Progress in low carbon BF-BOF bridge technology
In POSCO

December 5-7, 2023

Low-Carbon Iron and Steel Making R&D Center
PosLAB, POSCO

Dongjo Lee
POS CO’s Carbon Neutrality by 2050

**Commitment to reduce CO₂ emissions**

- 10% ↓ 2030
- 50% ↓ 2040
- Carbon Neutral 2050

**Pathway to achieving carbon neutrality**

- 78.8 (Mt CO₂) (Scope 1 & 2)
- Digital Transformation
- Increasing Scrap Use
- Partial H₂ Reduction
- Large Electric Arc Furnace
- CCUS

**POS CO is the first steelmaker in Asia to commit to carbon neutrality by 2050**

- Keeping domestic crude steel production by 38Mton in 2050
- CO₂ reduction by 2030 with optimization & improvement of the existing facilities
- Development and adoption of bridge technologies
- Development of hydrogen steelmaking by 2030 and stepwise transition from mid 2030s
R&D Roadmap

Essential Technologies for Carbon Neutral Transition

**Near-Term**
- Smartization
- Increase efficiency
- Energy Saving

**Mid-Term (~2030)**
- Partial Hydrogen reduction (Hybrid BF+FINEX)
- Low HMR* BOF
- FINEX with CCUS

**Long-Term (~2050)**
- Utilizing green electricity and H₂
- Carbon-Neutral Steelmaking

*HMR: Hot Metal Ratio

**Carbon**

**Carbon Neutral**

- ESF
- H₂ reduction fluidized bed reactor

With POSCO, We're the POSCO

The Breakthrough Technology Conference
Decarbonization technology that utilizes existing processes prior to commercialization of hydrogen reduced steelmaking (HyREX)

Production of low CO2 emissions products based on blast furnace/converter prior commercialization of HyREX
Low carbon Bridge technology (National Project)

- Companies: POSCO, HYUNDAI Steel,..
- Universities, Research Institutes

### COOLSTAR Overview

- **Ministry of Trade, Industry and Energy**

### Target: Develop technologies to reduce CO₂ emissions (direct/indirect) by 15% in steelworks

- **Sub 1**
  - Hybrid ironmaking technology based on BF
  - H₂ enriched gas injection
  - Application of low reduced iron

- **Sub 2**
  - H₂ amplification based on by-product gas

- **Sub 3**
  - BOF/EAF improvement based on substitution raw material

- **By-product gas (H₂ bearing gas)**
  - Fluidized bed reduction
  - LRI production
  - • Low-Reduced Iron
  - • Reducibility: 65~70%
  - • Direct Reduction ↓

- **Coke Oven**
  - COG (H₂ 56%, CH₄ 27%)

- **Hot compacting**
  - Coke re-design for H₂ reduction

- **LRI**
  - Coke
  - C rate ↓
  - • Replacing C by H₂
  - • BF H₂ reduction ↑

- **H₂ containing gas tuyere injection**

- **COG (H₂ 56%, CH₄ 27%)**

- **Sinter**

- **LRI production**
  - • Low-Reduced Iron
  - • Reducibility: 65~70%
  - • Direct Reduction ↓

- **Coke**

- **H₂ containing gas tuyere injection**

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Bridge Technology - Blast Furnace

Technology is required to produce less carbon, but high efficiency

Total optimization with AI will maximize productivity and reduce coal usage

- Increasing Pellets
- Reduced iron
- Hydrogen containing gas

Efficiency
- Al-based operation process
  (Data-based operation prediction and automatic control, etc.)
  ※ selected as Lighthouse factory (2019)

Pellet
- High Reducibility, Low Gangue compared to other ores
  (Basic Pellets, Semi-basic Pellets, etc)

Reduced Iron
- Energy saving for iron ore reduction in BF
  (HBI, DRI, LRI, Scrap, etc)

H₂ Reduction
- Replacement of reduction agent from C to H₂
  (LNG, COG, H₂, etc)
Similar to oriental doctor's diagnostic methods, experience plays a very important role.

**Function of the Furnace**

1. **Physical & Melting**
   - Solid Iron Ore $\rightarrow$ Liquid molten iron

2. **Chemical & Reduction**
   - $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$

- Real-time Gas composition analysis ($\text{CO, CO}_2, \text{N}_2, \text{H}_2$)
- Thermometer & Pressure sensor by direction/height

**Status of the furnace is estimated through the surface detected data**
Human Condition

Blast Furnace Condition

Food

Digestion, Absorption

Discharge

Furnace

Ore / Coke

Reduction, Melt

Tapping

“Human Condition”

“Blast Furnace Condition”

※ In the past, it was not possible to see the inside of the furnace, so manual operation depended on the experience and intuition of the operator.
### Raw material & Blast Model

#### Before
- Manual measurement (Size, Moisture) (40kg/time, 3times/day)
- Visual Judgement in field
- Manual control based on experience

#### After
- Real-time data conversion using high-definition video and AI
- Blast Prediction & Auto Control using AI

**Deep Learning (**CNN**)**

- **Input Data**
  - Operator experience
  - Operation data

- **Deep Learning Algorithm**

- **Blast Control**
  - Blast Prediction & Auto Control

*CNN: Convolutional Neural Network*
Bridge Technology - Smart Blast Furnace

Combustibility & Attachment Model

- Image classification and data conversion by learning with AI

[Combustibility Data (5,600 sheets)]

Normal

Fall of unreduced iron ore

Poor combustion

PCI Cut

[Attachment Data (60,000 sheets)]

Normal

Attachment

Caution

Warning

Attachment

Lack

※ Before : Visual judgement through the hole
※ Before : Judgement of Attachment based on experience

Combustibility & Attachment Prediction and Auto Control using Deep Learning

[Input Data]

Video Image

[Deep Learning Algorithm]

Combustibility, Attachment Control
(Solving chronic problems)

[Auto Control]
Molten Iron Temperature Prediction & Auto Control Model

- Real-time temperature and molten iron discharge data using Smart Sensor

[Real-time HMT measurement using IOT sensor] [Real-time molten iron discharge status data]

※ Before: Manual measurement (1time/2hours)
※ Before: Visual Judgement in field

- Prediction and automatic control of HMT after 1hour using Deep Learning

[Input Data] [Deep Learning Algorithm] [HMT Prediction, Control]

Operator Know-how Into Data
Data standardization (Video)

HMT Prediction, Control (After 1hour)
Bridge Technology - Pellet usage in BF

Characteristics of Pellet in BF

- Pellets reduce Coke & Coal rate with high reducibility and low slag ratio.
- Highest tendency to center segregation due to their high rolling properties.

Ref) Modern Blast Furnace Ironmaking An Introduction, 2015
Effect of pellet usage ratio on sintered ore basicity

- To maintain the basicity of tapping slag, the basicity of sintered ore needs to be increased.
- The difference in basicity between sintered ore and pellets gradually increases.

![Diagram showing the effect of pellet usage ratio on sintered ore basicity.](image)
Necessity of development of pellet charging technology

- Segregation of pellets/sintered ore causes imbalance in slag basicity in the furnace
- Deviation in fluidity and gas permeability, adhesion and tapping problem can occur

Fluidity Permeability Tapping Adhesion

Coke ash
Coke/PC ash

Reduction
Burden
Primary slag
Bosh slag
Tuyere slag
Final slag

Viscosity (poise)

<table>
<thead>
<tr>
<th>Viscosity (poise)</th>
<th>After Lee and Min 1723 K</th>
<th>Present study 1723 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeO=5% Al2O3=10% MgO=5%</td>
<td>FeO=10% Al2O3=10% MgO=5%</td>
<td>FeO=20% Al2O3=5% MgO=5%</td>
</tr>
</tbody>
</table>

Deviation in fluidity and gas permeability, adhesion and tapping problem can occur
Bridge Technology – Reduced Iron usage in BF

Characteristics of Reduced iron in BF

- Reduced irons reduce Coke & Coal rate with saving energy for reduction in BF
- Scrap among reduced iron requires shape control to prevent problems with charging equipment.

**Sinter/Pellet**

- < Pre-reduction
- > Disintegration
- > Gangue

**Reduced iron**

- Price <
- Shape >
Reduced iron usage in BF for low carbon

- Reducing agent ratio decreases and productivity increases depending on metalization of burden determined by type and amount of reduced iron.

![Graph showing the relationship between burden metalization and coke rate decrease.]
Necessity of development of reduced iron charging technology

- Segregation of reduced iron causes imbalance in temperature in furnace

Ref.: Austin et al., ISIJ Int. 1998
Details of Digital Twin model

① Burden structure
② Distribution of burden

Find charging method for high efficient pellet/reduced iron uses
### Hydrogen containing gas usage in BF for low carbon

- Hydrogen containing gas includes NG, COG, H2 generated with green power
- Reduce coal rate by suppressing direct reduction with increasing indirect reduction by H2

#### Chemical Reactions

1. **Indirect reduction ↑**
   - $3\text{Fe}_2\text{O}_3 + \text{H}_2 \rightarrow 2\text{Fe}_3\text{O}_4 + \text{H}_2\text{O} + 650\text{ cal/mol (Exothermic)}$
   - $\text{Fe}_3\text{O}_4 + \text{H}_2 \rightarrow 3\text{FeO} + \text{H}_2\text{O} - 18,430\text{ cal/mol (Endothermic)}$
   - $\text{FeO} + \text{H}_2 \rightarrow \text{Fe} + \text{H}_2\text{O} - 5,690\text{ cal/mol (Endothermic)}$

2. **Direct reduction ↓**
   - $\text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO} - 37,220\text{ cal/mol (Endothermic)}$
   - $\text{Fe}_3\text{O}_4 + \text{CO} \rightarrow 3\text{FeO} + \text{CO}_2 - 8,750\text{ cal/mol (Endothermic)}$
   - $\text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2 + 3,990\text{ cal/mol (Exothermic)}$

#### BF Types

- **Conventional BF**: Ore, Coke, Blast, PCI
- **H2 rich BF**: Ore, low Coke rate, Blast, low PC rate, Hydrogen containing gas
Gas flow Digital Twin linked to Charging D/T

- Gas flow
- Gas velocity
Bridge Technology - Gas Flow Digital Twin for H2 BF

Gas flow

- PC Single Injection
- PC and NG Dual Injection
- PC Particle Tracking In tuyere

Temperature

- PC and NG Dual Injection
- PC Particle Tracking Surface
Operating test results

HBI+Pellet+NG co-usage* test with improved smart BF & D/T technology at P2BF in 2023

* HBI 10% + Pellet 50% + NG 30kg/t-p

【Coke+PC Ratio】
(Unit: kg/t-p)

Before: 499.0
After: 406.1

△24.4%

【CO2 Emission】
(Unit: t-CO2/t-s)

Before
After

△24.4%
Heat balance in BOF

Process well balanced for 85% HMR – for lower HMR energy not balanced, not enough energy to melt down all cold inputs (Scrap, DRI) and reach target tapping conditions.
POS-OBM (Oxygen top and Bottom blowing Maxhuette)

- POS-OBM is very good for Post combustion control in vessel
  - Bottom O2 for De-C, Top O2 for Post combustion and De-C
  - Change of lance heights freely for control of post combustion ratio

Supplying oxygen to top and bottom parts simultaneously, a converter easily generates the heat required to increase the scrap ratio.
Utilization of biomass in steelmaking process

- Companies: POSCO, HYUNDAI Steel, ...
- Research Institutes: KIER, ...

Target: Utilization of Biomass in steelmaking process for coal replacement

Biomass Feedstock
- Survey the biomass feedstock
- Policy, Global R&D Collaboration

Biomass Upgrade
- Pyrolysis, Torrefaction
- Densification Technology
  (Briquetting & Pelletization)

Utilization in Steel industry
- Coal replacement in BF, FINEX
  (Coke/BQ 2%, Sinter 3%, PCI 5%)
- Bio-Carbon for ESF, EAF
Process based Lowest-cost-oriented Optimization Technology

- Cost & CO2 decision making through intelligent virtual steel mill implementation
- Digital transformation that combines data processing, operation theory model, and analysis

Entire process Simulation

Ironmaking

Steelmaking

Product

Calculate optimal Cost/CO2 emissions within conditions
POSCO’s CCUS approaches

- Establishment of system to capture or store carbon dioxide generated from blast furnace/FINEX
Details of CO₂ capture and utilization Government-led Project

**Project 1: CO₂ Capture**
- 80tCO₂/day
- CO₂ Capture
- CO₂ → COG

**Project 2: CO₂ Utilization**
- CO₂ → COG

Existing Coke Oven
- Coal → Coke Oven
- Coke Oven + CO₂ Injection
  - CO₂ + coke = 2CO

Coke Oven + CO₂ Injection
- CO₂ → Coke Oven
- Increased COG
- Coke
- COG + Light Oil(BTX), Tar
- Carbon
- COG + Air

By-product Gas

Flue Gas

Coke

COG

Light Oil(BTX), Tar

Carbon

Coal
Thank you for your kind attention!