Lecture 16
Furnace: Type and classification

Content of lecture

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What are the components of a furnace?

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Issues in Furnace design

Key words: Matte smelter, blast furnace, heat treatment, fossil fuel

What is a furnace?

A furnace is essentially a thermal enclosure and is employed to process raw materials at high temperatures both in solid state and liquid state. Several industries like iron and steel making, non ferrous metals production, glass making, manufacturing, ceramic processing, calcination in cement production etc. employ furnace. The principle objectives are

a) To utilize heat efficiently so that losses are minimum, and

b) To handle the different phases (solid, liquid or gaseous) moving at different velocities for different times and temperatures such that erosion and corrosion of the refractory are minimum.

What are the components of a furnace?

The principle components are

i. Source of energy
a) **Fossil fuel:** For fossil fuel one requires burner for efficient mixing of fuel and air. Arrangement of burner is important.

b) **Electric energy:** Resistance heating, induction heating or arc heating.

c) **Chemical energy:** Exothermic reactions

ii. **Suitable refractory material:** Refractory design is important. Thermal enclosure of the furnace is designed and constructed keeping in view the requirements. For example refractory facing the thermal enclosure must have high refactoriness, chemically inert etc. Whereas refractory facing the surrounding must have low thermal conductivity to minimize heat losses.

iii. **Heat exchanger:** Heat exchanger is becoming now as part of the fossil fuel fired furnaces in order to recover and reuse the heat of POC. Heat of POC can be used either external to furnace by installing a heat exchanger or internally by recirculation the POC within the furnace.

iv. **Instrumentation and control:** Furnaces are equipped with POC analyzer and temperature control.

**Furnaces and their applications in high temperature industries:**

Furnaces are used for wide variety of processing of raw materials to finished products in several industries. Broadly they are used either for physical processing or for chemical processing of raw materials. In the physical processing the state of the reactants remains unchanged, whereas in the chemical processing state of the reactants changes either to liquid or gas. In the table given below some applications of furnaces for physical and chemical processing are given (the reader may go through detailed description in order to appreciate the requirement of the design of thermal enclosure, i.e. furnace):

**PHYSICAL PROCESSING**
<table>
<thead>
<tr>
<th>Unit process</th>
<th>Purpose</th>
<th>Energy source</th>
<th>Temperature in °C</th>
<th>Type of furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonization</td>
<td>Conversion of coal to coke</td>
<td>Indirect heating by burning fuel</td>
<td>≈ 1000 to 1200</td>
<td>Coke oven</td>
</tr>
<tr>
<td>Calcination</td>
<td>Removal of CO₂ from CaCO₃ for cement production</td>
<td>Fossil fuel</td>
<td>≈ 1200</td>
<td>Rotary kiln</td>
</tr>
<tr>
<td></td>
<td>Production of anhydrous alumina for electrolysis</td>
<td>Fossil fuel</td>
<td>≈ 1300</td>
<td>Rotary kiln</td>
</tr>
<tr>
<td>Roasting</td>
<td>To convert sulphide into oxide partially or completely</td>
<td>Chemical + Fossil fuel</td>
<td>≈ 900</td>
<td>Multiple hearth furnace, Fluid bed roaster, etc</td>
</tr>
<tr>
<td>Heating</td>
<td>To eliminate segregation</td>
<td>Mostly oil and gas fired</td>
<td>Below the melting points of materials</td>
<td>Batch type or continuous type</td>
</tr>
<tr>
<td></td>
<td>To perform hot working</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To perform heat treatment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sintering</td>
<td>To produce compacts of particles</td>
<td>Fossil or electric</td>
<td>Below the melting point</td>
<td>Sintering furnaces</td>
</tr>
</tbody>
</table>

**CHEMICAL PROCESSING**

<table>
<thead>
<tr>
<th>Unit process</th>
<th>Purpose</th>
<th>Energy source</th>
<th>Temperature in °C</th>
<th>Type of furnace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrolysis of molten salt</td>
<td>To produce Al,Mg and Na</td>
<td>Electric energy</td>
<td>700 to 900</td>
<td>Hall-Heroult cell, Hall-Heroult furnace</td>
</tr>
<tr>
<td>Refining</td>
<td>To produce steel</td>
<td>Chemical and electric</td>
<td>1600</td>
<td>LD Converter, Electric furnace</td>
</tr>
<tr>
<td>Melting</td>
<td>To produce castings of metals and alloys</td>
<td>Electric and fossil fuel</td>
<td>Above the melting points of respective metal and alloy</td>
<td>Induction furnace, reverberatory furnace and melting furnace</td>
</tr>
<tr>
<td>Matte smelting</td>
<td>To produce matte</td>
<td>Chemical and fossil fuel</td>
<td>≈1200</td>
<td>Flash smelter, Reverberatory smelter</td>
</tr>
</tbody>
</table>
| Reduction smelting | i) To produce hot metal  
ii) To produce lead and  
iii) To produce Zinc | Chemical and fossil fuel  
Chemical and fossil fuel | ≈1700 to 1800 at the tuyere in all the cases | Iron blast furnace  
Lead blast furnace and  
Zn blast furnace |
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Converting</td>
<td>To produce copper from matte</td>
<td>Chemical energy</td>
<td>1100 to 1200</td>
<td>Side blown converter</td>
</tr>
</tbody>
</table>

**Issues in Furnace design**

1) Source of energy in processing of raw materials is fossil fuel in most cases. Even if electric energy is used, it is also derived from fossil fuels. Thus energy efficient design of thermal enclosure is important; particularly heat losses should be as minimal as possible.

2) In chemical processing, fluid flow is important. Liquid and gases are flowing at high temperature so erosion and corrosion of the refractory is important. In addition, fluid flow also influences the rates of heat and mass transfer. The dead zones (dead zones are those areas in which no movement of solid and liquid takes place) should be avoided while designing the furnace chamber.

3) Atmosphere in the furnace is also important to avoid oxidation of the material being heated.

4) Control of furnace temperature is also an important issue. Overheating and under-heating lead to inefficient utilization of fuel and also overheating or under-heating of material. Furnace should be equipped with temperature measurement and control devices.

5) Furnaces are both batch and continuous type. In the continuous type for example in heating of ferrous material for hot working, the furnace chamber consists of preheating, heating and soaking zones. The material enters through the preheating zone and exits the soaking zone for rolling. But the flow of products of combustion is in the reverse direction. Furnace design is recuperative type in that material exits at the desired temperature from the soaking zone and the products of combustion...
discharge the preheating zone at the lowest possible temperature. Different types of continuous furnaces are in use, like walking beam type, pusher type, roller hearth type, screw conveyor type etc.

6) In the batch furnaces, the load is heated for the fixed time and then discharged from the furnace. There are different types of batch furnaces like box type, integral quench type, pit type and car bottom type.

6) In many cases the furnace is equipped with either external heat recovery system or internal heat recovery system. In the external heat recovery system a heat exchanger like recuperator is installed outside the furnace. Here heat exchanger must be integrated with the furnace operation. In the internal heat recovery the products of combustion are recirculated in the furnace itself so that flame temperature is somewhat lowered. The objective is to reduce the NOx formation.

7) The products of combustion are moving at high speeds in the furnace. The flow of products of combustion is important to obtain rapid heat transfer and minimum thermal gradient.

Source: George E. Totten and M.A.H. Howes: Steel heat treatment handbook

P. Mullinger and B. Jenkins: Industrial and process furnaces