Introduction to Mineral Processing
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Lecture - 53
Flotation

Hello welcome back. So now, we will start another new topic which is probably the most important separation process for minerals. This is called in general flotation because earlier it used to be called froth flotation, but there are now many other say actually the various designs and the radius techniques are also adapted that is why I prefer to use it as a general term called flotation.

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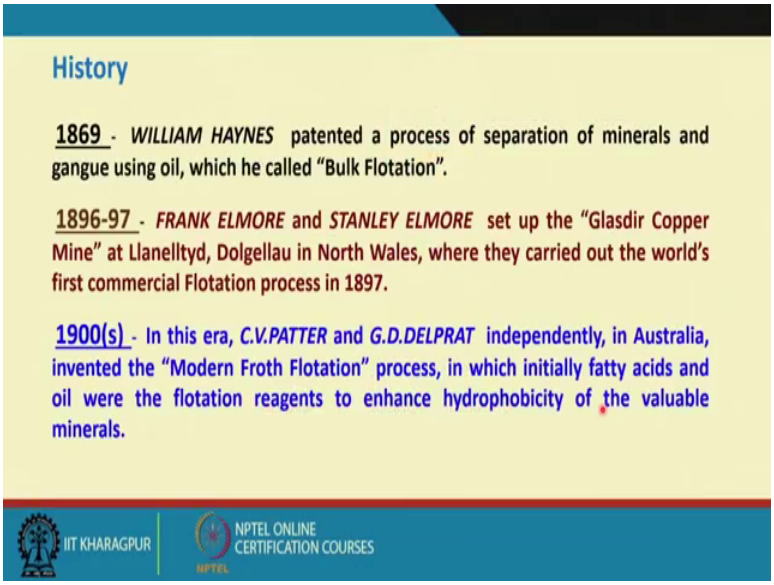

If you look at the history of this in 1869 William Haynes patented a process of separation of minerals and gangue using oil. Now, you see that so far whatever we have discussed about the separation processes, they are based on the principle of primarily based on the size and density and fundamentally they are based on the movement of solids in fluids with some additional your forces or maybe some kind of your design, features that how will you collect the product, how will you say increase the this settling phenomena are all sorts of things.

This is entirely a different phenomena that it is primarily based on your, the surface chemistry-based phenomena that is, when two particles they have a your differences in

their surface chemical properties that is your surface properties based on the your; So, that is called up your flotation process.

So, here you see that what it is saying that William Haynes patented a process of separation of minerals and gang using oil; that means, you added some chemicals that oil in general we call it chemical. So, which he called bulk flotation so the flotation name was first given by professor William Haynes in 1896 to 97 another two scientists Frank Elmore and Stanley Elmore set up the Glasdir Copper mine at Lentil Feet, Lanelltyd Dolgellau in north Wales where they carried out the world's first commercial flotation process in 1897.

So, this was the basic invention and this is the your commercial operation; however, in 1900 a C V Patter and G D Delpart independently in Australia invented the modern froth flotation process. So, these two are generally called the inventor of the modern froth flotation process; in which initially fatty acids and oil where the flotation reagents to enhance hydrophobicity of the valuable minerals; before we get into the next slide let me explain you otherwise you may be distracted and what happens when you have a very fine particle size ranges why should you have very fine particle size ranges.

Now, as the great of the minerals that a grade of the ores is deteriorated over time; It demands that your liberation size becomes finer and finer now most of the minerals these days they are liberated below say 100 micrometer sizes most of the cases they are below even 60 micrometer sizes or maybe below 40 micrometer sizes.

So, at those sizes it is very difficult to have a separation based on their size or density. So, in that case this new technique was adopted that is if we put water and if we try to mix them into a water some surfaces of the minerals or the ores the water gets easily attached to some surfaces it is very difficult that water gets adhered to.

So, when the surfaces they are having a liking towards the water; that means, the water gets easily adhered to the surfaces of the ore particle we call them as hydrophilic particle and when the water gets repelled from the surfaces to get adhered too we call them hydrophobic.

But many times, these differences in their relative hydrophobicity is not that obvious. So, what do we do we try to add some fatty acids or says in simple terms let me some oily

material. So, that this oily material sit on your targeted material particle surfaces, and which will make the particle surface hydrophobic that is the and then what you do that is, once you have a separation between the two particles based on the hydrophobicity and hydrophilicity, then by some intelligent means; if you have that to take them out in the separated stage then you can have a separation possible even at that finer size ranges.

And how we do it, what are the chemicals we add, when do you add, what are the effects of different chemicals, what are the machines we use, what is the chemistry part of that, what are the design part of the different machines these are all the subject matter of this your lecture series on this topic called Flotation.

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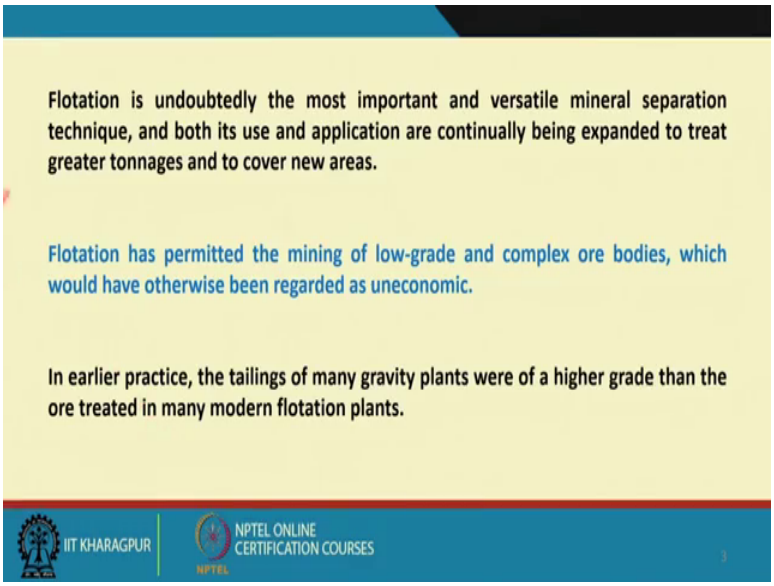

So, flotation is undoubtedly the most important and versatile mineral separation technique. And both it is use and application are continually being expanded to treat greater tonnages edges and to cover in new areas. Set aside the mineral part even if you look at that your some other application that is in place of minerals in some other areas also I will explain you where are those even the flotation technique is being used for separation between the two phases.

Rotation has permitted the mining of low grade and complex ore bodies which would have otherwise been regarded as uneconomic. If you remember that your consideration for your economic efficiency which tells that; your ultimately what is the contained value

per ton of your material and what are the cost of the processes of extraction that is that includes starting from mining mineral processing metallurgical operations and all this.

Now, what is happening? When as I said that normally we have seen that as we go down the seam that is when mining as bed of your particle layers that is your ore bodies how they are formed they are having a beds. So, when you are going down the arc cross that is if you going deeper and deeper, whatever you are mining they are having lesser and lesser quantities of your wanted materials and it is almost true for almost all the minerals now that demands when the it is low grade; that means, essay content is a very less.

So, in most of the cases it demands that it has to be ground to very fine particle sizes. Now, the gravity concentration technique fails to do that that we have explained that it has got a upper size limit the below certain size limit the efficiency drops significantly. So, the entire process becomes economically not viable.

So, if this process was not invented maybe the mining engineers would not have thought of mining such a low grade and complex ore bodies, many times as the grade may be good, but the way it is distributed across the matrix of a mineral that again it demands that very fine grinding. So, this is what I try to say that floatation has even permitted the mining of low grade and complex ore bodies, which would have otherwise been regarded as uneconomic that is would not have even mined them.

In earlier practice the tailings of many gravity plants; that means, what we are throwing out as a tailing of a gravity concentration process that your gravity concentration process cannot process it further because of their finest were a much higher grade than the ore treated in many modern floatation plants.

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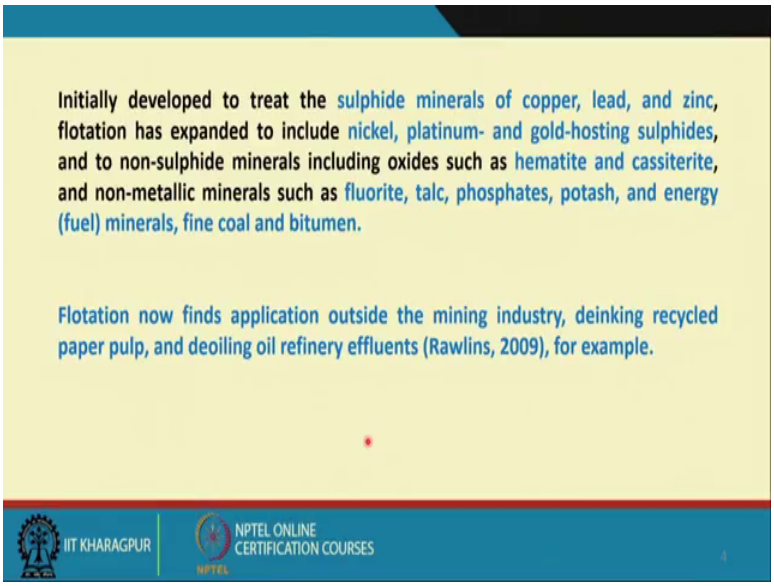

So, it was initially developed to treat the sulphide minerals of copper lead and zinc this was primarily developed targeting the processing of mainly copper and then also lead and zinc.

Now, the flotation has expanded to include even nickel, platinum and gold hosting sulphide minerals and to non sulphide minerals including oxides such as hematite, cassiterite and nonmetallic minerals such as fluorite, talc, phosphates, potash and energy minerals like mine coal and bitumen we can add many more.

Flotation process now also finds the application this is what I was just mentioning; that outside the mining industry like deinking of recycled paper pulp that is when you try to recycle your papers that is, used papers. You will have some inks into that how do I take out that ink this is why are again the flotation process is being used. And Deoiling oil refinery effluents and this is main sent by these gentlemen Rawlins in 2009 article and these are 4 examples.

So, what I try to emphasize upon here that what is the importance of this process what to the modern mineral processing engineers or the scientists who are busy in this field or maybe dreaming of a future giving up having a future in this area that, without having much knowledge in froth flotation or the flotation process in general, you will probably not called as a good mineral processing engineer, and this is why; I want to spend a say

more time on discussing this aspect that is a forth flotation process in subsequent lectures.

Although it is a very fast subject these days; So, I would try to just brief you about certain aspects of this process which I think that in this introductory course it should be told.

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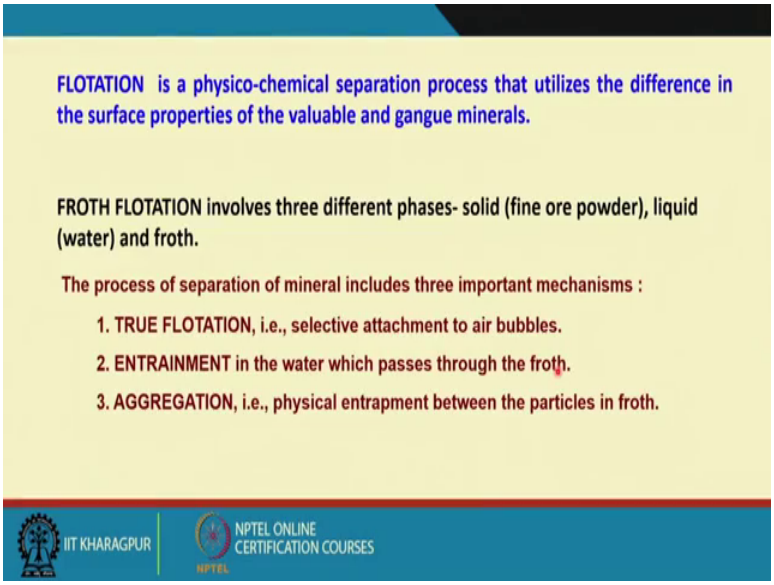

So, as I said that flotation is a physical chemical separation process that utilizes the difference in the surface properties of the valuable and gangue minerals. Earlier we have seen that we are trying to separate the valuable and gangue minerals based on their size means is the hardness or maybe some other properties that is your we say it will based on size or density. Here we are trying to utilize the differences in that physical in their say surface for properties into the surface chemical properties we say.

So, how do we do it and what are those surface properties we try to exploit that I will explain to you. Froth flotation involves three different phases that is solid that is, your fine your ore powder or maybe fine ore particles liquid that is your water and a froth phase froth phase means it is a you have got solid particles you have got water, but in that froth phase you have got air bubbles and you have got some kind of your oils and all this.

So, it is just like your foam type of material that is when you are cleaning your clothes with some kind of detergent what you get that is your some solid part is solid particles like in the form of dirt's. And then your air bubbles and then water also so that is called a froth.

The process of separation of mineral includes three important mechanisms. One is called true flotation I will explain it later on that is, your selective attachment to air bubbles that is what happens once I have made them one particle group as your hydrophobic another particle group is hydrophilic. Then what we do? The particles which are hydrophobic they are generally arrow feeling.

So, we try to pass we try to generate in C 2 some air bubbles and this hydrophobic particle gets added to these air bubbles that is surface of this air bubbles and because of your natural burn see the air bubbles try to rise up to a vessel and then they have on the top layer that is the froth phase and then we try to take out those froths and the air bubble when they passed because of the atmospheric pressure and many other reasons and then we take out that we collect we recover those particles separately. I will show you in subsequent pictures and the diagrams that how it is being done.

So, one is called so when the selective attachment to air bubbles that is called the true your floatation; that means, the bubbles or the particles which are hydrophobic they will selectively get adhere to the bubble surfaces selectivity means the particles which are hydrophilic they should not get adhered to the particle bubble surfaces so; that means, only your hydrophobic particles are being lifted up by the air bubbles there is a process called entrainment in the water, which passes through the froth; that means, when the water is also I said that in the froth phase you have got water also.

So, when the water is going up because of certain disturbances you have created in the water bodies in a vessel. So, these water will have certain amount of rising velocity. So, some particles may also get entrained in the froth phase along with the water these are little bit complicated thing I would try to explain you a bit on this later on. Then there is another process called aggregation that is the physical entrapment between the particles in froth that is the particles who are already there and the froth phase has been developed and they are just entrapped there they are just entrapped into that your phase.

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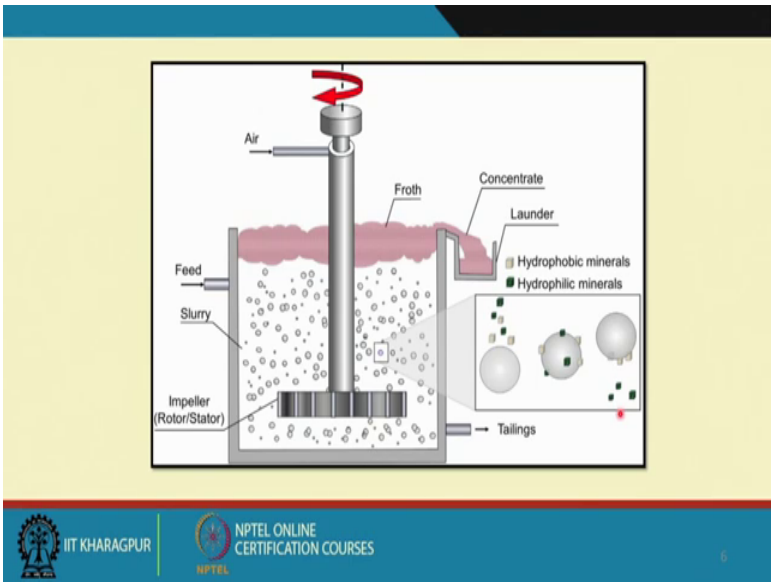

So, with this diagram I would like to explain you a bit that is what is this process and how it is being done. See this is a suppose we call it a froth flotation cell and here you have got a feed in the form of again the particle mixtures that is your wanted and your unwanted and your water. So, you have feeded here and that is your slurry now so that is your feed in the slurry form it is there. And you have got some with this feed material you also add some chemicals here that is say suppose there is some oily material oil oily type of material you have there.

So now you have got an impeller here and that impeller rotates. So, when the impeller is rotating. So, it is creating a motion to the entire your slurry and that slurry and because of that the particles will not settle because of their masses. So, you are trying to create a turbulent atmosphere here so that; the particles are not allowed to settle because of their size and density that is because of their masses.

And the another purpose is that stirring that the particles are homogeneously mixed or the dispersed into the slurry stream inside the container inside this vessel that is your flotation cell. Now, what we do this impeller many times there this part is made hollow and the impellers also they have got perforations and you inject air at certain pressure. So, you are rotating it and you are passing air at certain pressure.

So, when you are sending pressure air at certain pressure and this air we try to go out through this your yours perforations what do you have into the impeller blades.

Now, when this is a air compressed passes out through this impeller blades automatically there will be some bubble formations of various sizes air bubble formation of various sizes. You have feed the slurry along with or you may have added some chemicals here to make some particles intentionally those surfaces hydrophobic as some particles are inherently they are hydrophilic. So, what will happen? This bubbles because of the your pressure difference because of the burn see they will try to go up retaining their your say bubble shape and the bubble structure.

So, when this particle try to bubbles will try to go up these hydrophobic particles they if they if they get added to the surfaces of the bubbles and the bubbles get start getting concentrated on the top layer of this that is how a simple if you are washing your clothes in a washing machine. So, that is say your rotation that is basically you can say that that is the your like your impeller and that is where, basically you are rotating and in then because of the rotation you are creating some kind of your vortex flow. And there you have got entrained air and that entrained air is basically generating your air bubbles.

So, here you are you are just trying to push some air at certain pressure inside that. So, that the air bubbles are formed and you see that on top of the your washing machine that there will be some foam formation and similarly on top of these your fluid layer you will find that there is a froth layer we call it froth layer it is like almost like a foam. So, what is this froth layer consists of now. Now, this froth layer is having the air bubbles you have got the water you have got the particles which are hydrophobic particles and we will have some kind of your oily materials also what you have added.

So, this froth layer mainly consists of air bubbles water and the hydrophobic particles. Now we should have some kind of your mechanical arrangement that to remove this froth because the froth if they are too viscous it is very difficult to have a your to let the froth move, but you have you can if you know that how to control the viscosity of the froth layer.

And then if you have some mechanical means; suppose a scrapper and you are just scrapping it out and then collecting this froth separately into a launder so; that means, you have collected. Now, your hydrophobic material here and while transferring your some of your air bubbles will automatically be burst, will automatically burst and because of the consistent air pressure atmospheric pressure you have because of many

other reasons. And he will be now collecting your much lesser quantity of water than what you have feed, because the water at the top layer will be very less because you are having a thick froth layer and then you have got the particles and now you can. So, basically you have concentrated your hydrophobic particle now into this launder.

So, you have got a (Refer Time: 25:19) and you have left your hydrophilic particle inside the your flotation chamber. Now you should have some means of taking out your hydrophilic particles from the container to make it the continuous process. So, this is how this is you can have some kind of opening here through which you can take out by some means the your hydrophilic particles. This diagram I would like to show you say suppose how the particles get added to the bubble surface and how they are transported. Suppose, this is the lighter colored is representing the hydrophobic minerals and the darker colors they are representing the hydrophilic minerals.

So, initially when the air bubble is formed maybe the selectivity is not there maybe the both hydrophobic and hydrophilic particle they may get added to the surfaces of the bubbles because it depends on; what is the volume percentages of the bubbles you have generated. So, and they know what are their sizes what is so; that means, what is the surface area of this bubble you have got in relation to the particle surface area you have inside your froth flotation cell.

So, when the bubbles are getting adhered particles are getting adhered to the surfaces of this bubble. Now, the bubble has to rise from here to here. So, there is some time left within that time if the hydrophilic particles or hydrophilic minerals they will get dislodged from the bubble surfaces. And ultimately when the bubble has reached to this stage that is your froth stage most majority of these hydrophilic minerals they will get dislodged and they will come back to the flotation cell. And that is how you are selectively carrying upward the your hydrophobic minerals.

So, this is in sort how it works, but when I have described it you have understood that how difficult it is to control everything. What are the things we have to take care of? That is, first thing I will start with that is says suppose the impeller at what RPM it should be rotated, what should be the design of my blades and then at what is that air pressure I should have? What should be the your dimensions of my perforations that is about this your impeller and your air and all this.

Then how do we control the bubble sizes and their size distributions; How whether we need more stability or less stable bubbles because if they are too stable what will happen when they are not disclose. So, I will be having a much thicker froth layer which would be difficult to take it out

So and then how do I make the particles hydrophobic and hydrophilic selectively? How do I ensure that only hydrophobic particles are say reported in the froth phage? So, all these things create the problem or the is the challenges to the mineral processing engineers that; how do I perfect it and this is what I am going to talk in detail that what are the various aspects.

So, there is a machine design aspect, there is a chemistry related aspect, there is a bubble phase related aspect, then the material characteristics the reagents what we should use. And then how we will be collecting the products that is your from the froth phase as well as from the your flotation chamber, these are all like your the finer details of this process which we will talk in subsequent lectures till then.

Thank you very much.