Is Complete Recycling of Blast Furnace Sludge within the Integrated Steel Plant Possible?

Nordic Recycling Day 2017

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What is Blast Furnace Sludge?

Why should we care about BF sludge?

BF illustrated by SSAB in Stälboken
Why should we care about the BF sludge?

Swedish scenario (2014):
• Luleå: 9.3 kton (dry)
• Oxelösund: 10.9 kton (dry)
Not much compared to BF slag…

How about worldwide?
• Worldsteel: BF iron production 2016 was 1160 Mton
If everyone used cyclones…
• Swedish figures: 6.7 kg BF sludge per ton hot metal
• Rough estimation: 7.8 Mton BF sludge per year globally
• Usually landfilled!
Why should we care about the BF sludge?

**Landfilling:**
- It’s a lot of landfilling
- What are we discarding?

**Literature (nine sludges):**
- Average Fe: 35.2 wt%
- Average C: 23.9 wt%

**Annual landfill of Fe and C:**
- Fe: 2.7 Mton
- C: 1.9 Mton

Photos by Anita Wedholm
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More C than the C in the Swedish coke produced annually

BF sludge is an opportunity!
Why is BF sludge not recycled?

**Three principal reasons:**

i. **Water content**  
   - Difficult to dry

ii. **Fineness**

iii. **Zinc content (most important)**

That sludge contains 0.4% zinc and it’s still not recycled!
Why is BF sludge not recycled?

It’s not so much the actual content of zinc...
Why is BF sludge not recycled?

It’s not so much the actual content of zinc...
How to remove the zinc?

Characterization of the studied BF sludge
• Compared to the literature the studied sludge has:
  – Lower zinc content
  – Finer particle size distribution

Can previously reported methods be used?

<table>
<thead>
<tr>
<th>Method</th>
<th>% of Zn removed</th>
<th>% of Fe for recycling</th>
<th>% of C for recycling</th>
<th>% of solids for recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocyclone</td>
<td>74</td>
<td>66</td>
<td>37</td>
<td>59</td>
</tr>
<tr>
<td>Leaching(^1), pH 1</td>
<td>95</td>
<td>91</td>
<td>100</td>
<td>86</td>
</tr>
<tr>
<td>Leaching(^1), pH 3</td>
<td>80</td>
<td>96</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>Tornado</td>
<td>81</td>
<td>37</td>
<td>39</td>
<td>31</td>
</tr>
</tbody>
</table>

\(^1\) \text{H}_2\text{SO}_4, 80^\circ \text{C}
How to recycle the upgraded sludge?

**Utilizing the existing infrastructure**  
Adding upgraded BF sludge to the briquettes  
– What about the briquette strength?  
– Additional iron oxides, will they be reduced before the lower shaft?

**Can we test this in smaller scale?**  
Briquetting of three recipes:  
 i. Reference recipe  
 ii. 10 wt.% of upgraded BF sludge  
 iii. 20 wt.% of upgraded BF sludge

Upgraded sludge from the tornado

*Photo from SSAB webpage*
Recycling to the BF

**Tumbling strength (TTH) of the briquettes**

- No problem from a strength point of view

<table>
<thead>
<tr>
<th>Curing (days)</th>
<th>Reference</th>
<th>10 Wt.%</th>
<th>20 Wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>42</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>28</td>
<td>78</td>
<td>84</td>
<td>81</td>
</tr>
</tbody>
</table>
Recycling to the BF

**Laboratory scale BF simulation**

- Reduction in two heating programs under varied:
  - Heating rate
  - Gas composition
  - Mechanical pressure

- Evaluated using:
  - Mass loss recordings
  - XRF, titration and Leco for chemistry
  - XRD and SEM-EDS for mineralogy

- Finding that:
  - Reduction of 20wt.% briquette is satisfactory in wall descent
  - Reduction of 10wt.% briquette is satisfactory in center descent
Recycling to the BF

Basket samples in the LKAB EBF®

- Baskets containing the reference, 10 wt.% and 20 wt.% briquettes charged to the EBF
- Baskets excavated after quenching with $N_2$ from the top
- Evaluation: same approach as in lab scale
Recycling to the BF

Basket samples in the LKAB EBF®

- Adding up to 20 wt.% upgraded BF sludge leaves the briquette satisfactory reduced.
- No difference in structural properties after the reduction.
Recycling to the BF

Full scale trials at BF No. 3

• No upgrading in full scale
• BF sludge added to a briquette recipe
  – Reference period with ordinary briquettes
  – Trial period with briquettes containing 3.8 wt.% BF sludge
• No anomalies connected to the briquettes were observed during the three day trial period
• 11.4 kton of BF sludge can be recycled annually
• System analysis required for overall zinc balance

Photo by Torbjörn Tapani
How about the bleed of zinc?

This can be achieved!

Can we recycle this fraction too?
How about the bleed of zinc?

**Recycling to the steel plant studied (SSAB Luleå)**

- Desulfurization plant
- Basic oxygen furnace

*Illustrations by SSAB in Stålboken*
Recycling to the deS plant

Full scale trials at SSAB Luleå

• Briquetting
• Charging before tapping of torpedo
  – 100 kg per heat
  – 150 kg per heat
  – 300 kg per heat
  – Dusting when charging
  – Possibly some melt-in issues at 300 kg
+ No further problems
+ No effect on final steel quality
+ 5100 ton briquettes/year can be recycled

Photos by Mats Andersson
Recycling to the BOF

Full scale trials at SSAB Luleå

• Briquetting (same as deS)
• Charging with scrap
  – 600-1250 kg of briquettes
  – 6-17 ppm sulfur increase in crude steel
  + Slag formation improved
  + Dephosphorization improved
  + Suitable for some steel qualities
    + 8700 ton briquettes/year can be recycled

Photos by Mats Andersson
Conclusions

Upgrading
• Possible to create a dezinced fraction of BF sludge
  – Varying results regarding the efficiency

Recycling to the BF (No.3 SSAB Luleå)
• Possible to recycle 11.4 kton upgraded BF sludge/year
  – Covers more than the annual generation of BF sludge

Steel plant (SSAB Luleå)
• Possible to recycle a total of 13.8 kton briquettes/year
  – Requires a high content of upgraded BF sludge in the recipe to completely recycle the high-zinc fraction
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