Production of reduced iron from mill scale waste using A tilting rotary furnace

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Supervised by
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- Master’s Degree in Production Engineering (Iron reduction and steel waste management)
- From 2019 until 2022 He was Production Engineer in Borg El-Arab Foundries.
- Currently He is CTO & CO-Founder at Sequoia Foundry.
- CEO of Horizon a startup focuses on steel waste management.
Introduction

- The management of wastes generated by hot metal and steel has become an important issue due to ever-tightening environment regulations. Furthermore, the depletion of iron ores necessitates extensive research work to reuse the secondary raw materials produced as a by-product in steel companies and considered as waste materials.
Mill Scale

Mill scale, often shortened to just scale, is the flaky surface of hot rolled steel, consisting of the mixed iron oxides mainly Wustite.

Reduction Limitations:

- Low Reduction Porosity
- Oil contamination
Tilting rotary Furnace
Reduction Process Inside TRF

**Equations:**

1. CO₂ + C = 2CO
2. CO + FeO = Fe + CO₂

**Temperatures:**

- 900-1200°C

**Process Steps:**

- Exhaust
- FeO
- Coal
- Air + Fuel
- Partial melt of Fe₃C and softening in Fe fines
- Snowball effect >1300°C
Manufacturing process of TRF

Pilot Scale
200Kg SRI/Hr

Production scale
1500 KG SRI/Hr
Pilot Scale TRF
Pilot Scale TRF
Gas movement simulation

The CFD simulation illustrates the loop-like movement in the TRF. This movement enhances the thermal efficiency of the furnace and increases the chance of interaction between the reducing gases and the iron oxide.
Production scale furnace
Results and discussion

- Increasing the fuel with constant amount of air enhance the reducing atmosphere.
- The increase in the CO gas greatly improved the metallization degree and prevents the reoxidation of produced iron.
Results and discussion

XRD Results

<table>
<thead>
<tr>
<th>Fuel (L/Charge)</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>55</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (wt%)</td>
<td>9.6</td>
<td>15.5</td>
<td>42.8</td>
<td>53.4</td>
<td>70</td>
<td>86.3</td>
</tr>
<tr>
<td>Iron carbon (wt%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Wustite (wt%)</td>
<td>67.4</td>
<td>55</td>
<td>29.1</td>
<td>1</td>
<td>20.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Hematite (wt%)</td>
<td>23</td>
<td>29.5</td>
<td>13.7</td>
<td>45.7</td>
<td>3.3</td>
<td>1.9</td>
</tr>
<tr>
<td>Magnetite (wt%)</td>
<td>-</td>
<td>-</td>
<td>14.4</td>
<td>-</td>
<td>6.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Metallization Degree % = Fe Metal/Fe Total x 100

Metallization Degree > 90 %
Results and discussion

- cross-sectional diameter is related to the RPM of the furnace in an inversely proportional relation. This relation similar to the relation between iron pellets cross-section and disc rpm of the traditional disc palletizer used in traditional cold iron pellets production.
Results and discussion

✦ The produced SRD was added to several induction furnace charges and showed a great reduction in production cost due to the lower cost of the SRD than the conventional scrap. 40% of the total charge was SRD.

✦ For our long term experiments we have already used the produced reduced Iron as a direct replacement to the scrap with maintaining a liquid pool of 30% in The induction furnace

Soda ash is added in the ladle for sulfur treatment then the molten metal is tapped Into ingots. This ingots are used as a foundry grade pig Iron in the ductile cast Iron production.
Results and discussion
Economical overview on raw materials cost

The production cost of SRI was around 8000 EGP (250 USD) per tonne while the price of DRI imported to Egypt starts with a fob price of 420 USD and a final price to the end customer in Egypt is more than 20,000 EGP.

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Amount</th>
<th>price/unit</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>millscale</td>
<td>1480</td>
<td>2.2</td>
<td>3256</td>
</tr>
<tr>
<td>coal</td>
<td>350</td>
<td>4.8</td>
<td>1680</td>
</tr>
<tr>
<td>pet Coke</td>
<td>180</td>
<td>6.3</td>
<td>1134</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>150</td>
<td>8.25</td>
<td>1237.5</td>
</tr>
<tr>
<td>CaCO3</td>
<td>80</td>
<td>0.8</td>
<td>64</td>
</tr>
<tr>
<td>labor cost</td>
<td>6</td>
<td>35</td>
<td>210</td>
</tr>
<tr>
<td>Refractory</td>
<td>6</td>
<td>80</td>
<td>480</td>
</tr>
<tr>
<td>electricity</td>
<td>15</td>
<td>1.25</td>
<td>18.75</td>
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<tr>
<td>ForkLift Fuel</td>
<td>0.5</td>
<td>9</td>
<td>4.5</td>
</tr>
<tr>
<td>equipment depreciation</td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>SUM</td>
<td>8061.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Production cost of SRI
Conclusion

- In conclusion our aim to produce reduced iron in TRF was reached.
- No pre agglomeration of raw materials was required to produce reduced iron with High metallization degree.
- The presence of oil on the mill scale due to the cooling of steel in the steel mills did not harm the process otherwise it enhanced the reducing atmosphere due to gasification of oil at elevated temperature.

- Due to the relatively small size of the unit and no need of palletization, sintering or coke oven. So, the process can be carried in every large steel mill to recycle the mill scale produced in the facility.
- The use of SRI in the induction Furnace showed a metallic yield more >85% and effectively reduced the production cost of cast iron due to the Relatively low price of the SRI. 40% cheaper than traditional scrap
Future implementation
Production scale TRF

✦ In Egypt more than 200 thousand tons of mill scales are dumped as a waste due to the steel rolling annually. We implemented our findings in the pilot scale into a production scale that can transfer 1 thousand ton of wasted mill scale into more valuable reduced iron monthly.

✦ We aim into growing our production capacity to consumes the local annual waste of mill scale in Egypt by the end of 2024.

✦ The production cost of SRI was less than 8000 EGP per tone while the price of DRI imported to Egypt starts with a fob price of 420 USD and a final price to the end customer in Egypt is more than 20,00 EGP.
TRF implementation in green steel production

We are working on a new module that uses green hydrogen to directly reduce and smelt iron oxide fines.
THANK YOU