A Novel Flash Ironmaking Process

Advancing a Cost-Efficient Option to Produce Iron and Eliminate Pelletizing Operations.

Large-scale bench reactor facility layout. *Photo credit Berry Metal Company.*

Steel is used in a wide variety of manufactured products, such as skyscrapers, automobiles, and bridges. The coke oven/ blast furnace process that produces pig iron for steelmaking requires additional energy to prepare the raw iron ore as sinter and pellets, and consumes large amounts of carbon which is emitted as the greenhouse gas carbon dioxide. Alternative processes can avoid some of these issues, but are limited by low production capacities and raw material restrictions. Therefore, the U.S. steel industry would benefit from the development of a low capital cost process, scalable to large capacities, that can take advantage of the availability of inexpensive iron ore concentrate, and can use fuels that significantly reduce potentially harmful greenhouse gas emissions.

The novel, high-intensity flash ironmaking process is a viable alternative that uses iron ore concentrates that are plentiful in the United States. The process would use inexpensive, abundant natural gas to both heat the ore in the furnace and to remove oxygen and make a higher purity iron. One option is to immediately use this product in an integral, direct steelmaking operation to maximize energy savings. Alternatively, the product could also be collected as a solid to be transported to an Electric Arc Furnace for cleaner steelmaking.

A major advantage of flash ironmaking over existing ironmaking processes that use shaft or fluidized-bed furnaces is the elimination of sticking and particle fusion at high temperatures. The ability to use ore fines provides a cost advantage over processes that require ore to be agglomerated into pellets for ironmaking. The fine particles also cut the furnace's processing time to seconds. This translates to a smaller system for the same output, reducing both capital costs and operating costs. Other potential benefits include improved refractory life, and ease of feeding raw materials into the vessel.

Potential Benefits for Our Industry and Our Nation

The flash ironmaking process would reduce energy consumption up to 20% over historical values by using iron oxide concentrates that do not require pelletization or sintering, and could eliminate the use of coke ovens. Greenhouse gas emissions could be significantly reduced by using natural gas or hydrogen as the reducing agent instead of coke. Preliminary estimates show that the use of natural gas would emit 39% less carbon dioxide than with a blast furnace-based process.

Applications in Our Nation's Industry

The flash ironmaking process could provide steel plants with significantly more energy efficient and customized iron production facilities than that of competing processes.

Project Description

The project objective is to conduct a comprehensive bench-scale testing campaign for the flash ironmaking process concept to:

- Validate the design concept of the flash ironmaking reactor in terms of heat supply and metallization degree.
- Determine optimum operating conditions in terms of reaction temperature, reducing gas composition, and particle residence time.
- Identify and address potential technical hurdles, such as refractory lining and iron powder collection.
- Identify and address potential safety challenges, including emergency shut-off procedures.

- Design an industrial-scale pilot plant.
- Estimate costs for the industrial-scale pilot system.

Barriers

- Achieving 1,300°C–1,600°C by reducing heat loss.
- Achieving required particle residence time by optimizing the gas flow in the system to avoid "short circuit" paths.
- Identifying suitable refractory lining for extended service.

Pathways

Researchers will design and construct a large-scale bench reactor and address administration, safety and operation issues. The reactor will be commissioned and validation tests performed. Bench-scale reactor design verification will commence following commissioning while experimental work continues using the existing small-scale lab flash reactor.

Large bench reactor testing will then be launched with natural gas as the fuel/reductant. Information regarding optimum operating temperature, gas velocity, reactor dimensions, and refractory type will be determined as a result of the testing. Optimum operating parameters will be established through designed experiments.

The design team will use a physics-based analysis employing computational fluid dynamics and heat transfer to assist in the design of a pilot facility at industrial scale. The team will then provide a design concept with construction and operating cost estimates for an industrial scale pilot-plant.

Milestones

This project began in 2012.

- Complete the system design, specifications, and build requirements for a 1 kg/hr bench reactor at Univ. of Utah, compliant with all safety and environmental regulations (Completed).
- Build the system and commission the reactor, confirming temperatures to be greater than 1,400°C, ore feed rate to be greater than 1 kg/hr, and operation time to be greater than 6 hours (2015).
- Achieve greater than 95% metallization with 1.5 times the theoretical minimum amount of reducing gas (2015).
- Determine optimum conditions for the flash ironmaking process (2016).
- Outline cost estimates and preliminary design for industrial pilot plant (2016).

Commercialization

The American Iron and Steel Institute (AISI) has the expertise and will be responsible for formulating a commercialization plan. Options regarding the pilot plant will be provided and considered by the industrial steel participants. If a commercial partner is identified earlier in the process, this partner may participate in the design and construction of the pilot facility. AISI will also maintain and coordinate intellectual property activities regarding patents by means of a holding company. Initial entry into the mainstream market will likely be via steel manufacturing facilities looking for a more cost-efficient alternative ironmaking process with reduced carbon emissions.

Project Partners

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