Potential for CO2 emissions reduction in MIDREX direct reduction process

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World DRI Production

**DRI (Direct Reduced Iron)**

Direct Reduction: The removal of oxygen from iron ore without melting
TFe%: 90-94, MFe%: 83-89, Met%: 92-95, Carbon%: 1.0-3.5, Gang%: 2.8-6.0
World DRI production was 74 million tons in 2012

World DRI shipment increase gradually due to strong demands of DRI in advanced country.

Total DRI shipment was 14.8 million tons in 2012.

DRI ratio in EAF becomes 16% of total EAF charging materials.
World DRI Production by Process

- MIDREX is a wholly owned subsidiary company of Kobe Steel
- Kobe Steel is a leading company of this DRI production field

Total World Production in 2012: 74.02 million tons

- Coal based (SL/RN): 23.0%
- HYL: 15.8%
- MIDREX: 60.5%
- Other Gas: 0.7%
Why MIDREX?

- Of the 67 MIDREX Plants built and started-up since 1969, only 3 have been dismantled and taken completely out of service (Fig.1)
- 33 MIDREX Plants have been operating more than 20 years (Fig.2)
- The reason why MIDREX process covers 60% of world DRI production is due to high performance of stable and simple operation. (Fig.3)
Natural Gas Based DR Process (MIDREX)

MIDREX® DR Plant
Qatar Steel (II)

Country : Qatar
Start-Up : Dec., 2007
Capacity : 1,500,000 t/y
Natural Gas is used as a reductant.

Coke is not required. (Pellets/Lump Ore are reduced to produce DRI without being melt in the shaft furnace.)

DRI is fed to EAF to produce steel.
Reason why MIDREX is less CO2 Emission

- **As Fuel**
  
  Table shows the CO2 emission rates for combusting methane versus two types of coal. As the table shows, natural gas emits only about one-half the CO2 per unit of energy as does coal.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>CO2 Emissions (kg/GJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas (CH4)</td>
<td>49</td>
</tr>
<tr>
<td>Bituminous metallurgical coal</td>
<td>90</td>
</tr>
<tr>
<td>Bituminous steam coal</td>
<td>94</td>
</tr>
</tbody>
</table>

- **As Reductant**
  - \( C + O_2 \rightarrow CO_2 \) :Carbon can remove one mole O2 and produce one mole CO2
  - \( CH_4 +2O_2 \rightarrow CO_2 + 2H_2O \) :Methane can remove two mole O2 and produce one mole CO2

These characteristics make natural gas an ideal energy source for ironmaking.
Energy usage in direct reduction shaft furnaces has decreased by about 30% over the past forty years.

This has occurred gradually over the years in the course of overall process development.

Six stages of natural gas reduction are indicated, which equate to the following process upgrades:

1: 480°C combustion air preheat
2: in situ reforming
3: 540°C combustion air preheat and 400°C process gas preheat
4: 650°C combustion air preheat and 540°C process gas preheat
5: Top gas fuel preheat
6: Preheat of natural gas used for transition zone and enrichment
Carbon emissions can be further reduced by hot charging the DRI to the EAF. MIDREX has developed three methods for discharging the DRI at elevated temperature, transporting it hot to the meltshop, and charging it to the EAF at 600-700°C. These methods lower the electricity required per ton of steel produced, which also reduces CO2 emissions from the power plant. Electricity consumption can be reduced about 20 kWh/t liquid steel for each 100°C increase in DRI charging temperature. Thus, the savings when charging at over 600°C are 120 kWh/t or more.

Traditionally, MIDREX Plants have cooled the DRI and stored it for later charging to the EAF.
Production capacity of MIDREX plant has been increased year by year.

New MIDREX “SUPER MEGAMOD” DR plant is designed for an annual capacity of 2 million tons of HBI. It will be the largest single HBI producing module in the world.
Potential for CO2 emissions reduction by using DRI/HBI

(1) In EAF Steelmaking Process
(2) In BF/BOF Steelmaking Process
Difference between BF-BOF steelmaking process and EAF steelmaking process

- BF-BOF:
  - Iron Ore + Coking Coal → Sintering → Blast Furnace (BF) → Molten Iron → Basic Oxygen Furnace (BOF) → Rolling

- EAF:
  - Steel Scrap → Basic Oxygen Furnace (BOF) → Molten Iron → Rolling

- CO2 Emission for EAF is approximately 25% of that for blast furnace.
- The steel scrap normally contains impurities such as Cu, Sn, Pb, etc. which often limit its usage to satisfy the product quality.
EAF Crude Steel Production Ratio

- EAF steelmaking is rising due to more scrap in advanced countries.
Steelmaking by feeding either the DRI or the HBI to the EAF together with the scrap can significantly decrease the CO2 emissions while satisfying the steel quality by diluting the impurities containing in the scrap.

Reference: MILLENNIUM STEEL 2007
Potential for CO2 emissions reduction by using DRI/HBI

(1) EAF Steelmaking Process
(2) BF/BOF Steelmaking Process
US DRI Projects Status

- Falling gas prices a boon to DRI production in the U.S.A.
- There are two movements
  1. BF substitute
  2. HBI utilization in BF

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Capacity (kt)</th>
<th>Status</th>
<th>Start-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucor</td>
<td>Lousiana</td>
<td>2,500</td>
<td>Confirmed</td>
<td>2013</td>
</tr>
<tr>
<td>Nucor</td>
<td>Lousiana</td>
<td>2,500</td>
<td>Permitted - not approved</td>
<td>2015+</td>
</tr>
<tr>
<td>voestalpine</td>
<td>Texas</td>
<td>2,000</td>
<td>Confirmed - needs permitting</td>
<td>2016</td>
</tr>
<tr>
<td>Bluescope</td>
<td>Ohio</td>
<td>1,000</td>
<td>Under consideration</td>
<td>2016+</td>
</tr>
<tr>
<td>Essar Steel</td>
<td>Minnesota</td>
<td>2,500</td>
<td>Permitted - not approved</td>
<td>2016+</td>
</tr>
<tr>
<td>Severstal NA</td>
<td>Mississippi &amp; Trinidad</td>
<td>n/a</td>
<td>1.5m tpy project rejected</td>
<td></td>
</tr>
<tr>
<td>US Steel</td>
<td>Minnesota</td>
<td>n/a</td>
<td>Under consideration</td>
<td>2016+</td>
</tr>
</tbody>
</table>
Nucor Louisiana Project in the U.S.A. (2.5Mt/y)

Original Plan BF

Iron Ore → Sinter Plant → Coke Oven → BF → Hot Metal → Basic Oxygen Furnace → Rolling Mill

Coking Coal → Coke Oven

Current Plan Gas-DR

Iron Ore → Pellet Plant → Gas-Based DR Plant → DRI → EAF → Scrap → Rolling Mill

Pellet Plant → Gas-Based DR Plant

• Lower capital cost of a DRI plant – around half that for an equivalent blast furnace
• Lower greenhouse gas emissions.

• Reduction Cost Evaluation
  Coking coal=175$/t Gas=4$/mmBTU
  BF:144$/t Gas-DR:44$/t
  ↓ Diff. 100$/t

• 1st Phase: 2.5Mt/y mid-2013
• 2nd Phase: 6-7Mt/y

With the cheap shale gas, construction of the large-sized gas DR plant was started in the U.S. instead of construction of the BF
HBI utilized in BF

- The use of HBI in Blast Furnaces is not new
- AK Steel began using HBI in their Middletown blast furnace in 1989
- Blast furnaces in Canada, Western Europe and Japan have also begun using HBI
- HBI is typically less than 30% of the charge
- HBI is often used when additional hot metal is required
- For each ten percent (10%) of the iron charged into the blast furnace as metallic iron:
  1. Productivity is increased by 8%
  2. Fuel rate is decreased by 7%
- HBI also lowers the CO2 emissions per ton of hot metal produced

SSS NYC - Midrex Presentation 6-18-12
The decision on the construction of the Voestalpine direct reduction plant in North America has been made. The plant will be constructed on just outside the city of Corpus Christi, Texas, USA. The planned facilities are designed for an annual capacity of around 2 million tons of HBI and DRI. The investment volume is around EUR 550 million. The plant is due to begin operations in early 2016. This will provide the Austrian steel production sites in Linz and Donawitz with access to cost-efficient and environmentally-friendly HBI and DRI pre-materials, ensuring their competitiveness over the long-term.
Overseas shift of the reduction energy and utilization of HBI as energy container can realize significant CO2 reduction in the consumer site.

Transportation weight and related CO2 emission becomes half.
Conclusions

1. MIDREX gas-based DR technologies is the process to produce iron units which are advantageous in terms of the CO2 emissions. Because this process can use natural gas as a reductant and a fuel source.

2. Considering the increase of the scrap supply to the steel market, feed of the scrap in the EAF with the DRI/HBI is expected to be effective and practical solutions in terms of the CO2 emissions.

3. With the cheap shale gas, construction of the large-sized gas DR plant was started in the U.S. instead of construction of the BF.

4. Future ironmaking model will be to produce the direct reduced iron near the energy competitive sites and transfer these products as an energy container to consumer sites.
Thank you for your kind attention!