Iron Making
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Lecture - 08
Iron Making

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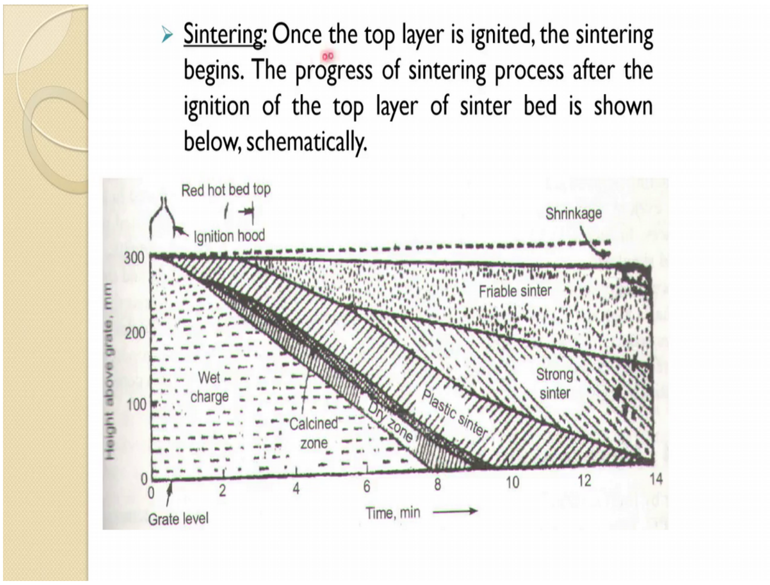

- Sintering: Once the top layer is ignited, the sintering begins. The progress of sintering process after the ignition of the top layer of sinter bed is shown below, schematically.

So, once the top layer is ignited the sintering begins the progress of sintering process after the ignition of the top layer of sinter bed is shown below schematically. So, there is a so, when the process I think probably it can be understand much better way from this figure how these zones.

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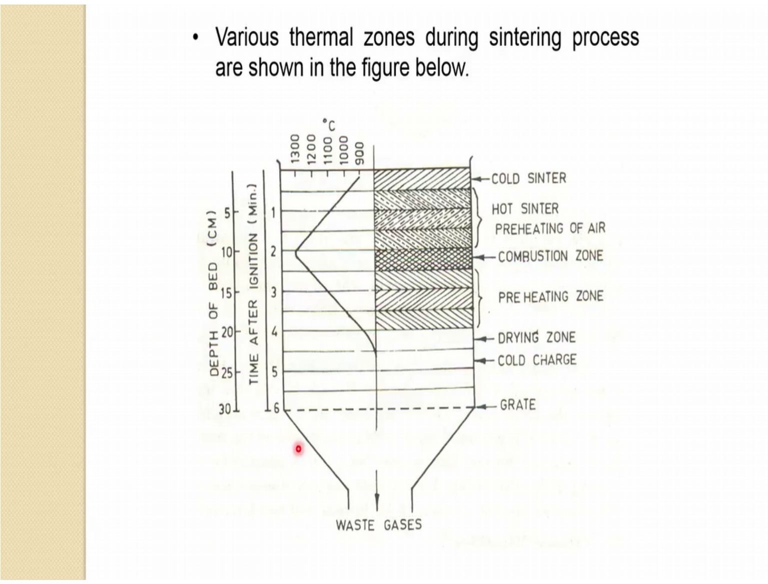

- Various thermal zones during sintering process are shown in the figure below.

So, in the starting you have a green pellet once this under the ignition hood this sintering is start from the top it comes it comes out that. So, this is all ready now top one is a sintered one, but because the wind works are located at the bottom; so, it is sucking the air the fresh air atmospheric one from the top. So, due to the forced convection we will talk a little bit about the heat transfer later.

So, the top sintered layer get cooled because there 25 degree or 30 degree Celsius air is entering from the top and so, which cooled it down the single top layer. And this sintered and suppose this sinter which has been made become or be this is actually showing somewhere here the intermediate region. So, like this layer is already sintered and became cold and this is getting sintered. So, this is the what this is also already hot and getting sintered and the combustion front has already moved forward after sintering this.

So, this is a hot sinter and the hot air now is coming there because this is a hot already sintered and assisting supplying the oxygen to this front the pre heated hot airs are coming in this one and this is a combustion zone. Now from the combustion zone, whatever air is coming out they are quite hot and they are under suction. So, what and below the combustion zone all the pellets they are green pellets. So, what it does it pre heat the green pellet in this combustion zone.

So, mostly calcination and those thing occurs in this these are already actually preheated because the temperature is very high. So, calcination and other thing is occurring in this zone and when it passes from this; a pellet get colder and colder. So, temperature keeps on dropping you can see the temperature this is the cold one. So, temperature actually it should start from here.

So, 25 degree it keeps on increasing because this flame front had travelled to here and when it reaches to the combustion zone that is the maximum temperature which you are having around 1300 degree Celsius. And then these gases start cooling down because you have the cold pellet. So, the these gets heated up and because the temperature is still very high in this region about 1100 or so,.

So, decomposition of carbonate occurs in this region and below that temperature then because this is all endothermic reaction. So, the temperature further drops and as the temperature is dropping then when the temperature is around 600 or like that you have a drying zone. So, like a pellet get dry or any other chemically bonded water and other thing comes out from this. And in fact, whatever moisture is there that also comes out in this region during drying zone so, and temperature continuously decrease.

So, what has happened because this zone is still quite hot about 4, 500 degree Celsius the moisture evaporation takes place. But once this moisture evaporation moistures now is coming with the gases over here. So, it and at the next layer it is a cold one; so, re condensation of the moisture occurs here. So, in at one place if the evaporation is occurring above this, but here re condensation of the moisture is occurring.

And so, pellet get quite wet actually at the bottom and even water can come out from the bottom condensation and temperature drops even quite low; in this region at the bottom. And this is the way and because this is moving; so, the top one keep on getting sintered and the flame is traveling downwards. So, the next layer keep on getting sintered and that get sintered and it travels further down. So, plastic sinters you have and then you have a dry zone as we discussed and by the time say comes out its all gets sintered.

So, this is showing more about the that how this sinter were look like.

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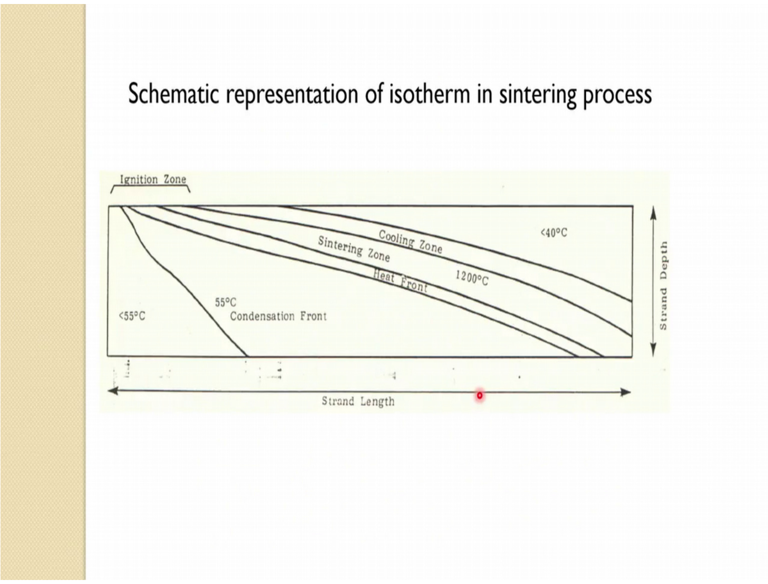

Schematic representation of isotherm in sintering process

And if we talk about little bit about the heat transfers here. So, that is the thing which we discussed the condensation is occurring. After that in this zone because the moisture which has evaporated re condensing in the lower temperature zone, you have a sintering zone about 1200 degree c then you have a heat front cooling zone and the top one really from the atmospheric air gets cooled down below this 40 degree.

And so, mostly you are having a force convection here conduction and radiation plays a small role in this region, but not that one is mostly the force convection if you are aware about the heat transfer; then about this I am talking if not to worry too much about it.

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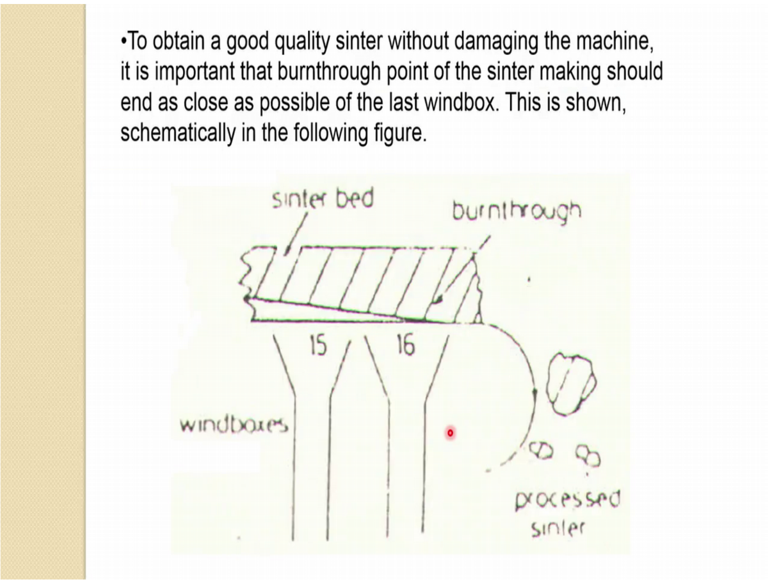

- To obtain a good quality sinter without damaging the machine, it is important that burnthrough point of the sinter making should end as close as possible of the last windbox. This is shown, schematically in the following figure.

So, the main now one important thing is you look at this; we are having at the flame front. If flame front is going to continue like this then it is going to really under temperature 13; 1400 degree Celsius and that is going to damage the strand and the hearth.

And so the main thing in the sintering to operate the sintering machine in a proper way. And the good quality sinter. It is important that burn through point of the sinter making should end as close as possible. So, sinter making should end as close as possible of the last wind box; so, this is shown here. So, this is a sin sinter where already sintered and you were saying this is a sort of a flame front.

So, it should finish the full sintering should finish almost at the end of the last wind box and where the discharging occurs. So, there is no damage to the sinter strand and immediately once a this finishes; it falls down and sinter breaker is there. So, top metallic material is usually cool, but this material it is a very high temperature one, but it is better to have that high temperature sintered one and it breaks down with this sinter breaker.

So, this is a very important thing for the sintering process. So, whatever people do they always talk about the burn through point; so, this is quite important.

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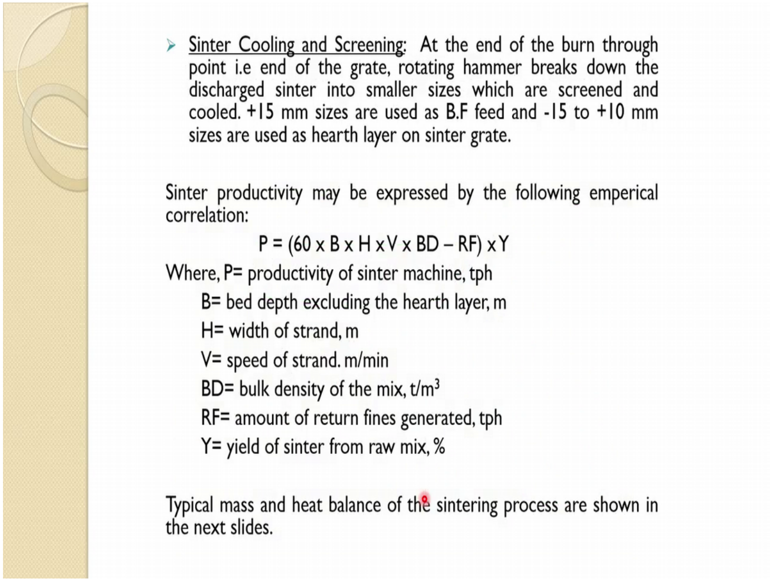

- Sinter Cooling and Screening: At the end of the burn through point i.e end of the grate, rotating hammer breaks down the discharged sinter into smaller sizes which are screened and cooled. +15 mm sizes are used as B.F feed and -15 to +10 mm sizes are used as hearth layer on sinter grate.

Sinter productivity may be expressed by the following emperical correlation:

$$P = (60 \times B \times H \times V \times BD - RF) \times Y$$

Where, P= productivity of sinter machine, tph
B= bed depth excluding the hearth layer, m
H= width of strand, m
V= speed of strand. m/min
BD= bulk density of the mix, t/m^3
RF= amount of return fines generated, tph
Y= yield of sinter from raw mix, %

Typical mass and heat balance of the sintering process are shown in the next slides.

So once this sintering is over then it comes about the cooling and screening of the sinter. So, which as you have seen those sinter screen one there in the figure. So, at the end of the burn through point end of the grate rotating hammer break down that the charged sintered into a smaller size and which are screened and cooled.

So, plus 15 millimeter goes to the blast furnace and this causes a hearth layer and below the 10 millimeter goes to the as a sinter return again to make the green pellets. So, some correlation has been proposed for the sinter productivity in this form. So, where P is the productivity of the sinter machine B is the bed depth excluding the hearth layer.

So, it is about the green pellet depth and H is the width of strand and V is the speed of a strand and that is in meter per minute. This is a bulk density of the mixture green pellets and RF is the amount of return fines generated and which has been put into these. So, in tonne per hour and Y is the yield of the sinter from the raw mix; based on that one can calculate the productivity of the sinter.

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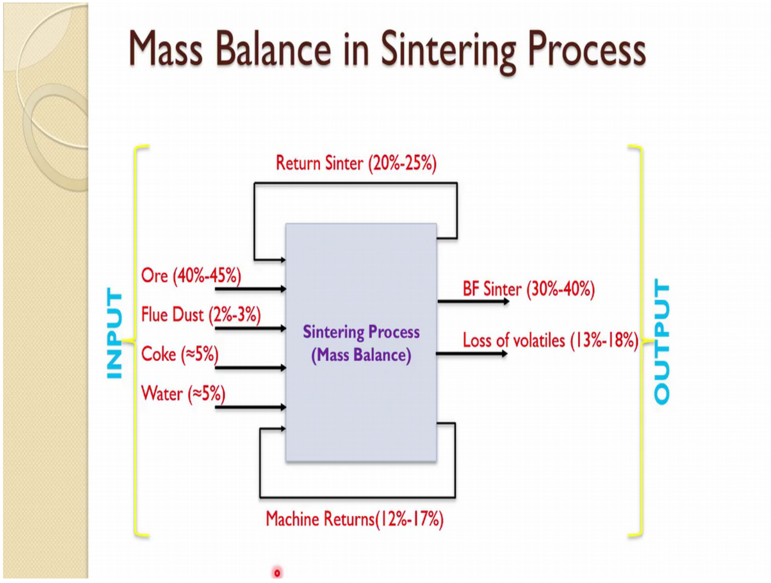

Mass Balance in Sintering Process

INPUT

Ore (40%-45%)

Flue Dust (2%-3%)

Coke (≈5%)

Water (≈5%)

Return Sinter (20%-25%)

Sintering Process (Mass Balance)

Machine Returns(12%-17%)

BF Sinter (30%-40%)

Loss of volatiles (13%-18%)

OUTPUT

And typical mass and heat valance on that sintering process is given in this one. So, the mass valance about 40 to 45 percent all goes in 2 to 3 percent fine dust about 5 percent coke and about 5, 6 percent water it goes and the return sinter return the return fines which also comes its about 20 to 22 percent

So, it is quite a high amount of sinter returns actually is put it into that. And then you have also the machine return they were very fine which is coming underneath of that machine that also constitute about 12 to 15 percent machine return. So, these are the input and the output of course, the return sinter blast furnace sinter about 35 to 40 percent you get it and loss of volatile 13 to 18 percent and about 15 percent machine returns is output of the process this gives the total mass balance of the sintering process.

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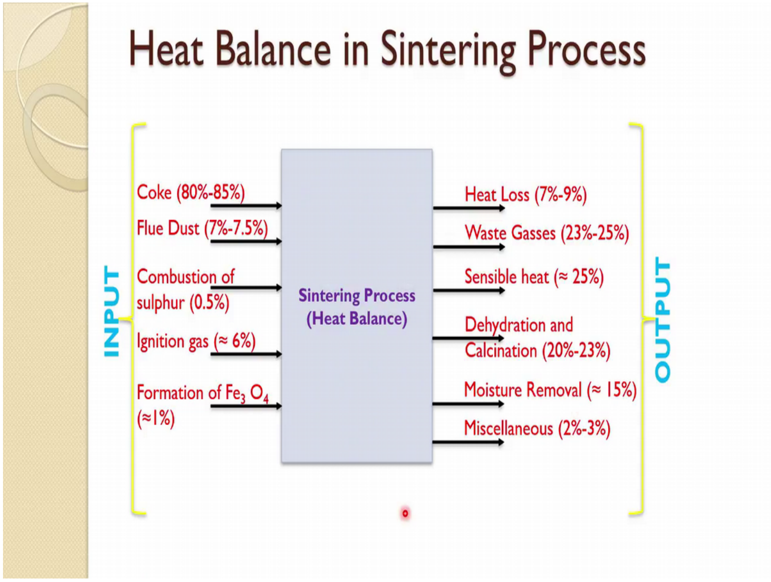

Heat Balance in Sintering Process

INPUT

Coke (80%-85%)

Flue Dust (7%-7.5%)

Combustion of sulphur (0.5%)

Ignition gas (≈ 6%)

Formation of Fe_3O_4 (≈1%)

Sintering Process (Heat Balance)

OUTPUT

Heat Loss (7%-9%)

Waste Gasses (23%-25%)

Sensible heat (≈ 25%)

Dehydration and Calcination (20%-23%)

Moisture Removal (≈ 15%)

Miscellaneous (2%-3%)

And for the heat balance we have this. So, in the heat balance 80 to 85 percent heat comes from the coke and a flue dust constitute that about 7 percent combustion of sulphur about 0.5, ignition of gases also through the burner its about 6 percent and a formation of F e 3 O 4. So, from hematite to magnetite it is a exothermic process essentially. So, about 1 percent comes from that and total heat loss.

So, heat loss to the environment machines and various other places is about 7 to 9 percent waste gases take away most of this heat of the order of 25 percent, sensible heat in the sinter is about 25 percent like dehydration and calcination constitute again quite a big amount 20 to 20 3 percent. So, as you can imagine how much heat is going into this one? And you are saving coke that much coke in the blast furnace to get rid of this action.

So, always it is good to put a flux with the sinter a moisture removal around 15 percent leather miscellaneous and the this goes at the heat loss. So, this shows the overall heat balance of the sintering process.

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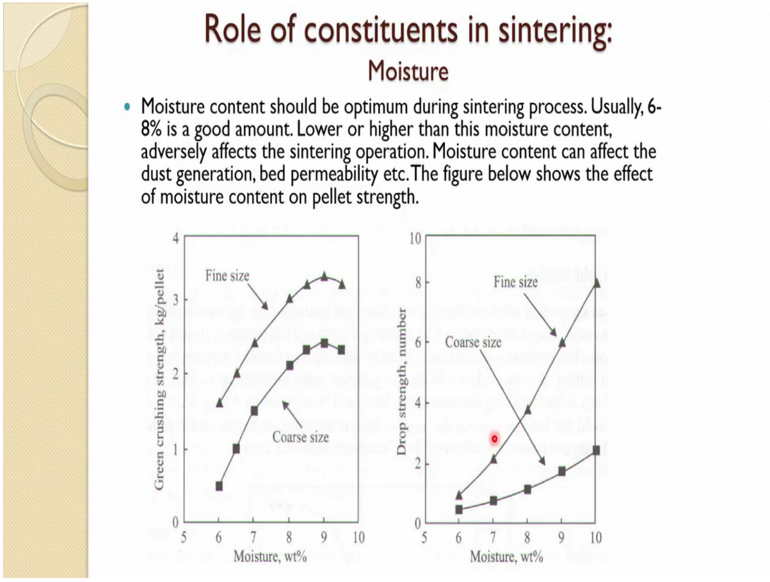

Role of constituents in sintering:

Moisture

- Moisture content should be optimum during sintering process. Usually, 6-8% is a good amount. Lower or higher than this moisture content, adversely affects the sintering operation. Moisture content can affect the dust generation, bed permeability etc. The figure below shows the effect of moisture content on pellet strength.

Now, we will talk a bit about the constituent role of constituents in sintering. So, as you know we have moisture during the granulation process. So, moisture content should be optimum during sintering process usually 6 to 8 percent usually in sintering process it is about 6 percent, but in palletization its a little higher it goes around 8 percent or so.

So, it is a good amount; so, lower or higher than this moisture content adversely affect the sintering operation. So, moisture content can affect the dust generation if it is low; so, quite a load test will generate and then it will affect the bed permeability and very high also it does.

So, if you look at this figure as the moisture content is increasing you can see the crushing strength of the green pellets it is increases up to a certain moisture content. So, 9 or below 9 percent, but after that it is start decreasing and fine size have higher strength; then the coarser size pellet So, but this is true in terms of when we are doing pelletization, but similar argument is held for the sintering also.

So, because crushing strength is very important when you are putting on the on the sinter strand the bed of the pellet; the section is very high and under that suction it must be strained that pressure drop.

So, they should not lose their shape otherwise it will affect the permeability and higher suction places you need and this probably will lead to many other problem. So, crushing strength that is where this factor comes into picture same thing about the drop strength to which they moisture content, but you cannot have a very high moisture just that ah, you need a reasonable drop strength; so, you can choose from that.

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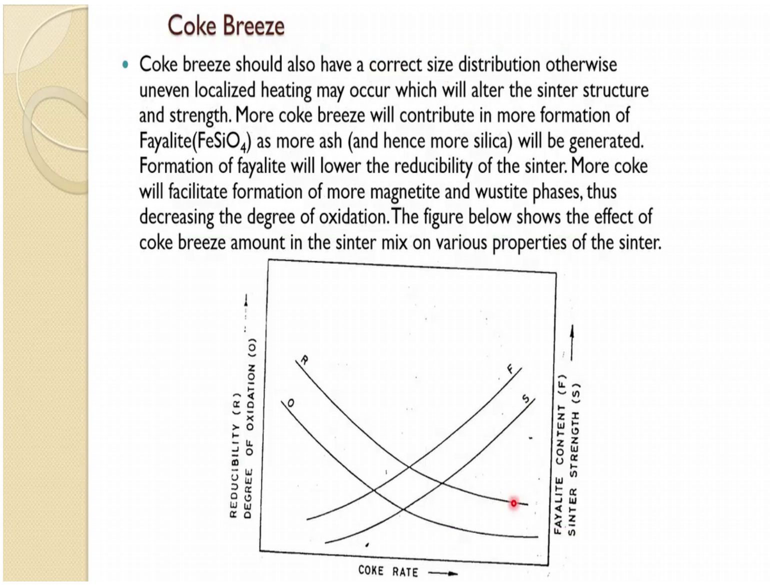

Coke Breeze

- Coke breeze should also have a correct size distribution otherwise uneven localized heating may occur which will alter the sinter structure and strength. More coke breeze will contribute in more formation of Fayalite($FeSiO_4$) as more ash (and hence more silica) will be generated. Formation of fayalite will lower the reducibility of the sinter. More coke will facilitate formation of more magnetite and wustite phases, thus decreasing the degree of oxidation. The figure below shows the effect of coke breeze amount in the sinter mix on various properties of the sinter.

So, 8 percent for the pellet it is a good one for coke breeze; so, this should have a correct size distribution otherwise uneven localized heating may occur. Because these all are fines and when you are looking at these particles 2 millimeter and 3 millimeter particle; so, the way heat would be released, it is sort of a localized in the within the pellet.

So, 2 millimeter will give a different amount of heat and 3 millimeter will give a different amount of heat. So, that will give a different temperature gradient and that will affect the structure of the sinter and phase formation. So, which is not good that is why the correct size distribution it is very necessary for the coke breeze the more coke breeze will contribute in more formation of fayalite.

Now as we know the coke is associated with S and S has silica in it and which formed that ions fayalite and silicate this. And formation of fayalite actually reduces the reducibility of this sinter which really we do not want in the blast furnace. However, it increases the strength of it, but the reducibility is much more important.

So, more coke will facilitate formation of more also the more coke facilitate formation of more magnetite and wustite phases. Thus decreasing the degree of oxidation which is also not good the figures this figures shows qualitatively how the coke percentage of coke rate is affecting the various property.

So, as you increase the coke percentage you can see the reducibility it decreasing which is due to the formation of fayalite phase. And degree of oxidation also decreases formation of magnetite and wustite phase. And sinter strength though increase it, but because these two are reducing. So, these are not good for the blast furnace as if we when we go there and we had discussed few of them including blast furnace description, but we will come again on this. So, proper percentage of the coke is also quite important in the sinter a limestone.

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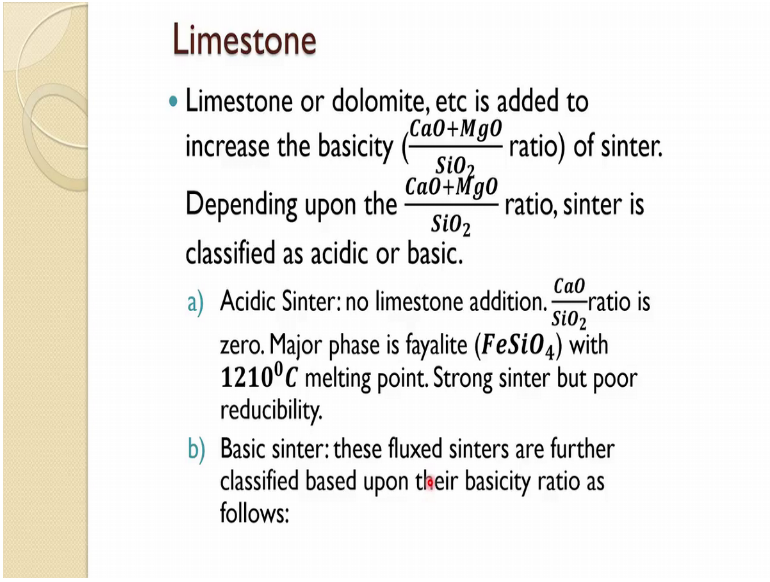

Limestone

- Limestone or dolomite, etc is added to increase the basicity ($\frac{CaO+MgO}{SiO_2}$ ratio) of sinter. Depending upon the $\frac{CaO+MgO}{SiO_2}$ ratio, sinter is classified as acidic or basic.
  a) Acidic Sinter: no limestone addition. $\frac{CaO}{SiO_2}$ratio is zero. Major phase is fayalite ($FeSiO_4$) with 1210^0C melting point. Strong sinter but poor reducibility.
  b) Basic sinter: these fluxed sinters are further classified based upon their basicity ratio as follows:

Limestone is very important as we said it; it is better to use limestone to using sintering then in the blast furnace; so, you can save the coke.

So, limestone or dolomite is added to increase the basicity is usually basicity if you do not have a dolomite or other magnesium bed flux; then you keep the basicity based on the ratio of CaO and SiO 2. But if you have a magnesium based flux also then because magnesium is also a basic in character like calcium.

So, these are combined and then you put the ratio in the combined form CaO plus M g O divided by SiO 2. So, this increase the basicity of this sinter when you are putting any flux; so, naturally this content is increasing. So, you will increase the basicity; so, depending on this resource sinter has been classified under acidic or basic.

So, acidic sinters when no limestone is added so, naturally the ratio would be 0 of this; when no limestone is there and major phase in that case is fayalite. So, you may you will get a stronger sinter, but poor reducibility. So, in some cases it may require, but mostly it is avoided. So, the basic practice nowadays is about the basic sinter.

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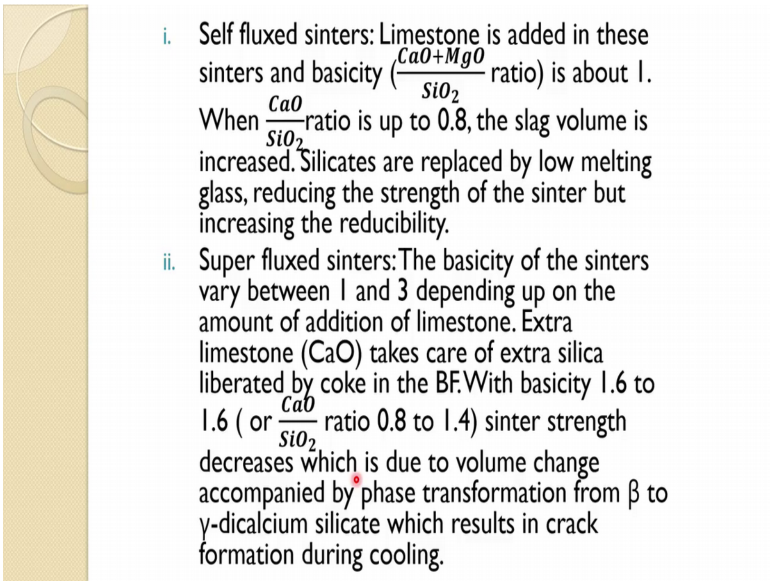

i. Self fluxed sinters: Limestone is added in these sinters and basicity ($\frac{CaO+MgO}{SiO_2}$ ratio) is about 1. When $\frac{CaO}{SiO_2}$ ratio is up to 0.8, the slag volume is increased. Silicates are replaced by low melting glass, reducing the strength of the sinter but increasing the reducibility.

ii. Super fluxed sinters: The basicity of the sinters vary between 1 and 3 depending up on the amount of addition of limestone. Extra limestone (CaO) takes care of extra silica liberated by coke in the BF. With basicity 1.6 to 1.6 (or $\frac{CaO}{SiO_2}$ ratio 0.8 to 1.4) sinter strength decreases which is due to volume change accompanied by phase transformation from β to γ-dicalcium silicate which results in crack formation during cooling.

So, basic sinter this flux sinter or further classified into again various basicity based on their basicity ratio. So, self flux sinter where the ratio of the basis this basic and acidic compound is about 1, we say basicity 1. So, so and in terms of Ca SiO 2 if it is about 0.8; so, so this actually called the self flux sinter.

And that increase a slag volume in this case is increased and the blast furnace because you have to really add extra flux and things to compensate edge from blast furnace coke and other places which is coming. Silicates are replaced by low melting glass here in the sinter reducing the strength of the sinter; but increasing the reducibility.

Super flux sinter the basicity of this sinter vary between 1 and 3; so, depending upon the amount of addition of the limestone, you can if you add more limestone certainly you are taking care of the extra silica which is getting liberated in the blast furnace through coke

So, there in that ways you are adding extra one here; so, it will take care of this silica which is getting generated in the blast furnace.

And that is why it calls super flux sinter and that will anyways reduce your coke consumption in the blast furnace. So, with basicity 1.6 to no actually 1 to 1.6; say (Refer Time: 23:44) long it is 1 to 1.6 or CaO SiO 2 ratio 0.8 to 1.4 sinter strength actually decreases in this due to volume change accompanied by phase transformation from beta to gamma dicalcium silicate; which results in crack formation during cooling.

So, this sort of basicity is not desired because due to the formation of gamma dicalcium silicate and this reduce a your strength of the sinter right.

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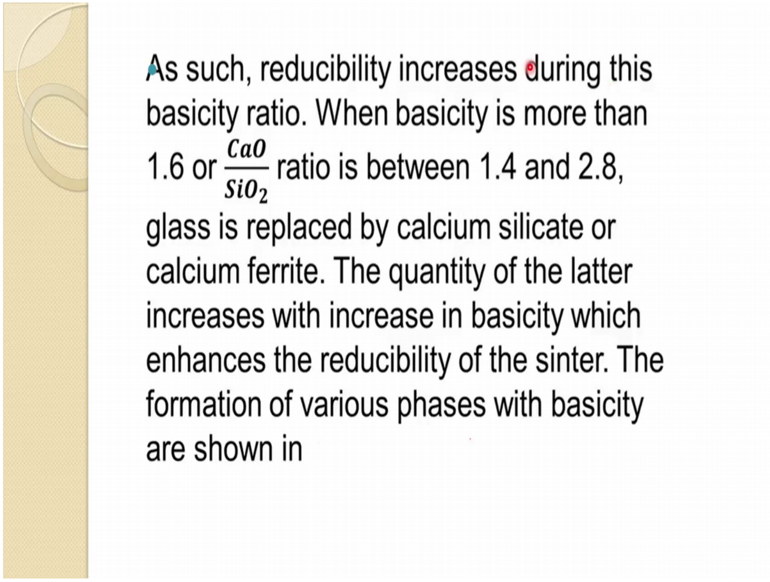

As such, reducibility increases during this basicity ratio. When basicity is more than 1.6 or $\frac{CaO}{SiO_2}$ ratio is between 1.4 and 2.8, glass is replaced by calcium silicate or calcium ferrite. The quantity of the latter increases with increase in basicity which enhances the reducibility of the sinter. The formation of various phases with basicity are shown in

But as you increase the basicity ratio more than 1.6 or in cai SiO 2; 1.4 to 2.8 and this is 1.6 to 3 then a glass formed by calcium silicate or calcium ferrite. So, the quantity of this latter increases with increase in the basicity which enhances the reducibility of the sinter and the formation of various phases shown in this.

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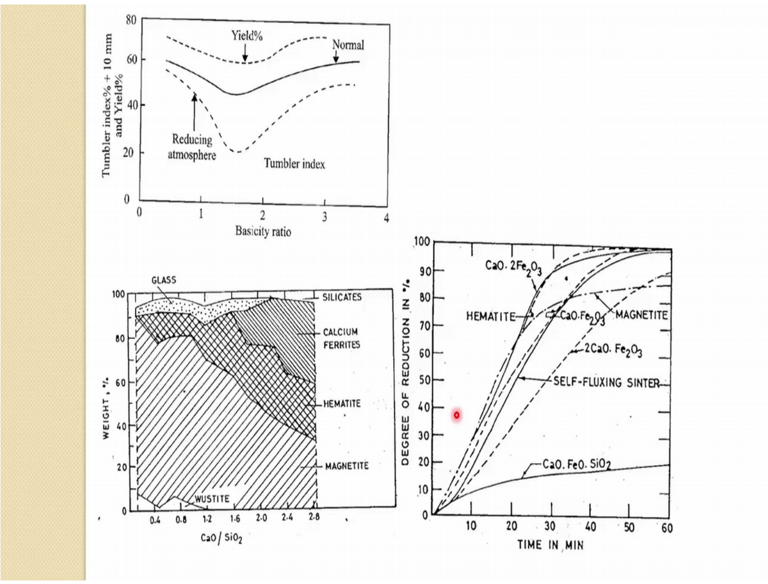

So, as we were talking at the basicity if goes beyond 0.8 and 1.6; your strength decreases, yield also decreases you can see that one. So, usually that basicity is avoided because tumbler index goes down that these we have talked during raw material selection. So, basicity somewhere here or in the super flux actually and this is the one where you use it and this keeps a good reducibility to the sinter.

And the various phases which are formed you can see as the basicity in increases your calcium ferrite and hematite formation actually facilitated hematite is a higher oxidize oxygen state; while magnetite is a less oxidize state; so, that reduces. So, in that way it is good in the blast furnace; so, this sort of super flux sinter are good for reducibility viewpoint or even the strength one.

And as you can see how these phases are appear in the sintering with the time hematite is this one; then you have a, so, hematite is going this you have a fell fayalite ah, you have a magnetite. So, I think longer to keep the duration to sintering more magnetite is form and then you have other phases.

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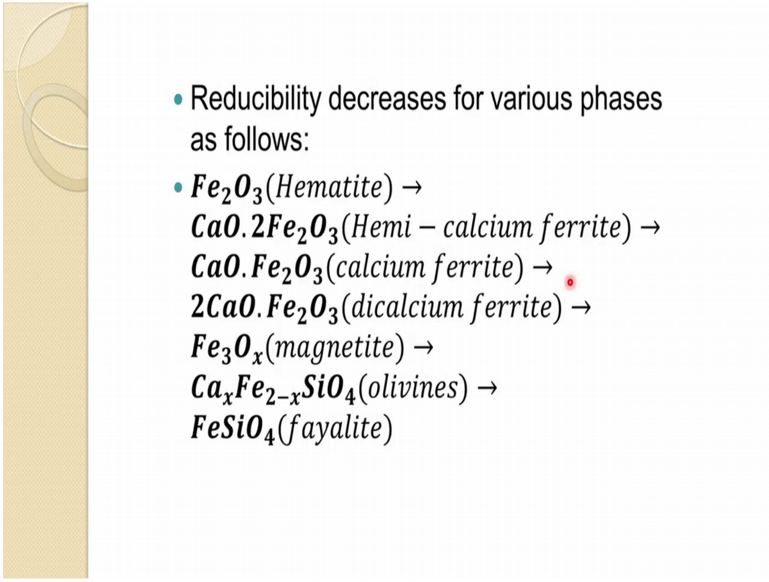

- Reducibility decreases for various phases as follows:
- $Fe_2O_3(Hematite) \rightarrow$
  $CaO.2Fe_2O_3(Hemi - calcium\ ferrite) \rightarrow$
  $CaO.Fe_2O_3(calcium\ ferrite) \rightarrow$
  $2CaO.Fe_2O_3(dicalcium\ ferrite) \rightarrow$
  $Fe_3O_x(magnetite) \rightarrow$
  $Ca_xFe_{2-x}SiO_4(olivines) \rightarrow$
  $FeSiO_4(fayalite)$

In fact, the reducibility of these as you can see the degree of reduction how it will affect; the reducibility decreases quite high reducibility then hemi or hematite calcium ferrite this is second lowest one actually is the fayalite where the reducibility is very low.

So, this is in the order of decreasing reducibility. So, mostly you would like to have these phases in the sinter for the good reducibility and super flux one that we had seen gives these phases quite good.

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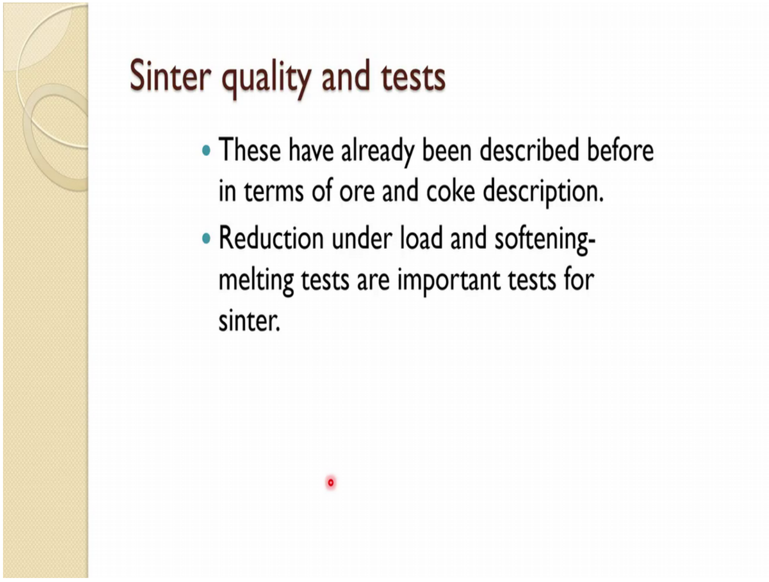

Sinter quality and tests

- These have already been described before in terms of ore and coke description.
- Reduction under load and softening-melting tests are important tests for sinter.

The syntax quality and test ah, but I think before that I will this is the also another one which we have not talked about the alumina and magnesia effect on the sintering.

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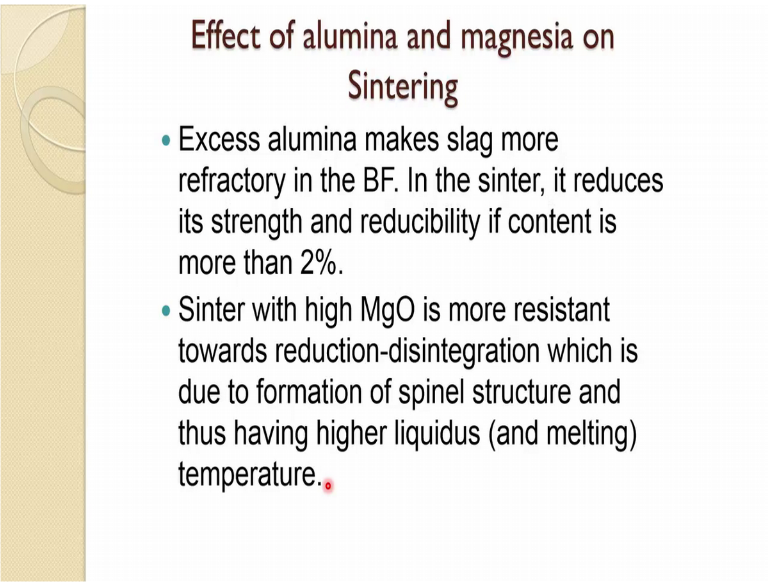

Effect of alumina and magnesia on Sintering

- Excess alumina makes slag more refractory in the BF. In the sinter, it reduces its strength and reducibility if content is more than 2%.
- Sinter with high MgO is more resistant towards reduction-disintegration which is due to formation of spinel structure and thus having higher liquidus (and melting) temperature.

So, excess alumina makes slag more refractory; so, this is actually not good. So, it reduces the strength and the reducibility if it is more than 2 percent However, the magnesium content it is more resistant toward the reduction disintegration. So, it is good to have these which is due to formation of spinel structure and thus having a higher liquidation melting temperature.

This also increases those a cohesive zone becomes narrower and which is required, which you wanted that cohesive zone should be bit liquid at temperatures should become higher. So, melting should occur at high temperature which is good requirement in the blast furnace and that helps the magnesium here and now we will come to this sinter quality and test

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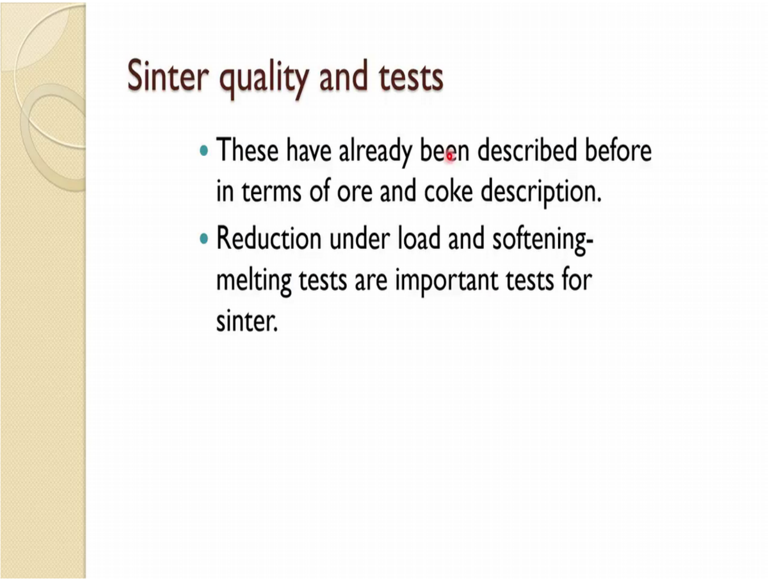

Sinter quality and tests

- These have already been described before in terms of ore and coke description.
- Reduction under load and softening-melting tests are important tests for sinter.

So, these we already discussed during the iron ore and coke description; so, not going to repeat really, but some important one is that reduction under load and softening melting test are important one in the in the sinter which are routinely carried out to check its quality.

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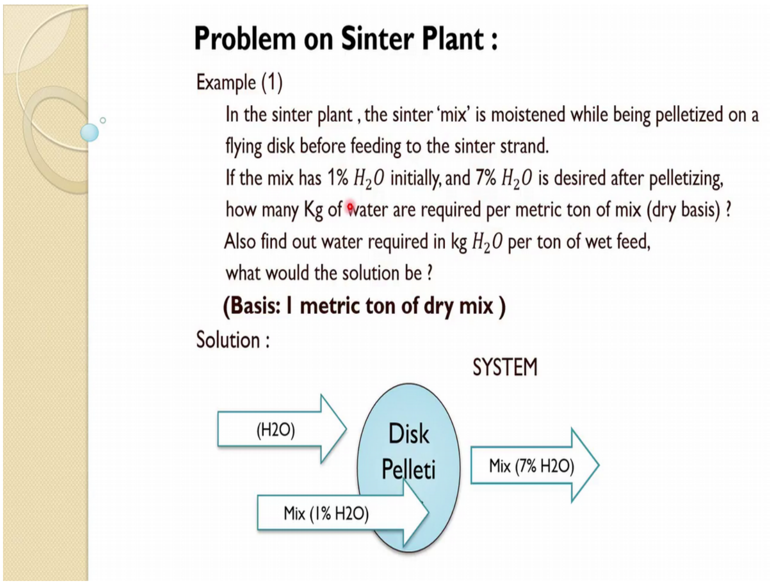

Problem on Sinter Plant :

Example (1)

In the sinter plant , the sinter 'mix' is moistened while being pelletized on a flying disk before feeding to the sinter strand.

If the mix has 1% H_2O initially, and 7% H_2O is desired after pelletizing, how many Kg of water are required per metric ton of mix (dry basis) ?

Also find out water required in kg H_2O per ton of wet feed, what would the solution be ?

(Basis: I metric ton of dry mix)

Solution :

Now, there is one problem on this sinter plant which is given here. So, the example one; so, this says in the sinter plant the sinter mix is a moistened while being pelletized on a flying disc before feeding to the sinter strand. If the mix has 1 percent of water initially and 7 percent water is desired after pelletizing; how many kg of water are required per metric ton of mix on dry basis? Also find out the water requirement per ton of wet feed and what should be the solution?

So, what we are assuming a 1 metric ton of dry mix. So, mix is having a 1 percent water initially and 7 percent that is the one which is coming out ok. So, we have a this disc that is palletizer the input each 1 percent H 2 O water and that mix and you are adding extra water to get pellets having a 7 percent water in it.

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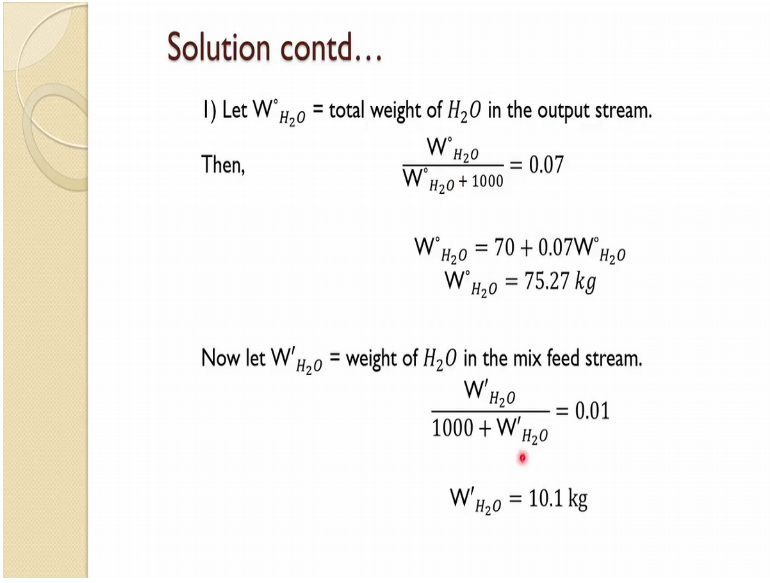

Solution contd…

I) Let $W^{\circ}_{H_2O}$ = total weight of H_2O in the output stream.

Then,
$$\frac{W^{\circ}_{H_2O}}{W^{\circ}_{H_2O}+1000} = 0.07$$

$$W^{\circ}_{H_2O} = 70 + 0.07W^{\circ}_{H_2O}$$
$$W^{\circ}_{H_2O} = 75.27\ kg$$

Now let W'_{H_2O} = weight of H_2O in the mix feed stream.

$$\frac{W'_{H_2O}}{1000 + W'_{H_2O}} = 0.01$$

$$W'_{H_2O} = 10.1\ \text{kg}$$

So, if the total weight of water in the output stream. So, this we can is a W naught H 2 O; if that is the total weight. So, normal mass balance of the water will give W naught divided by this and weight of the water should be 0.7. So, if we solve this; so, essentially what we get the amount. So, 1000 is coming and because we are doing an metric ton basis.

So, the added amount of the water not the added amount the amount in the output pellet in a 1 metric ton of these it is about 75.27. So, now, in the feed how much we are mixing we can calculate because its gives a 1 percent is having. So, again in the same way doing the mass balance if weight of the water in the mix feed stream is W prime, then again the same sort of a mass balance will give you 10.1 kg.

So, essentially the water which we are adding would be and this 75 minus this because this 10 gets kg is being carried over with that.

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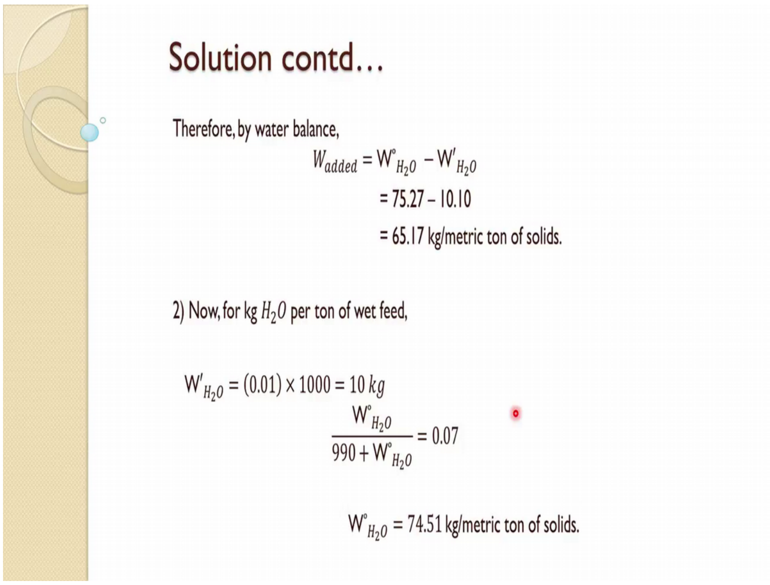

Solution contd…

Therefore, by water balance,

$$W_{added} = W^{\circ}_{H_2O} - W'_{H_2O}$$

$$= 75.27 - 10.10$$

$$= 65.17 \text{ kg/metric ton of solids.}$$

2) Now, for kg H_2O per ton of wet feed,

$$W'_{H_2O} = (0.01) \times 1000 = 10\,kg$$

$$\frac{W^{\circ}_{H_2O}}{990 + W^{\circ}_{H_2O}} = 0.07$$

$$W^{\circ}_{H_2O} = 74.51 \text{ kg/metric ton of solids.}$$

So, that gives you about 65.17 kg per metric ton of solid. Now in terms of wet feed we are already we have put 0.1 I am saying 1 metric ton. So, essentially 10 kg of water we have supplied in the feed is carrying over that much. So, again if we do the mass balance and W naught the way we have defined here the weight of the water in the final feed; the simple mass balance will gives you now this 10 kg has to subtracted from 1000. So, essentially dry this over is 990.

So, that should gives you this much; so, it is coming about 74.51.

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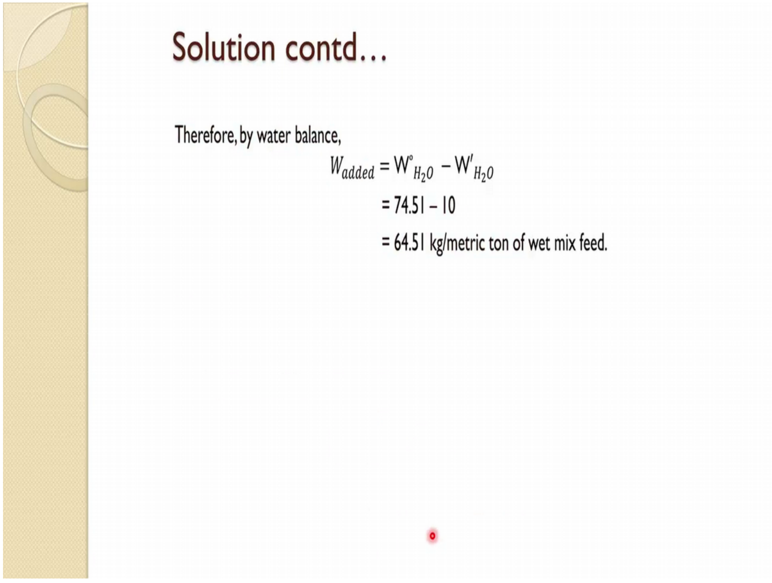

Solution contd…

Therefore, by water balance,

$$W_{added} = W^{\circ}_{H_2O} - W'_{H_2O}$$
$$= 74.51 - 10$$
$$= 64.51 \text{ kg/metric ton of wet mix feed.}$$

Similar way we can then calculate if we subtract the one which is coming with the feed; the actual amount which should be added is about 64.51; 51 k kilogram per metric ton of wet mix And in the previous one it was 65; so, about 1 kg difference which is coming out.

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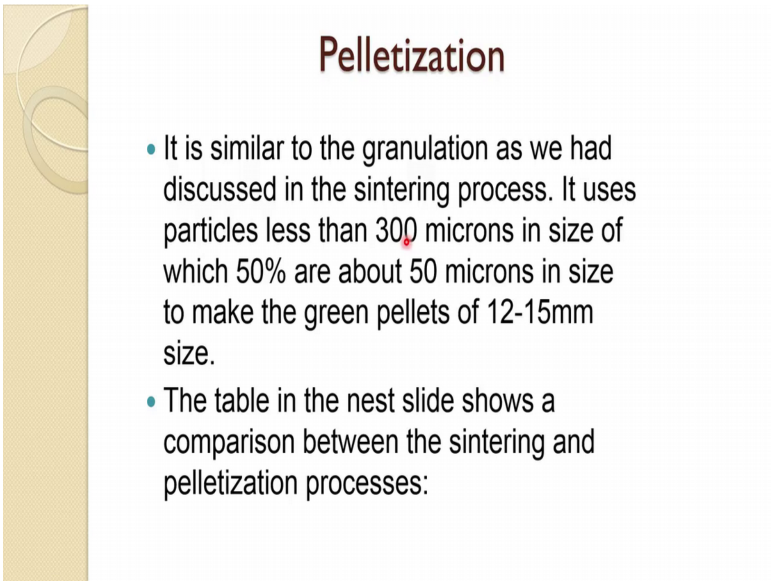

Pelletization

- It is similar to the granulation as we had discussed in the sintering process. It uses particles less than 300 microns in size of which 50% are about 50 microns in size to make the green pellets of 12-15mm size.
- The table in the nest slide shows a comparison between the sintering and pelletization processes:

Now, we will come to the palletization as I said this is another name of the granulation we can say. So, it is similar to the granulation as we had discussed in the sintering process; only difference it uses a particle less than 300 micron size and in which 50 percents are about 50 microns in size to make the green pellet of 12 to 15 millimeter in size. And the next table is actually shows a comparison between the sintering and palletization process.

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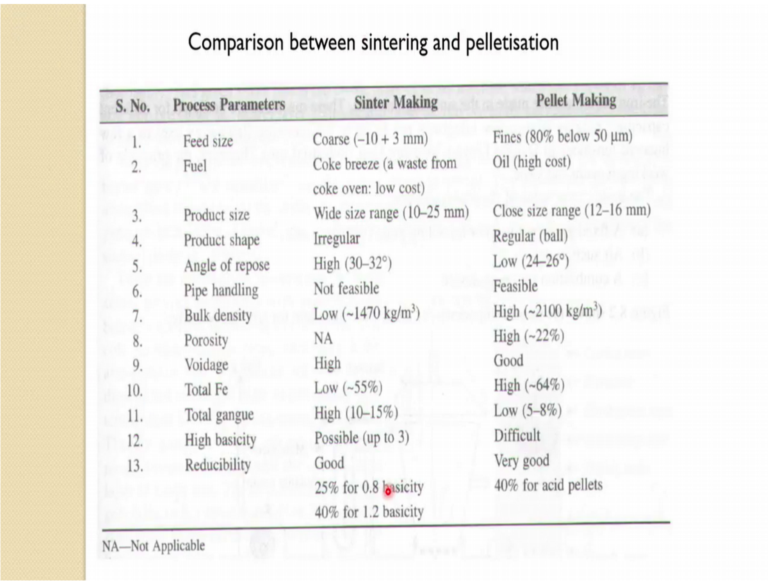

Comparison between sintering and pelletisation

S. No.	Process Parameters	Sinter Making	Pellet Making
1.	Feed size	Coarse (–10 + 3 mm)	Fines (80% below 50 µm)
2.	Fuel	Coke breeze (a waste from coke oven: low cost)	Oil (high cost)
3.	Product size	Wide size range (10–25 mm)	Close size range (12–16 mm)
4.	Product shape	Irregular	Regular (ball)
5.	Angle of repose	High (30–32°)	Low (24–26°)
6.	Pipe handling	Not feasible	Feasible
7.	Bulk density	Low (~1470 kg/m^3)	High (~2100 kg/m^3)
8.	Porosity	NA	High (~22%)
9.	Voidage	High	Good
10.	Total Fe	Low (~55%)	High (~64%)
11.	Total gangue	High (10–15%)	Low (5–8%)
12.	High basicity	Possible (up to 3)	Difficult
13.	Reducibility	Good 25% for 0.8 basicity 40% for 1.2 basicity	Very good 40% for acid pellets

NA—Not Applicable

So, if you look at from this table the feed side in sintering is in this range; while in pellets is in that range. So, this is the major difference between the pelletization and sintering when we are making the granules, mechanism wise it doesnt make much difference except a little.

Here as a fuel you use coke breeze here as oil which is high in cost product size 10 to 25 and here 12 to 16 millimeter. Product shape of course, irregular; here its regular angle of repose high 30 to 32; 24 to 26. And this is an important thing usually you need a low repose angle so, that the when you are charging in the blast furnace ah, though it could be much flatter the layer and which is important thing.

So, probably we will come about this later pipe handling in this of course, irregular not feasible; feasible. Bulk density low this is quite high and porosity of course, this is this is high Voidage is very good in sintering; not that good low iron you have a high iron here gangue is higher here, but here it is less.

High basicity here difficult to maintain that then you have a problem with the strength and other thing. Good reducibility here you have a very good one and that depends on the as your basicity what sort of basicity you put it. So, this is sort of the basic difference between sintering and palletization.

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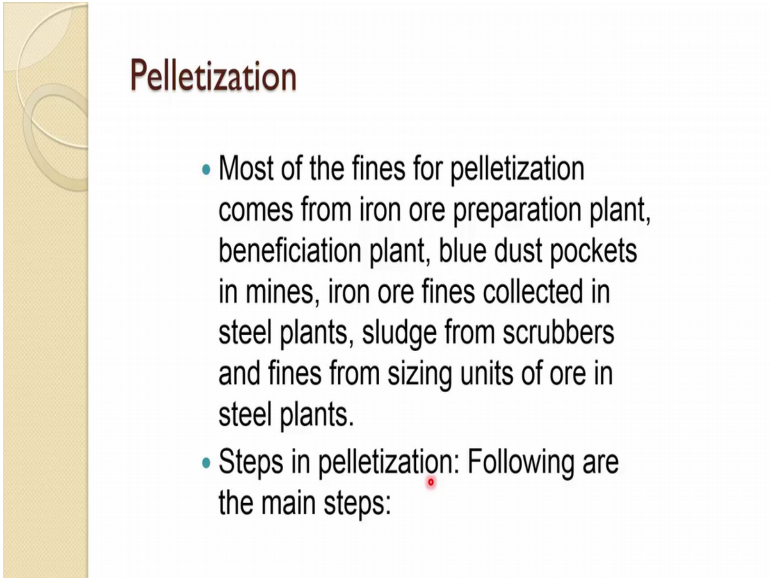

Pelletization

- Most of the fines for pelletization comes from iron ore preparation plant, beneficiation plant, blue dust pockets in mines, iron ore fines collected in steel plants, sludge from scrubbers and fines from sizing units of ore in steel plants.
- Steps in pelletization: Following are the main steps:

Ah In terms of; so, most of the points for palletization comes from iron ore preparation plant; beneficiation plant blue dust pocket in mines, iron ore fines collected in a steel plant, sludge from a scrubber and fines from sizing unit of ore. So, as we discussed during our ore section you do grinding, crushing; so, lots of fines are generated.

Similarly in sludge when you are removing the dust of claw from the blast furnace covers, you get that from the steel plant you collect quite a lot milli scale and B o basic oxygen furnace lots of iron fines are generated. So, these all goes to the pelletizing plant.

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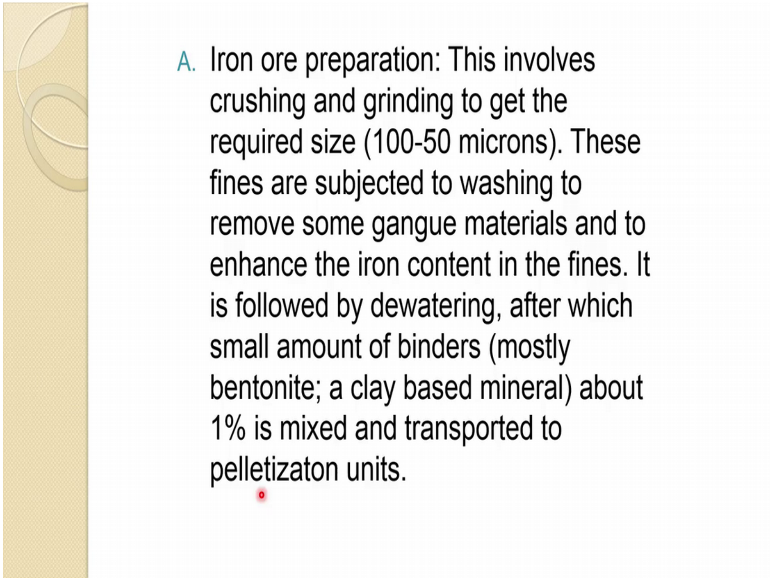

A. Iron ore preparation: This involves crushing and grinding to get the required size (100-50 microns). These fines are subjected to washing to remove some gangue materials and to enhance the iron content in the fines. It is followed by dewatering, after which small amount of binders (mostly bentonite; a clay based mineral) about 1% is mixed and transported to pelletizaton units.

So, following steps are there in palletization one is the iron ore preparation. So, naturally because many of these feed they do not have the correct size; so, you have to do the crushing and grinding and make sure the required size you get it between 100 to 50 micron and these fines are subjected to washing to remove the gangue material and enhance the iron content in the ore.

And it; so, when you do the washing naturally it has to follow the dewatering. And after which in especially in pelletizations you put a small amount of binders; mostly it is a bentonite which is a clay based mineral about 1 percent or so, you mix it and after the mixing you send it to the palletization plant there; for pelletizing unit; so, this is a important difference here.

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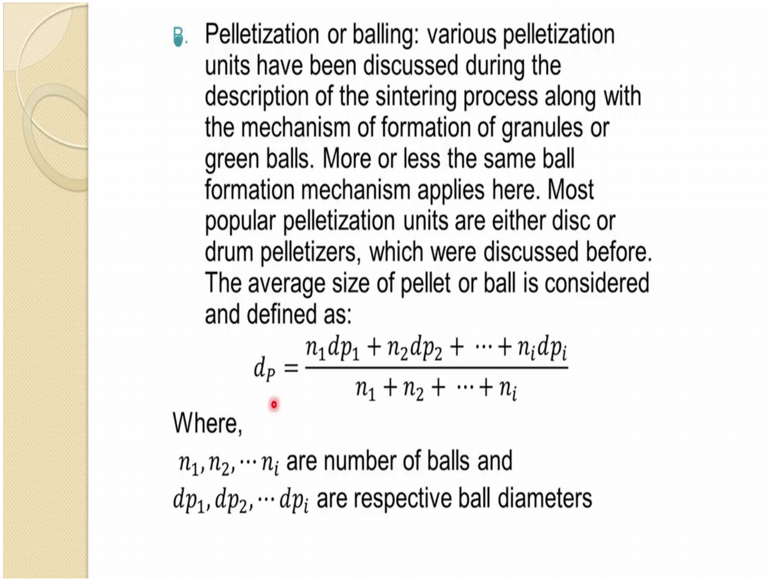

- Pelletization or balling: various pelletization units have been discussed during the description of the sintering process along with the mechanism of formation of granules or green balls. More or less the same ball formation mechanism applies here. Most popular pelletization units are either disc or drum pelletizers, which were discussed before. The average size of pellet or ball is considered and defined as:

$$d_p = \frac{n_1 dp_1 + n_2 dp_2 + \cdots + n_i dp_i}{n_1 + n_2 + \cdots + n_i}$$

Where,

$n_1, n_2, \cdots n_i$ are number of balls and

$dp_1, dp_2, \cdots dp_i$ are respective ball diameters

And so, palletization or balling so after this once it go to the penetration plant, we have already seen how the this palletizer worked how is the what is the mechanism of pelletizing nucleation, transition, then ball growth and the size it proportional to the feed rate and the water which you have putting the capillary effect; all those come into the picture and we have already discussed this in during the sintering in granulation.

So, same apply to here, but here the difference is the various palletization unit we have described before. So, more or less the same ball formation mechanism applies here; most popular palletization units are is the disc or drum pelletizer which were discussed before. And usually you present the result in terms of average size of the pellet which of course, you can define using this formula where n 1, n 2 are number of balls and d p 1, d p 2 are the respective diameter of the ball. So, normal averaging formula by which you can define the average ball pellet diameter.

Once you get this pellet form; now, you have to harden them because these are the green pellet does not have much strength.

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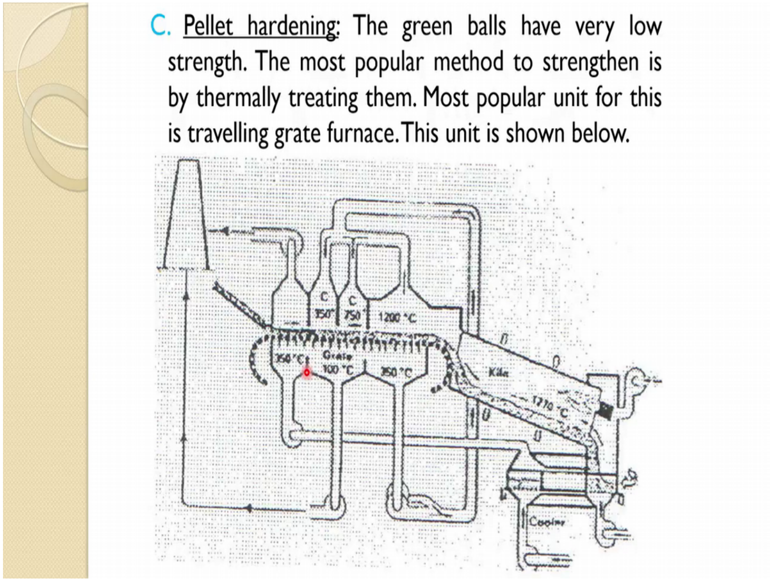

C. Pellet hardening: The green balls have very low strength. The most popular method to strengthen is by thermally treating them. Most popular unit for this is travelling grate furnace. This unit is shown below.

So, it goes to pellet hardening process in the previous one it is first going to the sintering one, in this one it is a pellet hardening. So, individual pellet usually they keep their shape in this case. So, it is not the fusion stage; so, temperature is little lower in this case. So, as you will see the this figure shows the in duration machine.

And in this one you will see it is a quite similar to the sintering machine, but there are many differences your main ok; so, most popular method to strengthen is thermally treating them and most popular unit is traveling grate furnace. The important difference is sometime you are having a up draft; so, the gases are being sucked of from this starting, we put it the green pellet comes feed from here on the traveling strand; they come over here and they are subject to the drying first here.

So, this is actually the updraft thing gas gases are being sucked from the top and from the bottom these gases are being supplied and, but these gases are the hot gases of about 3 50 degree Celsius which are coming from the cooling of the pellets; which are at 350 degree Celsius from the bottom layers, then sucked from the top of the suctions unit.

So, this keeps the drying of the pellet then they come to the next section where it is like a preheating of the pellet. So, temperature 350 to 7 50 degree Celsius zone and here you are having a down draft the way we had in the sintering. So, here suction is applied underneath of the moving grate and these hot air which are coming; these are coming actually after induration we will come to that section. So, here is a down draft before is a up; so, there is a difference.

After passing; so, here is the same thing is happening much more heating and other associated those evaporation and chemically bonded water is going away. Then it come to the high temperature zone about 1200 degrees Celsius when it comes to that one So, the fusion of the thing is occurring and you have a updraft here.

So, now, before that you had a downdraft now you are having a up draft and the hot gases actually are coming from this (Refer Time: 43:47). So, these from it these hot pellets; they fall they have feed to the kiln where the temperature is quite high about 1200; 1270 degree Celsius and from this to this journey; the induration of the pallet with fusion of that occurs and the change in the phase phases occurs.

And as I show in one of the slide previously that swelling of the pallet occurs. So, all those neurological changes may come and that is why it is necessary to have a proper control of the raw material. So, swelling of this should not occur otherwise this will create a problem in the blast furnace permeability. So, once its comes through the kiln the pellet totally are indurated and it comes out

And here the cooling is done and when you are blowing the cold air that become hot and that is the one which is used for the drying purpose. So, here you can see a little complex you are having a down draft and up draft of the air and that is how the induration unit have works.

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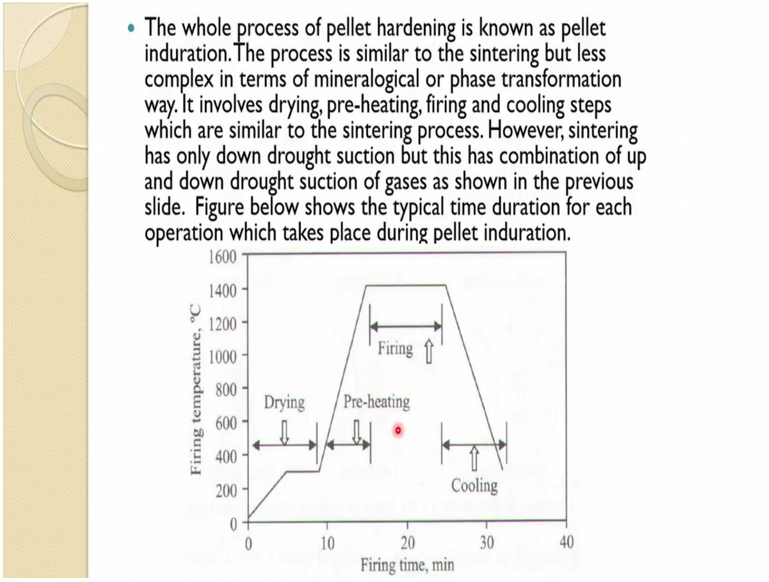

- The whole process of pellet hardening is known as pellet induration. The process is similar to the sintering but less complex in terms of mineralogical or phase transformation way. It involves drying, pre-heating, firing and cooling steps which are similar to the sintering process. However, sintering has only down drought suction but this has combination of up and down drought suction of gases as shown in the previous slide. Figure below shows the typical time duration for each operation which takes place during pellet induration.

Otherwise most and you can see from this figure how the different phenomena are occurring; how much time it takes. So, drying about 10 minutes preheating another 5 minutes and mostly then the firing about 10 minutes takes and then the cooling. So, these are the sort of steps which similar to the sintering one. So, only the problem you have a combination of down and up draft here.

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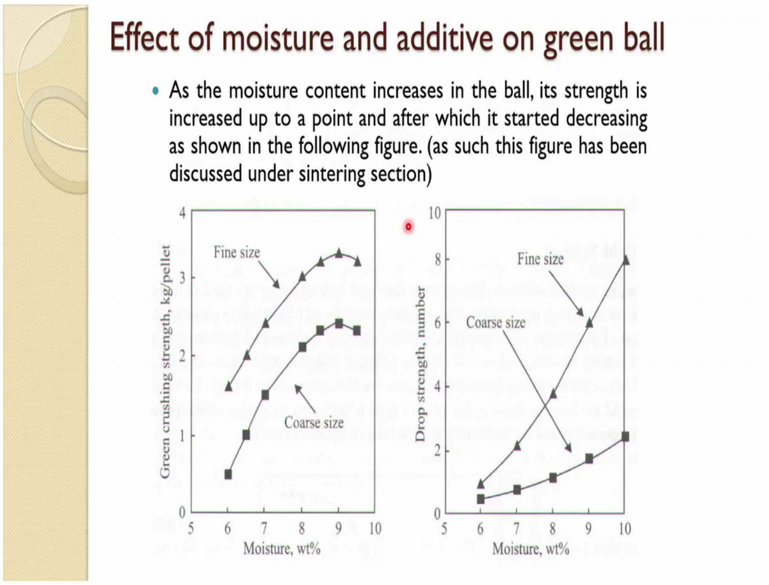

Effect of moisture and additive on green ball

- As the moisture content increases in the ball, its strength is increased up to a point and after which it started decreasing as shown in the following figure. (as such this figure has been discussed under sintering section)

Now, the effect of moisture content that we have seen that time previously; so, we are not going to discuss this, but as we said here finer size when we are talking we are talking more about the pelletized pellet; coarse size when we said this is more relevant to the sintering one.

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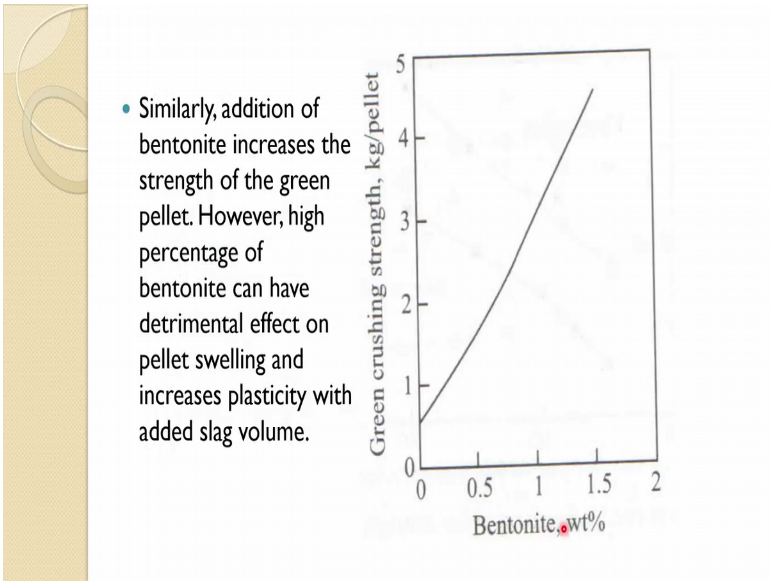

- Similarly, addition of bentonite increases the strength of the green pellet. However, high percentage of bentonite can have detrimental effect on pellet swelling and increases plasticity with added slag volume.

Ah Now bentonite when we said as you increase the bentonite, you can see the green crushing strength is increased which is actually a good, but you cannot use a very high bentonite because it gives a detrimental effect on pellets swelling and increase the plasticity with added slag. So, up to some extent it is fine; sometime even molasses is also used in place of bentonite.