Iron Making and Steel Making
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Module-4
Lecture – 19
Coking Process

Welcome. This is module 4 and the lecture number 19 and I will talk about the coke making Process.

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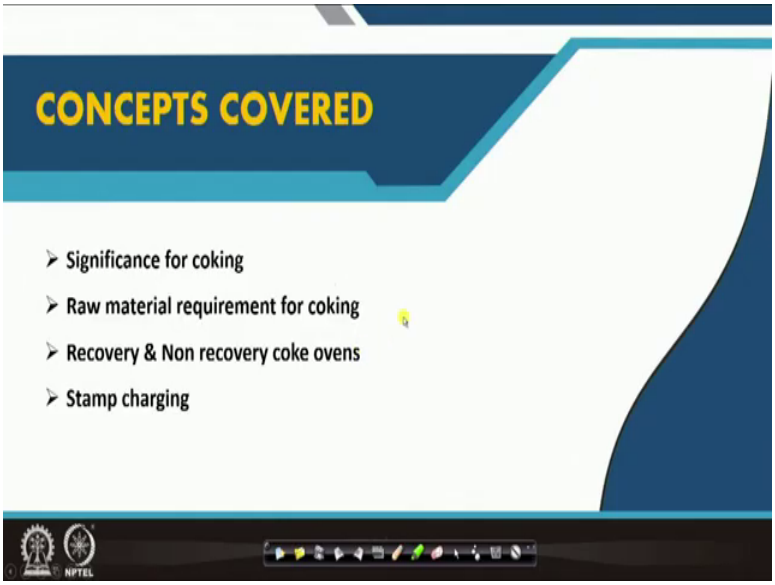

The topics that will be covered are: significance of coking, why the coke making is required, raw material requirement for the coke making, types of coke ovens, namely recovery and non-recovery coke ovens, special kind of coke making processes.

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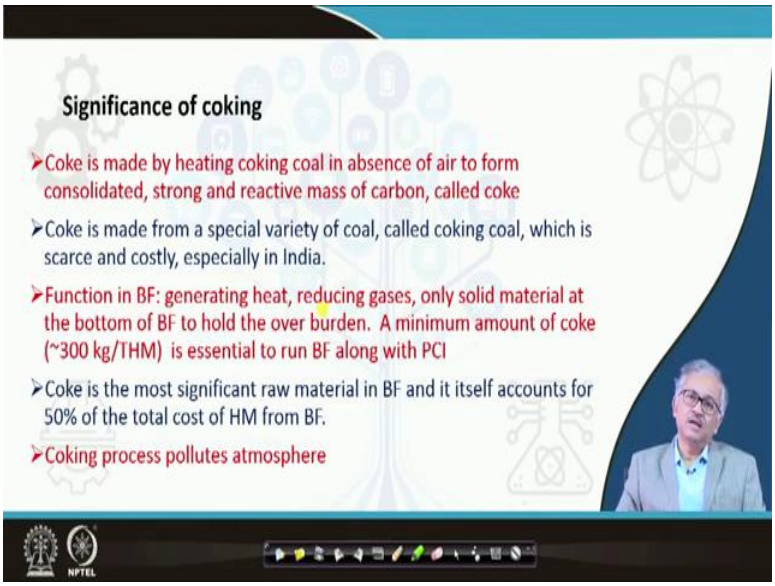

Now, let us understand the significance of the coke making You are aware that carbon is used in the form of coke in the blast furnace. and coal cannot be directly used in the blast furnace. Coke has the following functions in blast furnace: heating through carbon oxidation, producing reducing gas CO, maintain bed permeability to restrict pressure drop and furnace irregularities and finally last but not the least, the function of holding the over burden. Coal can do the first two functions but last two functions could not be performed by the coal. Since, coal is fragile and would produce dust during its descent and chemical degradation in blast furnace; it would hamper the bed permeability increasing pressure drop both in dry and wet zone of the furnace. Coke is the only material in blast furnace which is solid in the lower part of the furnace and hold the over burden through column of Deadman's coke that either may seat on hearth or float. Coal would not have sufficient strength to hold the overburden; but would crumble under pressure, drastically reducing the permeability of lower part of the furnace, restricting the movement of liquid downward towards the hearth. Besides, fixed carbon in coal is less due to presence of volatile and as a rate higher coal rate would be required reducing productivity. Therefore, coal is not suitableTo be added from the top of blast furnace. However, it is definitely added through tuyer as PCI. Therefore, therefore, coke is required and coke is made from destructive distillation of coal (heating in absence of air); where volatile matter from coal is removed leaving a hard and reactive mass of carbon called the coke. After volatile removal, coal char particles get fused and welded to each other forming the hard mass. Of course, ash is retained in the coke. Therefore, ash should be low in coal (not exceeding 15%).

A special type of coal with optimum volatile content is required to make the coke, called coking coal.

Coking coal is very scarce over the world and specially in India. In India, we have only 6 billion ton of reserve for prime coking coal and total 32 billion ton of coking coal including semi- coking coal. So, coke is very costly and as you have mentioned cost of coke constitute a major share of the total cost of iron making. .

. So, people are concerned with this coke from the beginning; and as discussed before in details that different process developments in blast furnace have taken place over the years and coke rate has decreased significantly.Besides, reduced coke rate also increased the productivity of blast furnace.

And today, the the bench mark in coke rate is 300 kg per ton of hot metal and it is supplemented by 200 kg of PCI in the blast furnace.

But major problem is that coking process pollutes the atmosphere that is also another thing we have to keep in mind. That is why, nowadays people are looking for routes which are coke free alternative routes of iron making And that is why, the coking process in its present form (byproduct coking process) is not a very sustainable, and non-recovery coking process are favoured, which pollutes atmosphere much less. In non-recovery coke oven coal volatiles are burned inside and therefore, it does not have scope to atmosphere during by product generation in case of conventional recovery coke ovens.

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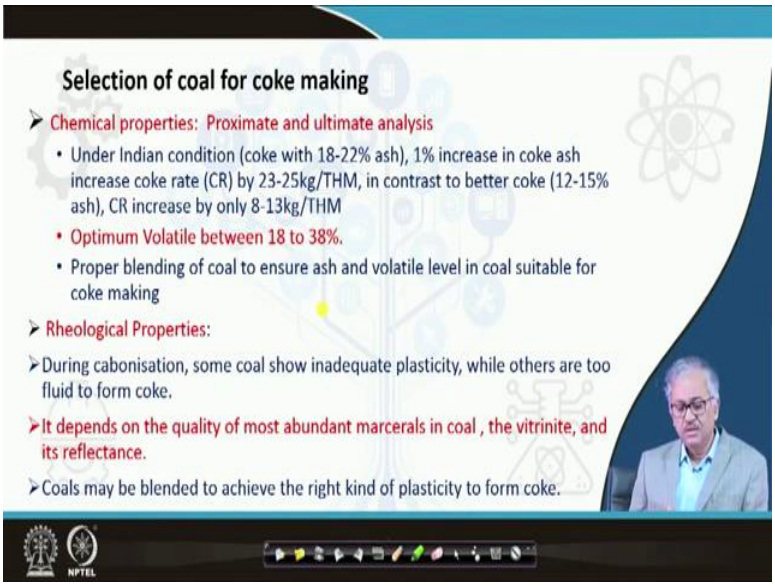

Now, let us discuss selection of the coals for coke making. What are the coals that you can use? First of all the chemical properties, i.e., proximate and the ultimate analysis of the coal.

Indian coking coal may contain ash up to 30 percent and since washability of Indian coal is also poor, after washing Indian coal may contain more than 20% ash. In India, finally coke has an ash content from 15 to 18 %, which is made after blending imported coal with comparatively high ash washed coking coal from India. Coke ash is an very important in terms of blast furnace coke rate and productivity; In this level of coke ash1 percent increase in the coke ash can increase coke rate by 23 to 25 kg per ton of hot metal. For better coke with 12 to 15% coke ash, 1% increase in coke ash increase the coke rate at a much lower level, i.e., 8-13 kg/ton of hot metal. Next important property of coal for coke making is the optimum volatile content of coal between 18 to 38 percent. If volatile is less than 18 percent (or 14 percent on dry basis) coking is not possible.

For coking, moderate amount of volatile is required. If coal have too much of volatile, then the fixed carbon decreases and then also the coking is not possible. You should have sufficient fixed carbon for making the fused hard mass of carbon, called coke. And proper blending of coal has to be there because in Indian condition, basically we usually blend the imported high grade coking coal with our medium coking coal with high ash content and then, our blending should be such that your that ash content remain low as possible

and the volatile matter between 18 to 38 percent. So, if it is high or low volatile, it is not possible. So, blending should be proper.

Rheological property of coal is also very important, that is the fluidity or the plasticity of the coke is very important. During heating, the plasticity of coke particles should not be too high; if they are too fluid, then coking will not take place and if fused char are too viscous, or, plasticity is lacking; then also coking will not take place. So, we should have some optimum plasticity; optimum fluidity of the coke particle at high temperature. During carbonization, some coal show adequate plasticity and while others too fluid to form the coal. Plasticity depends on the quality of the abundant marcerals in coals that is called the vitrinite; it is the quality of the vitrinite and its reflectance. In every coal vitrinite is there, but its composition and quality varies from coal to coal and that can be identified by checking a parameter, called the reflectance of coal. So during coal blending, attention should be paid such that the resultant coal has proper amount and quality of vitrinite that ensures optimum plasticity of the coal for coking process.

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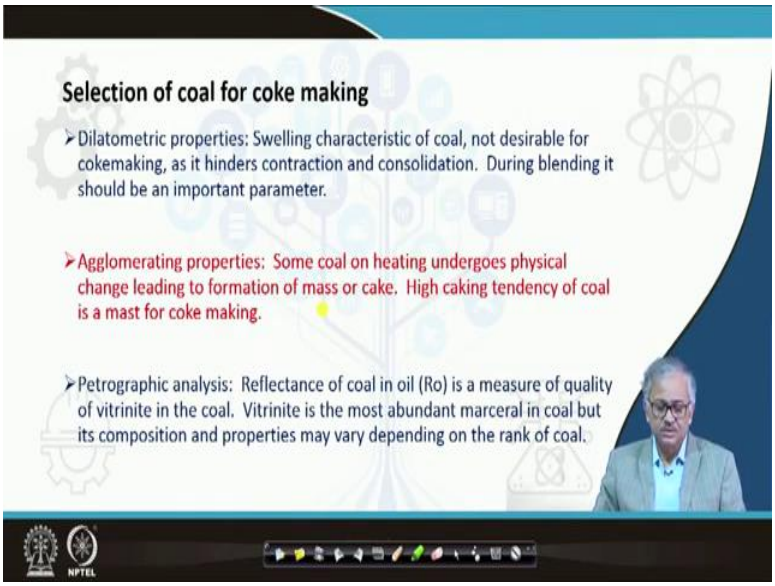
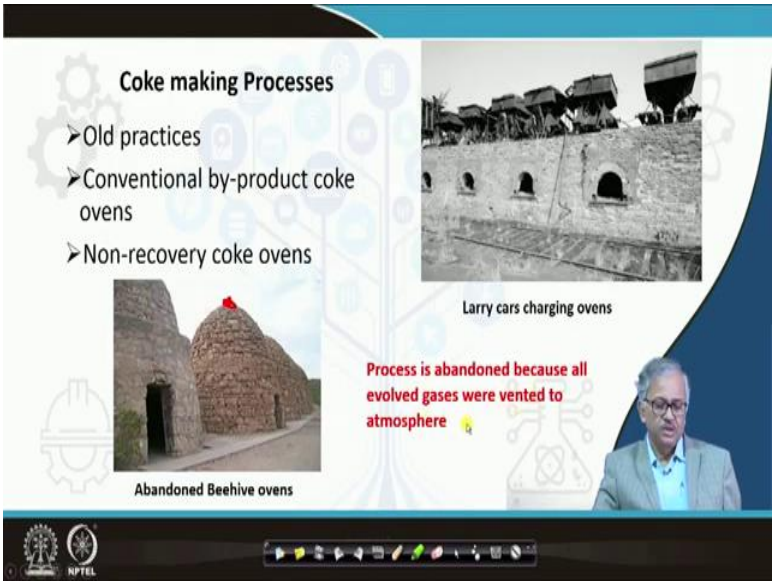


Another important property of coal suitable for coke making is its swelling property. Dilatometric test is there to measure the volume change, the swelling property..

Swelling characteristic coal is not desirable for coke making, as it hinders the contraction and the consolidation.

Then, agglomerating properties: basically, if you heat the coal, chemical changes will take place. But through physical change, some of the coal try to agglomerate into a mass or cake, called the caking tendency. High caking index coal is a must for making the coal and that also depends on the rank of the coal, quality and amount of vitrinite and its reflectance. And the petrography analysis that basically gives you the rank of the coal through measurement of reflectance. It indicates the extent of light reflection from coal surface, when light is focused on it. (Refer Slide Time: 14:28)



Let us discuss the coke making process. As I have said when coal is heated in absence of air, coal volatile is removed and then remaining coal char get fused and finally solidified in a hard mass of carbon, called the coke. We will discuss some abandoned, old practices, followed by conventional coke making coke oven battery; byproduct coke ovens, where volatile matter is processed to get various liquid, and gaseous by products. There is also non-recovery coke oven, where the raw volatile matter is completely burned into the furnace such that it does not scope to leak and pollute the atmosphere.

Coke oven gas is a fantastic useful product used in steel plant as a fuel. But, conventional by-product coke oven is not very sustainable today considering the environmental norms.

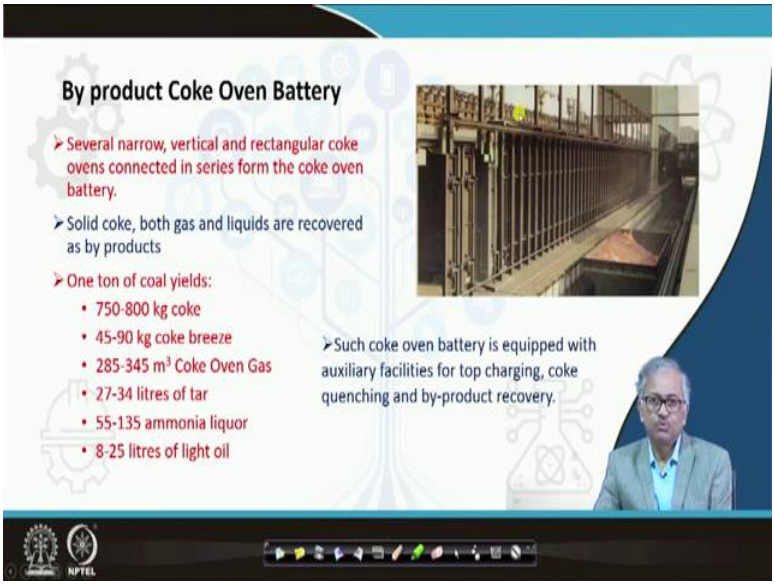
Now, let us have some look at abandoned beehive ovens (Figure 19.1)

(a) (b)

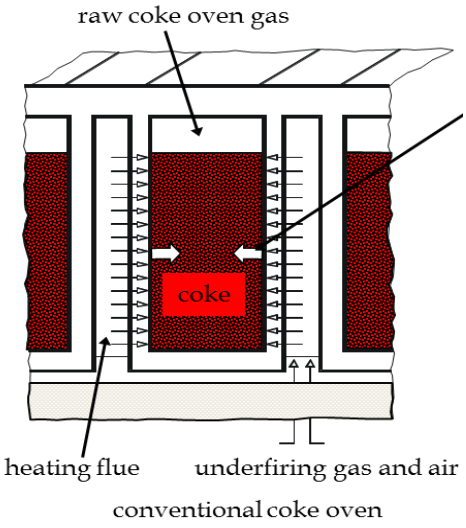
Figure 19.1 (a) Abandoned beehive oven, (b) Larry car feeding series of such coke ovens.

. The oven looks like a beehive; that is why it is called the beehive ovens. Coal is fed through a hole at the top and then oven is ignited also from the top. Obviously such dom structure limits the access of air through the small top hole only to burn the coal partially to generate the heat for coal carbonization. Exir door is located at the bottom through which coke can be taken out. Figure 19.1(b) shows how the so called Larry cars used to

fed such oven in series. Total volatile is vented to the atmosphere and pollutes the atmosphere and therefore such oven are abandoned today. (Refer Slide Time: 19:10)



Now, by product coke oven battery. It is called battery because several narrow vertical rectangular coke ovens are connected one after another in series (Fig. 19.2)



(a) (b)

Figure 19.2 (a) Coke oven battery, (b) heat transfer in by-product coke oven

. Coke ovens are heated externally by two gas fired burners on either side of the coke oven. Gas burners are also narrow vertical rectangular chamber connected to each other to utilize the off gas generating from the upstream chamber. Fresh fuel (coke oven gas) is also added to each chamber. A fraction of coke oven gas is used as fuel in the burners and

rest is used for downstream application in steel plant. Heat is generated in the burner is conducted through the bed in transverse direction. For heat to penetrate to the center and making the coking process complete across the cross section during the processing time, the thickness should be minimum.

The product are: solid coke, and both gaseous and liquid by-products. 1 ton of coal after fractional distillation yields around 750 to 800 kg of solid coke, 45 to 95 kg of coke breeze, 285 to 345 meter cube of coke oven gas, 27 to 34 liters of tar, 55 to 135 ammonia liquor, and 8 to 25 liters of light oil. So, these are the byproduct that is extracted from the coke oven battery.

Coke oven batteries are equipped with auxiliary facilities like top charging. Finally, hot coke coke is air quenched using turbo air blower..

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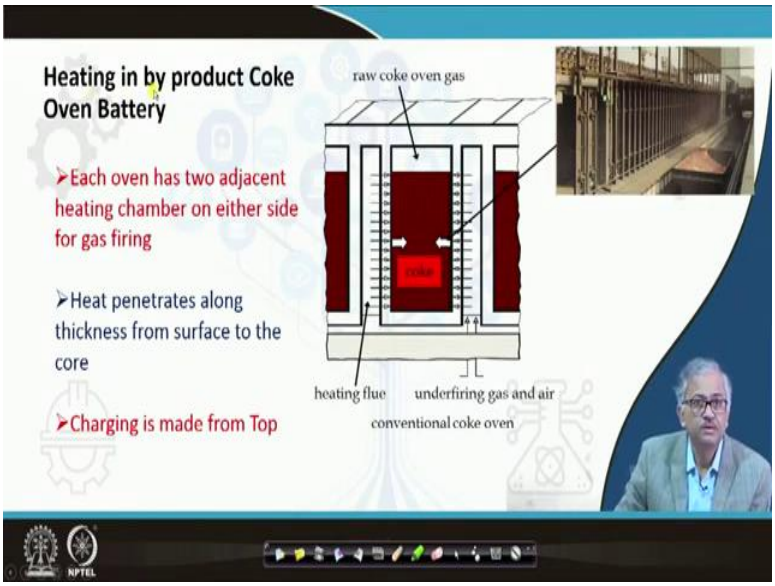

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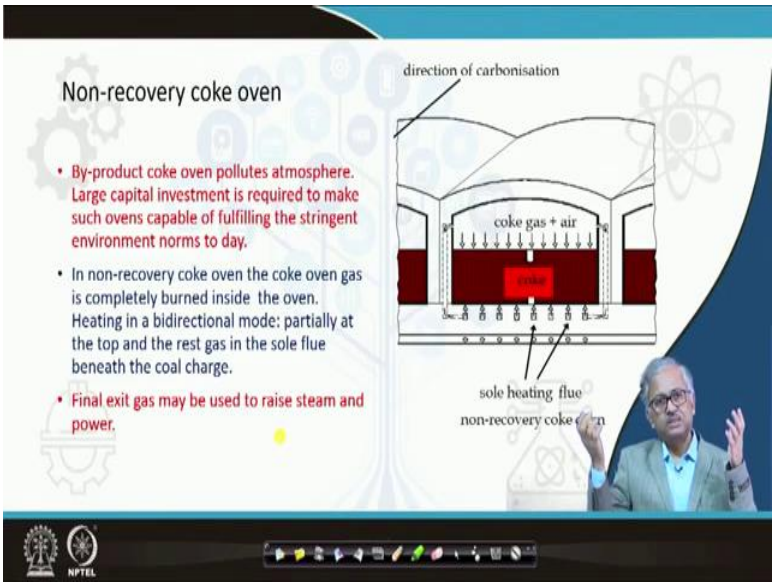

Let us now discuss the non-recovery coke oven (Figure 19.3)

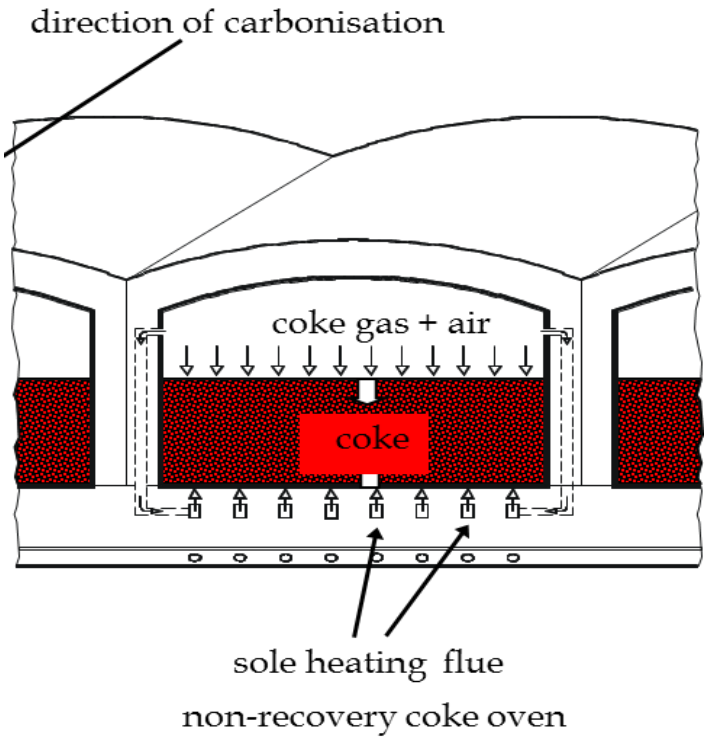

Figure 19.3 Non-recovery coke oven

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As I have mentioned that all these volatiles are burned out inside the reactor to generate heat. Here, heating of coke bed is done across depth and heated from both top and bottom. The volatile is partly burned at the top of the furnace and partly it is taken off and then, it is trnasported to the sole flue for burning those at the bottom of the coke bed and heat it from the bottom.

So, coke oven gas is partially burned at the top and partially at the bottom and thus generating heat both from the top and bottom; then the heat progress in vertical direction towards the center of the bed both from top and bottom. Therefore for efficient coke making the bed should be shallow but wide for enhanced productivity.

So, non recovery oven takes more land space. In case of the byproduct oven, oven increases in vertical direction for producing more. So, to produce the same amount of coke, non-recovery coke oven requires more land space compared to recovery coke oven. It is called non-recovery because we are not recovering the byproducts and all the coke oven gas is burned inside the furnace. But, it has been found that exit gas from non-recovery coke oven has large thermal potential considering its volume, sensible heat, and chemical heat, which can be used for steam raising and power generation, making the process profitable.

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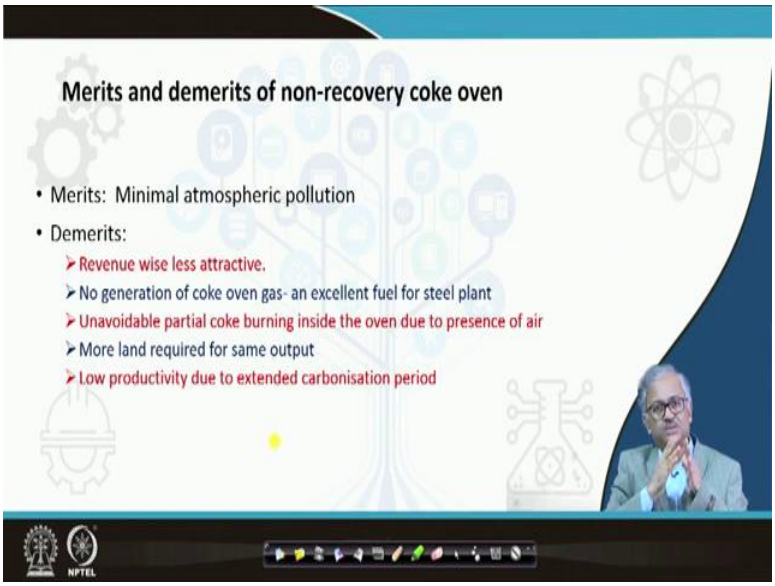

So, merits and demerits of the non-recovery coke oven. Merits is minimal atmospheric pollution. This is the advantage that is why it is sustainable and demerits if you see revenue

wise less attractive because you are not generating any byproduct; and then no generation of the coke oven gas an excellent fuel for the steel plant for downstream application. Basically, if you do not have supply of the coke oven gas, then you have to think for the fuel gas to sustain lot of process in the steel plant. So, for non-recovery coke oven to be economic and meaningful, power generation using waste gas should be taken us. Another disadvantage of non-recovery coke oven is that partial coke burning inside the oven is unavoidable due to presence of air, which is supplied to burn the coke oven gas; thai is likely to decrease the yield. Also the productivity of non-recovery coke oven is less due to extended carbonisation process, which is attributed to comparatively slow kinetics.

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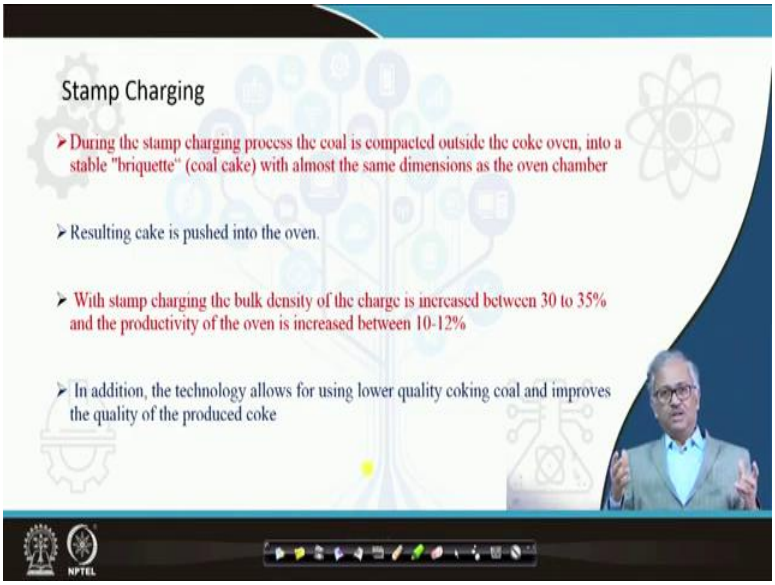
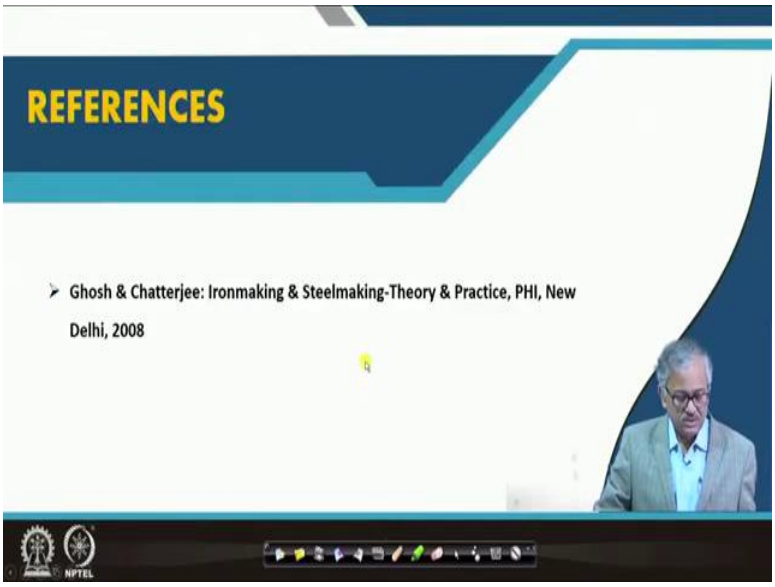


Now, another very innovative coke making process is called the stamp charging. In stamp charging, you blend imported coking coal with poor grade coking coal from India; subsequently the mixture is compressed to a stable briquette called coke cake with almost the same dimension as the coke oven to enhance the raw bulk density (by the process the bulk density of the cake is increased by 30 to 35% compared to the raw mix directly charged in the oven) and then, it is pushed into the coke oven battery and carbonization is carried out. Since, the starting material has a higher bulk density the coke formed will be much stronger, inspite of using comparatively poorer raw material. This is a patented Tata Steel Technology.

In conventional coke oven battery, coal mix is charged from the top in the oven and it remains loose with comparatively higher porosities compared to stamp charged cake. So, in conventional coke oven, to produce coke of similar quality, better coke with optimum high temperature plasticity should be provided; this invilvs better quality coal and associated cost.

The productivity of the oven is also increased by 10 to 12 percent. (Refer Slide Time: 31:23)



Ghosh Chatterjee, this is the book you can study.

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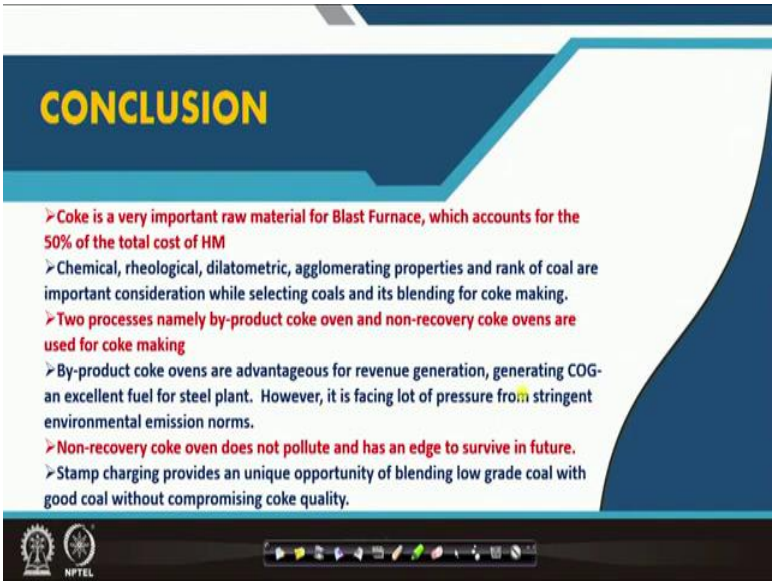

Conclusion: Coke is a very important raw material for blast furnace, which accounts for approximately 50 percent of the total cost of the hot metal production in blast furnace. Coke is produced by heating coal in absence of air and in the process coal volatile is removed and coal char are fused and solidified to form a strong mass of carbon called the coke. The process is called carbonization and coke can be made from a special variety of coal called coking coal. And while making the coke, coal should have several desirable properties of the coal in terms of chemical, rheological, dilatometric, agglomerating properties and the rank of the coal. Two major coking ovens mainly by-product coke oven and non-recovery coke ovens are used for coke making and non-recovery coke ovens are more sustainable because they pollute less. Although, by-product coke ovens are advantageous for revenue generation through liquid and gaseous by product generations, especially coke oven gas - an excellent fuel for the steel plant. However, non-recovery coke oven also becomes sound both economically and energy-wise; if waste gas is utilized for power generation.Non-recovery coke oven does not pollute much and has an edge to survive in future.

A patented technology from Tata steel, the Stamp charging, provides an unique opportunity for blending the low grade coal with good grade coal without compromising the coke quality.