Valorisation and dissemination of EAF technology

VALEAF

Seminar

Off-gas measurement techniques and development as support to process monitoring and management

Dusseldorf 19th June 2015
Summary

- Overview of the state of the art for off gas monitoring
- Off gas monitoring as support to evaluation of airtight concept
- Activities on off gas measurements selection
- Implementation of off gas monitoring in dynamic modelling
- Implementation of off gas monitoring in on-line process management
Applications of off gas monitoring

- Knowledge off gas composition to support control of chemical injections through post combustion optimization.

- Off gas composition for detection of water leakages

- Off gas composition at IV hole coupled with other measures to complete the dynamic mass and energy balance for global process control.

- Off gas composition detection with reduced time delay

- Support to analyse specific cases - Airtight concept

- Evaluation of off gas condition to evaluate possible energy recovery and reduction of dioxin emissions.
Technologies for measurements off gas composition ad IV hole.

Analysis on gas extraction

- In case of gas extraction and external off gas analysis a certain delay of the answer occurs.

**TDLAS**

- In case of TDLAS the analysis is done without gas extraction and the delay of answer < 2sec.
### Summary of RFCS project referring to Off gas measurements

<table>
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<tr>
<th>Contract Report</th>
<th>Title</th>
<th>Participants</th>
<th>Start / End</th>
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<td>7210-PR/170 EUR 21138</td>
<td>Control of CO-postcombustion inside EAF with the FTIR (fourier transformed infrared) spectroscopy system</td>
<td>RWTH-IEHK, UNIV Reading, SWT, Messer Griesheim</td>
<td>1999-07-01 to 2002-06-30</td>
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<td>ECSC 7210-PR/328 - 2001-2004</td>
<td>Development of operating conditions to improve chemical energy yield and performance of dedusting in airtight EAF</td>
<td>CSM, BFI, RWTH, ORI, GMH, TKN</td>
<td>01/07/2002 to 01/07/2005</td>
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<td>RFSR-CT-2006-00004 EUR 25048</td>
<td>Improved EAF process control using on-line offgas analysis (OFFGAS)</td>
<td>RWTH-IOB, CRM, CSM, DEW, Marienhütte, ORI, TENOVA, TKN</td>
<td>2006-07-01 to 2009-06-30</td>
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<td>RFSR-CT-2003-00031 EUR 23920</td>
<td>Dynamic control of EAF burners and injectors for oxygen and carbon for improved and reproducible furnace operation and slag foaming (EAFDYNCON)</td>
<td>BFI, CRM, AM Long Carbon, Sidenor I&amp;D, GMH</td>
<td>2003-09-01 to 2007-02-28</td>
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<td>RFSR-CT-2007-00008</td>
<td>Cost and energy-effective management of EAF with flexible charge material mix (FlexCharge)</td>
<td>CSM, BFI, CRM, FERALPI, GHM, MEFOS, OVAKO, SIDENOR</td>
<td>01/07/2007 to 31/12/2010</td>
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<td>RFSR-CT-2014-00007</td>
<td>Optimization of scrap charge management and related process adaptation for performances improvement and cost reduction (OptiScrapManage)</td>
<td>CSM, BFI, CRM, ACAL Tecnalia, Gerdau, TATA</td>
<td>01/07/2014 to 30/06/2017</td>
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Airtight in European projects

1) Airtight operations have been investigated at pilot and industrial scale
   *Evaluation of airtight furnace technology (reduction of air ingress in EAF)*
   ECSC 7210-PR/202 - 2000-2003

2) Airtight conditions and benefits have been extensively studied in industrial tests carried out in batch and continuous furnaces
   *Development of operating conditions to improve chemical energy yield and performance of dedusting in airtight EAF*
   ECSC 7210-PR/328 - 2001-2004

3) Solution for process monitoring have been studied
   *Control by camera of the EAF operations in airtight conditions*
ECSC project “Airtight EAF”: Extractive off-gas analysis with mass spectrometer

- Analysis of all relevant off-gas components via a mass spectrometer
- Determination of off-gas and leakage air flow rate via Argon and Nitrogen balance
- Delay time of about 30-40 seconds due to probe gas sampling and analysis
Off-gas measurement via mass spectrometer

- Extractive measurement with probe gas sampling at the furnace roof
- Off-gas analysis via mass spectrometer, all relevant off-gas components can be measured
- Determination of off-gas and leakage air flow rate via Argon and Nitrogen balance
- Measurement of off-gas temperature via pyrometer
- Calculation of the losses via the off-gas
  - Sensible heat from flow rate and temperature
  - Chemical energy content from flow rate and CO / H2 content
Airtight operations

To operate an EAF in airtight conditions implies two types of actions

1) To close the openings for air ingress and set up the operation control at higher pressure in the EAF

2) To implement system for internal monitoring and continuous measurements
Airtight operations

1: Slag door
2: Gap between EAF roof and EAF vessel
3: Gap between EAF elbow and EAF roof
4: Gap between EAF elbow and gas duct

In the CSC 7210-PR/328 strategy for reducing air ingress and control the operations have been studied
Airtight operations

The air-tightening of an Electric Arc Furnace is realised by means of a series of operations.

The closure of the slag door is not sufficient.

It is also necessary to fill other gaps (e.g.: between the roof and the vessel) The control of the air entrance is based on the measurement of the pressure, which is controlled by means varying the gas extraction power.

For correct operations reliable and continuous measurements of gas composition and temperature are necessary.
Airtight operations

Control of airtight conditions in Consteel-EAF furnace

-15% of air inside the furnace with EAF pressure control and slag door closed

-5-7% of air inside the furnace with only slag door closed

Mass Spectrometer: analysis of the off-gas
Main evidences obtained by “Airtight” projects:

Airtight EAF makes sense only if well controlled post-combustion is carried out.

In the project 7210-PR/202 first tests in airtight conditions were performed at pilot and industrial scale.

These first tests demonstrated the feasibility of airtight operations, but without postcombustion the benefit in terms of electrical reduction is none or negligible.

Only in presence of controlled postcombustion with oxygen the electrical energy consumption is reduced.

The extrapolation of the tests to real industrial conditions indicated that with a reduction of air ingress of 80% and post-combustion a potential reduction of electrical energy of the order of 100 kWh/t is possible.
The benefits of post-combustion was extensively studied in the project ECSC 7210-PR/328

$PC_{CO}$ is the post-combustion degree of CO to $CO_2$

$CO_2/(CO+CO_2)$

Electrical energy consumption in experimental tests in airtight conditions at two different pressures inside the EAF as a function of injected oxygen for postcombustion and low carbon in charge.

(test in EAF-Consteel)
Airtight and post-combustion

The benefits of post-combustion was extensively studied in the project ECSC 7210-PR/328

Electrical energy consumption in experimental tests in airtight conditions at two different pressure inside the EAF as a function of injected oxygen for postcombustion and high carbon in charge (test in EAF-Consteel)

$PC_{CO}$ is the post-combustion degree of CO to CO$_2$ $\frac{CO_2}{(CO+CO_2)}$
Airtight and post-combustion

Post-combustion in useful up to a certain degree.

Increasing the post-combustion ratio above a value of 0.5 has no effect on electrical energy consumption. The only effect is an increase of off-gas temperature. (test in EAF-Consteel)

$PC_{CO}$ is the post-combustion degree of CO to CO$_2$

$CO_2/(CO+CO_2)$
Airtight and post-combustion

Post-combustion effect in batch charging EAF

Increasing the post-combustion ratio decreases energy consumption and power-on time.
(test in batch furnace at GMH)
Consideration on consumptions by Airtight projects

Airtight operations resulted beneficial in terms of energy consumption.

Electrical consumption can be reduced using controlled postcombustion. For example in the EAF-Consteel an average gain of about 25-40 kWh/t was obtained. The best results in terms of decrease of the electrical energy demand is of about 50 kWh/t with optimized post combustion has been obtained with high coal additions (28 kg/t) and postcombustion ratio of 45%. The same results could be obtained with almost complete airtight conditions and 30% postcombustion.

Similar results has been obtained in batch furnaces. Increasing airtight the need of oxygen can be reduced maintaining same electrical consumption (750 kWh/t) but reducing total energy combustion (30 kWh/t) reducing coal and oxygen. Alternatively, with higher chemical energy the electrical energy demand can be reduced of 20-30 kWh/t.

This flexibility made applicable the airtight operations in a useful way also to the production of stainless steel, where postcombustion practice is not applicable for the problem of chromium oxidation.
RFCS project “Offgas”
Commissioning of off-gas analysis systems

Example: DEW Siegen

Systems installed
- DEW Siegen: conventional (ABB)
- TKN Bochum: conventional (ABB)
- Marienhütte: Lindarc
- ORI Martin: EFSOP
- AM Differdange: conventional

General notes on measurement positions

**Point A**
- Close to the EAF process (no/small time delay)
- Off-gas composition can be representative for EAF atmosphere
  - Inhomogeneous off-gas composition in radial direction
  - High temperature load of equipment
  - Risk of mechanical damage due to moving parts

**Point B**
- Homogeneous gas composition in radial direction
- Lower gas temperatures
  - Dilution of the furnace off-gas with leakage air
  - Time delay depending on distance to the EAF
In-situ off-gas measurement via LINDARC® system

- Laser based delay-free in-situ off-gas analysis installed in the elbow of the furnace [12]
- Analysis of CO, O₂ and CO₂ possible
- For measurement of CO₂ in addition to CO a separate laser is required
Comparison of LINDARC® to conventional off-gas analysis system

Comparison of the LINDARC system with the conventional off-gas analysis system of RWTH Aachen University

🔗 Good agreement between conventional and Lindarc analysis systems
FLEXCHARGE
Off gas analysis testing

In this project the it has been realized the implementation of the off gas analysis in tools for process control and test realized in amore extensive way. Different systems has been tested in different sites:

In GMH - Mass spectrometer with gas extraction has been tested

Acciaierie di Calvisano - After first trials with TDLAS the system with gas extraction has been subsequently adopted

To increase the available time of estimation of on-line control systems the knowledge of off gas conditions at IV hole on-line has been completed through application of virtual sensors to Off gas conditions estimation at IV hole (Calvisano).

Based on measurement available as virtual sensor are estimated:
- Off Gas flow rate at IV hole
- Off gas temperature at IV hole
FLEXCHARGE - Application to GMH

- The mass spectrometers has been used for gas analysis at IV hole
- The knowledge of off gas composition in terms of CO, CO2, O2 H2, CH4 have been used as input to a dynamic mass and energy balance for estimation of:
  - Off gas post combustion
  - Off gas sensitive energy

- The information from off gas analysis at IV hole has been coupled with process inputs with conditions of water cooled thermal panels in a control module realized by BFI in collaboration with GMH
- The estimation of the bath temperature along the heat has been realized
- Correlations for estimation of off gas flow rate and temperature at IV hole have been coupled with off gas composition detection at IV hole
Using information obtained by off gas conditions at IV hole the on line estimation of FeO weight formed in refining has been used as guideline for process management.
- Application of off gas measurements at IV hole has been furtherly to GMH to couple the application of dynamic control model of BFI with other measures (as acoustic measure) to apply techniques of dynamic control of chemical injections.
RFCS support to industrial applications

RFCS projects has given support to developments in application of EAF control based on off gas measurements with:
- Application of sensors for off gas composition
- Adoption of off gas knowledge to verify new EAF configurations
- Application of control rules
- Application on completion of dynamic mass and energy balance
- Definition of correlation in substitution to measurements

Off gas measurements as support to process management
- This approach became commercially available in several systems (iEAF)
- The virtual sensor and IOR approach is still available for further project and till running.

Strategies for off gas condition completion at IV hole
- The approaches developed are still running or in development in further RFCS projects
Thanks for your attention!

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