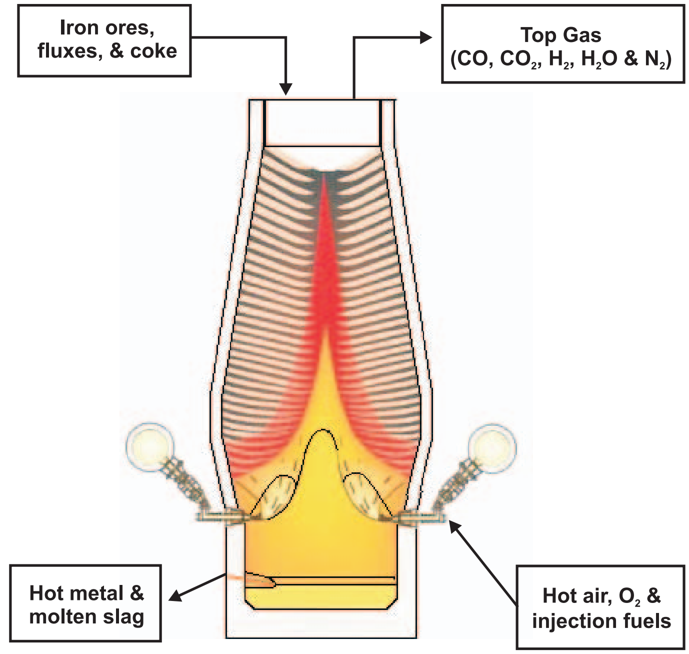
Optimizing Blast Furnace Operation to Increase Efficiency and Lower Costs

State-of-the-Art Computational Fluid Dynamics Model Optimizes Fuel Rate in Blast Furnaces



A typical Blast Furnace Ironmaking Process

Illustration courtesy of Purdue University Calumet.

The blast furnace (BF) is the most widely used ironmaking process in the U.S. A major advance in BF ironmaking has been the use of pulverized coal which partially replaces metallurgical coke. This results in substantial improvement in furnace efficiency and thus the reductions of energy consumption and greenhouse gas emissions. According to industry projections, pulverized coal is expected to supply almost 40% of the energy needed in blast furnaces by 2015. As coal use increases, the permeability of the solid materials charged into the BF, or burden, along with the gas distribution through the BF will alter the BF's productivity and stability.

Measuring a BF's gas distribution is a challenging task. However, it can be readily modeled by high fidelity computational fluid dynamics (CFD) numerical simulations, a major product of this project. Although 3-D modeling has been previously attempted, this project will introduce a comprehensive BF model that includes fluid flow and chemical kinetics. The development of advanced CFD models for blast furnaces will thus represent a significant technological leap for the steel industry in the U.S. and will enable metallurgical coke use and carbon emissions to be minimized.

Benefits for Our Industry and Our Nation

- Increase pulverized coal injection rate and fuel efficiency
- Reduces carbon emissions and energy use
- Optimize BF efficiency

Applications in Our Nation's Industry

The CFD model will enable the identification of optimized gas and burden distributions that can minimize fuel rate, thereby maximizing blast furnace energy efficiency and minimizing environmental emissions.

Project Description

The CFD model emphasizes the complex physics and chemistry found within the upper part of the BF. Specifically, the model can be used to: (1) investigate the impact of key operating and design parameters (2) develop strategies to maximize gas utilization and fuel efficiency and to minimize environmental emissions.

Barriers

The technical hurdles to overcome include:

- Developing new 3-D CFD model for the upper part of the furnace which includes gas distribution, gas-solid reductions and gas-liquid/solid heat exchange for the given burden distributions
- Developing CFD model for a 3-D multiphase reacting flow for pulverized coal injection processing that can predict coal, coke, and natural gas combustion in a BF
- Optimizing burden and gas distributions to increase the fuel efficiency of BF ironmaking

Milestones

This project has the following objectives:

- Develop a state-of -the-art 3-D CFD model for simulating the gas distribution inside a BF at given burden conditions, burden distributions and blast parameters. (Completed)
- Conduct measurements of top temperature and gas composition distributions as well as validations of the CFD model. (Completed)
- Optimize the burden and gas distribution for maximizing gas utilization with proper furnace permeability for given burden materials, productivities, coal injection rate, and BFs.
- Optimize the burden and gas distributions for high fuel injection rate and low coke rate with the best fuel efficiency for given burden materials, productivities, and BFs.

Commercialization

The project team has conducted an initial market study and developed a marketing plan. There are 28 BFs currently operating in the U.S., of which 13 are operated by this project's industrial partners. The newly developed CFD technology will be implemented in each industrial partner's BFs during the project period. Within five years of successful project completion, the remaining BFs in the U.S. will be targeted for implementation. A final marketing and technology transfer plan will be developed as part of the final deliverables of this project.

Project Partners

Lead Research Organization

Purdue University Calumet
Calumet, IN
Principal Investigator: Dr. Chenn Zhou
E-mail: qzhou@calumet.purdue.edu

American Iron and Steel Institute
Washington, DC
Project Director: Joseph R. Vehec
E-mail: aisiap@aol.com

ArcelorMittal USA
East Chicago, IN

ArcelorMittal North America
Hamilton, Ontario, Canada

Severstal North America
Detroit, MI

U.S. Steel
Pittsburgh, PA

U.S. Steel Canada
Hamilton, Ontario, Canada

Union Gas
Chatham, Ontario, Canada

For additional information, please contact

Gideon Varga
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-0082
E-mail: Gideon.Varga@ee.doe.gov

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

DOE/EE-0563 • May 2011
Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.