Clean Coal Technology
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Week-02
Lecture-07

Hi, I am Professor Barun Kumar Nandi. Welcome to the NPTEL online certification course on clean coal technology. In module 2, we are discussing coal cleaning. Today is lecture 2 of module 2. So, we will continue from our previous class on coal cleaning. When we clean coal, there are various considerations that are taken into account during coal cleaning or coal washing. The first consideration is that the properties of coal vary with the specific gravity of coal. For example, if coal has a lower specific gravity, then its ash content is less, it will have a better GCV, and it will have a higher amount of hydrocarbons. So, this is the first point to consider during coal washing: if we want to get coal with low ash, we have to select coal with low specific gravity.

Similarly, if coal has a higher specific gravity, it will have a higher amount of ash. As coal will have a higher amount of ash, it will have an inferior or lower GCV and lower hydrocarbons in combined fixed carbon and volatile material. As we have discussed or seen in the previous class, typically hydrocarbons have a specific gravity around 1.2, and the mineral matter-rich material has a specific gravity around 2.6. So, in between these specific gravities, coal properties, coal GCV, and coal ash content will vary. So, we have to identify any suitable cut-off material. Specific gravity like 1.5 or 1.6 is used to achieve the desired coal quality as per the industry's requirements. So, the main purpose of coal cleaning or coal washability analysis is to identify the suitable cut-off ash or GCV, which is required and indirectly derived from the cut-off specific gravity of coal. Like in any industrial application, we need a particular calorific value of coal. Suppose ROM coal has an ash percentage of 35 percent. In our application, we may need ash of 30 percent. So, we have to reduce the 5 percent ash from the coal. To achieve this 30% ash coal, we first need to identify the corresponding specific gravity of that coal for 30% ash.

So, we first need to identify that cut-off specific gravity at which coal will be washed or separated from the other high-ash coal. So, for this purpose, different experiments are carried out to separate ROM coal based on their individual specific gravity. So, in this experiment, we separate ROM coal into different fractions based on their specific gravity, and different liquid mediums or specific gravity mediums are prepared to obtain different specific gravity coal. So, coal of different cut-off specific gravities are prepared and analyzed. So, initially, at the first stage, we have to prepare a liquid medium containing different specific gravities. These liquid mediums are mostly prepared using organic solvents like kerosene, tetrachloroethylene, bromoform, or inorganic salts like zinc chloride solution. So, these solutions—zinc chloride solution, kerosene, tetrachloroethylene, bromoform—have their higher and lower specific gravities. So, when they are mixed in a blend, particularly organic compounds like zinc, kerosene has a specific gravity around 1.8, whereas bromoform has a specific gravity of more than 2.

So, these two are mixed in different volumetric ratios to prepare individual solutions of different specific gravities. As these organic compounds are sometimes toxic, zinc chloride is also used as a replacement in some other cases. So, after preparing all these liquids, coal samples are sent to their individual cut-off specific gravities, and individual coal will be separated based on their cut-off specific gravities, and detailed plots are prepared to identify for which specific gravity what the properties of coal are. So, these plots are where, with cut-off specific gravity, their coal properties are analyzed. So, this detailed analysis is called the washability analysis. So, for this washability analysis, at the first stage, different liquid specific gravities containing specific gravities of 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2, maybe 2.1, 2.2, etc. are prepared depending on the requirement. In some cases, intermediate specific gravities like 1.35, 1.45, 1.55 may be required. If we find that intermediate cut-off specific gravity, we want to analyze for their particular specific gravity of coal.

And for this purpose, coal is crushed to a smaller size, as per maybe in the 12 mm range, or maybe 25 mm size, or maybe 5 mm size, a suitable size is selected. So, initially, coal is crushed and it is sent to the first bath. Say, initially, we have this coal sample. Initially, that coal sample will be sent to this first bath. So this first bath may have a specific gravity of 1.3. So, what is the role of this specific gravity solution of 1.3? That if the solution's specific gravity is 1.3, any material lighter than 1.3 will float on the top side, and anything heavier than 1.3 will sink. So, it is like its density is 1300. If any material or any coal-containing particle is there where the specific gravity is 1200, then it will float. Whether its density is 1400 It will sink.

So, these things happen in the first bath. So, in the first bath where the entire coal is sent to the first bath. In the first bath, if its specific gravity is 1.3, there we will have some float coal where the specific gravity of that corresponding coal will be less than 1.3. And in the sink bath, its specific gravity will be more than 1.3. So, by this way, we can separate coal having a specific gravity of 1.3 and specific gravity less than 1.3, which means it is low ash coal. So, further, this 1.3 specific gravity coal that we got from the sink is sent to the second solution where the specific gravity may be 1.4. So, in the 1.4 solution, it will have the same phenomena where any material or any coal having a specific gravity less than 1.4 will come as float, and anything more than 1.4 will come as sink. And this will continue; then further, the 1.4 sink will be sent to the second bath where the specific gravity may be 1.5. So here also, we will get some float where the specific gravity is less than 1.4, and we will get some sink material where the specific gravity will be more than 1.5. So, then it will go to the next one, maybe a specific gravity of 1.6. Here also we will get one product of 1.6 float and another product of 1.6 sink. This 1.6 sink will further go to another bath containing 1.7, where it will get 1.7 as one product and more than 1.7 as another product. So, in this sequence, all the liquid solutions are placed, and coal is flowed across the system in this way. So, crushed coal is fed to the first bath, say 1.3; we will get lighter coal of specific gravity 1.3, which will float, and the heavier coal particles of specific gravity more than 1.3, which will sink. So, both products are collected individually, and we will get one product as 1.3 float. So, the 1.3 sink products are further fed to the specific gravity of 1.4 liquids. So, lighter coal particles of specific gravity less than 1.4 will again float, and heavier coal particles of specific gravity more than 1.4 will again sink. So, both products are collected, and we will get one main product as 1.4 float coal. So, in this way, we will go for further sink floats to obtain 1.5 float, 1.6 float, 1.7 float, 1.8 float, 1.9 float, 2.0 float, and 2.5 as the residual coal.

So, in this way, what we can get is that individual ROM coal is segregated based on its specific gravity. So, if the entire coal has a mass of 500 kg, then from that, we will get individual 1.3 float, 1.4 float, and in this way, 2.0 float and 2.0 sink. So, all that means the entire 500 kg coal will be segregated into 10 or 11 different fractions, depending on the number of solutions we have prepared. And in some cases, we may find that intermediates like 1.35 are required. In that time also, intermediate liquids are prepared, and we get 1.35 float, 1.45 float, 1.55 float, and maybe intermediate also 1.325 float, 1.375 float, 1.425 float. So, in this way, we segregate the coal based on its specific gravity. And during this, like if you see in this picture, we have placed some coal samples. So, if the specific gravity of that sample is 1.5, if the specific gravity of the sample is 1.5, what will happen? Any coal particle less than 1.5, like coal particle A,

It will float there, and any coal particle having density or specific gravity more than 1.5, it will sink. So, we will separate here to get coal A particle as float and get B particle as sink. So, in this way, we will get all the previous fractions like 1.5 float, 1.6 float, 1.7 float, and others. And there can be some particles where the density will be just near the cut density. Like there may be some coal particles where the density is like 1.495 or 1.505. So, their specific gravity is just near to the cut density or liquid density, what we have used. So that this particle will take a lot of time to decide whether it will sink or it will float, and there can be that probability that either this 1.505 particle may go to the float plot whereas 1.495 particle may come to the sink plant. So, there is some uncertainty in this part. And a very minor quantity of coal particles will be there which will take a lot of time to decide whether to sink or to float. Basically, their density or their distribution of mineral matter and fixed combustible material is such that it will take a lot of time whether it will sink or it will float. So, this type of material, if present in coal, such coal is very much problematic and difficult to wash.

It will take a lot of time to wash that coal, and generally, such cut density is avoided. Otherwise, there may be errors, or there may be different types of results than what we expect. If the cut density of coal and the cut density of the liquid, as well as the coal's specific gravity, just match. So, in this case, what we plot is the type of analysis we get after washing is complete. We get individual types of coal like 1.354, 1.425, which will be their average specific gravity. We can have 1.475, and we can have 1.525. And in this way, we will get different types of coal in different shares of mass percentage. And we will get their mass percentage like only 2% mass of the coal has a specific gravity, on average, of 1.35. Only 5.935% of the mass has a specific gravity of 1.425. 19.82% of the coal will have a specific gravity of 1.475. 31.33% of the coal may have a specific gravity of 1.525.

So, when we wash the coal, we decide at what location this red line or this cut density will be. If we want that... and if we analyze their further proximate analysis, ultimate analysis, GCV analysis, and the entire analysis is done. Now, depending on that, we have to select at what cut density we will wash the coal. Like in this plot, we have seen that we have fixed the cut density like 1.5 to 5. So, any material, we will consider this material as clean coal where the ash percentage will be less than 27 percent, whereas the residual part will be refuse coal or reject coal or another product of coal which may need further washing will have an ash percentage of more than 34 percent or other. Now, depending on this ash percentage, at what percentage we need to wash the coal because some industries may need only 18 percent ash coal. So, in such a case, they will cut the coal or they will wash the coal at this part only so that only this part will report to the clean coal, and the remaining part will go to the refuse coal or the secondary byproduct of that coal. So, the purpose of this entire coal cleaning or entire coal washability analysis is to get such data, and further, we will have that cumulative mass percentage like if we cut the coal or if we wash the coal at this percentage, we will get 2.8, 2.08 plus 5.93 plus 19.82 plus 31.33. This summation, we will get or this mass percentage of coal we will get as clean coal if we wash it at 1.525 cut density. So, if we wash the coal at 1.35 cut density, we will get only 2.808% mass of coal as clean coal, and the remaining 98% of coal will be reject coal. So, the purpose of this washability analysis is to get detailed information about that at what specific gravity, what coal properties we can expect, what is their moisture content, what is the volatile material, fixed carbon, and further many more analyses are done like gross calorific value, their FTIR analysis, their ash composition, their HGI, all the properties are further analyzed depending on the requirement. So, the purpose of this washability analysis is that to get detailed information and to get the particular cut density, at what density we should cut the coal or we should wash the coal. Based on that coal properties and clean coal characteristics requirement, based on the requirement of the industry, this cut density is selected. So, this cut density may be 1.5 or 1.55 or may be 1.45 or may be 1.35. So, this depends individually on the coal as well as the requirement of the particular industry. If any industry needs low ash coal, they will select the low specific gravity medium, and if they need high ash coal, then they have to wash it at a higher part because if we wash the coal at even a lower specific gravity, the coal we will get is that the total yield. The total mass percentage present in this particular section will be very less. Like out of 100% of coal, only 5% or 6% or maybe 10% will be reported to the clean coal, which will have very good market value. But the other part of the coal, which will have 80% or 90% of the coal, will not have very good market value. So, this is also a techno-economical decision whether to wash the coal at what percentage. It will be a cut density at 1.475 or 1.425.

The entire analysis is done, which is further plotted in different ways. So, if we summarize, the purpose of this coal cleaning or washability analysis is to first determine the specific gravity corresponding to the GCV and hydrocarbon part of coal. So, we first need to identify at what specific gravity the hydrocarbon composition and GCV can be obtained, typically high. High specific gravity means high mineral matter content, as coal has a higher density, whereas lower specific gravity means low mineral matter content. Hydrocarbons have lower density, and mineral matter has higher density. So, the purpose of this washability analysis is to identify a suitable cut-off ash or GCV. We first need to identify the cut-off ash or GCV because these are the two most important parameters for selecting either coking coal or non-coking coal. If it is coking coal, typically the ash percentage is selected. Mostly, coal with less than 18% ash is used in coke making. So, any coking coal that is washed will have a cut-off ash of 18%.

Some plants also use coking coal with 16% or 15% ash in their coke making. So, the plant first needs to select the ash percentage at which they should wash the coal. So, in such cases, any coal with ash less than 15% or less than 18% will be their clean coal or main product. In the case of thermal coal or non-coking coal, GCV is the primary concern. So, they match the GCV of the coal to its specific gravity, whether they wash the coal at 1.5, 1.55, or 1.5 to 5. That is done. So, coal will be washed at a cut density of 1.5 or 1.555, whatever is based on the coal characteristics. So, accordingly, any coal having a specific gravity less than 1.5 or 1.55 will be reported or considered as clean coal, and any high specific gravity coal above 1.55 will be reported as reject coal, middling coal, or any other by-product which may need to be washed again for other purposes. And for this laboratory scale, we typically use organic liquids like kerosene, tetrachloroethylene, and bromoform as they have different specific gravities or densities. So, they are mixed in different volume percentages like to prepare a solution of 1.5, we may have to mix 40% kerosene and 60% bromoform. To prepare a solution of 1.9, we have to mix tetrachloroethylene and bromoform So, that we can get an exact specific gravity of 1.9. For this purpose, a separate specific gravity meter is also used to exactly measure the specific gravity of that liquid. And sometimes zinc chloride is also used as it is somehow less costly and easily available. So, in washability analysis, we will prepare detailed plots to get the cut-off specific gravity for the desirable coal properties. And these plots particularly cut-off ash percentage Cut-off ash with different coal properties are plotted. Sometimes ash percentage with the specific gravity, sometimes specific gravity with the gross calorific value, specific gravity with the mineral matter percentage, and many others. Specific gravity with the yield percentage, all types of plots can be obtained from this washability analysis to decide what will be the cut-off density or cut density for coal cleaning. And another concern is that this type of coal, if coal has an intermediate part or this type of coal is present, which is called the near gravity material. Like if you are using a gravity of 1.5, there can be some coal having a specific gravity of 1.495 or 1.505. So, such coal will take a lot of time. To either sink or float as their specific gravity is just exactly near to the liquid specific gravity. So actually, they will take a lot of time to settle down or to float as their density almost matches with the liquid density.

Their settling velocity will actually be very less and they will take a lot of time for settling. That's why this type of plots or this type of material is called the near gravity material and if this near gravity material is present in coal then it is very difficult to wash because even in clean coal we can have a high ash percentage or high specific gravity or maybe in the reject coal we can have a low ash percentage. So, during coal washing, such densities are always avoided. Like in such a case, if this is the matter, it may be washed at 1.51 or 1.52 to avoid such complexity. And finally, in the washability plot, we plot all these data either in the differential plot or maybe in the cumulative plot with the cumulative mass percentage. Their yield percentage cumulative as percentage cumulative other percentage are plotted. So that to identify the exact cut density of coal which should be used to get the clean coal and this deciding parameter this red line this selection criteria is important at what line we should wash the coal sometimes this washing is done even at this point if we use it for the thermal coal where 40 percent ash coal can be used But if we use it for the coking plant or coke making plant, their ash percentage is less, then we have to get the coal of 18%. Even if we want to use it for high value application where less than 10% ash coal is required, we have to wash the coal even at 11% ash. But in such a case, overall yield percentage or mass percentage reported to the clean coal, it will be very less. So, it will be finally a techno-economical decision to what cut density coal should be washed and coal should be cleaned. So that we can maintain both yield of the coal as well as the ash percentage and other parameters of the coal.

Thank you.