Towards high temperature (>500˚C) excess heat recovery in Steel Industry

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Some illustrations of high temperature processes in steel industry
Introduction

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Master in Energy Systems - Diplôme d'ingénieur
2006 - 2011 | INSA Rouen, France

PhD in Industrial Processes – Materials Heat Transfer & Fluid Dynamics
2012 - 2016 | Institut Jean Lamour, University of Lorraine, Nancy, France

Energy Program Leader - Researcher - Creativity Coach
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ArcelorMittal

The world's leading steel and mining company, with around 158,000 employees in more than 60 countries.

Leader in all major global steel markets, including Automotive, Construction, Household appliances and Packaging, with leading R&D and technology.

Primary steelmaking facilities in 16 countries expose the company to all major markets, from emerging to mature.

A major producer of steel in the EU, North and South America, Africa and in the CIS region, and a growing presence in Asia, namely in China and India.

One of the world’s largest producers of iron ore and metallurgical coal strategically positioned to serve our network of steel plants and the external global market.

Crude steel production ~ 79 Million t (2021)* (~ 5% World)
Annual sales ~ 76 571 Million $ (2021)**

*Worldsteel
Global Research and Development
2022 key figures

1600 researchers

$286m spending

Comprehensive portfolios
100+ ongoing programmes

14 geographical sites

12,000 patents and patent applications
79 new inventions protected (2022)
Our commitment to sustainability

Carbon neutral (group) by 2050
-25% (group) & -35% (EU) by 2030
Problem statement: How to decarbonize steel industry and…
- Reduce final energy intensity?
- Keep and Improve steel product quality?
- Retain flexibility for future energy sources?
- Avoid displacement of problem?
Steel manufacturing process
Integrated steelmaking route
(75% of world's production)

Theoretical energy needs

<table>
<thead>
<tr>
<th>Process</th>
<th>Minimum</th>
<th>Actual (bench)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw mat prep + BF</td>
<td>10.4 GJ/t</td>
<td>14.3 GJ/t</td>
</tr>
<tr>
<td>BF only</td>
<td>10.4 GJ/t</td>
<td>11 GJ/t</td>
</tr>
<tr>
<td>BOF</td>
<td>- 0.6 GJ/t</td>
<td>- 0.47 GJ/t</td>
</tr>
<tr>
<td>Reheating + rolling</td>
<td>0.8 GJ/t</td>
<td>1.7 GJ/t</td>
</tr>
<tr>
<td>Total</td>
<td>10.6 GJ/t</td>
<td>18 GJ/t</td>
</tr>
</tbody>
</table>

+70%
Energy flows in the integrated steel plant

Sankey diagram

Energy: MJ/t-coil
Energy use in steelmaking
Past, Present & Future

Today, average steel production is energy intensive (18 to 25 GJ/t). However, improvements in energy efficiency have led to **reductions of about 60% in energy** required to produce a ton of crude steel since 1960.

It's more and more difficult to improve existing processes already near their optimal efficiencies.
List of waste heat sources in the integrated plant

*Energy (MJ/t) and Temperature (°C)*

- **Sintering Machine**
  - Exhaust
- **Coke Oven**
  - Combustion Exhaust
- **Hot Stove**
  - Exhaust
- **Heating Furnace**
  - Exhaust
- **BFG**
  - SH
- **COG**
  - SH
- **BOFG**
  - SH
- **Coke**
  - SH
- **Slag**
  - BF
  - BOF
  - BF slag
  - BOF slag
- **Sintered-ore**
- **Product**
- **Cooling Water**
- **Radiant Heat Loss**
- **Sintering Machine Exhaust**
- **Cooling Water SH**

**Amount of Waste Heat [MJ/T-crude steel]**

- **0** to **200**
- **200** to **400**
- **400** to **600**
- **600** to **800**
- **800** to **1000**
- **1000** to **1200**
- **1200** to **1400**
- **1400** to **1600**

- **Unrecovered**
- **Recovered**

**ISIJ Heat Economy Technology Committee**

**Need breakthrough new processes**

**Low temperature energy recovery**
Remaining challenges in our processes to recover energy from gases and solids at very high temperature (>1000°C)

- Recovery of high temperature waste heat with **gas/gas** or **liquid/gas** exchangers
  
i.e. converter gas (1600°C), EAF fumes (1500°C), highly fluctuating streams
  Big losses not yet recovered
  (nothing done, or water quenching)
  → How to cool these processes with higher temperature fluids than cold water to allow efficient heat recovery and use?

- Recovery of high temperature waste heat with **solid/gas** or **solid/solid** heat exchangers
  
  → How to transfer energy with high global efficiency and low Capex from high temperature solids (like coke, sinter, slags, slabs, coils) to produce high temperature gases or steam or endothermic chemical reactions?
Problem statement: How to recover high temperature slab heat
- At low CAPEX (low payback) ?
- More than 80% energy?
- Reasonable space footprint ?
- No impact to steel quality ?

Loss of 0.5 GJ/t of metal (~ 200 Nm3 of NG/slab)

Energy savings of 0.4 - 0.5 GJ/t
P_{out} \sim 15 \text{ MW}_{th}

Process steam use
7 to 25 barg

CO2 abatement

ArcelorMittal in-house technology § (TRL 5)
Hot solid heat recovery (>500 °C) using fluidized bed

4 Slabs/h 800 °C
Hot slab (800 °C) immersion in a fluidized bed pilot

4 Slabs/h 400 °C
To slab yards

\( T_{slab} \sim 1000^\circ \text{C} \)
ArcelorMittal in-house technology§ (TRL 5)
Hot solid heat recovery (>500°C) using fluidized bed

From 1st semi-industrial demonstrator

Main achievements:
• First semi-industrial demonstrator of FB slab heat recovery in iron & steel industry
• Heat Transfer Coefficient evaluated
• Heat recovery rate confirmed

Towards 1st industrial demonstrator in AM pilot plant

Next Challenges:
- Low CAPEX, high reliability
- Integrate into existing plant layout
- Hot slab handling & logistics
- Batch to continuous process
- Recovered heat reintegration according to plant requirements

§ several patents filed
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