Pyrite Roasting an alternative to Sulphur Combustion
Sulphuric 2009, Runkel / Sturm

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Agenda

- Introduction

- Description of the Fluid Bed Technology and References

- Comparing Acid Production via Pyrite Roasting and Sulfure-Burning

- Conclusion
**Introduction - SO₂-Source for Acid**

Sulphidic ores

- Pyrite
- Sulphur

Tail/flue gases: \( \text{H}_2\text{S}, \text{CS}_2, \text{COS} \)

**Roasting, Smelting, Sintering**

**Sulphure Combustion**

**Oxidation, concentration**

\( \text{H}_2\text{SO}_4 \)

**Fertiliser production**

**Waste water treatment**

**Titanium dioxide**

**Other applications** (metal processing, batteries)

**Decomposition**

\( \text{MeSO}_4 \rightarrow \text{Me}_x\text{O}_y + \text{SO}_z \)

**Processing of organic/inorganic acids**

**Metal-Sulfate**

**Organic, inorganic compounds**
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Different Fluidized Bed Systems

**Stationary Fluidized Bed** characterised by:
- Low gas velocities (Pyrite: 0.4 – 1.5 m/s)
- Grain Size: 70 µm – 6 mm
- Bubbling bed with defined bed surface
- Limited solids carry over
- Low slip velocity
- Number of plants: 264

**Circulating Fluidized Bed** characterised by:
- Higher gas velocity (Pyrite: 3 – 6 m/s)
- Grain Size: 55% minus 38 µm (gold)
- Increased solids entrainment
- Intensive internal and external recycle of solids
- Maximum slip velocity
- Very intensive mixing
- Excellent heat and mass transfer rates
- Number of plants: 172

**Flash Reactor** characterised by:
- Very high gas velocities
- Minimum slip velocity

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Gas Velocity

Solids

Increasing Expansion

Increasing solids density
### Example of Pyrite roasting plants

<table>
<thead>
<tr>
<th>Location</th>
<th>Roaster Type</th>
<th>Roaster Grate Area</th>
<th>Raw Material</th>
<th>Feed</th>
<th>S content in feed</th>
<th>Capacity</th>
<th>Roast Temperature</th>
<th>Steam Production</th>
<th>Steam Parameters</th>
<th>Cinder</th>
<th>Offgas Roaster</th>
<th>Acid Production</th>
<th>Power Consumption Roasting kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gidji (Gold)</td>
<td>CFB</td>
<td>8.5</td>
<td>flot. Pyrite</td>
<td>slurry</td>
<td>33</td>
<td>575</td>
<td>640</td>
<td>no steam</td>
<td>no steam</td>
<td>20</td>
<td>58,000</td>
<td>no acid</td>
<td>1000</td>
</tr>
<tr>
<td>ETI (Pyrite)</td>
<td>SFB</td>
<td>100</td>
<td>flot. Pyrite</td>
<td>dry (9% H2O)</td>
<td>48</td>
<td>650</td>
<td>850</td>
<td>43</td>
<td>4.2/400</td>
<td>20</td>
<td>60,000</td>
<td>750</td>
<td>1250</td>
</tr>
<tr>
<td>Tongling (Pyrite/Pyrrothite)</td>
<td>SFB</td>
<td>138</td>
<td>Pyrite/Pyrrothite</td>
<td>dry (6% H2O)</td>
<td>37</td>
<td>1130</td>
<td>900</td>
<td>82</td>
<td>3.82/450</td>
<td>41</td>
<td>100,000</td>
<td>1200</td>
<td>1400</td>
</tr>
</tbody>
</table>
Gidji/W.A. KGCM
ETIBANK-Bandirma – Turkey
Tongling - China
Roasting technology for pyrite concentrate, latest plants installed

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Number &amp; Plant Type</th>
<th>Concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Syama, Mali</td>
<td>1 x 590 t/d CFB</td>
<td>Pyrite (Gold)</td>
</tr>
<tr>
<td>2007</td>
<td>Tongling, China</td>
<td>1 x 1130 t/d SFB</td>
<td>Pyrite / Pyrrohtite</td>
</tr>
<tr>
<td>2004</td>
<td>ETI, Turkey</td>
<td>1 x 630 t/d SFB</td>
<td>Pyrite</td>
</tr>
<tr>
<td>1996</td>
<td>Wengfu, China</td>
<td>2 x 600 t/d SFB</td>
<td>Coarse Pyrite</td>
</tr>
<tr>
<td>1991</td>
<td>KCGM/Gidji W.A.</td>
<td>2 x 575 t/d CFB</td>
<td>Pyrite (Gold)</td>
</tr>
<tr>
<td>1984</td>
<td>Almagrera, Spain</td>
<td>1 x 725 t/d SFB</td>
<td>Pyrite</td>
</tr>
<tr>
<td>1983</td>
<td>Siilinjärvi, Finland</td>
<td>1 x 420 t/d SFB</td>
<td>Pyrite</td>
</tr>
</tbody>
</table>
Steps after Roasting
Agenda

- Introduction
- Description of the Fluid Bed Technology and References
- Comparing Acid Production via Pyrite Roasting and Sulfure-Burning
- Conclusion
# Example and Comparison of Process Parameters of recently designed Acid Plants

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pyrite Roasting SFB</th>
<th>Pyrite Roasting CFB</th>
<th>Sulphur Burning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity sulphuric acid t/d</td>
<td>1200</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Feed Rate t/d</td>
<td>1130</td>
<td>1800</td>
<td>490</td>
</tr>
<tr>
<td>Furnace Offgas volume Nm³/h</td>
<td>105000</td>
<td>130000</td>
<td>120000</td>
</tr>
<tr>
<td>SO₂ in process gas vol%</td>
<td>~ 11</td>
<td>~ 11</td>
<td>~ 18</td>
</tr>
<tr>
<td>High pressure steam t/mt Mh</td>
<td>1.35 - 1.6</td>
<td>~ 70</td>
<td>1.25 - 1.4</td>
</tr>
<tr>
<td>Power Consumption kWh/mt Mh</td>
<td>-</td>
<td>Cinder</td>
<td>~ 50</td>
</tr>
<tr>
<td>By-Product - Cinder</td>
<td>-</td>
<td>-</td>
<td>no by - product</td>
</tr>
<tr>
<td>Effluents / Waste - Weak acid</td>
<td>-</td>
<td>-</td>
<td>Filter Cake</td>
</tr>
</tbody>
</table>

- SFB: Suspension Fluidized Bed
- CFB: Circulating Fluidized Bed

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## Types of pyrite concentrate

<table>
<thead>
<tr>
<th>Type</th>
<th>Composition</th>
<th>Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrite Concentrate (flotation)</td>
<td>S 47-48 wt%; Fe 42–43 wt%</td>
<td>fine particles 55% &lt; 45µm</td>
</tr>
<tr>
<td>Coarse Pyrite</td>
<td>S 47-48 wt%; Fe 42–43 wt%</td>
<td>coarse particles 0 – 6 mm</td>
</tr>
<tr>
<td>Pyrrhotite Concentrate (flot.)</td>
<td>S 34-38 wt%; Fe 50–54 wt%</td>
<td>fine particles 55% &lt; 45µm</td>
</tr>
<tr>
<td>Coarse Pyrrhotite</td>
<td>S 28-29 wt%; Fe 47–50 wt%</td>
<td>coarse particles 0 – 4 mm</td>
</tr>
</tbody>
</table>
Any influence of the location of the plant is excluded.
Transportation Cost for Sulfure is excluded.
Extracost for Calcine Deposit is excluded.
Assuming an average S-content in Pyrite without As (FeAsO$_4$).
Revenues for valuable Metals in Calcine like Au, Ni, Cu etc. are excluded.
Consumption figures such as fuel, water and labour are not significant different.
### Comparison

<table>
<thead>
<tr>
<th></th>
<th>Pyrite Roaster</th>
<th>S-Burning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>SFB: max. 1.200 t/d</td>
<td>max. 5.000 t/d</td>
</tr>
<tr>
<td></td>
<td>CFB: max. 1.500 t/d</td>
<td></td>
</tr>
<tr>
<td><strong>Capacity for Comparing</strong></td>
<td>1.000 t/d Acid (LSTK)</td>
<td></td>
</tr>
<tr>
<td><strong>Investmentcost</strong></td>
<td>80 Mio. € (one line SFB)</td>
<td>40 Mio. €</td>
</tr>
<tr>
<td><strong>Rawmaterial Price (04/2009)</strong></td>
<td>35 US$/t</td>
<td>150 US$/t</td>
</tr>
<tr>
<td><strong>Operating Cost (estimation)</strong></td>
<td>41US$/t acid</td>
<td>74 US$/t acid</td>
</tr>
</tbody>
</table>
Comparison

Pyrite Roasting

Pyrite Air

Fluid Bed Reactor

Heat Recovery

Hot Gas Dedusting

Wet Gas Cleaning

Sulphuric Acid Plant

Cinder

Effluents

Water

Acid

Sulphur Combustion

Sulphur Melting

Sulphur Filtration

Sulphur Burning

Sulphur Burner

Heat Recovery

Sulphuric Acid Plant

Air

Filter Cake

Water

Acid
Pyrite Roasting

Fluid Bed Reactor → Heat Recovery → Hot Gas Dedusting → Wet Gas Cleaning → Sulphuric Acid Plant

Pyrite → Air → Cinder → Effluents

Sulphur Combustion

Sulphur Melting → Sulphur Filtration → Sulphur Burner → Heat Recovery → Sulphuric Acid Plant

Sulphur → Air → Filter Cake → Water

acid
After 5 years pyrite roasting has higher returns.

- Capital cost for the sulphur burning plant is lower than pyrite roasting.
- Breaks even earlier than the pyrite roasting plant at three years.
- However, the operating cost for pyrite roasting is so lower,
- Pyrite roasting break even a mere 12 months after the sulphur burning plant,
- Pyrite Roasting also gains equal returns by the fifth year and
- Exceeds the returns of sulphur burning by the sixth.
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Conclusion

- Throughputs in a single roasting line for stationary fluid beds of up to 1.130 t/d
- Circulating fluid beds of up to 1.800 t/d based on pyrite concentrate and depending on chemical composition.
- At the capacity range described, the pyrite roasting process can be the favourite process route especially when looking at long-term revenues.
- The economic benefit of a roasting plant as an alternative to the sulphur burning can be significant after an operation of approximately five years.
Thank you for your attention
Pyrite Roasting an alternative to Sulphur Combustion

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Circulating Fluid Bed Roasting (CFB)

- **Gidji – Gold Roaster**
- **Pyrite with Gold Content**
- **Grain size: 55% minus 38 µm**
- **Higher gas velocities in the range of 3 – 6 m/s**
- **Temperature 650°C (ore very temperature sensitive)**
- **Solid Residence Time: 30 Minutes**
Stationary Fluid Bed Roaster (FB)

- First developed for dry pyrite feeding
- For Acid Production + Steam Production.
- Pyrite grain size 70 µm (flotated) - 6 mm
- Gas velocity in the fluid bed: 0.4 (70 µm) - 1.5 m/s (6 mm)
- Temperature 850°C