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

Lecture – 47
Closed-Circuit Grinding

Hello welcome everybody so, in the last 2 lectures we have discussed about the concept of mass balancing and some applications with some numerical examples. In this class I would like to extend that into a very important topic in mineral processing that is called a closed circuit grinding and here I would like to show you that how you can apply the concept of mass balancing for various purposes, but before I go to the numerical examples let me explain a bit about closed circuit grinding.

We have already discussed it during hydro cyclone operation or say during the topic of hydro cyclone and during the ball mill operation or grinding in general even closed circuits we said we discussed about closed circuit crushing, but here I will give more emphasis on closed circuit grinding.

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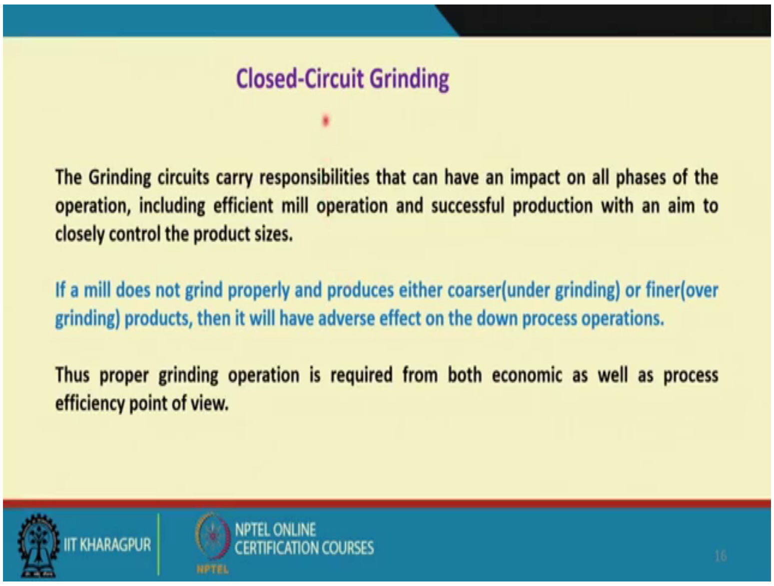

So, why we give more emphasis on closed circuit grinding, because the grinding circuits carry responsibilities that can have impact on all phases of the operation like the grinding circuit because of the most of the metal affair source and the other lean grade ores like platinum group minerals like even for gold minerals like gold, they are day by day his quality or the assay contained of the ore is deteriorating.

So, the liberation because of that the liberation size is becoming finer and finer. So, for that you have to make the entire ore to be ground precisely to a very fine size and for that depends on the efficiency of the grinding operation and grinding operations mostly that quality control is through a classifier that is a hydro cyclone and that is why I am writing this that is it carry responsibility that can have impact on all phases of the operation including efficient mill operation and successful production with an aim to closely control the product sizes.

Because if the product sizes that is if they are not liberated properly or they are liberated at it to fine sizes then what it requires then it will have adverse effect on the downstream processor normally what is froth flotation process. If a meal does not guide properly and produces either coarser that is under grinding or finer over grinding products then it will have adverse effect on that downstream process operations, because if it is too coarse then also downstream processes we will have operation because the material is not properly liberated it is too fine it will create problem with the slurry geological aspects.

So, the proper grinding operation is required from both economic as well as process efficiency point of view.

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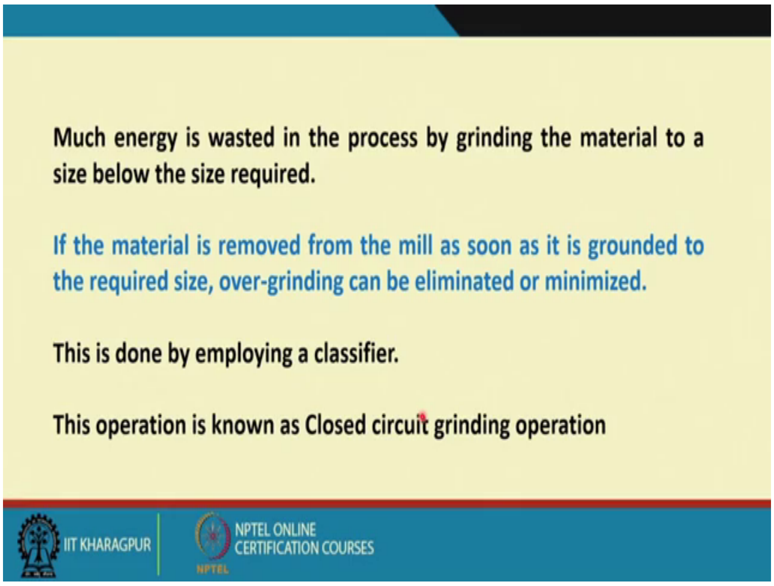

And if the material is ground to fine then what is required unnecessarily we will be wasting much of this energy, if the material is removed from the mill as soon it is ground to the required size over grinding can be eliminated or minimized, but as I said that it is impossible to know that whether my grinding mill has produced the desired size or not if you do not have a classifier that is a hydro cyclone. So, this operation that is when we have a hydro cyclone and a your ball mill or as a grinding mill or maybe another mill we call it a closed circuit grinding operation that is where having a quality control check through the classifier of the products hidness.

Closed circuit grinding consists of one or more mills discharging ground product to classifiers which in turn return the coarse product from the size separation back to the mill for further grinding. It is we have already discussed it that you have got a mill or you may have a series of meals and the products that is your overflow that is your what is coming out from that in the form of slurry we are sending it back to a classifier to check that whether my particles are ground to that desired size or not definitely you do not be ground to that desired size.

So, whatever the materials are whatever the particles are ground to that finer sizes we are taking it out from the circuit through the cyclone overflow we are sending it to the downstream processes it may be your gravity concentration process, it may be your magnetic separation process, but usually it is the flotation process and the material which is coming from cyclone under flow that we send it back to the grinding mill for further grinding it.

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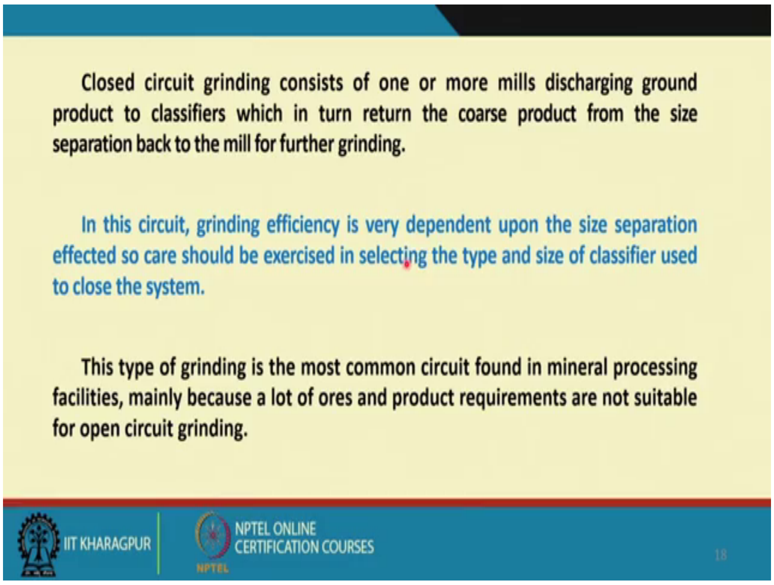

In this circuit grinding efficiency is very much dependent upon the size separation affected so, care should be exercised in selecting the type and size of classifier used to close the system that is what is the importance of selection of appropriate design of a cyclone is important. This type of grinding is the most common circuit found in mineral processing facilities mainly because a lot of ores and product requirements are not suitable for open circuit grinding.

Because most of the cases you cannot guarantee so, we hardly use open circuit grinding these days because you need to generate very fine sizes of particle as your liberation size demands.

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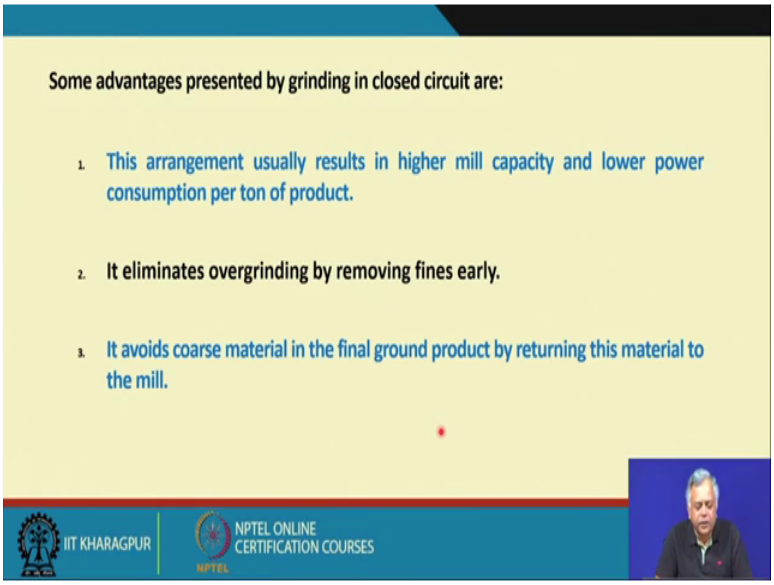

So, what are the advantages of this the closed circuit grinding, one is that is this arrangement usually results in higher mill capacity how, no because you do not have to give more than they have required residence time in inside the residence time of the particle inside the meal. So, what we can do, that is material going in the form of slurry into ball mill.

So, you can run the mill at a much faster speed so, that your capacity increases, but you have got a quality check. So, what will happen, now you are just optimizing the grinding time because I am sending it back the material which is not ground to that your desired fine size I am recycling it back. So, that is what you are using the higher mill capacity a lower power consumption per ton of product.

Because you are doing exactly you are grinding it to you minimizing the over guiding phenomena into a grinding mill. It also eliminates over grinding by removing fines early it avoids coarse material in the final ground product by returning this material to the mill. So, in a sense you are controlling the product quality also.

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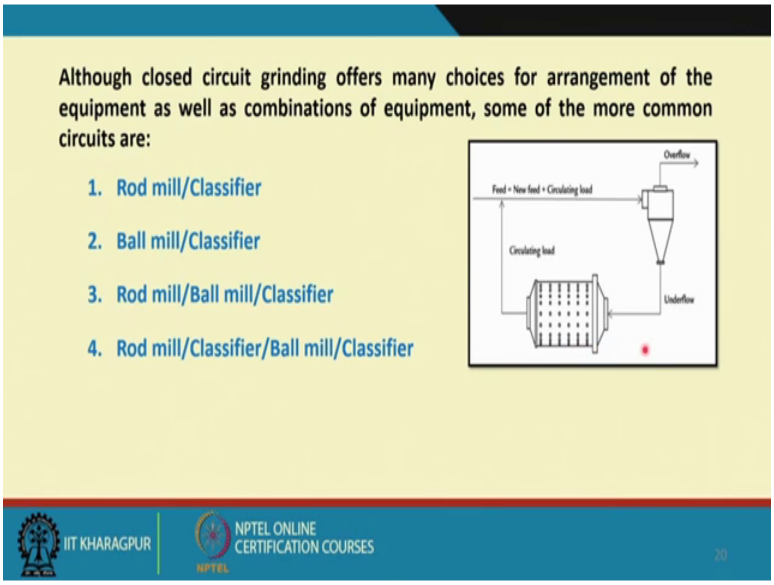

There is a schematic of a your common grinding circuit mill that is your say suppose your you have got a feed that is your new feed plus circulating load and that feed material, why you are sending it to a cyclone? No first you want to take out because my feed which is coming from my crusher suppose I want your 40 micrometer particle that is my grinding mill is supposed to grind my material 100 percent below 40 micrometer, but that is the particle which is getting in here that may be around your say 10 millimeter sizes, but that is coming from your crusher that is a tertiary crusher may be upstream, but that crusher may already have produced some portion of minus 40 micrometer particle.

So, why to send it directly to a ball mill if that is the situation. So, why do not we send it to a hydro cyclone fast to take out the already ground product what is there in the feet. So, that is why there is the your new feed and plus the material which is being your already not ground not finer than the your desired size that is the circulating load. So, new feed plus circulating load first you are sending it to cyclone and again you are checking that whatever the finer material is there finer means you have decided that I need to have a 100 percent or 95 percent below 100 micron side.

So, whatever material is below that size I am taking it out and the remaining is coming through under flow that I am sending it to a ball mill and the ball mill product as a circulating load I am feeding it here. So, you have got now a circulating load plus your fresh feed that is the new feed. So, all the closed circuit grinding offers many choices for arrangement of the equipment as well as combinations of equipment some of the more common circuits are that is your rod mill classifier that is you can have a rod mill and then you can have a classifier.

They another orientation of this it could be that is your you can feed here the material and the product distance can go to the hydro cyclone and then you are taking out the material whatever it is already ground to that size and through the overflow and that your undersized product that is your whatever the material is coming relatively coarser material through the cyclone under flow that you can send it back here so, that could be the circulating load in that case.

So, it could be a ball mill classifier circuit, it can be a rod mill ball mill classifier circuit, it can be a rod mill classifier that is you have got a first coarser grind, then you are checking it that is you can have a classifier, then you can have a ball mill and then you can have another classifier; that means, you are controlling the sizes of the particle at each stages.

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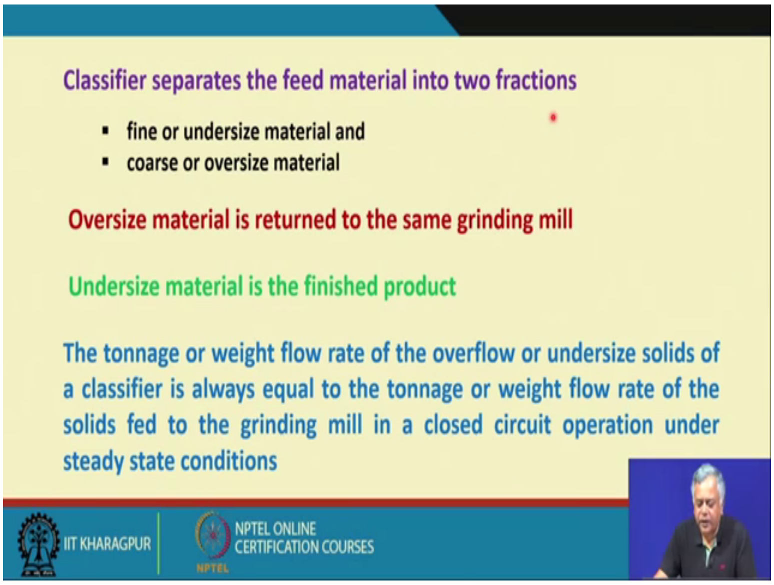

Classifier separates the feed material into 2 fractions, that is fine or undersized material. And coarse or oversize material, because classifier is in this case is hydro cyclone again and again I am mentioning that oversize material is returned to the same grinding mill undersized material is the finished product for that circuit it is being sent to the next your downstream processes.

The tonnage or weight flow rate that is your tonnage or weight flow rate of the overflow or undersized solids of a classifier that is how much of material is going out through the classifier is always equal to the tonnage or weight flow rate of the solids fade to the grinding meal in a closed circuit grinding operation under steady state conditions the very vital statement.

So, what is happening, you are feeding materials suppose at 100 tons per hour and you are when you are starting it that that is 100 tons per hour your fresh feed you have started with now what will happen, now only 40 tons per hour of fines you are separating out. So, how much you are getting it in the underflow that is 60 tons per hour. So, next one, but you can only feed total 100 tons per hour so, 60 tons is your recycled feed. So, the fresh feed next one next step you can only feed only 40 terms. So, that is 40 plus 60 so, that is your 100 turns so, 60 is getting recycled back. So, what this statement is saying that, your amount of fresh feed is equal to how much of fines you have taken it out from the circuit other remaining portion will be recycled back.

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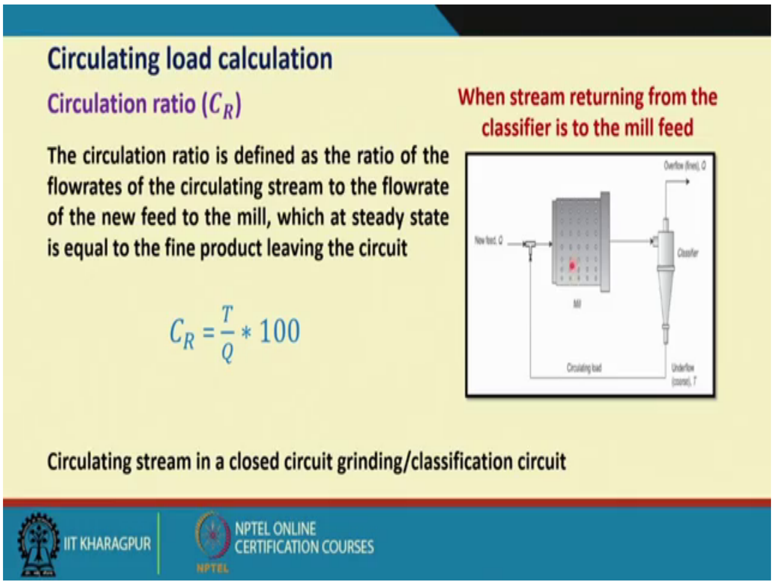

So, this is a circuit I was talking about that is you can have I have shown you one circuit that is you can make it that is if I have your fresh feed some particles which are already finer than that I can have a orientation like this that is first feed can go to the cyclone and then it can be recycled like this way and most common one is this one, that is you have got a new feed and you are sending it to a mill it may be your grinding any grinding mill they the product from this grinding mill you are sending it to feeding it to a classifier that is a cyclone that overflow which is already finer than sizes that that what you desire that is you are taking it out. So, remaining the coarser material you are just sending it back along with your fresh feed and then the total that is yours this is called the circulating load plus your new feed you are sending it to the grinding mill.

Now, my grinding mill operation is basically will have the best performance when the you are at a fixed or at a consistent your percentage solid that is contained. So, I have to check it I have to calculate it that how much of is that circulating load. So, I can control that what should be the new feed. So, that there is no disturbance in the relative percentage of solids and water as well as the total charge that is your volume occupied by the total charge where you have got the steel balls in many cases you may not have balls it may be add mill or it may be sack made relative percentage of your balls may be less, but the total volume of the charge you cannot change.

So, the balls you are not changing water and your solid you should have a typical percentage. So, you have fixed it that my mills should be working at a 50 percent solids by weight. So, you have to maintain that otherwise the performance of the meal will be deteriorated. So, the circulating load how do I calculate, circulating ratio before we calculate go for circulating load calculation let me define you another ratio that is what frequently used that is called the circulation ratio it is represented at capital C R.

So, circulation ratio is defined as the ratio of the flow rates as the ratio of the flow rates of the circulating stream to the flow rate of the new feed to the mill, which at steady state is equal to the fine product leaving the circuit that is what I have already explained you that is how much is the as the ratio of the flow rates of the circulating stream to the flow rate of the new feed to the mill, which at steady state is equal to the fine product leaving the circuit.

So, C R that is here you see that that is the new feed that is the Q and this is the over flow pines is designated as Q and underflow that is the coarse material is designated at T. So, then C R is equal to that T by Q that is what is that your ratio between the flow stream to the flow rate of the new feed, ratio of the flow rates of the circulating stream. So, what is the flow rate of the circulating stream? That is the T that is whatever is coming from the cyclone under flow. So, that is the circulating stream. So, that is the capital T and what is the fresh feed that is the fresh feed to the mill is Q. So, that is the new feed or the fresh feed. So, it is T by Q into 100. So, C R is the ratio between the circulating load divided by the fresh load that is T by Q into 100. So, circulating stream in a closed circuit grinding at classification circuit that is what is shown here.

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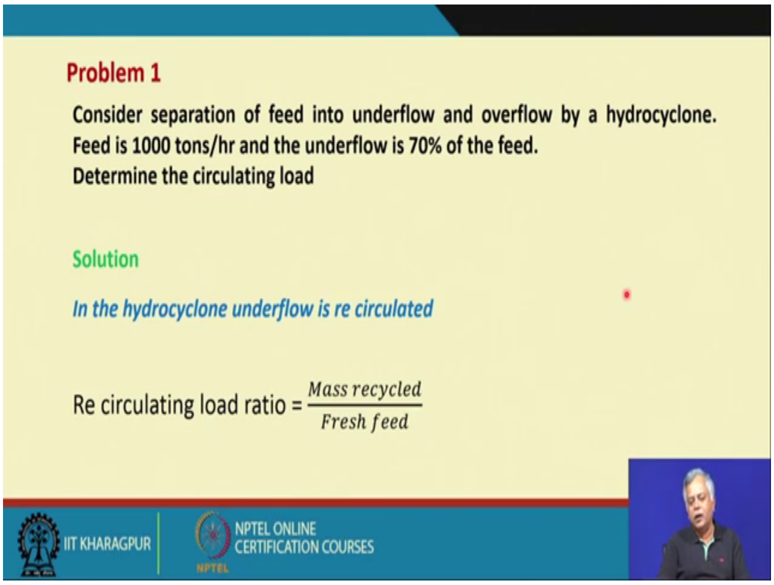

Now let us see that how we can apply this concept of circulating load ratio or how we can calculate this then I will show you that in combination of this circulating load ratio and the mass balances what we have learnt so far how we can apply to mass balance a particular system. So, this is a problem it is if we consider a separation of feed into underflow and overflow by a hydro cyclone that is if we consider that we have got a hydro cyclone and you have got a feed and that gets separated into 2 products under flow and overflow.

Feed is 1000 tons per hour and under flow is 70 percent of the feed determine the circulating load. So, what should be the circulating load now in the hydro cyclone under flow is re circulated that is the underflow what is being re circulated. So, the re circulating load ratio is mass recycled divided by fresh feed.

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So, now, if I do a material balance so, 70 percent of the feed is under flow mills mass of underflow is 70 percent of 1000 tons is 700 tons. So, remaining 300 tons because it is in steady state it has to go to the overflow so, the mass of overflow is 300 tons right. So, what will be the fresh feed? So, that is the 300 tons which is taken out from the circuit on a hourly basis it is 100 tons per hour.

So, every hour we are taking out 300 tons of material from the circuit now to maintain that 1000 tons so; that means, every time 300 tons per hour is the fresh feed. So, that is why I said that your the how much of fines. So, that is the overflow is taken out per unit time is equal to the amount of fresh feed. So, now, what is the re circulating load ratio, that how much is the mass of underflow that is 700 and what is the amount of fresh feed so, that is 700 by 300 so, that is equal to 2.33. So, that is how we can calculate the re circulating load ratio.

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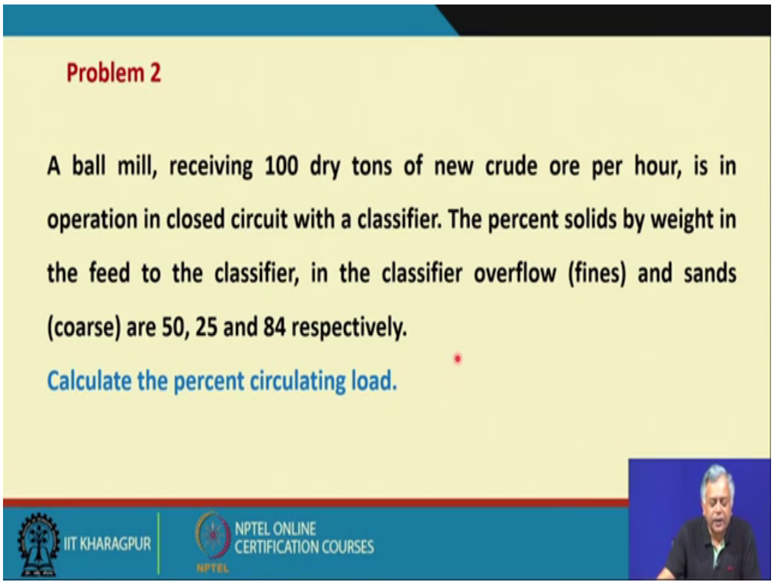

Now, you see that another problem a ball mill, receiving 100 dry tons of new crude ore per hour, there is a fresh feed is your 100 dry tons is in operation in closed circuit with a classifier right. So, the percent solids by weight in the feed to the classifier that is the percentage solids by weight in the feed to the classifier in the classifier overflow that is a fines and sands that is the coarse fraction are 50, 25 and 84 respectively.

So, the percent solids by weight in the classifier feed is 50 percent, in the classifier overflow it is 25 percent and underflow it will be much more concentrated because you have less water so, it is 84 percent. Now, I want to calculate the circulating load. So, what is given you are given with the fresh feed that what is 100 dry tons and your percentage by weight of the cyclone feed under flow and overflow is given how do I calculate.

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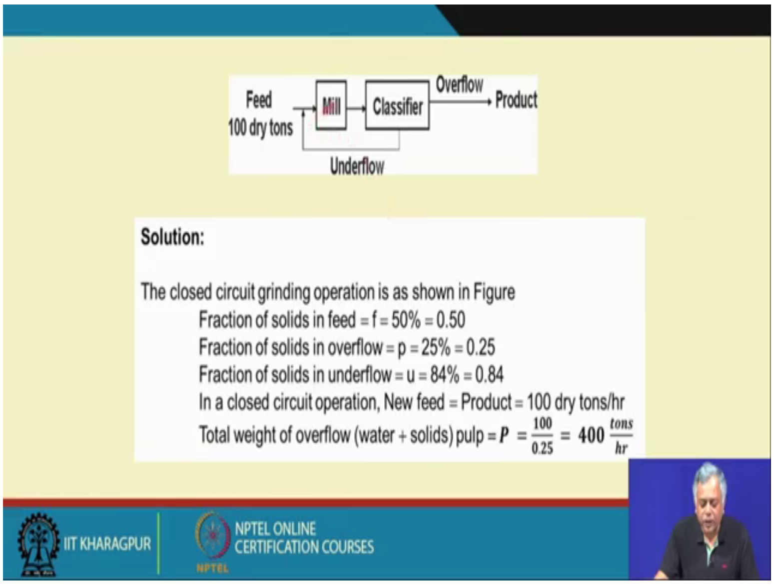

So; that means, this is a circuit that is you have got the feed that is 100 dry tons and that is the mill. So, you have got a classifier that is a hydro cyclone now you have got overflow and you have got an underflow. So, this one that is at what rate it is going so, this one is 50 percent solids by weight so, that is the ball mill discharge.

So, that is the mill discharge overflow is dilute that is 25 percent by solids by weight and underflow is 84 percent of solids by weight I need to calculate the circulating load ratio, how do I do it? Here I have to use the concept of mass balance also. So, the closed circuit dining operation is shown in this way. So, whenever you are given this type of problem it is better to draw the circuit. So, that you do not have any confusion that is what personally I also do.

So, the fraction of solids in feed that is feed to the classifier I am talking that is 50 percent. So, that is we have to convert it into fraction because we are balancing it through the fraction. So, it is 0.5 similarly fraction of solids in overflow is 25 percent; that means, it is 0.25 and it is 0.84 the underflow in a closed circuit operation. So, new feed is equal to we have already said that what is the new feed, what is the fresh feed.

So, this is the total feed that is a new feed plus your re circulating re circulated feed. So, your new feed is equal to product that is equal to 100 dry tons per hour. So, the feed is equal to the new feed is equal to 100 dry tons of per hour. So, the new feed means that that is the 100 dry tons per hour. So, here, we are sending out we are taking out 100 dry tons of that solid per hour. So, total weight of overflow that is you have a 0.25 that is your 25 percent of solids by weight here. So, how much is the slurry here how much is the slutty that I have to calculate. So, the total weight of overflow is water plus solids that is the pulp is equal to 100 by 0.25.

So, that is 100 tons you are taking it out and that is equal to 25 percent of the total material. So, what is the total slurry I am taking it out. So, 25 percent is equal to 100 tons. So, 100 percent is equal to 400 tons per hour. So, we get the value of total weight of overflow is 400 tons per hour right I hope it is clear to everybody.

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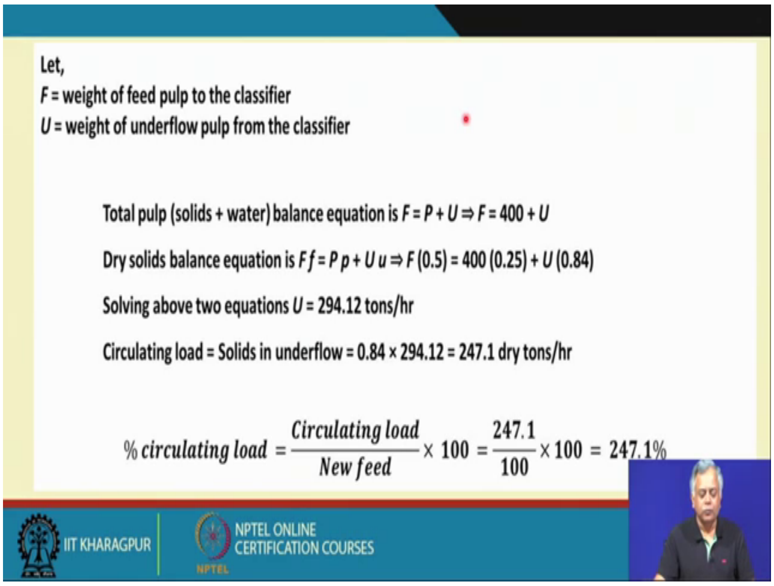

Now, so, if we assign that capital F is equal to weight of heat pulp to the classifier I do not know how much is going there into the classifier and U capital U is the weight of underflow pulp from the classifier I do not know also this U that how much is going there well I only know that this is 400 tons per hour that is total that is solid so, 8 plus water weight.

So, what I can write that is total pulp solid plus water balance equation is F is equal to P plus U we have already learnt that is total feed weight is equal to total weight of your overflow product and plus your underflow product. So, P we have said that this is the product weight suppose so, that is equal to 400 we have already calculated. So, we can write that F is equal to P plus U. So, F is equal to 400 plus U, I do not know what is the value of F and what is the value of U and that is what I want to solve.

Now I can use that mass balancing formula based on that dry solids balance. So, what is that equation the dry solids balance equation is F f if f is the fraction of solids by weight in my feed. So, that is F f is equal to P p plus U u and we know the solid percentage. So, we have already converted them into fraction of solids by weight that is F into 0.5 is equal to 400 I know that is the capital P and this is 0.5 0.25 that is small p is 0.25 because we already said that your overflow is having 25 percent solids by weight. So, that is 400 into 0.25 plus U capital U into 0.84. So, now, you have got 2 unknowns F and U you have got 2 equations.

So, easily we can solve it for we can easily solve that how we can solve it now we can put the value of F here in this equation that is 400 plus C U into 0. 5 is equal to that. So, we can find a value of U is equal to 294.12 tons per hour again I am requesting everybody that please do these calculations on your own otherwise you will have your you will your concept will not be clear.

So, when we solve this that is by putting the value of others in this equation we get a value of U is equal to 294.12 tons per hour. So, now, the circulating load is equal to I have to calculate that what is the circulating load. So, circulating load means what is the solids coming out from this under flow through this cyclone under flow. So, that is the solids in under flow we already know that has got 84 percent your solids. So, the circulating load is that is the total your slurry. So, wait your water plus your solid so, that will be 0.84 into 294.12. So, that is 247.1 dry tons per hour so, that is your 247.1 dry tons per hour of solids in the underflow.

So, percentage circulating load is equal to circulating load by new feed into 100. So, what is the circulating load, it is 247.1 divide by new feed is 100 into 100. So, it will give you 247.1 percent. Now here I want to explain that what is the meaning of this circulating load, suppose in one case my circulating load is 500 percent what do I do. So, in that case maybe the product quality we are assuring, but your capacity of the mill will be drastically reduced because you are having almost 5 times the fresh feed that is the recycle material.

So, your fresh feed that will dictate that at what rate your processing the entire your mill how much is it is capable of accepting the new feed, but if your circulating load is 0 so; that means, your cyclone is not properly separating that, it is impossible that your grinding mill is producing 100 percent finer than material what you desire. So, this is also again a measure that is the circulating load will also give you an idea that whether my circuit is performing well or not and it is the it depends on the what type of material you want and what type of what is the degree of accuracy you want in your product quality based on that you decide that what should be the ideal percentage circulating load.

And this example basically tells you that is how do I use my mass balancing equations event to have a control or to have some measures that is for optimization of my closed circuit grinding operations and even for any mineral processing circuit if you know if you apply this mass balancing equations you can know the clearer picture that is whether you have to take any action or remedial measures for improving the performance or not or you may be convinced that my mill is or my entire plant is working at it is best operating conditions.

That is why I said that mass balancing helps in process control in optimization of your say entire mill entirely your mineral processing plant, this application of this equation may be little bit complicated when suppose you are processing laid zinc ore. So, in this case your wanted material may be 3 4 different materials, that is you can your lead maybe your wanted material, copper may be wanted material zinc could be wanted material and you have got number of unit operations.

So, there you can if you know how to apply that to product formula and then you can say apply this formula for each particle classes and or say each material of your interest and then you can derive the formulas for even some multi product systems like many times you have 3 product from coming out from a circuit. So, I do not want to in this introductory course I would like to stop here related to the topic of mass balancing I hope you have understood it.

Thank you very much.