Energy conservation in Cupola Furnace

Training Programme
Energy Conservation in Foundry Industry

11-13 August 2014
Indore
Areas/Levels of energy savings and investments

<table>
<thead>
<tr>
<th>Level</th>
<th>Area 1: Auxiliaries</th>
<th>Area 2: Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Operating practice improvement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E.g. Compressed air leakage</td>
<td>E.g. BOP</td>
</tr>
<tr>
<td>Level 2</td>
<td>Retrofit</td>
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<td></td>
<td>E.g. VFD for screw compressor</td>
<td>E.g. Retrofit DBC</td>
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<tr>
<td>Level 3</td>
<td>New plant</td>
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<tr>
<td></td>
<td>E.g. Inverter compressor</td>
<td>E.g. New DBC</td>
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</tbody>
</table>
Cupola

- Vertical shaft cylindrical furnace

- Heat released from combustion of coke in the bed melts the metallics

- Advantages
  - Lower capital cost
  - Lower energy cost
  - Better metallurgical properties promoting machinability
Classifications

- Cold blast operated cupola
- Hot blast operated cupola
  - Benefits if the blast air temperature $400^\circ C +$
  - Second-hand imported hot blast cupolas are difficult to rebuild and operate
- Continuous tapped cupola
  - more energy efficient
- Intermittently tapped cupola
Important design parameters

Blast rate (air volume) of blower

- Optimum blast rate
  - 375 ft³/min per sq foot or 115 m³/min per sq metre of cupola cross-sectional area
  - Blower should deliver 15%-20% more than the optimum blast rate

- Higher blast rate (very common)
  - Higher coke consumption
  - High oxidation losses

- Lower blast air
  - Lower heat generation (high coke consumption)
  - Lower metal temperature
  - Slower melting
Important design parameters...contd.

- Blast air pressure (function of cupola diameter)

  \[ P = 0.005 D^2 - 0.0134 D + 39.45 \]
  
  Where,
  
  \[ P = \text{Blast pressure, inch } H_2O \]
  
  \[ D = \text{Internal diameter at the melting zone, inches} \]

<table>
<thead>
<tr>
<th>Diameter of Melting Zone, inch</th>
<th>Recommended Blower Capacity, m3/min</th>
<th>Discharge Pressure, kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>40.2</td>
<td>10.5</td>
</tr>
<tr>
<td>30</td>
<td>62.3</td>
<td>11.0</td>
</tr>
<tr>
<td>36</td>
<td>90.0</td>
<td>11.5</td>
</tr>
</tbody>
</table>
Lower blast air pressure
Important design parameters

Tuyere number and size

- Tuyere size determines the velocity of the blast air in the bed
  - For a cold blast system, the total area of the tuyeres is about 20% of the melting zone area
  - Size of each tuyere can be calculated by dividing the total tuyere area by the total number of tuyeres

- Recommended number of tuyeres per row
  - Cupola internal diameter less than 30 inch: 4
  - Cupola internal diameter between 30 inch and 42 inch: 6
  - Cupola internal diameter between 42 inch and 60 inch: 8
  - Cupola internal diameter between 60 inch and 84 inch: 12

- The shape of the tuyere can be either round (preferable) or rectangular
Other design parameters

- Stack height (tuyere to lower edge of charging door)
  - 16 ft to 22 ft depending upon its diameter
  - Well depth

- Influences the carbon pickup and the metal tapping temperature
  - Increasing the well depth leads to higher carbon-up but reduces the tapping temperature of the molten metal.
  - Drop of 1 °C for every inch increase in the well depth
Energy Efficiency Calculation

- Parameters measured
  - Bed Coke
  - Charged coke
  - Metallics charged
  - Melting time (blower operating hours)

- Melting rate (tph) = \frac{\text{metallics charged (tons)}}{\text{melting time (hr)}}

- Charged coke consumption (%) = \frac{\text{Charged coke}}{\text{Metallics charged}} \times 100
Divided Blast Cupola (DBC)

How DBC works
- A cooler reduction zone is produced about 1 m above the tuyere due to formation of CO (endothermic reaction)
- By introducing secondary air by double row of tuyere reduces CO formation
TERI’s development and demonstration of improved DBC

- Diagnostic studies to assess energy efficiency and operating practices of existing cupolas

- Development & demonstration of improved DBC design
  - Pooling of expertise for technology development
    - Cast Metals (BCIRA), UK
    - TERI, India
    - Sorane Sa, Switzerland

- Demonstration of best operating practices (BOP)
DBC

- Advantages of ‘properly designed’ DBC
  - Reduce coke consumption (20 to 40%)
  - Increases melting rate (by 1.5 times)
  - Better metal consistence and chemistry

- TERI has introduced several innovations in DBC design
  - Correct specifications of the blower (pressure & flow rate)
  - Cast iron tuyeres
  - 10D straight length of blast air mains
  - Butterfly valves on blast mains and each tuyere
  - Sight glass on each tuyeres
  - Higher stack height
  - Bucket charging
Demonstration Plant at Howrah (West Bengal)

Commissioned 1998
DBC – Divided Blast Cupola
Bucket charging system

Pollution Control System
venturi-scrubber
100 ft free standing chimney
Energy efficiency in typical small-scale foundry units

![Energy Efficiency Chart]

- Single blast (Agra): 26.5%
- DBC (Agra): 15.8%
- Single blast (Howrah): 18.0%
- DBC - 1 (Howrah): 14.8%
- DBC - 2 (Howrah): 13.6%
- Demo unit (Howrah): 8%
Energy performance

Coke charge in CC 13.6%
Coke charge in DBC 8.8%
Energy savings 35%
\[
\frac{(13.6 - 8.8)}{13.6}
\]
Environment performance

- **Without gas cleaning system**: 3900 mg/Nm³
- **With existing gas cleaning systems**: 800 mg/Nm³
- **Demonstrated system**: 50 mg/Nm³

Emission limit for more than 3 tonnes per hour
Emission limit for less than 3 tonnes per hour
Detailed Fabrication Drawing

Design includes

- Fabrication drawing (of all MS components)
- Pattern drawings of CI components
- Specifications of blower
- Skip hoist design
- Plant layout
Conventional Cupola to DBC – Rajkot, Gujarat

Then and Now
DBC
Technology replication
Aquasub, Coimbatore
Spreading the technology to Bangladesh
TERI-PCRA R&D Project – 18” ID DBC
B S Engineers & Founders - DBC
Best operating Practices

See BOP film
Energy cost – Induction Vs Cupola

Induction furnace
- Sp. elec. consumption: 650 kWh/tonne
- Price of electricity: 10 Rs/kWh
- Energy cost: 6500 Rs

Cupola
- Coke:Melt: 1:10
- Price of coke: 30,000 Rs/ton
- Energy cost: 3000 Rs/ton

Savings per ton: Rs 3500
Savings per 100 ton: Rs 3,50,000
## Energy cost – For duplexing operation

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only Induction Furnace</td>
<td></td>
</tr>
<tr>
<td>• Energy cost</td>
<td>6500 Rs/ton</td>
</tr>
<tr>
<td>Cupola + Induction Furnace</td>
<td></td>
</tr>
<tr>
<td>• Cupola energy cost</td>
<td>3000 Rs/ton</td>
</tr>
<tr>
<td>• Induction superheating</td>
<td>100 kWh/tonne or 1000 Rs/ton</td>
</tr>
<tr>
<td>• Total</td>
<td>4000 Rs/ton</td>
</tr>
<tr>
<td>Savings per ton</td>
<td>Rs 2500</td>
</tr>
<tr>
<td>Savings per 100 ton</td>
<td>Rs 2,50,000</td>
</tr>
</tbody>
</table>
Thank you for your kind attention!

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