Introduction to Mineral Processing
Prof. Arun Kumar Majumder
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture – 23
Grinding

Hello welcome, to this week 5 of this lecture series. So, previous week we have discussed about the crushers where we try to break the particles from a roa more to a relatively coarser sizes, but many a times as because the liberation sizes of the ores they become finer and finer we need to break the particles too much more finer sizes, and the machines which you use for breaking the particles to a micrometer sizes. Normally, we call them grinding machines. So, this week we will try to discuss about this different grinding machines and some calculations related to that and where we should use what kind of grinding machines that also will form the part of this lectures.

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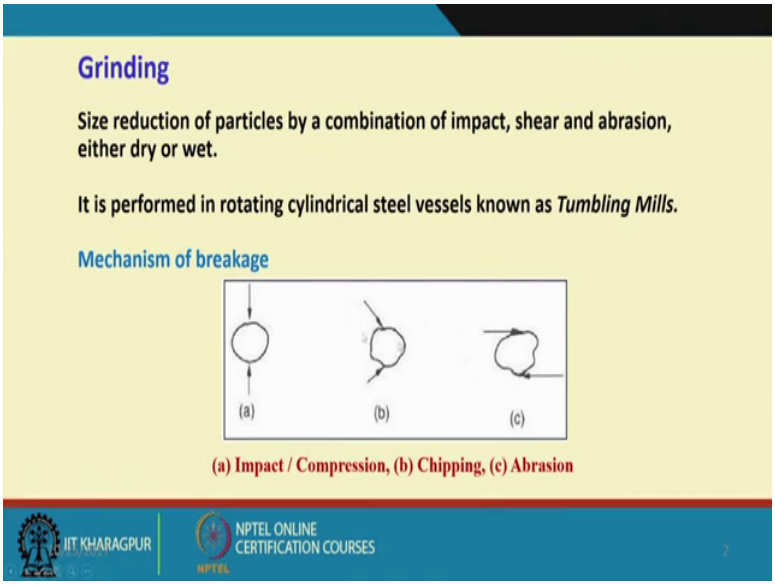

Now, if you look at Grinding, as you know that when the particles are a bit coarser sizes, it has got some inherent cracks and it consumes much lesser energy to be broken to a relatively finer sizes which is still in the coarser size ranges. In comparison to materials or the particles which we try to break it to in the micrometer sizes, because when we are trying to break it to very fine sizes we are going to the say the atomic very close to the your atomic stages or nearing to the atomic your configuration stages. So, you have hardly got any advantages of

the internal cracks because the internal cracks when you have these are the weaker zones and when you have a shearing action or maybe a compact forces or the compressive forces these zones through that your particle gets broken, but for a very finite sizes you do not have this advantages of having internal cracks.

So, the Grinding is the size reduction of particles by a combination of impact shear and abrasion either dry or wet, because you have to not a single mechanism or the single force can give you the your say particle breakage to the exchange you need for a grinding operation. So, what do we do we try to use a combination of impact forces, shearing actions and the abrasion either in dry condition or in wet condition where we use dry grinding where we use wet grinding that we will also discuss. How do we do that? How do we impart impact shear and abrasion all 3 in one go? So, it is generally performed in rotating cylindrical steel vessels in general terminology we call them tumbling mills; that means, we try to rotate the particles into a tumbling mills.

So, if you look at the mechanism of breakage that is by impact this is basically chipping or the shear forces and then we have got the abrasion.

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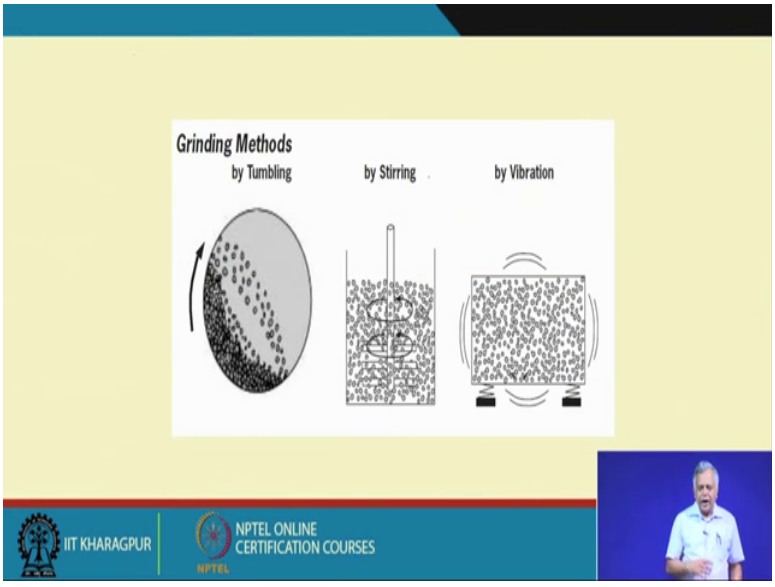

So, in a grinding methods even in the tumbling mills the particle breakage these are by tumbling mills that is normally conventionally we go for the grinding operation in mineral processing plants by through tumbling mills will discuss more about that, but in other applications like when we need very finer particles sizes, like 4 nano material nano particle

generations there are other mechanism that is by steering by stirring that is, you have got the made of particles and you have got errors made our very hard surfaces and you try to rotate that star and then there is a basically your impact of the particles between the wall of that you are stirring chamber and the you are there will be a friction between the stirring your start material surface and the particles and there will be particle collisions and because of that you get a grinding. Even we are using the vibration also these days for particle size reductions, but these 2 are hardly used in metal processing operation because mineral processing operation essentially requires large scale of material to be broken at per unit time. So, this discussion we will mostly focus on the tumbling mills.

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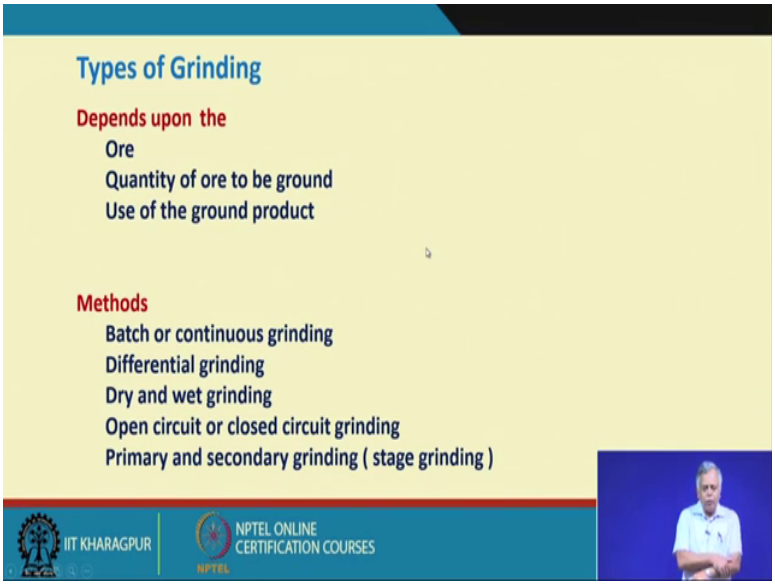

Now what are the types of grinding? Whether we will use a white grinding, whether we use a dry grinding, whether it is a batch grinding, whether it is a continuous grinding, or whether we need a differential grinding, that is differential grinding means we want to grind a particular material into an agglomerate of materials that is you have got a hard material you have got a soft material and you want to preferentially grind only the softer materials. So, depending on the nature of that so there are various types of grinding and it depends on the ore that is what is your material characteristics. Then quantity of ore to be ground how much of material you want to grind per unit time and then what is the use of the ground product? Why it is important?

Now, what is the use of the ground product means says like say suppose cement industry. So, we try to break the your clinkers we want to grind the clinkers to make the cement. So, we cannot use a weight process because the cement essentially is having a or mass binding property. So, if we add water into that during the manufacturing of the cement. They in the it will not be a free-flowing material and then during the application of cement it will not have it is effect for what it was meant for. So, that application is very important many times you want to use the ground product for leaching. That is your by you want to add some chemicals and you want to extract your valuable minerals.

So, the leaching operation is essentially a wet process because you will be using some kind of your dilute acid. So, if I already have a wet product. So, I do not have to worry about the mixing because that wet product is it is already mixed my particle surfaces are already wet. So, it helps in the in accelerating the process of leaching. So, this is what I try to mean that use of the ground product that is where I will use dry guiding, where I will use wet grinding and the methods as I said that it could be batch grinding or it may be a continuous grinding. It could be a differential grinding it could be a dry grinding or wet grinding. Then what should be the circuit of these grinding operations again similar to your crossing operation it can be a open circuit or closed circuit grinding operation.

Open circuit and closed circuit grinding the distinct difference is that you are having some kind of your size control parameter device and is you can have screens or you can have other type of or other group of equipment which helps in separating a particular material based on their differences in the sizes.

So, when it is placed into the circuit for negotiating for interrogating that whether the product is already finer than what I require. Then and then I will say that that will be my final product. So, it is not recycled back and the material if it is not broken, below that sizes then it will be recycled back to the grinding mill and what it is being done that is called the closed circuit grinding operation and open circuit means I do not want to control that because I am very sure that my discharge sizes will be acceptable by my downstream processes or by my clients.

Then it can be also stage grinding like your crusher. So, that we have done it that is your primary crusher secondary crusher tertiary crushes here also we can have primary grinding and secondary grinding that is we can have that your grinding operation in stages. So, that I

minimize the generation of your ultrafine particles that may ultrafine means my liberation size is 40 micrometer size and I do not want much of the particles to be finer than below 10 micrometers, because that will induce. So, that will induce more problems in my successive operations.

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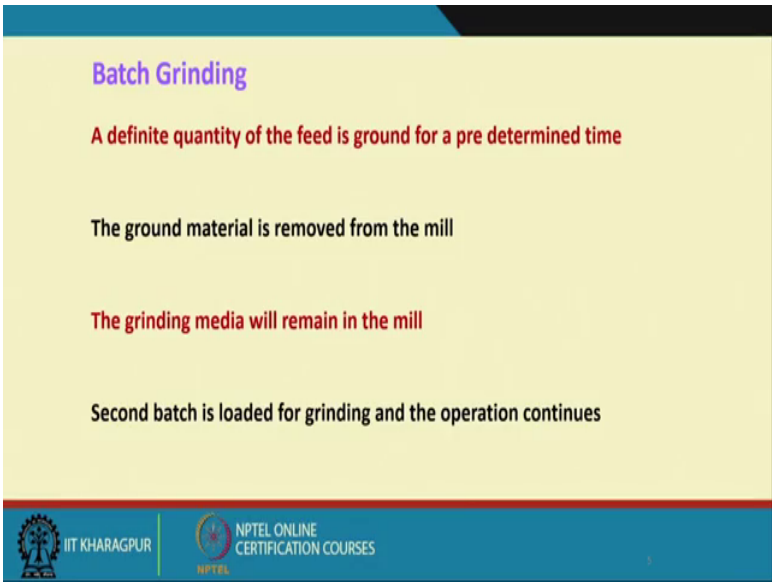

So, batch grinding what is batch grinding now a definite quantity of the feed is ground for a predetermined time; that means, you have a tumbling mill and you are having say suppose one kilogram of material you are pouring in you are putting in into that machine into that tumbling mill and you just operate it for a predetermined time of say suppose 30 minutes. So, then you are just taking out the material and the ground material is removed from the mill and the grinding media will remain in the mill, how we can take it out that is you can put it into a seep and you can take it out and the balls you can return it back to the grinding media you can return it back to the mill.

Second batch is loaded for grinding and the operation continues; that means, you have first ground one kilogram of material for a predetermined time and then you are taking it out and then again you pour one kilogram of material and like that you keep on doing it in batches. So, that is called the batch grinding.

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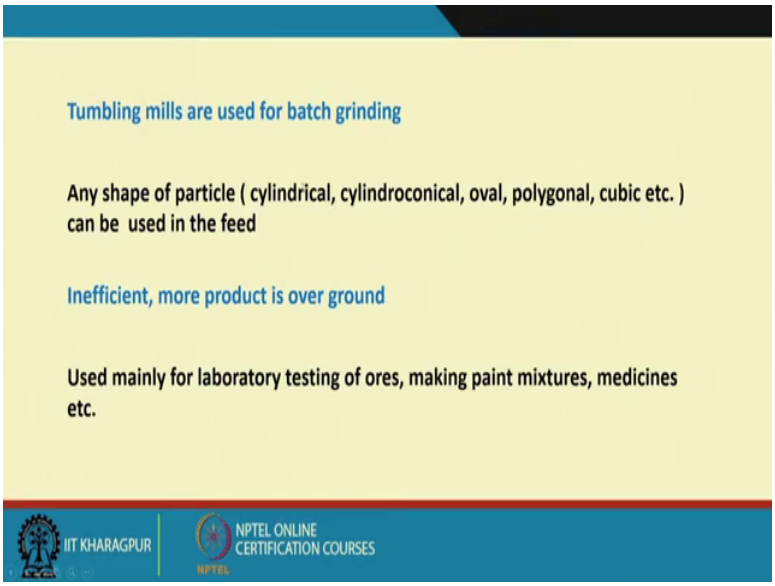

and tumbling mills are used for batch grinding any shape of particles. Whether it is cylindrical, cylinder, conical, oval, polygonal, cubic etcetera can be used in the feed that is you do not have to control the shape of the particle a very inefficient more product is over ground because you have already pre-fixed the time. So, in 30 minutes maybe you have an assemblage of a soft and hard material and the softer material may be over ground, because you have a pre-fixed time because that finer softer material may require only 10 minutes to be ground from a feed particle size to a your desired product size.

Where we use the batch, grinding is used mainly for laboratory testing of ores and sometimes in industrial applications like your making paint mixtures, medicines etcetera where you use your batch grinding processes where the capacity is not a great issue because you need to process a very minimal quantity of material per unit time, but they are hardly used in actual mineral processing operations because the mineral processing operation has to be large operations.

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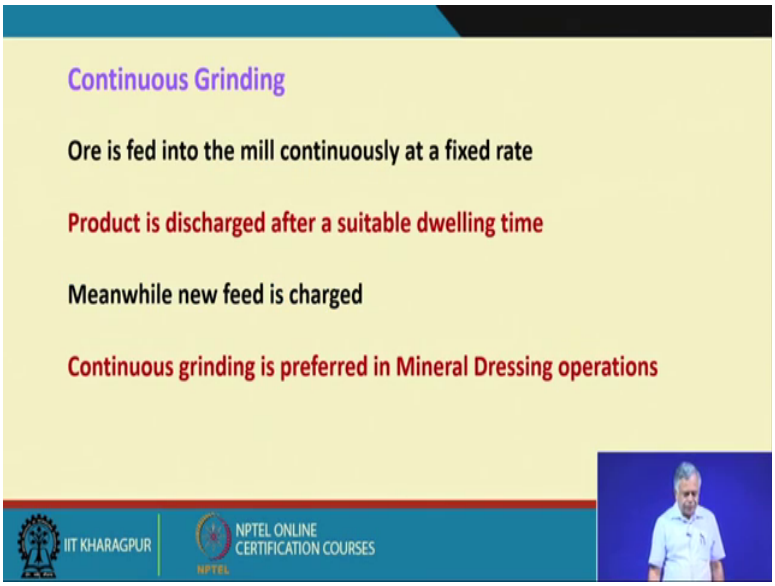

Continuous grinding ore is fed into the mill means is the tumbling mill continuously at a fixed rate so; that means, you have got a mill and it is continuously fed at a particular feed rate and it is getting discharged also at a particular rate.

So, you can calculate what is the detention time that is what is the volume of that mill and at what rate it is being fed at, what rate it is being discharged based on mass balancing we can get to know that what is the residence time of the material inside the mill. So, product is discharged after a suitable dwelling time that is by controlling the feed rate and the discharge rate you can control that what is the retention time of the material in the middle and the more harder the material you need more retention time. So, and depending upon the ore characteristics that you can decide that what is my dwelling time or the retention time required.

Now, meanwhile new feed is charged that is you can mostly you can have this continuous operation in a closed-circuit operation. So, what will happen there will be some recycled material which is being fed into the mill which is still not finer than what than your desired size. So, you have got a your recycled feed and you have got a new feed to compensate with your feed flow rate what do you what it is designed for, continuous grinding is preferred in mineral dressing operations because as I kept on saying that essentially my mill has to cope up with the your the capacity of the entire way or mineral processing operation.

So, it has to be in a continuous mode otherwise in a batch grinding operation the capacity will be very big issue.

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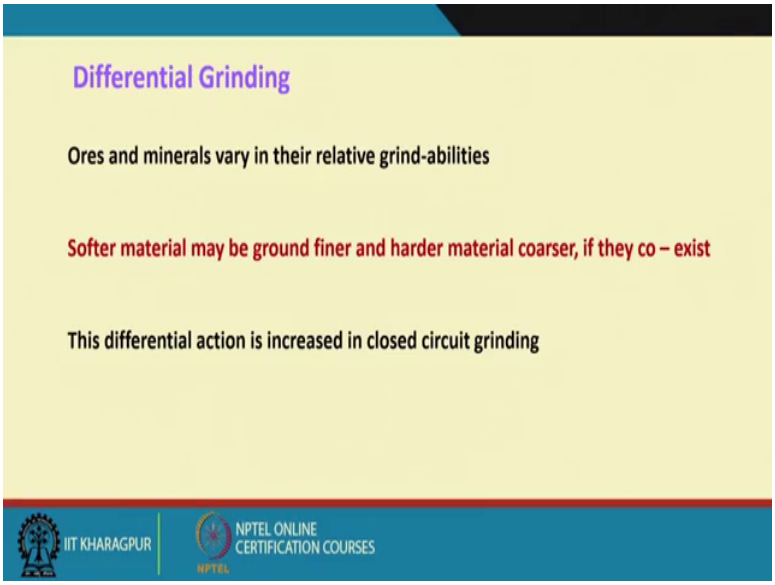

Differential grinding and is ores and minerals vary in their relative grind abilities like as I said that you can have a very hard material you can have a very soft material a combination of that like a typical example suppose for example, you want to grind coal. So, coal you have got a softer part that is the coldest part which is relatively softer than your mineral rich part that is coal is basically a combination of organic materials and your inorganic compounds. So, they are basically we call it shell and this shell part is basically much harder because they are essentially silicate materials.

So, you will have a differential or preferential grinding of the coldest part. So, like that there are many mineral processing many minerals which have your basically the different grind abilities and you want to grind a part regular type of material which is soft a relative to others and there we use these differential grinding or preferential grinding operations. Softer materials may be ground finer and harder materials coarser if they coexist this differential action is increased in closed circuit grinding operations.

Now, in closed circuit grinding what will happen? Now the particles which are softer they will be already finer than what you desired. So, they are going out of the system and you are recycling back only the relatively harder materials. So, after a certain point of time the your grinding mill may be overcrowded by the relatively harder materials and your recycled

recirculating load will keep on increasing. So, your new feed per unit time the at what rate you will be feeding that has to be controlled because of the over or because of the accumulation of these relatively harder materials.

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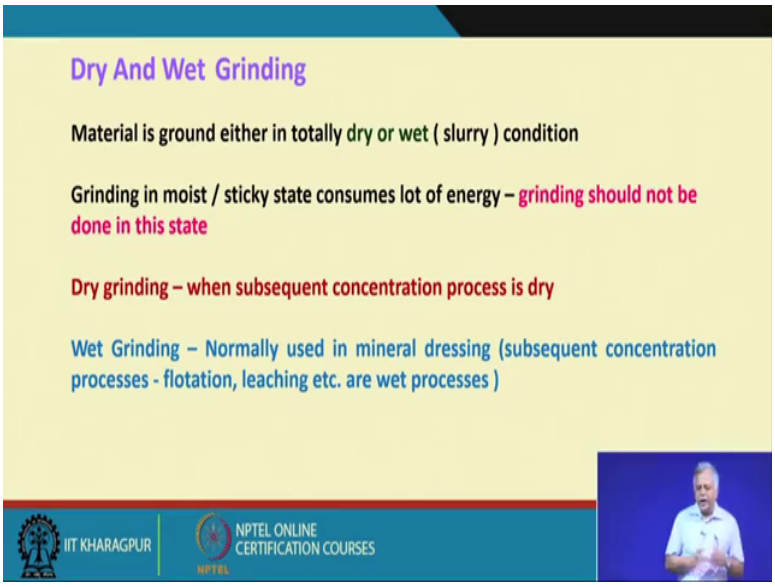

Where should I use dry grinding? Where should I use wet grinding? Or what are the advantages and disadvantages associated with the dry and wet grinding?

There is a very important decision you have to make. Now normally material can be ground either in totally dry or in wet conditions; wet means as a slurry condition; that means, you mix water also with that now why should we use water in some cases that is grinding in moist sticky state consumes lot of energy; that means, when the when you have clay material and you also have your moisture into that. So, what will happen the material will essentially become sticky. So, it is not free flowing material. So, remember it that even inside the middle the material has to flow material has to travel through that your mill, otherwise it will not pass through that your discharge end. So, when the material is not free flowing. So, if they are sticky. So, it will have problem in the free-flowing condition.

So, in this case if the if it is a moisture and if it is sticky state, then it consumes lot of energy because the residence time of the particle will be increasing as the materials are sticky and they are flow rate within the mill inside the mill is less. So, it will consume lot of energy grinding should not be done in this state. So, when you have a sticky material or moisture contained high moisture contained in the material there may be you can either you dry it

before grinding if it is essential that you have to go for dry grinding or you may have to add more moisture into that more water into that so that they are that water helps in free flowing of that material inside the mill.

Dry grinding when subsequent concentration processes dry I have already given the example of cement processing. Wet grinding normally used in mineral dressing because subsequent concentration processes mostly are water-based processes these processes are like flotation gravity concentration method leaching these are all weight processes. So, there is no problem if I am using a or what are a wet grinding method. And as I said that weight grinding also helps in having your proper w8ing of the mineral surfaces there are other advantages also.

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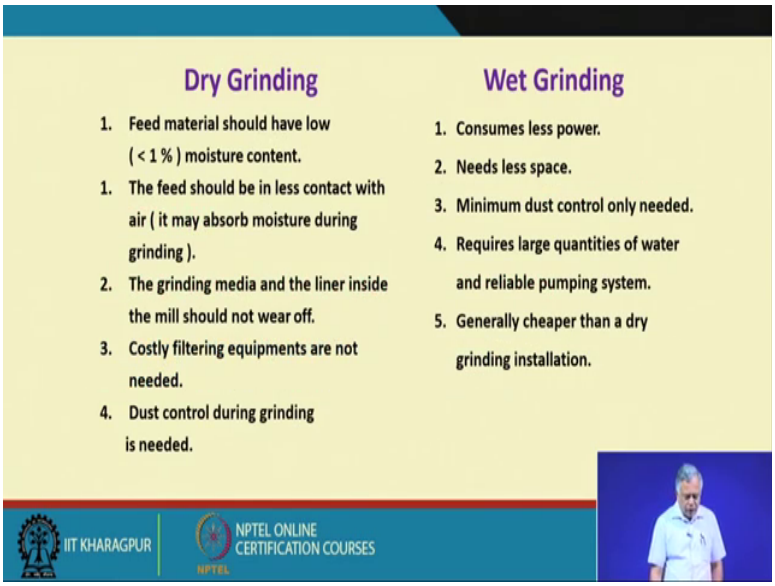

We will discuss it through these comparative statements, like the dry grinding versus wet grinding. The dry grinding is normally your done when the feed material should have low moisture content that is less than one percent.

So, we will adapt dry grinding if it is essential for my end user it should have low moisture content less than one percent. Now suppose I have to grind the limestone for or maybe some other material also suppose limestone for cement making processes, and it has got moisture so what I have to do? I have to take out this moist drying method or say drying technique. And so, that the moisture contained is very less otherwise it will consume lot of energy in grinding processes. Then the feed should be in less contact with air it may absorb moisture during grinding, because ever is because normally in air we have got the moisture contained

we call it humidity. So, if it is exposed to the material is exposed to the relative here humid atmosphere then the materials because they are already finite in sizes it will consume more or it will absorb more moisture from the atmosphere and it will consume more energy during the grinding operations.

The grinding media because we need some kind of media, when we discuss about the tumbling mill details you will understand this, but we need some kind of your grinding media to break the my materials to or my ores to a very finest sizes. So, the grinding media and the liner inside the mill should not wear up; that means, my grinding surfaces and the grinding media they should not be the owner out. So, where it can happen? Now in the dry grinding process if my material what we are trying to grind if they are basically very abrasive in nature.

Then there will be lot of we're into the my grinding media surface and my liner surface that is why grinding your surfaces of the mill. The advantages associated whether dry grinding is that you do not require filtering equipments, and not needed because in when we are using the water as a grinding medium, then I have to recycle back this water also in many cases. So, I have to have a filtering operation at the end of either the grinding operation or maybe your subsequent wet processing operation like your flotation or maybe leaching operation to make my product dry as well as sometimes to recover the water from the circuit.

So, it does not require the filtering equipment because it is already dry grinding operation, but when it is dry condition dry grinding it requires dust control during grinding is needed otherwise, as because you are generating very finer many fine sizes. So, you will have airborne particles and your threads or your colleagues in the environment may object to that and you have no right to pollute your atmosphere because of your operation. So, you should have adequate dust control devices to capture those materials preventing them from becoming airborne. Wet grinding if we look at it consumes less power. Why? Why it consumes less power in comparison to dry grinding? Because the losses as we said that if you remember the winds your research that he said that the during the particle breakage a good amount of energy is being lost in terms of heat.

So, when we use the wet condition these it provides the generation of heat and this is one of the reasons that why it consumes less power and then the materials are free flowing. So, and they are dispersed also within the mill and when they are dry many times they may start

getting agglomerating because of the new surface is created and you have to again break this agglomerate unnecessarily. So, this is the reason that why wet grinding normally consumes less power in comparison to dry grinding it needs less space also because you do not need any dust control devices and all this and minimum dust control only needed requires large quantities of water a reliable pumping system.

However, the wet grinding processes it consumes large quantity of water and because you have to feed the mixture of your water and your particles in the form of slurry. So, you need the reliable pumping system like your slutty pumping system. So, that is also an additional cost for your operation. Wet grinding is generally cheaper than a dry grinding installation because the energy losses are less in relation to your dry grinding operations, and as I have already explained that why energy losses are less in comparison to dry grinding processes. That is why the wet grinding is generally found to be cheaper than a dry grinding installation.

So, if we summarize it that you are the grinding machines it can be your tumbling mills, it can be stirring mill, it can be through vibration, but most limited processing operation we use the tumbling mill types. The what kind of machine we will use that is dictated by your ore characteristics, your how much of quantity of material you want to process per unit time and your say requirement for your say end uses.

And then whether we use dry grinding or wet grinding that is your we have discussed that what are the your advantages and disadvantages associated with a dry and wet grinding, but normally in mineral processing operations we prefer we go forward grinding because the downstream processes are mostly with wet processes, exceptions are like your cement industry and some other industry where we need dry products then your say wet products. Even grinding is used in other industries like your pharmaceutical industries where we use normally the dry grinding processes. So, we will carry on this topic for the next few lectures. So, till then.

Thank you very much.