CHAPTER 6

IMPROVEMENT IN COST OF PRODUCTION THROUGH ENERGY OPTIMIZING FURNACE ROUTE

The cost of production is location-specific with regard to the price of raw materials and transportation cost. The process costs are common to operations in all the furnaces and therefore, the process costs are not location specific. In a steel processing unit, the cost of production is inversely related to the productivity. If the productivity is high, the cost of production is low. It has been already established through literature survey and the cost incurred by certain operating plants that the EAF based steel plants are having higher cost as compared to the EOF steel making route is shown in Table 6.1 as explained in “Making, Shaping and Treating of Steel” in Chapter 13.

Based on this bench marking, the following areas for cost reduction were identified for EOF:

1. Improvement of charge to liquid metal yield
2. Reduction in the blowing time
3. Reduction in the refractory cost

6.1 IMPROVEMENT OF CHARGE TO LIQUID METAL YIELD

Charge to liquid metal yield is a very important cost element in steel making. The higher yield of the metal not only gives that much extra production but it also brings down the consumption figures of the other consumables such as, ferro alloys, refractories, fuel, electrode, oxygen etc.
Table 6.1 Operating and total cost of producing liquid steel

<table>
<thead>
<tr>
<th>Charge Mix</th>
<th>BOF 80% Hot Metal 20% scrap</th>
<th>EOF 50% Scrap 50% Hot Metal</th>
<th>EAF 50% Scrap 50% DRI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input (cost/unit)</strong></td>
<td><strong>Units</strong></td>
<td><strong>Cost</strong></td>
<td><strong>Units</strong></td>
</tr>
<tr>
<td>Hot Metal ($145/MT)</td>
<td>0.85</td>
<td>123.30</td>
<td>0.55</td>
</tr>
<tr>
<td>Scrap ($120/MT)</td>
<td>0.22</td>
<td>27.50</td>
<td>0.55</td>
</tr>
<tr>
<td>DRI/HBI ($130/MT)</td>
<td></td>
<td></td>
<td>0.541</td>
</tr>
<tr>
<td>Flux ($55/MT)</td>
<td>0.06</td>
<td>3.00</td>
<td>0.04</td>
</tr>
<tr>
<td>Oxygen ($40/MT)</td>
<td>0.07</td>
<td>2.60</td>
<td>0.10</td>
</tr>
<tr>
<td>Carbon $70/MT)</td>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Electricity ($0.05/KWh)</td>
<td>65.00</td>
<td>2.60</td>
<td>20.00</td>
</tr>
<tr>
<td>Refractories (Kg/MT)</td>
<td>1.00</td>
<td>1.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Labour ($30/mh)</td>
<td>0.30</td>
<td>9.00</td>
<td>0.20</td>
</tr>
<tr>
<td>Desulphurization</td>
<td>7.00</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>20.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td><strong>Total Operating Cost</strong></td>
<td><strong>196.00</strong></td>
<td><strong>195.00</strong></td>
<td><strong>198.20</strong></td>
</tr>
<tr>
<td>Cost of Capital at 8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation and 8% ROI</td>
<td>13.30</td>
<td>9.00</td>
<td>15.20</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>209.30</strong></td>
<td><strong>204.00</strong></td>
<td><strong>213.40</strong></td>
</tr>
</tbody>
</table>

Experiments for charge to liquid metal yield were conducted in the 45 MT EOF, which was having smooth operations.
The charge to liquid metal yield is dependent upon the following factors.

(a) Hot metal Chemistry (% Carbon and % Silicon)
   This is a controllable factor and hot metal chemistry within the acceptable range (C % - 4.1 to 4.3, Si % - 0.4 to 0.7), was only poured in the EOF.

(b) Hot Metal temperature:
   This is also an external factor and therefore, hot metal having temperature above 1250ºC was poured in the EOF. Low temperature hot metal results in long oxidizing period and higher oxidation of Fe resulting in lower yield.

(c) Non-metallics in the solid charge.
   This is also a controllable external factor. Scrap was cut to the desired size and non-metallics were removed to the extent possible before charging in the EOF.

(d) Liquid Metal loss through the slag door.
   Any loss of liquid metal through slag door reduces the yield. Hence, during processing, care was taken to minimize liquid metal loss through the slag door, especially when there was excessive boil inside the EOF.

(e) Fe losses in the form of FeO in slag:
   Loss of FeO through slag can be minimized by avoiding over-oxidation of the bath. This is the main area for control, to improve the yield in the EOF during processing. Several experiments were conducted to avoid over oxidation of the steel bath through the “catch carbon” implementation, which help in improving the charge to yield.
The result of liquid metal yield improvement is shown in Figure 6.1.

![Figure 6.1 Liquid metal yield improvement (45MT EOF)](image)

**Figure 6.1 Liquid metal yield improvement (45MT EOF)**

The charge to liquid metal yield figures shown above is the average yield achieved during the particular campaign and in each campaign 700 to 900 heats were produced. The improvement in the yield was achieved by controlling the external factors such as hot metal chemistry, hot metal temperature scrap processing, metal loss during heat processing etc. However, external factors are easier to control with operating discipline. The process related factor, i.e., to avoid over oxidation of steel bath also significantly contributed towards yield improvement.

### 6.2 REDUCTION IN THE BLOWING TIME

The blowing time in EOF is the main activity and therefore, out of total tap to tap time of 50 minutes, the blowing time itself is about 35 minutes. Any reduction in the blowing time would also reduce the tap to tap time and
therefore, result in higher productivity and lower cost. The various parameters which affect the oxygen blowing time are as under:

a) Hot metal chemistry -
   This is an external factor which can be controlled by pouring hot metal having certain specified levels of percent carbon silicon in the EOF for processing as specified earlier.

b) Hot metal temperature:
   This is also an external factor which is controllable by pouring hot metal with above 1250º C in the EOF.

c) Scrap and Hot Metal ratio:
   This is also an external controllable factor because 20% solid charge and 80% hot metal was fixed ratio for the EOF during the period under consideration.

d) Oxygen blow profile:
   The Oxygen blow profile, through tuyeres, atmospheric injectors, supersonic lances and hand lancing, is perhaps most important factors which control the blowing time. The Oxygen blow profile was fixed for all heats.

e) Supersonic Lance:
   Two supersonic lances were used in place of one lance to reduce the blowing period.

f) Catch Carbon implementation:
   The blowing period in the EOF reduces when the steel is tapped at the desired level (as close to the final carbon percentage) while achieving the tapping temperature of 1630º C.
The reduction in the blowing time in the different campaigns is shown in Figure 6.2

![Figure 6.2 Improvements in blow time (45 MT EOF)](image)

Figure 6.2 Improvements in blow time (45 MT EOF)

The blowing time shown in the Figure 6.2 is the average blowing time for the particular campaign in which 700 to 900 heats are produced in each campaign. The above blowing period was achieved by controlling the external factors stated above and also by implementing the process related factor namely the catch carbon process.

### 6.3 REDUCTION IN THE REFRACTORY CONSUMPTION

The process variables which control the refractory consumption in the EOF are as under:

a) Silicon percentage in the hot metal:

This is an external factor where hot metal having Silicon percentage from 0.4 to 0.7 only is charged in the EOF. Higher percentage of silicon in the hot metal result in excessive silica
formation which reduces the basicity of the slag and also has a chemical reaction on the basic refractory.

b) Hot Metal temperature:
This is an external controllable factor and hot metal above 1250ºC is only to be charged in the EOF. If hot metal is charged below 1250ºC, oxygen lancing will take place at low temperature of hot metal resulting in very high generation of FeO and hence lower yield.

c) Slag basicity:
This is also a controllable factor. Lime addition in the EOF is controlled in such a way that slag basicity is controlled between 2.8 to 3.2. Since in the EOF the refractory as well as gunning material is basic in nature, lower basicity slag would be erosive on the refractory.

d) High tapping temperature:
High temperature in the EOF causes refractory erosion. This is an external factor and proper ratio of solid charge and hot metal is used to avoid high temperature. In the new furnace when the height and diameter ratio of the EOF hearth was more favourable high temperature of liquid steel is controlled through addition of sponge iron or iron ore in the EOF. The normal tapping temperature in EOF is 1630ºC to 1650º C.

e) Refractory quality:
To ensure good quality refractory, the refractory material is purchased only from approved sources.
f) Catch Carbon implementation:
An over oxidised steel bath results in high FeO in the slag, which erodes the refractory. To avoid the same, proper catch carbon was implemented. This is a process related factor where maximum effort was made to get the desired results.

The total refractory consumption in EOF consists of the consumption of refractory bricks and the consumption of gunning material. Data were logged for each campaign how the gunning material and refractory brick consumption in Kg/MT of steel produced. The refractory brick consumption was higher in the beginning of the campaign and continuously reduced as the campaign progressed with increased steel quantity produced. However, the gunning material consumption was low in the beginning and it continues to increase as the campaign life progresses. The total refractory consumption was monitored which was the sum of brick consumption and gunning material consumption. The refractory consumption (campaign no. 48) in Figure 6.3 shows the variation of refractory brick, gunning mass and total refractory consumption vis-à-vis campaign life.

![Figure 6.3 Refractory consumption (campaign 48)](image-url)
However, the cost of bricks was higher (Rs.40 per Kg) while the cost of gunning material was Rs.25 per Kg. Ultimately it is not refractory consumption in Kg/MT that matters but it is the refractory consumption in Rs./MT that is important. Hence, when refractory cost in Rs/MT started to increase, the EOF campaign was stopped at the earliest opportunity thereafter and the spare shell was brought into operating position.

The refractory consumption was reduced during the various campaigns as shown in Table 6.2 and Figure 6.4.

![Figure 6.4 Reduction of total refractory consumption (45 MT EOF)](image)

**Table 6.2 Reduction of refractory consumption**

<table>
<thead>
<tr>
<th>Campaign life</th>
<th>Total refractory</th>
<th>Campaign (46 - 50)</th>
<th>Campaign (51 - 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 – 700</td>
<td>Consumption In (Kg/MT)</td>
<td>9.70</td>
<td>8.04</td>
</tr>
<tr>
<td></td>
<td>Cost In Rs/MT</td>
<td>299.00</td>
<td>252.00</td>
</tr>
<tr>
<td>700 – 800</td>
<td>Consumption In (Kg/MT)</td>
<td>9.44</td>
<td>8.23</td>
</tr>
<tr>
<td></td>
<td>Cost In Rs/MT</td>
<td>282.00</td>
<td>259.00</td>
</tr>
<tr>
<td>800 – 860</td>
<td>Consumption In (Kg/MT)</td>
<td>10.25</td>
<td>9.10</td>
</tr>
<tr>
<td></td>
<td>Cost In Rs/MT</td>
<td>304.00</td>
<td>273.00</td>
</tr>
<tr>
<td>860 – 920</td>
<td>Consumption In (Kg/MT)</td>
<td>9.41</td>
<td>7.39</td>
</tr>
<tr>
<td></td>
<td>Cost In Rs/MT</td>
<td>276.00</td>
<td>226.00</td>
</tr>
</tbody>
</table>
The above data shows how by systematically controlling the external factors as well as process related factors the total refractory consumption in EOF could be reduced by 2.4 Kg per ton and the EOF life could be increased from 700 to above 900 heats per campaign.

From the above experiments, it was found that implementation of proper “catch carbon” process is the key control point during steel processing to achieve improvements with regard to liquid metal yield, blowing time and refractory consumption. The external factors were also controlled to achieve the above results. The main challenge for improving the productivity and reducing the processing cost was to master the technique of “catch carbon” in the EOF. The catch carbon process was implemented very effectively in the 45 MT EOF at SISCOL, which would be discussed in more details in the subsequent chapter as this is the main area around which research has been carried out. With good control of catch carbon process, the overall cost comes down and productivity improves as shown in Figures 6.1, 6.2 and 6.3 above. Effective control of catch carbon in EOF is a very strong point in favour of EOF when compared to LD converters. From the above it is very clear that EOF being new technology, there is very good scope for quantum improvements. However, EAF and LD being matured technologies, as stated by John E Bonestell et al (1989), there is little opportunity for further break through that can substantially reduce operating costs. From the above results in the EOF, it is very clear that through systematic approach it is possible to cut down the cost of production and be competitive with the other routes of steel making.