Introduction to Mineral Processing
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Lecture – 22
Crushers (Contd.)

Hello welcome. So, in the previous class we are discussing about the roll crusher. So, let us continue a bit on that and I promised you that I will show you that how to calculate the particles which it can accept as a feed material.

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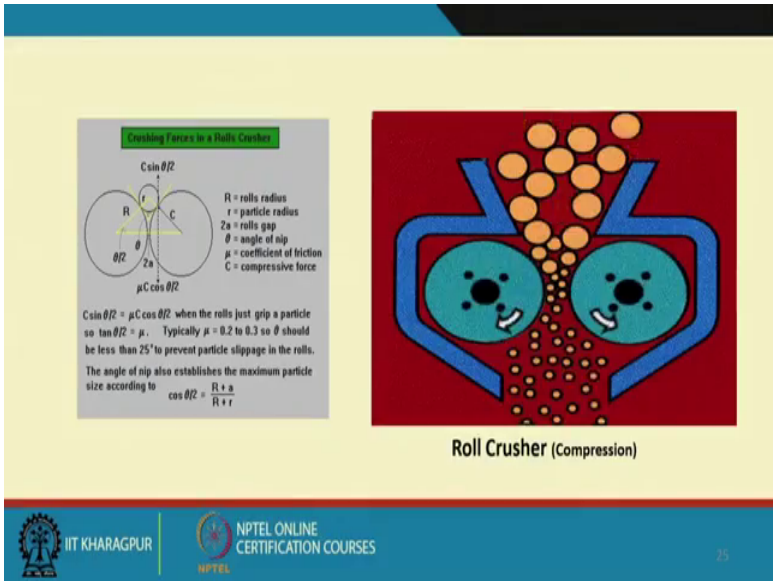

Now if I look at here suppose if I have 2 rolls now and a roll diameter is designated as capital R as suppose the particle we assume that that is a spherical particle and that particle radius is represented as a small r and this angle.

That is called your angle of neap that is whatever angle between these 2 roll surfaces and the material that is being created that is called the theta, and that is called the angle of neap that is very important to know and 2 a; a suppose as a rolls gap; that means, the gap between the 2 rolls it may not be visible, but that is the gap between the 2 rolls that is your gap between the 2 rolls here that is equal to 2 a and this is the angle of neap that is what is the angle here. So, that is designated here as the angle of neap that is called the theta. And you should also have the mu that is the coefficient of friction between the

material and the roll surfaces, and say suppose capital C is the compressive force acting in this direction because when the material is falling this.

So, the compressive force will act in this direction. So, what will happen? If I do a four simple force balance at this point that how much is the; what is the force balances here. So, we can write that C sin theta by 2 that is the force acting in the normal direction is balanced by the mu that is the coefficient of friction between the particle and the roll surface C that is the your compressive force cos theta by 2, because if I do a little bit of geometry vehicle calculations. So, if this angle is theta. So, this your small angle which is created here that has to be theta by 2 by simple geometric relations if we can get it. So, that is C sin theta by 2 is balanced by mu C cos theta by 2.

When the rolls just grip a particle. So, when the material when the rolls just grip a particle here; that means, if I have 2 rolls moving like this, you will find that if you drop a particle sometimes the particle may not be gripped. So, they will pass if it is very fine a little bit bigger they may be jumped out from that your surfaces between the 2 rolls and a particulars within a particular size range the material will be gripped. So, when the material is just gripped. So, that a C sin theta by 2 is equal to mu C cos theta by 2. So, we can write tan theta that is sin theta by 2 by cos theta by 2 is equal to mu. So, that is mu is equal to tan theta by 2 that is your coefficient of friction is equal to tan of theta by 2 where theta is the angle of knee.

So, typically this mu value is 0.2 to 0.3. So, the theta should be less than twenty five degree; that means, at what angle it should be. So, that we can get it because we have seen that the mu value varies from 0.2 to 0.3 and if we take it like that. So, theta should be less than 25 degree because if your mu has to be 0.2 to 0.3 to prevent particle slippage in the rolls so; that means, the particle will not sleep it will griped if your angle that is your angle of neap is less than 25 degree the angle of neap also establishes the maximum particle size that is what is the maximum particle size it can accept that is if I know the angle of neap that is cos theta by 2.

What I can write that is cos theta by 2 is equal to R plus a; that is your capital R, capital R plus a because this this gap is 2 a. So, half of this s a and divide by this. So, that is your R that is also R plus your small r. So, from this relationship we can also find out that what should be the value of small r, because if we know the distance between the 2 rolls

if we know the angle of neap and if we know the roll diameter we can calculate what is that your size maximum particle size that can be your say gripped by these roll crusher. So, what is that maximum particle size it can be processed conversely?

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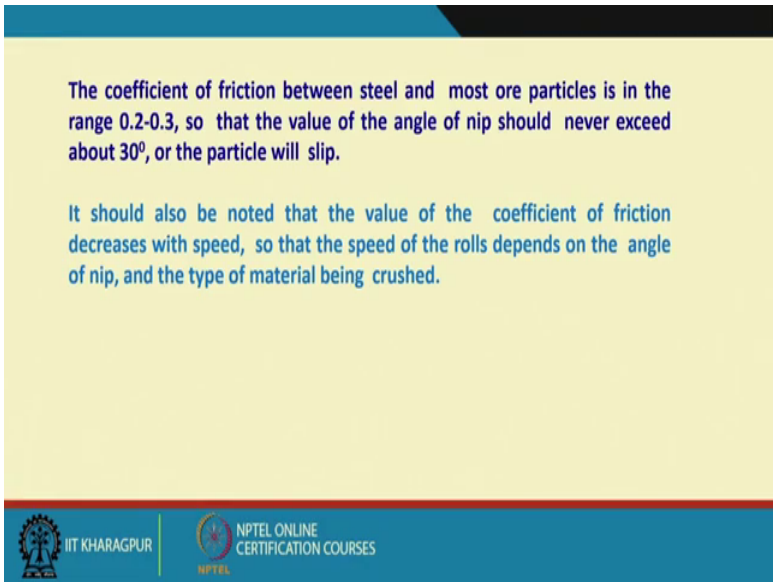

We can say the coefficient of friction between steel and most ore particles is in the range of 0.2 to 0.3. So, that the value of the angle of nip should never exceed 30 degree because it varies from 25 to 30 degree depending upon the; what is the value of mu or the particle will slip. It should also be noted that the value of the coefficient of friction decreases with speed so; that means, we should also consider the dynamic coefficient of friction. So, that the speed of the rolls depends on the angle of nip and the type of material being crushed anyway you do not have to go into that depth.

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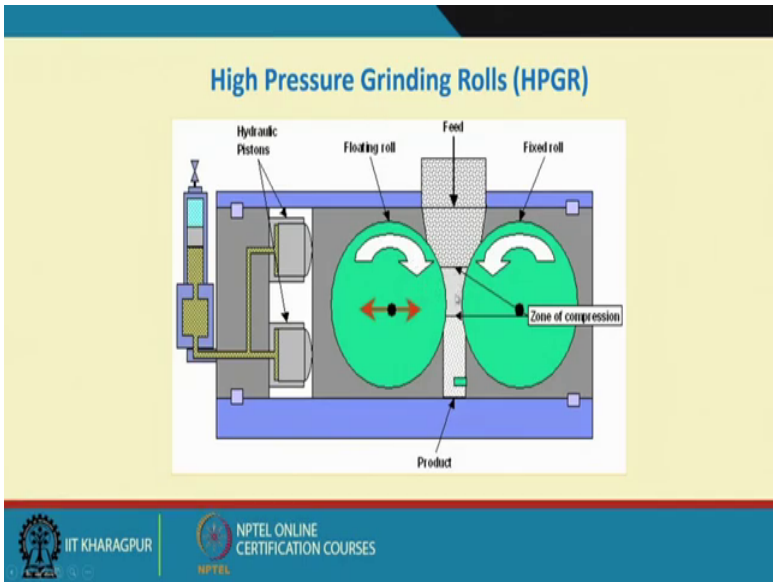

Now, this is another crusher which is relatively new and which is going to revolutionize these combination processes, it has already find it has already been found wide acceptance in many industries this is called a high pressure grinding roll.

This was developed by Professor Schoenert and there is a relatively new machine which has come to the market. So, what is this high pressure grinding roll doing? It is a simulate to a roll crusher, but what is happening here that this is a fixed roll and you have a floating roll, and what you are doing that you have got a hydraulic system, which is basically through which you have got a piston a hydraulic piston hydraulically driven piston, which basically the forces the material which has fed here to get compressed at the. So, what is happening the feed is coming like this.

So, you have got a fix roll. So, the material is trying to pass through that, but this floating roll says suppose I want to break a material from 500 millimeter to 10 millimeter, and if I know that how much of crushing force is required, based on that I can calculate that how much of your compressive force I have to induce through this pressure and we can calculate that your pressure energy and we can impart that much of pressure energy to those particles to break it to exactly what we want, but it may not be that precise always because the particle characteristics they vary from each other. So, this is where what is the advantage of that, that basically you can withdraw you may not require some of the secondary crushing stages.

So, you can have a primary crusher product and you can even grind it to a very finer sizes by this type of mechanism in one go. So, it can reduce the number of stages, what in conventional mineral processing plants you have in the communication section by having this high pressure.

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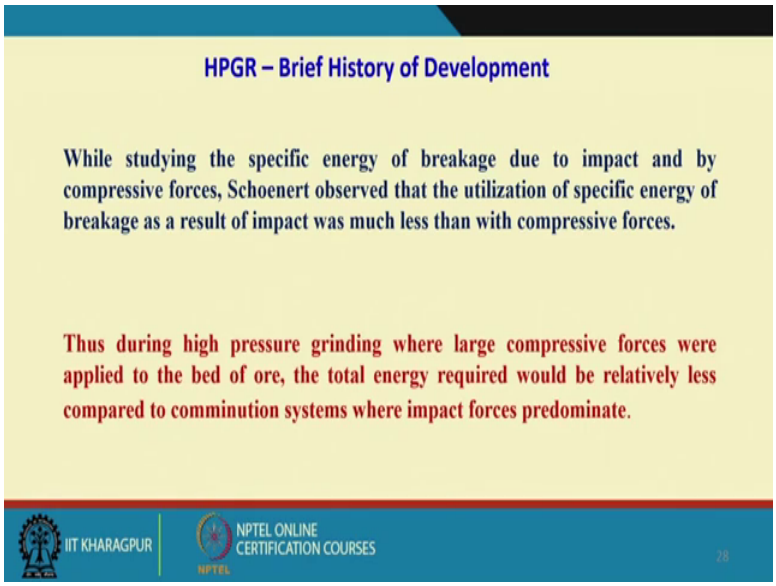

Grinding rolls. So, let me discuss some of the because it is a new one and you will be working in your some modern plants. So, maybe you have to work with this HPGR, we call it in short form HPGR high pressure grinding roll. So, if we look at the brief history of development that Professor Schoenert while studying the specific energy of breakage due to impact and by compressive forces and as he was comparing.

That how much of specific energy is required when we break it or say it is utilized for effective breakage when we use a impact crusher and or say impact force or and by a compressive force. So, Professor Schoenert observed that the utilization of specific energy of breakage as a result of impact was much less than with compressive forces. So, there is a very big observation that if I use that your specific energy a breakage, which is being utilized by the material for having a desired fragmentation and the machine I used which uses impact force and another group of machine I have selected which uses compressive forces.

So, it has been observed that the energy utilization for effective breakage while using the impact forces was much less than with the compressive forces. And that has given in the

idea that is how we can use the compressive forces much more effectively. So, during high pressure grinding who had large compressive forces because he was squeezing it were applied to the bed of ore. The total energy required would be relatively less compared to combination systems where impact forces predominate and that observation has prompted him to design a machine, where you will be using a large compressive force.

To be applied to a bed of particles so that the total energy required would be relatively less compared to combination systems, where impact forces predominate because you have seen that most of the crushes they use the impact forces.

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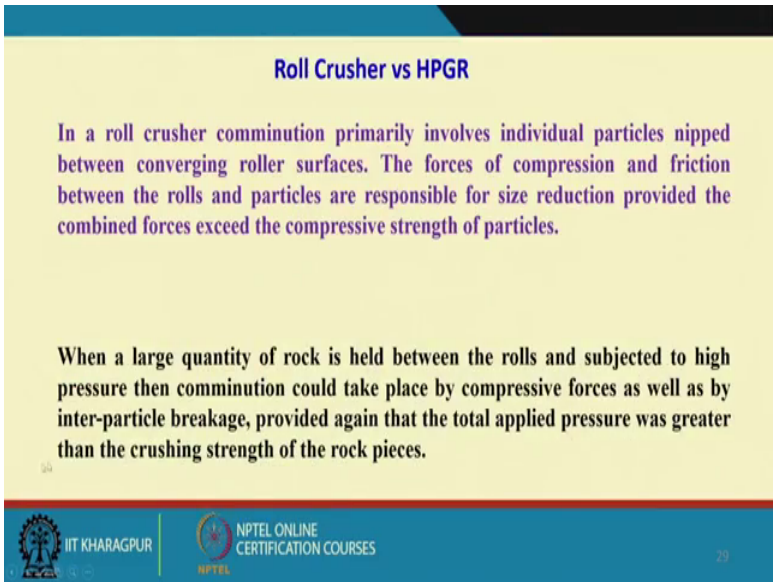

If we make a comparison between roll crusher and a HPGR, because it looks similar because you have got 2 rolls even the single roll crusher, you have got a fixed roll and you may have a single roll only and you have a fixed surface you may be breaking it. So, if I look at them if we compare the roll crusher and the HPGR, we can say that in a roll crusher combination primarily involves individual particles nipped between converging rollers surfaces.

Because you have only one point of contact, it is basically you are it involves the individual particles nipped between the converging roller surfaces. The forces of compression and friction between the rolls and particles are responsible for size reduction provided the combined forces exceed the compressive strength of particles,

because the when the particles has to be broken your external forces should be more than the compressive strength of the particles otherwise it will not break. Now when a large quantity of rock is held between the rolls and subjected to a high pressure. Then combination could take place by compressive process as well as by inter particle breakage.

Because what will happen now when you are putting a pressure energy, you have not only created a you have induced some internal breakage or internal cracks, but that pressure energy travels through that those cracks and it may keep on creating more cracks. So, provided again that the total applied pressure was greater than the crushing strength of the rock pieces. So, there is a fundamental difference between this 2, that what a large quantity of rock is held between the rolls that is what we are doing it into HPGR, has subjected to high pressure then combination could take place by compressive process as well as by inter particle breakage now what are the applications of HPGR or what are the advantages associated with HPGR.

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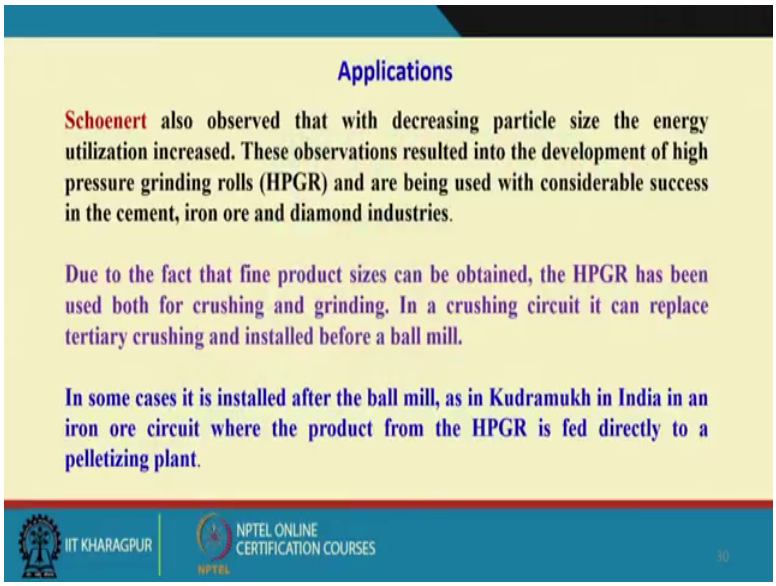

So, professor Sonnet also observed that with the decreasing particle size the energy utilization increased; that means, in relation to other breakage devices. These observations resulted into the development of high pressure grinding roles and are being used with considerable success in the cement iron ore and diamond industries, but HPGR is being researched for much more wider applications for different minerals. There is a

burning topic for the combination engineers or the combination scientists due to the fact that fine products sizes can be obtained the HPGR has been used both for crushing and grinding; that means, in a single stage you can do both the job.

That is your crushing and grinding that is for coarser size breakage and the finest size breakage because you can squeeze it further unless and until it breaks down to a bellows your say finer sizes than you desire. So, it is in your hand and you can control it that how much of pressure you will be inducing depending upon the ore characteristics in a crossing circuit it can be replaced tertiary crushing and installed before a ball mill; that means, it has been shown that it can replace the tertiary crushing and it can be installed before a ball mill where you need very find grinding even you can replace some of the your secondary crushers also depending on the ore characteristics. In some cases it is installed after the ball mill as in Kuduremukh in India in an iron ore circuit.

Where the product from the HPGR is fed directly to a pelletizing plant, because in a I do not know industry many times when you have a palletizing plant the ore has to be ground below 63 micrometer. But the ball mills are basically designed for we are breaking the materials to have below 150 micrometer sizes. So, HPGR can also be used for fine size grinding which has been observed in kudhuremukh.

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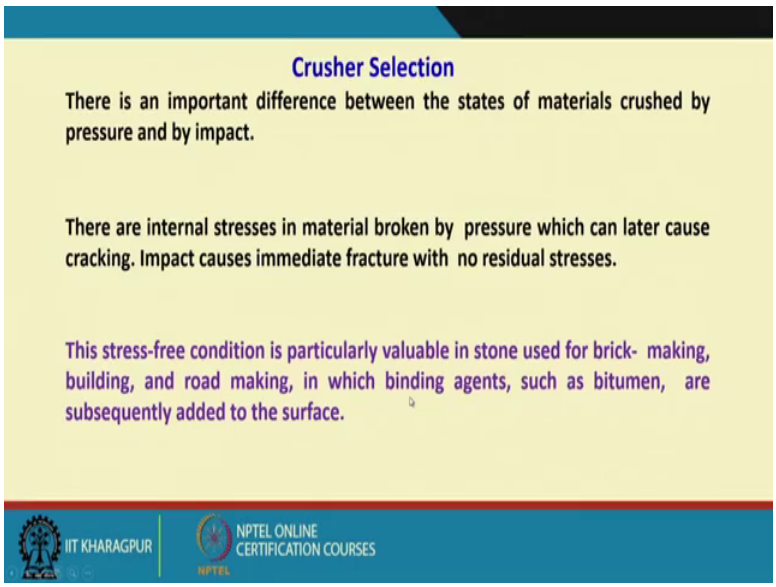

Now, question is we have discussed about the various types of crushes like primary crushers and various types of secondary crushers, tertiary crushers, HPGR now in

primary classes also you have got different variations, in secondary crashes also you can have different variations, we have only discussed about some of the important crushers, but there are many more other varieties of crushes available.

Now, question comes that; how do I select my crusher for a given application. So, if I look at it, it we start with this fundamental say you know say your differences between the crushing. So, if we look at that there is an important difference by doing the states of materials crushed by pressure, and by impact and is in HPGR we try to break the particles by pressure energy, and in other crusher mostly we try to break the particles by impact forces. So, what will happen in a pressure, when we are trying to break the particles based on pressure energy? So, as you already said let me repeat that there are internal stresses in material, broken by pressure which can later cause cracking that means the pressure when you are applying the internal stresses, they are not immediately released.

So, they are still there and it may lead to further breakage of the material, but impact causes immediate fracture with no residual stresses so; that means, the effective utilization of pressure energy is fundamentally as more it appears to be more effective than the impact forces. So, this now is it always required probably not. Now when we where we will use, when we use the impact crushers that is when we need a stress precondition that the materials are not material surfaces are stress free. So, this stress free condition is particularly valuable in stone crushing used for brick making, building purposes.

Road making in which binding agents such as bitumen are subsequently added to the surface why. Now if I use a pressure energy for by your stone crushing. So, what will happen there will be residual stresses, and the particles may have internal cracks. So, what will happen? The material will be weaker and when we use bitumen, it will consume more bitumen unnecessary because that bitumen will get penetrate into the get penetrated into the internal cracks or internal voids within the materials. So, it will the consumption of bitumen will increase and the material will essentially be weaker.

So, that is why we should have a impact crusher for stone quarries, same thing with the brick making processes because it will consume more water even for building purposes material will be weaker.

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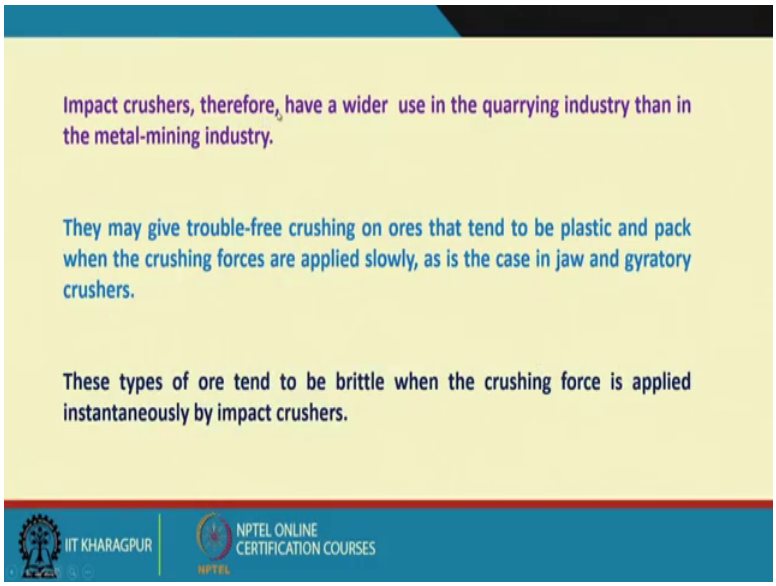

Impact crushes therefore, have a wider use in the querying industry than in the metal mining industry. They may give travel free crossing on ores that tend to be plastic and back when the crushing forces are applied slowly, as is the case in jaw and gyratory crushers, we have already discussed this point before. So, these types of ore tend to be brittle when the crushing force is applied instantaneously by impact crushers; that means, it needs only several impacts to crush it and there is no residual stresses inside that.

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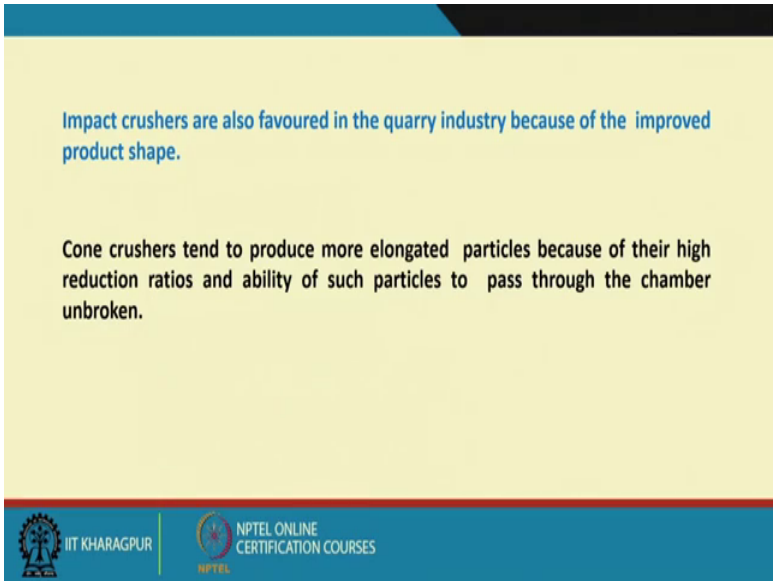

Impact crushers are also favored in the query industry, because of the improved product safe because what will happen in a HPGR because of prolonged compression if the product shape may be little it normally is elongated a flaky type. So, what will happen this flaky type of shape may not give you the ideal or orientation or ideal texture what do we require for the end users of the query products like your brick making for road making, etcetera, etcetera. C 1 crushers tend to produce more elongated particles even the code crushers, because it is also heading like this and because of their high reduction ratios without the cone crushers read out what is the reduction ratio, that what is the average feed size that is the F 80 and what is the P 80 that is your product size the ratio between these 2.

Will give you a reduction ratio we will discuss this at a later stage and ability of such particles to pass through the chamber unbroken. So, cone crushers tend to produce more elongated particles, because of their high reduction ratios and ability of such particles to pass through the chamber unbroken, because what will happen if they are elongated and because of the orientation change they may pass through the your shit that is the or discharge may or opening without having further breakage.

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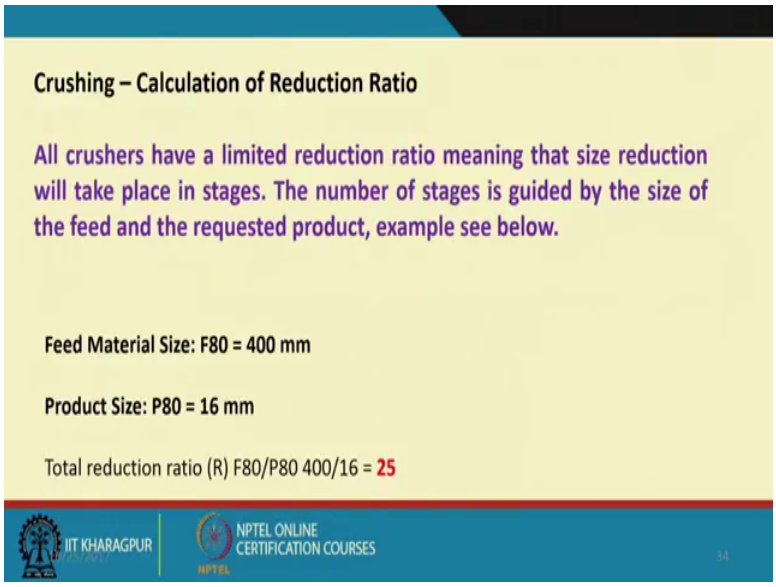

Now, let me discuss now how to calculate the reduction ratio. So, all crushers have a limited reduction ratio what does it mean? That it mean that it means that the size reduction will take place in stages; that means, each crusher is designed to break from a

top size to a certain bottom size and that is why we need the number of stages. The number of stages is guided by the size of the feed and the requested product size; that means, that how many number of stages is required that should be dictated by the what is the average size of your feed material and what is that average product size you aim for.

This is an example for that, suppose your feed material size F 80 that is your 80 percent passing size of your field is 400 millimeter, and I want a product size P 80 that is 80 percent passing size of the product of 16 millimeter; that means, I am asking you to give me a your crushing circuit which should be able to crush my material from a 80 percent passing size of 400 millimeter to a 80 percent passing size of 16 millimeter. So, how many stages we require? Then we will come back to what crusher; crusher's selection; we have already discussed. So, here what is the deduction ratio we are looking for that is your F 80 by P 80. So, the total reduction ratio we are looking for F 80 that is 400 millimeter by P 80 is 16 millimeter. So, that is 400 by 16 that is equal to 25. So, we are aiming for a reduction ratio of 25.

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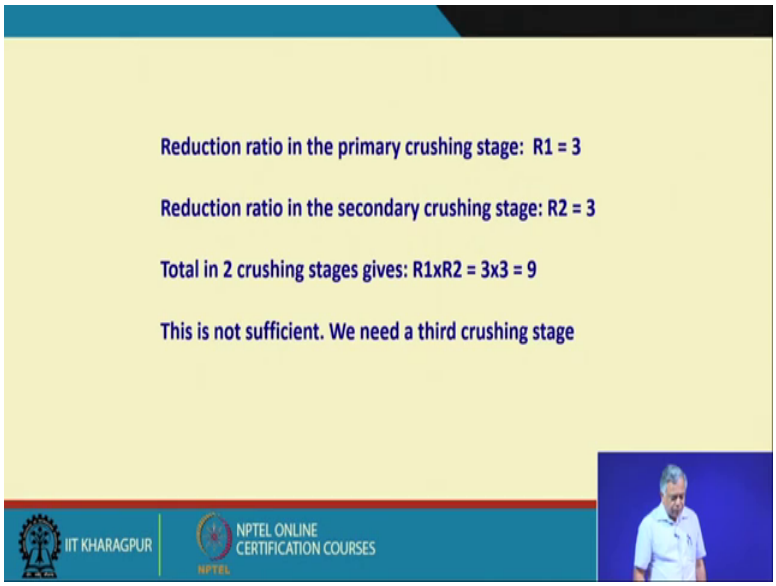

Now, suppose we know the reduction ratio in the primary crushing stage normally, that is around 3 event for the secondary crossing stage in the reduction ratio is three; that means, is F 80 by P 80 is around 3. So, if I have to that is one primary crusher and one secondary crusher. So, my the after secondary after second crushing stages will give me a reduction ratio of R 1 into R 2 that is 3 into 3 that is 9, but our required ratio reduction

ratio is twenty five; that means, I will get a one 9; that means, from a 400 to 400 divided by 9 so; that means, around say your say 40 the 5 millimeter I will get if I have only one primary crusher and one secondary crusher, but I need a product size of 16 millimeter so; that means, we need a third crushing stage, because if we assume that that is also three. So, we can get 3 into 3 into 3 that is 27.

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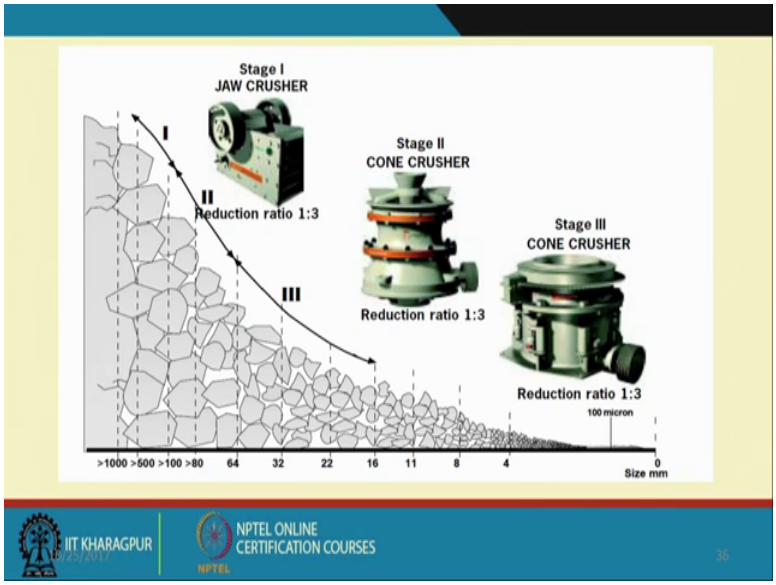

So, it is just a there is a beautiful representation of that again I have got it from open source. So, any that I want suppose this let us assume that this is 400 millimeter and these are the; this is the F 80 or this the P 80, what we want here. So, you have a your reduction ratio 1 is to 3; that means, you have broken it to one by third and then one by third and then one by third and you are ultimately getting the your final product. So, you have got difference 3 different stages of these crushing operations.

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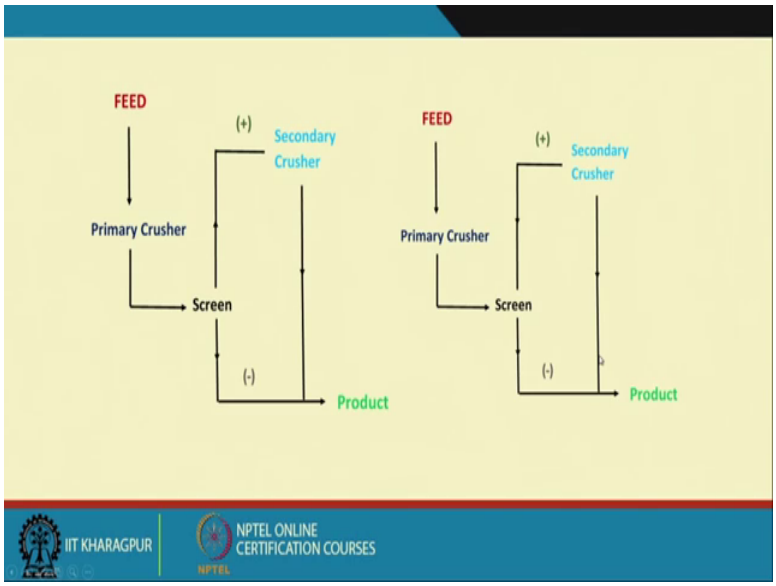

So, this crushing operation may be a closed circuit and open circuit we had already discussed it, but for recapitulation let me tell you that we have already said the primary crushers are hardly in close circuit.

They are never actually in closed circuit, but why we are saying, it is open circuit you say that the feed is coming to the primary crusher and that primary crusher discharge is fed to a secondary crusher through a screen because we are ensuring that the material has to be your say broken down to a particular size. And then what we do that it is being fade that is your overflow oversize material, we are sending it to a secondary crusher and the material which is already finer, than the discharge product of the secondary crusher we are mixing them together and we are getting a product that is why the secondary crushers capacity is always less than the primary crushes, because the primary crusher has already done a part of the job what my secondary crusher is supposed to do.

So, why to feed unnecessary this material to the secondary crusher, when it is already broken down the say broken to a size, which is below the discharge sizes of my secondary crusher? So, this is the open circuit because we are not interrogating that whether my secondary crusher has given me the right kind of size or not whereas, in this circuit you see that the primary crusher product is coming to a screen and the undersized material you are sending it to a product whereas, the secondary crusher product that is which is oversized that is again sending through a screen and unless and until it is finer

than that it is not getting to a product stream. So, you are basically recycling back the oversize material of the secondary crushers, which is already finer that you are sending it to the product stream; otherwise you are sending it back to the screen. And then you are sending it to the again secondary crusher and that is the difference between your primary your open circuit and crushing and your closed circuit crushing.

Thank you very much.