Clean Coal Technology
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Week-01
Lecture-01

Hi, I am Professor Barun Kumar Nandi. Welcome you in NPTEL online certification course on Clean Coal Technology. In this course, we will be studying various aspects of coal properties and their impact on their coal utilization and various ways to reduce environmental impact from coal utilization. Entire course is divided in 12 different modules.

In the first module, we will be studying the different aspects of coal properties, coal quality parameters, which are important for their utilization in thermal power plant, cement plant, steel plant, DRI plant, concept and role of gross calorific value as volatile material during their utilization, and finally, types of sulfur present in coal and their impact. So, when we want to know about the coal, we have to know how this coal has been formed and their origin. Coal is actually naturally available combustible black color or brownish black sedimentary found in different parts of Earth.

It is originated from different types of plants, their branches, roots, etc. So, there are different theories describes how coal has been formed across the world. Most of the theories agreed with the concept that coal is generated or originated from the plants. Such plants were on the earth's surface billions of years ago and during some of the natural calamities or similar phenomena, they buried below the earth's surface and they get mixed with the nearby clay, soil, rock etc.

During these billions of years , such plants they undergo different type of natural decomposition process such as heat, pressure, humidity etc. along with the microbial activity this process is known as the coalification process and depending on the years present below the earth surface extent of natural degradation such fossil fuel or coal are classified in different categories broadly known as peat, lignite, bituminous and anthracite. If we want to know the origin of coal, this different theory says that in the earth surface, there was different type of trees and plants. Now, across the globe or across even in a particular country or even in a particular city or village, there are different types of trees or plants are present. Now these trees or plants, their origin or their types are different, like maybe somewhere has the mango tree, somewhere has the eucalyptus tree, somewhere has the sale tree, somewhere has the sagon tree and others. And there is also different type of maturity is there. Because the tree goes in a year by year they grow and every year some new tree grows. So, when some natural calamity was happened in billions of years ago. All these trees go below the earth surface. And as their maturity is different.

All trees have different type of hydrocarbon presence. As a result, the coal which has been formed from this tree, they can have the different type of hydrocarbon present due to their different types of trees, different species of tree as well as their maturities of the tree. And after the millions of years, there goes different type of natural decomposition. So, this natural decomposition was due to the presence of heat below the earth's surface.

Any organic compound or any organic matter if we keep on the earth's surface by natural temperature and atmospheric condition, there goes for some natural decomposition. by this natural decomposition moisture initially released from that organic matter then different type of hydrocarbon they started decompose and releasing different type of gases. As a result, different type of hydrocarbon rich compound they released from the particular organic matter and residual material they reach in carbon content and others so during coalification process. Similar thing has been happened and this happens in past millions of years or billions of years so this was caused by heat as well as the pressure from the earth surface because they go below the earth surface maybe 5 feet 10 feet or maybe more than 100 feet or 1000 feet. Due to the load or weight of the clay material on the earth surface, so it is actually one type of chemical reactions happen or chemical conversion happens by which this decomposition occurs and where this pressure temperature as well as the moisture or humidity, they act as a reactant or catalyst for this natural decomposition.

Also, some of the microbial activity was there, because in everywhere we will find some of the microorganism, bacteria's etc. So they all helps in decomposing these organic compounds or organic matter that was originally started from the trees so after millions of years so these residue has been converted to coal what we see at the present times now depending on the years of projects if some of the coal source or coal mines are of originated from five millions here or some mines can have been for 10 million years or some mines can have been there for 100 millions of years. Because this natural calamity was happened billions of years ago and no one was there to see what has been happened. So it is assumed that the different maturity of the coal is originated from the time limit, how or from what time they were below the earth's surface. and up to what extent this natural decomposition of these trees and plants has been there. So, if this natural decomposition is in the very initial phases, so they are almost like an organic matter or almost like a tree or wood, which are known as the peat. Further, if this coalification process goes on, they modified to lignite coal and in this way they become bituminous and anthracite and in between some of the stages is also available or seen in different mines like semi bituminous, semi anthracite etc. So, this process we called is as the coalification process by which this natural decomposition is occurred.

So, depending on the coalification process, at what stage this coal is actually present, we call them peat, lignite, bituminous and anthracite. If the coal is at the very initial stage or beginning stage, we call it as peat. If it has been decomposed or modified to further, we call it lignite.

Then we call it bituminous and finally, we call it anthracite. So, difference between this peat, lignite, bituminous and anthracite is their maturity. Peat is almost very much similar to like a woody biomass, where we can see the different type of layers of woods are there and it contains large amount of residual moisture as it is like that and wood. In case of lignite amount of moisture is little bit less but overall, it is on the higher side, and in bituminous and anthracite it is on the lower side. In case of anthracite, very less amount of moisture is there as it is assumed that coalification process is entirely completed in this case now depending on the original plant characteristics Actual hydrocarbons present in coal are different across different coal seam and coal mines. This is one of the most important parameters for the coal. As we can see the coal properties available across the different coal mines are different. Some of the coal mines have very good amount of energy available, whereas in the other coal mines, we can see their mineral matter or clay content is extremely high. So, their main reason is that the original plant characteristics. If any tree, it was of different species like mango tree, jamun tree, Segun tree and others. So, by their origin, their hydrocarbon types are different and their structures are different. So, if coal is originated from the different type of plants,

It is expected that their final residual part, which is known as the coal, that will always have the different properties. Also, if we see the tree, the same tree available at the different parts of the world, like same Sal tree, what is available in West Bengal, what is available in Jharkhand, what is available in Chhattisgarh or North Eastern states. They have minor differences in their properties as a result we in real time we found their fruits, their leaves are not exactly of same color, same shape etc. So, it varies across the different species even within the same species depending on the source and location, these characteristics varies. So, depending on the original plant characteristics, actual hydrocarbons present in coal are different. As these hydrocarbons are different, their coal properties also get different.

Even inside the same mines, we get different type of coal seam. So, these coal seams are actually the different layers of coal, which we can see because if in a coal mines, we can see it is made of 10 meters or 15-meter thickness. But top layer may be of some different properties of coal is available. In physical observation, we see that it is maybe of deep black color, whereas in the bottom layer, maybe black color intensity is less. Maybe it is like the light black or similar color. So, this here was due to the different types of hydrocarbons as well as their coalification process. So, this coal available in the different location of the earth or even in the same city or same mines, their coal properties vary across the mines as well as across the coal seams of the mines. So effectively what this information tells is that the hydrocarbon present in each layer of coal are different. So, as their hydrocarbons are individually different, so it is expected that their coal properties will be somehow different across the coal seam, coal mine as well as the city or particular country. Now during the formation of coal, some of the clay materials present nearby the plants also get mixed. When this coalification process happens

some of the nearby clay material, it gets mixed with the woody biomass or wood now during this process as some of the clay material get mixed. So, in the final form of coal, what we extract from the coal mines, they will always contain some clay material or inorganic compounds, which is known as the mineral matter. Now, all these clay materials are mixed with the plants to a such extent that they may be or may not be separated easily. As this coal formation has been happened across the billions of years ago and across the billions of years, these mineral matters or clay matter get mixed with the wood. Sometimes it is very difficult to separate the clay material from the residual or remaining coal. Sometimes it is easy, sometimes it may not be easy. So, after the formation of coal, these clay materials remain as part of coal and we call them as the mineral matter.

Now depending on the types of original hydrocarbon present in the plant and extent of conversion during the past millions of years, different coals have different types of hydrocarbons present and that shows different characteristics during the utilizations. And all these hydrocarbons, we call it as the combustibles part of coal. So, what we understand from this discussion is that coal will have some of the hydrocarbon part which can be originated from the different types of trees or plants as well as their locations or species of that trees. So, these hydrocarbons present inside the coal will be varying or it will not be exactly same. So, the types of hydrocarbons present in this coal, we will be deciding the properties of coal and it will impact their utilization when we will be utilizing this coal. So, types of hydrocarbon present will show that some of the coal properties are not exactly same across the different coal mines or even in the same coal mines across the different seam. Like maybe top layer coal a particular coal mine, it will be very good weather is the bottom layer coal may not be of same quality, of same maturity as their hydrocarbons are different and second part is that the clay material which get mixed during their coalification process and which are very difficult to separate at present days so as this mineral matter or inorganic material they are present in coal, they will also impact their utilization characteristics like this mineral matter they have some their chemical properties. So, these chemical properties may be helping their coal utilization or may be inhibiting their coal utilization, when we utilize this coal in a particular plant. So, depending on the types of clay materials mixed during the entire coalification process, mineral matter composition, overall mass percentage of mineral matter also varies in different coal. Inorganic material present in body parts of the original plants or tree, they also contribute to the mineral matter composition. and composition of the coal.

So, what this two point gives us information is that even in the clay material there are different compositions of clay material available like soil or clay available in particular location is different from that of soil characteristics in other location. Like if we say soil characteristics in Kolkata city, soil characteristics in Chennai city, in Delhi city, in Dhanbad, they are different. So, their clay composition or soil characteristics are different. As their soil characteristics are

different, when they get mixed with the woody biomass or wood or plants, so origin of this clay material is different so the mineral matter composition will be different like some of the clay material or soil may have reach in alumina other location. It may have reach in silica may be another location. It may be reach in iron content as their mineral matter composition are different.

So, due to their change in or variation in the mineral matter composition, their utilization will also get impact. Second part is the amount of mineral matter present in some of the coal mines. We will find that mineral matter percentage is less maybe some location it is 30 percent mineral matter is there. May be another mine, it may have 40 percent mineral matter so as their mass percentage of mineral matter is different across the different coal mines. The coal properties will also get different and it is particularly very much seen in different coal seam of in a same coal mine. So, the types of clay material or mineral matter their composition is also important as well as their percentage is also important and also, some of the inorganic materials are present inside the tree. In any living body, in any living tree, there is always some mineral matter like sodium, potassium, calcium, magnesium, etc. are available at different parts of the tree and others. And for these reasons only, we take different type of fruits and vegetables in our body. We take them, we eat them. so that we get different type of minerals. So, these inorganic materials present in different parts of the trees, they also varied. What information it gives is that, that may be tree from Dhanbad city or any particular same tree from the Kolkata city or from the New Delhi city, it will have different mineral matter composition present.

As that mineral matter composition present inside any of the tree are different and they also remain in the part of this woody biomass and finally in the coal, so they also contribute to the mineral matter of this coal. So, this inorganic material or mineral matter, it can come from the external source from the clay material as well as it can be parts of the body parts of the trees or it is the internal mineral matters. So, both contributes to the mineral matter present in the coal. And apart from this mineral matter, always some of some quantities of moisture are present in the coal, which can be inherent and external moisture. During this coalification process, the different type of hydrocarbon decomposed and during this decomposition process some of the moistures are generated. So, during this coalification process at what stage this coalification process is going on this moisture content can be different. Typically, this is known as the inherent moisture which is inside part of the coal structure. And apart from that, there can have external moisture which are present in different pores and in the structure of coal, which can be easily removed or they can be easily removed by natural drying. So, these moistures are also present in coal. They can have inherent moisture as well as the external moisture.

All such material present in coal impact their utilization in any of these specific applications. So, what we understand from these discussions is that in any coal, it can have moisture content this moisture content can be inherent moisture as well as the external moisture it can have the

clay material, which can be inherent clay material originated from the body parts of the tree. It can be external type of moisture with external type of mineral matter which is originated from the nearby clay material it can have the hydrocarbons variation originated from the different types of trees and their species. So, all such materials present in coal impact their utilization or their usefulness in any particular applications.

In general, hydrocarbon present in coal are very useful part and desirable part because we use this hydrocarbon part in this coal to get the calorific value or energy content for applications. In some of the cases mineral matters are present. This mineral matter sometimes is useful and most of the cases are not useful part. So, in general mineral matter are undesirable part of this coal. We want this mineral matter to be less. In some of the cases, what we find is that this mineral matter or inorganic part also contains some of the valuable metals and others. That's why in some of the regions or some of the coal mines, these mineral matters are useful. But that is a very rare case. In general, for coal utilization, this mineral matter is the undesirable part of the coal. And we want that this mineral matter parts should be as less or as lower as possible because it is creates problem during their utilization some amount of moisture is always present in coal and this should be on the lower side is expected because this moisture content does not gives any amount of calorific value or energy or it doesn't have any carbon content so it should be on the lower side but this moisture content present in coal are also sometime useful because this moisture present at this coal structure and when they are removed around 100 degree centigrade, it creates some vacant pores so due to this vacant pores where oxygen and other reacting gases can be present and they can stay there and it improves the surface area or pore characteristics, pore surface, pore volume etc. So, it helps in reacting coal with the oxygen and other media.

So, moisture is not desirable part of the coal and actually by this analyzing this moisture content. We can also guess or get an idea about the maturity level of the coal as woody biomass or initially tree, it has the higher amount of moisture present and during this coalification process. This moisture gets reduced. They release to the nearby surface so this moisture content reduced so by analyzing the moisture. If we find that the moisture is on higher side like 30 or 40 percent moisture is there, we assume that it is of lower rank coal like it is in the initial stages of coalification process. We call it like peat and as this coalification process goes on, this moisture content reduces so we call them like in the lignite, it may be around 20% moisture is there. In the bituminous, it may be around 4 to 5% or like 10% may be there. And in the anthracite, it will be almost less than 5%. So, this moisture also gives us indication about the coalification process. At what stage this coalification process is going on. And hydrocarbon part or combustible part, mineral matter part moisture all plays important role during their utilization it is not that only combustible part is very helpful or takes role in the utilization, whenever we want to utilize it either in the steel plant or thermal power plant or cement plant

All these parts play their role either as a chemically reacting or as a physically creating some pores and others or changing or modifying the heat transfer rate and others during the utilization. So as a coal, if we see it originates from different types of trees and plants and it is sometimes of combustible a black color or sometimes brownish black sedimentary rock. So, this rock, it is like a naturally available stone type of material, we can see as we have shown in this picture. So, it is a black color or a brownish black color rock. And their maturity depends on the coalification process at what stage this coal is present. So, if this coalification process is at the beginning process, your rock characteristics or there will be different color of the sedimentary rock.

If it is at the end process of the coalification, its color or its mechanical properties, its hardness, it can have varied. So, depending on these edges or the coalification process, at what stage we this at what stage this present this coal is there coal are classified or their rank like this peat, lignite, bituminous and anthracite. Peat means it is at the just beginning stage of this coalification process. It is the coalification process; it has just been started. So typically, it will have higher moisture content and hydrocarbons present. It will be almost very much similar to that of any wood. So, it will be reached in lignin, cellulose, hemicellulose, etc. And by microscopic observation and other analysis, we can see that these types of materials are present. And sometimes, some of the scientists even does not consider peat as a coal. Second path will be the lignite coal or lignite. It will be characterized by higher moisture content. and not measuring the hydrocarbon structure, which we see in a typical coal. So, lignite is also one type of coal. It is typically not like a black color. We have some touch or background about the wood from which it has been formed. So, in general lignite is a part of coal. But in general, this lignite is one type of coal but not like a full-fledged coal. Full-fledged coal what we utilize in plants are mostly the bituminous and this anthracite.

These two coal are mostly used in the industrial units. Lignite is used where there is a shortage of coal supply, coal availability and other is there. If the coal is less, bituminous and anthracite supply is not there. Some of the country or some of the coal mines, some of the states use lignite as an energy source or as a coal. And depending on the original plant, if original plant has similar type of structure or it can have a different type of organic structure. So, when we analyze or when we talk about the coal hydrocarbon, we have to think about this entire or similar type of coal structure. So, it is like a complex hydrocarbon. It is not like a simple hydrocarbon like methane or ethane. So, in general this coal means this complex structure is present. So this complex structure we can see like there can have C100 or C200. That means there can have 200 carbon atoms inside this coal structure. This is only an imaginary concept to express what is actually coal. So, when we talk about the coal, their hydrocarbon, we have to think about that it has maybe C100 or 200 type of, 200 numbers of carbon molecules are there. And it is a complex aromatic or anthracite or similar structure, their hydrogen part will be less. Their

hydrogen will not be like c 100 it will not be h 200. It may be 5 or h maybe 10 or 15. So when we talk about the coal on theoretical aspects when we talk about this coal. This coal we can think about like it is a compound of c 100, But hydrogen will be maybe 10 or 15. So there is more in carbon content and less in hydrogen content. So, this is the major thing or most important thing we have to know or when we analyze their properties, we have to think like this. Coal means it is a hydrocarbon which is rich in carbon content but less quantity in hydrogen. If hydrogen content is different and accordingly we can have different type of coal. Like if we see in a peat, their carbon content will be less, hydrogen content will be somehow more. But in case of anthracite, it will have more hydrogen, more in case of anthracite, it will have more quantity of carbon and less amount of hydrogen is there. Whereas in the peat and lignite, there will be more quantity of hydrogen and maybe similar or nearby quantity of carbon is there. So, due to their all these variations, we can find that their coal properties, it varies.

So, what we find is that their hydrocarbon is different. That means it can have C100, H_2O, it can have aluminum, silica, iron etc. As mineral matter it will have H_2O as a moisture content. So, if we think all about this coal, we have to think about this complex structure of this hydrocarbon. So, coal is like a one type of hydrocarbon-based fuel, which has carbon content is high, hydrogen content is relatively less along with some inorganic compounds of aluminum silica iron and their salts like aluminum sulfate, sodium phosphate, silicon oxide, etc. It will have some moisture. So coal in an overall constitutes of all these mixture of hydrocarbons, mineral matter as well as moisture. So, this combustible part means we will be discussing about this hydrocarbon part which actually gives different type of energy that's why this we you call it alike and fossil fuel there will have some mineral matter which is of internal mineral matter originates from the body or original parts of the tree as well as originates from the different type of clay material. It will have the moisture which is also divided like an inherent moisture which is present inside the coal structure and some of the moisture which is part of external structure of this coal which is present in different pores of this coal. So, when we call about this coal, we have to know about all these materials present in this coal and their utilization will be based on all these materials.

So, next part we will be discussing their different aspects of this mineral matter and fixed carbon and others.

Thank you.