed 6 millimeter to 45 microns. Like stirred mill from 100 microns to 2 microns.

So, how do I select this mills. Firstly, I need to know that what is that final product I require and what is my initial feed size. So, what is the f 80, and what is the p 80, I require. And then where that p 80 that is your product will be utilized that is what is the will it be sent to a gravity concentration method or will it be sent to a flotation method or will be sent to a magnetic separation circuit. So, depending on the capacity, which is not mentioned here that how much your material per unit time you want to process. So, this is only a guiding tool. And when the capacity requirement is very high maybe you can think of going for SAG mills or AG mills and it all depends on what is the your characteristics of your input material that is your feed material.

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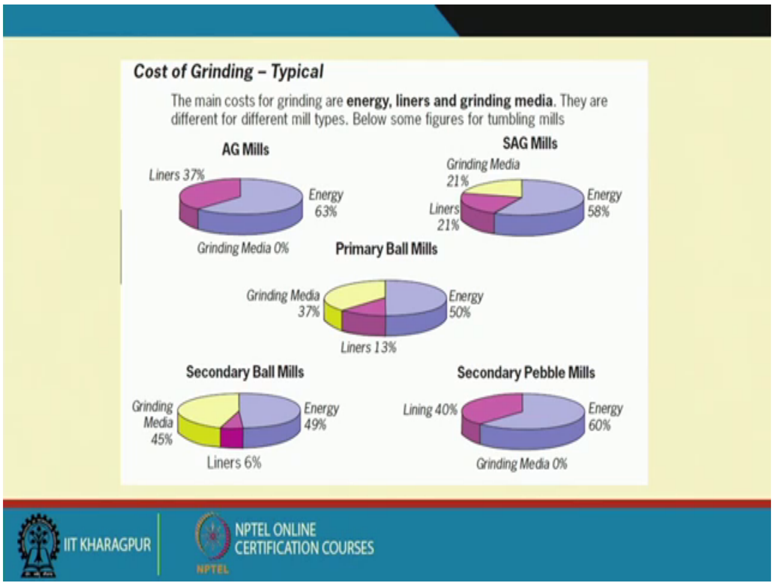

If we will look at cost of grinding, because grinding is very energy intensive process; it consumes more energy in any is consumes the highest energy in any mineral processing circuit. So, the main cause for grinding are energy, so that is the energy cost then the liner where that is your liners, and the grinding media where because the you have to replace the liners or a certain duration on a certain time interval then the grinding media you have to replace. They are different for different mill types and it is what will be the energy consumption, what will be the liner cost, what will be the grinding material cost they are different for different mill types. Some fingers below are given for the tumbling mills just your general information purposes.

You see that in a AG mill the liners they consume around the cost around 37 percentage of the total cost of grinding, whereas the energy cost is 63 percentage and you as because you are not using any grinding media, so grinding media cost is 0. So, it is 37 percentage is a liner energy cost is 63 percentage. When you are you looking at SAG mills you look at the grinding media costs around 21 percent say is 21 percent liners say 21 percent and energy is 58 percent. So, if you add them together it becomes 42 the grinding media a liner. So, SAG mill if you look at that your liner and grinding media cost is more than your liner we are here AG mill because here you are using your balls which are much your harder and then they are very costly materials also.

In primary ball mills, the grinding media share the total cost of grinding 37 percent, liner is 13 percent and energy cost is 50 percent. Secondary ball mills like grinding media 45 percent, liner 6 percent, energy 49 percent. And secondary pebble mills lining 40 percent, grinding media 0 percent, and energies 60 percent, because pebble mill we do not use any grinding media we are using the ball it is synonymous to AG mills.

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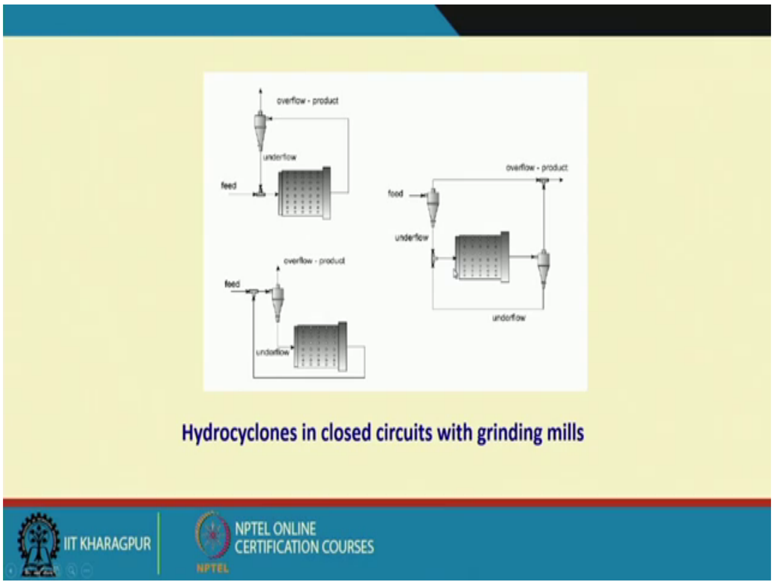

And mostly the as I said the grinding mills are in closed circuit. So, the circuit configuration could be like this. Here we do not use screens because the screens and they when we discuss about the industrial screens in my next series of lectures that will be my next topic. So, we use a classifier called hydrocyclone where we use a centrifugal force for size separation. So, you see that here the feed material enters and then the your overflow that is the product and then it is being sent to a hydrocyclone that is a size separating device. So, the overflow generally gives you the finer product and the underflow is the coarser product. So, the material which are already ground finer than what do we require, so that we get it at the cyclone overflow. And then this is sent back to the mill.

Here you see that there is a feed and then you are using a classifier that is you try to take out in the feed whatever material is already finer than your desired size because why to over grind them. So, you take out and then the underflow you send it to the mill and then again you have another cyclone and this overflow we match we mix it with the already finer product here. And we assume that they are of both they are of equal sizes, and this under flow again is recycled back here. Similarly, you can have different types of orientations, which are self-explanatory. So, these are called the closed circuit grinding operations. And we will discuss at length in some other lecture series on hydrocyclone because it is a very important device in any mineral processing operations. And the efficiency of this closed circuit grinding operation relies heavily on the efficiency of separation of this hydrocyclone.

Thank you very much.