Clean Coal Technology

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Week-03

Lecture-11

Hi, I am Professor Barun Kumar Nandi, welcoming you to the NPTEL online certification course on clean coal technology. We are in Module 3. In this module, we will discuss various coal cleaning methods. So, in this module, under the various coal cleaning methods, we will discuss various industrial methods or practices used for cleaning coal or beneficiation of coal, for both larger-sized coal particles as well as finer-sized coal particles or coal fines. For larger-sized coal particles, typically jigging, dense media, spiral concentrators are typically used for the larger or coarser-sized coal particle processing, whereas froth flotation, oil agglomeration, and similar methods are used for the finer-sized coal particles. Apart from these two methods, there are also some biological or biochemical coal cleaning methods involving microorganisms, as well as different chemical coal cleaning methods using various types of inorganic chemicals. for cleaning coal to remove mineral matter as well as sulfur from coal. So, we are in the topic of coal cleaning methods, Lecture 1. So, jigging or jigs are primarily used for washing coal. These jigs are typically low-cost equipment used in many coal washeries, particularly for non-coking coal. It is mostly used for coking coal as the primary cleaning method, and further cleaning is done by other secondary methods. In non-coking coal, mostly jigs are used as both the primary and secondary coal cleaning methods in jigging. Here, jigging of coal or mineral beneficiation techniques, in these techniques, we separate coal particles using their specific gravity. So, as we have discussed in our previous lectures or classes, during coal cleaning, some parameters are identified for coal with higher particle density as well as lower particle density. So, in this method of jigging, we use differences in their specific gravity and, accordingly, using their differences in specific gravity as particles—some particles are heavier and some are lighter in nature. So, using any suitable fluid medium, like air or water, or it can be any other third liquid or similar suspension, which will act as a medium to enhance the differences in the properties. And we use the pulsating force to create or provide additional external forces so that particles segregate by their gravitational force or by their specific gravity into two or three different fractions. Primarily, during this jigging process, coal is crushed to a lower desirable size. This lower desirable size depends on the industrial scale where it is used. If we are using it for ROM coal, a large amount of ROM coal cannot be crushed to a very small size. Typically, at the initial stage, some jigs are used which handle coal particles of around 50 mm in size, and further, in a secondary unit, coal particles of 25 mm or 12 mm in size can be used. So, initially, coal is crushed to a lower desirable size

depending on the requirement as well as the coal properties and is fed to one unit that has some oscillating motion based on the equipment. These oscillating motions are used in this jig. This oscillating motion is created by any nearby equipment, which will generate some oscillation movement in the water, air, or similar fluid medium—whatever is used. So, basically, in any equal medium, some water will be present. So, water will be given some pulse like this. So, using the pulse, some coal particles will try to move upwards, and then, next time, they will move downwards. This type of oscillating movement or oscillating motion is created from external sources using some air or any other mechanical-based equipment.

So, what happens during this oscillation? From the bottom of the coal bed, a suitable liquid, typically water, is used as it is widely available, cheap, and a non-corrosive liquid or fluid medium. But any other fluid can also be used. As it is on an industrial scale, water is cheaply available almost cost is zero or very minimum cost is there. Mostly water is used. But in theoretically, we can use any other fluid medium. to improve the efficiency of these jigging methods as density of water or density of fluid also plays an important role during this jigging. So, from the bottom of the coal bed or maybe top of the coal bed. Some suitable liquid mostly water is pulsed to move up and down. So we try to whatever the water level is there we try to make it upwards and downwards. So that water will create some oscillating motion. So, whatever the coal particle that oscillating motion will be transferred to the nearby coal particles. So pulsating fluid will have some kinetic energy causes coal particles to move upwards. So initially coal particles will try to move upwards and during the next cycle of pulse. When we off the pulse coal, particle will try to settle down in a fluid medium and that settling will be based on their settling behavior or settling velocity. So here this settling velocity or settling behavior, we will be trying to modify using the different coal particle, different fluid medium etc. and due to their differences in the settling behavior, heavy particles which having higher particle density they gets higher amount of gravitational force they try to or they settles quickly in the lower part whereas the lighter coal particle they will stay in the air or they will stay in the fluid or water for the longer time like if we see this particular schematic diagram of this equipment here what is happened initially water particles at this level waters are at this level and from outside we add the feed coal and there is some piston is fitted. So, this piston will try to move both in direction sometimes upward and downward direction. So, if we put this piston to downward direction. what will happen this entire water or this entire water will go to the upward direction and while this piston is off, then it will try to go back to the previous position. So, by moving this piston upwards and downwards, we will create some pulsating motion like this and that motion will be transferred to the feed coal particle.

So, here a piston and water system are used to create this pulse. And this pulse can also be created by any other equipment or mechanical devices, etc. So, what will happen to this coal particle here? So, if we see initially, this coal particle will have some white particles, or these

particles have some other density. These gray or black color particles have some other particle density. So, they have different coal particles of different sizes and particle densities. And if we see, whatever is entering at this point, you can see this coal particle will try to get, and they will get this pulsating motion from the water. So, as this coal particle is getting a pulsating motion, this coal particle, by this action of force, will try to move up. So, all these particles will try to move up due to this pulsating motion. When these pulsating motions are present, all the coal particles will move in an upward direction. So, the entire coal particle may be coming to this particular position. Now, when this pulsating motion is off. When this pulsating motion is off, that means the piston will come back to its original position, then what will happen? As there are no external forces acting on this coal particle, the coal particle will try to settle down on its own. So, what actually happens to these particles is like that. There are some coal particles there, and initially, through some pulsating motion, we give some force on these coal particles.

So, coal particle will come to like this position. and once this force gets withdrawn or force get zero then this particle will try to settle down and come to its original position. Now when they are trying to settle down what parameters are important if coal particle mass is higher, coal particles volume is higher, coal particle density is higher. So, if coal particle has higher volume that means it will have higher particle density or higher amount of weight. So gravitational force acting on this particle. So, this gravitational force mg will be higher if coal particle volume is more or if coal particle density is more. So based on their gravitational force or mass of the coal particle or volume of this coal particle. So, this coal particle will try to settle down and they will try to come back here. So, after one cycle, we will get it that that heavier size or bigger size coal particle which particle has got higher amount of gravitational force. If coal particle volume is more it will have higher amount of gravitational force , if coal particle has higher amount of density. It will also get higher amount of gravitational force whereas lighter coal particle or smaller volume coal particles, smaller size coal particles, their gravitational force will be less so settling velocity for this smaller size coal particle will be less they will take much more time to settle down whereas the bigger size coal particle or heavier coal particle will try to settle down quickly or easily. As a result, what will happen is that after some cycle we can see that the bigger size coal particle they will come to this particular location because they have got higher amount of or this coal particle has higher settling velocity. So, they will come to the bottom layer of this particular location whereas the lighter coal particle will be remained in the top layer. So, this until and unless these pulsating motions are goes going on. So, due to this pulsating motion if we continue it for a certain time maybe one minutes two minutes or five minutes depending on the design or depending on the properties of coal if we continue this pulsating fashion motion for longer time. Ultimately, we will find it that heavier coal particles settle down at the bottom of the layer and lighter coal particle will settle down at the top of the layer. So, we continue it for certain fixed time.

So, after this time is over, we can find it that all the heavier coal particle they settle down at the bottom and lighter coal particle will settle down at the top of this particular container. What does that mean? Lighter coal particle means their specific gravity is less. So, they will have less amount of ash, higher amount of GCV. Whereas this bigger size coal particle or higher density coal particle means they will have higher amount of ash or lower calorific value. So in this way we can arrange this coal particle in each and every layer which will continue. Until and unless we get desirable amount of separation. After the separation, desirable amount of separation is achieved based on some preliminary experiment. Entire equipment or entire process works either on continuously or maybe in a case of batch equipment, it works for 2 minutes, 3 minutes, 4 minutes and other similar times. So that we will get a complete separation.

In terms of they will come to an individual layers of cold particles. So, these properties we can further describe here. So, in the next if we continue from the previous one during the next cycle or particle, particle settle down in the fluid medium based on their settling behavior and heavy particles quickly settle down and lighter particle takes later. So, in the next proceeding session similar phenomena occurs and particles settle down as ascending orders of their specific gravity with lower specific gravity coal particles at the top and higher specific gravity coal particles at the bottom as Coal of high ash or GCV varies. As coal ash or GCV varies with the specific gravity, clean coal is separated from the desirable layer. So ultimately, after some process, we have to identify some cut density up to which specific gravity we will take coal or we will consider coal as a clean coal. So, we can separate in layers and separation, this oscillating motion separates the bed into layers of different densities with heaviest particles at the bottom. So, overall if we see that initially the raw coal can have at this particular shape. After this pulsating motion going on or this Jigging motion goes on, we will get coal particle with the specific gravity light as coal particle density will be at 1.3 at the top.

Then continuously it will increase so then we will get in between we can get 1.35 1.4 like this so what we will get it there like 1.3 next will be 1.31, 1.32 in this way it will go and finally in this layer we will get coal particles of 1.4. Then we will get specific gravity of coal particles of 1.5 ,1.6, 1.7, 1.8, 1.9 etc. Then we can Identify suitable location or suitable cut density from where we will collect this entire material as the clean coal. So, this data up to what specific gravity we should cut that information we will get from the possibility curve or possibility analysis. So, after this Jigging is complete for 5 minutes, 10 minutes or whatever. we have to identify up to what depth of this cut whether we should cut at this point or whether we should cut at this point. If we cut it at this point maybe we can get like 18 percent ash. If we cut it at this point we may get some 10 percent ash and if we cut at this level we may get like 27 percent ash. Here we can get about 30 percent ash. So, in this way, coal will be arranged with increase in the specific gravity from top to bottom. So, overall jigging is very efficient method if coal

particles are crushed to desirable size. Typically, water is mostly used as a beneficiary method. Sometimes, dry or using air beneficiation is also done. In some cases, if we can use the dry beneficiation or air beneficiation method, advantage is that We may not require water as a liquid so we can save large amount of money in terms of cost of water as well as we don't have to treat the water use after this beneficiation. After this beneficiation process what happens actually is that some of the mineral matter as well as the hydrocarbons from the coal which are soluble in water they go to water phase. So, water will have different amounts of contaminants either from organic contaminants like benzene and other compounds will also be present in water as well as some of the inorganic salts whatever is soluble like sodium chloride, sodium sulfate, calcium phosphate etc. They are also get dissolved in water so whatever water used in this beneficiation method that needs to be treated before discharging it to the river or nearby water bodies or they have to be recycled back. If we use air such system or such method is not required we can easily recirculate the water. Second is that if we use water coal gateway and they may get some as some of the hydrocarbons get soluble in the water.

Coal calorific value or its quality some minor decrease in quality may be observed because we are using water and some of the compounds from coal is getting dissolved in water. Nowadays for better efficiency for clean methods, people are preferring some air or dry beneficiation method but as in the air density is very less compared to water. It will take lot of time to settle down but people are trying with both or in industrial scale both weight beneficiation method as well as dry beneficiation method both are used but mostly weight beneficiation method is used as density of water is on higher side. So as density of water is higher, we can easily modify the settling behavior of the whole particle by modifying the density of water and if we see compare this method operating cost of this method is comparatively it is cheap or it is very less compared to any other method. As we are not involving any type of major chemicals in this method, so there is no cost of chemicals involved in this method. As well as we are only doing some physical activity or it is only some physical coal cleaning is there, only using some equipment and fluids to arrange the coal or get the clean coal, overall operating cost of this cleaning is very less. And only cost of water, its treatments, its beneficiation is only involved and cost of electricity and equipment are only there. Overall cost of beneficiation for this is very less. That is why it is mostly preferred as the primary cleaning method in most of the coal washery. And if we use higher other high-density liquid or suspension they also can be used if we try to modify the settling characteristics because settling characteristics of particle in fluid medium is largely depends on the density of particles as well as density of the fluid medium so here density of the particle like density of coal and density of water is involved there. So, and their differences the density of coal particle minus density of water. This is the main driving force here for separation of these coal particles. So, if we want to modify or if we want to improve the separation characteristics if we want to try to modify the settling characteristics of this coal particle. We want to try that settling may be done very quickly or we want very slow

slightly depending on our requirement cost etc. We can use any other high-density liquid or low-density liquids anything we can use as per our choice based on the economics or the process. So that by modifying the density or using other density liquid, we can modify the settling behavior of the particles and we can design our equipment accordingly. Several industries plants they use this method and there are almost all the coal cleaning plants or all the coal washery, we can find that this method is used either as an only primary method or maybe combination of primary and followed by a secondary coal cleaning by other method. So, in most of the industries we can found this jigging as the one of the coal cleaning method and equipment design and capacity can be easily modified based on the coal properties as well as the feed coal size and there is different type of jigs are available that we can change the design of these jigging equipment depending on the requirement or the plant requirement. The different types of jigs are available like this in this case of jig only we create the pulsating motion by this piston here we can create some air chamber which will be acting or controlling by some air valve through some compressor so that will create the pulsation motion here. Here we can similarly by this piston clears the pulsating motion. There can have other type from the bottom side also we can create the pulsating motion so that coal particles in this layer they can get arranged.

So, this, and even from the water, can be given here so that lighter coal particles can come to this side also. So, we can get separation of coal particles in this way also. And particularly in this design, if you see, we send the pulsating water from here. There is some piston and screen here. So, whatever the lighter coal particles and heavier coal particles are there, if lighter particles go there and we allow the water to flow through this, so lighter coal particles will try to move and even go to this side. So, we can even get the lighter coal particles on both sides, where we can get the heavier coal particles from this side. So different designs are based on the requirement or based on the particular type of coal. Different designs of equipment are available in this batch scale.

Even in the continuous scale, these jigs are also used. Like from this side, from the bottom side, we create a pulsating motion and we continuously send the coal and water slurry. What will happen is that coal and water slurry will come from here, and from the bottom side, we create the pulsating motion. As pulsating motion is there, as well as flow, basically water will have velocity on this side as well as it has velocity on this side for gravity force as well as this is the velocity based on the velocity of water. So as a result, tangential coal particles will move towards this, and whether coal particles will move towards this or could move towards this depends on the density of coal particles. If the mg value or mg force is higher, they will try to easily settle down, and if the mg force is less, then it will go almost towards this velocity direction. So, in a continuous system, these pulsating motions are created at this location. So,

through this screen, we can easily separate the lighter coal particles from the heavier coal particles in the other direction. So, there are different designs of jigs available worldwide.

And the spiral concentrator is also another equipment which is used in many coal industries for processing fine particles. If coal particles have density or size smaller, they have to be treated in a different way. In the case of spiral concentrators, these devices are used to separate solid components of a slurry based on a combination of solid particle density as well as the particles' hydrodynamic properties. So here, one type of spiral design is there. So, coal particles are fed from the top, and they can move across this spiral design. And this coal particle or slurry—because if the coal particles are of 0.5 mm or nearby that size—they create some slurry. So, this slurry will be fed from the top side, and during this rotational movement, it will be getting both the centrifugal force, gravitational force, and all types of similar forces acting on this slurry. So, coal particles with different specific gravity or different Mass they will act differently in this spiral concentrator. So initially, fine coal particles are mixed in water to create a water slurry. The slurry is sent from the top of the spiral concentrator through a pump and is released from the top side. As the slurry flows downward, particles get separated from the slurry depending on their settling velocity and centrifugal force. Whenever these particles start moving there, whenever they come to this point, whenever they are moving in this direction—downward—they experience gravitational force as well as velocity, resulting in centrifugal force in terms of mv^2/r. So both forces will act on these coal particles. Depending on the centrifugal force and gravitational force, individual particles will segregate into lighter coal particles and higher-density coal particles because gravitational force and centrifugal force will differ. So, as it moves downward over a longer distance, particles get separated from the slurry depending on their settling velocity. Lighter particles take more time to settle and mostly move toward the outer side, and centrifugal force will also act on them. So, heavier coal particles move along the inner line of the spiral, and lighter coal particles move toward the boundary of the spiral because heavier coal particles experience a greater gravitational force. After traveling a significant distance—such as 10, 20, or 50 meters, as it moves in a spiral—separation of lighter and heavier coal particles is achieved, and they can be collected as two or three products from the bottom. So, at the bottom, we can separate them into two or three products. This is the actual design of the spiral equipment. As it moves down, this part contains slime—low-density particles—while this part contains higher-density coal particles. For this design, lighter-density coal particles move toward the boundary, whereas heavier-density coal particles move toward the inner line. And if we see this particular design, this one correspondence to the high-water region, to region of maximum velocity, this region will have the maximum velocity. This region will have the separating zone, this particular distance after travelling distance. So, after travelling from this distance, we can see that particles have been segregated based on their density we can get it. So, segregation of dense particles, we can get it here and segregation of super concentrate or higher density particles we can get it there. So,

by this way, we can separate these particles and this is also used in other mineral processing also. So, equipment is on the design is similar in all the cases. So, process down from the spiral separation of particles occurs according to their specific gravity and the heavier particle or the reject coal progresses to the inner line and lighter particle forced towards the outer line along with most of the water and lighter coal particle at the bottom of each spiral layer they are separated and they can be adjusted ensure that optimum recovery and valuable iron coal particles.

So, both this spiral concentrator as well as these jigs both are used in coal particle or coal processing or coal beneficiation units. Typically, jigs are used for the bigger size coal particle as their pulsating force can easily act on this and bigger size coal particle can easily settle down. So, we can get very good amount of recovery or separation of different density coal particle. And this spiral concentrator, this is mostly used for the fine size coal particles. As fine size coal particle has higher difference in their settling velocity. So, as their settling velocity is less, they cannot be easily separated from this jig. So, jigging, we cannot easily separate the fine coal particle. They will take lot of time. So, through jigs, we cannot separate the fine particles.

So, for that only, we can use spiral concentrator and even within a small height, even within a span of small height of 10, 15, 20 meters or 30 meters, particles can move a distance of 15, 20 or maybe 100 meters depending on the design of spiral. As well as we can change the inclination of this spiral, like whatever the angle of inclination is there. Whatever the angle of inclination is there, we can easily modify it based on the design of these coal particles. Like if coal particles are very near density coal particle, but if we still want a very good separation efficiency, we can change this inclination like this inclination whatever is there. This particular inclination, this inclination path, this part we can make it like straight, we can make it like more sharp, we can make it like in this way, so we can change the inclination of this spiral to get separation efficiency as per our requirement so both spiral concentrator as well as jigs are used. They are doesn't involve any type of chemicals or others. Only some cost of pumping and water is there in both the methods that's why they are called the physical separation method without involving any chemicals which will chemically react with the coal particles. As a result, their major advantage is that their cost of this coal cleaning or segregation of coal particles is very less so that we can match the cost of higher-grade coal even after beneficiation. Like if we beneficiate the low-grade coal of maybe grade 5 which is of inferior coal , if we want to improve this grade to up to grade 2 and considering this price difference between grade 2 and grade 5 whatever the cost involved by this grading and that we can be easily make up by this type of physical separation process. So, what finally we get it that We can have the ROM coal or coal. We get it from one coal as the clean coal which will have less amount of ash and we will also get some tailing or reject coal of Higher density.

Intermediate density particles we can also get from the spiral if we create an intermediate point for collection. Like in this design, if we collect it from this point and center point and other point. So basically, from these different points, we can collect it in the jigs so that we can get different density coal particles. And we can easily get 2 products, 3 products, 4 products as per our choice from this spiral concentrator.

Thank you.