Road Map for future EAF technology - Scrap control

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Agenda

• Scrap characterisation
• Scrap mix optimisation
• Adaption of EAF operating patterns
• Pre-treatment and pre-heating of scrap
• Road map for improved scrap control
Scrap characterisation

- **Properties to characterise**
  - Chemical composition, specific melting energy requirement, density, yield coefficients, environmental emissions, etc.

- **Melting tests**
  - Lab scale, pilot scale, industrial scale
  - Chemical composition (element-wise yield), energy consumption, emissions

- **Physical analysis**
  - Surface analysis, spot analysis, bulk analysis, ultrasonic measurements
  - Chemical composition (total), density

- **Image analysis**
  - Density, size distribution, object recognition

- **Statistical regression methods**
  - Multiple linear regression, partial least squares, non-linear regression
  - Chemical composition, specific melting energy requirement, density, yield coefficients
Scrap characterisation – Lab scale melting tests (ca 100 kg samples)

- Tested in projects
  - FLEXCHARGE (Cost and energy effective management of EAF with flexible charge material mix), 2007-2010

- Advantages
  - Controlled conditions, High accuracy

- Disadvantages
  - Time consuming, Not representative, Long response time
  - Only suitable for light scrap

- Field of application
  - Initial testing of new and uncommon materials considered for charging in the EAF
  - Determination of the variability within a delivery of scrap
Scrap characterisation – Pilot scale melting tests (ca 5 ton heats)

- Tested in projects
  - FLEXCHARGE (Cost and energy effective management of EAF with flexible charge material mix), 2007-2010

- Advantages
  - Controlled conditions
  - High accuracy
  - Representative

- Disadvantages
  - Time consuming, Expensive, Long response time
  - Pretreatment/cutting of heavy pieces may be necessary

- Field of application
  - Quality control of supplier compliance with grade specifications
  - Verification of suspected deviations in quality
Scrap characterisation – Industrial melting tests

- Tested in projects
  - FLEXCHARGE (Cost and energy effective management of EAF with flexible charge material mix), 2007-2010
  - Quality of heavy market scrap: development of new and simple methods for quality assessment and quality Improvement, 1996-1999

- Advantages
  - High accuracy, Quick response, Results directly applicable at steel plant

- Disadvantages
  - Time consuming, Risk of process disturbance
  - Risk of downgrading of test heats, Expensive

- Field of application
  - Determination of composition of high alloyed scrap (stainless steel, speciality steels)
  - Confirmation or updating of scrap properties used by scrap mix optimiser tools or process models
Scrap characterisation – LIBS (Laser Induced Breakdown Spectroscopy)

- Tested in projects
  - LCS, 2006-2009/IPRO, 2010-2013

- Advantages
  - Quick response
  - Non-contact measurement

- Disadvantages
  - Low accuracy
  - Spot measurements on surface, not always representative

- Field of application
  - Classification and sorting of scrap
  - On-line analysis of scrap flow (i.e. consteel conveyer belt)
  - Mainly a technology for quality improvement in the added value chain for the scrap supplier and sorting companies
Scrap characterisation – Gamma ray technology

• Tested in projects
  • SCRAP probe, 2008-2011
• Advantages
  • Bulk analysis of scrap
  • Contact-free measurement, quick response
• Disadvantages
  • Not fully developed technology, Expensive equipment and materials/emitters, deteriorating sensitivity with time
  • Limited number of elements can be analysed
• Field of application
  • Quality declaration of dispatched deliveries of scrap (from suppliers)
  • Quality estimation or confirmation of received deliveries of scrap (at steel plants)
Scrap characterisation – scrap density

- Tested in projects
  - Characterisation of the scrap density, 2000-2003
  - CONOPT SCRAP, 2005-2008

- Advantages
  - Online scrap density -> improved process control:
    - time to charge the second basket.

- Disadvantages
  - Status of development?
  - Online scrap monitoring system, need to be adapted to specific steel plants.

- Field of application
  Online scrap monitoring system aiming at following the scrap basket loading in real time.
Scrap characterisation - Statistical regression on historical data

• Tested in projects
  • FLEXCHARGE (Cost and energy effective management of EAF with flexible charge material mix), 2007-2010
  • Quality of heavy market scrap: development of new and simple methods for quality assessment and quality Improvement, 1996-1999

• Advantages
  • Low cost solution
  • Integrated validation of estimations
  • Many types of properties can be estimated (chemistry, yield, energy consumption, density, etc.)
  • Automated routines for updating of estimations possible

• Disadvantages
  • Only possible for frequently used materials
  • Estimations based on old data that may be obsolete
  • Slow response time to changed scrap quality

• Field of application
  • Estimation of properties of frequently used scrap grades at each site
  • Limited number of scrap grades combined with significant variation in charge mixes

Standard deviation: 0.0247 %
Optimisation of scrap mix
Scrap mix optimisation – Model based

• Pre-requisites
  • Estimation of charge material properties
  • Process model
    • Calculation of element-wise yield to steel, slag and dust
    • Calculation of steel and slag chemistry and amount
    • Calculation of energy consumption, Calculation of production costs, etc.

• Set of restrictions
  • Steel quality limits, Slag quality limits, Steel temperature
  • Consumption limits for individual materials and/or groups of materials.
  • Optimisation algorithm

• Optimisation algorithm (production costs, productivity, energy, quality, profit, etc.)

• Field of application

• Field of application
  • Single heat optimisation (off-line)
    • Finding the ideal scrap mix for each grade
  • Heat sequence optimisation (on-line)
    • Finding the optimal use of available materials on the scrap yard
  • Purchasing strategy optimisation (off-line)
    • Finding suitable scrap for the foreseen customer order list
Scrap mix optimisation – Statistical based

- Pre-requisites
  - Prediction models (based on specific consumption of scrap grades) for
    - Steel chemistry
    - Metallic yield
    - Specific consumption of
      - Electricity, oxygen, fuel (LPG, NG, Oil, etc.), carbon, slag formers
      - Basket filling degree or scrap volume

- Set of restrictions for
  - Steel quality limits
  - Consumption limits for individual materials and/or groups of materials.
  - Calibration window for prediction models
  - Optimisation algorithm

- Field of application
  - Scrap characterisation and material property estimations not necessary!
  - Suitable for production with limited scape types and variation in steel grade
Scrap mix optimisation – Model based vs. statistical approach

<table>
<thead>
<tr>
<th>Feature</th>
<th>Model based</th>
<th>Statistical</th>
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<tbody>
<tr>
<td>Process model</td>
<td>Analytical (simple or complex)</td>
<td>Empirical (linear or non-linear)</td>
</tr>
<tr>
<td>Material properties (chemistry, density, etc.)</td>
<td>Needed</td>
<td>Not needed</td>
</tr>
<tr>
<td>Number of scrap grades</td>
<td>Not limited</td>
<td>Limited (ca 25 grades)</td>
</tr>
<tr>
<td>Historical charge mix variability</td>
<td>Not needed</td>
<td>High variation needed</td>
</tr>
<tr>
<td>Calibration window</td>
<td>Wide (depending on process model)</td>
<td>Narrow (depending on variation in historical data)</td>
</tr>
<tr>
<td>Introduction of new materials</td>
<td>Possible (if properties are known)</td>
<td>Not possible (historical production data needed)</td>
</tr>
<tr>
<td>Adaption to changed material properties</td>
<td>Quick (depending on new characterisation)</td>
<td>Slow (depending on new historical data)</td>
</tr>
<tr>
<td>Calculation accuracy (for static liner model)</td>
<td>Slightly lower</td>
<td>Slightly higher</td>
</tr>
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Adaption of EAF operating patterns (according to variations in charge mix)

- Dynamic heat and mass balances using scrap characterisation estimations have been used to develop **virtual sensors** for steel chemistry, slag chemistry, steel temperature and off-gas flow and temperature within the FLEXCHARGE project.
- Accuracy of developed virtual sensors have been evaluated in industrial trials with physical sensors and additional sampling of steel and slag.
- New operating practices regarding chemical energy input (natural gas, oil, LPG, oxygen, carbon, etc.) and post combustion have been developed, resulting in lowered energy consumption and reduced Fe losses to the slag.
Pre-treatment and pre-heating of scrap

- Many pre-heating concepts are available
  - Integrated solutions, e.g. Consteel, Finger Shaft furnace
    - Process optimisation of Consteel have been performed in the RFCS project “Scrap continuous charging to EAF”, 1999-2002.
  - Stand-alone solutions, e.g. basket preheating
- New concepts are emerging
  - Quantum EAF, COSS scrap pre-heater
- Methods for surface cleaning (of Zn and organic coatings) have been developed and tested in some RFCS projects:
  - PROTECT (Processes and technologies for environmentally friendly recovery and treatment of scrap), 2010-2013
- Could be of interest for use of coated scrap in the BOF process
- Decoating of scrap for removal of Zn and organic materials are not necessary for use in the EAF
Road map for improved scrap control

- Melting tests
  - Already well developed method
- Non-contact chemical analysis of scrap
  - Gamma ray technology already present for bulk analysis of flow of light scrap. Problems with expensive sensors and deteriorating sensor sensitivity remains to be solved for cost effective applications.
  - Bulk analysis for heavy scrap or baskets/trucks (gamma ray or hyperspectral analysis) need further development.
  - LIBS technology is being exploited for scrap sorting purposes. Accuracy needs to be improved for time- and cost effective replacement of melting tests as state-of-the-art method for quality control of scrap.

- Statistical regression for characterisation of scrap
  - Automated routines for updating of regression models need to be adopted
  - Ready for implementation on almost all non- and low-alloyed meltshops
  - Solutions are available at the market

- Feedback regarding systematic deviations from expected process results in connection to use of specific scrap grades need to be considered when updating estimations of scrap properties.

- Density measurements of scrap
  - Further development of technology needed (e.g. ultrasonic measurements, muon absorption, etc.)
  - Objective reference measurements for filling degree in baskets and furnace needed
Road map for improved scrap control

- Scrap mix optimisation
  - Solutions (also integrated with statistical scrap characterisation) are available at the market
  - To take full advantage of the potential of the solutions, the scrap optimisation tools need to be connected to production queue, order lists and availability of scrap grades at the scrap yard and at the market.
  - To further expand the possibilities with scrap mix optimisation, tools for simultaneous optimisation of scrap mix and process operating patterns should be developed.

- Scrap pre-treatment and Pre-heating
  - Pre-heating solutions are available and new concepts are being developed
  - Further development of surface cleaning of scrap not necessary
  - Research regarding process/scrap optimisation of new preheating/melting concepts (Quantum, COSS, Telescope EAF) is essential in the future

- Scrap processing and sorting
  - Previous RFCS projects in this area are missing, national projects have been carried out
  - Research regarding optimisation of for example shredders and/or sorting methods combined with melting tests (lab/pilot/industrial scale) should be performed

- Scrap quality degradation in combination with cost effective charge mix optimisation?
- Integration with downstream processes, use of clean scrap in the EAF or refining?
- Scrap flow in society?
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