Steel Recycling with Graphite Electrodes
- An Industrial Success Story -

2nd German – Polish Symposium
October 16th 2013
TU Bergakademie Freiberg
Steel Making Processes
Blast Furnace & Electric Arc Furnace

Blast Furnace (BOF)
- Iron Oxide
- Iron ore, limestone, and coke
- Blast furnace
- Hot air
- Molten iron
- Slag

Steel

Electric Arc Furnace (EAF)
- Steel Scrap
- Graphite electrodes
- Furnace shell
- Molten steel
- Eccentric bottom tapping (EBT)
- Teeming ladle

Steel
Steel Making Processes
World Steel Market

27% - 31% of the total steel between 2008 & 2012

EAF steel output  BOF steel output
Graphite electrodes are used in so-called mini mills. These are steel plants, where steel scrap is melted in a recycling process. The electrode enables an energy transfer to melt steel scrap via an electric arc.
Improvements in Electrode Production
- Some Examples -
Graphite Electrodes – Major Developments
Raw Material Improvement: Needle Coke

Needle coke for GE:
- Elongated shape orientation in green processing
- Low in ash content
- Low CTE along needle
- High thermal conductivity
- Low electrical resistivity along needle
- High graphitizability

https://www.osha.gov/dts/shib/shib082903c.html
Graphite Electrodes – Major Developments
Raw Material Improvement: Needle Coke

- needle coke + extrusion = axial grain orientation

⇒ Full employment of graphite’s anisotropic properties:
  - Low resistivity & low CTE in strand direction
  - High tensile strength in strand direction
  - High bending strength in perpendicular direction
Graphite Electrodes – Major Developments

Graphitization

Acheson graphitization
indirect heating

Decreased specific energy consumption

Castner or length-wise graphitization (LWG)
direct heating

Increased productivity
Graphite Electrodes – Major Developments

Diameter Increase - Break-through for a new generation of high-power EAFs

Productivity increase at constant tip loss rate

SGL Group 1st to present 800 mm GE in 2000
Improvements in Furnace Technology
- Some Examples -
Improvements in Furnace Technology
Major Developments

~ 1920
- Slag foaming

2010
- UHP (U > 1000 V, i >= 25 A/cm²)
- Water spraying
- Oxygen lances
- Electrode diameter
- Taping weight
Improvements in Furnace Technology
Ultimate Furnace (300 mt)

SIMETAL\textsuperscript{CIS} ULTIMATE 300t EAF
At COMMISSIONING

SIMETAL\textsuperscript{CIS} Ultimate and RCB – ATS VDEH
Technology Improvements in Furnace Technology
Electrode Consumption Mechanisms

Continuous

Discontinuous

Tip sublimation
Surface oxidation
Stub end losses
Breaks
Summary
Steel Recycling with Graphite Electrodes
An Industrial Success Story

Technology Innovations:
- 1810 Electric arc, Davy
- 1866 Dynamo concept, Siemens
- 1891 Electric arc furnace, Moissan
- 1896 Acheson / Castner graphitization
- 1906 EAF steel, Remscheid

Electric arc furnace technology:

Graphite electrode production:

- Q, lances
- Foamed slag
- Water spraying
- DC-technology
- Lance manipulation
- High voltage > 1000V

EAF steel production, mio t

Graphite consumption*, kg/t

* w/o ladle furnaces

From carbon to graphite electrodes
- GE 350
- GE 500
- GE 600
- GE 700
- GE 800

Chamber coking / pitch coke
- Delayed coking/petrol coke
- Needle coke
- Super needle coke
- X needle coke

Acheson graphitization
- Castner graphitization

1810 Electric arc, Davy
1866 Dynamo concept, Siemens
1891 Electric arc furnace, Moissan
1896 Acheson / Castner graphitization
1906 EAF steel, Remscheid

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Confidential
Thank you for your attention!
Backup
Steel Recycling with Graphite Electrodes
Crude Steel Production 1995 to 2025

- Steel Production will further demonstrate a sound Growth.
- EAF Steel will grow stronger than BOF.
- Areas of EAF Growth will be Asia, Near & Middle East, and Africa.
Steel Recycling with Graphite Electrodes
Effects of Graphitization

Graphitization = crystal development (from amorphous to polycrystalline material)

.change of physical material properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Increase</th>
<th>Decrease</th>
<th>Impact on Application in EAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Conductivity</td>
<td>X</td>
<td></td>
<td>very good</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>X</td>
<td></td>
<td>very good</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td></td>
<td>X</td>
<td>worse, but ...</td>
</tr>
<tr>
<td>CTE</td>
<td></td>
<td>X</td>
<td>good</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td></td>
<td>X</td>
<td>good - indifferent</td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td>X</td>
<td>no direct impact</td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td>X</td>
<td>no direct impact</td>
</tr>
<tr>
<td>Porosity</td>
<td></td>
<td>X</td>
<td>no direct impact</td>
</tr>
<tr>
<td>Apparent Density</td>
<td></td>
<td>X</td>
<td>no direct impact</td>
</tr>
</tbody>
</table>

Additionally ➔ material gets softer and easier to machine.
Steel Recycling with Graphite Electrodes
AC vs. DC Furnace Technology

AC - Furnace

Some Pros
- Lower capital cost
- Lower maintenance cost
- Higher operation reliability
- Less impact on the electrical grid
- Less oxidation

DC - Furnace
Steel Recycling with Graphite Electrodes
Typical Figures for an AC Furnace with 600 mm Electrodes

- Shell diameter: 6 - 8 m
- Secondary current: 50 - 70 kA
- Secondary voltage: 600 - 1500 V
- Column length: 6 - 8 m (3 electrodes)
- Tapping weight: 80 - 130 t
- Tapping temperature: 1620 - 1680 °C
- Tap to tap time: 50 - 80 min
- Power on time: 42 - 75 min
- Electric energy consumption: 350 - 550 kWh/t
- Total energy consumption: 600 – 700 kWh/t
- Oxygen consumption: 15 - 45 Nm³/t
- Electrode consumption: 1.2 - 2.8 kg/t