Iron Making and Steel Making
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Module - 11
Lecture - 51
Alternative routes of Iron making: Introduction to Direct Reduction (DR) and Smelting Reduction (SR) Processes

In this lecture, we will talk about the alternative routes of ironmaking.

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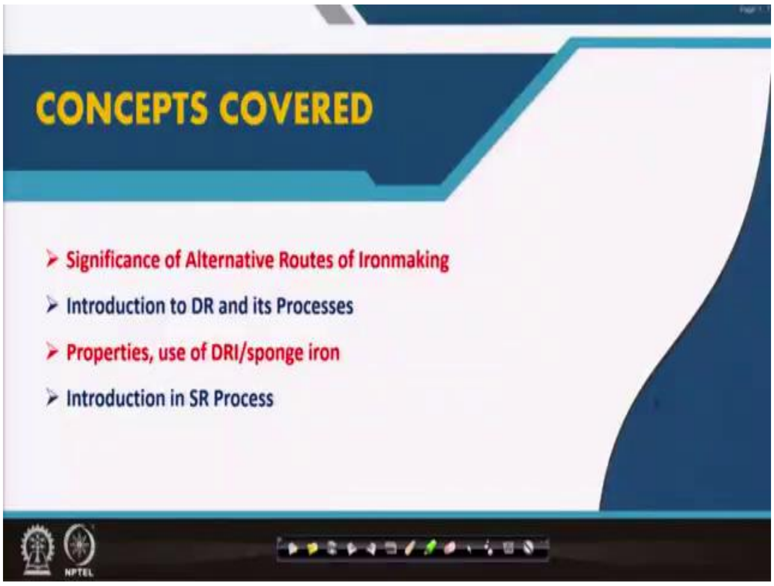

Topics covered in this lecture will include the significance of the alternative routes of iron making, introduction to the DR and its processes, properties and use of DRI and the sponge iron, and finally the introduction to the smelting reduction process.

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The driving forces for alternative routes of iron making: First we need the coke free process. As I have mentioned that coke constitutes around 50 percent of the total cost of liquid hot metal production, due to limited reserve for coking coal, and that too with high ash content of Indian coking coal.

So, we are dependent on importing the costly coking coal from Australia. Then of course, we blend it with the non coking coal or other medium coking coal to meetup the economics. India has also invented techniques like stamp charging to increase the proportion of non-coking coal in the coal blend and several other inventions are on the pipeline to enhance the utilization on non-coking coal, the reserve for which is plenty.

Parallelly, researchers throughout the globe are looking for processes, which could be coke free and run on non-coking coal. Second concern is that coke making is not an environmentally friendly process. Thirdly, researchers are looking for an alternative process that can also utilize iron bearing solid waste from the plant. For example, EAF dust, BF dust, and slimes produced during the iron ore beneficiation contains large amount of iron. So, all this solid wastes has to be utilized towards a zero waste process. Fourthly, Iron bearing fines generated during mechanized mining; coal fines also needs a route for their utilization. Finally, researchers are looking for scrap substitutes, which is depleting day by day because of technological development like continuous casting technology that reduced in-house scrap generation significantly.

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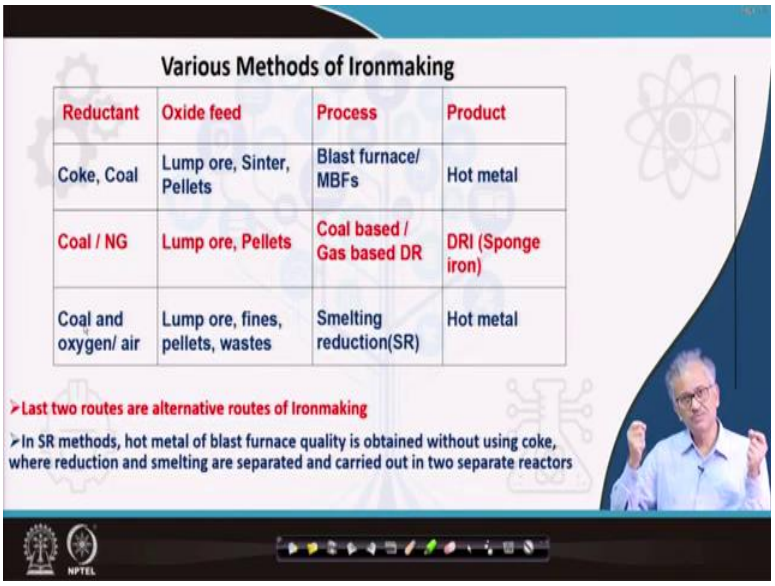

So, now let us see the various methods of iron making. Conventional iron making process is the blast furnace (BF)/mini blast furnace (MBF) ironmaking. MBFs are similar to the blast furnace and as the name suggest it is lower in volume and height. Because of lower shaft height, quality of raw material might be compromised in MBF and popularly used by small scale pig-iron producers. Tata Metaliks at Kharagpur runs a mini blast furnace. MBF can be run on charcoal also, called the charcoal furnace. Oxide feed in BF/MBF ate lump ore, sinter and the pellets. Reductant could be coke, charcoal and product could be hot metal/pig-iron.

Two alternative ironmaking routes that have emerged are direct reduction (DR) process and smelting reduction (SR) process. In DR, the iron ore is converted to iron in a solid state using non coking coal directly (coal based DR) or using reformed natural gas (gas based DR). DR derives its name from coal based DR where carbon directly participate in the reaction through in-situ carbon gasification reaction in solid state at high temperature. Subsequently, gas based reduction in solid state is also called the direct reduction. Lump ore (coal based rotary kiln) or pellets (gas based shaft reactor) are used as raw material and the product is direct reduced iron (DRI) or sponge iron.

The second alternative process is called the smelting reduction process. Here, iron ore is melted first followed by reduction in the liquid state. Here coal is burned by pure oxygen to generate intense heat to melt the iron ore directly. The iron burden could be lump iron ore, fines, pellets, iron bearing solid waste. The beauty of this process is that it uses non-coking coal yet produce hot metal of blast furnace quality. Besides, it offers great flexibility in terms of iron burden, and solid waste utilization. SR process exists in two forms-single reactor process or two reactor process. In case of two reactor process, it consists of two independent reactors one for solid state reduction and other for melting and reduction. Conceptually it divides the function of blast furnace in two independent reactors and makes the operation mush simpler. From this point of view blast furnace is complex reactor which maintains the dry and wet zone separated by cohesive zone in the single reactor and that makes it very choosey about raw material. However, blast furnace is very efficient in terms of gas utilization. The SR process generates a very rich off gas and unless it is utilized efficiently, the process can not be economically viable.

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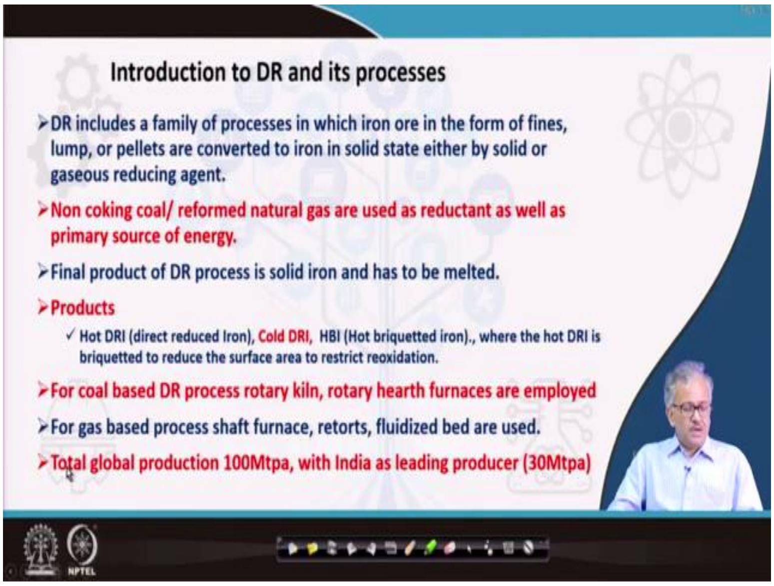

Now, we talk about the introduction to the DR processes. Direct reduction includes a family of processes in which iron ore in the form of fines, lump ore and the pellets are converted into the solid state iron either by using solid or the gaseous reductant. Coal and reformed gas are also used as the source of energy in these processes. Depending on the raw material, reactors are different. Lump ore, pellets are reduced in a shaft furnace using reformed natural gas; while fines are reduced in fluidized bed using reformed synthetic gas. Lump ore and coal are used in rotary kiln. In rotary kiln, coal is burned from exit gate to generate heat as well as coal is used from entry gate as reductant. In gas based process, natural gas is also partially burned to generate heat required for the process. There could be retort process where iron ore and coal mixture kept in saggers are heated by burners in tunnel-called tunnel kiln.

The product could be hot DRI. Here hot DRI is directly charged to EAF for melting, which saves energy. DRI directly can be directly fed to EAF in a distance place through dedicated channels, called the high temp process. The other produce could be Cold DRI. Here, DRI is cooled, stored and used later. The product could be HBI (hot briquetted iron). It reduces surface area of fine DRI to restricts its oxidation and burning.

Today, total global production is around 100 million ton, out of which India produces around 30 million ton and is the leading producer of DRI.

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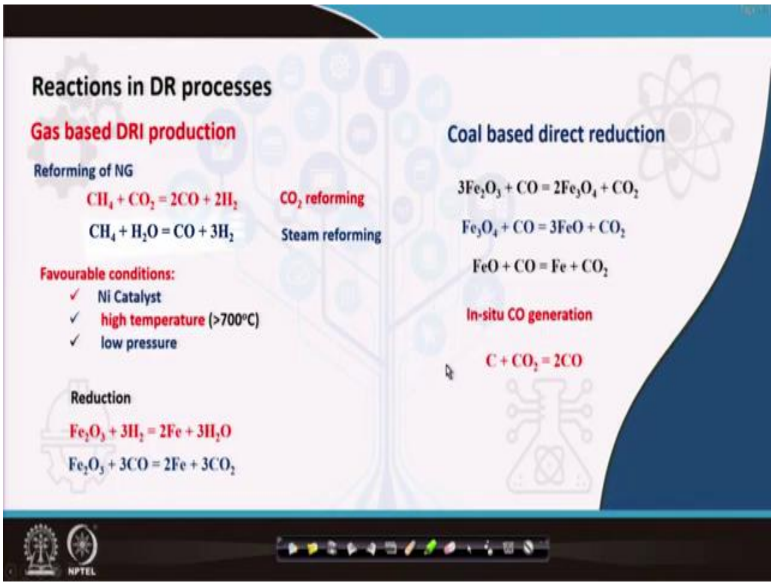

The reactions involved in the gas and coal bed processes are presented below:

Gas based Process:

CO_2 reforming of natural gas:

$$CH_4 + CO_2 = 2CO + 2H_2 \tag{51.1}$$

H_2O reforming of natural gas:

$$CH_4 + H_2O = CO + 3H_2$$

(51.2)

Favourable conditions are: Ni catalyst, high temperature (700°C), low pressure.

Reduction reactions:

$$Fe_2O_3 + 3H_2 = 2Fe + 3H_2O$$

(51.3)

$$Fe_2O_3 + 3CO = 2Fe + 3CO_2$$

(51.4)

Equation (51.3) can be represented as combination of (51.5 to 51.7), representing te overall reduction reactions. Actually, reduction proceeds through these elemental steps.

Coal based direct reduction: Here the reductant gas (CO) is generated by in-situ carbon gasification reaction. Relevant reactions are:

$$3Fe_2O_3 + CO = 2Fe_3O_4 + CO_2$$

(51.5)

$$Fe_3O_4 + CO = 3FeO + CO_2$$

(51.6)

$$FeO + CO = Fe + CO_2$$

(51.7)

The insitu CO is generated by carbon gasification reactions given by reaction (51.7) that takes place appreciably at temperature above 1000°C.

$$CO_2 + C = 2CO$$

(51.7)

I will continue this lecture in lecture 52.