ALTERNATIVES FOR HOT METAL PRODUCTION: CUPOLA, INDUCTION AND ARC FURNACE

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Alternatives for hot metal production

Content:
- Introduction
- Cupola
- Induction Furnace
- Arc Furnace
- Influencing factors
- Trends
- Conclusions
Introduction

- To obtain liquid ferrous metal departing from cold charge, several technological alternatives are available.
- For a greenfield new foundry or brownfield capacity increase, these alternatives must be evaluated.
- The advantages and drawbacks are discussed of:
  - Cupola
  - Induction furnace
  - Arc furnace
Cupola

- Modern cupola features:
  - Fume take off below charge
  - Hot blast
  - Off gas treatment
  - Liningless larger furnaces
  - High automation level
Cupola

Standard layout showing:

- Bucket charging
- Below charge gas take off
- Dry slag granulation
- Vertical combustion chamber
- Hot blast recuperator
- Heat recovery bundles
- Baghouse
- Exhaust fan and stack
Cupola

- Fortresses
  - Thermal efficiency, in larger units
  - Acceptation of wide range of metallics
  - Less sensitivity to scrap oxidation
  - Design variants for specific aims (plasma, cokeless, oxycup)
  - Hot blast: low melting cost for larger tonnages
Cupola

- Weaknesses
  - Big off-gas generation
  - To have good environmental performance, heavy investment is necessary
  - For ductile iron production, downstream equipment is convenient
  - Temperature and chemistry control is more complex
Induction furnace

- Fortresses
  - Coke or electrodes not required
  - Possibility of producing an ample range of materials
  - Easy and fast control of liquid metal temperature
  - Easy temperature adjustment
  - Fast change of melting rate
  - Good environmental performance, with low investment
Induction furnace

- Weaknesses
  - Limitations in metallics to be charged (turnings and borings, dirty scrap, scrap size)
  - Limitations for metallurgical tasks requiring slag-metal interaction
Induction furnace

- High power
- Automation

- Becoming usual:
  - Fume extraction
  - Push out system
  - Backslagging
  - Robot for sampling and other furnace operations
Arc furnace

- Fortresses
  - Capacity to melt everything, including turnings and borings
  - Ability to reach high temperatures (advantage for cast steel production)
  - With basic lining, possibility to decrease sulphur or phosphorus via slag-metal interaction
  - Simple and reliable equipment
Arc furnace

- Weaknesses
  - Noise
  - Off gas generation (when oxygen injection is used)
  - Need to control emissions
Arc furnace

- Features of modern arc furnaces
  - High power
  - Water cooled panels
  - Slag foaming
  - Excentric bottom tapping
  - Oxygen, coal, gas and lime through injectors
  - Electroconductive arms
  - Digital system for electrode regulation
Arc furnace
Arc furnace

- Off gas treatment
Influencing factors

- Availability and cost of raw materials and consumables
- Grades to be produced
- Investment cost
- Operating cost
- Environmental restrictions
Raw materials and consumables

- Types of scrap available and cost
- Need of recycling turnings and borings
- Availability and cost of electric power, coke and electrodes
## Influencing factors

### Grades to be produced

<table>
<thead>
<tr>
<th>Country</th>
<th>Gray iron (%)</th>
<th>Ductile iron (%)</th>
<th>Cast steel (%)</th>
<th>Aluminum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>36</td>
<td>32</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Germany</td>
<td>49</td>
<td>28</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Japan</td>
<td>40</td>
<td>32</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>China</td>
<td>60</td>
<td>20</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>India</td>
<td>70</td>
<td>9</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Brazil</td>
<td>86</td>
<td></td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Argentina</td>
<td>49</td>
<td>34</td>
<td>6</td>
<td>11</td>
</tr>
</tbody>
</table>
## Operating cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Cupola (USD/t)</th>
<th>Induction (USD/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallics</td>
<td>135.4</td>
<td>151.7</td>
</tr>
<tr>
<td>Additives</td>
<td>9.3</td>
<td>13.0</td>
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<tr>
<td>Melting</td>
<td>23.4</td>
<td>29.6</td>
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<tr>
<td>Labour</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Refractories</td>
<td>1.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Maintenance</td>
<td>6.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Building and others</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>191.8</strong></td>
<td><strong>216.8</strong></td>
</tr>
</tbody>
</table>

Greenfield; 40 t/h; 16 h/day; 4000 h/year. Hot-blast cupola; medium frequency coreless induction furnace. US costs. Kuttner study, 2001
### Operating cost

<table>
<thead>
<tr>
<th>Item</th>
<th>Savings when replacing arc furnace melting by induction melting (USD/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting energy</td>
<td>2.7</td>
</tr>
<tr>
<td>Energy demand</td>
<td>-3.3</td>
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<tr>
<td>Electrodes</td>
<td>33.4</td>
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<tr>
<td>Metallic charge</td>
<td>-20.2</td>
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<tr>
<td>Labour (production)</td>
<td>5.4</td>
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<tr>
<td>Refractories</td>
<td>1.0</td>
</tr>
<tr>
<td>Maintenance (materials and labour)</td>
<td>18.0</td>
</tr>
<tr>
<td>Polution control</td>
<td>4.8</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>0.9</td>
</tr>
<tr>
<td>Total</td>
<td>42.8</td>
</tr>
</tbody>
</table>

John Deere, year 2000, when analyzing a modernization with Capacity increase. Cupola in intermediate position.
France

- 1997: cold-blast cupola the cheapest (236 €/t); induction furnace the most expensive (265 €/t)
- 2003: Induction furnace the cheapest (252 €/t), followed closely by hot-blast cupola (253 €/t)
- 2005: hot-blast cupola the cheapest (295 €/t)
France – quantity of furnaces for ductile iron, cast iron and malleable iron (1999 162 units; 2002 140 units)
Trends

- France – tonnage ductile, gray and malleable iron (1999, 1,530,000 t; 2002 1,400,000 t)
Trends

- Argentina (Ricardo Velazquez, Foundry industry in Argentina, COLFUN 2010)
  - 1980 80% cupola, 20% induction
  - 2010 20% cupola, 80% induction

- Brazil (Roberto de Deus, private communication)
  - 2010 30% cupola, 70% induction
Conclusions

- Worldwide trend to replace melting capacity of cold-blast cupolas by induction furnaces
- For big production, using hot-blast cupola as primary melting unit is still competitive
- To make the right decision, it is always convenient to evaluate the furnace alternatives, comparing CAPEX, OPEX and other factors