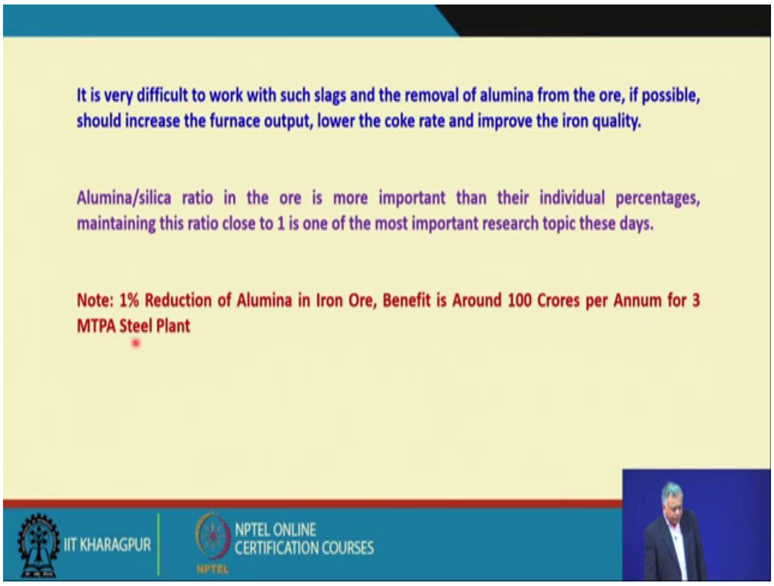
Introduction to Mineral Processing
Prof. Arun Kumar Majumder
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture – 64
Flow Sheets (Contd.)

So, we are discussing about the iron ore beneficiation. In India this is just for an example that how the mineral processing flow sheets are designed keeping in mind up clients requirement as well as the your the constraints imposed by even the cost is given by the mind ore characteristics.

(Refer Slide Time: 00:45)



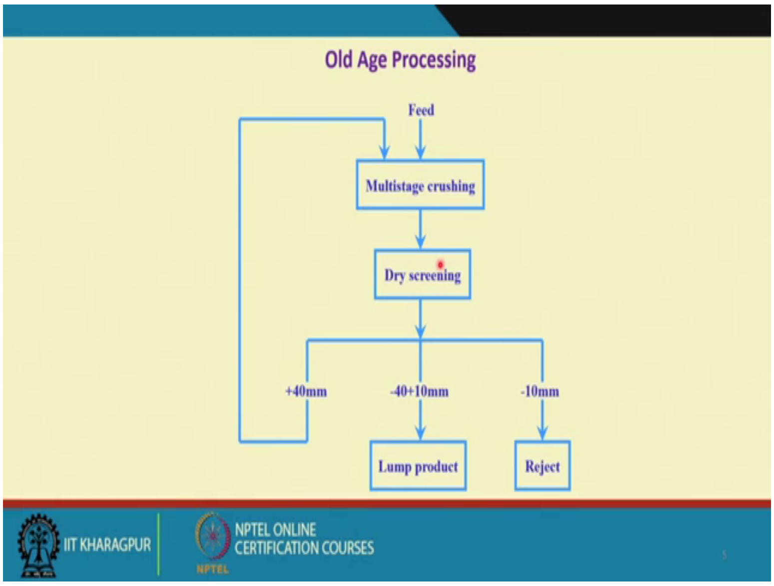
Now, when you have more alumina in your eye iron ore it is very difficult to work with such slags and the removal of alumina from the ore if possible should increase the furnace output that is, it is not only the viscosity related issues this alumina if it has removed before it is fade into a furnace it increases the furnace output lower the coke rate and improve the iron quality.

And it is not only the alumina or the silica it is the alumina silica ratio in the ore is more important than their individual percentages. Maintaining this ratio close to 1 is one of the most important research topic these days. That is the client the (Refer Time: 01:50) is there have imposed this restriction to you that it is not only the removal of alumina you have to maintain a certain ratio of alumina to silica, and that should be close to 1. Then you get the highest price for your iron ore if you can supply that. Sometimes if your alumina content is high even though your grade is good, the metallurgist may not buy your iron ore.

The last note you see that in terms of finance that 1 percent reduction of alumina iron ore, 1 percent only 1 percent benefit is around 100 crores per annum, 100 crores means it is an Indian unit we use it is 10 to the power 7; that means, your 100 into 10 to the power 7 rupees per annum for 3 million ton per annum steel plant its huge. That means, 1 percent reduction of alumina in iron ore benefit is around 10 to the power 9 rupees per annum for a 3 million ton per annum steel plant.

So, if I have this figure in my mind I know that how much of money I can invest on per ton of ore I want to process, and that we tell me that what kind of equipment I can use because based on their cost and operating cost capital investment all this you can keep it in mind. I am not going into that detail.

(Refer Slide Time: 03:53)



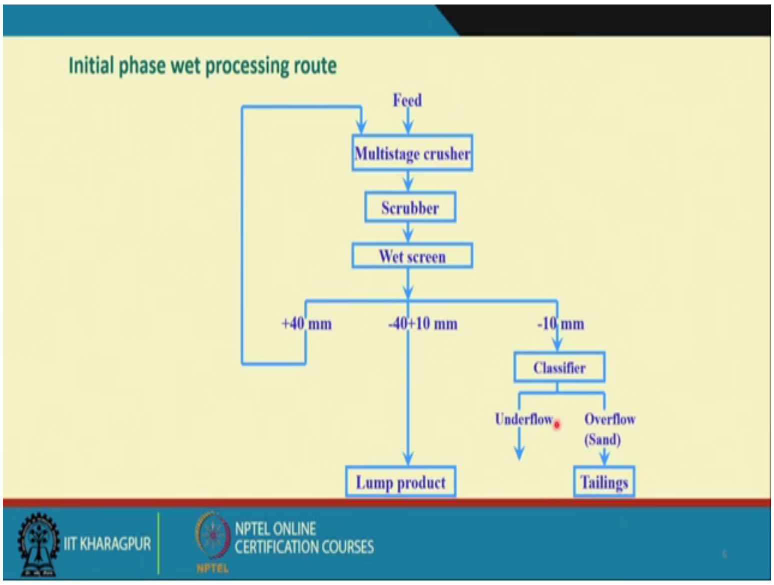
But now I will show you that how this separation proceeds they are getting complicated as the time passes by because my iron ores which you are mining today are much much different than what we used to mine before. This is called the old age processing there that time my client was interested only to have minus 40 plus 10 mm are iron ores because there are no techniques, there are no technologies to use minus 10 mm particles in blast furnace.

So, what do we used to do that is you have got a run up mine ore that is the feed and then you go for multi stage crushing. So, that I do not produce much of this minus 10 because I will be not getting any money for that and then you go for dry screening because these are course materials and you take out minus 40 plus 10 that is called the lump product, plus 40 again you recycle it back I try to do it, and minus 10 you are just simply rejecting it. So, the aim of this processes there is no separation process it is only the crushing and screening that is why I say the many times your clients requirement could be only the specific size.

So, that time even the metallurgists do you know that how to use minus 10 millimeter particles and that is why they used to call that these are fines, the steel called the fines and these are the lumps. So, as the quality of my as the grade of my iron ore is quite high I do not require to upgrade it. So, my old iron ore processing plant we are only having some crushers that is the combination circuit and finally, your product was the lump sizes that is minus 40 plus 10 mm and minus 10 mm material we were basically throwing it out.

Now, with the development of the techniques of increasing the sizes you may ask me question that why minus 40 plus 10 in the metallurgist one for that I would suggest you to go through the basic iron making books through blast furnaces, you will try to understand. So, minus 10 mm materials now, the metallurgists have come up with a process that is called sintering process. With the development of sintering processes now, meteorologist started showing interest in buying also minus 10 millimeter particles. But then they say it that there is minus 10 mm particles we should have this alumina silica ratio to be maintained at a particular level and the iron content should be high because when you are crushing it this most of the silicon materials they are going with the minus 10 mm material.

(Refer Slide Time: 07:40)



Now, with the development of sintering technology, now you see the next round of your processing, now, you have started that was a dry process because it was only a crushing and screening. Now, we have started thinking of implementing of weight processing. (Refer Time: 08:00) and you have got (Refer Time: 08:01) mine ore now, you have got multi stage crushers, and you have scrubbers, scrubber means you have got basically the clays associated with your mined iron ore.

Now, the clays I want to get rid of by means of your shaking it or cleaning the surfaces and then you use a wet screen because the scrubber also you are using water to get the clay material detached from the surfaces of my iron ores. And with the wet screen what we try to do? We try to take out minus 40 plus 10 mm that is my lump product anyway that is my direct product which I can sell plus 40 mm again you are sending it back for your crushing circuit and minus 10 mm.

Now, what we are trying to do? We are first having a classifier. Now, this classifier is basically set at a size of 150 microns, so 150 below 150 micrometer particle now, we think that we cannot sinter it and it has got more of alumina and silica. So, it is better to get rid of this throw it as tailings. So, you want to remove the minus 150 micrometer particles. So, you have got a classifier. So, the classifier overflow which has the finer particle we call it sand because they are mostly having the alumina and silica mostly the silicates and we used to dump it in the tailing pond, and the underflow that is minus 10 plus 150 micrometer particle that is again a product which you can sell it to steel plant which they are not directly charging to blast furnaces, but they are going for a size aglomaralation process called sintering and after that they are using it, but you are getting much lesser price than the lumps.

So, these tailings now, they are very fine particles minus 150 micrometers. Now, when the tailings are very fine materials, you have got huge surface area and what is happening my mining friends because you need to produce more of this iron ore we are going for more of mechanization. More mechanization means the more of these your fine fraction you are generating, and more of this fine fraction means we call it slimes that is more of these tailing material you are producing, and more material you are feeding per unit time so more generation of these tailings are there.

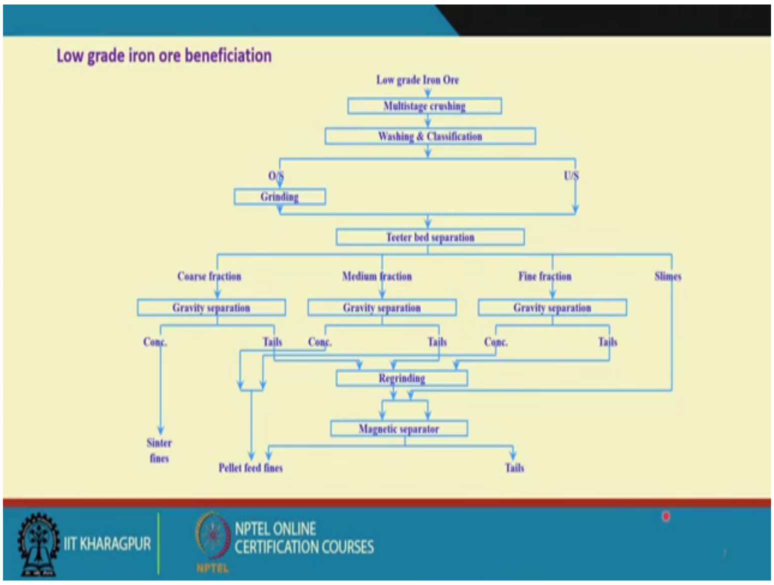
Now, if you go to these some of these old Indian iron ore mines you will find that there are huge tailing ponds. So, it requires huge land to store them and to prevent them from getting airborne you need to have water sufficient quantity of water added to that. So, that is a huge loss of water and there are some metals which can be as a dissolved solid, dissolve metal they can contaminate the groundwater also. So, there are environmental related issues you need huge land all sorts of troubles are there with the tailings.

Now, again what happened there are development of again another size reduction, another size enlargement process with the development of that that is called the palletization. That means, even the minus 150 micron particle they can be their sizes could be increased by a process called palletization that is again engineered by the metallurgist and because of the palletization process now, people want to use the minus 150 micrometer particles. And your the modern mining methods and the crushers heavy duty crushers and screens effectiveness using the different your say high capacity crushers we are generating lot of tailings that is your below 150 micrometer particles. In certain cases it may exceed more than 30 to 40 percent of the total mined ore.

So, these fraction if it is 30 to 40 percent of your total mined ore. So, it is a huge quantity and it is a waste of natural resources, they are environmental threats and there is a technology available for size enlargement that is, that means, the iron available here in the tailings that can be utilized by metallurgies for further extraction of iron. But the trouble here that you have got more amount of more percentages of alumina and silica, so you cannot directly use the tailings even if you make the pellet us you cannot directly charge to blast furnaces because they will have all the associated problems. So, for that the beneficiation of these tailings that is below 150 micrometer particles now, it has become essential. Now, that is why it is one of the hot research topic in most of the countries including India.

Now, you see that what happened that your grade of your ore is basically getting decreased day by day. So, even the lump sizes. Now, needs require required the grade should be improved and below 10 millimeter particles also the grade should be improved and also the removal of alumina and silica is also essential for the use of the 3 different factors that is your lump and your fines and the slimes the below 150 million particle we call it slimes. Now, metallurgists also they have compromised the way to the sizes. Now, they are saying that even in place of minus 40 plus 10 we are ready to accept minus 32 plus 8 mm in most of the places because the mineral processing people they say that the liberation is better if you crush it to below 32 millimeter in certain cases.

(Refer Slide Time: 15:23)



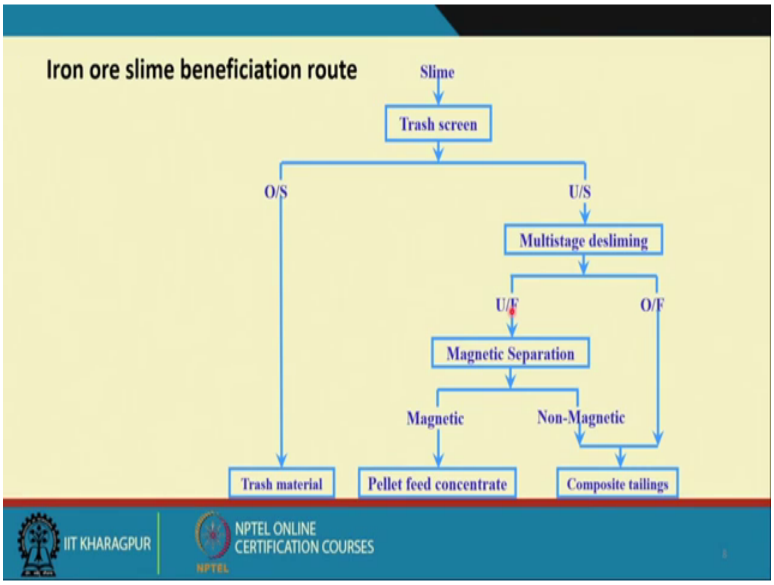
Now, you see that how complicated now, the iron ore processing plants are becoming with time. Now, you are getting low grade iron ore now, again we are going for multi stage crushing you are going for washing and classification that is to get rid of your slimes then the oversize material what you are trying to do. That is you are going for grinding that is your and the undersized materials you are sending it to teeter bed separation, that is for a gravity separation and then you are having 3 different fractions or 4 different fractions like coarse fraction, medium fraction, fine fraction and slimes.

So, you have to follow the arrows ok, where it is coming. The coarse fraction now, you are separating it up grading it using a gravity separation even the gravity, from the gravity separation you are getting a concentrate which are called the sinter fines and the tails now, it is getting reground and now, we are going we have to follow the arrows tails of gravity concentration they are reground because of liberation related issues and at that finer sizes now, you are going for magnetic separation. And with this magnetic separation the non magnetic particles are basically the tails now, and the magnetic particles they are now, mixed with the pellet feed fines that is the these particles will be now, eventually pelletized.

The medium fraction again gravity separation and the concentrate you are sending it to pellet feed fines, tails you re-grinding it and sending it to that circuit. Fine fraction gravity separation concentration and then your tails you are again going to that section. So, finally, even the slimes directly you are sending it to magnetic separation and you are going for. So, ultimate decision making the quality control is being done the by the magnetic separators.

So, this is why the capacity of magnetic separators with the out compromising with the effectiveness has to be increased, otherwise you need many more magnetic separators. And this is one approach for low grade iron or benefit and circuit is being proposed, but again and again I am saying that it is not hard and fast that you have to follow these strategies only you can have different options and the options should be driven by your mind ore characteristics.

(Refer Slide Time: 18:16)

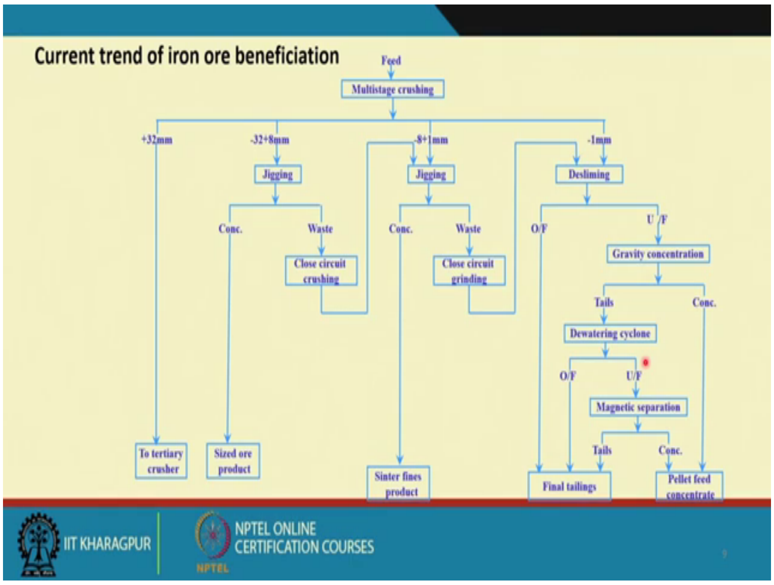


Now, the slime part, that is the most difficult part to separate because of his finest as we kept on discussing that what will happen if the particles become more finer then the body forces become weaker, so the separation becomes difficult.

Now, for the slime beneficiation, lot of research is being done till today that there are trash screen that he just removed the trash screen means remove the unwanted metallic minerals, metallic your components and the oversize they are trash material; that means, you are throwing it an undersized one you go for multistage disclaiming; that means, you try to get rid of the clay materials. And then the overflow of that it is you are mixing it with the non magnetic materials what you are getting from a magnetic separation. Under flow you send it to a magnetic separation and even again you are making a pellet feed concentrate.

Now, these magnetic whether you should use a magnetic separation or a floatation here, that depends on many other factors that is what is the cost of floatation process, what is the effectiveness of floatation process, how much water will be required and the same thing I have to look at for magnetic separation processes the pros and cons we have to always compare it.

(Refer Slide Time: 19:55)



Now, if you look at the current trend of iron ore beneficiation. If we look at the detail your size by sizes brake up, so what I have to look at? That is when I have a complicated flow sheet like this I have to track the size wise, that is you follow the arrows, that is what I am trying to ask you to learn that is how to understand a flow sheet. You say that feed is coming that is rom ore, multistage crushing, the need you know, so that crushing circuit I am not showing here.

A multi stage crushing first you have got a plus 32 millimeter material, so that that that plus 32 you are sending it to a tertiary crusher. So, that circuit is not complete ok. Here the current rate of a iron ore beneficial what I want to emphasize on the minus 1 mm material.

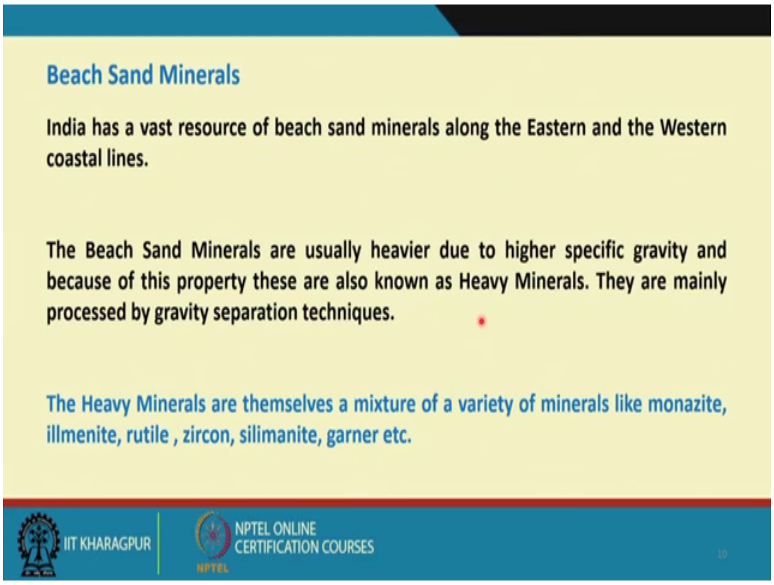
And then you have got in between sizes minus 32 plus 8 mm there I can go for jigging and the concentrate is the sized ore product; that means, it is the lump now, I can directly sell it to steel plant. Now, whatever the waste is coming from the jigging that is you are sending it to closed circuit crushing because they are coarse, so I may have much more iron ore which are not liberated at that sizes and then closed circuit crushing I am crushing it to below 8 mm that is your minus 32 plus 8 now, we are crushing it to below 8 mm. And again from a multi stage crushing we have got another product minus 8 plus 1 mm, so I am mixing it. So, I need to do the mass balancing how much of material where it is going. Again here we are using a jigging here also we are using jigging, here also we are using jigging, but the sizes they are using it they are different, these are very important.

So, what type of jig I will be using that will be also dictated by the particle size range you will be using and then how much of quantity of material I will be requiring, and what is that targeted quality I want to achieve, that will also tell you that what type of jig will be using. So, the identical jigs are not used here may a (Refer Time: 22:31) identical principle the dimensions could be different and now, we get a concentrate, now we are calling it that is the sinter fines.

The waste I am putting it into a closed circuit grinding that means, I have got a hydro cyclone also, and that your we are sending it to a desliming unit because I want to get it up minus 150 micron particle, and from multistage crushing we are also having minus 1 mm material and we are mixing it. Now, we are having it after that desliming unit what are the overflow that is a your mostly the clays we are trying to separate it that is called the final tailings. And now, this under flow we are putting it into a gravity concentration and again dewatering cyclone and then we are sending it to magnetic separation and then we are getting a pellet feed concentrate like that.

So, that is how what I try to tell you that depending on the need of my client, depending on the mineralogical characteristics of my ore, and depending on the advancement in technology in my metallurgical industry, as well as the advancement in my mineral processing technology the flow sheets have to be developed to for optimal use of my resources. So, that we can accrue maximum economic benefit from my natural resources and this would be appropriately utilized.

(Refer Slide Time: 24:17)

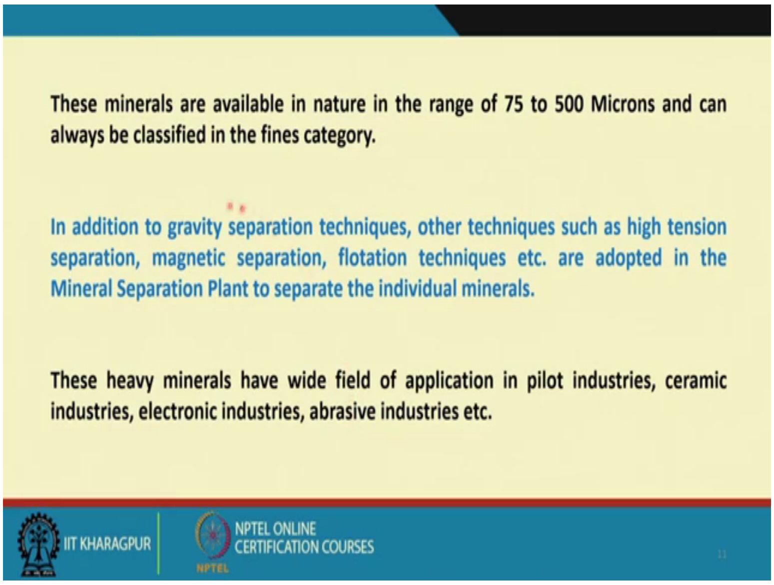


Take another example so that is about iron ore. Another example I would like to show you that is the beach sand minerals. Now, why we need to process the beach sand minerals and what is that let me first tell you. India has a vast resource of beach sand minerals along the eastern and the western coastal lines.

The beach sand minerals are usually heavier due to higher specific gravity and because of this property these are also known as heavy minerals. They are mainly processed by gravity separation techniques. I will explain you what they are.

The heavy minerals are themselves a mixture of a variety of minerals like monazite, illmenite, rutile, zircon, silimanite garnet, it is not garner its garnet etcetera along with quartz, along with the sand. So, these densities is a combined density or the specific gravity of monazite, illmenite, rutile, zircon, silimanite, garnet its more than 5.8 and your silicates are maximum 2.65. So, there is a huge difference between their specific gravities and this minerals have what many industrial uses and they are strategic minerals also in some cases.

(Refer Slide Time: 26:07)

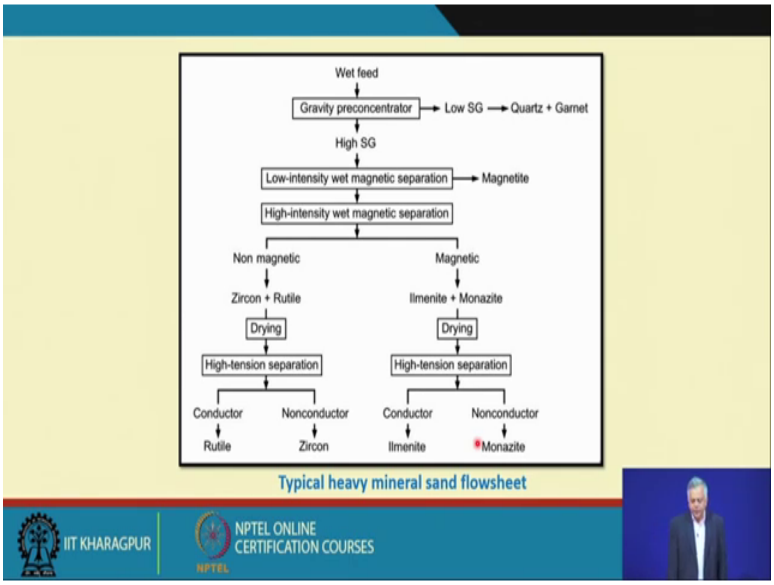


These minerals now, look at the sizes are available in nature in the range of 75 to 500 microns and can always be classified in the fines category, that mean they are fine materials.

Now, in addition to gravity separation techniques other techniques such as height tension separation, that is electrical separation, magnetic separation, floatation are adopted in the mineral separation plan to separate the individual minerals, because it is not only the separation of the heavies and lights because quartz you can separate it based on the gravity concentration method.

But if you look at the density differences between these heavy minerals they are very less. So, the gravity separation processes you cannot use it effectively to have a separation between my 110 minutes everything every mineral each mineral is my wanted, but if they are not in separated state I cannot utilize them for different purposes. So, these heavy minerals have wide field of application in pilot industries, ceramic industries, electronic industries, abrasive industries, many other industries.

(Refer Slide Time: 27:38)



Now, how they are being separated? How these be sent your minerals are being processed in a mineral processing plant that I will try to show you. That is first you have got a wet feed because it is a beach sand means it is in wet condition how do you mine it is by through drazzing method you normally mined up the beach sand.

You have got a wet feed, put it into a gravity concentrator because here my target is to separate my quartz that is your low density material from the mixture of low and high density minerals your assemblage. So, the wet feed is coming and using a gravity preconcentrator, I will separate the low specific gravity minerals they are normally the quartz and garnet. So, this quartz and garnet they are separated and now, the high specific gravity mineral. Now, compose off the most of my valuable minerals or the wanted minerals. Now, I cannot use now, the gravity concentration because as I said that they have very less difference in their specific gravities. Now, what we apply? That is I look at different other properties that is, whether some of these minerals they are magnetic, some of them are ferromagnetic, some of them are paramagnetic and some of them are diamagnetic.

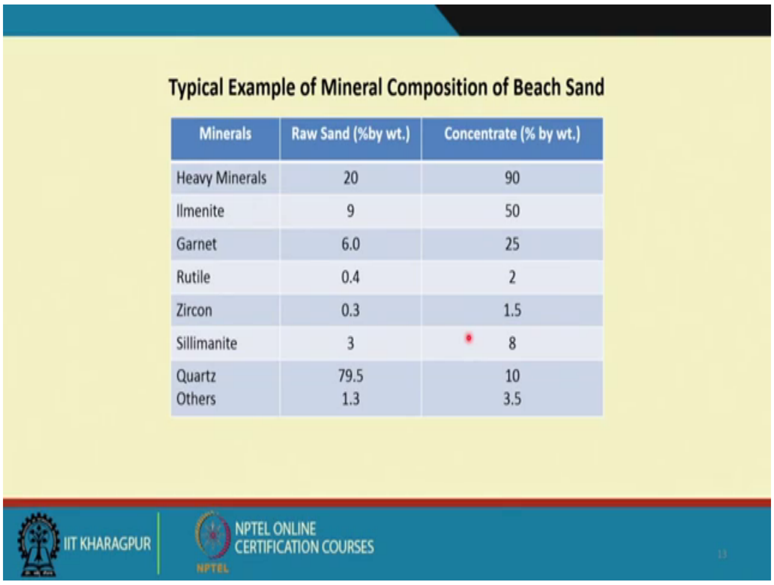
So, what do we do? We use low intensity wet magnetic separator first to remove the magnetite bearing material, that is normally the magnetite you have, so you take it out because you need it is a ferromagnetic material. Then once this is done then what we do we subject them, now they are not your this your materials which is coming out from them, they are basically we are having a separation between the ferromagnetic material from the rest. Now, we try to separate based on the electrical conductivities because the electrical conductivities if you remember I mentioned that the magnetic part magnetic particles amongst the magnetic particles some may be electrically conductive some may be electrically non-conductive, even non-magnetic particles will have the similar properties.

Now, we put it into a high intensity wet magnetic separation first. Now, wet high intensity magnetic separation what will happen? You will have a magnetic particle you have a non magnetic particle and this magnetic particle are illmenite, and monazite non magnetic particles are zircon and rutile. So, by using a low intensity magnetic separation I separated of magnetite that is a ferromagnetic particle. Now, I am having a separation between your paramagnetic and diamagnetic separate say particles by using a high intensity wet magnetic separation.

Now, these non magnetic particles are zircon and rutile. Now, how do I separate them? Now, I want to use a electrostatic separation. Now, for effective, increase the effectiveness of electrostatic separation they have to be dried, so you use a dryer and then you pass it to a high tension separation, based on the conductivity of these two the rutile is a electrical conductive material. So, I get a rutile and zircon to be separated here. Similarly the illmenite and monazite are the magnetic particles and you dry it and you put it into high tension separation you get it illmenite and monazite separation. That is how you are getting rutile, zircon, ilmenite, monazite, magnetite and quartz they are all separated garnet they are all separated.

This is only the simple representation of this actual flow sheet it is much more complex than that. But here what I wanted to so, that you do not have any liberation problem they are already liberated. So, you do not need a combination circuit. So, mineral processing separation does not always mean that you should have a combination circuit.

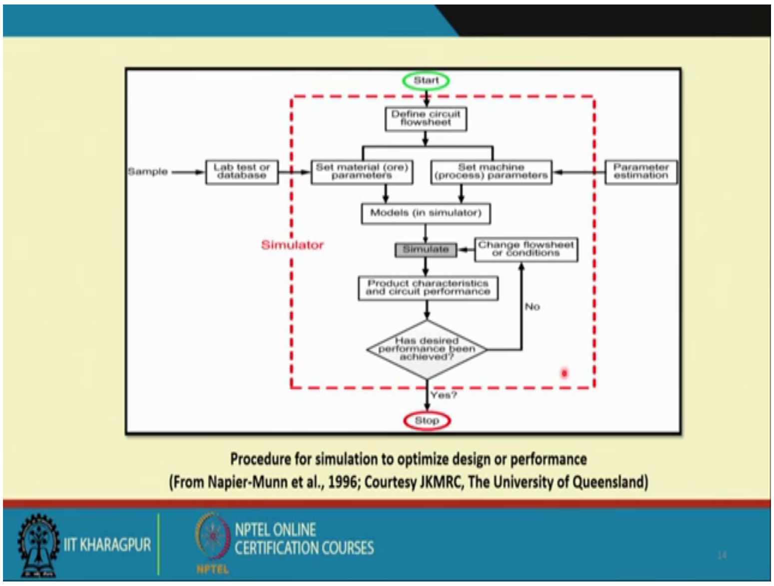
(Refer Slide Time: 32:41)



Minerals	Raw Sand (%by wt.)	Concentrate (% by wt.)
Heavy Minerals	20	90
Ilmenite	9	50
Garnet	6.0	25
Rutile	0.4	2
Zircon	0.3	1.5
Sillimanite	3	8
Quartz	79.5	10
Others	1.3	3.5

Typical example of mineral composition of beach sand if you are interested to know, heavy minerals are around 20 percent in a raw sand in a concentrate it is around 90 percent, and you have got the different proportions of the your ilmenite, garnet, rutile, zircon, sillimanite and quartz and others are like that.

(Refer Slide Time: 33:05)



So, now, this is my last slide of this lecture and it normally the modern days what people are doing and is you have to optimize so many things in your mind. So, you are going for your commercial softwares, professional software is developed by many educational institutes. One is the developed is very popular software and it is called J K Schnitt, by the J K Marc Julius Kruttschnitt, Mineral Research Center in Australia under the University of Queensland.

And what do they do that is you have a simulator that defines circuit flow sheet that is you want to have you want to test the different flow sheets that which circuit will give you the best. And based on that you put it into that your condition that is the parameter set by the machine and parameters set by the lab test for databases, and then you try to simulate and you see the product characteristics and circuit performances, if they are not optimized they are not giving ad optimum your performances then you change the circuit flow sheet. And once you are satisfied with the performance then you freeze the flow sheet. So, that is how the modern days the flow sheets are being designed to treat difficult ores, difficult low grade ores.

So, the use of this software can only be advised once you are very familiar with the basic principles of mineral processing, and you understand each and every processes quite well. I hope you enjoyed this course thoroughly I would like to get the feedback from you, be honest in giving your feedback so that the course content can be improved and the subsequent year. So, when we they throw it for the students and other industry people you can give me suggestions that, these are the parts where it needs maybe a little bit of improvement. So, I look ahead to have more interactions with you at different some higher different your media.

Thank you very much.