Iron Making and Steel Making
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Module - 11
Lecture - 53
Coal Based DR Processes-Rotary Kiln Process

We will discuss about the Coal Based DR Process in this lecture.

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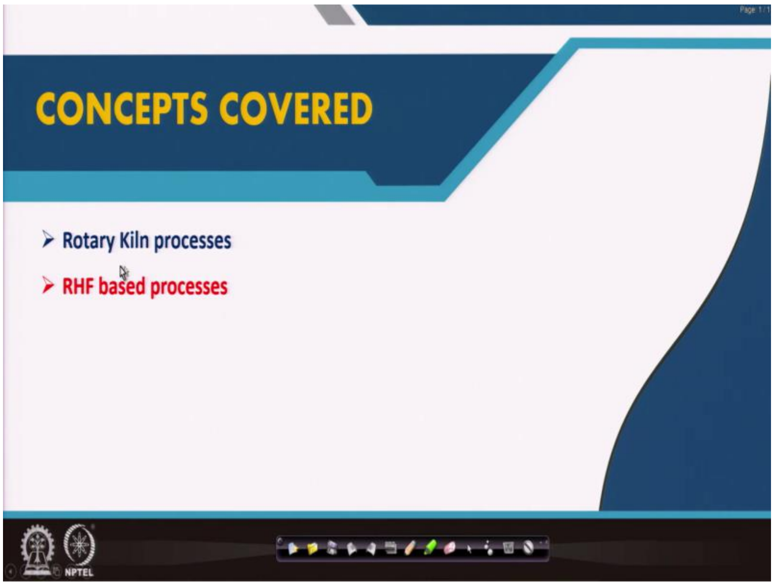

Two coal based processes based on rotary kiln and Rotary Hearth Furnace will be discussed. (Refer Slide Time: 00:58)

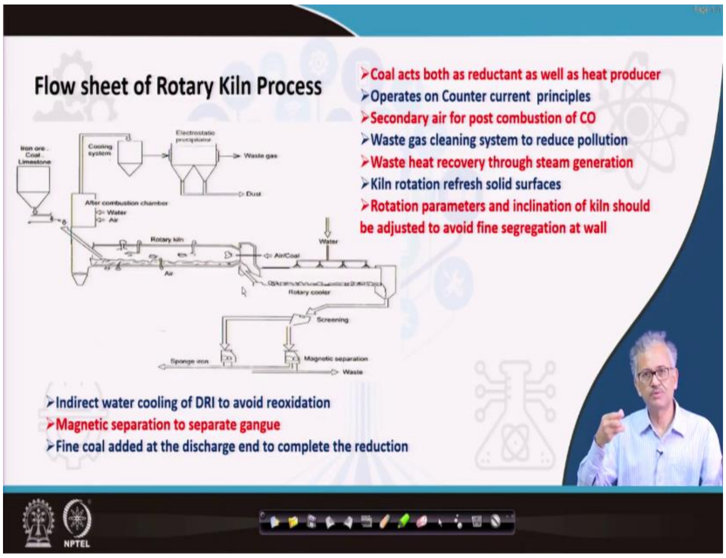

Figure 53.1 shows the flow sheet of Rotary Kiln Process. Iron ore and coal and limestone are charged from the inlet of rotary kiln furnace. Limestone is used to scrub the Sulphur from coal such that Sulphur in sponge iron remain low. Iron ore is added in the form of lump ore; sometimes iron ore pellets are also used.

Coal acts both as reductant as well as heat producer. Coal added from inlet is used for direct reduction of ore. Coal fines along with air is also added from discharge end as fuel to generate the heat for the process. Thus hot gas flows over the solid bed in a counter current direction.

Reduction takes place in a cylindrical reactor called the rotary kiln that is inclined to horizontal to a certain angle and rotate at certain rpm. The rotation renews the surface area of the ore as well as kiln surface to the hot furnace atmosphere, enhancing heat exchange and the kinetics of the process. Rotation and inclination of the reactor also helps in forward movement of the ore under gravity.

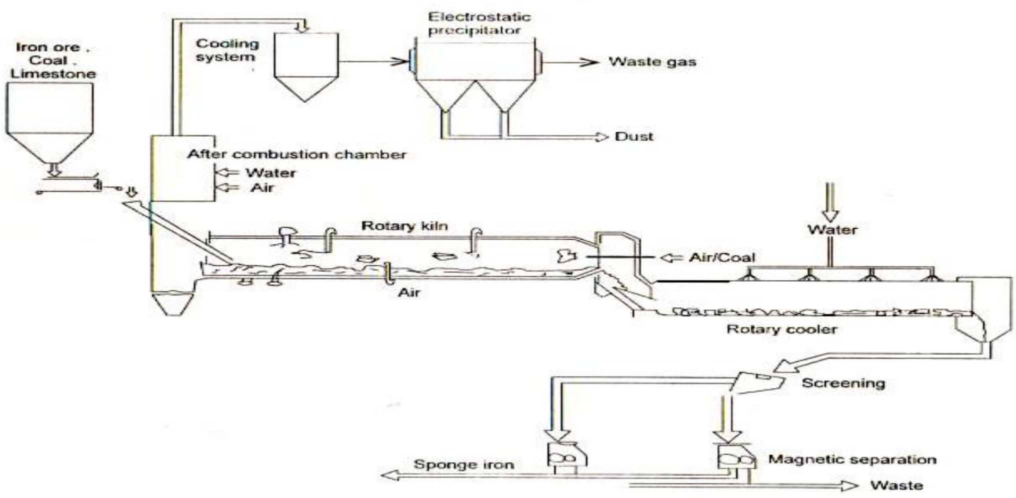

Figure 53.1: Flow sheet of Rotary Kiln

There also some ports on the circumference of the cylindrical reactor through which secondary air is injected for post combustion of CO for heat generation in the kiln in a controlled manner depending on the waste gas fuel value requirement for power generation outside. The DRI after emitting from discharge end is cooled a rotary cooler by indirect water quenching. Finally, DRI is crushed, sieved, and undergone magnetic separation before it is stored as sponge iron and gangue as solid waste.

Rotary kiln generates large amount of dust laden waste gas, which is required to be cleaned before it could be used for power generation and partially for preheating of raw materials. Gas cleaning is done through dry, wet scrubber, and finally electrostatic precipitator. Around 30 to 40 percent input heat energy is carried through the waste gas. Therefore utilization of the off gas is essential for process economics. Gas cleaning also make the process environmentally sustainable.

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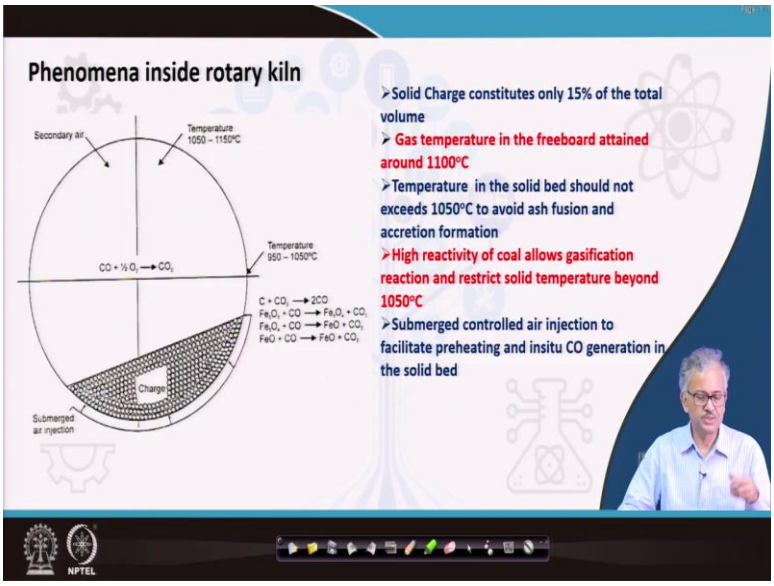

Figure 53.2 shows the cross sectional view of the kiln. It is seen that solid charge occupies a very small volume (15% of the total volume) leaving a large free board to accommodate large amount of dust laden gas.

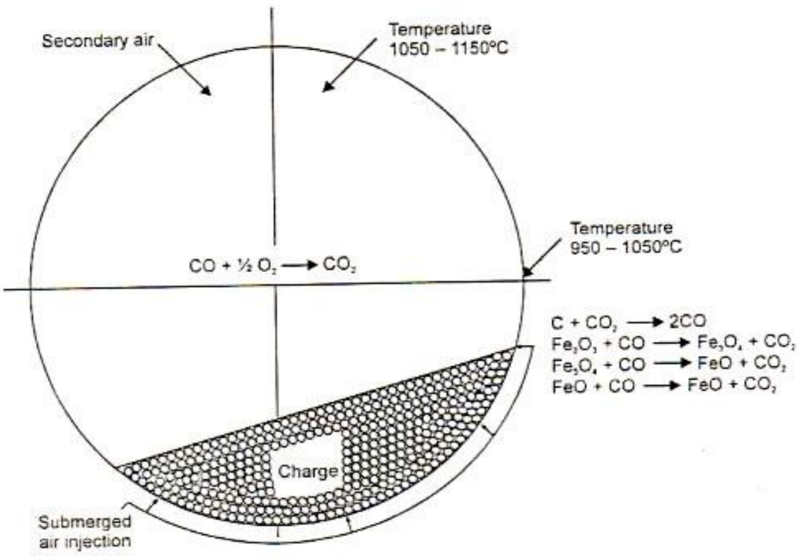

Figure 25.2: Cross sectional view of the rotary kiln

Gas temperature in the freeboard attained around 1100^{o}C. Temperature in the solid bed should not exceeds 1050^{o}C to avoid ash fusion and accretion formation. High reactivity of coal allows gasification reaction and restrict solid temperature beyond 1050^{o}C. Some provision are there for submerged controlled air injection to facilitate preheating of the solid bed.

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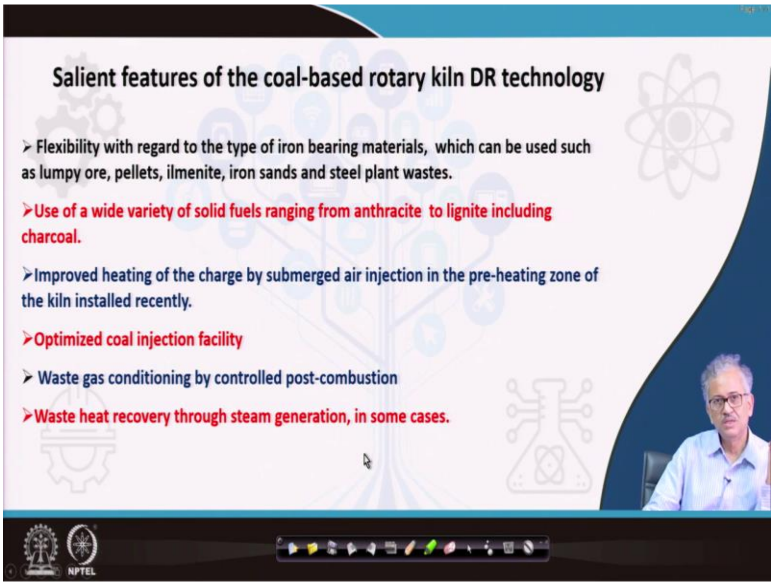

Some salient features of rotary kiln process: (i) There is flexibility with regard to the type of iron bearing materials, which could be lump ore, pellets, ilmenite, iron sands and steel plant wastes.

(ii) Use of a wide variety of solid fuels ranging from anthracite to lignite including charcoal. Wide variety of solid fuels, starting from anthracite to the lignite coal could be utilized. Lignite is reactive and furnace could be operated at comparatively lower temperature but it has less fixed carbon that requires larger volume of coal. Therefore, low grade lignite could be blended with high grade coal and could be used. So, such kiln is equipped with optimized coal injection facility.

(iii) Waste gas conditioning by controlled post-combustion. It means depending on the fuel value required for power generation, the post combustion in the kiln may be controlled.

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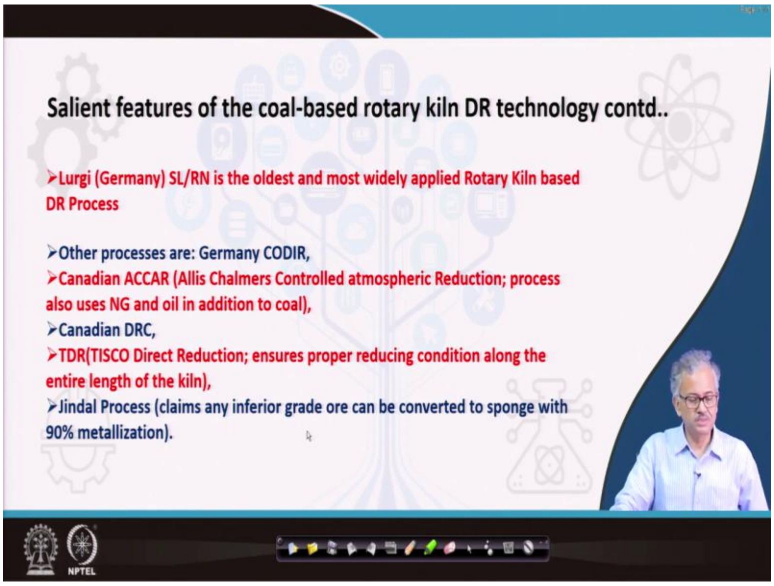

(iv) SL/RN is the oldest and most widely applied Rotary Kiln based DR Process, developed by Lurgi (Germany). Important other processes are: Canadian Allis Chalmers Controlled atmospheric Reduction (ACCAR), which also uses NG and oil as fuel in addition to coal to control the furnace atmosphere. TDR (TISCO Direct Reduction), which ensures proper reducing condition along the entire length of the kiln. Jindal Process, claims any inferior grade ore can be converted to sponge with 90% metallization.

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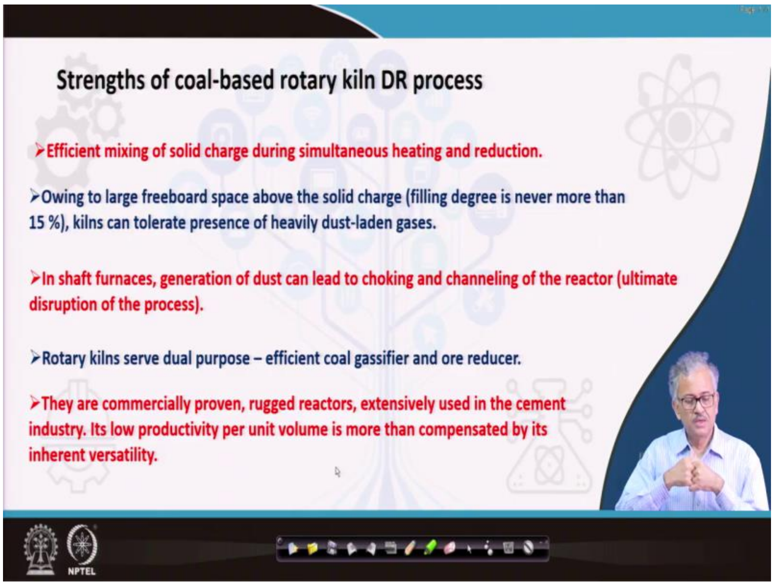

Now, I will talk about some of the strengths of the coal based rotary kiln DR process. (i) Efficient mixing of solid charge during simultaneous heating and reduction. The kiln rotation renews the solid charge to furnace atmosphere enhancing the heat and mass transfer to solid. (ii) Due to large freeboard space above the solid charge (filling degree is never more than 15 %), kilns can tolerate with the presence of heavily dust-laden gases. In shaft furnaces, generation of dust can lead to choking and channeling of the reactor (ultimate disruption of the process). This make this process suitable for coal based process. (iii) Rotary kilns serve dual purpose – efficient coal gassifier and ore reducer. (iv) Finally, these reactors are commercially proven, rugged reactors, extensively used in the cement industry. Its low productivity per unit volume is more than compensated by its inherent versatility.

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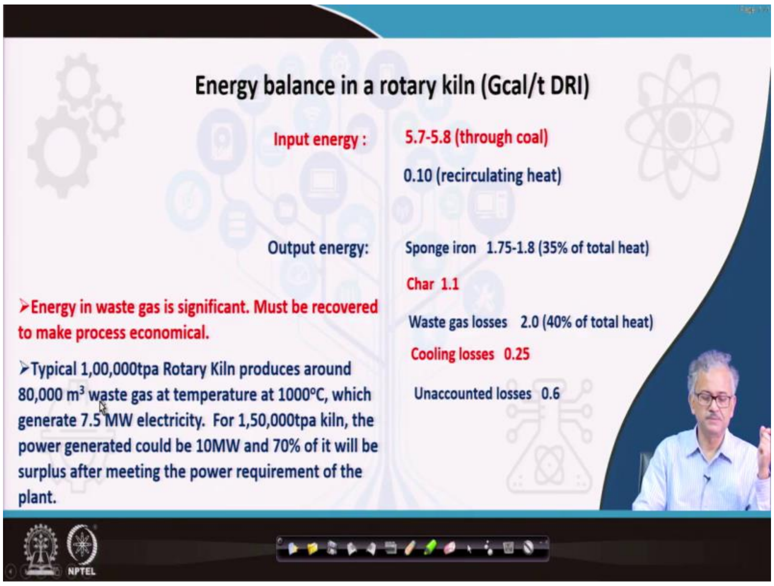

Energy balance: Major input energy to rotary kiln is through coal (5.7 to 5.8 Gcal per ton of DRI produced). Heat input through solid preheating by waste gas only counts for 0.1 Gcal/ ton of iron produced.

Only 35% of the output energy is associated with sponge iron (1.75 to 1.8 Gcal/ton). And 40% of the output energy (2 Gcal/ton) passes through waste gas. Therefore, waste gas contains significant chemical heat in the form of CO, which could be burned for heat generation for raising steam and power generation to make the process economic. Typical

1,00,000 tpa rotary kiln produces around 80,000 m^3 waste gas at temperature at 1000 ^oC, which could generate 7.5 MW electricity. For 1,50,000 tpa kiln, the power generated could be 10MW and 70% of it will be surplus after meeting the power requirement of the plant. Lot is heat is associated with the char produced (1.1 Gcal/ton) which could be recycled back as fuel.

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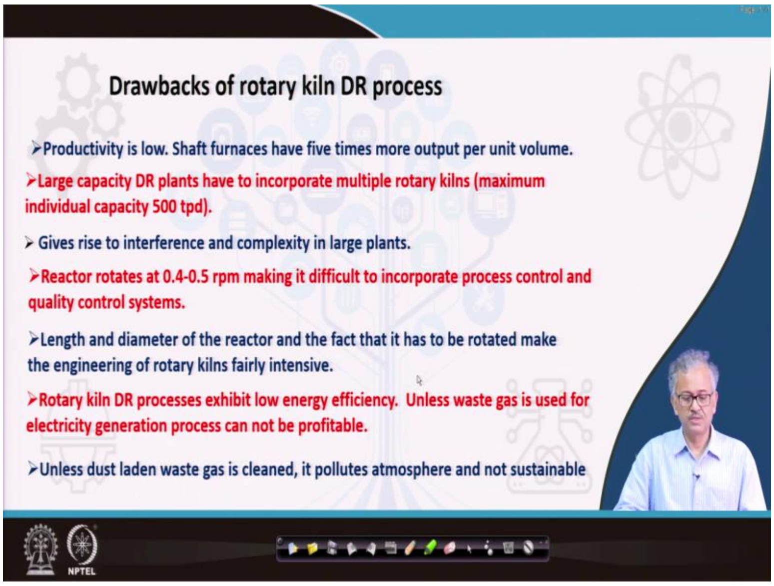

Drawbacks of the rotary kiln process:. (i) Productivity is low and shaft furnace have five times more output per unit volume compared to coal based process. Maximum capacity of a single rotary kiln hardly exceeds 500 tons per day and therefore, large capacity DR plant has to incorporate multiple rotary kiln units in series, which increases specific operating cost. This gives rise to interference and complexity in large plants. (ii) Due to rotation of the reactor, instrumentation of the reactor for process control becomes difficult. (iii) Most importantly, the waste gas has to be cleaned before it could be disposed to atmosphere. The waste gas contains lots of dust particles, toxic gases like SOx, NOx. The process will not be environmentally sustainable, unless the gas is cleaned. (iv) Accretion formation is anothe major problem in rotary kiln process. Kiln rotation promotes size segregation; fines try to align on the wall surface and the coarse on the free surface. Therefore, fines gets heat directly from hot wall and if the ash fusion point exceeds, it fuses and from accretion on the wall, which subsequently grows to large accretion and almost stop the solid movement through the furnace (Fig. 25.3).

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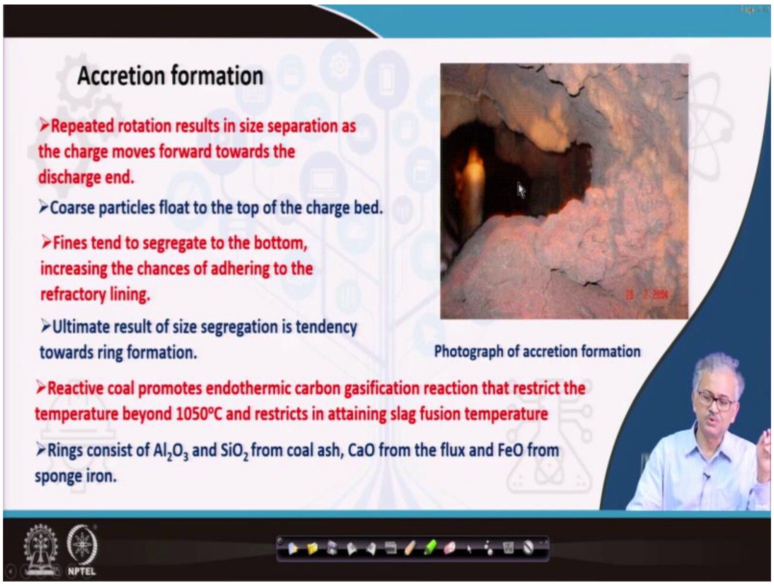

Figure 25.3: Extensive accretion formation in rotary kiln

Accretion formation may be controlled by selecting raw material with high ash fusion point, optimum kiln rotation that produces minimum size segregation, and using high reactive coal that can promote carbon gasification, which will not only promote reduction but also will restrict the solid temperature.

The lecture will be continued with another important coal based DR process based on Rotary Hearth Furnace in the next lecture.