Iron Making and Steel Making
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Module - 01
Lecture – 02
Various Routes of Steelmaking

Welcome to the lecture 2 of module 1. In the lecture one, I just gave an introductory lecture, on basic difference between iron and steel and basic definition of iron making steel making and basic thermodynamics involved into the iron making and steel making processes. Now, today I will just talk about the Various Routes of Steelmaking today available in the market.

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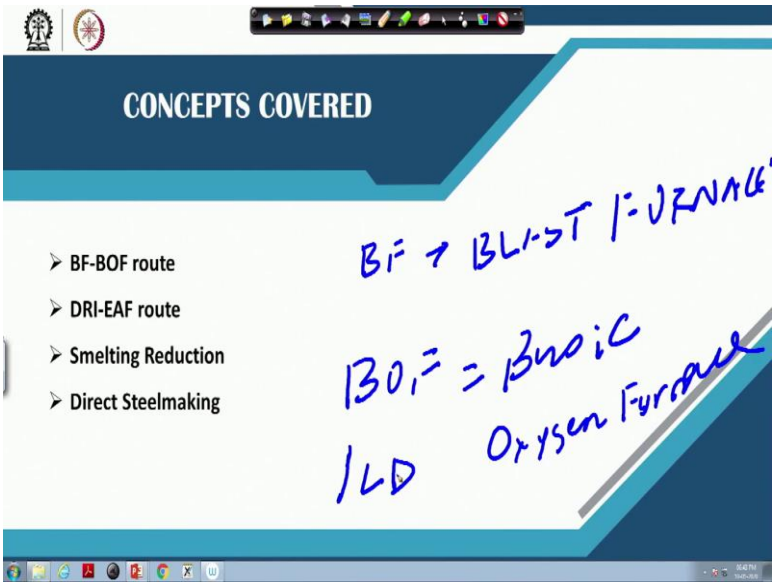

The major route of steelmaking is by the BF BOF route. BF stands for Blast Furnace and BOF stands for Basic Oxygen Furnace. Basic oxygen furnace mostly represent the LD furnace.

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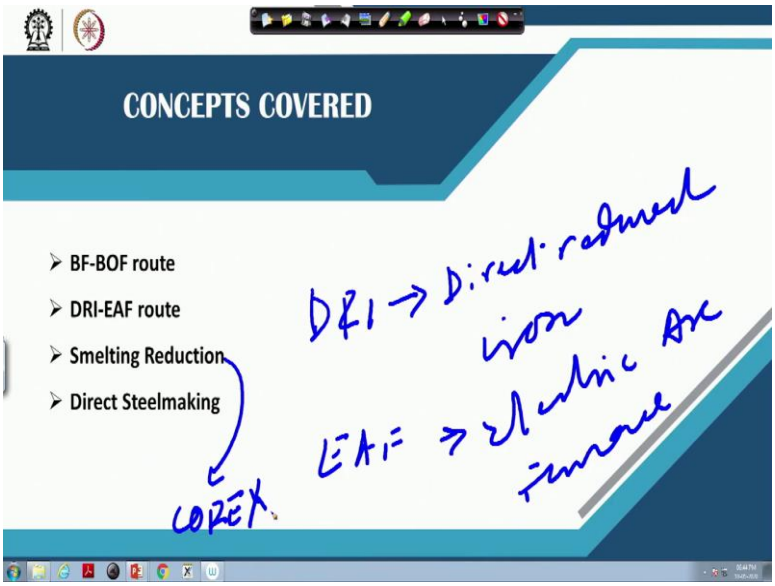

Another route is DRI EAF route and here, the DRI stands for Direct Reduced Iron, or sponge iron. And EAF stands for Electric Arc Furnace. In this route, DRI along with hot metal is refined in EAF. In smelting reduction (SR) route hot metal equivalent to blast furnace is produced using non-coking coal in especial SR reactor. One of the popular SR unit is the COREX process. Direct steelmaking is a potential route of producing crude steel in a single reactor using non-coking coal.

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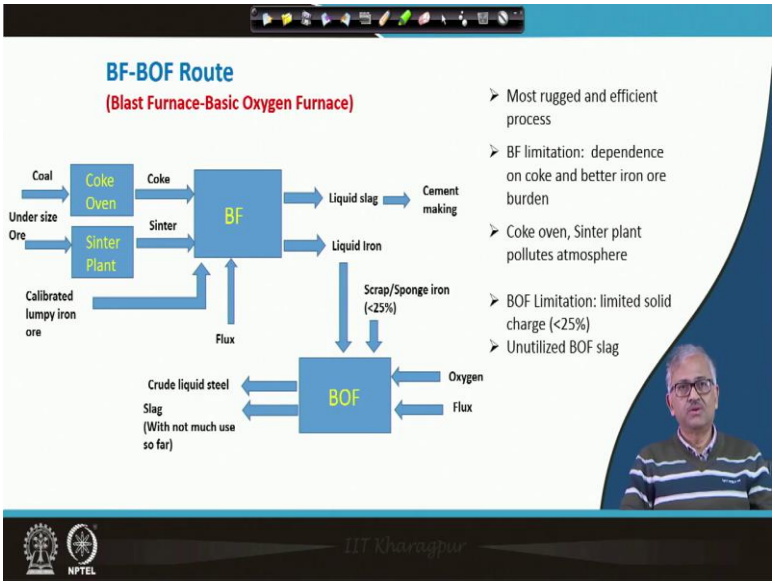

Next let us discuss about what is the BF BOF route. So, BF BOF route we have the blast furnace and then in the blast furnace, what are the input? Inputs are coke, made in a coke oven from coking coal; sinter, made by agglomerating undersize iron ore and iron bearing solid waste to some extent. And then you have calibrated lumpy iron ore , those are run of mine ores. Run of mine ores represents lumpy iron ore directly from mines, which are calibrated in size like 40 millimeter id diameter. Sinter is a better iron burden in blast furnace than lumpy ore due to its better strength and reactivity and consequently it has a large share for iron burden charge. And then you have to add flux to convert the gangues to liquid slag for its separation from hot metal. Obviously, you require hot air blast for combustion of carbon to generate the required heat to run the furnace.

So, for blast furnace these are the input and then what are the output you get? You get the liquid slag and the liquid iron, and the blast furnace gas. Liquid iron, or hot metal is used as raw material for steelmaking. BF liquid slag is mostly used for cement making after granulating by water quenching. BF gas after cleaning is used in hot blast stoves for air blast preheating and downstream application.

Hot metal from BF goes to BOF, or LD furnace for steelmaking, where the liquid iron is charged along with some coolant like scrap up to 25 percent. And BOF is an autogenous process where heat is generated by the impurity oxidation and the heat generated is more than to sustain the process, which allows charging of some cold charge like scrap as coolant. The other input to BOF process are pure oxygen and the flux. And, what you get as products are crude steel liquid steel and liquid slag. But unlike BF slag, LD or BOF slag contains FeO and P_2O_5 significantly. FeO is of the order of around 15 to 18 percent in the slag. These constituents are not suitable for cement making and render the LD slag mostly unusable. LD slag might require some post processing to get that into cement making, but economically viable process has not yet been found. Lots of investigations are on to find avenues to utilize the LD slag, which is otherwise is piling up near to the plant site.

So far, majority of crude steel production is through BF-BOF route because both te furnace are rugged, well tested and efficient. From the point of view of chemical and thermal efficiency, blast furnace is fantastic, and it is a very beautiful reactor. Only problem in the blast furnace as you can see is that it requires very stringent raw material requirement. For example, coke has to be used in place of coal, sinter and pellets in place

of frazile lumpy ore, which requires separate reactors, like coke ovens, sinter and pelletizing plants.

Strength of the burden material is important because as the burden moves down through the blast furnace, those undergoes impact and abrasion and if they do not have sufficient strength they will generate fines and reduce the bed permeability and hampering the counter current gas solid reaction in the dry zone of the blast furnace. In the wet zone at the lower part of the furnace coke has a great role to play by providing the path for gas passage. BF is a complicated reactor combining dry zone, wet zone through an interface called the cohesive zone and maintain a nice balance heat and chemical exchange and quality of the burden is very important to run such unique and complex process.

On the other hand, the major limitation of BOF is that it has limited capacity to accept the solid charge. Being an autogenous process, it can accept on 25% solid charge. But today, solid charge are increasing in terms of DRI/sponge iron (by utilizing non-coking coal and reformed natural gas) and therefore, a reactor with more flexibility in terms of acceptance of solid and liquid charge in any proportion like, EAF is getting an edge.

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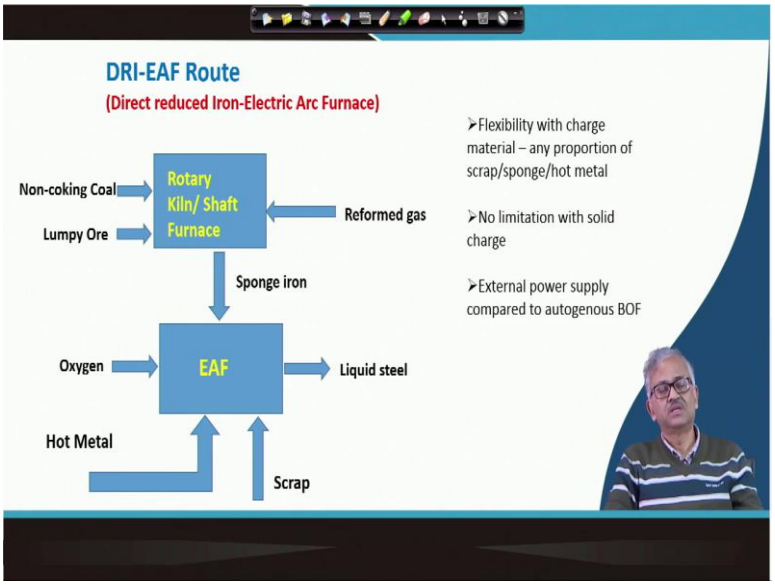

Now, let us go to the DRI -EAF route, i..e, the direct reduced iron and the electric arc furnace route. DRI/sponge iron is produced in reactors called the rotary kiln or the shaft furnace. In rotary kiln is a coal based DRI unit where lumpy iron ore is reduced using non-coking coal. Required heat is also generated by burning coal fines inside the reactor.

Shaft furnace are the gas based DRI units where reformed natural gas is used to reduce the iron ore pellets/lumpy iron ore. Natural gas is reformed by nickel catalyst to CO and H_2, which are subsequently is passed into shaft reactor for reducing iron ore in solid state to sponge. Now-a-day, synthetic gas prepared by coal gasification is also being considered for DRI production in shaft reactor.

The product, sponge iron is subsequently is melted in the electric arc furnace. MSMEs operate EAF based on solid charge like scrap and DRI. But in integrated steel plant hot metal also constitutes a major part of charge material in EAF. EAF has the flexibility is accepting DRI/Scrap/hot metal in any proportion depending on the current inventory, which gives it an edge over BOF furnace. This is very important for integrated steel plant equipped with sponge iron units, BF, and SR units.

The energy source in electric arc furnace is electric arc and electricity in most of the cases is generated using fossil fuel. Electricity is generated from carbon at an efficiency of only 40%, that makes te carbon footprint of EAF quiet high. Therefore, saving energy, using hot metal in EAF reduces its CO_2 emission.

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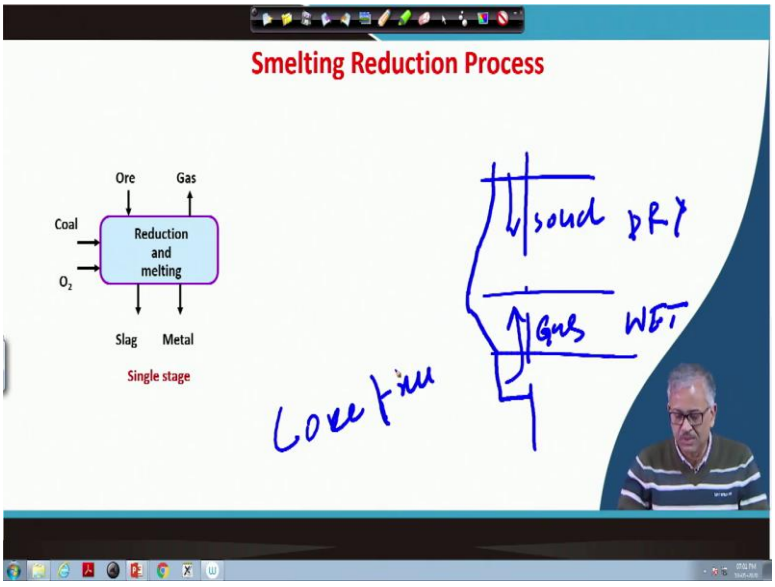

The idea in smelting reduction is to melt the iron ore first followed by reduction in liquid state. However, most of the commercialized smelting reduction is a two stage process. In the first stage the iron ore is partially reduced in a reduction unit followed by melting of partially reduced ore in a smelting gasifier (MG) unit. In the MG, non coking coal is

combusted using pure oxygen to generate sufficient heat for melting, gasifying and reduction. The product is hot metal similar to blast furnace. Thus it does both the function of blast furnace but in two separate reactor. As I have mentioned that BF is a complicated single reactor with two separate zones like dry and wet zone interfaced by a cohesive zone and running such system with countercurrent gas, solid, liquid movement in steady state, raw material requirement is very stringent. The smelting reduction process separates the two functions of blast furnace in two separate reactors reducing the complexity of the process that allows it to accept comparatively inferior raw material like non-coking coal but produce the similar product to that of BF. Use of coke is a bottleneck in BF operation. The cost of coke is around 50% of the total cost of hot metal from blast furnace. Besides, coke making process is polluting and therefore direct reduction (DR) and smelting reduction (SR) processes evolved as coke-free processes.

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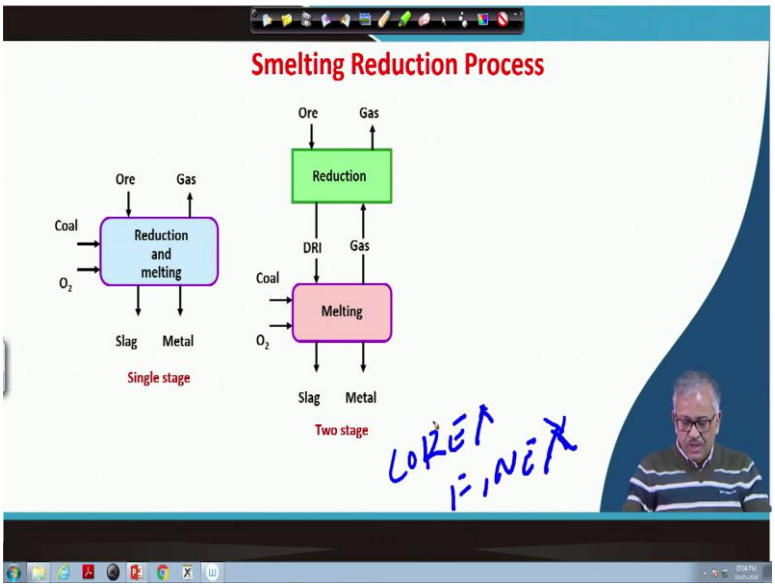

COREX and FINEX are two stage smelting reduction processes. In case of corex, iron ore pellets and lumpy ore are partially reduced in the high pressure reduction unit and in case of Finex, iron ore fines are reduced in fluidized bed and briquettized before putting those in smelter gasifier.

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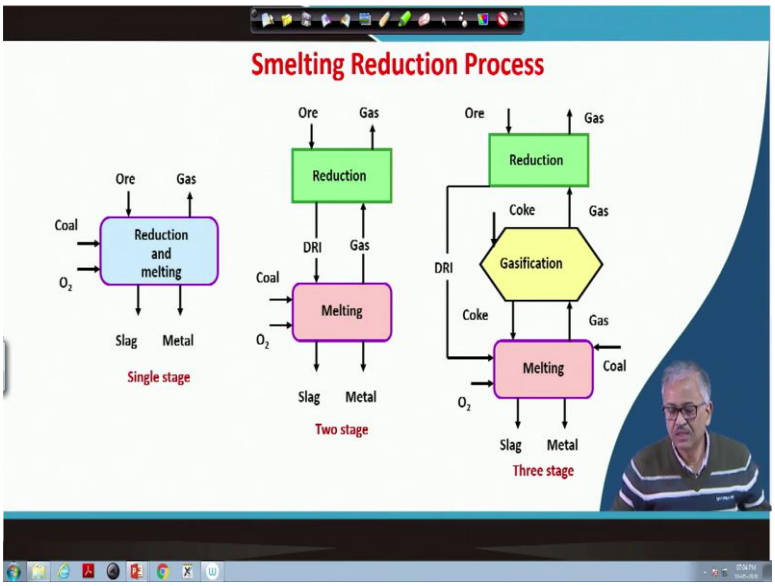

In three stage smelter gasifier, the gasification of coal is carried in a separate unit; but such process is yet to be commercialized. Here is a scope of using different grades of coal in different unit. Besides, separating different function in different units makes the process more efficient with respect to wide flexibility in raw materials.

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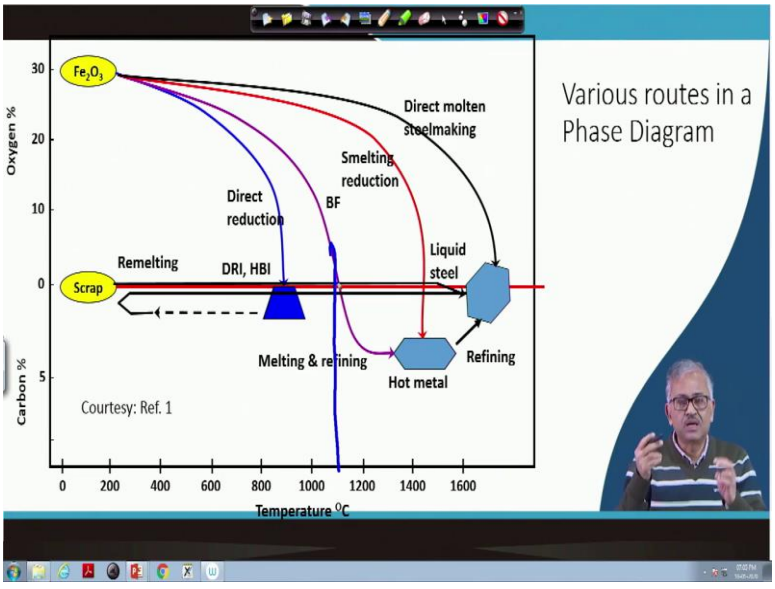

Now, in brief this is various routes of steel making in a phase gram like plot. Various stable phases with respect to temperature and composition are DRI, hotmatal and liquid

steel are shown. Different lines indicates how to reach these products in the temperature composition diagram starting from Fe_2O_3.

From the curve representing BF (Blast Furnace), you can see most of the oxygen is removed by around 1100°C in the dry state and the rest of the reduction take place in the liquid state, may be around 5 percent or even less than that. Subsequently, it melts and carburized in lower part of the furnace.

From the DR line you can find, almost all oxygen is removed in solid state at temperature 900°C. Coal based reduction may take temperature around 1100°C (to susten in-situ CO generation by carbon gasification) but gas based DRI are produced by 900°C. Coal based DRI contain veru low carbon (max 0.2 wt%); while gas based DRI may contain more than 2%.

From the curve representing the SR line, it is apparent that majority of the oxygen is removed at high temperature (1400°C) at liquid state.

The curve representing direct steelmaking, it is seen oxygen is carried out at much higher temperature, steelmaking temperature of 1600°C.

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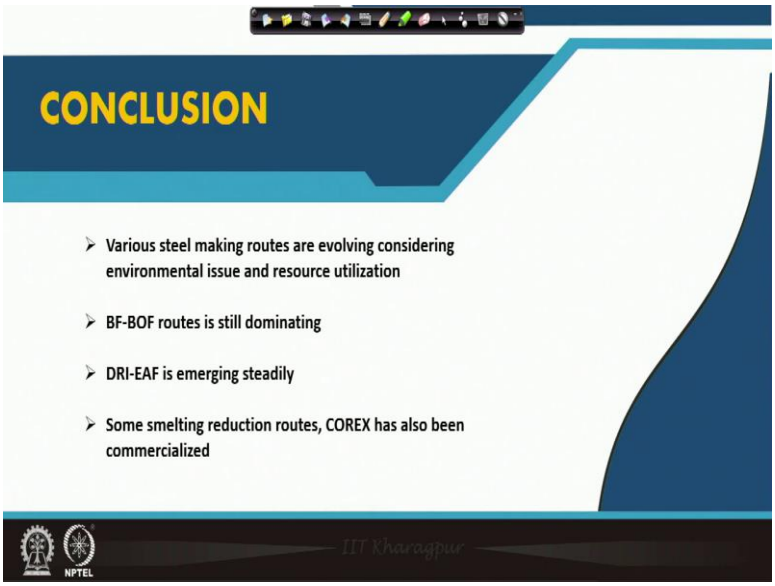

This is the concluding slide. So, we have covered various steelmaking routes. These processes are evolving considering two major issues: environmental issue, another is the resource utilization. We have to use non-coking coal for which we have large reserve and

we need to go for process integration to save energy and CO_2 mitigation. Therefore, DR and SR processes have evolved as a coke free process and using non-coking coal producing product similar to that of blast furnace. Use of lean grade ore and iron bearing solid waste of the plant is another objective for alternative routes-some DR processes based on Rotary hearth Furnaces, single stage SR processes like ROMELT are also potential technologies in this direction.

BF, BF route is still dominating today; while integrated steel plants are evolving with DR, SR units along with BF and EAF is emerging as the refining unit.

Thank you very much.