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State of the Art Anode Baking

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Introduction

Anode Quality:

High impact on:

- net carbon consumption
- aluminum production cost

Theoretical consumption:

1 MT Al $\rightarrow$ 334 Kg of Carbon
(with an efficiency of 100%)

$2 \text{Al}_2\text{O}_3 + 3 \text{C} = 4 \text{Al} + 3 \text{CO}_2$

Theoretical consumption 334 kg C / t Al

Electrolytic consumption 334 / CE

Excess consumption

Net consumption

Butts

Gross consumption

Anode consumption as quantification of anode performance kinetics
(Source: Meier, Fischer, Müller "Influence of Anode Quality on Aluminum Production Cost"
Introduction

Baking process: Most expensive step in the production of anodes

Anode properties influenced by baking process:

- CO$_2$ reactivity
- Thermal conductivity
- Air reactivity
- Mechanical strength
Anode Baking Facility

Case study: typical layout for 150.000 MT/a

- FTC – Fume treatment center
- AFS – Auto Firing System
- Anode conveyors
- Anode storage area
- Baking furnace
- Anode cleaning and grouping station
State-of-the-art Baking Furnace

Targets

- Proven design
- Low CAPEX with high productivity
- Low energy consumption
- Low maintenance
- Optimum product quality
- Environment aspects / HSE
- Reliability
Typical Furnace Performance Parameters of a Riedhammer OPEN Top Furnace with firing system of R&D Carbon

- **Max. baking temperature (flue gases):** 1,300 °C
- **Anode final baking temperature (average):** 1,100 ±20 °C
- **Fuel consumption:** 1,8 – 2,2 GJ/tba
- **Baking scrap:** ≤ 0,5 %
- **Packing material consumption (CPC):** 8 – 10 kg/tba
- **Expected flue wall service life:** 150 – 180 cycles (8 to 10 years)
- **Furnace substructure service life:** > 400 cycles
- **Productivity (throughput per pit):** up to 850 kg/h
State-of-the-art Baking Furnace

Maintenance strategy

General repair works (renewal of all inner flue walls)
AFS – Auto Firing System

**AFS : characteristics**

- Optimized temperature profiles for furnace operation
- Excellent temperature homogeneity
- Reduced consumption figures
- Maximum combustion of volatile matters  → reduced emissions
- Furnace and operative related safety aspects

Example of baking profile to illustrate key parameters to be optimized for high quality anodes (*courtesy of R&D Carbon*)
AFS – Auto Firing System

AFS: characteristics

3D view of a flue wall cross section with indication of flow pattern

Cross section of a fire-group, indicating main components of the AFS

Flue gas ring mains Exhaust manifold Measuring ramp Burner ramps Cooling ramps Unloading Loading

Preheating Main fire Cooling

Fire advance direction
AFS – Auto Firing System

**AFS: layout** (based on R&D Carbon firing system)
Optimization of flow distribution

Application of numerical methods and algorithms to solve and analyze problems that involve fluid flows inside a flue wall of the ABF:

**Targets:**
- ensure a lowest possible pressure drop of the flue wall
- temperature distribution with minimum variation

With the support of R&D Carbon and in collaboration with the University of Applied Science of Nuremberg
Optimization of flow distribution

To improve anode quality, it's important to achieve a good flow distribution in order to maximize temperature homogeneity inside a pit.

The flue wall design has a substantial impact on the anode quality, leading to a lower carbon consumption in the reduction cell, also with improvement of environmental aspects.
ADVANCED Baking Furnace

Requirements of the aluminum industry

1. Increased furnace throughput (MT/CAPEX)
   - Faster fire cycle
   - More pits per section (> 8 pits)

2. Baking of “longer” anodes
   - Pit design / Pit height
   - Refurbishment of existing furnaces

3. Increased refractory lifetime
   - Furnace re-engineering
   - Material engineering
   - Maintenance: procedures + effort

4. Lower energy consumption
   - In contrast to higher furnace throughput
   - Not a primary goal
   - Influenced by several parameters
**ADVANCED Baking Furnace**

**CASE 1: Increased furnace throughput**

- **a. Faster fire cycle**
  - 7 sections heat-up configuration
  - 6 x 28 h = 7 x 24 h ➔ + 16%
  - More negative pressure required
  - Higher specific fuel consumption
  - up to 65,000 tba / a

- **b. Number of pits per section**
  - > 8 pits per section
  - up to 10 pits are feasible
  - building span > 42,500 mm
  - up to 70,500 tba / a

- **c. Combination of “a + b”**
  - > 10 pits / 7 sections heat-up
  - up to 82,500 tba / a
CASE 2: “Longer” anodes

Pit design / Pit height

- Increased pit height leads to
  - higher energy consumption and
  - extended baking / soaking time

- Retrofit of existing furnaces to cope with new anode dimensions
CASE 3: Increased refractory lifetime

Furnace redesign:
- Optimization of bake furnace design
- Location of expansion joints
- Cross over modification

Material engineering / development:
- Use of refractory with improved characteristics
- Use of top blocks with lower thermal conductivity

Maintenance:
- Optimized refractory maintenance
- Permanent servicing of expansion joints
CASE 4: Lower energy consumption

In contrast to higher furnace throughput for the following reasons:

- Increased pit height (but also pit width)
- Faster fire cycle

Not the primary goal, rather a consequence of other important requirements:

- Anode quality
- Furnace lifetime (less maintenance)

Other parameters influencing the energy consumption:

- Furnace design (flue wall cavity)
- Final baking temperature
- Anode pitch content
- Furnace production rate
- Furnace operation and condition
**ADVANCED Baking Furnace**

Furnace performance parameters (typical)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. baking temperature (flue gases)</td>
<td>1.300 °C</td>
</tr>
<tr>
<td>Anode final baking temperature (average)</td>
<td>1.100 ±20 °C</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>2.1 – 2.5 GJ/tba</td>
</tr>
<tr>
<td>Baking scrap</td>
<td>≤ 0.5 %</td>
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<td>Packing material consumption (CPC)</td>
<td>8 – 10 kg/tba</td>
</tr>
<tr>
<td>Expected flue wall service life</td>
<td>&gt; 180 cycles (8 to 10 years)</td>
</tr>
<tr>
<td>Furnace substructure service life</td>
<td>&gt; 400 cycles</td>
</tr>
<tr>
<td>Productivity (throughput per pit)</td>
<td>up to 900 kg/h (future 940 kg/h)</td>
</tr>
</tbody>
</table>
FTC – Fume Treatment Center

Introduction

Characteristics

- Low maintenance
- Low energy consumption
- Redundancy: 100%
- Highest environmental standard
** FTC – Main aspects**

<table>
<thead>
<tr>
<th></th>
<th>( H_x C_y )</th>
<th>HF</th>
<th>( SO_x )</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSS – Dry scrubbing system</td>
<td>**</td>
<td></td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>RTO – Regenerative Thermal Oxidizer</td>
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</tbody>
</table>

* \( SO_x \) level depending mainly on:
  - Type of fuel:
    - natural gas: low \( SO_x \)
    - Heavy fuel oil: high \( SO_x \)
  - Characteristics of packing coke
  - Firing system operation: too high final baking temperature can lead to desulphurization effect

** Abatement level of \( H_x C_y \) can be substantially improved by reducing temperature of inlet flue gases (105–110°C) in filter system by means of e.g. water injection (cooling tower). By relatively high S content, formation of sulphuric acid (by temperatures below acid dew point) can lead to corrosion problems of filter steel structures.

*** \( SO_x \) abatement: marginal adsorption by \( Al_2O_3 \), but further release in the reduction cells.
Anode Handling

FTA – Furnace Tending Assembly

Characteristics

- State-of-the-art MPC:
  - Handling of anodes
  - Packing / unpacking of fill material
  - Displacement of AFS equipment
- High level of availability
Anode Handling

Storage with ASC (Anode Stacking Cranes)

Characteristics: ASC
- Fully automatic
- "Intelligent" ASC - linked with MPC, anode handling system and green mill

Characteristics: Anode Store
- Highest safety standards
- Flexible storage
- Automatic anode cleaning system
Anode Handling

Conveyors and cleaning station

- Anode lift
- Anode cleaning station
- Furnace conveyor
- Green anodes
- Baked anodes
- Green anodes from green mill
- To rodding shop

Green 10'000 t
Baked 10'000 t
Green anodes
Furnace conveyor
Baked anodes
Green anodes from green mill
To rodding shop

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Anode Handling

Conveyors and cleaning station

- Baked anode storage conveyor
- Furnace conveyor
- Tilting and weighing
- Cleaning station
- De-dusting unit
- Baked anode lift
- De-grouping station with down-ender and turntable
- Grouping station with pusher and up-ender
- Green anode lift
- Anode weighing and measuring
- Green anode storage conveyor
Conclusion

Smelter Requirements

Riedhammer and R&D Carbon are joining forces and continuously promoting equipment and process enhancements in order to provide solutions for increasing and challenging requirements of the Smelter, mainly in terms of:

- Higher productivity
- Better anode quality with minimum variation
- Environmental aspects: lower emissions
- Extended brickwork lifetime
- Overall energy consumption
Riedhammer GmbH and R&D Carbon Ltd. are cooperating closely to provide the industry with improved concepts and technologies for future cost competitive anode plants.