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 Approach

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

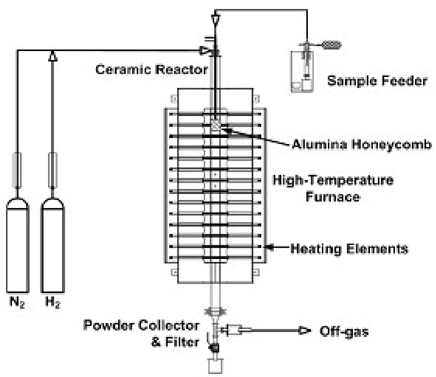
✓ Rapid reaction rate and favorable Net Present Value (NPV)

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
      - Bench reactor fabrication
  - University of Utah
    - Lead Research Organization


Large-Scale Bench Reactor Facility at the University of Utah

Transition and Deployment

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 (2012-2017)	**Industrial Pilot** **TBD** (2017+)
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
Funding	Federal, \$350k **Industry, \$150k** Total, \$500k	Federal, \$ 0 **Industry, \$ 4.8million** Total, \$4.8million	Federal, \$ 8.2 million **Industry, \$ 2.7 million** Total, \$10.9 million	\$10 – 75million **Funding TBD**

Transition and Deployment

- 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 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

Task	Description	Milestones: Key Inputs	Criteria	Date
1	**Bench Scale Reactor**	**Go/No Go Decision # 1:**		11/30/2015
	-Installation	Operating Temperature	1400°C	
	-Commissioning	Solid feed rate	>1 kg/hr	
		Operation time	>6 hr	
2	**Testing Program**	**Go/No Go Decision # 2:**		6/30/16
	-Existing lab flash reactor	Metallization	95%	
	-Drop-tube reactor	Min. amt. reducing gas	3.0x	
	-Bench reactor	**Go/No Go Decision # 3:**		11/30/16
	-CFD model	Metallization	95%	
		Min. amt. reducing gas	1.5x	
		Milestone # 4:		6/30/17
		Metallization	95%	
		Solid feed rate	>5 kg/hr	
3	**Industrial pilot reactor**			
	-Design			
	-Cost estimate			
4	**Program Administration**			8/31/17

Total Project Budget	
DOE Investment	$ 8,200,000
Cost Share	$ 2,700,000
Project Total	$10,900,000

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