MXCOL®: A breakthrough in coal-based direct reduction

INTRODUCTION

Since 2000, world steel production has increased at a compound annual growth rate of over 5 percent, as shown in Figure 1. This has been driven by growth in the developing world, especially China, which now accounts for 46 percent of global steel output. Steel demand depends on economic expansion and growth in China, India, Southeast Asia, Latin America, and the Middle East/North Africa has propelled the steel industry to new heights. With the continued growth of the emerging markets, many experts forecast that world steel output will reach two billion tons by 2020.

FUTURE STEELMAKING GROWTH

To achieve the steel production growth that is forecast, what are the options? Certainly, the blast furnace/BOF route, which now accounts for 70 percent of world steel production, will continue to be the predominant method. However, there are a number of issues. First, the blast furnace requires coke, and coking coal is not available in many countries. The need to import coal or coke puts those areas at an economic disadvantage, since coking coal prices have increased greatly in recent years. In addition, there may be environmental issues with the BF/BOF route and the capital costs can be high.

The electric arc furnace (EAF) steelmaking route is an excellent steelmaking choice for developing countries. However, those countries do not produce a lot of scrap and some source of iron must be added. Direct reduction using natural gas-fired shaft furnaces (such as the MIDREX® Process) or coal-fired rotary kilns is a good option for supplying the necessary iron units. World DRI production increased to 69 million tons (Mt) in 2010 and may rise to 120 Mt by 2020.

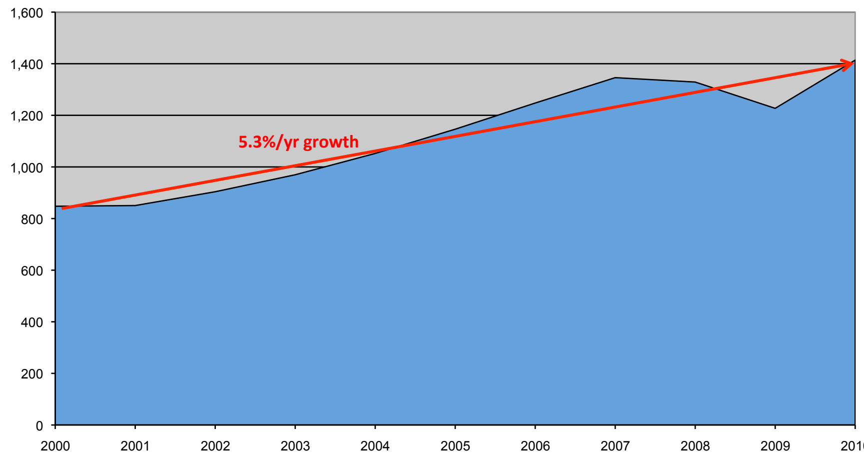

FIGURE 1 *World Steel Production (million tons)* Source: WorldSteel

There is a need for another direct reduction alternative because not all regions have abundant, inexpensive natural gas, and there are issues with rotary kiln production. Many rotary kilns have been installed in India and other countries, but there is a limit to the growth of this technology because they cannot be built larger than about 200,000 tpy. Also, there are product quality issues because of the use of lump ore and coal with high levels of ash and sulfur.

MXCOL®: USE OF SYNGAS FROM COAL IN A MIDREX® PLANT

An alternative option generating significant interest in India and elsewhere is MXCOL, which is the use of synthetic gas (syngas) made from coal in combination with a MIDREX® Direct Reduction Plant. Syngas options include a coal gasifier, coke oven gas or BOF gas. The big advantage of coal gasification is that lower grade, inexpensive domestic coals can be used to produce a high quality reducing gas for the MIDREX Shaft Furnace.

Coal Gasification

There are three general types of coal gasifiers: fixed bed, entrained flow and fluidized bed. All three technologies are based on partial oxidation (gasification) of a carbonaceous (carbon containing) feed material.

The general partial oxidation reaction is:

$$2\ CH_n + O_2 \ \text{------->}\ 2\ CO + n\ H_2$$

In addition to the desired CO and H_2, the syngas exiting a gasifier also contains CO_2, H_2O, CH_4, H_2S, NH_3 and particulates. If a fixed bed gasification technology is utilized, the syngas will also contain aromatic organic compounds.

While each of the gasifier types can make an acceptable reducing gas for a MIDREX DR Plant, the fixed bed and fluidized bed technologies will be the preferred choices for many locations because they can accommodate the high ash domestic coals. Countries of interest include India, China and the CIS. The leading fixed bed process is the Lurgi Gasification process; it is well-proven, with over 102 gasifiers in commercial operation worldwide, the earliest of these built in 1955. Figure 2 shows Lurgi gasifiers at the Sasol Plant in Secunda, South Africa. There are a number of fluidized bed processes, including the KBR Transport Gasifier, known as TRIG™, and the U-Gas Process, which is licensed by Synthesis Energy Systems. These processes are in the early stages of commercialization, but show good promise.

FIGURE 2 *Lurgi Gasifiers in Secunda, South Africa*

THE COAL GASIFICATION PROCESS

Figure 3 shows a simplified MXCOL process flowsheet. In the gasification processes, coal is gasified at elevated pressures by reacting with high pressure steam and high purity oxygen to produce a syngas suitable for the production of fuels and chemicals, power generation or the reduction of iron ore. The fixed bed and fluidized bed gasifiers operate at a temperature below the ash melting point so the coal ash is discharged from the gasifier as a solid. Because of this low operating temperature, these technologies require significantly lower quantities of oxygen than the entrained flow gasification processes which melt the ash.

The syngas exiting the gasifier is hot, dirty, and contains a significant amount of non reducing gas components. Downstream of the gasifier, the syngas is cleaned and conditioned to remove most of the undesired components and produce saleable commodities such as sulfur and petrochemical plant feedstocks.

MIDREX® DIRECT REDUCTION PLANT

The cleaned, high pressure syngas (reducing gas) exiting the gasification plant contains approximately 85 percent H_2+CO, 2.5 percent CO_2, and 10-12 percent CH_4. Table I shows the syngas quality required for MXCOL.

TABLE I *MXCOL Syngas Quality*

Syngas Characteristic	MIDREX Requirement
CO_2 content	2.0-3.0%
Gas Quality*	≥ 10
Gas Requirement	~ 2.2 net Gcal / t DRI
Pressure	> 3 barg
H_2/CO ratio	1 - 2.0
Sulfur content	< 5 ppmv
Particulates content	< 10 mg / Nm_3
N_2 + Ar content	< 0.5 %

** Gas Quality is defined as (% H_2 + % CO) / (% H_2O + % CO_2)*

GASIFICATION PLANT / MIDREX® PLANT FLOWSHEET

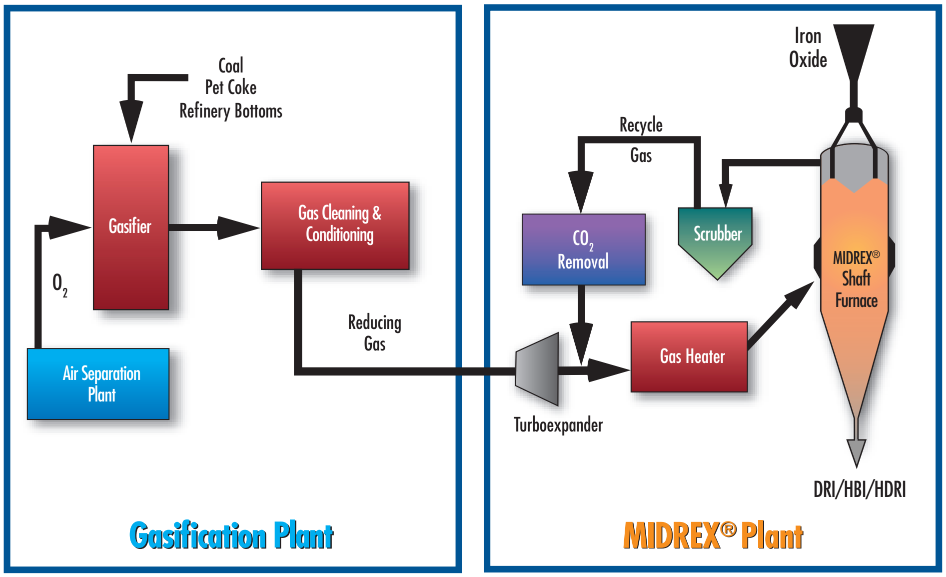

FIGURE 3 *MXCOL Flowsheet*

In the MIDREX Plant, the cold syngas is depressurized to about 3 barg in a turboexpander, which generates electricity. The low pressure syngas is mixed with recycled gas to produce the required reducing gas. The mixed gas is then heated to over 900° C and enters the MIDREX® Shaft Furnace, where it reacts with the iron oxide to produce DRI.

The reduction reactions are shown below:

$$Fe2O_3 + 3H_2 \text{ -------> } 2Fe + 3H_2O$$

$$Fe2O_3 + 3CO \text{ -------> } 2Fe + 3CO_2$$

The spent reducing gas (top gas) exiting the shaft furnace is scrubbed and cooled, then passed through a CO_2 removal system. This reduces the CO_2 content to 2-3 percent or less, which ensures that the mixed reducing gas (syngas from the gasification plant and recycled top gas from the MIDREX Plant) has an acceptably high reductants (H_2+CO) to oxidants (H_2O+CO_2) ratio for efficient iron oxide reduction. The CO_2 removal system will also remove the sulfur gases contained in the recycled top gas. The recycling of the top gas makes MXCOL a very efficient process.

The CO_2 recovered from the gasifer gas cleaning and conditioning plant and the CO_2 removal system in the MIDREX Plant are high purity. These streams could be sequestered or sold for enhanced oil recovery or use in a petrochemical or other operation. Emissions from MXCOL are shown in Table II.

TABLE II *MXCOL Emissions*

	PM10 mg/Nm³	SO_2 mg/Nm³	NOx mg/Nm³	CO_2 kg/t DRI
Reheater	<20	<15	<200	218.9
CO_2 acid gas stacks				
DR plant	<20	trace	<320	306.1
Coal Gas Island	<20	trace	<320	374.8
Aux. Boiler	<20	150	<700	265.9
		(90% FGD)	(0.5 lb/10^6 Btu's)	

TABLE III *Lurgi Gasification Plant + MIDREX Plant Combination Predicted Major Operating Consumptions for Indian Conditions*

Basis: MIDREX MEGAMOD® with capacity of 1,800,000 tpy of hot DRI [1]
Lurgi Gasifier using typical high ash Indian coal

Input	Units	Quantity per t hot DRI [2,3]
Iron Ore	t	1.42
Coal (as mined)[4]	t	0.75
Coal (ash free)[4]	t	0.41
Oxygen	Nm³	150
Electricity	kW-h	150
O & M costs	USD	27

1. The hot DRI product characteristics are: 93% metallization, 1.8% carbon, and 700° C discharge temperature
2. Quantities are for the combined Lurgi Gasification Plant and MIDREX DR Plant
3. The consumption values will vary depending on the actual coal quality and the project requirements
4. Value assumes typical high ash Indian coal

MIDREX PLANT OPTIONS

A major advantage of MXCOL is that it uses the well proven MIDREX Shaft Furnace and ancillary systems. Since 1969, there have been 74 MIDREX Modules built or under construction, with a total rated capacity of 56 Mt. The largest of these plants has a capacity of 1.8 Mtpy.

There are many options available for MXCOL Plants, including DRI capacity, product form and hot transport method. Plants can be designed for capacities of 2 Mtpy and higher. Product forms include cold DRI, hot briquetted iron (HBI) and hot DRI (HDRI). Combinations of product forms can supplied, providing the plant operator great flexibility in using and selling the product. There are three options for transporting the DRI to the meltshop and charging it to the EAF: hot transport containers, a hot transport conveyor and HOTLINK®. Since 2003, over 22 Mt of MIDREX HDRI has been charged to EAFs worldwide.

JINDAL STEEL & POWER MXCOL PLANT

Jindal Steel & Power Ltd. (JSPL) is building one of India's leading corporations, with a major presence in iron and steelmaking. JSPL is building a 12.5 Mtpy integrated steel complex in Angul, Odisha State with an expected investment of $10 billion. As part of this project, JSPL contracted with Midrex Technologies for a 1.8 Mtpy MXCOL Plant, the world's first coal gasifier based unit.

OTHER SYNGAS SOURCES

In addition to a coal gasifier, other applications of coal-based syngas are possible. Midrex is working on flowsheets to use BOF offgas and coke oven gas as reducing gas in a MIDREX Plant. It would also be possible to supplement coal syngas with gas made from biofuels or wastes, creating an even "greener" technology.

CONCLUSIONS

MXCOL is an excellent option for producing high quality DRI using syngas made from coal. It provides a good solution for areas of the world without abundant and inexpensive coking coal or natural gas.

Advantages of MXCOL include:

- Can use any coal gasification technology, including the well-proven Lurgi Gasifier or emerging fluidized bed processes such as KBR TRIG and U-Gas
- The fixed bed or fluidized bed gasifiers can readily use the low rank, high ash domestic coals in India and China
- Potential to use coal syngases from other sources such as coke oven gas or BOF gas
- Uses the well-proven MIDREX Direct Reduction Process. This technology can readily use domestic iron oxides as feed material.
- Produces DRI with quality comparable to natural gas-based MIDREX Plants
- The DRI can be hot charged into a nearby electric arc furnace (EAF) to significantly reduce the EAF electricity requirement and significantly increase the EAF productivity.
- The MXCOL Plant can be paired with an EAF-based mini-mill to produce high quality long or flat steel products
- No coke, coke ovens or sinter plant required.
- Lower specific capital cost than an integrated steel works
- Lower air emissions than an integrated steel works
- Ability to capture high purity CO_2 for sequestering or injecting into oil and gas fields
- DRI capacities of over 2 Mtpy in a single module

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