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., ~1,000,000 tpy of iron)
  - Use the main raw material (i.e., iron ore) with minimal pretreatment

Technical Innovation

Current practice

Blast Furnace

$Fe_3O_4 + C \rightarrow Fe + CO_2/CO$

- Produces >90% iron
- Large capital investments
- Special coal for cokemaking
- Needs pelletization/sintering
- Significant Energy Consumption and CO_2 emissions

New Approach

Flash Ironmaking Process

$Fe_3O_4 + H_2/CO \rightarrow Fe + H_2O/CO_2$

- Gas-Solid Suspension Reduction

Natural Gas, Hydrogen, Coal Gas

- Iron concentrate WITHOUT
  - Cokemaking
  - Pelletization
  - Sintering

✓ Significant Reduction in CO_2 & Energy Consumption

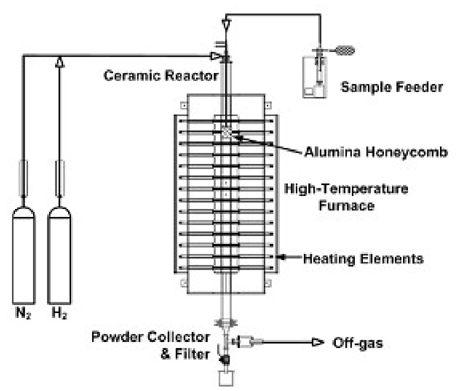
✓ Rapid reaction rate and favorable Net Present Value (NPV)

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
  - University of Utah

Large-Scale Bench Reactor Facility at the University of Utah

Transition (beyond DOE assistance)

Project Objectives	**Kinetic Feasibility** Technology Road Map (2005-2007)	**Proof of Concept at Lab Scale** AISI CO_2 Breakthrough (2008-2011)	**Process Validation/ Scale-up** Innovative Manufacturing Initiative (2012-2018)	**Industrial Pilot** **TBD** (2018+)
Experimental Apparatuses				Approaches 1. **Large scale** <u>75-100k tpy</u> 2. **Modest-scale**: <u>10-25k tpy</u> 3. Expand U of Utah work: <u>Similar to bench reactor but larger</u>
Funding	Federal, \$350k **Industry, \$150k** Total, \$500k	Federal, \$ 0 **Industry, \$ 4.8million** Total, \$4.8million	Federal, \$ 8.3 million **Industry, \$ 2.6 million** Total, \$10.9 million	\$10 – 75million **Funding TBD**

Transition (beyond DOE assistance)

- 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
  - Low 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 CO_2
- Potential energy savings: ~3.5 GJ/ton Fe vs. avg. BF
- CO_2 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.

Metric	H_2-based process	Reformerless natural gas process	Blast Furnace process
Energy Requirement (GJ/ton of hot metal)	11.3	14.5	18.0
CO_2 emission (tons/ton of hot metal)	0.04	1.02	1.60

- *NPV for standard case (15 year period): $401M (2010)/(1 M tpy) Natural gas cost: $5/M (2010) BTU HHV*

Project Management & Budget

- Budget Period 3 : 6/1/2017 – 8/31-2018
- Milestone – Establish optimum operating parameters
  - Issue Report
  - Feed rate – 5 kg/hr
  - 1400°C
  - 95% metallization

Total Project Budget	
DOE Investment	$8,254,301
Cost Share	$2,696,800
Project Total	$10,951,101

Results and Accomplishments

Date	Wall Temp.	Stream Temp.	Conc. Feeding Rate	Mass of Collected powder (kg)	Multiple of Min. Reducing Gas (EDF)	RD/ Metallization (%)	Notes
	(°C)	(°C)	(kg/h)				
10/18 2016	1250	1290 ~1230	1.8	0.5	< 1.5 (0.5)	79/72	particle size < 32 μm
10/25 2016	1150	1130 ~1200	5.0	1.3	< 1.5 (0.8)	74/65	particle size > 32 μm
11/01 2016	1250	1220 ~1290	2.85	0.3	≈ 1.5 (0.85)	85/80	particle size > 32 μm
11/08 2016	1250	1210 ~1290	2.5	0.2	≈ 1.5 (0.9)	98/97	particle size > 32 μm
11/15 2016	1250	1240 ~1290	3.5	0.3	≈ 1.5 (1)	90/87	particle size > 32 μm
3/8 2017	1330	1350-1200	5.2	0.2	≈ 3 (4)	90/87	As-Received Concentrate
3/14 2017	1330	1350-1200	4.3	0.3	≈ 3 (4)	85/80	As-Received Concentrate
3/21 2017	1330	1350-1200	4.7	0.3	≈ 1.5 (1)	99/99	As-Received Concentrate
3/28 2017	1330	1350-1200	4.5	0.35	≈ 1.5 (1)	99/99	As-Received Concentrate