Valorisation and dissemination of EAF technology
VALEAF

2nd Seminar

EAF Energy saving in EAF production

Milano, April 9th 2015
Summary

- Overview and technology evolution - Energy efficiency
- Slag foaming
- Airtight concept
- CONOPTSCRAP
- FLEXCHARGE
- Further steps
Energy efficiency in EAF

Approaches of process improvement leading to an increase of energy efficiency:

1 - Reduction of energy demand - via operating practices management

2 - Increase of steel weight at tap - via reduction of metallic losses

3 - Reduction of energy losses - via water cooling and off gas

4 - Reduction of energy demand by charge - via more flexible scrap selection.

5 - Increase the rate of energy recovered - via recovery by off gas or other ways.
Main steps - Energy efficiency

Historical technology developments:

A - Before 1990 the energy efficiency increase via:
- plant developments / increase of sizes / Increase of power
- increase of chemical contribution,
- modification of the structures,
- assessment of the basic practices (slag foaming).

B - Dup to 2000, a better use of the energy available via:
- systems for scrap preheating
- practices/charges tuning applying basic/statistical approaches.

C - After 2000, finer process understanding and monitoring
- advanced modelling approaches (process simulators and control systems)
- off gas on-line monitoring for the completion of the mass and energy balance.
## RFCS project referring to energy efficiency

<table>
<thead>
<tr>
<th>Contract</th>
<th>Title</th>
<th>Participants</th>
<th>Start / End</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECSC 7210-CB/116</td>
<td>Economical and ecological steelmaking</td>
<td>British steel, CSM, IRSID, BFI, KTN</td>
<td>01/07/1993 to 30/06/1996</td>
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<tr>
<td>ECSC 7210-CB/206</td>
<td>Improvement of the EAF performances through an optimization of the foaming slag practice.</td>
<td>CRM, CSM, ProfilArbed, BFI, MEFOS</td>
<td>01/07/1995 to 31/12/1998</td>
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<tr>
<td>ECSC 7210-PR/202</td>
<td>Evaluation of airtight furnace technology (reduction of air ingress in EAF)</td>
<td>Arcelor Research, CRM</td>
<td>01/07/2000 to 01/07/2003</td>
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<tr>
<td>ECSC 7210-PR/268</td>
<td>New cooling panels for reduction of heat losses in EAF steelmaking</td>
<td>CRM, CSM, Dalmine, ProfilArbed</td>
<td>01/07/2001 to 01/06/2004</td>
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<tr>
<td>ECSC 7210-PR/328</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, THN</td>
<td>01/07/2002 to 01/07/2005</td>
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<tr>
<td>RFSR-CT-2004-00008</td>
<td>Control by camera of the EAF operations in airtight conditions</td>
<td>CSM, BFI, AM R&amp;D, CORUS UK, MORE SRL</td>
<td>2004-07-01 to 2007-12-31</td>
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<tr>
<td>RFSR-CT-2006-00004</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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<tr>
<td>RFSR-CT-2005-00003</td>
<td>Control and optimisation of scrap charging strategies and melting operations to increase steel recycling ratio (ConoptScrap)</td>
<td>CRM, PROFILARBED, CORUS UK, CSM, DUFERCO, MEFOS</td>
<td>01/07/2005 to 31/12/2008</td>
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<tr>
<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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<tr>
<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>
</tr>
</tbody>
</table>
Improvement of the EAF performances through an optimization of the foaming slag practice.

CRM, CSM, PROFILARBED, BFI, MEFOS

Dalmine 2005/2008
Slag foaming detection through acoustic detection

- Acoustic detection has been tested as approach for evaluating the arc covering by foaming slag
- At reduced signal detection the arc covering is estimated as evidence of a good foaming slag
- Through detection of UV signal the estimation of arc covering is shown.
- The lower UV signal detected is index of improved both arc covering and slag foaming.
Through a radio-waves system on EAF roof a mapping of the area has been tested evidencing where slag foaming is not well developed.
Test results with application of noise level have shown lower energy consumption for heats with lower noise detected (better slag foaming).

Through application of optical detection of UV signal as evidence of the proper foaming slag procedure also lower energy consumption has been obtained.
Evaluation of airtight furnace technology (reduction of air ingress in EAF).

Arcelor Research, CRM

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Dalmine 2005/2008
Airtight operations

In ECSC 7210-PR/328 strategies for reducing air ingress and control the operations have been studied.

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 systems for internal monitoring and continuous measurements (off gas, camera monitoring the internal reactor conditions).

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
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
Airtight and post-combustion

About the study of conditions with airtight EAF:

- 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 operation, but without post-combustion the benefits in terms of electrical reduction is negligible.

- The set-up of airtight conditions needs a control in off gas post-combustion.

- Only in presence of controlled post-combustion 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.
Airtight and post-combustion

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

Test in batch furnace at GMH

Decreases energy consumption and power-on time increasing the post-combustion ratio.

Test in EAF-Consteel

Electrical energy consumption reduction in tests of airtight conditions at two different pressure inside the EAF with increase of postcombustion and high carbon in charge.
Examples

CONTROL AND OPTIMISATION OF SCRAP CHARGING STRATEGIES AND MELTING OPERATIONS TO INCREASE STEEL RECYCLING RATIO (CONOPTSCRAP)

CRM, PROFILARBED, CORUS UK, CSM, DUFERCO, MEFOS

Dalmine 2005/2008
ConoptScrap topics

- Monitoring of scrap mix charged in basket
- Monitoring of melting evolution and foaming through optical sensor
- Application of process simulators/optimizer for adaptation of operating practices to charge mix adopted
- Testing of operating practices improvement
CoSMes sensor has been developed and tested to detect scrap presence and slag foaming efficiency to be used coupled with operating practices simulator for process improvement.
Conopt Scrap - Process simulators for improvement of Operating Practices

A tool to simulate the process evolution and final results with operating practices and charges selected has been developed.

Previsions of EAF process results depending by operating practices are necessary to select conditions of lower energy consumption.
The process simulator has been used to determine Improved Operating Practices tested on the plant obtaining process benefits. Trials done with practices obtained by practices Optimizer.
Cost and energy-effective management of EAF with flexible charge material mix (FLEXCHARGE)

Dalmine 2007/2009
Flexcharge topics

- Development of approaches and mathematical tools for scrap characterization.
- Development of scrap mix optimizers.
- Operating practices optimization following the optimal scrap mix defined and increase of energy efficiency.
- On-line application of operative guidelines based on monitoring of off gas conditions.

This started by the availability of off gas composition at IV hole by previous developments on sensors by industrial and RFCS activities (RFCS project “OffGas”).
**October 2010 heats sequence**

<table>
<thead>
<tr>
<th>scrap type group</th>
<th>consumed scrap amounts / t</th>
<th>optimised scrap amounts / t</th>
<th>scrap type group</th>
<th>consumed scrap amounts / t</th>
<th>optimised scrap amounts / t</th>
</tr>
</thead>
<tbody>
<tr>
<td>pig iron skulls</td>
<td>6304</td>
<td>10117</td>
<td>E5M</td>
<td>9483</td>
<td>26487</td>
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<tr>
<td>pig iron</td>
<td>1109</td>
<td>3813</td>
<td>E5H</td>
<td>131</td>
<td>0</td>
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<tr>
<td>cast iron</td>
<td>375</td>
<td>0</td>
<td>briquetted turnings</td>
<td>1099</td>
<td>0</td>
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<tr>
<td>E1</td>
<td>4622</td>
<td>536</td>
<td>steel skulls</td>
<td>1074</td>
<td>10088</td>
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<tr>
<td>E2</td>
<td>5313</td>
<td>8847</td>
<td>casting residuals</td>
<td>3890</td>
<td>0</td>
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<tr>
<td>E3</td>
<td>19363</td>
<td>651</td>
<td>return Cr</td>
<td>3554</td>
<td>0</td>
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<tr>
<td>E8</td>
<td>22511</td>
<td>355</td>
<td>return CrMo</td>
<td>1788</td>
<td>0</td>
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<tr>
<td>E1 / E3</td>
<td>5203</td>
<td>1349</td>
<td>return CrNiMo</td>
<td>2249</td>
<td>0</td>
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<tr>
<td>cans</td>
<td>376</td>
<td>5056</td>
<td>E40</td>
<td>5066</td>
<td>29314</td>
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<tr>
<td>E6</td>
<td>5511</td>
<td>4557</td>
<td>remaining scrap types</td>
<td>228</td>
<td>0</td>
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</table>

**Optimised scrap mix leads to a cost benefits of 8.9%**

<table>
<thead>
<tr>
<th>menu</th>
<th>4.1</th>
<th>4.3</th>
<th>4.6</th>
<th>4.7</th>
<th>4.8</th>
<th>6.2</th>
<th>6.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of usage</td>
<td>133</td>
<td>82</td>
<td>59</td>
<td>66</td>
<td>60</td>
<td>62</td>
<td>63</td>
</tr>
<tr>
<td>cost benefit</td>
<td>8.5%</td>
<td>9.3%</td>
<td>9.3%</td>
<td>7.2%</td>
<td>7.8%</td>
<td>12.0%</td>
<td>11.9%</td>
</tr>
</tbody>
</table>
Process simulation/optimisation and statistical tools have been linked, in order to provide the information for developing the control tool for heat management.

- **Charge recipe optimized by statistical tools** *(task 3.1)*
- **Virtual sensors** *(task 2.4)*
- **Field test** *(WP4)*
- **Process simulation** *(task 2.3)*
- **Charge & SOP definition** *(task 3.2 & 3.3)*
- **Steel plant**
### Table:

<table>
<thead>
<tr>
<th></th>
<th>Scrap Charged ton</th>
<th>Coal Lump kg</th>
<th>Injected Coal kg</th>
<th>Tot Coal kg</th>
<th>Secifc coal kg/ton</th>
<th>FeO in slag %</th>
</tr>
</thead>
<tbody>
<tr>
<td>STD (SOP)</td>
<td>90.5</td>
<td>389</td>
<td>369</td>
<td>758</td>
<td>8.3</td>
<td>40.7</td>
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<tr>
<td>Preliminary Test</td>
<td>91</td>
<td>803</td>
<td>302</td>
<td>1105</td>
<td>12.1</td>
<td>33.6</td>
</tr>
<tr>
<td>September</td>
<td>90.1</td>
<td>681</td>
<td>415</td>
<td>1097</td>
<td>12.2</td>
<td>33.8</td>
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<tr>
<td>October</td>
<td>90.3</td>
<td>886</td>
<td>218</td>
<td>1104</td>
<td>12.2</td>
<td>36.2</td>
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<tr>
<td>November</td>
<td>89.2</td>
<td>543</td>
<td>527</td>
<td>1070</td>
<td>12.0</td>
<td>29.9</td>
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<tr>
<td>AVG (Sept_Nov 2010)</td>
<td>89.9</td>
<td>697</td>
<td>395</td>
<td>1092</td>
<td>12.1</td>
<td>33.4</td>
</tr>
</tbody>
</table>

### Graphs:

- **OOP vs SOP - Basket 3**
  - Oxygen – CH4 (Nm³/h)
  - Injected Coal (kg/min)

- **OOP vs SOP - Basket 4**
  - Oxygen – CH4 (Nm³/h)
  - Injected Coal (kg/min)
Using informations 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.
# Main RFCS results for energy efficiency increase

## Systems/approach available after CONOPTSCRAP and FLEXCHARGE project

- Testing of shell panels for energy losses reduction
- Sensors for monitoring of process evolution and slag foaming
- Mathematical tools for scrap characterization
- Tools for optimization of charge mix for energy consumption reduction
- Mathematical tools for process simulation
- Tools for Operating Practices Optimization
- Management route with Operating Practice Optimization depending by Optimal charge mix definition.
- Definition of methods for on-line operative guidelines based on off gas monitoring
- Criteria and practices testing for energy efficiency increase depending by improved off gas post-combustion, slag foaming, optimal charge mix selection ....