Process Integration in the Steel Industry

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Short facts

• Independent research institute
• Founded 1963, situated in Luleå
• 97 employees
• Turnover SEK 125 million/year
• 35 member companies
• Customers all over the world

Business idea

We create, refine and convey research results in process metallurgy, heating, metalworking, environment and energy technology. We carry out applied research to meet customer needs for technology and expertise and contribute to economic and competitive production.
Centre for Process Integration in Steelmaking

- Founded 2006
- 8 Industrial partners + 2 academic + 2 institute
- Based at Swerea MEFOS with 10 full-time researchers plus partners
- Coordinated IEA IETS ANNEX XIV

- holistic solutions
- energy efficiency and material efficiency
- entire production system from mine to finished product to recycle
- Industrial symbiosis
Steelmaking routes

1. **Coal** → Coking → Coke
2. **Iron ore** → Blast Furnace → Liquid iron
3. **Scrap** → BOF → Liquid steel
4. **Iron ore** → Direct Reduction → DRI (solid iron)
5. **EAF** → Liquid steel
6. **Ladle treat**
7. **Products**
   - Slabs
   - Blooms
8. **Casting** → To rolling, other treatments
## Process Gas

<table>
<thead>
<tr>
<th></th>
<th>BFG</th>
<th>BOFG</th>
<th>COG</th>
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<tbody>
<tr>
<td>CO</td>
<td>%</td>
<td>23</td>
<td>57</td>
</tr>
<tr>
<td>H₂</td>
<td>%</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>CH₄ (+)</td>
<td>%</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>CO₂</td>
<td>%</td>
<td>23</td>
<td>14</td>
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<tr>
<td>LHV</td>
<td>MJ/nm³</td>
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<td>8</td>
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<td>Energy</td>
<td>GJ/t HRC</td>
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</table>
PI – do we draw the line

Industrial symbiosis? Geographic limitations?

External industries

Energy integration

By-product production

End of life

Manufacturing

Production optimization

Recycle

Energy recovery

Resource planning

Energy integration

Material integration

Real time?

LCA?
PI in Integrated Steelmaking Context

- Wide as possible -> anywhere PI "thinking" is needed
- Process level optimization: e.g. Hot stoves/blast furnace
- Multiple processes: e.g. BF-BOF
- Whole plant: Raw materials to HRC quality; power plant
- System level: Raw materials to HRC, slag use, waste generation, power and heat production & use
- Life cycle: raw material to manufactured products to recycle/waste
Methods

Optimization tools:
Mathematical programming; Pinch analysis; Exergy analysis; GAMS, etc.

Assisting tools:
Aspen, FactSage, HSC, Matlab, Masmod, CFD, RIST, HEATSEP, etc.

Under consideration: Modelica (dynamic)
Masmod Excel-based model + other techniques

Core steelmaking processes + additions

- Other modeling methods used and results converted to Excel to link the system together.
- Unit models can be linearized, input to ReMind
- Calibrated to "Typical EU steelplant"
- Bespoke plants
Industrial application – example Hot stoves

A change in hot stove operating mode resulted in a reduction in coke consumption in the blast furnace at SSAB. Costs have been reduced by **SEK 6.5** million per year.

Hot Stoves

28 May 2012

- **Blast temperature**
  - calculated + 85 °C
  - achieved + 60 °C
- **Coke saving**
  - circa 5 kg/tHM
- **Cost saving** of 6.5 MSEK per year
- **No investment cost!**
Example material efficiency

- System model including slag/steel thermodynamics

Fluxes: -30 kg

Net slag to storage: -41 kg

Analysis of metallurgical processes and slag utilisation in an integrated steel plant producing advanced high strength steels
Mats Brämming, Katarina Lundkvist, Mikael Larsson, Caisa Samuelsson, Scanmet IV, June 10-13, 2012, Luleå
CO₂ – Where to start?

"Energy" or "Steelmaking"

Electricity-based System

- Electrolysis
- H₂ reduction -> EAF
- ?? C-recycling??
CO$_2$ from current Gas Processing Plant

- Biomass processing
- Coke plant
- Sinter plant
- Hot Stove

Additional Energy

- Process gases
- 90% of C

H$_2$ to power

H$_2$ to combustion processes

CO$_2$ CCS?

Products

H$_2$ to power

H$_2$ to combustion processes
COst$_2$Cap

- Aims at identifying low-cost and near future alternatives for partial carbon capture

Maria Sundqvist et al, to be presented at 9th Trondheim Conference on CO2 Capture, Transport and Storage, June 2017
Gas Processing (CCU) Pilot Projects
EU funded H2020 Projects

Stepwise Grand Opening at:
IEAGHG Chemical Looping Network Meeting 4-5 Sept., Luleå
Energy System Change

Iron ore → Energy Supply → Bio-carbon → Electrolysis → Gasification → Gas separation → Direct Reduction → EAF → Steel

Water Loop: H₂, H₂O [CO, CO₂]

Carbon & Hydrogen Loop: CO, H₂, CO₂ → CO₂ use → Products

CO₂ use → Products
Fossil-Free Steelmaking

Energy system

- Production
- Balance
- Societal demand
- Cost

H$_2$/electricity

Steel production

Rate of change
Industrial needs

• Critical mass of personnel – too few people in organizations
  • Education
  • Networks/Centres/Partners - collaboration
• Overcoming built-in suboptimization/inflexibility – individual process targets to system-wide
• Trust & confidence in methods
  • Data handling, visualization tools & communications to different levels in organizations
  • Bringing together departments, different companies
• Multiple sectors involved to mitigate climate change
Professional Education

supported by:

RawMaterials

2016 – 2018
1st course planned: autumn 2017

PRISMA, The Center for Process Integration in Steelmaking, including LTU, SSAB, LKAB, Höganäs and Swerea MEFOS (a RISE institute) have worked with in a structured way since 2006 to make PI studies and implementation in industry. ArcelorMittal has successfully applied PI in the steel industry. The University of Liège contributes new potential application of CCUS and how best these technologies could be integrated within industry. The course is designed to incorporate industrial and academic experience of the consortium and transfer these to EIT Raw Material members, SMEs and, space permitting, other external partners. Inclusion of participants from other metallurgical and extractive industries is desired.

Objectives

The 3-day course is designed to give the participants:

- knowledge of suitable methods that can be applied and the advantages that can be realized
- clear and structured examples of implementation
- opportunities to develop network for future collaboration
Conclusions

• Steel industry is developing its own approaches to PI
• PI may play strong roles from real time optimization to strategic studies
• Success stories are being generated -> more are needed
• Education, cross-sectoral approaches, collaboration in multi-disciplinary teams needed
• PI has an important role in planning and achieving real greenhouse gas mitigation – across multiple industries
  • Steel moving towards CCUS and energy system change

“Work within the PRISMA programme helps us to demonstrate the overall effects for the whole plant, and not just our own department, something which is difficult for us who mainly work with the blast furnace. This means we can avoid suboptimisation, which is a common pitfall in a steelworks.” – Erik Olsson, SSAB    (emphasis mine)
Scientific Work for Industrial Use
www.swerea.se