Iron Making and Steel Making
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Module - 11
Lecture - 54
Coal Based DR Processes
(RHF Based Processes)

In this lecture I will cover the coal based Rotary Hearth Furnace Processes.

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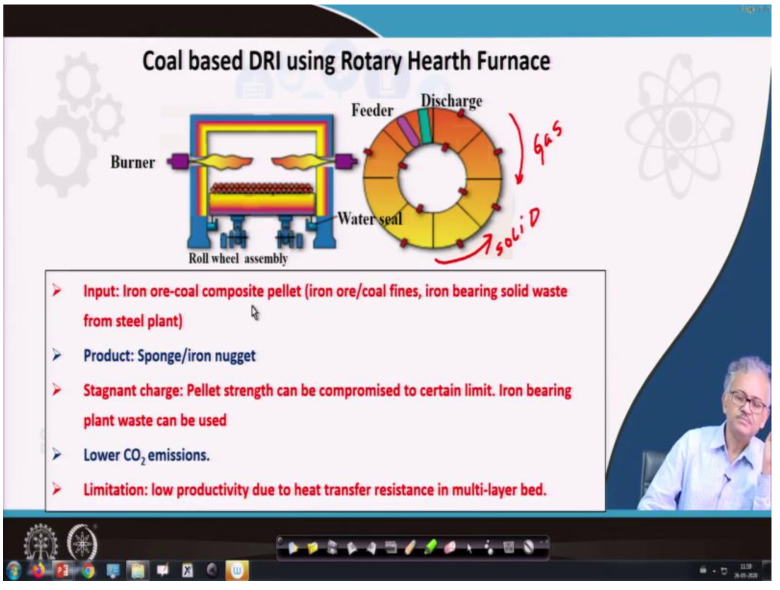

Rotary Hearth Furnace is a doughnut shape reactor (Fig. 54.1). The raw material is carried by the rotating hearth through different temperature regimes, like preheating zone, reduction zone, slag metal separation zone and then cooling zone. Since the material does not move of their own, strength of the raw material could be compromised and cold bonded iron ore-coal composite pellets is usually used as a feed material and heat is supplied from gas fired furnace atmosphere for reduction. The output of RHF could be sponge iron or, iron nuggets. Conventionally RHF is utilized for producing sponge from iron bearing solid waste of the plant. It also uses non-coking coal fines in the composite pellets as reductant. However, for iron nugget formation, it requires an extra high temperature zone in the RHF for slag/metal separation and such process is also choosy about the raw material. Since the reductant carbon is intimately mixed with the ore particles in the pellet, the process yields higher carbon efficiency and less CO_2 emission. Heat transfer to the solid bed takes place by radiation from furnace atmosphere to the top surface of the solid bed and subsequently the heat transfer across the thickness of the bed takes place by heat conduction only. Therefore, there is serious heat transfer limitation that restricts the thickness of the bed. More than three pellet layer bed has been found to yield low metallization at the bottom layers.

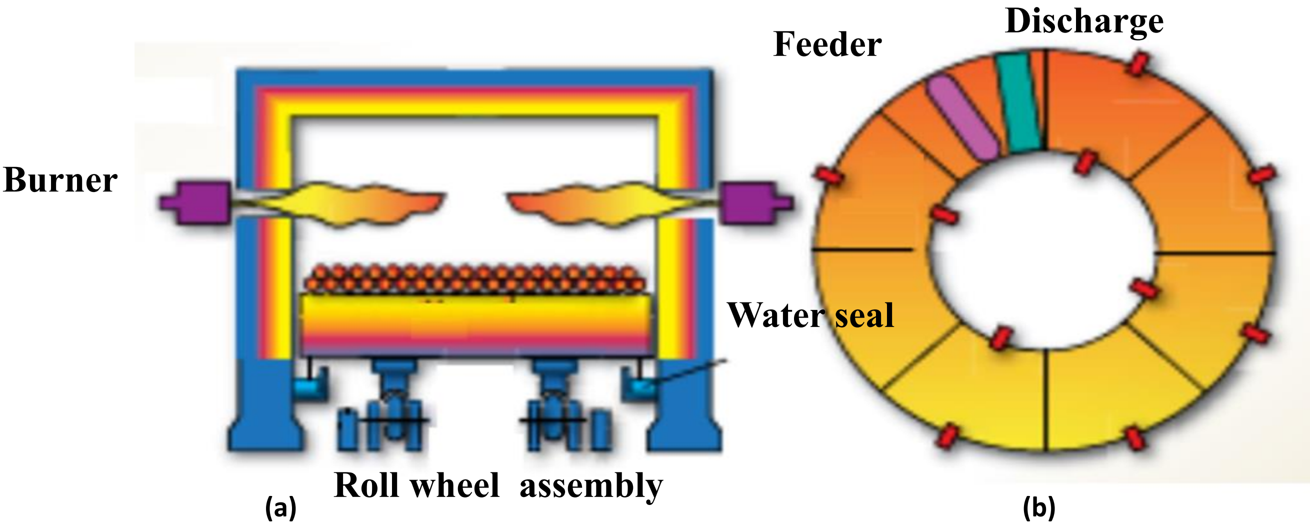

Figure 54.1: Schematics of RHF (a) side view, (b) top view

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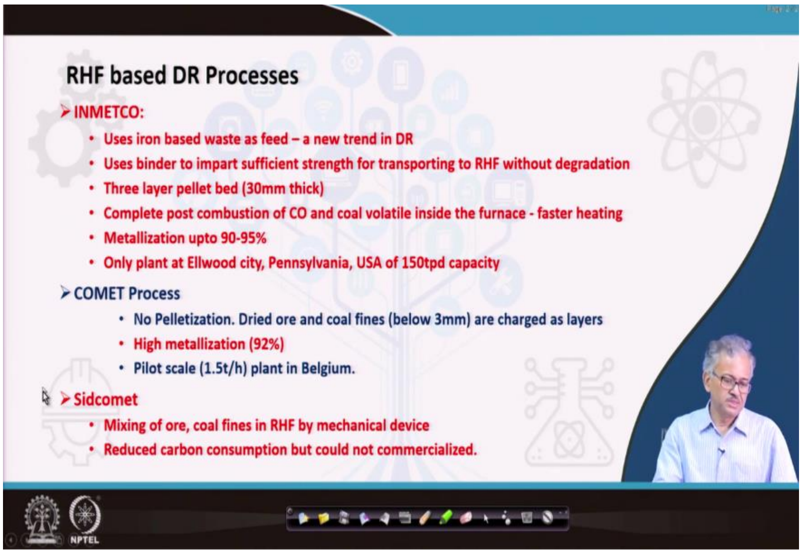

RHF are fuel fired furnace. Burners are situated at the side wall and gas moves counter current to the direction of solid movement. The grade of the sponge (total iron in sponge) depends on the grade of the iron ore. Depending on the grade of the sponge they could be charged in EAF or in BF as metallized iron.

I will now talk about few important RHF based DR processes. (i) INMETCO process: INMETCO is a subsidiary of International Nickel Company (INCO), engaged in metal (Ni, Co) reclamation from plant waste. INMETCO subsequently get engaged in sponge iron production from iron bearing solid waste generated in the plant. It is a RHF based DR process. The feed to RHF is iron oxide carbon composite pellets. It uses binder to impart more strength to composite pellets for transporting to RHF without degradation. Three layer pellet bed of 30 millimeter thick is used and complete post combustion of CO is done to generate heat. Major heat requirement is supplied by post combustion of CO and fresh fuel is used to supplement the total heat requirement. Furnace temperature is kept high to increase the heat capacity of the gas to maintain three layer solid bed. Degree of metallization is kept at 70%, and melted in submerged arc furnace to produce synthetic metal for subsequent refining.

(ii) The COMET (Belgium) process: In COMET process dried iron ore and coal fines are charged as layers over the hearth. The gangue and Sulphur in the DRI is less because coal and ore layer remain discrete. It has high metallization (90% and above). Not yet been commercialized but tested on pilot scale 1.5 t/hr.

SIDCOMET: It is an improved process over COMET process. In this process the iron ore and coal fines are mixed using mechanical device and reduced carbon consumption. The process also could not commercialized finally.

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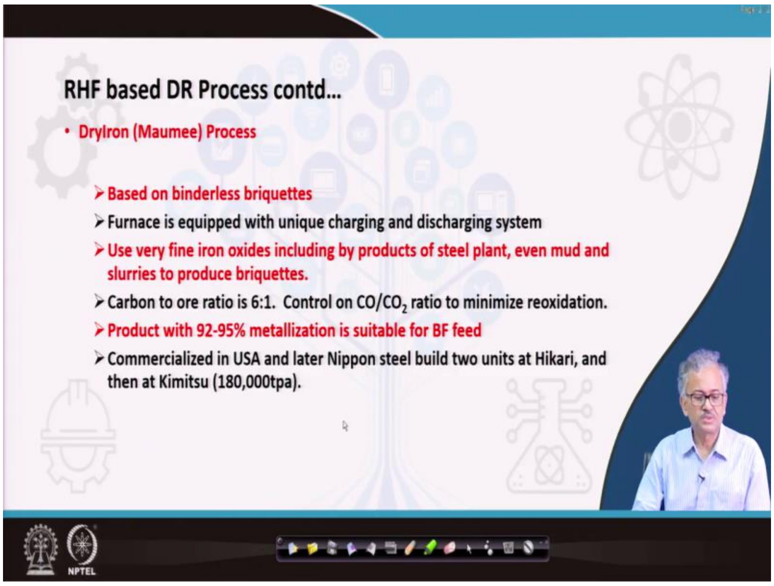

Dryiron (Maumee) process: It uses binderless briquettes without pre-drying. Furnace is equipped with unique charging and discharging system to deal with soft raw material. Use very fine iron oxides including by products of steel plant, even mud and slurries to produce briquettes. Carbon to ore ratio is 6:1. Control on CO/CO_2 ratio to enhance reduction rate and minimize reoxidation. Product with 92-95% metallization is suitable for BF feed (as the grade of the sponge is lower due to use of high gangue solid waste). Commercialized in USA and later Nippon steel build two units at Hikari, and then at Kimitsu (180,000tpa).

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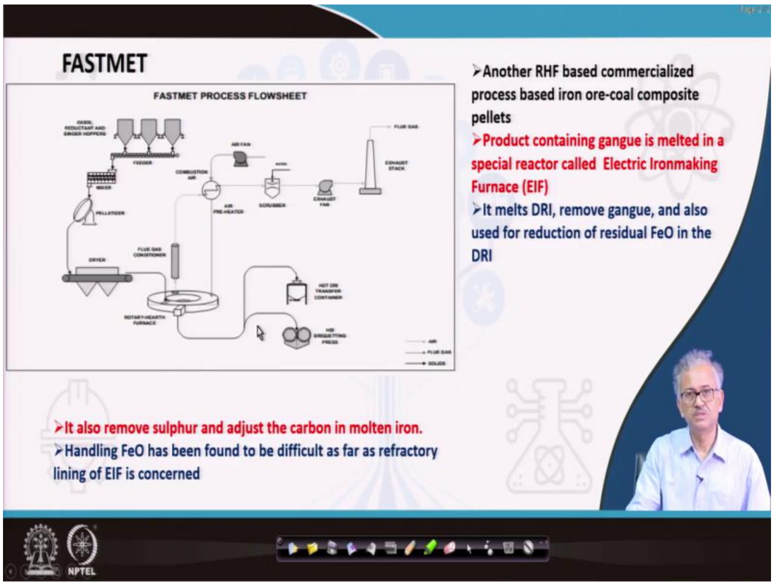

Another commercialized and popular process is the FASTMET process (Figure 54.2). It can process either virgin iron oxide in the form of iron ore-carbon composite pellets, or iron bearing solid waste as briquette. The RHF always run on single layer but it is very fast process and the pellets remain in the hearth for 6-12 minutes only and yields 90-95% metallization. In case of solid waste, it has also provision to recover Zn, lead. Binder is used for palletization and does not require drying step. In case of hot charge, DRI at 1000^{o}C is kept refractory lined container for transporting to EAF, or it is sent for HBI (Hot briquetted iron). HBI reduces specific surface area reducing the chance of re-oxidation. Beauty of the process is that all the solid and off gas stream are put in closed circuit in this process.

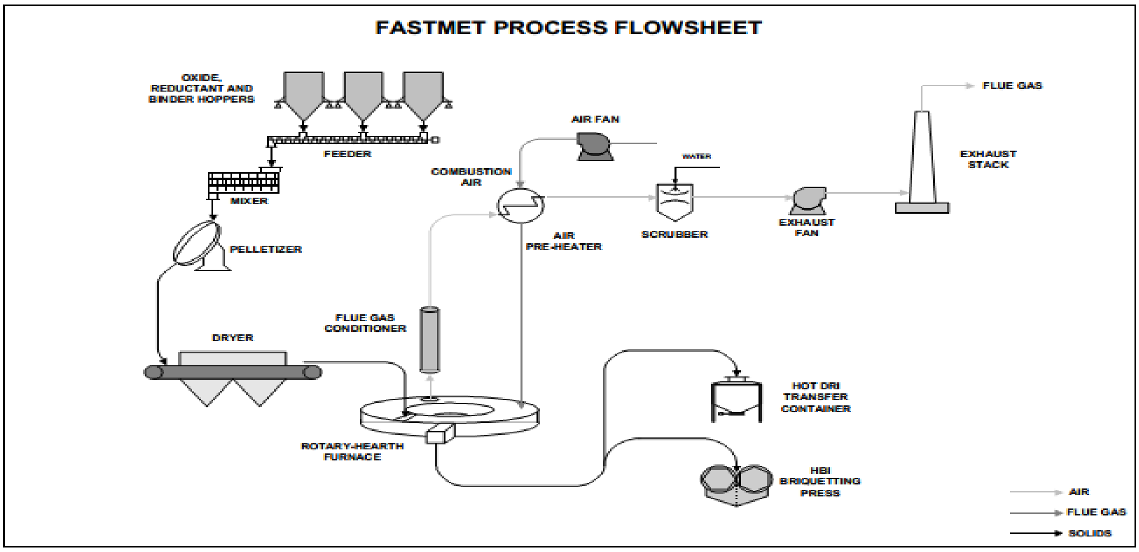

Figure 54.2: Flowsheet of Fastmet process

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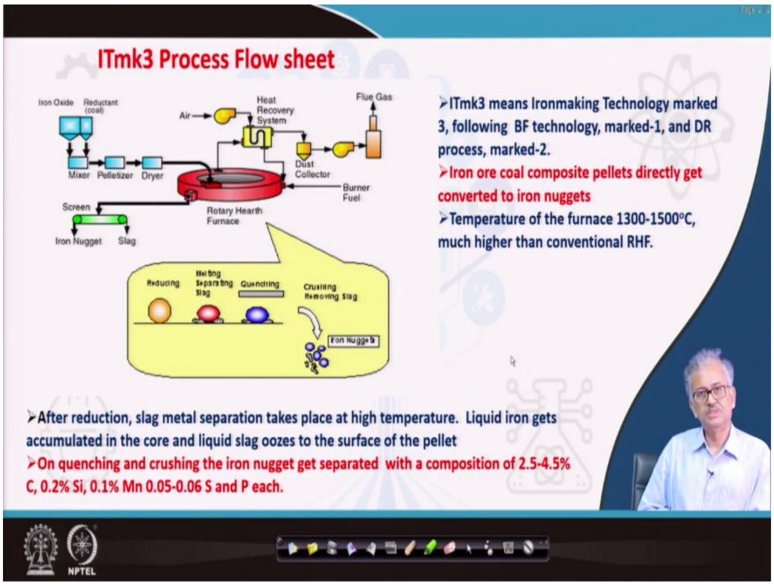

ITmk3: iron making technology mark 3. The conventional blast furnace is called the iron making technology mark 1. Then direct reduction process is called iron making technology mark 2 and finally the nugget production directly from the iron ore, is called the iron making technology mark 3, ITmk3.

ITmk3 process flow sheet is shown in figure 54.3. In this process iron ore coal composite pellet is directly converted to the iron nuggets and not to the sponge iron. ITmk3 has one more compartment in the rotary hearth furnace beyond the reduction zone, which has a much higher temperature around 1300 to 1500^{o}C. So, after reduction slag metal separation take place at this high temperature zone. Reduced iron is carburized and melts at this temperature and accumulates at the core; while semisolid slag oozes out to the surface. Once solidified in the cooling zone, iron nugget is formed inside with slag at outer surface. By crushing, iron nugget could be separated.

Typical composition of iron nugget is 2.5 to 4.5 percent of carbon, 2 percent silicon, 0.1 percent manganese, 0.05 to 0.06 sulphur and phosphorus each. So, this is a very promising technology, and it has a pilot scale plant in Mesabi, USA. The product is called the Mesabi nuggets also, but the process is yet to be commercialized.

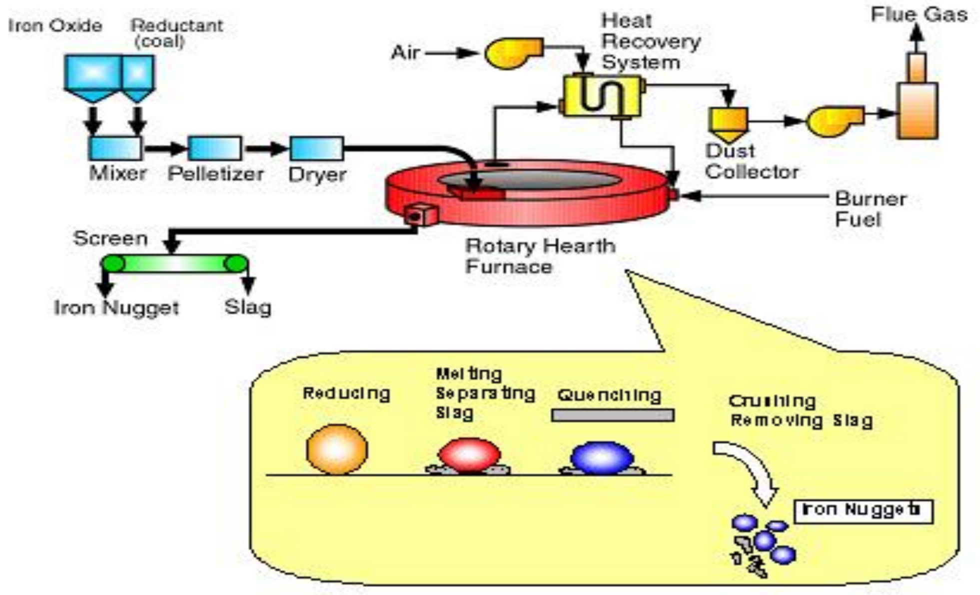

Figure 54.3: Process flowsheet of ITmk3 Process

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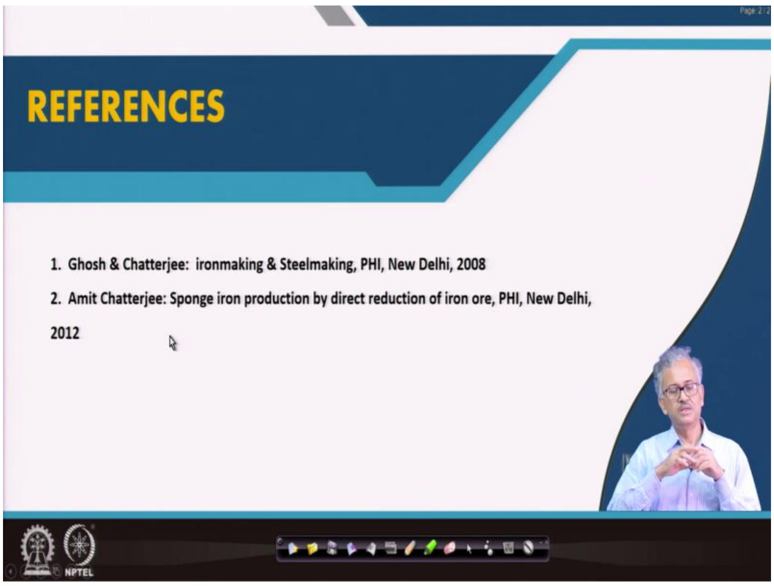

Reference books listed in the slide above.

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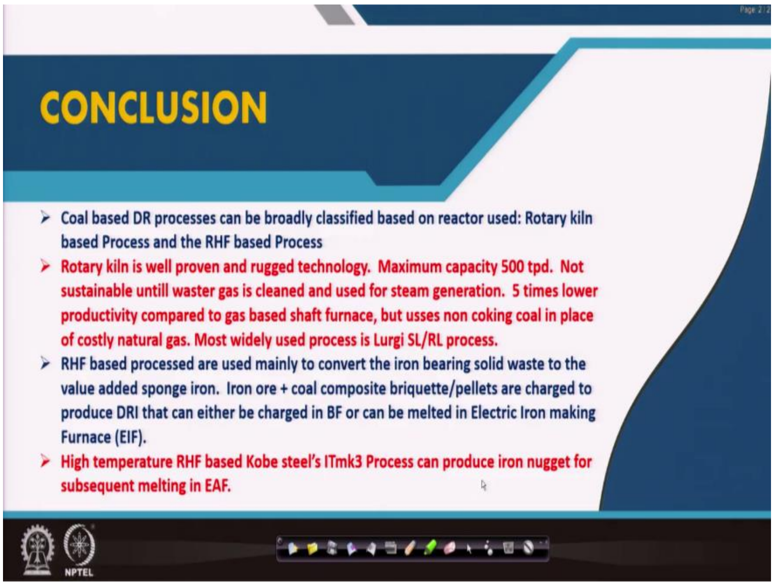

Conclusion:

- Coal based DR processes can be broadly classified based on reactor used: Rotary kiln based Process and the RHF based Process
- Rotary kiln is well proven and rugged technology. Waste gas carries around 40% of input energy and therefore, for economic running of the kiln, power needs to be generated using waste gas. It is also not environmentally sustainable process until dust laden waste gas is treated for dust separation and toxic gas absorption. It has about five times lower productivity compared to gas based shaft furnace, but uses non coking coal in place of costly natural gas. It has maximum capacity 500 tpd. So for large production several rotary kilns has to be added in series, which increases specific operating cost. Most widely used process is Lurgi SL/RL process.
- RHF based processed are used mainly to convert the iron bearing solid waste to the value added sponge iron. Iron ore - coal composite briquette/pellets are charged to produce DRI that it can either be melted in Electric Furnace or can charged in BF as metallized iron, depending on sponge grade.
- High temperature RHF based Kobe steel's ITmk3 Process can produce iron nugget for subsequent melting in EAF.