**Iron Making**
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**Lecture - 29**
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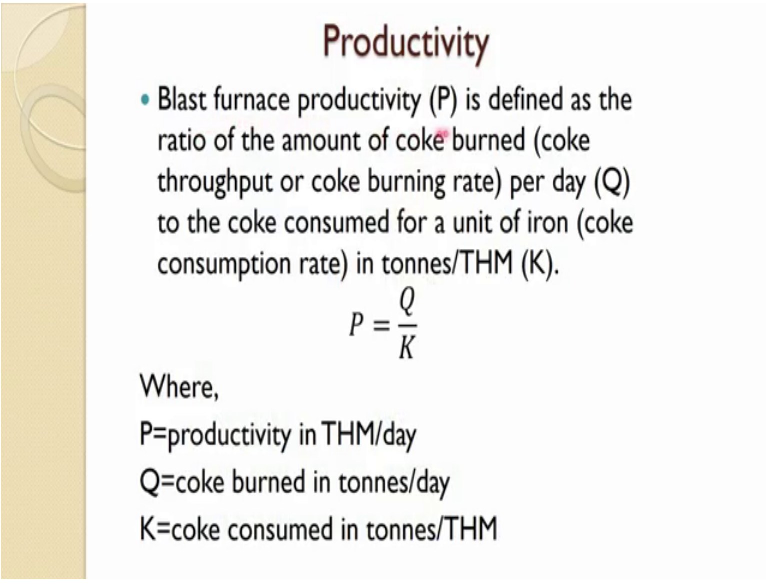


In this lectures we would be discussing about the Blast furnace productivity. So, blast furnace productivity is defined as the ratio of the amount of coke burned; that is coke throughput or coke burning rate per day to the coke consumed for a unit of iron; that is coke consumption rate in tonnes per tonne of hot metal. So, we can say P the productivity is equal to the amount of coke point Q divided by K; that is coke consume per unit of iron or coke consumption rate.

So, where P is given in tonne hot metal per day, Q equal to the coke burned in tonnes per day and coke consumed in tonnes per tonne of hot metal is given by K. There are various ways this productivity can be defined. So, this is one of the way commonly used. But there are many other ways by which it can be defined.

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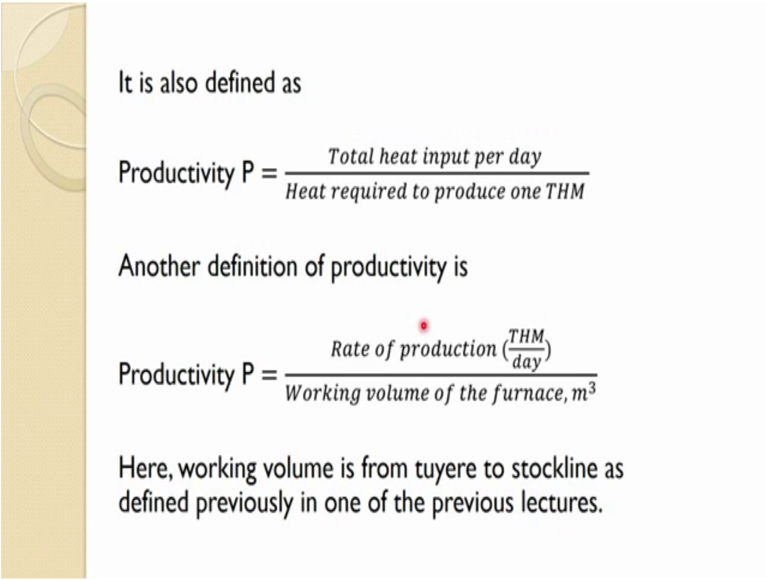


So, the other way of defining it in terms of heat input. So, productivity is the ratio of total heat input per day to heat required to produce one tonne of hot metal. So, heat input per day to heat required to produce one tonne of hot metal. And another definition of productivity is accessing is in terms of rate of forward production, tonne of hot metal per day divided by working volume of the furnace meter cube. So, when we say the working volume of the furnace, this we have defined before in the beginning of this course. As such the working volume is from tuyere to stock-line that we take in calculation of this productivity definition.

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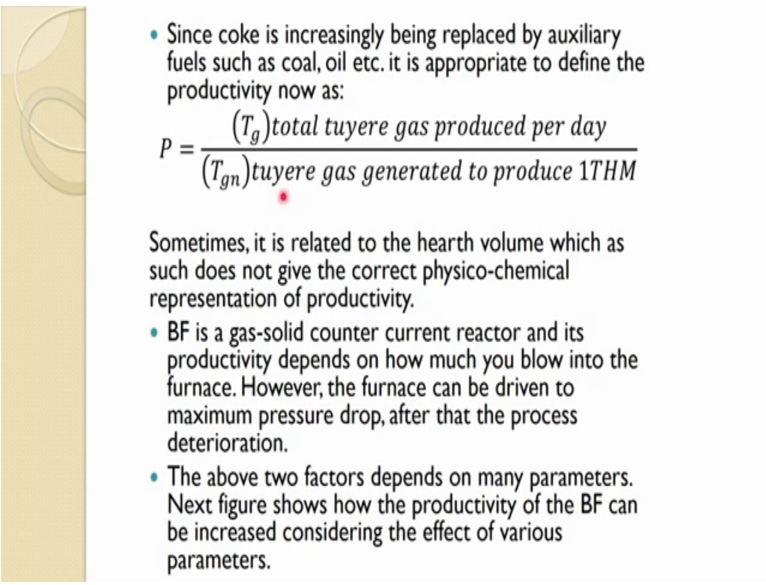

Nowadays, because we use quite a bit gas and PCI those fuel and other thing so there is another way of defining the productivity we took care of this fuel such as coal and oil. So, since coke is increasingly being replaced by auxiliary fuel such as coal, oil etcetera even some natural gases. So, it is appropriate to define the productivity now as: total tuyere gas produced per day divided by tuyere gas generated to protein to produce 1 tonne hot metal. So, it is a ratio of tuyere gas produced per day and the gas generated to produce 1 tonne of hot metal.

So, sometime it is related also to the hearth volume which as such does not give the correct physic-chemical representation of the productivity. So, there are many ways by which the as you can see the productivity of the furnace has been defined. But mostly this is a good way of defining the productivity in terms of coke burning now. Because the coke burning the now it being replaced quite a bit with a PCI of fuel and like that if that is the case then this would be a good definition of the productivity.

So, Blast Furnace is a gas-solid count counter current reactor and it is productivity depends on how much you blow into it. So, how much air actually you can blow into it. However, the furnace can be driven to maximum pressure drop and after that the process deteriorate. So, there is a maximum pressure drop across the whole furnace and above that if you keep it, then the furnace will deteriorate and your productivity will decrease.

The above two factors depends on many parameters. So, next slides shows, how the productivity of the blast furnace can be increased considering the effect of various parameter. So, as you can know there are two things how much you can blow into the furnace and the maximum pressure drop which you can reach safely without affecting the productivity. So, these two parameter, how do they get affected by other parameter we will see in this slide.

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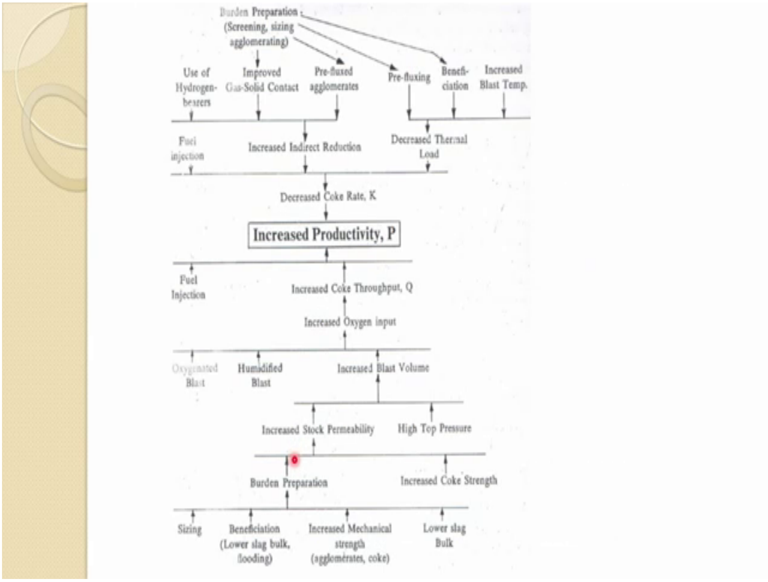


So, this is about if you want to increase the productivity then as we saw in the first definition, either you decrease this and increase Q. So increase Q means, the amount of coke burn per day that if it is increased productivity is increases or coke consumption rate tonnes per tonne of hot metal it should be decrease. Then you can get the higher productivity.

So, that is why how we can decrease the coke rate. So, it is a Burden Preparation is screening, sizing, agglomeration. So, use of Hydrogen Bears, bearer material ore, in this one because hydrogen has higher reduction potential. So, it is then beneficial it will decrease the coke rate, improve gas solid contact. So if surface area can be increased and keeping the proper size of the material. Pre-fluxed agglomerate; so you, agglomerate and use the fluxing agent. So, in that way also you can decrease the coke rate for pre-flexing use with the agglomeration, sintering and other thing.

So also if you increase the Blast Temperature, that will also lead to decrease in coke rate. Most of these factor we have discussed before. Now we are talking in terms of how they will affect the productivity. Fuel injection, of course that also again you are substituting so, that will be the fuelled. So, if we reduce the coke rate Increased Indirect Reduction. We had discussed this one in details about the contribution of direct reduction and indirect reduction in the production of iron. And what would be the optimum value of both of that. So, one can do that one and that is going to decrease the coke rate if one can achieve that optimum iron indirect reduction reaction. And so, that this leads to decrease thermal load. So, these all is going to decrease your coke rate, your productivity is going to increase.

The other end is about the P Q factor which coke through throughput which we say. So, that if we can increase Q naturally our productivity increase and how the Q is affected by other parameter? One Sizing, Beneficiation, Mechanical strength, Lower slag. Of course, sizing is very important and beneficiation is also important. If you take care at this stage you can reduce slag volume. So, you do not have to put that much as your silica or lime. So, those slag, volume also will decrease and not is only that if you decrease the slag volume, means chances of flooding would be low. And you can blow more volume in the blast furnace and that is one of the things which we had mentioned previously. So, that will help in blowing more blast furnace without getting it flooded so it is very important.

Increased mechanical strength this is by using agglomerate. And as we had discussed before how you can control the quality of these agglomerate and try to reduce the thickness of the cohesive zone and should move to high temperature zone and that will again help to increase the coke throughput. Loads slag volume we already discussed. So, this is in the burden preparation and if we can increase the coke strength this is also very important. Because coke is taking part in many thing in the reaction and when the gases reaction is occurring that time actually coke is getting classified.

So, strength becomes down become goes down. It becomes more porous and near the dripping zone and the tear, it has to go with lots of attrition and harsh condition. So, coke quality is very important. If we can maintain that we can have a increased coke throughput.

Similarly, permeability of the region, this is I do not have to emphasize. We have devoted lots of time on this previously, which directly affect the productivity. Permeability is not good. Then you will be having a high pressure drop, high resistance to the gas and you cannot blow much volume into the blast furnace and that is ultimately going to decrease your productivity. High top pressure is also one of the things we will discuss little bit again in this. And that is a High Top Pressure actually lead to increase in volume blow volume in the black blast furnace. So, that certainly is going to increase the coke throughput and increase the productivity.

You can of course, Humidified and Oxygenated the blast furnace which we talked that will increase the flame temperature and other thing and for we will increase yours, coke throughput. So, and even the fuel injection so, this is the way we can increase Q factor which ultimately increase the productivity of the blast furnace. So, these are the factors, which affect the blast furnace productivity. Many of them we have discussed before, but I will touch upon some of the important one here again.

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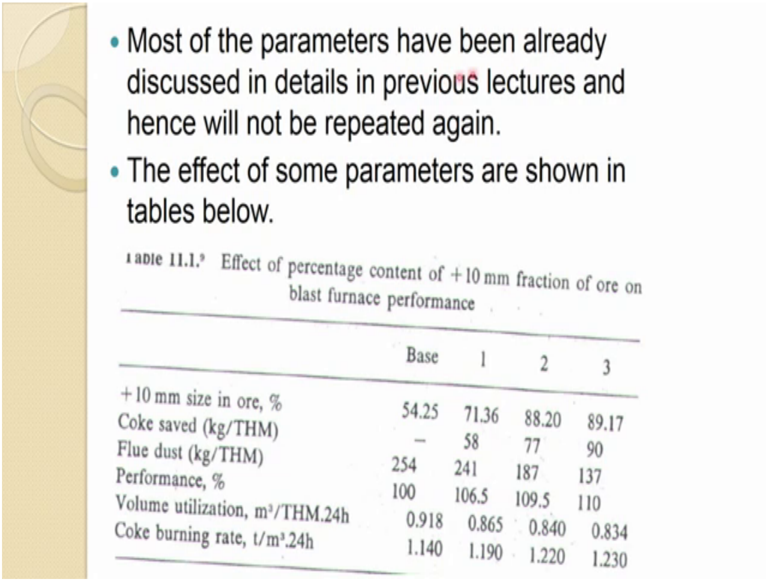


| | Base | 1 | 2 | 3 |
|---|---|---|---|---|
| +10 mm size in ore, % | 54.25 | 71.36 | 88.20 | 89.17 |
| Coke saved (kg/THM) | – | 58 | 77 | 90 |
| Flue dust (kg/THM) | 254 | 241 | 187 | 137 |
| Performance, % | 100 | 106.5 | 109.5 | 110 |
| Volume utilization, m³/THM.24h | 0.918 | 0.865 | 0.840 | 0.834 |
| Coke burning rate, t/m³.24h | 1.140 | 1.190 | 1.220 | 1.230 |

So, most of the parameter we have discussed in previous lecture so not repeated again. The effects of some parameters are shown in this table. So, effect of percentage contents of plus 10 millimeter fraction of ore in the blast furnace. So, Base condition is this. So, plus 10 millimeter not it is 54 percent. If you increase that one to 71 percent, so savings you can see. How much? 58. This these are actual plan data.

So, coke saving 58 kg per tonne of hot metal. If you increase to 88 or increase to 89, you can save almost 90 kg per tonne of hot metal in this one. So, very important of having a good size in the blast furnace or more in a way the uniform instead of mixed.

Fuel dust flue dust: fuel dust also because of course, you have already saved the coke and other thing. And because you are having a more 10 millimeter size, certainly flue dust is going to decrease. So, it decreased for 90 percent of millimeter size ore from 254 to 137, almost half 40 5 percent or so. And that is a big reduction and that is a good saving especially in the gas cleaning system, electrostatic precipitator and other thing. Performance increased from 100 to 110 percent of the tuyere furnace.

Volume utilization; meter cube per tonne of hot metal. It is almost 0.83 point from 0.91 24 hours. And coke burning rate also decrease per tonne, a tonne per meter cube from 1.1 to 1.2. So, one can see the benefits of having a close size range. This burden and plus 10 millimeter in the side, size range having more percentage in it.

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- Ore size in two or three categories indicate that ore layers of one size are fed after a few hours of ore size two layers and so on. So, you don't mix the wider range size ore into one but you separate them into two or three categories to narrow down the size range so that voidage does not deteriorate.

Table 11.2.[10] Effect of charging different sizes in layers

| Types of charge | $\%CO_2$ in top gas | Coke rate kg/THM | %, expected output increase |
|---|---|---|---|
| Mixed ore | 11.0 | 1180 | – |
| Ore sized into 2 categories | 12.1 | 1070 | +9.3 |
| Ore sized into 3 categories | 16.1 | 960 | +18.5 |

So, ore size also, now we said only 1 plus 10 millimeter, now see the effect of different ore size. So, ore size in two or three categories indicate that ore layers of one size are fed after a few hours of ore size two layers and so on. So, you do not mix the wider range size ore into one but you separate them into two or three categories to narrow down the size range so that voidage, voidage does not deteriorate.

This is actually quite important in practice actually. It is very difficult to maintain one size due to various region. However, one thing can be done anyway, screening is done. You can divide that is charge two-three categories. And if you do that way as we had seen before in the lecture the mixer charging layer and in they talk when they are mixing of permeability is reducing the voidage reducing. Same thing is happening here because if you have a higher size of particle and then putting immediately the lower size one, then they will settle in the intrinsics of the bigger particle. And the then will reduce the permeability of the charge and that will create a problem.

So, this shows the effect of that. So, if you are having a mixed or everything mixed together percentage of CO 2 in the top gas is 11 percent, which means you are probably having a more CO. So, it is not properly utilized. Coke rate is very high, but of course, these are the old data. So, coke rate is very high almost 1.2 tonne per tonne of hot metal of course, no increase in the output.

Now, if we divide this one into 2 categories, two size categories. You can see the CO 2 in top gas has increased indicating good utilization of CO and even the coke rate is decreases almost 500 kg. And the expect output has increased almost by 9 percent and if we divide further down into 3 categories a more kilos range we are doing it. Though we are having a same material same charge, only thing what we are doing we are dividing it into 3 category, three different sizes and narrowing the size range. If we do that way in 3 categories it is it is substantial increase in CO 2 in the top gas, which means much more utilization of the reduction potential of the gas.

And the coke rate has decreased again quite substantial substantially almost from here to 220 kg and this is gone to 18 percent more than that output has increased. So, one can clearly see how the production or how the ore size is affecting the product or output. So, these are few practical things which and blast furnace can be done to increase it is productivity.

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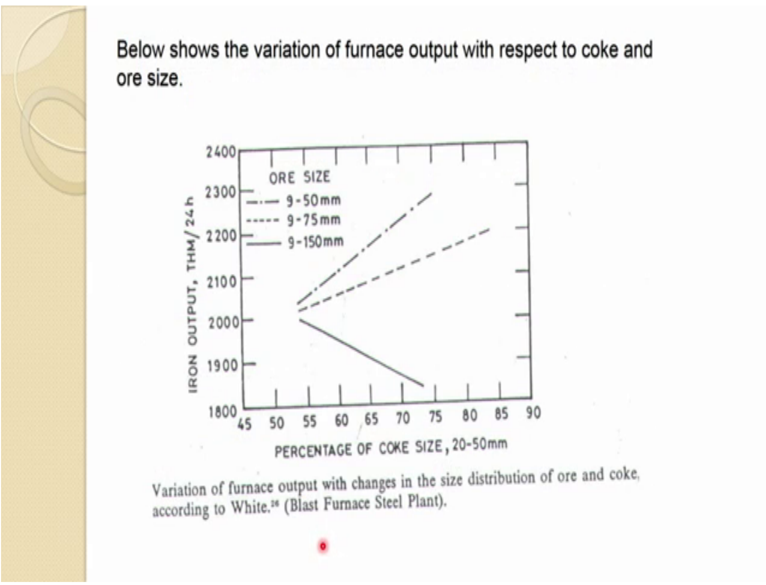

And this figure again is emphasizing more about the size range of the charge or here in ore size. So, iron output you can see when ore size between 9 to 50 millimeter. Though it is also a wide range, but still one can see and the percentage of coke size is this. Your productivity, of the coke size actually is increasing quite substantially. Now, if you increase this range, instead of decreasing you are increasing. So, more what will happen the smaller particle will occupy the space in between the big particle and we reduce permeability of the charge and that is where you can see the production is decreasing though coke size percentage increase but quite substantially it has decreased.

And if this range is too high say 9 to 150 millimeter, then it is a very bad situation. Then certainly the permeability will deteriorate quite a lot. In that case and certainly is your iron output will decrease, decreasing substantially. It increasing the of the cock size in this range so, that so it is again the importance of controlling the charge size or adopting the procedure categorizing the charge size into a two or three categories and then feeding it into the blast furnace and that will certainly increase the productivity of the blast furnace.

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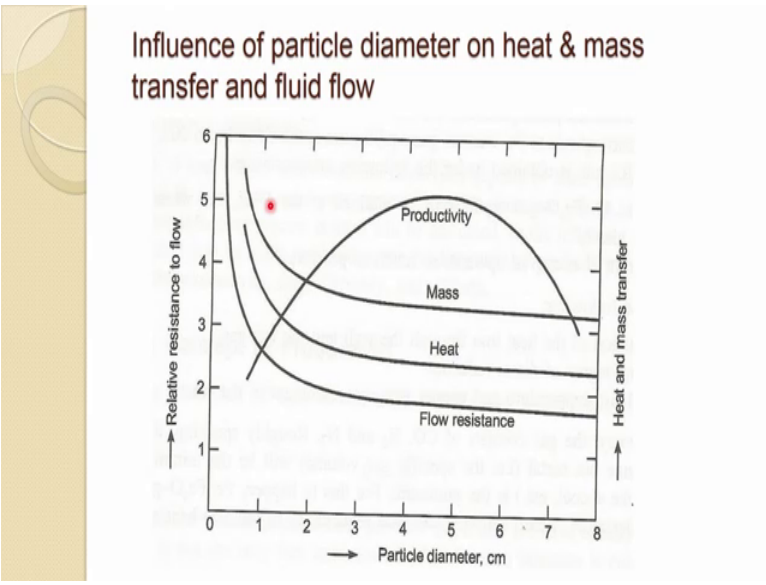


And when we talked about the size and other thing you can also see another thing from this. As your size decreases you can see more heat transfer and mass transfer takes place especially below 10 millimeter. It is sort of increase bit exponential way. um. So because the surface area is very high, when the size is less than 10 millimeter, the surface area is very high. So, heat and mass transfer certainly would be a very high. However, the flow resistance, resistance to fluid flow will increase substantially because the surface area is very high that will also give a big resistance to the gas flow and this is not desirable at all. And if it is a big resistance you cannot put a more volume into the blast furnace. Your productivity will is going to say decrease certainly.

So, one has to optimize that thing. So, this is not a very good situation at all. So, it is particle size below 10 must be avoided and should not be fed into the blast furnace. And if you look at the plus 20 mm particle size there is not much difference in the heat and mass. Of course, a little decreases increase but it is a it is not substantial.

So, one can avoid one can avoid minus 10 millimeter and can go towards little larger size particle and if you look at that way the productivity reach to the maximum about somewhere when your particle size is about 45 millimeter or 4.5 centimetre. And so, that is where the highest productivity you have. You can blow more air, less coke rate and good heat and mass transfer, flow resistance is also less in that case. So, this shows how the effect of size or size affect the mass transfer, heat transfer and fluid flow.

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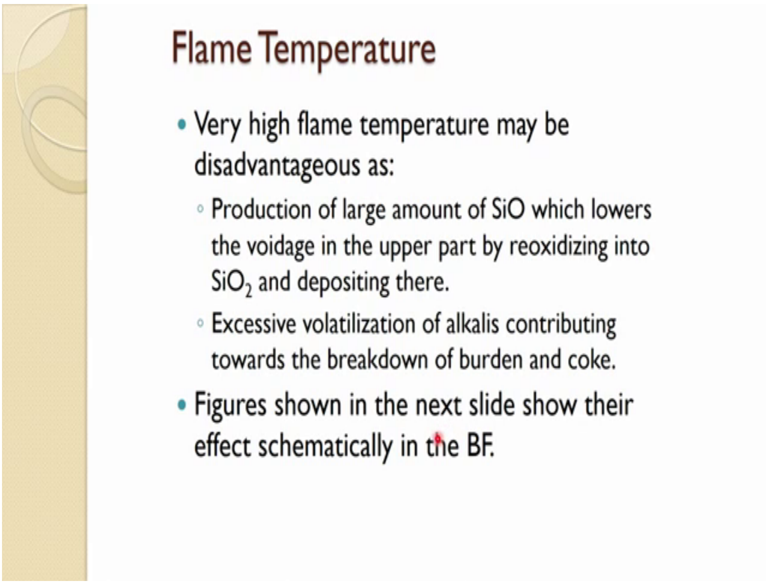


Now, we will talk a another parameter that is Flame Temperature, which also affect the productivity of the blast furnace. So, very high flame temperature may be disadvantages because production of large amount of SiO which so, yes you have a high flame temperature. We had discussed that at high temperature SiO is formed, when we were talking about the silicon transfer reaction. So, production of large amount of SiO; which lowers the voidage in the upper part by reoxidizing into SiO2 and depositing there and we did mention about it that is SiO it is not that much useful one. Of course, it incre[ase]- it is absorbed in the liquid metal. It is increase the silicon content in the iron. And another one it also travels upward which is the cooler region 1300 like this and even less cooler then it reoxidized is from SiO2 which is solid. It deposits in between the voidage reducing the permeability, affecting the productivity adversely.

Excessive volatilization of alkalis contributing towards the breakdown of burden and coke, this also be discussed in the starting the bad effect of alkali and the alkali cycle. It is lower part of the blast furnace, temperature is high. So, the vaporize, go up and the content deposit air and again come down with slag and the cycle keeps on and this also contribute alkali deposits charge in the breakdown of the burden. So, furnace will generate. So, this is also not a very good thing. So, excessive temperatures can further deteriorate this situation. So, these next figure shows about this thing how these different things are there, reacting in the blast furnace.

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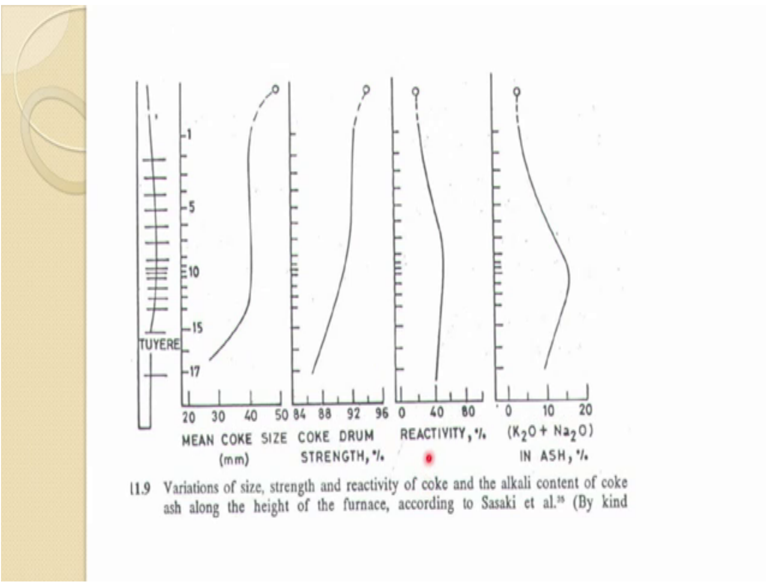


So, this is a tuyere level. If you look at coke size, so you will see that the tuyere level, the cock size is about 25 or 30 millimeter. So, you are feeding about 50 millimeter soil and they starting. And by the time it comes to the tuyere region, it reduces almost 50 percent. And even if it reduces 50 percent, one has to make sure this coke because this is the harshest condition in the blast furnace here. It is moving in the raceway, attrition all those things are happening it should be able to be stained all these things. Even though, it has reduced to 50 percent in size.

So, this shows most of the direction of this coke is occurring from let us say valley region tuyere region rapidly. And nothing little bit here, but nothing much in the thermal reserve zone. Same thing you can see the coke drum strength is quite fairly quite good until the stroke line. But once it comes to cohesive zone and bosh region it decrease decrease. But it still it has maintained near the tuyere level almost 86. So, not that much decrease it is a good indication. So, coke with almost 86 percent of it is strength.

And reactivity of the coke increases from almost like 20 25 percent to almost 40 percent. Somewhere in between reaches maximum and that it could think that a it is maintaining it is reactivity, which is important to produce CO. And we look at the alkali production that is very low and at the top. But as it comes down alkali percentage increases, it becomes quite high in the middle zone almost in the valley region or cohesive and at a tuyere.

Then it start decreasing the region of maximum here because much of the vaporization of these alkali is occurring here which builds a goes up and condensed and builds up there. So, there is you have a maximum alkali content and it comes with a slag and again re-circulating and deteriorating the quality of the burden. So, one has to be careful about the percentage of alkali in the ash. So, this is a typical distribution of these coke size, coke strength, reactivity and alkali in the blast furnace from top to bottom.

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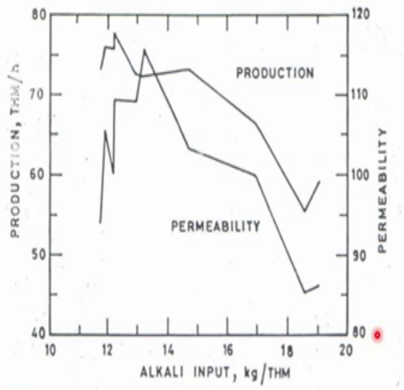


Effect of alkali input on permeability and blast furnace production, according to Davies et al.[41]

And due to this alkali input as we said that because the permeability increased. As you can see as the alkali input increases in kg per tonne of hot metal, it will adversely affect the permeability of the burden and similar then the production will go down. So, productivity also decreases. This is quite clear from that. So, alkali percentage should be kept minimum as much as possible in the raw material. So, like a beneficiation other thing can take care of it.