A Novel Flash Ironmaking Process
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American Iron and Steel Institute/University of Utah
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Project Objective

- Develop a new ironmaking process w/ significant reduction in energy consumption and CO$_2$ generation
- Blast furnace requires pelletization and/or sintering of iron ore concentrate
- Consumes large amounts of energy and carbon $\rightarrow$ CO$_2$ emissions
- Alternative ironmaking processes must have:
  - Large production capacities (e.g., $\sim$1,000,000 tpy of iron)
  - Use the main raw material (i.e., iron ore) with minimal pretreatment
## Technical Approach

<table>
<thead>
<tr>
<th>Current practice</th>
<th>New Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blast Furnace</strong></td>
<td><strong>Flash Ironmaking Process</strong></td>
</tr>
<tr>
<td>Fe$_3$O$_4$ + C $\rightarrow$ Fe + CO$_2$/CO</td>
<td>Fe$_3$O$_4$+H$_2$/CO$\rightarrow$Fe + H$_2$O/CO$_2$</td>
</tr>
<tr>
<td>➢ Produces &gt;90% iron</td>
<td>➢ Gas-Solid Suspension Reduction</td>
</tr>
<tr>
<td>➢ Large capital investments</td>
<td>Natural Gas, Hydrogen, Coal Gas</td>
</tr>
<tr>
<td>➢ Special coal for cokemaking</td>
<td>• Iron concentrate WITHOUT</td>
</tr>
<tr>
<td>➢ Needs pelletization/sintering</td>
<td>• Cokemaking</td>
</tr>
<tr>
<td>➢ Significant Energy</td>
<td>• Pelletization</td>
</tr>
<tr>
<td>Consumption and CO$_2$</td>
<td>• Sintering</td>
</tr>
<tr>
<td>emissions</td>
<td>✓ Significant Reduction in CO$_2$</td>
</tr>
<tr>
<td></td>
<td>&amp; Energy Consumption</td>
</tr>
<tr>
<td></td>
<td>✓ Rapid reaction rate and favorable</td>
</tr>
<tr>
<td></td>
<td>Net Present Value (NPV)</td>
</tr>
</tbody>
</table>
Technical Approach

• Install, commission & conduct test on a new large scale bench reactor at the University of Utah

• Multidisciplinary team:
  • American Iron and Steel Institute
    • ArcelorMittal USA
    • TimkenSteel
  • United States Steel Corporation
  • Berry Metal Company
    • Bench reactor fabrication
  • University of Utah
    • Lead Research Organization
## Transition and Deployment

<table>
<thead>
<tr>
<th>Project Objectives</th>
<th>Kinetic Feasibility</th>
<th>Proof of Concept at Lab Scale</th>
<th>Process Validation/Scale-up</th>
<th>Industrial Pilot</th>
<th>Funding</th>
</tr>
</thead>
</table>

### Experimental Apparatuses

- Approaches
  1. Large scale: 75-100k tpy
  2. Modest scale: 10-25k tpy
  3. Expand U of Utah work: Similar to bench reactor but larger

- Industrial Pilot TBD (2017+)

### Funding

- Federal, $0 Industry, $4.8 million
- Total, $4.8 million
- Industry, $2.7 million
- Total, $10.9 million

- $10 – 75 million Funding TBD
Benefits steel users and steel-related industry
North American steel industry is end user
To be used to produce iron as a raw material for steelmaking resulting in:
  • Direct use of iron ore concentrate
  • Lower capital cost
  • Scalable to large capacities
  • Avoidance of cokemaking
Commercialization through licensing & royalty
Sustainable as a more energy efficient and lower-emitting ironmaking process
Measure of Success

• If successful, iron will be produced at a lower cost, using less energy, and emitting less CO₂
• Potential energy savings: \(~3.5 \text{ GJ/ton Fe vs. avg. BF}\)
• CO₂ emission: Less than 36% vs. avg. BF process
• If 40% of US iron production is replaced by this process, only 3% of US natural gas production would be consumed.

<table>
<thead>
<tr>
<th>Metric</th>
<th>H₂-based process</th>
<th>Reformerless natural gas process</th>
<th>Blast Furnace process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Requirement (GJ/ton of hot metal)</td>
<td>11.3</td>
<td>14.5</td>
<td>18.0</td>
</tr>
<tr>
<td>CO₂ emission (tons/ton of hot metal)</td>
<td>0.04</td>
<td>1.02</td>
<td>1.60</td>
</tr>
</tbody>
</table>

## Project Management & Budget

### Total Project Budget

<table>
<thead>
<tr>
<th>Description</th>
<th>DOE Investment</th>
<th>Cost Share</th>
<th>Project Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$8,200,000</td>
<td>$2,700,000</td>
<td>$10,900,000</td>
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</table>

### Key Inputs Criteria Date

#### Bench Scale Reactor
- **Go/No Go Decision # 1:**
  - Operating Temperature: 1400°C
  - Solid feed rate: >1 kg/hr
  - Operation time: >6 hr
  - Date: 11/30/2015

#### Testing Program
- **Go/No Go Decision # 2:**
  - Metallization: 95%
  - Min. amt. reducing gas: 3.0x
  - Date: 6/30/16
- **Go/No Go Decision # 3:**
  - Metallization: 95%
  - Min. amt. reducing gas: 1.5x
  - Date: 11/30/16
- **Milestone # 4:**
  - Metallization: 95%
  - Solid feed rate: >5 kg/hr
  - Date: 6/30/17

#### Industrial pilot reactor
- Design
- Cost estimate

#### Program Administration
- Date: 8/31/17
Results and Accomplishments

- Commissioning complete; process milestones met Q4 2015
  - Achieved and held 1400°C for eight hours
  - Achieved prescribed gas and material flow rates
Next Steps

• Begin experimental program aimed at operational flexibility, scale-up costs, process control and optimization.
• Continued process modeling
• Additional milestones later in 2016