Clean Coal Technology

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Week-12

Lecture-59

Hi, I am Professor Barun Kumar Nandi, welcoming you to the NPTEL online certification course on clean coal technology. We are in module 12, discussing UCG, CBM, CMM, and case studies. So, in the previous lectures, I have discussed UCG, CMM, CBM, and AMM. So, in this lecture, I will be discussing some case studies where the clean coal technology concept has been used in real-time plants to reduce environmental impacts. So, let's start lecture 4 on clean coal technology with some case studies. Now, these case studies I have taken from one of the published papers in an international journal, the Coal Preparation Journal, published by Professor S. Bhattacharya and Asim Kumar Mitra. This case study was related to the impact of coal beneficiation on rail transport in India, which is the title here. Now, if we see the background of this case study, In India, coal is transported mostly through railway tracks or railway lines. A small quantity or very minimal amount of coal is transported through road transport, via trucks and other means, where the distance between coal mines and power plants is very short, within 10, 15, or 20 kilometers. But if the distance is longer, like 200 to 400 kilometers or more, railway transport is the primary medium for coal transportation. So, in such cases, the Indian Railways (IR) is the principal transporter of coal in the country.

To meet the coal demand for different power plants located across the country—from Punjab to Haryana, Rajasthan, Gujarat, Southern India, and all other regions— Power plants are located across the country. However, coal is available in very few locations, as per the location of mines—like ECL in Asansol, Raniganj coal beds; BCCL in Dhanbad coal beds; CCL in the Ranchi-based area, SCCL in Bilaspur, Raipur, and the northeastern coal fields, mostly in the Singrauli area. Some coal sites are also located in the Mahanadi coal fields and other coal mines.

So overall, from all these coal mines located in particularly seven or eight states, they deliver across all the states where the thermal power plants are located. Now, during this coal transportation, if we transport the ROM coal, run-of-mine coal, it is sent directly to the power plant. And if we see that whatever coal is ROM coal, it has higher ash content. Some of the coal has ash content or thermal quality coal. It is about 30% to 35% ash coal. And in some cases, ROM coal has fortified to 50% or maybe even 40% ash coal, which is typically higher than the usual level of 33% to 34% ash coal. So, in some cases, coal is beneficiated to improve the quality of coal delivered to the market. So, particularly in this study, that evaluates the benefit or beneficiation of coal, like the washing of coal. If we do the coal washing before transportation, how its impact will be on the carrying capacity of the Indian Railway as well as other impacts. So, typically in the Indian case, the power coal or the thermal coal used for thermal power plants is washed to a target ash content of 34%. So, this 34% ash or 33% ash is different from coking coal, which is washed at 18% or 16% ash. For non-coking coal, this target value of clean coal is around 33% to 34% ash. Unless otherwise specified, it generally provides a clean yield of around 70% to 80%. So, if the coal has around 45% or 50% ash and is washed at 34% ash cut-off, in such cases, the overall yield of clean coal is around 70% to 80%, and the yield of reject coal is around 20% to 30%. Whereas the washing is shallow partially because the mandatory use of coal only with less than 34% ash at all power stations located more than 1000 km. So, when the paper was published, that time the government guideline was that if coal has ash more than 34%, such coal cannot be transported more than 1000 km. as the environmental impact or cost is not effective to transport such high ash coal beyond 1000 km. So, during this year 2007 or 8, that time what was the government of India guideline was there, that if any coal has more than 34% ash, so such coal must be washed at the source itself, then only This coal can be transported at lower ash percentage beyond 1000 kilometers.

And if we see the distance between the coal mines across Dhanbad or Raniganj coal fields and power plant located at the Punjab, Haryana, Delhi or Gujarat, this distance is always more than 1000 kilometers. So, if any coal has to be transported from the Dhanbad, Ranchi or Raniganj coal fields to the western India, in such case it must be washed. So, in such case that guideline was that coal must be washed at the source itself and also for those located in urban and environmental sensitive location and this guideline was also important if the Thermal power plant is located nearby any big city or any some locations where it has too much environmentally sensitive is there. That means if in such locations where minor environmental pollution create will a major impact on our daily living.

So, in such case the guideline was that they must use coal of less than 34% as that means if plant is located nearby any big city or any such location which are environmentally sensitive in such case also they must use coal with as less than 34%. However, at later stage, this guideline has been modified so that this coal must not be transported more than 500 kilometers. Later government has modified this guideline by reducing this distance of coal travel from 1000 kilometers to 500 kilometers. So, Power coal consumed at the feed head and within the railway distance of 1000 kilometers at present are generally not washed. So typically, if we see that if the coal has 40% ash or 45% ash and they are within the allowable distance of 1000 kilometers, now it is 500 kilometers. Typically, they are not washed unless any power plant is located near an environmental sensitive location or nearby to any urban or very big metro cities. And particularly in the case of India, the thermal power plants are not yet inclined towards washing using washed coal. Typically, in India at present, the concept is that only clean coal is required for the metallurgical industries where low ash is mandatory for making good quality coke.

However, for thermal power plants, for non-coking coal or thermal coal, coal washing is not so popular, and in most cases, they use whatever coal is available, whether it is high-ash coal, low volatile material coal, or whatever coal is available because there are issues of supply and demand network, as well as not all the plants yet go for coal washing. So, coal washing in the case of thermal power plants is very less. And the major reason is that emission norms in India are not as strict as in most of the developed countries. If we see other developed countries in European countries and other locations, emission characteristics are very strict, and any environmental emissions from thermal power plants are strictly monitored. But in the Indian case, it is not so strictly monitored.

It is a little bit wide, and there is little restriction on the generation of fly ash. And the norms for guiding land disposal of fly ash are not yet rigid. Remember that this is the case study which was conducted in the year 2007. So, during that time, any generation of fly ash, disposal of fly ash, particularly occupying some land, was not as strict. So, any power plant could dispose of some fly ash there. However, at present days, this fly ash is also consumed or used in different other industries. And another major reason for the discrimination of thermal power plant washing is a grade-based pricing mechanism for the non-coking coal. As we have already discussed in our introductory lectures or initial lectures, in India, thermal coal is typically priced based on its calorific value. So if coal has a sufficient amount of calorific value, it will have very good value or price, although that coal can have a very high amount of ash. In typical cases for Indian coal, what is different from other countries' coal is that in the case of Indian coal, even if it has 45 to 50 percent ash, that coal still has a very good amount of calorific value, which is required for the thermal power plant. So, in the case of considering only the calorific value of the coal, even 45 percent or 50 percent ash coal is, in some cases, suitable, and always 40 percent ash coal is sometimes excellent for some power plants. That is the typical characteristic of Indian coal—that even at high ash content, its calorific value is significantly on the higher side. So thermal power plants, as they think mostly about the calorific value being important, do not bother about the ash content of the coal. So, any ash reduction or improvement in calorific value is itself not sufficiently justifiable to make non-coking coal washing cost-effective. If we wash the coal, particularly a large amount of non-coking coal, there is some cost involved. So, per metric ton of coal, some amount of cost is involved, and plant installation cost is there. That's why most power plants are not so interested in using washed coal for their power plants to improve their efficiency, particularly for non-coking coal. So, the primary requirement is that if we wash the coal, there should be at least an improvement in the grade of 2 or 3. Like if it is G11 coal, so after washing, it should be at least G8 or G9 coal. Only in such cases is coal washing economically feasible. But if there is a minor increase in the grade, like from G11 improving to grade 10, sometimes it is not economical to operate the plant.

As a result, most thermal power plants are not yet inclined toward washing coal. So as a result, in most cases, ROM coal is directly sent to the power plant, irrespective of the ash percentage. So irrespective of ash percentage, if the coal has the required amount of calorific value, this coal is directly sent to the thermal power plant. So here, the correlation is that that is, the ash percentage and GCV. If plant received that ROM coal meets the GCV criteria, they transport the coal for long distance. nearby thousand kilometers irrespective of their ash percentage and typically in Indian context the railway tracks and railway wagons are very much busy. In Indian case always the same railway tracks are used for the passenger transport for express and high-speed trains, local trains as well as the same railway track is used for transportation of goods as well as the coal. So, always the railway tracks are very much busy and similarly the availability of suitable number of wagons is also there, so they are always busy. So, the creation of railway infrastructure, land requirement and infrastructure development for separate railway tracks are very much expensive and it is also time consuming. That is the main reason or main problem with the Indian Railway which always faces issues with the availability of railway tracks. Railway tracks are always busy and wagons are also not available to transport such large quantity of coal. So, in this study, if we assume that clean coal yield is about 80%, that means if we are washing the coal, clean coal will have 80% mass and clean coal will be transported to the plant for better GCV in view of the typical clean coal of yield of 80 percent so unaltered payload part trends after the beneficiation would provide a savings in that effect of 20 percent. So, if we consider simply that if it was the coal at with 80% yield, whatever the calorific value or energy content present in 100% ROM coal, that same amount of calorific value is present at 80% mass clean coal. That means if the ROM coal, it's GCV what whatever is there that same calorific value or same amount of energy is available with the 80 percent clean coal with the similar quantity of calorific value. So, whatever the total energy content available in this coal that is same with the hundred percent that means the plant utilizing ROM coal of hundred percent mass The same plant will use now 80% coal with improved calorific value. So, whatever the energy requirement for the plant was there initially, so that will be met by this clean coal of 80% yield. So, if we consider a movement of 276 million tons of coal, so in such case savings will be 20%, that means 55 million tons of coal will not have to be transported. and which is equivalent to 41 trains per day so initially if we clean the coal so initially coal has to transport 276 million tons of coal now it has to transport 50 million tons less coal because 20 percent of the coal is kept as reject coal in the source itself so now the assumption is that in such case that Indian Railways will transport 80 percent of the coal, and 20 percent directly mass reduction will occur, which will yield that railway tracks will not have to transport 21 trains per day. So clearly, this will be a very good relief or immense relief for the saturated railway network of Indian Railways, especially concerning long-distance movement of more than 500 km. So, if Indian Railways has to transport less quantity of coal, that is 20% less, the railway tracks will not have to transport it. It will ensure that railway tracks will be available, they will be much freer and easier, and it will be a very big relief for Indian Railways. And particularly for Indian Railways, where it is transporting coal more than 500 kilometers and the distance between the coal loading point and the power station point varies from 651 to 1569 kilometers. So, the total transport output generated in terms of net transport kilometers was about 33,000 kilometers. 150 miles, and if out of 21.7 percent were attributed to the worst coal. So out of this, 78.3 percent was obtained through the movement of ROM coal. So, if all the coal is beneficiated, the savings will be 20 percent, which is more than 5,191 net kilometers. So, the cost of moving one NTKM for freight in Indian Railways is approximately 0.51 rupees.

So, at a cost of 0.51 per NTKM, the total savings in transportation cost will be like 14,025 million, so in terms of US dollars, it is about 323 million. So, if worst coal is used, whatever the beneficiation or advantage Indian coal will have, there will be significant savings in transportation cost. So, these are some of the results when the beneficiated coal is transported compared to the fresh ROM coal. For example, if ROM coal of 250 mm size is transported, and typically this is the ash percentage of the coal. In the initial lectures, I have discussed that if we increase the ash percentage of the coal, the coal particle density increases, and as a result, the overall mass to be transported increases. So, if we see the 250 mm ROM coal is used and if it is transported with 25 percent ash, then for 25 percent ash coal, it will have a density of 1503 kg per meter cube. That means an approximate specific gravity of 1.503. In such a case, the overall mass or load to be transported by Indian Railways will be like 4,904 tons. Now, if the same coal with 35% ash is transported, it will have a density of 1610 kg per meter cube. In such a case, Indian Railways has to transport a material of 5,254 tons. And if 45% ash coal is transported, in such a case, the density of coal is 1520 kg per meter cube. So here, the total mass of material to be transported is 5,613 tons. So, there is a significant increase if we transport high-ash coal. If we transport low-ash coal, the overall load on the railway tracks will be much less. And overall, the load on the railway wagons will be much less. So, the energy consumption to transport such high-mass material will be significantly less. This shows how ROM coal properties, if its ash percentage increases, impact the total mass of material to be transported and how it affects the total load on the railway tracks, which causes regular wear and tear in the railway tracks. It will change. Similarly, if this coal is washed to clean coal with a size of less than 100 mm, in such a case, we can see for 33% ash coal—that means if all such coals are washed to 33% ash— in such a case, for 100 mm size 33% ash coal, although it has a significantly higher amount of moisture, the density will be around 1524 kg per meter cube kg per meter cube and it has to transport about 4973 kg of mass which is significantly higher compared to all of significantly lower compared to these mass. So that means if we watch the coal here the 33 percent as railway tracks has to transport lower quantity of mass Because of removal of ash particles, shale and higher mineral matter rich material and improving the calorific value of the coal, so railway tracks load will be much less. Similarly, if we transport the 50 mm coal. which is of smaller size in such case if we reduce the size of the coal then the void space inside the railway wagons is much less so in the same wagons they can transport higher quantity of material so if we transport 50 mm size coal of 33 percent ash in such case density of coal particle will be 1541 and in such case overall the load on railway tracks will be 4855. So overall if we see from this particular two column in earlier case railway has to transport higher quantity of mass or material but if we transport washed coal railway tracks on the washed coal, transportation will be much less. So that is the major effect in drop of specific gravity. Because we are using washed coal, we are using mineral matter rich coal. So, in such case load on the railway tracks will be much less. So same it will improve in the railway engine whatever is used to transport this coal and other. So every in all those aspects. There will be significant savings in terms of railway engine capacity, its electricity or diesel consumed to transport this coal, wear and tears with the railway wagons and others. In all aspects, it will be very much improved. Similarly, if we see the abrasion index for the washed coal as well as the clean coal, this abrasion index is the regular wear and tear or regular damage happens to the railway wagons as well as the other material. So, if we see that for different type of coal, if we see that a float coal means it is the clean coal and if it is a sink load that means it is the reject coal or high ash coal.

So, even if you see in some cases, if we get an abrasion index at 1.6 specific gravity, if we measure the abrasion index for coal with a specific gravity of 1.6 and if we wash that coal, that means 1.6 specific gravity coal, if we wash it, For different cases like coal A, coal B, coal C, coal D, coal E, and coal F. So, this study was for the six different source coals where the float coal will have a 66% yield, whereas the sink or heavier material will have a 33% yield. And there will be a significant decrease in the ash percentage and a significant improvement in the So, in all such cases, we can see that from coal to coal, overall, it is varying, but there is a significant decrease in the abrasion index for different source coals. That means if we are using washed coal in the plants, both railway wagons, as well as all the material handling sections in coal, it will get a significant amount of a longer time period.

So that the abrasion index of the coal will reduce because we will not be transporting highly abrasive material or mineral matter-rich material that will be kept at the source itself, so there will be a significant improvement in the lifespan of the coal handling section. Similarly, this section shows the typical abrasiveness of ROM coal linked to the thermal power plant coal. And if we see the different types of coal fields like Raniganj coal fields, their average abrasion index is 18 to 26, whereas in other cases, Rajmahal coal fields, their abrasion index is such value. So, with their ash percentage, Raniganj coalfield has a typical ash percentage of 25 to 30, where the abrasion index is much less. And if we see the other source coals, where ash percentage is significantly higher, from 35 to 38, abrasion index is 40; here, 36 to 42, abrasion index is 28. Even from the different coal mines or coal seams, you can find that if the ash percentage of the coal is increased depending on the source. So, in such cases, the abrasion index value increases significantly. That means it causes much more damage to the coal handling material. So, if such coals are washed at 35% or 34%, there will be a significant decrease in the abrasion index. which will cause significant improvement in the lifespan of the entire coal handling section and others. Similarly, that means if we consider this abrasion index on the lifespan of the rake, like because there is a shortage of railway rakes to transport coal, if we increase this abrasion index, that means the lifespan in months can increase by 7%, and if we transport it, then it can be even up to 10%. That will, in terms of cost, result in significant improvement in the cost as well. So, if we use the washed coal, the railway wagon life will be much more improved as we are using less abrasive material. So, railway rakes can be used for much more time, their lifespan will be increased, and that will be a very good saving for the Indian Railways. Similarly, one example for that where some plants are using dual power plant-based dual-cycle coal washing, where the feed coal is washed to operate different types of plants. That is, one power plant near Asansol. They wash the ROM coal from their own mines. And they have both types of power plants. But in such cases, the washery cleans the coal at the mine source itself. And the mine source, where they have the coal mines, has coal which is around 45% ash.

So, at the source of the mines itself, they wash the coal. That means whatever the ROM coal is 45%, they get it. They wash the coal to about 33%, which they transport to about 200 to 250 kilometers away from the coal washery because such plants are located near Kolkata or nearby cities. So, they transport this 33% ash coal to the plant, which is located around 200 to 250 kilometers away, and the reject coal or high-ash coal, they typically run it or burn it in their FBC unit, which is operated near the plant or at the source itself. Overall, this pulverized coal power plant is located about 200 to 250 km away from the coal washery, and the reject coal is sent to the adjacent power plant. So, this power plant is just nearby the coal washery, and whatever high-ash coal or reject coal is generated is burned at the source itself so that this high-ash, abrasive material, or mineral-matter-rich coal will not be transported to the wagons; rather, it is burned at the source itself by the fluidized bed combustor, and there it produces electricity of 40 to 50 megawatts, whereas this 33% ash coal is transported long-distance to their other plants located near Kolkata and Haldia and similar locations, where it is burned at 33% efficiency. As a result, overall, if we can see that the same ROM coal, if they have to transport it long-distance, there will be some—that means if the same ROM coal is transported 200 to 250 kilometers, they have to pay much more money in terms of railway wagon transportation cost, railway transportation cost, and they will get less efficiency. Whereas, as they are transporting only 33% ash coal, there are savings in the transportation of coal as well as wear and tear of the plant. Additionally, whatever high-ash coal is generated is used at the source itself by burning it in the fluidized bed combustor and producing electricity, which is used to meet their own power demand as well as to supply to the nearby electricity grids and If we see some of the annual transportation benefits due to the washed coal in a 500-megawatt If any

500-megawatt plant uses the washed coal, then what will be the advantage in terms of transportation? So, if the coal is using G11 and they can use G12 and G13, that is washed up to 34% ash, and in the second case, it is G11, G12, and G13. So, if the coal is transported about 500 kilometers, they will have savings for G11 coal, they will have savings of about 3%. And if the coal is transported to 1000 km, for G11 coal, savings will be 11%. Similarly, for G12 coal, their savings will be 12%. And if it is transported to 1000 km, it will have savings of 38%. And in the case of coal washed at 32%, that is 2% less than the previous case.

In such cases, for G11, savings will be 7%, and for G11 over 1000 kilometers, savings will be 23%. So, they can save 23% more. Money in terms of transportation of coal can be saved if they wash the coal. If the travel distance is less than 250 kilometers, savings are 7%. If the coal travels for more than 1000 kilometers, savings will be 23%. In the case of G13 coal, savings can be up to 82%, and in another case, savings will be 70%. Thus, there will be significant savings in the transportation of coal. A lower mass of coal has to be transported. Similarly, we can also assume or calculate how it will impact the transportation of the ESP. Because the ESP is the major electricity or auxiliary power consumption in a thermal power plant, where electricity is used to capture the fly ash. Now, if the coal has a lower quantity of ash, the overall fly ash generated from the plant in terms of mass will be less. As a result, the ESP will consume less electricity, and the plant will have to handle less ash in terms of fly ash as well as bottom ash. Overall, ash handling will be significantly reduced if the plant uses washed coal. Similarly, the flue gas desulfurization unit will also be affected because the amount of sulfur released from high-ash coal will be significantly higher, as high-ash coal contains more pyritic and sulfate sulfur.

Thus, overall sulfur capture in the flue gas desulfurization unit will also be reduced. So, they will also face less load, and the operating costs for these units will be much lower. Similarly, here are some additional results: NTPC Satpura Thermal Power Station uses about 34% ash coal in their 210-megawatt unit. Their planned load factor increased from 73% to 96% when they switched to washed coal with 34% ash compared to the ROM coal they were using. After switching to washed coal, their planned load factor increased from 73% to 96%. Coal consumption was reduced by 29%. That means earlier, it was 7.77 kg per kilowatt-hour coal that had to be consumed. Now they are burning a lesser quantity of coal, 0.5 kg. 5 kg per kilowatt-hour. So, as the coal GCV is improving significantly, the percentage is less. So, overall coal consumption in terms of kilowatt per hour means coal required to burn one unit of electricity.

Earlier it was 0.77 kg. Now it is 0.55 kg. That also results in auxiliary power consumption in terms of coal crushing and coal transportation inside the plant, as well as consumption in the electricity and mill power required to grind the coal. In all aspects, they have savings in terms of 1.5% auxiliary power consumption. The mill is now operating much more smoothly. So, there is a slight reduction in the downtime of the mill because the abrasive material in the coal is less. So, mills are operating for a longer time with much more efficiency, and typically, if they are using 34% ash coal, its ignition or combustion characteristics significantly improve compared to ROM coal. So, no auxiliary fuel or fuel oil is required to maintain the flame temperature or the fireball temperature inside the plant. So, the fuel oil support has almost become zero, and boiler efficiency increases up to and coal mill power consumption also decreased by 48%.

As now the mill has to only grind good quality coal, 34% as coal compared to earlier ROM coal where a significant amount of mineral matter was present. So, the mill or the pulverizer used to grind the coal that was consuming a higher amount of electricity earlier. So, there is about 48% savings in this aspect. Similarly, this is the other plant, NTPC Dadri plant, they used washed coal around 34 to 35 percent ash. In there also, they are savings in terms of all aspects: increase in operating hours by 10 percent, increase in plant load factors up to 4 percent, and plant utilization factor is about 12 percent. Reduction in breakdown period of 60 percent, overall efficiency of 1.2 percent, and electricity generation per day is also significantly improved. Similarly, there is a significant improvement in the fuel oil required for maintaining the flame temperature. Reduction in specific coal consumption is also significant. Increase in total units sent for power is also improved. Savings in land area for ash damping is also significantly improved. And overall, there is a significant improvement in CO2 emissions also. This CO2 emission is considering both railway transportation where the coal is transported. There also, electricity is consumed or diesel oil is consumed to turn the railway as well as the coal consumption also. Similarly, another plant is also there. They also have two plants of 2 into 250 megawatts, and they use washed coal of about 33% ash. So, after using this, they can see that there is a significant reduction in ash generation, plant rule factor also increased significantly. Cost per unit also decreased by 10%. Plant availability also increased significantly. Fuel oil consumption decreased significantly, auxiliary power consumption also decreased, and power generation increased by 16%. So, in this way, we can see that overall, if we observe, any plant using clean coal thermal power plants using washed coal with about 30 to 33 percent ash content, there is a significant increase in power generation because the coal quality improves and the mineral matter quantity is reduced. Overall, there will be a significant increase in electricity generation, making it much more economical. Using cleaner fuel in such plants will significantly improve auxiliary power consumption, auxiliary fuel consumption, mill lifespan, mill maintenance, and even railway transportation. Now, they have to transport less coal, reducing the load on coal transport, allowing Railway tracks to be used for other material transportation. Thus, railways can gain an additional 7.5 to 8% increase in net capacity. Using washed coal can also reduce emissions from existing power plants by about 10%, and the combined use of washed coal and other clean coal technologies in capacity additions of 50,000 MW could reduce carbon emissions by 7.5 million tons per year. Overall, summarizing the general impact or benefit of using washed coal, we gain both indirect and direct benefits. Directly, coal combustion and other plant operations benefit; indirectly, railway transport and other facilities improve, and ash handling is enhanced. Within the power generation process, plant efficiency increases, equipment system capacity improves, auxiliary power equipment is reduced, and issues like slagging, fouling, NOx, SOx, and other emissions are minimized. Maintenance costs improve, emission-related taxes decrease, replacement power costs reduce due to unit availability and capacity building, and fuel and transportation costs decline. In all aspects, plant operations improve significantly when using clean coal and clean coal technologies in conventional thermal power plants.

Thank you.