Author: Ka Wing Ng
Date: 18 November 2024

Net Zero Emissions Steel R&D: Alternate Reductants Utilization

Background

In responds to the CSPA call for climate action (Canada's Steel Industry: A Sustainable Choice), CCRA has developed a research program to address the technical challenges in achieving net-zero emission steel production by 2050 (New Ear for CCRA). In the CCRA research program, activities are categorized into 5 pillars for promoting collaboration between research groups and with industrial partners. Alternate reductants utilization is one of the R&D pillars.

Alternate reductants refer to biogenic carbon, hydrogen and electricity from renewable sources for converting iron ore into metallic iron. It focuses on enabling the utilization of reductants from renewable source to replace the currently used fossil carbon reductants in steel production processes. Current efforts emphasize on the utilization of alternate reductants in existing steel production processes to facilitate implementation in near future. It includes utilization of alternate reductants in iron ore pellet induration, cokemaking, blast furnace ironmaking, EAF steelmaking and DRI production. In long term, electrolytic ironmaking will also be addressed when the technology is more mature.

Goal Statement

- To enable replace of fossil carbon reductants by renewable alternate reductants in existing steel production processes
- To inform renewable alternate reductants producers on properties requirement for further enhancement in products suitability for steel production utilization
- To inform steel producers on process modifications in accommodation of alternate reductant utilization while maintaining productivity and products quality

Specific Objectives

- To address the technical challenges in utilization of highly reactive solid alternate reductants for replacement of coke breeze in iron ore pellet production
- To incorporate solid alternate reductants in cokemaking coal blends while maintain resultant coke quality suitable for blast furnace ironmaking
- To replace pulverized coal for blast furnace direct injection by pulverized solid alternate reductants
- To replace nut coke by densified alternate reductant pellet in blast furnace ironmaking
- To replace solid fossil carbon injection for slag foaming in electric arc furnace operation by solid alternate reductants
- To enable utilization of gaseous alternate reductants in direct reduced iron production without affecting energy efficiency of the subsequent melting step

Projects Overview

Iron Ore Pellet Production

- **Substitution of Coke Breeze in Iron Ore Pellet Production**
  - Combustion characteristics evaluation
    - Development of TG-DSC-FTIR analysis technique
    - Application of analysis technique for potential candidates' suitability evaluation
  - Combustion characteristics enhancement
    - Effect of raw biomass feedstock and pyrolysis conditions
    - Post treatment of biocarbon
  - Utilization of alternate carbon in iron ore pellet production
    - Agglomeration of alternate carbon with iron ore
    - Effect on resultant iron ore pellet quality
  - Industrial scale plant trial

Cokemaking

- **Incorporation of Biocarbon in Cokemaking Coal Blend via Partial Briquetting**
  - Coal/Solid Biocarbon/Biobinder briquette production
    - Briquette composition optimization
  - Proof of principle
    - Small scale carbonization of coal/briquette mixture
  - Pilot scale demonstration
    - Pilot scale carbonization of coal/briquette mixture for resultant biocoke quality quantification
  - Resultant biocoke quality enhancement
    - Microscopic analysis of resultant biocoke to reveal effect of biocarbon incorporation on surrounding coal transformation into coke
    - Selection of coal with optimal property for briquetting with biocarbon to enhance resultant biocoke quality

Blast Furnace Ironmaking

- **Substitution of Pulverized Coal Injection by Biocarbon Injection**
  - Grindability of coal/biocarbon mixture
    - Effect of biocarbon substitution on injectant pulverization
  - Biocarbon combustion behavior
    - Injection rig assessment
  - Industrial scale plant trials
- **Substitution of Nut Coke by Densified Biocarbon Pellet**
  - Candidate suitability assessment technique development
    - Physical properties (density, impact strength, abrasive strength)
    - Devolatilization and CO2 gasification behavior
    - Effect on iron ore pellet reduction performance
  - Potential candidates' suitability assessment
    - Application of the developed technique for suitability assessment
  - Handling and storage
    - Laboratory weathering of potential candidates
    - Properties assessment of weathered sample
    - Leachate analysis for environmental impact assessment
  - Industrial scale plant trial

Projects Overview

Electric Arc Furnace (EAF) Steelmaking

- **Substitution of Injection Carbon for Slag Foaming**
  - Interaction between molten slag and biocarbon
    - Tensiometer observation of interfacial phenomena for assessment of potential candidates' foaming capability
    - Technology development on potential candidates' foaming capability enhancement
  - Delivery of material to slag surface
    - Assessment of biocarbon flowability for pneumatic transportation
    - CFD modeling on particle trajectory in furnace and interaction with molten slag surface
  - Slag Foaming Capability of Assessment
    - Setup of injection facilities for physical simulation of carbon injection for slag foaming
    - Physical assessment of potential candidates' foaming capability
    - Generate data for CFD model develop to assist scale up
  - Industrial scale plant trial

Direct Reduced Iron

- **Biogenic gas utilization in DRI shaft furnace**
  - Reduction and Carburization by H2/Biogenic gas
    - Setup of laboratory facilities for examining reduction and carburization of iron ore pellet
    - Technical feasibility of biogenic gas utilization
    - Chemical and mineralogy characterisation of resultant DRI
    - Melting characteristics of resultant DRI
    - Define biogenic gas composition requirement

Project Team

Research Area	Canmet Lead	Industry Lead
Iron Ore Pellet	Xianai Huang CanmetENERGY-Ottawa xianai.huang@NRCan-RNCan.gc.ca	
Cokemaking	Kun Liu CanmetENERGY-Ottawa kun.liu@nrcan-rncan.gc.ca	
Blast Furnace	Ka Wing Ng CanmetENERGY-Ottawa kawing.ng@NRCan-RNCan.gc.ca	
Electric Arc Furnace	Christopher DiGiovanni CanmetMATERIALS christopher.digiovanni@nrcan-rncan.gc.ca	
Direct Reduced Iron	Xianai Huang CanmetENERGY-Ottawa xianai.huang@NRCan-RNCan.gc.ca	