Introduction to Mineral Processing
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Lecture – 24
Grinding (Contd.)

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Hello welcome. So, we are discussing about grinding. So, we will continue that. So, see that even in so like crushing in grinding also we have primary grinding and secondary grinding. Why do we do it, again we do we try to do it in stages to read minimize the generation of fines. Primary mills work faster and they try to set at the feed; and the secondary mill it is like your fine tuning, they work gently and uniformly finer products are formed and that is the aim of this primary and secondary mills. The grinding could be again like your crushing like open circuit grinding and close circuit grinding.

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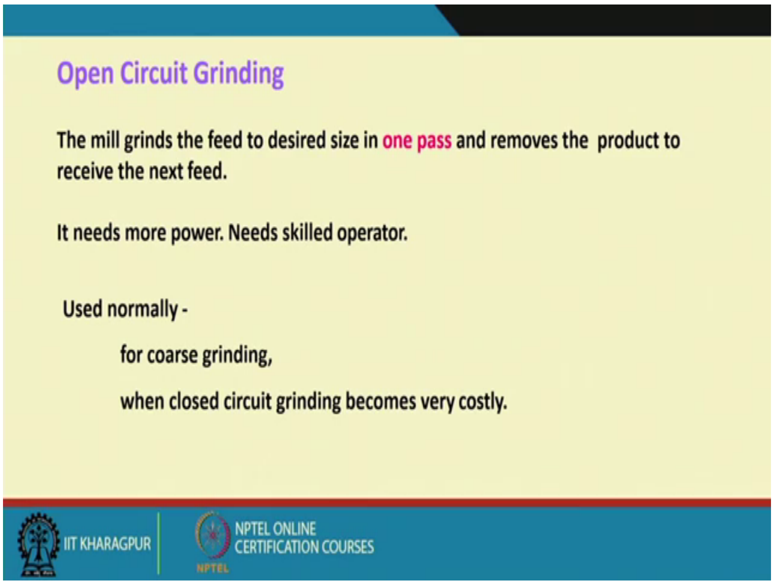

Open circuit grinding means the mill grinds the feed to desired size in one pass and removes the product to receive the next feed that means, the material is coming, there is a mill and when it is done that that is you are given a predetermined residence time to the material for grinding and then it is going out. So, material going in and material going out, and the time to travel this inside the mill that decides that how much is the retention time and there is no control on the quality of what is being discharged so that is what it is called the open circuit grinding.

It needs more power because you will be having relatively harder materials also and softer materials, so you need more power to break this hard, relatively harder materials and the finer materials will be ground to vary further. And it requires skilled manpower skilled operator that is who is skilled that who knows that if that is my product discharge quality and I want to bring it back to this quality. So, what should be there my control parameters that is what should be the rpm of my mill, what should be the flow rate of this mill - input flow rate, and all sorts of things that is whether I have to reduce the water quantity in to that or the feed say concentration I have to reduce. So, all these decisions have to be taken by the skilled operator.

This open circuit grinding used normally for coarse grinding that means, here we are not trying to go for the finished product, mostly they are in say relatively finer sizes, but when it is desired that we need relatively coarser grinding then probably we choose or we select the open circuit grinding operations. And many a times the closed circuit grinding becomes very costly because of the nature of the ore, and then we try to select as a compromise solution the open circuit grinding.

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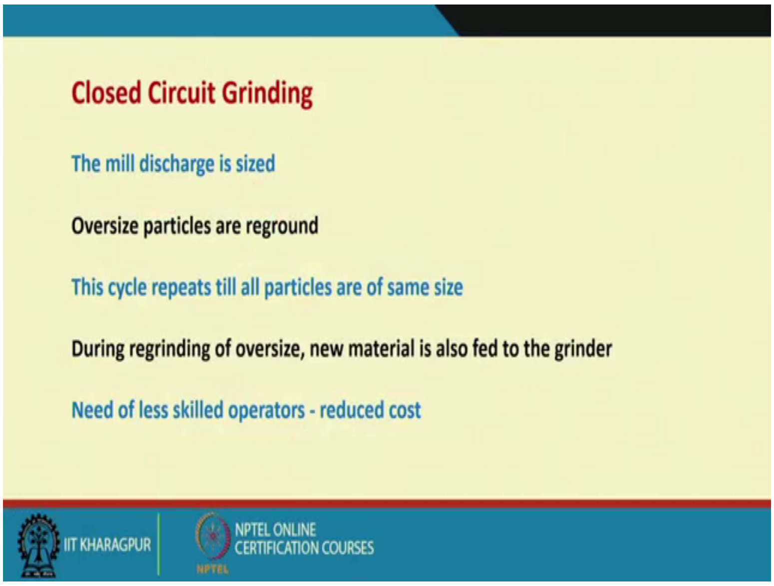

The closed circuit grinding means it is like analogous to our closed circuit crushing that means, you have got a your say mil discharge and in that discharge is basically you are checking that what is the size of that discharge, what is the size distribution of that. So, that is why I have written that mill discharge is sized. And then say suppose I want my material to be ground to below 40 micrometer. So, I will have some size separation device and the discharge end, so the mill output that is your grinding mill output will go to the classifier or go to the size separating device. And whatever material is below 40 micrometer that will be taken away from the circuit, but the materials which are not yet ground below 40 micrometer they will be recycled back and they will be added to the fresh feed.

So, this is basically the oversize particle are reground the cycle repeats till all particles are of same size; ideally we try to do it, we try to repeat it, unless and until all the particles what you are feeding they are finer than a predetermined size. During regrinding of oversize, new material is also fed to the grinder as I said that you are having new feed, and you are having a recycle field. So, how much is the recycle field, and how much is the new feed that we should be knowing. And there are some calculations which we will do in due course of time, I will try to show you that how to do that those calculations.

Needs of less skilled operators, and it is reduced cost, and then we can automate it or because in the size separation device, we can fix that, whatever is the material finer than that that will automatically be taken out and coarser than that will be coming back to the feed, and it will be mixed. So, we can automate the operation also, it does not require much of skilled operators.

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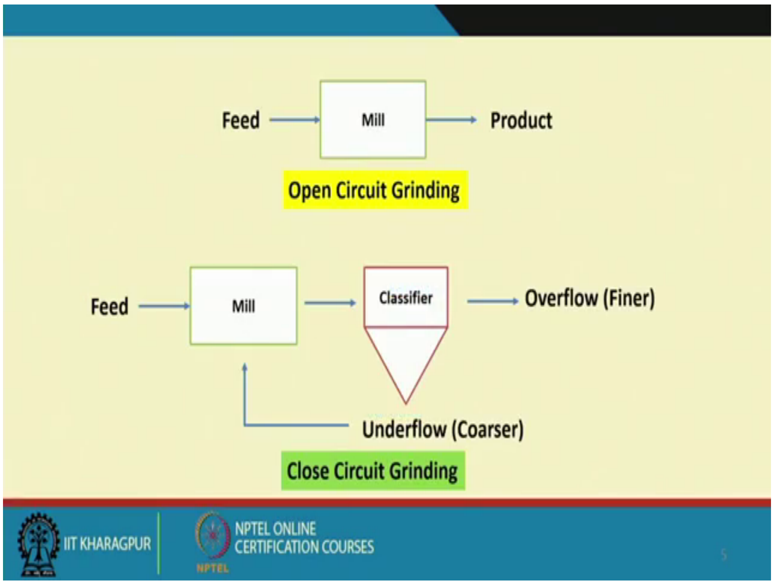

Now, this is the schematic I wanted to show you that what is that open circuit grinding is like a mill. We call it grinding mill. So this is the feed and it is coming there and then it is getting discharged as a product and when it happens like this so that means, we are not controlling any the product quality we call it open circuit grinding.

You see here that in closed circuit grinding that the mill discharge or the product is not directly discharged like your open circuit gardening, but it is going to a classified, classified is nothing but a sized separation device for very fine particles the size ranges. And here the classifier overflow means the particles which are finer than your desired size. So, they will be just your product and the underflow which are relatively coarser, they will be mixed with the new feed actually, this arrow should be here. So, they are again sent back to the mill. So, this is called closed circuit grinding so that means, you are ensuring the discharge product quality here that we are it is guaranteed that all the material which is passing through this circuit they are finer than a particular size. So, this called a closed circuit grinding.

Now, where closed circuit grinding is required, now where we have know that by liberation size of my material is below a typical size says suppose 40 micrometer or 50 micrometer so that means, irrespective of the nature of the material, we have to grind all the particles all the feed particles to below 40 or 50 micrometers. So, that is what we try to ensure it through this your closed circuit grinding operation that yes whatever is going out of the circuit that is finer than that 40 or 50 micrometer size. Because my process efficiency of my downstream unit operations largely depend on these say actually quality of my say particles that is based on the size so that means, if they are coarser, they will create some more problems in the downstream processes.

But here another thing also if they are to fine that also will create some problem to the downstream processes so that is we have to have proper choices of these mill parameters and the classifier parameters that decides separation devices parameters. So, that we do not generate much of artifice that means, say suppose I need build of 40 micro meters, I should not end up generating 90 percent of the particle below 10 micro meters.

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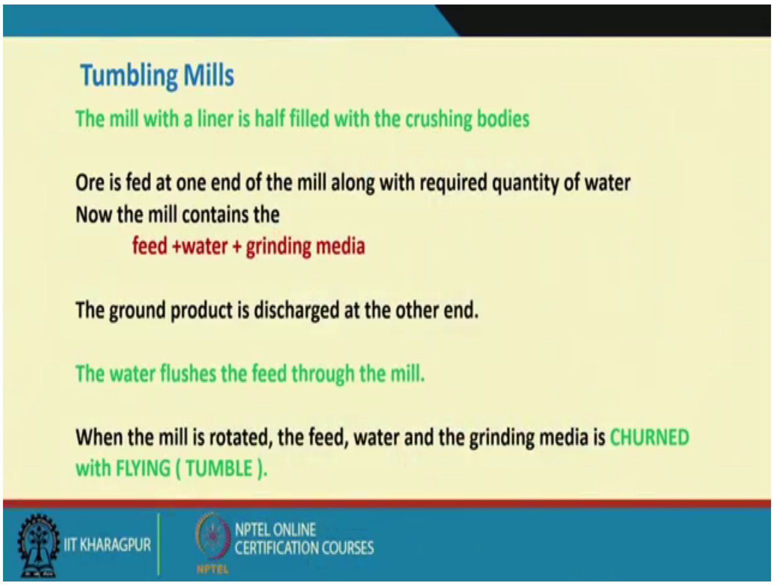

Then where this grinding ah say occurs what are the equipment we use we call them in general that is tumbling mills because they are rotating type of mills. And the mill with a liner because we use a liner that is your grinding surface inside the mill, it is just like you tube or as a tubular shape. And then we introduce my material we also introduced some grinding media and then we try to rotate it along with the water or it may be dry also and so that is called the liner. Why do you use liner now because that material is susceptible to wear, so while it is worn-out, we do not have to replace that entire mill, but we can replace the liner in state. So, the mill with the liner is half filled with the crushing bodies that is crushing bodies means that is the medium through which we are basically trying to grind.

Ore is fed at one end of the mill along with required quantity of water means mostly as I said in the previous class that the grinding is mostly done in wet conditions because of several advantages associated with this. So, what is the feed down now we have on the feed like we have got the feed material that is your ore plus water plus grinding media. Grinding media means is an artificially artificial media which we try to introduce which has to be much harder and much bigger than my particles to be broken, because those particles we try to break. I will show you in say next within the next few minutes there how the grinding occurs then you will try to understand it properly that what do I mean by grinding media.

So, the ground product is discharged at the other end. The water flushes the feed through the mill. So, the water helps in say in transporting my materials that is which are ground through the discharge end because material is coming through this, it has to go out through that. So, if it is totally dry material, so the material flow will be a problem, but when you are having water, and then you are trying to rotate it, and there is some inclination also of that mill.

Now, because of that that water is flowing and that because of the flow of water it will carried my particles also which helps in basically the throughput or say discharge of my mill product. When the mill is rotated, the feed water and the grinding media is churned with flying that is your tumble. So, everything gets tumbled.

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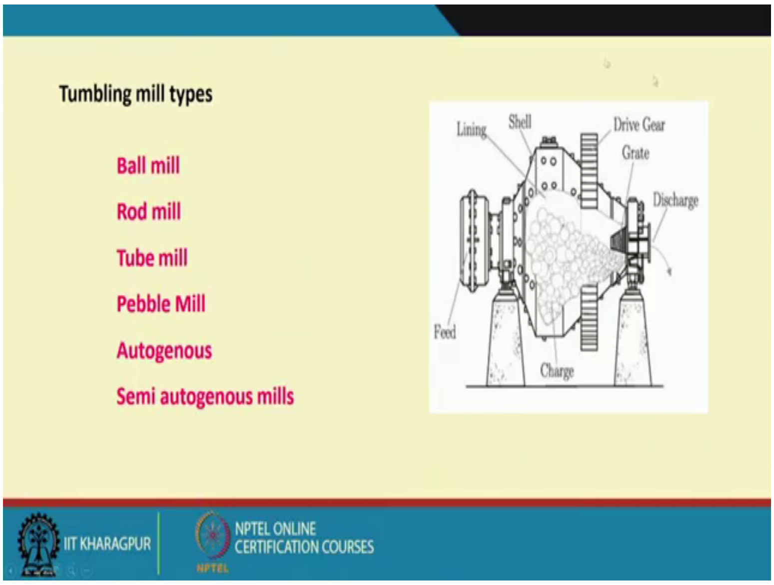

Now you see that this is one example of a mill. And you say this is called this is one of the tumbling mills. And here you see that it is not necessary that the mill has to be a cylindrical shape, you can have various types of shapes, and that based on that your different varieties of shapes and then depending on the nature of the grinding media you are using we give different names to these type of grinding mills.

So, here basically you see that this is the lining, and this is the shell, and this is the drive gear, this is a gear that is we are discharged that is your that is the discharge end and this is the feed end, and this is my material which are to be ground. So, this is called a charge. Charge means it is a mixture of my ore plus water plus your grinding media. So, the charge means so every entire thing is getting tumbled in this mill. Now, tumbling mill types depending on the as I said that the dimensions of the mill that is the geometry of the mill and based on the type of media you use we have so given different names to this grinding mills.

We have got ball mill, we have a rod mill, we have tube mill, we have got pebble mill, we have got autogenous grinding mill, we have got semi auto genous grinding mills. I will discuss some of the important mill types which is being used in the industry not all of them are very popular in the industry, so I will skip some of them, but I will discuss at length some of them in detail which are frequently used in the industry.

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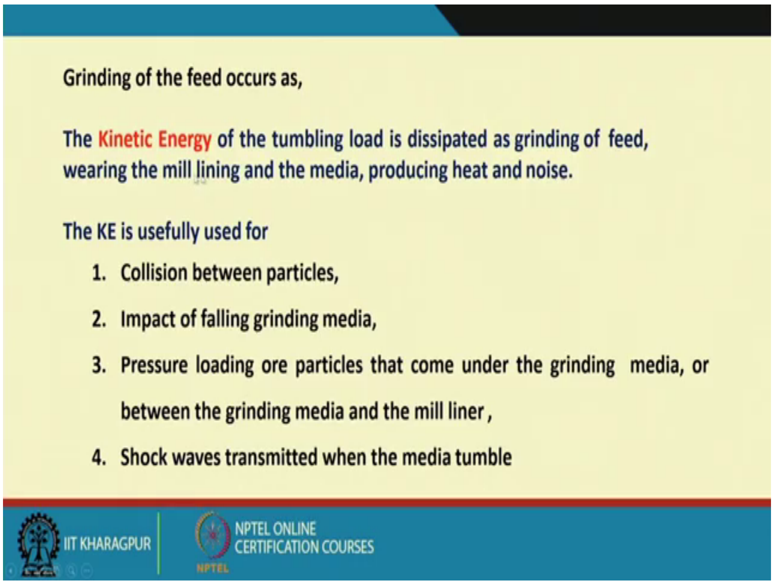

How the grinding occurs. So, grinding of the feed occurs as the kinetic energy of the tumbling load is dissipated as grinding of feed that means, when you are rotating the entire charge as I said that it is the mineral or it is the ore plus your water plus your grinding media. So, when the everything is tumbled, so what happens the kinetic energy is produced and then it also it not only grinds the feed material, it also wear the mill lining because of your impact because of abrasion and because of many other phenomena it may be corrosion also.

And the media also gets shown out producing heat and noise, so because of the churning action it also generates heat and noise. So, these are the basically how you are utilizing the kinetic energy or say whatever kinetic amount of kinetic energy were generating majority of them are being lost as you are in terms of heat and noise or the wear of mill lining and the media. And some part of that is being utilized for your grinding of heat material for which purpose it has been developed.

So, here the energy utilization is very less or conversely I can say the energy consumption per ton of material to be ground to a particular size is huge in this grinding mills. So, kinetic energy is usefully used for collision between particles. So, there will be a particle-particle collision impact of falling grinding media that is when your mill rotates. So, there will be a impact of the falling media on the particles, and then the pressure loading ore particles that come under the grinding media or between the grinding media and the mill liner. Shockwaves transmitted when the media tumble. So, there are many ways this kinetic energy is getting utilized, but effective utilization for the breakage is percentage utilization of that is very less.

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So, what are the grinding media we use, and why do you need grinding media. So, grinding media we need because when it is basically being rotated, so that grinding media also falls and if they are heavier than mine because as I said that they have to be bigger sizes than my material which I want to break. And then they are much higher density they are much harder material than my material what I want to grind.

So, when the material when the grinding media falls on top of the say particle because of the impact there will be breakage even when the entire charge is being rotated. So, there will be abrasion between the ball surfaces and liner surfaces, and in between the particles they will be having some shearing action, so that is the shearing. So, we have got impact, we have got shearing, and there are many other mechanism through which the grinding occurs.

So, what are the media grinding media we use we normally use steel balls or varying sizes from 25 to 125 millimeter dia that depends on the mean size, that depends on my product size or I want even that debates on what is the material I want to break. They are also made of had field manganese steel chromium steels, chromium molybdenum steels even there are some instances where we can use we also use tungsten carbide or ceramic balls. They are costly, but it has got long life because the wear is very less.

So, what is the problem with this though well in the material whenever we are using your steel that is it may be I had filled steel or chromium steel or chromium molybdenum steel, so they gave also get worn to wear out. So, it is not the replacement cost only, but this worn out material they also contaminate my ore material. So, what will happen in the downstream processes or maybe in the extraction processes, they create lot of problem. So, many a times when it is not wanted. So, although they are costly, but sometimes the tungsten carbide or ceramic balls are used, but because of their long life and because of less chances of contaminating your products.

Large pieces of ore are also used as grinding medium we call it autogenous grinding. So, what do you do know as a larger particle breaking the smaller particle to much more finer sizes so that means, when we have a wide size distribution like we have got say suppose 50 millimeter particle, and we have got also up to say 1 millimeter particle. So, if we try to rotate this, so the 50 millimeter particle may will when it hits the one millimeter particle, they will be broken further even the 50 millimeter particle because of repeated your rotation they may also be broken to very finest sizes. So, here we do not use any media artificial media, it is basically bigger particle hitting the smaller particle and then you are generating much more finer particles. So, when you use this we call it autogenous grinding.

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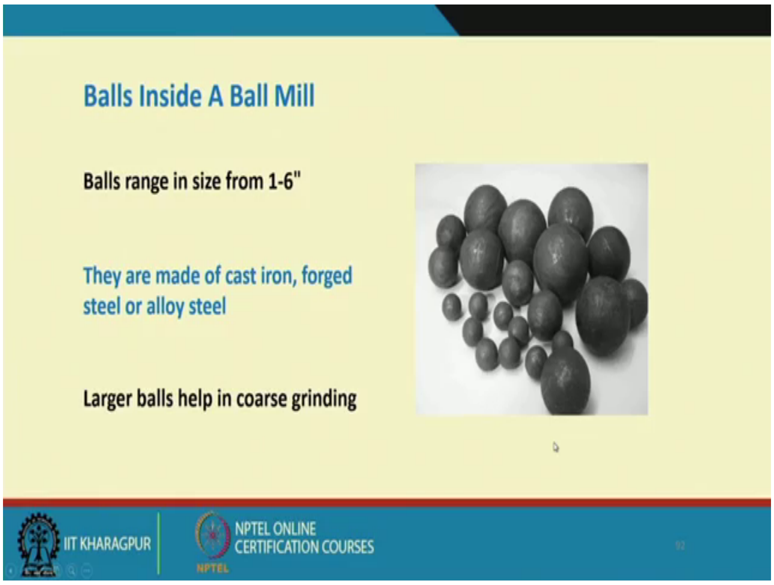

These are some of the say snap sorts of some of the your balls which are being utilized it used in a ball mill. And you see that there are various sizes. So, balls range in size from 1 to 6 inches they are made of cast iron may be many times, forged steel or alloy steel. And larger balls help in coarse grinding because what happens when you have larger balls, so the void spaces created in between the larger space and larger balls is much bigger than when you are utilizing a mixture of your smaller balls and the larger balls. Because what happens that now why do we have only larger balls, so we have got huge void spaces and the particles sit there and so they will not be ground further because it is they are sitting in the void spaces.

So, you end up ultimately generating relatively coarser product then when you have a mixture of saying smaller balls and bigger balls. So, when I want a finer product, I should use a mixed sizes of the balls because these smaller balls will again hit the particles which are sitting in between the void spaces of the bigger balls, and then it will generate much more finer products. Otherwise we use only so that is why we try to use a size distribution of the balls.

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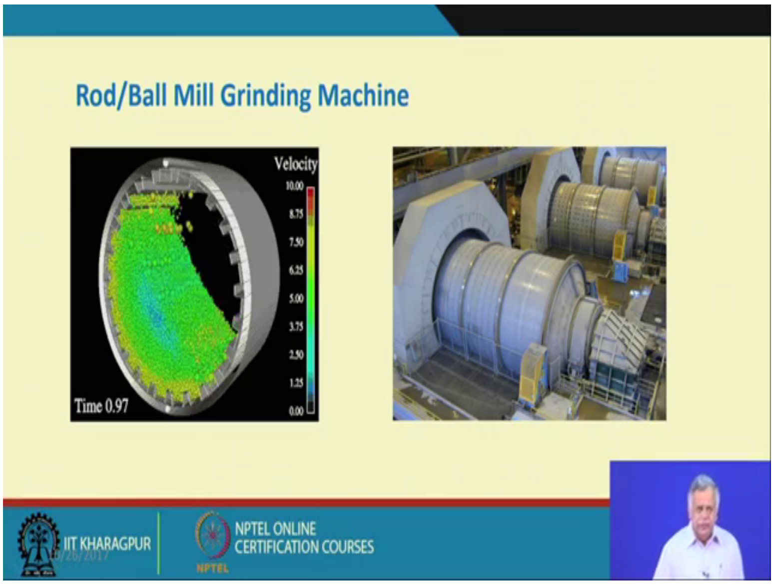

The series this is the animation which is showing how your mill it may be a rod mill, it may be a ball mill how the grinding occurs. So, this is basically your charge material sorry. So, when the charge material is basically rotated and then what will happen everything will falls back will fall back at a different your axis. So, what will happen is because of M b square by R.

So, you see that, so where the aim is more is basically for the grinding media balls that is a grinding media that means, mostly the steel balls they are having more of your masses. So, they will be hitting, they will be falling back at the last at the end of the entire cycle. So, the lighter particle that is mostly in this case that is your ore materials they will fall faster than the because they will be say rotated to a lesser distance than my steel balls. So, the materials may fall here and after that the ball will hit here. So, this is called the toe region. And then because of the impact the particles get broken.

Another way of breakage is when the material is being transported like this. So, what happens there will be a shear forces, there will be abrasion between the particle and particle, between the surface of the my grinding media and the particle and even there will be your say abrasion between your media surfaces and the particle surfaces. And some particle may be entrapped in between my grinding media surface and the your say the liner surfaces and then because of the abrasion there may be some so there will be particle breakage.

So, there are many ways and then we will discuss say later on that how it actually helps in breaking we will go to the mechanism. And these are some of the mills which are being used is a gigantic mills in industry. So, these days even the mill of a tumbling mill of 10,000 tons per hour they are also available and they have to be robustly built unless and until they are robustly built it cannot have or it cannot withstand the stresses. So, the material has to be strong enough and then to have the to ensure that the life of the mill is say very good; otherwise the replacement cost of these meals are very high.

So, here the problem main problem is that that is the challenge to the meander processing people is that how do I minimize the energy cost because it has been shown that around only 1 to 2 percent of the total energy input energy is being utilized for effective grinding. Remaining around 98 to 99 percent of that input energy is being lost in the form of your heat or maybe in the noise it may be in the wear of different materials and your shock waves like that. So, in the next lecture, we will continue this.

And till then thank you very much.