Current state and ongoing development of a dynamic EAF process model

EASES 2021

Thomas Hay

16-18.06.2021
Dynamic EAF Process Model

Comprehensive, Analytical, Fast

- All relevant phenomena
  - Heat and mass transfer, chemistry, phase changes etc.

- Complete process from tap to tap

- Applicable to different types of furnaces without adjustment of core model

- Extrapolation capability

- Fast enough for online applications
Model Overview - Development

Based on Logar et al. and Meier

- Initial publications by Logar et al. in 2011-2012
- Validation with 80MVA industrial EAF
  - Gas phase
  - Radiative heat transfer
  - Automatic generation of operation chart
- Validation with 140t industrial EAF

Source: Logar, V.; Skrjanc, I.; Electric Arc Furnace Simulator; ISIJ 2012, Vol.52
Model Overview – Recent Development

Further Development after 2017

- Thermochemistry
- Radiative heat transfer
- Stability and speed
- Simulator with real-time input and output
- Automatic generation of operation charts
Model Overview - Structure

Zones and Heat Sinks/Sources

- Zones with homogenous temperatures and compositions

- Heat transfer
  - Between zones in direct contact
  - Through radiation

- Mass transfer
  - Melting/Solidification
  - Chemical reactions
  - Injection/charging

- Chemical reactions
  - Melt/slag
  - Injection of carbon and oxygen
  - Gas zone
  - Limited heterogeneous reactions
Off-line/Validation mode

Data from industrial EAF

- Operation chart
  - Electrical power
  - Mass flows
  - ...

- Charged masses, tapped mass...

- Validation
  - Continuous
    - Off-gas temperature and composition
    - Cooling water temperature
    - Electrode position
  - Spot
    - Slag and melt composition
    - Melt temperature
Automatic Control Mode

Evaluation of Control Strategies

- Automatic determination of operation chart based on Meier

- Based on rules and parameters
  - Steps for input values
  - Conditions for selection of steps
  - Desired steel grade and temperature

- Different possible operation charts for the same outcome
  - Different conditions
  - Optimization
Simulator Mode

Real-Time Interaction

- In- and output through user interface
- Variable speed of the simulation
- Higher stability necessary due to more extreme possible inputs
- Possible applications in training and education
- Alternative use as soft sensor by using real-time measured data as input
Results: Validation

Measured Data from several EAF

- Continuous and spot measurements
- Similar levels of accuracy as Meier with significantly improved speed
- Base for parameter adjustment and model validation
Results: Automatic Control

Case Study Results

- Case 1 to match measured profile, Case 2 to evaluated alternative oxygen source
- Same tapping temperature in all cases
- Increase in electrical and chemical energy consumption
- Increased tap-to-tap time
- Potentially compensated by cheaper oxygen

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric energy</td>
<td>1</td>
<td>1.06</td>
</tr>
<tr>
<td>Oxygen (lance)</td>
<td>1.1</td>
<td>1.17</td>
</tr>
<tr>
<td>Oxygen (post-combustion)</td>
<td>1</td>
<td>1.06</td>
</tr>
<tr>
<td>Injected carbon</td>
<td>0.9</td>
<td>0.96</td>
</tr>
<tr>
<td>Off-gas</td>
<td>1.06</td>
<td>1.13</td>
</tr>
<tr>
<td>Natural gas</td>
<td>0.99</td>
<td>1.04</td>
</tr>
<tr>
<td>Oxygen (gas burners)</td>
<td>1</td>
<td>1.07</td>
</tr>
<tr>
<td>Total oxygen</td>
<td>1.07</td>
<td>1.14</td>
</tr>
<tr>
<td>Tap-to-tap time</td>
<td>0.99</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Calculated performance indicators for the studied cases relative to measured values
Results: Automatic Control

Control of Carbon and CH$_4$ Injection

- Late onset of burner operation for second basket for both cases
- Longer injection and burner operation for case 2
- Similar profile of injection and burner operation with slight delay but with similar total consumption
- Case 2 increased consumption to offset N$_2$ content
Conclusion

Current status and next steps

▪ Comprehensive and flexible model with different operating modes

▪ Validation based on measured data from different EAF

▪ Consolidation and translation into Python for more flexibility

▪ Application of real-time model and model based operating strategies in industrial steel mill
Thank you for your attention

Thomas Hay
RWTH Aachen University
Department for Industrial Furnaces and Heat Engineering
Kopernikusstraße 10
52074 Aachen

Mail: hay@iob.rwth-aachen.de
Tel.: +49 (0) 241 – 80 260 74
Fax: +49 (0) 241 – 80 222 89
Web: www.iob.rwth-aachen.de