Workshop “Road map for future EAF technology”

Sensors and measurement techniques for monitoring and control of the EAF process

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Agenda

- Off-gas analysis
- Electrode consumption
- Process visualisation
- LIBS slag analysis
- Scrap distance
- Liquid steel temperature
In-situ off-gas measurement

- Laser based, nearly delay-free in-situ off-gas analysis installed in the elbow of the furnace
- Analysis of CO, O₂ and CO₂ possible
- Additionally measured temperature is not representative for the off-gas temperature
- For measurement of CO₂ in addition to CO a separate laser is required

RFSR-CT-2006-00004 (OFFGAS)
Distance-to-scrap sensor
Scrap Evolution Range Finder (SERaFin)

- Measurement of distance to scrap from burner tip to monitor the melting of scrap
- Set-up of an individual and automated control of each injector for:
  - controlling power increase during the starting phase
  - switching off each burner when efficiency decreases (no more scrap)
  - moving from burner to lancing mode
  - alarming the operators in blow-back hazard situation
- Pulsed infrared laser (time-of-flight measurement)
- Electronics located away from furnace
- Able to measure on high T-target (>1650 °C on liquid steel)
**SERaFin**

**Process control**

**Burner operation (first basket)**

- Industrial sensor available to:
  - Prevent blowback (burner damage/obstruction)
  - Optimise charging/unloadings
  - Assess bath height
  - Using identified control rules
Electrodes monitoring

- Image processing to:
  - evaluate the electrode wear through the detection of electrode tip for a basic approach and the analysis of the shape of the electrode tip to identify the wear mechanism

- Parameters extracted from the images
  - tip width
  - oxidized length
  - detection of cracks, with their length and size

Camera located on the rear wall in an air cooled housing

RFSR-CT-2003-00024
Electrodes monitoring: evolution

Before basket melting
Continuous consumption
After basket melting

Circumferential crack
Crack loss
Before basket melting
After basket melting

Nipple junction
Tip fall-off
Stub end loss

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Electrodes monitoring: conclusions

- Camera-based systems allowing monitoring the state of the electrode after the melting of each scrap basket

- Dedicated image analysis and processing routines for:
  - detecting the position of the electrode tip,
  - determining the precise shape of the lower part of the electrode (including the measurement of the oxidised length),
  - following-up crack formation (length and size)
  - detecting crack losses and graphite chunks drop-offs (stub-end losses)

- Industrial results revealed three main mechanisms for electrode consumption:
  - continuous consumption
  - crack losses
  - stub end losses
**Laser-induced breakdown spectroscopy – LIBS for inline multielement analysis**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Data</th>
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<tbody>
<tr>
<td>material</td>
<td>metallic, non-metallic, solid, liquid, gaseous</td>
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<tr>
<td>analytes</td>
<td>all elements</td>
</tr>
<tr>
<td>distance between optics and measuring object</td>
<td>1 cm – 10 m</td>
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<tr>
<td>measuring time</td>
<td>&lt; 100 µs</td>
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<tr>
<td>limit of detection</td>
<td>100 ppb – 1 000 ppm</td>
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<tr>
<td>measuring frequency</td>
<td>0.1 Hz – 1 000 Hz</td>
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Inline scrap monitoring by LIBS

- Controlled blending of different steel grades
- Sorting for defined EAF input quality
- Internal recycling
- Monitoring
Direct analysis of liquid steel and slag with LIBS

- Inline analysis of liquid slag in 24/7 steel plant operation
- Slag quality evaluation for correct dumping pit selection
- Liquid steel analysis feasibility demonstrated on lab scale
Laser-Based Inline Analysis

- Inline sensors for all-optical determination of multi-element composition
- Inline analysis open new applications for process improvement by
  - Defined quality of input raw materials
  - Feedback on process status
  - Assessment of products and by-products
- Enhanced efficiency by reducing uncertainties and safety buffers
EAFCAM - Overview

- The developed camera-based technology is an infrared camera for observing the scrap melting process inside EAF operated with a closed slag door.

- Recordings have provided new and interesting insights into the EAF melting process. Images showing:

  - the melting characteristics of different size scrap pieces; scrap-drop events; scrap melting completion time; thermal contours after end-of-arcing; the extent and duration of slag foaming; and details of the tapping operation (including the size of the hot heel), have been demonstrated and these directly online.

- Views of operations inside the furnace would inevitably provide the operator with improved control of the process.
Detailed images of processing events were linked directly with furnace operating parameters.

Several images were selected within the EAF processing time, especially after particular events.

Processed image (based on the real thermal view) in order to provide a clearer picture.
Hot heel level assessment with dip sensors and camera systems

Steel bath level measurement with dip sensor
- Probe mounted on lance manipulator

- Monitoring of the liquid bath level after tapping of the furnace with opened furnace roof
- Several cameras from different angles of view
- Subsequent image analysis

→ Liquid bath level has to be converted into amount of hot heel, e.g. by using information on furnace hearth refractory wear status

RFSR-CT-2014-00004 AdaptEAF
Continuous steel bath temperature measurement

Contactless optical system inside burner

- Optical sensor inside a coherent jet burner
- For measurement the slag pushed aside by a coherent inert gas stream
- Fast and safe quasi-continuous measurement with no significant needs of consumables
- Accuracy deteriorated due to uncertain emissivity of steel bath surface
Fibre-optical steel bath temperature measurement

Fibre-optical continuous temperature measurement (BFI DynTemp®) using
- Lance
- Bottom nozzle
- Monitor continuously the liquid steel temperature during the refining phase
- Determine process conditions to perform representative measurements in dynamic inhomogeneous melts
- Fibre feeding ensures high accuracy throughout complete measurement duration

RFSR-CT-2013-00002 (MeltCon)
Continuous measurement during refining for 11 minutes

Thermocouple spot measurements via slag door and continuous fibre-optical measurement via bottom nozzle

Initially the nozzles are operated with N\textsubscript{2}. Switching to O\textsubscript{2} blowing -> T > 2000 °C

Detailed monitoring of T evolution at bottom during N\textsubscript{2} purging:

- Lower T at bottom than top due to arc heating
- Higher heating rate at bottom
- Fluctuations decrease during homogenisation

RFSR-CT-2013-0002 MELTCON
Feedback of the seminar participants on additional requirements for sensors and measurement techniques for monitoring and control of EAF process are:

- Lining wear
- Volume in the EAF
- Energy recovery
- Process control

22 participants
Roadmap for sensors and measurement techniques for future EAF technology

- RFCS projects provided or supported major developments for EAF process monitoring and control
- Developments became commercially available in several systems
- Still many issues remain needed
  - Implementation of promising optical measurement techniques such as LIBS or fibre-optical temperature measurement
  - In-line liquid steel temperature / analysis
  - Off-gas temperature and flow rate measurement
  - Monitoring of carbon injection systems
  - Monitoring/Imaging the closed/airtight furnace
  - Accurate hot heel level measurement / slag height measurement
  - …
Thank you very much for your attention!

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