

9th European Coke and Ironmaking Congress (ECIC 2024)

Coal, Coke, Biocoal, Biocoke, Biochar and
Iron Reductions

Bardolino, Italy
16-18 October 2024

ISBN: 979-8-3313-1079-0

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571

Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2024) by Associazione Italiana di Metallurgia (AIM)
All rights reserved.

Printed with permission by Curran Associates, Inc. (2025)

For permission requests, please contact Associazione Italiana di Metallurgia (AIM)
at the address below.

Associazione Italiana di Metallurgia (AIM)
Via Filippo Turati 8
20121, Milano
Italy

Phone: +39.02.76021132
Fax: +39.02.76020551

aim@aimnet.it

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

INDEX



OPENING SESSION

- [ecic_097] The way the European steel industry wants to become carbon neutral** 1
H. B. Lünen, P. Schmöle

BIOCOAL | BIOCHAR

- [ecic_056] BioCoDe: biomass for cokemaking decarbonization** 13
V. Pepe, A. Sorino, R. Attrotto, A. Vecchio, G. Fiorenza
- [ecic_106] Bio-coke for manganese ferroalloys production - results of the BioCoke4FAI R&D project implementation** 18
M. Rejda, A. Sobolewski, M. Wojtaszek-Kalaitzidi, B. Mertas, M. Książek, S. Y- Larsen, P. Szecówka
- [ecic_065] Assessing biochar functionality for EAF use** 19
G. Seenivasan, A. Andersson, H. Ahmed, L. Sundqvist-Öqvist
- [ecic_080] Modelling of processes for upgrading biomass before its use in steel industry** 25
I. Matino, V. Colla, O. Toscanelli
- [ecic_040] Research on the potential role of biocarbon in future ironmaking process** 30
G. Kim, H. Oh, J. Lee, Y. Lee, Y. Bae, J. cho, J. Kwon, J. Park, J. Lee
- [ecic_125] Reduction of a basic manganese ore using biochar Kernel palm shells** 35
G. I. Kayombo, MK Wa Kalenga

BLAST FURNACE IRONMAKING - EQUIPMENT

[ecic_087] Material tracking	40
C. Dengler, X. Rooss, D. I. Durneata, L. Wu	
[ecic_074] 37 year campaign of IJmuiden blast furnace 6	45
J.R.H. Stuurwold, B. Nugteren, G.J. Tijhuis, F. Kerkhoven, R. van Laar	
[ecic_015] Method evaluation for understanding the reduction behaviour of cold-agglomerated pellets	51
M. Bennett, R. Joyce, P. Warren	
[ecic_059] Gasification reactivity of coke microtextural constituents to CO₂	56
H. Lomas, S. Khoshk Rish, A. Jayasekara, A. Tahmasebi, T. Congo, K. Steel	
[ecic_075] Latest generation dry blast furnace gas cleaning technology: improved energy efficiency and carbon footprint	61
P. Klut, J. de Weerd, G. Bakker	
[ecic_047] How are Ironmakers investing in existing blast furnace assets?	73
D. Osborne, R. Horwood, G. Jemison	
[ecic_091] Innovative two-stage blast furnace gas cleaning technology implemented at Blast Furnace no 2 in ArcelorMittal Poland Dąbrowa Górnicza plant	78
M. Czaplicka, M. Niesler, A. Ryfa, M. Kocot	
[ecic_073] Danieli Top Charging Unit: simple and flexible design, easy maintenance	83
A. Glazer, E. Tesselaar, E. Engel	
[ecic_123] Introduction of POSCO's NO.4 Blast furnace relining and sinter facilities construction	88
J.y. Jo, B.s. Yoo, T.h. Park, W.h. Byun	

BLAST FURNACE IRONMAKING – OPERATIONS

[ecic_031] Innovative ultra low carbon ironmaking technology with massive HBI charging in blast furnace	93
M. Yakeya, A. Kasai, M. Sakamoto, T. Tagawa, K. Miyata	
[ecic_088] Techno-economic assessment of ammonia and HBI as flexible green energy carrier for BF-BOF steel making	98
J. Ji, E. Taktak, P. Kinzel, M. Baniyadi, F. Mauret	
[ecic_122] Coke behavior with H₂O in a hydrogen-enriched blast furnace: A review	103
K. Li, F. Zhou, J. Zhang	
[ecic_046] The green transformation in the Chinese ironmaking Industry	108
J. Zhang, K. Li, Z. Liu, T. Yang	
[ecic_051] Evaluation of the conversion behavior of Alternative Reducing Agents in a test rig under raceway conditions	113
T. Nanz, M. Bösenhofer, J. Rieger, H. Stocker, C. Feilmayr, M. Harasek	
[ecic_005] Softening and melting behaviour of ferrous burden under simulated blast furnace process conditions	118
Y. Xiao, A. Craamer, M. Martinez Pacheco, T. Peters	
[ecic_023] CFD investigation of blast furnace raceway: Effect of the co-injection of coke-oven gas (COG) and the injection method in the tuyere level	123
A. Islas, M. Baniyadi, P. Goedert, P. Bermes, A. Feiterna, D. Durneata, A. Janz, F. Demirci	
[ecic_039] Influence of blast furnace technology and design features on heat losses in the cooling system and coke consumption for compensation of them	128
O. Chaika, B. Kornilov, A. Moskalyna, M. Alter, V. Naboka, S. Safonov	



BLAST FURNACE IRONMAKING – OPERATIONS

- [ecic_076] BF-BOF steelmaking CO₂ emissions reduction options** 133
R. van Laar, D. Verma, J. de Weerd
- [ecic_119] Recovery of a blast furnace to normal operation after a “chilled hearth” event** 138
M. Alter, O. Chaika
- [ecic_062] CO₂ reduction technology through COG injection and low-reduced iron charging to the blast furnace** 144
J-O. Park, W-J. Lee, G-H. La, Y-S. Lee, S-H. Yi
- [ecic_029] Start-up and usage of coke oven gas at HKM on our mission to green steel and CO₂ reduction** 149
F. Perret, F. Demirci, A. Janz, R. Peter, T. Semleit, S. Schulte
- [ecic_068] Insights into the segregation in the blast furnace charging system: from the stockhouse to top hoppers** 154
A. Hadi, Y. Pang, D. Schott, A. Adema, J. van der Stel
- [ecic_027] Spotlight on Na₂O and K₂O behaviour in blast furnace operation** 159
P. Warren, M. Geerdes

CO₂ MITIGATION INCLUDING CCUS

- [ecic_012] Options for reducing CO₂ emissions for iron and steel plants and energy efficiency considerations** 164
S. Kumar, Y. Gordon, P. Krawchuk, R. Maia
- [ecic_057] Integration of carbon capture and utilization process in a steel mill during the transition phase towards net zero emissions** 169
C. Mühlegger, O. Maier, A. Sasiain Conde, A. Spanlang, T. Keplinger, A. Werner
- [ecic_067] Technologies and status of hydrogen, syngas, and carbon capture use in ironmaking** 174
H. Alshawarghi, J. von Schéele, P. Mathur

CO₂ MITIGATION INCLUDING CCUS

- [[ecic_061](#)] **New ways to harness the CO₂ footprint in sintering** 179
E. Fehringer, [M. Böberl](#)
- [[ecic_085](#)] **Transforming blast furnace into environmentally friendly EASyMelt™ through the utilization of ammonia and carbon capture for achieving net-zero emissions** 184
[F. Mauret](#), [M. Baniasadi](#), [J. Ji](#), [P. Kinzel](#), [H. Saxén](#)

COKE MAKING

- [[ecic_060](#)] **Effect of coal blending and pretreatment on coke quality and its reactivity** 189
[W.-J. Lee](#), [D.-M. Jang](#), [J.-O. Park](#), [G.-H. La](#)
- [[ecic_063](#)] **Measurement and analysis of semi-coke contraction** 194
[S. Khoshk Rish](#), [D. R. Jenkins](#), [A. Tahmasebi](#)
- [[ecic_050](#)] **Development of coke structure under stamp charged coking condition** 199
[S. Khoshk Rish](#), [A. Wang](#), [M. Mahoney](#), [A. Tahmasebi](#)
- [[ecic_055](#)] **Measurement of coke quality** 204
[R. Pearson](#), [D. E. Pearson](#)
- [[ecic_064](#)] **Biocoke under blast furnace atmosphere with increased amounts of hydrogen** 212
[A. Heikkilä](#), [J. Haapakangas](#), [A. Koskela](#), [T. Fabritius](#)
- [[ecic_082](#)] **High temperature shrinkage measurement development as a tool to extend lifetime of coke ovens** 217
[A. Oudhuis](#), [B. Gols](#), [J. van der Plas](#), [L.J. Pille](#), [P. Put](#), [B. van Vliet](#), [A. Tahmasebi](#), [S. Khoshk Rish](#), [D. Jenkins](#)
- [[ecic_111](#)] **Demonstration of CO₂ utilization in ironmaking industries: CO₂ reaction with unused hot carbon in coking chamber** 224
[H. W. Park](#), [S. Joo](#), [B.-S. Kim](#), [G. Kwon](#), [C. H. Rhee](#)



COKEMAKING

- [ecic_036] Mineral effects on coke performance at high temperatures: reactivity and dissolution** 229
R. J. Longbottom, B. J. Monaghan
- [ecic_086] The role of the coke dry quenching technology in the frame of the transition to the green steel** 234
A. Fabbri, F. Strobino, R. Calcagno, A. Ferraris
- [ecic_028] Optimizing coal blending in coke production: A logistic approach** 241
J. Kim, D. Jang, H. Jeong, S. Lee

DIRECT REDUCTION AND SMELTING REDUCTION

- [ecic_070] Hlsarna for processing almost all waste materials an option for iron making** 246
J.L.T. Hage, H.K.A. Meijer, J.E.B. Fradet, C. Zeilstra, J.W.K Van Boggelen, J. Van Der Stel
- [ecic_011] Green steel and vanadium production in Uzbekistan** 251
Z. Adilov, T. Kodirov, D. Atakhanov, M. Bodley, M. Sidawi, S. Thakuridin, Y. Gordon, G. Dressel, S. Kumar
- [ecic_003] Hy³ (Hy-CUBE): Hyundai Steel's initiative for carbon avoidance steelmaking** 256
H. Kim, M. Sun
- [ecic_024] Refractory lining challenges in transitioning from established to hydrogen-ready operations in DRI shaft furnace technologies** 260
D. Gavagnin, E. Kyrilis, E. J. Estrada Ospino, M. Spreij, S. Postrach
- [ecic_117] Fe₃C as an alternative iron source to DRI** 265
Y. Sasaki, K. Ikeda, H. Kubo
- [ecic_072] High resolution characterization of DC arc parameters in a Hydrogen Plasma Smelting Reduction furnace** 269
C. R. Quick, E. Reichel



DIRECT REDUCTION AND SMELTING REDUCTION

- [ecic_013] The behavior of trace elements in the smelter** 274
A. Pfeiffer, B. Voraberger, G. Wimmer
- [ecic_006] Electric smelting furnace technology and implementation readiness** 279
K. Chomyn, S. Ge, T. Koehler, C. Walker, D. Rudge
- [ecic_004] Estimating heat and material balances in direct reduction plants under various operating conditions** 284
M. Sun, H. Kim
- [ecic_037] Smelter - A new Pathway for green iron making** 288
G. Wimmer, A. Pfeiffer, B. Voraberger
- [ecic_025] Quantitative study for COG-based production of DRI of a high carbon content in a fluidized-bed reactor** 293
J. O. Jo, J. R. Lee, H. Kim, K. Yoo
- [ecic_038] Applicability of a laboratory counter-current BORIS reactor to study non-isothermal reduction of iron oxides with hydrogen** 298
Y. Graz, Y. Maurice, A. Husson, R. Santos Ferreira, O. Nechyporuk, J. Barros Lorenzo
- [ecic_103] Exploring the effects of lateral hydrogen injection in the hydrogen plasma smelting reduction process** 303
D. Ernst, M. Farkas, M. Zarl
- [ecic_092] Investigation of the behaviour of phosphorus, sulfur and copper during the hydrogen plasma smelting reduction process** 308
B. Adami, D. Ernst, J. Schenk
- [ecic_113] Carbon-free electrodes in hydrogen plasma smelting reduction: an innovative approach for low emission steelmaking** 313
M. Zarl, M. Farkas, B. Geier, D. Ernst
- [ecic_021] Hydrogen based reduction behavior of MgO rich magnetite pellets** 318
P. Garg, H. Ahmed, C. Andersson, C. Samuelsson, J-O. Wikström



DIRECT REDUCTION AND SMELTING REDUCTION

- [ecic_009] The Extended Discrete Element Method (XDEM) as a common simulation framework for traditional and green steelmaking** 323
B. Peters, X. Besseron
- [ecic_022] Blast furnace transition towards DRP, CO₂ reduction and hydrogen usage in ENERGIRON® plants** 333
M. Lapasin, D. Pauluzzi, M. Mahmoud
- [ecic_019] Coolbrook's RotoDynamic Heater™ - electrifying high - temperature process heat and reducing fossil fuel emissions in the steel industry** 344
T. Paananen
- [ecic_044] Reduction of sinter in hydrogen containing atmosphere** 352
A. Szemalikowska, M. Niesler, J. Stecko, J. Marcisz, W. Szulc
- [ecic_034] First steps in the endeavour to determine particle properties in the direct reduction process of iron ore pellets** 357
S. La Manna, S. Z. Ajabshir, D. Barletta, M. Poletto, K. Qyteti, V. Scherer
- [ecic_078] Simulation of Direct Reduction Processes to be included in a process chain multipurpose simulation toolkit** 363
I. Matino, V. Colla, A. Vignali
- [ecic_042] Iron ore sintering tests for direct reduction in H₂-containing atmosphere** 368
A. Szemalikowska, M. Niesler, J. Stecko, J. Marcisz, W. Szulc

H₂ AND SYNGAS EXPLOITATION

- [ecic_081] Influence of hydrogen injection on basic iron ore sinter reduction at blast furnace center conditions** 373
A. Abdelrahim, A. Koskela, M. Iljana, T. Fabritius, C. van der Kroon, V. Pridhivi
- [ecic_104] On the influence hydrogen-bearing injected fuels in the ironmaking blast furnace** 378
S. Nielson, T. Okosun, O. Ugarte, C. Q. Zhou, K. Leontaras, J. Entwistle



H2 AND SYNGAS EXPLOITATION

- [ecic_116] Hydrogen production technology from solid-oxide electrolysis using waste heat from the ironmaking process** 383
Y. Yang, H. Kim, J. S. Ahn
- [ecic_026] Production of hot hydrogen-rich syngas in integrated plants for efficient injection in the blast furnace and CO₂ mitigation (ProSynteg)** 388
E. L. Faraci, M. Gili, D. Ressegotti, D. Garot, A. Oblanca Gutiérrez, C. Morelli, L. Micheletti
- [ecic_110] CO₂-free hydrogen production technology from ammonia/methane using direct reduced iron** 395
S. Joo, G. Kwon, C. H. Rhee, B-S. Kim, Y. Yang, H. W. Park
- [ecic_077] Influence of a higher hydrogen based reduction share from coke oven gas injection on the blast furnace process** 399
H. Bartusch, T. Hauck, F. Demirci, A. Janz

MEASURING TECHNOLOGIES AND INDUSTRY 4.0

- [ecic_010] EMF-timeseries analysis implemented as predictive tool in BF-tapping control** 404
S. Moll, J. Eisbacher-Lubensky, C. Weiß, J. Felser, G. Lengauer
- [ecic_007] Campaign life extension of COREX furnaces** 409
W.L. Ying, A. Sadri, Y. Gordon
- [ecic_032] A soft measurement model construction method based on machine learning and CFD** 414
Y. Wang, S. Li, J. Zhang, Z. Liu
- [ecic_017] Integrated steel plants challenges during transition to green steel - a holistic quantitative evaluation of CO₂ reduction potentials using digital twins in m.simtop** 418
B. Weiss, R. Millner, H. Völkl, B. Hiebl



MEASURING TECHNOLOGIES AND INDUSTRY 4.0

[ecic_048] Advanced thermal camera technology for tuyere raceway temperature measurement 423

P. Warren, I. Scott, S. Ibrahim, T. Stoakes

[ecic_008] Monitoring strategies for blast furnaces and electric arc furnaces 428

W.L. Ying, Y. Gordon, S. Kumar, A. Sadri

SINTERING AND PELLETIZING

Keynote [ecic_058] Influence of metallic iron structure and molten slag formation on softening behavior of pre-reduced pellets under high temperature loading condition in inert atmosphere 433

K-i. Ohno, T. Kon, T. Orimoto, N. Yasuda

[ecic_016] Atomic-scale structural analysis of calcium ferrite in sintered ore by scanning transmission electron microscopy 438

K. Takehara, K. Ikeda, T. Kawano, T. Higuchi

[ecic_002] Effects of gradual substitution of coke breeze with charcoal on the sinter process 441

J. Eisbacher-Lubensky, F. Kittinger, S. Pichler, C. Weiß, H. Stocker, S. Wegscheider

[ecic_079] Revealing the softening and melting behavior of sinters and lump ores under a real blast furnace working line by analyzing the quenched burdens 446

W-c. Tsai, Y-n. Chiu, K-c. Chang, K-c. Hsieh, S-k. Lin, P-c. Cheng, J-S. Shiau, H-l. Chen

[ecic_069] Investigate effects of sintering condition on the agglomeration behavior of iron ore sinter with high SiO₂ content 451

P.-c. Cheng, K-c. Chang, S-x. Liu, K-c. Hsieh, S-k. Lin, J-s. Shiau

[ecic_083] Comparative analysis of different sinter strand modeling techniques in flowsheeting: insights for steelmaking optimization 456

A. Walk, B. Weiss, W. Wukovits

SINTERING AND PELLETIZING

- [ecic_084] Investigating the oxidation behaviour of magnetite ore: impact of particle size fraction and mineralogical composition** 461
A. Laarich, C. Andersson, H. Ahmed, T.K Sandeep Kumar, D. Marjavaara, K. Wiegel, S. Richter, J-O. Wikström
- [ecic_054] Development of convergence engineering simulation technique based on the image data obtained by X-ray computed tomography for ironmaking packed bed deformation** 466
S. Natsui, R. Honda, H. Nogami
- [ecic_098] Mechanism for iron burden reduction of blast furnace process-a laboratory scale simulation** 471
Y.-j. Kuo, Y-n. Chiu, K-c. Chang, Y-j. Hu, W-c. Tsai, P-c. Cheng, K-c. Hsieh, J-S. Shiau, H-l. Chen, S-k. Lin
- [ecic_033] Reduction disintegration behavior of self-fluxing pellet at 600°C and 700°C under high hydrogen blast furnace condition** 476
K. Momma, T. Murakami
- [ecic_053] Mineral phase and structural evaluation of the influence of iron ore concentrate on melting and assimilation phenomena in the sintering process** 481
S. Yamazaki, T. Adachi, H. Taguchi, K. Koga, K. Miyagawa
- [ecic_052] The effect of gangue phase existing state on gangue removal behavior in the iron ore upgrading process by reduction-crushing-separation** 486
T. Adachi
- [ecic_041] Utilization of biocarbon in iron-ore sintering for CO₂ reduction** 491
I. Song, Y. Lee, J. Lee, J. Yoo, D. Kim

POSTER

- [ecic_043] Characterization of sinters after reduction in hydrogen containing atmosphere** 496
R. Rozmus, A. Janik, K. Radwański, M. Niesler, J. Stecko, A. Szemalikowska
- [ecic_126] Use of artificial neural network to predict energy consumption in the reduction zone during high carbon ferromanganese production** 501
MK Wa Kalenga, DK Nyembwe