Iron Making
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Lecture - 36
Iron Making

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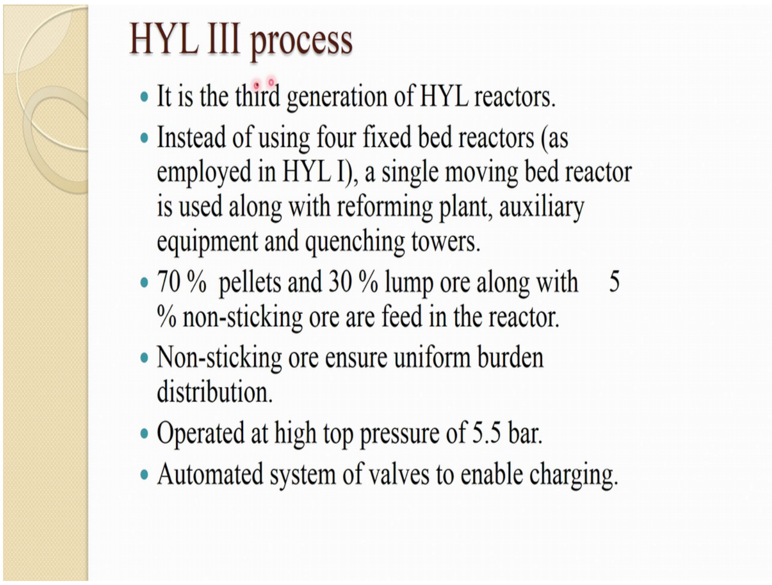

HYL III process

- It is the third generation of HYL reactors.
- Instead of using four fixed bed reactors (as employed in HYL I), a single moving bed reactor is used along with reforming plant, auxiliary equipment and quenching towers.
- 70 % pellets and 30 % lump ore along with 5 % non-sticking ore are feed in the reactor.
- Non-sticking ore ensure uniform burden distribution.
- Operated at high top pressure of 5.5 bar.
- Automated system of valves to enable charging.

HYL 3 process, it is the third generation of HYL reactors, instead of using four fixed bed reactor, which is do it in the first HYL, a single moving bed reactor is used along with reforming plant, auxiliary equipment and quenching towers. So, reforming plant is essential part of most of the gas based process. So, 70 percent pellet us and 30 percent lump are lump ore are along with 5 percent non sticking ore are fed into the reactor, non sticking ore ensure uniform burden distribution so it is taking, does not occur, operated at high top pressure 5.5 bar, automated system of valves enable to enable the charging.

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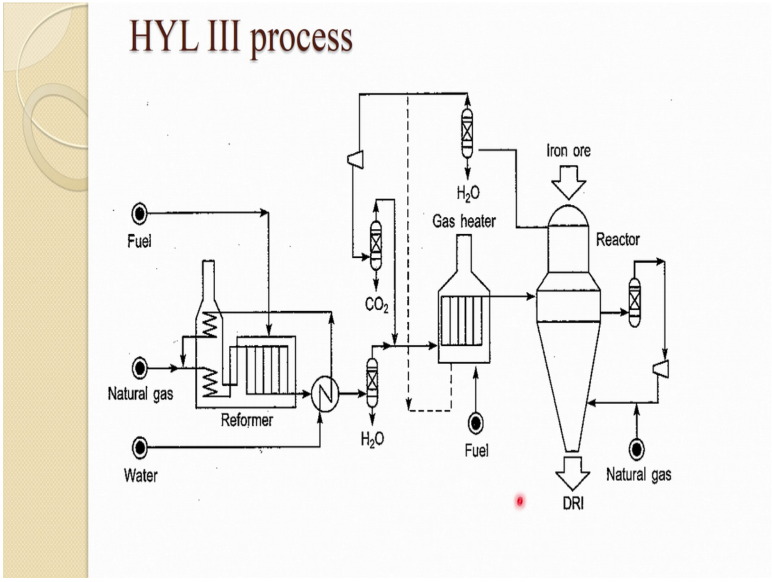

HYL III process

So, this is a typical flow sheet of HYL 3 process. So, if we set reformer, this initial part of these gas based, natural gas based process. So, natural gas reforms fuel for setting it up, this is a reformer while if you get the proper CO and hydrogen content into the gas and this is a fed again into the sort of gas iterate, these are temperature to increase norm and to remove the H 2 O, and this is just burner, no heater into the form and those heat heated gas goes to the reactor. So, this is a device section actually.

So, that is where this gas is goes from the bottom of this and go up and the iron ore is coming down in the this fence; that is where the most of the reaction which is occurring and the top gas is now again goes back and utilize them on heating and up the heating up the this reform gases and then, then some natural gas put it there the, because the this is the fluidize where actually (Refer Time: 02:56) mostly in fluidize condition.

So, and or actually time iterate is less, size is less in that, so it is gets reduced in the fluidize condition and quite hot, you need a sort of a coal or natural gas not that heated because it cooled it down and it comes into form of DRI from the bottom. So, this is the sort of essential operations of, not just HYL 3 process many of the fluidize bed process, these are the essential part of the it, sometime in some of them if it is hot there put there we get machine to make it into briquette form of this hot iron, it directly reduce silently it comes into the briquette form. So, descent rate is controlled by rotary valve at the exit of the reactors.

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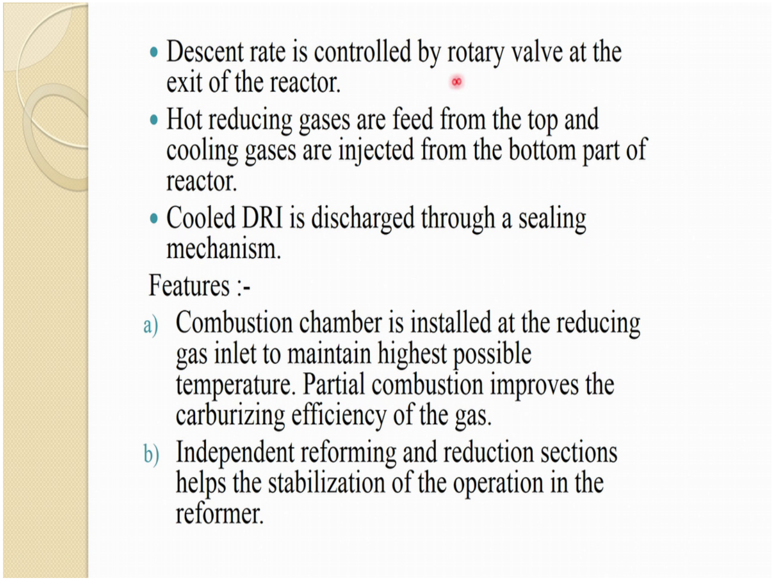

- Descent rate is controlled by rotary valve at the exit of the reactor.
- Hot reducing gases are feed from the top and cooling gases are injected from the bottom part of reactor.
- Cooled DRI is discharged through a sealing mechanism.

Features :-

a) Combustion chamber is installed at the reducing gas inlet to maintain highest possible temperature. Partial combustion improves the carburizing efficiency of the gas.

b) Independent reforming and reduction sections helps the stabilization of the operation in the reformer.

So, he use a rotary valve by which control this exit descent rate. Hot reducing gases are feed from the top, and the cooling gases are injected from the bottom part of the reactor as said before. So, cooled DRI is discharged through a sealing mechanism. Combustion chamber is installed at reducing gas inlet to maintain highest possible temperature. Partial combustion improves the carburizing efficiency of the gas and independent reforming and reduction section helps the stabilization of the operation in the reformer.

So, these are the features of HYL process of fluidize bed one. Remember matrix process is not a fluidize bed process, it is a just a peg bed process, so that the basic difference and most of the products and I think almost 67 percent has also as shown in that figure comes through this of the world, and a remaining comes from this and S L R R in process.

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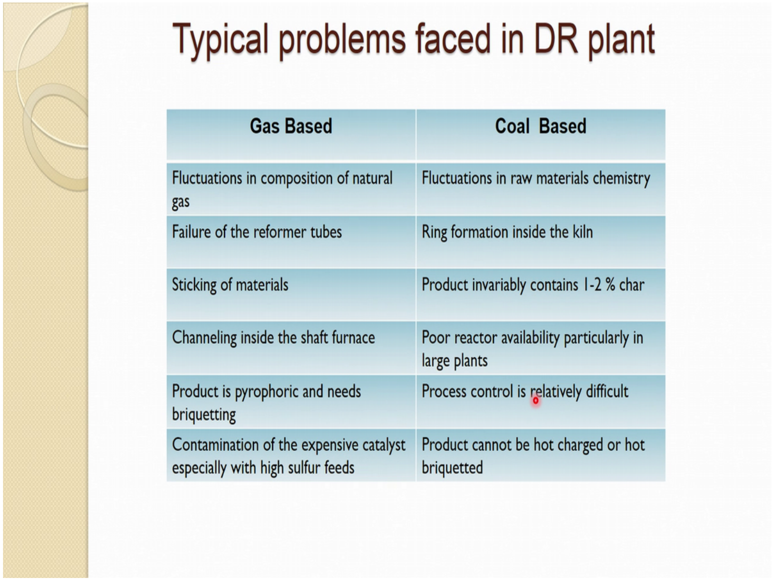

Typical problems faced in DR plant

Gas Based	Coal Based
Fluctuations in composition of natural gas	Fluctuations in raw materials chemistry
Failure of the reformer tubes	Ring formation inside the kiln
Sticking of materials	Product invariably contains 1-2 % char
Channeling inside the shaft furnace	Poor reactor availability particularly in large plants
Product is pyrophoric and needs briquetting	Process control is relatively difficult
Contamination of the expensive catalyst especially with high sulfur feeds	Product cannot be hot charged or hot briquetted

So, typical problems faced in DR plants, usually in the gas based you have a fluctuations in composition of natural gas. So, it is a sometime becomes difficult to maintain the right composition always some fluctuation is there. So, one has to be quite careful in that one and keep on checking the composition. Failure of the reformer tubes, this is also quite common problem in the gas based reformer units, a sticking of materials, they.

This is one of the major problems, especially withdrawing the material after reduction and some raw melting gang or something is formed or some sticking problem may occur and that is quite prevalent channeling inside the glass and inside the shaft furnace similar to the blast furnace, product is pyrophoric and needs briquetting. So, especially with a fluidize one, because the size is a small, so it like a pyrophoric in that once again it briquetting before comes out and expose to the atmosphere. Contamination of a expensive catalyst especially with high sulfur needs.

So, these are few problems with the gas based and in the coal based fluctuations in the raw materials chemistry. So, though still it except a quite variety of composition, but it still one has to be careful and they chemistry composition the raw material. Ring formation that is related to more about kiln based DR processes. Product invariably contains around 1 to 2 percent charge. Poor reactor availability particularly in large plant, process control is relatively difficult, product cannot be hot charged or hot briquetted that is also going problem in the coal based plant then the gas based plant.

So, these are the few problem in both of them and this is also one of the region, not only just base the main reason, is about as i said it gives a sort of solid product, and so does not retain the sensible heat and in the hot, when you briquette it liquid form like from the blast furnaces liquid metal, it retains the sensible heat and which can be used in the still making of lesson at a later stage ah; however, in this one um, because again it has to go to the electrical furnace and other, so (Refer Time: 08:52) again it has to be heated up to the melting point to make the steel.

And this is one of the reason till now this process is, though they use coal or gas, but they are far away to take over the glass furnace and last half century or more than that, hardly even a less than a 5 percent is the contribution today total hot metal products and in that case, but nevertheless due to many other advantage, this smaller unit at a smaller place places using of coal, they are a still quite popular at a small scale.

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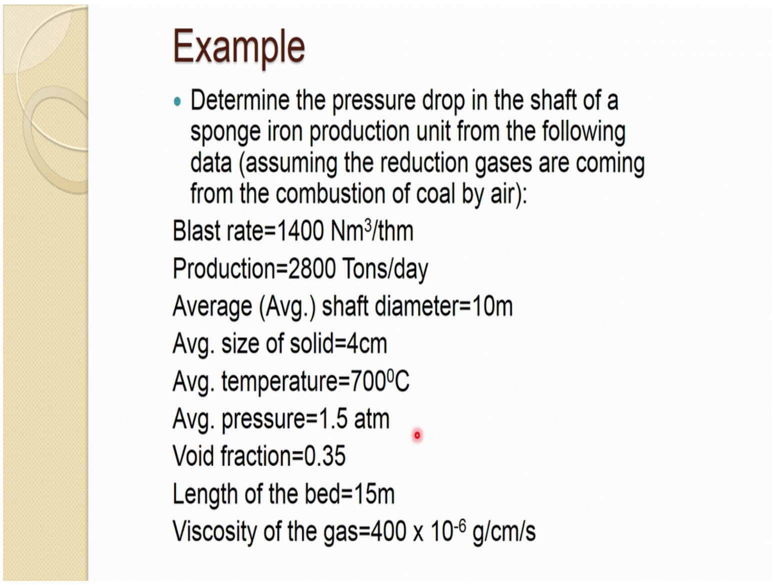

Example

- Determine the pressure drop in the shaft of a sponge iron production unit from the following data (assuming the reduction gases are coming from the combustion of coal by air):

Blast rate=1400 Nm^3/thm

Production=2800 Tons/day

Average (Avg.) shaft diameter=10m

Avg. size of solid=4cm

Avg. temperature=700^0C

Avg. pressure=1.5 atm

Void fraction=0.35

Length of the bed=15m

Viscosity of the gas=400 x 10^{-6} g/cm/s

Now we will through an example and this is more based on like a shaft, shaft type sponge iron unit. So, determine the pressure drop in this shaft of a sponge iron production unit from the following data. This type modify the, modify these assuming the reduction gases or reducing gases are coming from the combustion of coal by air.

So,. So, when your saying reducing gases is coming combustion of coal by air, so it would be having a CO CO 2 and nitrogen into the this. So, like, like a blast furnace sort of gases. So, and that condition you have to determine the pressure drop in the shaft. So, blast rate, the blast rate is given 1400 normal meter cube per 10 of hot meter, production rate is 20 2800 tons per day, average shaft diameter is 10 meter, average size of solid 4 centimeter, average temperature 700 degree Celsius, average pressures 1.5 atmosphere, void fraction is 0.35, length of the bed may be taken as 15 meter, viscosity of the gas may be assume as 400 into 10 to the power minus 6 gram centimeter second.

So, giving these data we have to determine their pressure drop. So, naturally we need to know the Reynolds number and not only the Reynolds number we need to know the density of the gas. So, we have to density of the gas, we can find out only once we know the composition of the gas. So, those are the few essential things which we have to find out first, and then only we can go for the pressure drop, and for pressure drop we can use simply the organic equation that we have discussed in the case of blast furnace.

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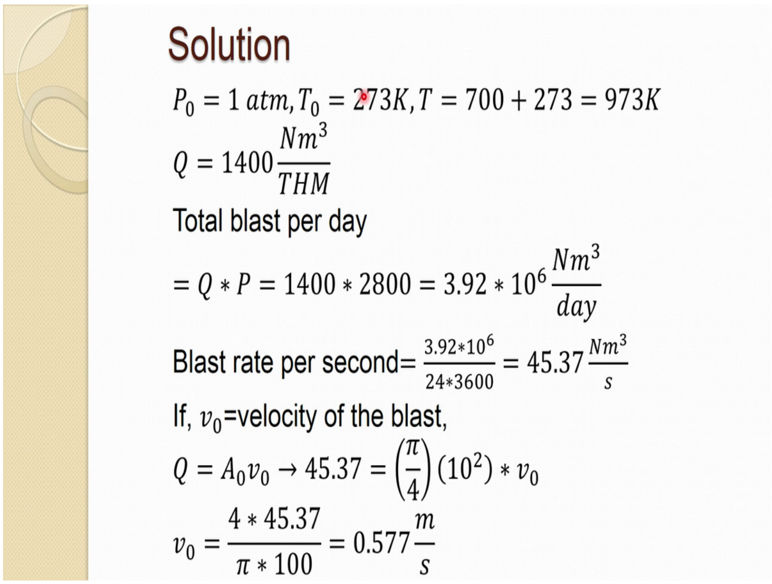

Solution

$P_0 = 1\,atm, T_0 = 273K, T = 700 + 273 = 973K$

$Q = 1400 \frac{Nm^3}{THM}$

Total blast per day

$= Q * P = 1400 * 2800 = 3.92 * 10^6 \frac{Nm^3}{day}$

Blast rate per second= $\frac{3.92*10^6}{24*3600} = 45.37 \frac{Nm^3}{s}$

If, v_0=velocity of the blast,

$Q = A_0 v_0 \rightarrow 45.37 = \left(\frac{\pi}{4}\right)(10^2) * v_0$

$v_0 = \frac{4 * 45.37}{\pi * 100} = 0.577 \frac{m}{s}$

So, let us see the a one atmosphere, initial, i can consider T naught 273. Now 700 degree Celsius the process is operating. So, it is 973 Kelvin the that is a given in the blast rate it is a 1400 normal meter cube per 10 of hot meter, actually it is per 10 of briquette, where have this hot meter it is essentially direct reduced iron. So, per 10 of DRI its, it is.

So, it is a per 10 of DRI. So, total blast per day would be you know already their blast rate, and we know the production. So, that will give us the total blast per day. So, total blast per day would be this, so much normal meter cube per day. Now in terms of second we have to convert a day into second, so 24 hours into 3600 second will give you the blast rates about 45.37 normal meter cube per second, so this is the blast rate.

Now once we know the blast rate we can calculate the velocity, because their shaft diameter is given. So, we can assume this relation, so we can divide by the area. So, blast rate per second is nothing area, cross sectional area of this shaft and the gas velocity. So, this is we have already calculated 45.37 normal meter per cube, area is pi by 4 into 10 to the power 2 diameter is given.

So, and then the velocity and. So, because it is a pi r square that is why 4 is coming over here if we converted into diameter and we notice the velocity. So, that really gives you the supper spatial velocity and that is what we need it even for the pressure drop. So, this simply, if you rearrange this parameter, it will give you 0.577 meter per second the supper spatial gas velocity. Now we know the gas velocity.

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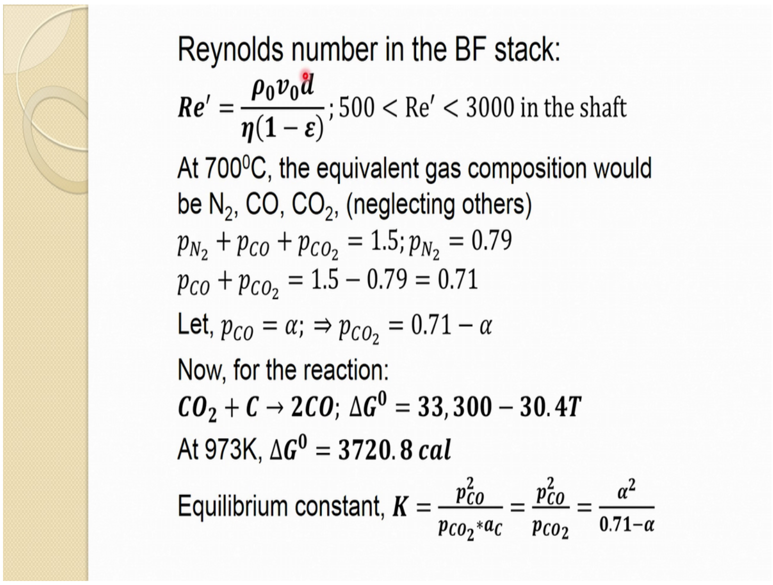

Reynolds number in the BF stack:

$$\boldsymbol{Re'} = \frac{\boldsymbol{\rho_0 v_0 d}}{\boldsymbol{\eta(1-\varepsilon)}}; 500 < \mathrm{Re'} < 3000 \text{ in the shaft}$$

At 700^{0}C, the equivalent gas composition would be N_2, CO, CO_2, (neglecting others)

$p_{N_2} + p_{CO} + p_{CO_2} = 1.5; p_{N_2} = 0.79$

$p_{CO} + p_{CO_2} = 1.5 - 0.79 = 0.71$

Let, $p_{CO} = \alpha; \Rightarrow p_{CO_2} = 0.71 - \alpha$

Now, for the reaction:

$\boldsymbol{CO_2 + C \rightarrow 2CO;\ \Delta G^0 = 33,300 - 30.4T}$

At 973K, $\Delta G^0 = \boldsymbol{3720.8\ cal}$

Equilibrium constant, $\boldsymbol{K} = \frac{p_{CO}^2}{p_{CO_2} * a_C} = \frac{p_{CO}^2}{p_{CO_2}} = \frac{\alpha^2}{0.71-\alpha}$

We can also, we can calculate the Reynolds number, but before that we need also the density of the mid gas, so it is 700 degree Celsius. The equivalent gas composition would be nitrogen CO CO 2, neglecting other smaller amount. So, we know it is says 1.5 at atmosphere it was. So, total pressures of partial pressure nitrogen, carbon monoxide and carbon dioxide should be equal to 1.5 and you know this gases which we are getting by combustion in presence of air.

So, air you have partial pressure of nitrogen about 0.79. So, this we know we substitute in this one. So, we get the partial pressure of CO and partial pressure of CO 2 about 0.71. now so we know let us say the pco, one of them having a partial pressure alpha, so other one would be having; obviously, pco 2 equal to 0.71 minus alpha, because total is 0.71 of CO and CO 2. So, now, we have to use the reaction. So, CO 2 plus C gives 2 CO, this is quite extended one and free energy of the reaction is given by this.

So, we can calculate the free energy from this. So, at we know that temperature 700 so degree celsius of free energy for this reaction is 700 degree celsius is 3720.8 calories. So, now we know this. So, we can, we know the, from this reaction that equilibrium constant of this reaction is not increase, CO is quite divided by pco 2 and a c activity of carbon can be taken h 1. So, essential it is a s o, pco is square by pco 2, this we have done this sort of example before.

So, i bit encourage you to go look at the previous examples like this. So, pco we have already assumed alpha, so that is alpha square and pco 2 we have calculated here is this. So, what now we need the K, the equilibrium constant value in order to get the alpha and equilibrium constant value can be calculated using now free energy for this reaction.

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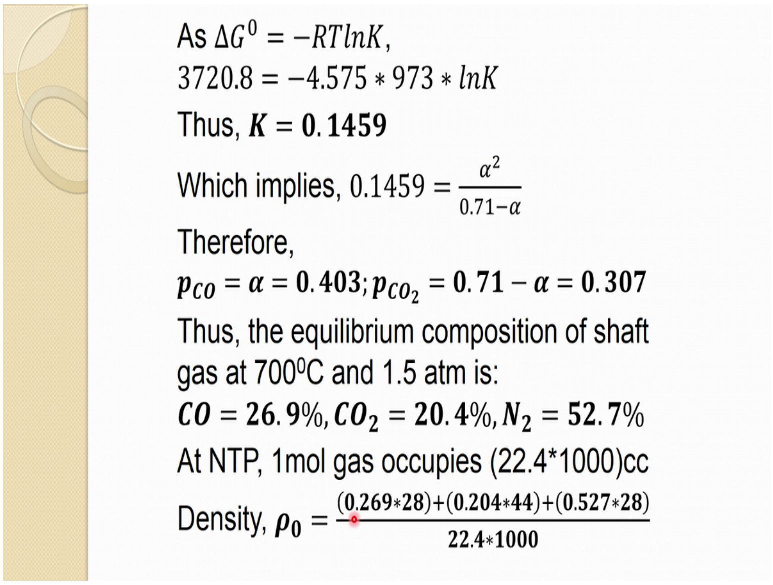

As $\Delta G^0 = -RTlnK$,

$3720.8 = -4.575 * 973 * lnK$

Thus, $\boldsymbol{K = 0.1459}$

Which implies, $0.1459 = \frac{\alpha^2}{0.71-\alpha}$

Therefore,

$\boldsymbol{p_{CO} = \alpha = 0.403; p_{CO_2} = 0.71 - \alpha = 0.307}$

Thus, the equilibrium composition of shaft gas at 700^{0}C and 1.5 atm is:

$\boldsymbol{CO = 26.9\%, CO_2 = 20.4\%, N_2 = 52.7\%}$

At NTP, 1mol gas occupies (22.4*1000)cc

Density, $\rho_0 = \frac{(0.269*28)+(0.204*44)+(0.527*28)}{22.4*1000}$

As you know for that free energy with the equilibrium constant can be represented by this equation delta G naught equal to minus R T log K. So, delta G naught now calculated, R and T unit proper unit be taken then log then K. So, these are known and K is the only thing which is unknown, one can calculate the K th K value comes to 0.1459.

Now, this K value we can put it into this relation over here. So, we can get the value of alpha, it can be solved, all are known as alpha. So, this alpha gives 0.403, so pco is nothing, it is a partial pressure of CO. Then once we know this, then partial pressure of CO 2 nothing points have been 1 minus alpha equal to 0.3 or 7. So, we got the partial pressure of CO and CO 2. So, now, we can, we know the equilibrium composition of the gases at 700 degree celsius and 1.5 atmosphere, it is about in percentage 26.9 percent CO, 20.4 percent CO 2 and nitrogen is 52.7 percent.

So, from this fraction you can calculate this percentage, this has been done before quite a lot. And now we been know these percentage of, fraction of these thing in percentage form, then we can calculate the density of the gas. So, we know at N T P normal temperature and pressure 1 mol of gas occupies about 22.4 litre which is into a 1000, so many cc's

So, the density of this would be 0.269 into 20 28, it is CO molecular weight then 0.204 multiplied with the molecular weight of CO 2 44, then 0.527 multiplied with the molecular weight of nitrogen and divided by 22.4 into 1000; that is going to give you the density of the gas and density of the gas comes to 1.4 into 10 to the power minus 3 gram per cc.

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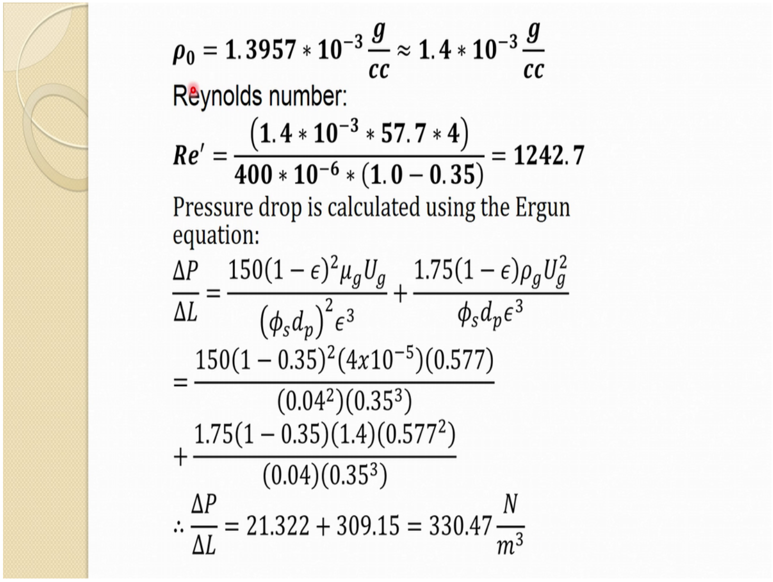

$$\rho_0 = 1.3957 * 10^{-3}\frac{g}{cc} \approx 1.4 * 10^{-3}\frac{g}{cc}$$

Reynolds number:

$$Re' = \frac{(1.4 * 10^{-3} * 57.7 * 4)}{400 * 10^{-6} * (1.0 - 0.35)} = 1242.7$$

Pressure drop is calculated using the Ergun equation:

$$\frac{\Delta P}{\Delta L} = \frac{150(1-\epsilon)^2\mu_g U_g}{(\phi_s d_p)^2\epsilon^3} + \frac{1.75(1-\epsilon)\rho_g U_g^2}{\phi_s d_p \epsilon^3}$$

$$= \frac{150(1-0.35)^2(4x10^{-5})(0.577)}{(0.04^2)(0.35^3)}$$

$$+ \frac{1.75(1-0.35)(1.4)(0.577^2)}{(0.04)(0.35^3)}$$

$$\therefore \frac{\Delta P}{\Delta L} = 21.322 + 309.15 = 330.47\frac{N}{m^3}$$

Now we know already and we know that Reynolds numbers, definition of this one. So, we already got now density, we got velocity, diameter is Kelvin, viscosity is also given, by fraction is also given. So, we can calculate the Reynolds number. So, this is our density, velocity, diameter, viscosity, bolds fraction. So, the viscosity is given, density we just calculated, velocity we calculated and the size of the particle is given for centimeter.

So, that gives you the Reynolds number 1 to 4 2 and what this is applicable, where we said Reynolds number lies between this range, it is coming between only that range. Now we can calculate the pressure drop, the, that is what is actually is required that the question is asking and pressure drop is you know is given by Ergun equation, which we had discussed before. And those blast furnace examples in detail and organic equation is given by this formula, where phi is s with the self vector and mu g is the viscosity and gas velocity, gas viscosity, void fraction, gas density, particle size and the self factor.

Now, self factor in this case would be one, because that particles are spherical that assumes, so self factor between one. So, now, we can put these values voids fraction, viscosity. This velocity of the gas. Now S I unit here has been used. So, you can see a little difference in this and then the particle size, void fraction, this is for this part and for this part, is similarly can be given in this form. So, delta P of delta L is given.

So, once you solve this 21.33 309, it comes 330.47 normal per meter cube. Now per meter. Now remember these, we have discussed about this two terms and we said this is more pressure drop due to laminar flow pressure drop due to turbulent flow. So, you can see here turbulent flow is quite dominating, then the laminar flow is almost not just 10 time is almost 14 times or so than laminar flow. So, total pressure drop comes into this and which for the, in the whole.

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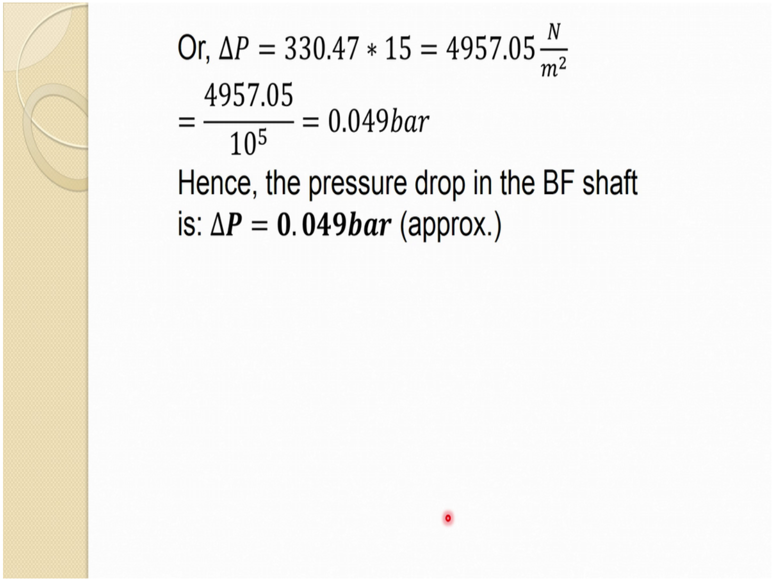

Or, $\Delta P = 330.47 * 15 = 4957.05 \frac{N}{m^2}$

$= \frac{4957.05}{10^5} = 0.049 bar$

Hence, the pressure drop in the BF shaft is: $\boldsymbol{\Delta P = 0.049 bar}$ (approx.)

Now this is on a. Now delta L is there and del delta L is given 15 meter. So, we multiply with that so, our this comes (Refer Time: 25:27) Newton per meter square, the pressure drop and that Newton per meter square can be converted into bar. So, it is about 0.05 bar. So, hence the pressure drop in the actually shaft furnace is 0.05 bar, so that is a, the pressure drop. Now we will talk a. now we will switch over to the, another process.

So, when we said alternative truth of iron making, we said direct reduction by reduce iron, then we talked also smelting reduction. So, these are the two main processes by which iron is produced in alternative way. So, direct reduce iron or direct reduce processes you are familiar. Now the second process is known as the smelting reduction. So, that is the one which we would be talking now and as you are aware in this direct reduction, we said repeatedly that it gives the solid product.

So, sensible heat is lost and what is preferred for a steel making, is in liquid form and that is how this smelting reduction came into picture on to existence, using the almost the same cheap raw material ah; like coal, ore fines and like that. So, now, we will talk about smelting reduction.

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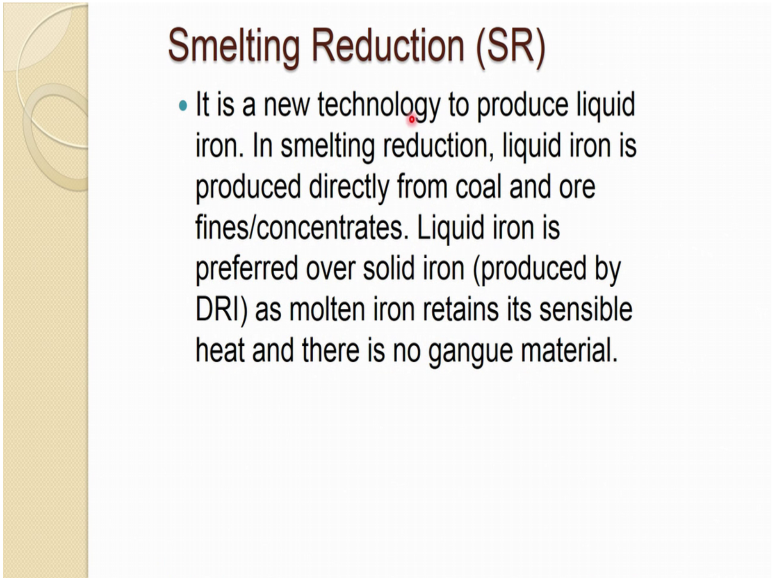

Smelting Reduction (SR)

- It is a new technology to produce liquid iron. In smelting reduction, liquid iron is produced directly from coal and ore fines/concentrates. Liquid iron is preferred over solid iron (produced by DRI) as molten iron retains its sensible heat and there is no gangue material.

So, it is a new technology to produce liquid iron. In smelting reduction, liquid iron is produced directly from coal and ore fines concentrates. So, liquid iron is produced directly from coal and ore fines. Liquid iron is preferred over solid iron as molten iron, retains it is sensible heat and there is no gangue material. Another advantage there is no gangue material. So, slag formation is quite low in the subsequent process, where and it still making a reducing a DRI. So, more slag form is another problem in subsequent operations.

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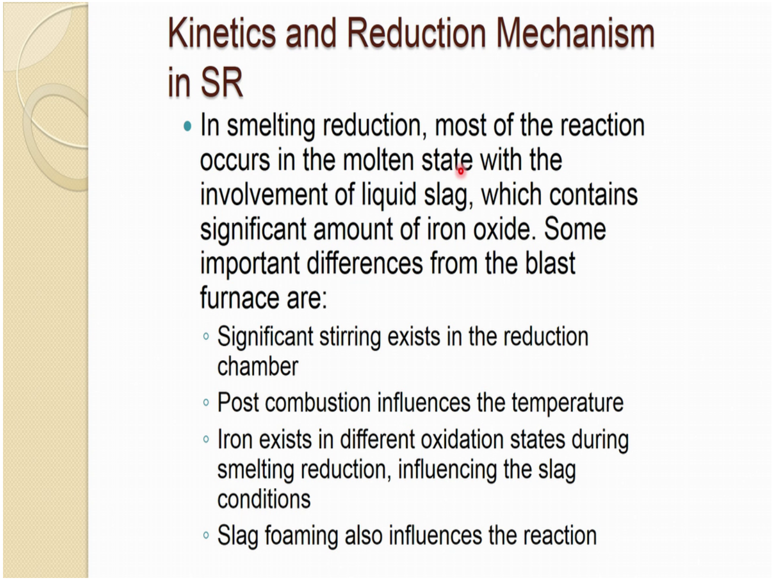

Kinetics and Reduction Mechanism in SR

- In smelting reduction, most of the reaction occurs in the molten state with the involvement of liquid slag, which contains significant amount of iron oxide. Some important differences from the blast furnace are:
  - Significant stirring exists in the reduction chamber
  - Post combustion influences the temperature
  - Iron exists in different oxidation states during smelting reduction, influencing the slag conditions
  - Slag foaming also influences the reaction

So, now again before we go to describing about the process smelting reduction processes, which have been double up the commercialized, is what they talk little bit about the physical chemical nature of it or the kinetic reduction mechanism of it, as we have discussed for direct reduction processes um. So, in smelting reduction, most of the reaction occurs in the molten state with the involvement of liquid slag, which contains significant amount of iron oxide, some important differences from the blast furnaces are significant, stirring exists in the reduction chamber post combustion influences the temperature we will come to this term. I will explain a little bit it you have not come across this term.

So, I will explain little later when we come to the process what does it mean, the post combustion I will tell later. So, iron exists in different oxidation states during smelting reduction influencing the slag condition, because continuously changing the oxidation stage slag foaming, also influences the reaction this also, I think may be Newton for you, I will talk about it little bit when I will describe about the process, so kinetic aspect of this, because as mentioned most of the reduction is occurring in the liquid stage. So, most of the reaction occurs in a molten state, so reduction by solid carbon.

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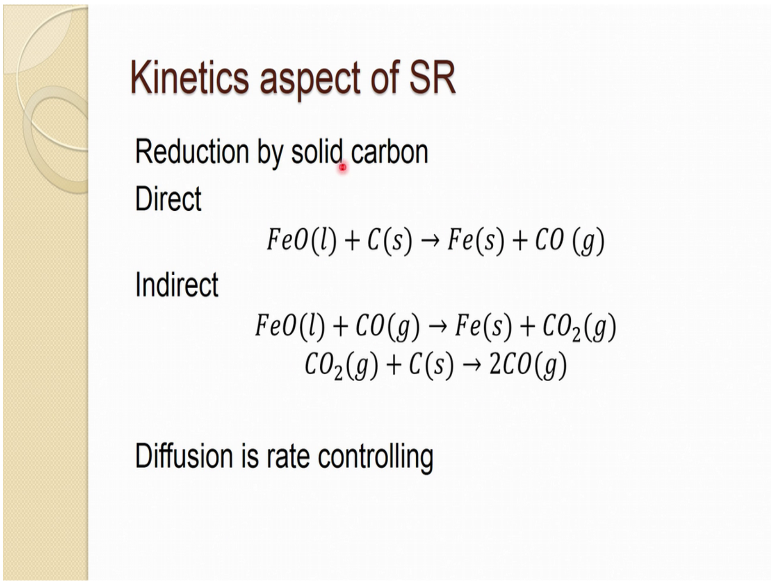

Kinetics aspect of SR

Reduction by solid carbon

Direct

$$FeO(l) + C(s) \rightarrow Fe(s) + CO\ (g)$$

Indirect

$$FeO(l) + CO(g) \rightarrow Fe(s) + CO_2(g)$$
$$CO_2(g) + C(s) \rightarrow 2CO(g)$$

Diffusion is rate controlling

So, F e O sort of a liquid state, carbon solid produce iron and CO gas in indirect way, even through a CO gas, it can be reduced F e O liquid state, gas state iron and CO 2 and

CO 2 again react with carbon, which is available to form CO which are can reduce with this.

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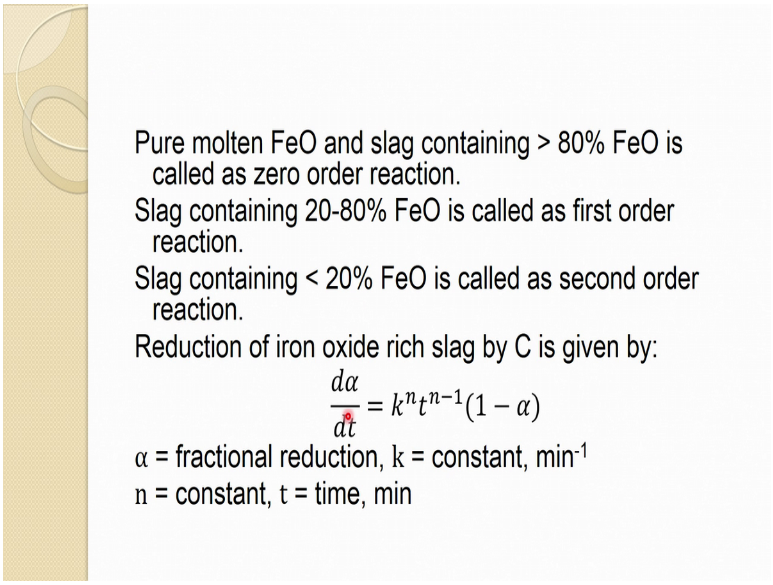

Pure molten FeO and slag containing > 80% FeO is called as zero order reaction.

Slag containing 20-80% FeO is called as first order reaction.

Slag containing < 20% FeO is called as second order reaction.

Reduction of iron oxide rich slag by C is given by:

$$\frac{d\alpha}{dt} = k^n t^{n-1}(1-\alpha)$$

α = fractional reduction, k = constant, min^{-1}

n = constant, t = time, min

So, it is a sort of diffusion rate controlling, but kinetics is quite complexes in this one. We will lots again pure molten F e O and slag containing 80 percent F e O is called as a zero order reaction. So, if the slag is containing 80 percent F e O and that is a mixture, then usually the kinetic is a zero order reaction. And if it is between 20 and 80 percent of F e O, then it is a first order reaction and less than 20 percent, then it is second order reaction. And usually this iron oxide is slag by carbon, kinetics is present by this equation, where n is a constant and t is the time and alpha is the fraction reduced and k is a constant and experimentally one has to determine.

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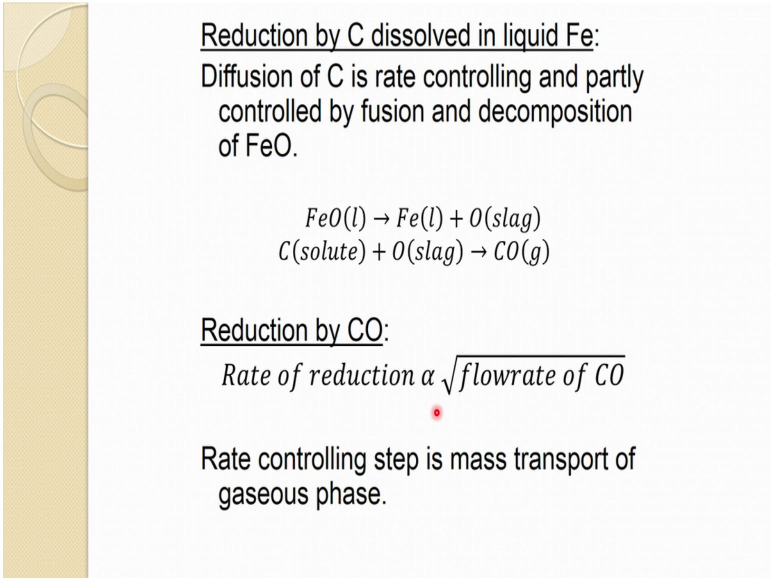

Reduction by C dissolved in liquid Fe:

Diffusion of C is rate controlling and partly controlled by fusion and decomposition of FeO.

$$FeO(l) \rightarrow Fe(l) + O(slag)$$
$$C(solute) + O(slag) \rightarrow CO(g)$$

Reduction by CO:

$$Rate\ of\ reduction\ \alpha\ \sqrt{flowrate\ of\ CO}$$

Rate controlling step is mass transport of gaseous phase.

So, it is a quite complex reaction in liquid stage and not this sort of very definite kinetic which is established, because it depends on many parameters. So, reduction by carbon dissolving liquid iron this of course, we have seen in related to blast furnace in the earth region. So, diffusion of carbon is rate controlling and partly controlled by fusion and decomposition of F e O.

So, F e O also can decompose, because this operating at high temperature in a liquid state to F e and O and this solid carbon from react with oxygen and forms CO gas. So, this is sort of a diffusion rate controlling, when reduction by solid carbon and liquid iron state. And reduction by CO, then rate of reduction is proportional to the flow rate of CO, the rate by CO is generating.

So, rate controlling is step in this one is the mass transport of the gaseous space; that is CO. So, related to kinetic smelting reduction which about, that much which is a little complex and quite a lot work has been done, but it still there are many relation available in different conditions, but these are the main reaction which occurs and rate controlling sort of a, this type of reaction first order, second order, the third order.

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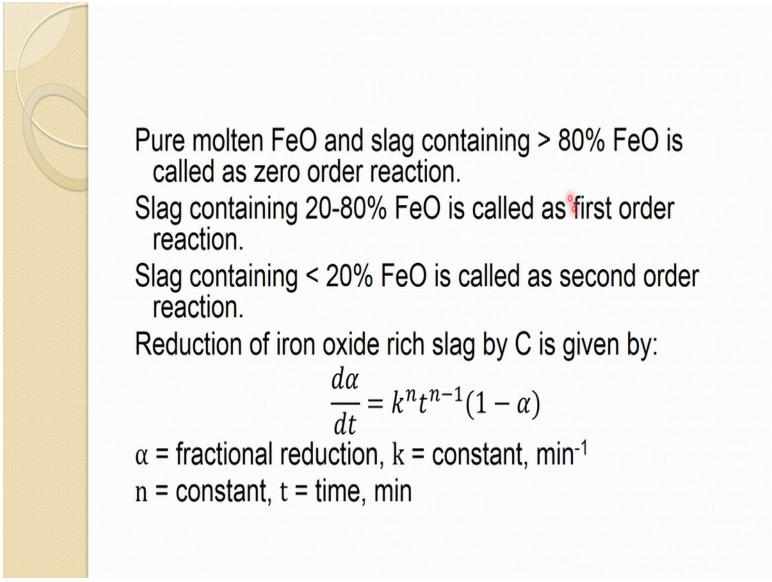

Pure molten FeO and slag containing > 80% FeO is called as zero order reaction.

Slag containing 20-80% FeO is called as first order reaction.

Slag containing < 20% FeO is called as second order reaction.

Reduction of iron oxide rich slag by C is given by:

$$\frac{d\alpha}{dt} = k^n t^{n-1}(1-\alpha)$$

α = fractional reduction, k = constant, min^{-1}

n = constant, t = time, min

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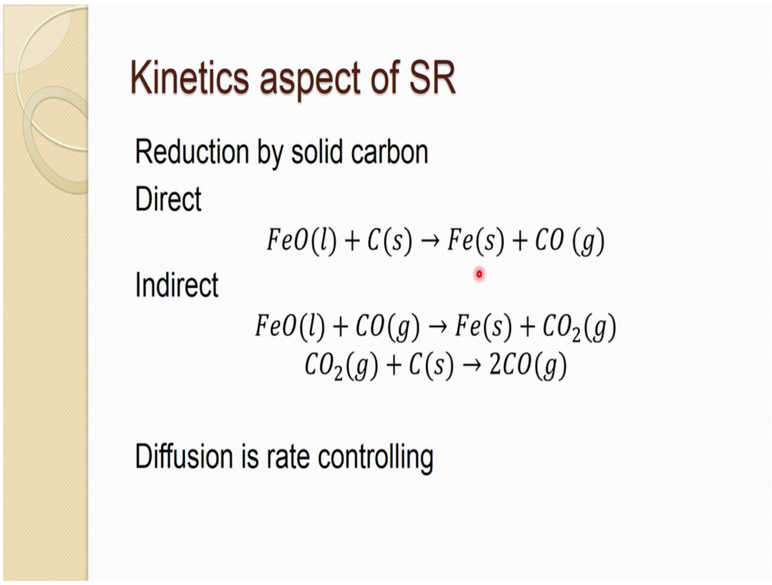

Kinetics aspect of SR

Reduction by solid carbon

Direct

$$FeO(l) + C(s) \rightarrow Fe(s) + CO\,(g)$$

Indirect

$$FeO(l) + CO(g) \rightarrow Fe(s) + CO_2(g)$$
$$CO_2(g) + C(s) \rightarrow 2CO(g)$$

Diffusion is rate controlling

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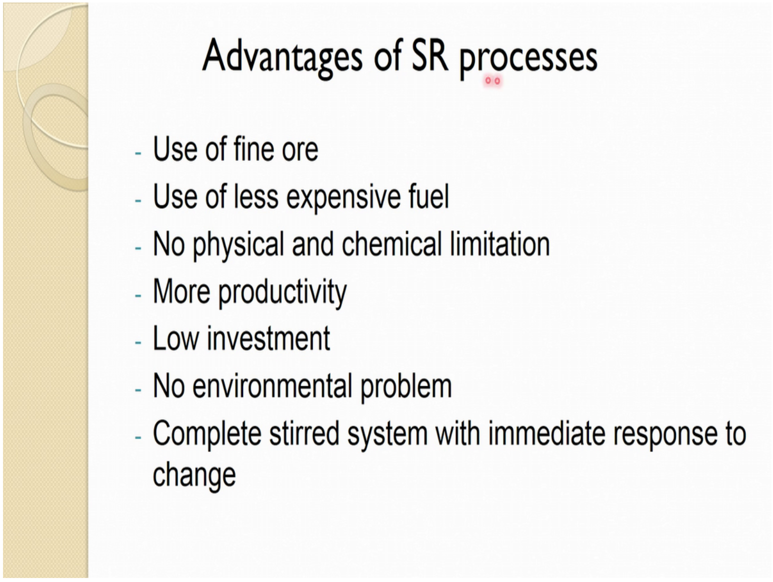

Advantages of SR processes

- Use of fine ore
- Use of less expensive fuel
- No physical and chemical limitation
- More productivity
- Low investment
- No environmental problem
- Complete stirred system with immediate response to change

These are the basic thing one should be knowing about this smelting reduction. So, advantage is, of this smelting reduction processes are; use of fine ore. This is very important actually, even in the blast furnace mining and others subsequent operation in the raw material refining, lots of fines are generated, in transportation, so the. So, then you have to establish this igrome relation; like sintering and pelletization plant and like that and another energy intensive unit.

So, when, in this process you can directly use the fine ores and your eliminating all those unnecessary unit, so agglomeration and pelletization, sintering and the (Refer Time: 34:41) having an energy and environmental term in that way, use of less expensive fuel. So, here you do not have to use even coal, and again one more environmental problem and you can use coal directive and this less expensive. No physical and chemical limitation, more productivity, low investment. These are also work like a DRI, DRI sort of way; you can put the small units at localized place.

So, quite a low investment, in that way we can little popular. it is not an no environmental problem, environmental, reduced an environmental problem, complete stirred system with immediate response to the change like, unlike blast furnace, when you want to see the effect of anything or any change, it takes hours. Here you will get the immediate response of any change which you want to do it. So, these are the quite few advantage of smelting reduction processes.

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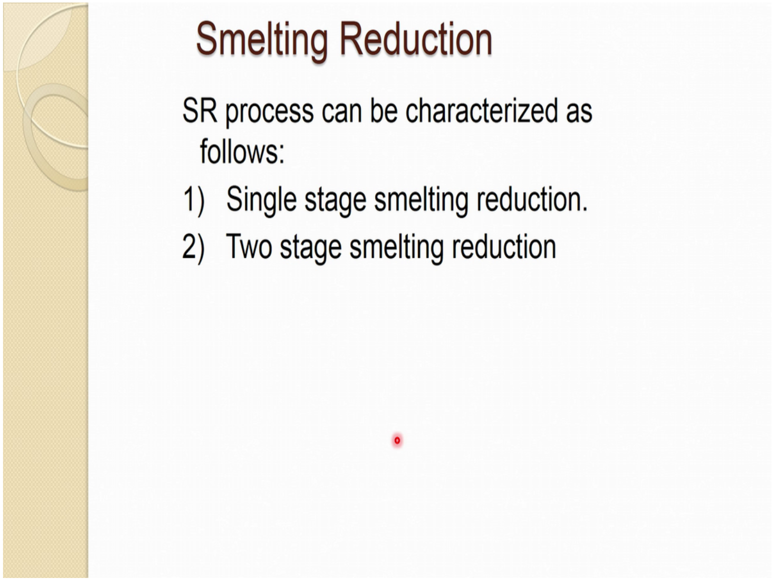

Smelting Reduction

SR process can be characterized as follows:

1) Single stage smelting reduction.
2) Two stage smelting reduction

So, smelting reduction processes can be characterized either single stage smelting reduction or two stage smelting reduction, and the single stage the, is smelting ok.

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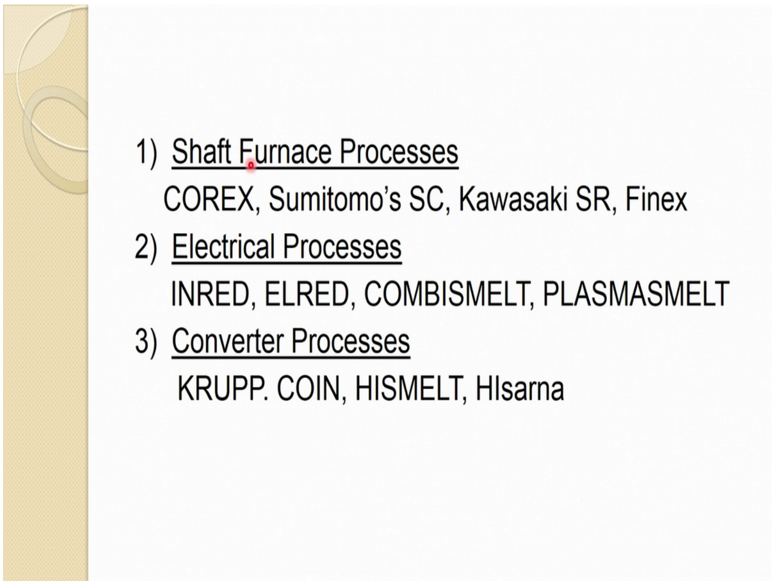

1) Shaft Furnace Processes
   COREX, Sumitomo's SC, Kawasaki SR, Finex
2) Electrical Processes
   INRED, ELRED, COMBISMELT, PLASMASMELT
3) Converter Processes
   KRUPP. COIN, HISMELT, HIsarna

So, shaft, shaft furnace process COREX Sumitomo's Kawasaki Electric Arc, these are smelting reduction processes.