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SMELTING

Smelting is a process of applying heat to ore in order to extract a base metal from its ore.

- Used in extraction of many metals.
  Ex: silver, iron, copper etc.

- Heat and reducing agent used for decomposing ore.

- Reducing agent is the common source of carbon.
TYPES OF SMELTING:

- Matte Smelting
- Reduction Smelting
MATTE SMELTING

- Involves the use of sulphidic sources of metals with flux.
- No reducing agent used.
- Carried out in reverberatory furnace or flash smelter.
MATTE SMELTING

Sulphidic source concentrate + flux = matte + slag + gases

- Example: smelting of Cu or Ni ore

Molten mixture of sulphide

The gangue associated with starting sources
REDUCTION SMELTING

- Ore is reduced by carbon in presence of flux to give molten metal and slag.

- Carried out in blast or electric furnace.

\[
\text{Mineral} + \text{reducing agent} + \text{flux} = \text{metal} + \text{slag} + \text{gases}
\]

- Example blast smelting of iron
SMELTING OF IRON
REDUCTION

Ore, coke, limestone

Blast Furnace

Used for smelting

Hot air
Slag out

Molten metal out
\[ 2C + O_2 \rightarrow 2CO \]
\[ Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2 \]
\[ CaCO_3 \rightarrow CaO + CO_2 \]
\[ CaO + SiO_2 \rightarrow CaSiO_3 \]
PROCESS INVOLVED DURING SMELTING

- Burning of fuel which produces carbon monoxide.

- Carbon monoxide reduces hematite (Fe$_2$O$_3$) to iron in case iron ore smelting.

- Limestone is decomposed and produces lime (CaO).

- This lime reacts with impurities like sand and thus impurities are reduced.

- Thus crude iron from hematite ore obtained.
REDUCTION

- Final, high-temperature step in smelting - oxide becomes the elemental metal.
- A reducing environment (often provided by carbon monoxide, made by incomplete combustion in an air-starved furnace) pulls the final oxygen atoms from the raw metal.
- The required temperature varies over a very large range, both in absolute terms and in terms of the melting point of the base metal.
- Generally it refers to reduction of metal oxide to metal by carbon being the most common reducing agent. (Carbothermic reduction)
- The lower oxide (CO) becomes more stable at higher
• Carbon occupies a unique position as a reducing agent because of its easy availability and low cost. Also it forms two volatile oxides, viz. CO and CO$_2$ which are automatically eliminated from the system.

• Reduction of metal oxide by carbon is represented by the following equations:

\[
\text{MO(s,l) + C(s) = M(s,l) + CO(g)}
\]

\[
\text{MO(s,l) + CO(g) = M(s,l) + CO}_2\text{(g)}
\]

Example of carothermal reductions are:

\[
\text{FeO + C = Fe + CO}
\]

\[
\text{FeO + CO = Fe + CO}_2
\]
METALLOTHERMIC REDUCTION:

- A compound can also be reduced by metallothermic reduction process, in which aluminium or silicon is used as reducing agent.
- These metal combine with oxygen to produce most stable oxides.
- The reduction of Fe$_2$O$_3$ by aluminium is the basis of highly exothermic reaction used in joining process called Thermit Welding. The reaction is:
  \[
  \text{Fe}_2\text{O}_3(s) + 2\text{Al}(s) = \text{Al}_2\text{O}_3(l) + 2\text{Fe}(l)
  \]
- Many oxides can be reduced by calcium also because calcium forms a stable oxide, CaO. Reactions in such cases would be called calciothermic reduction.
REDUCTION OF HALIDE:

- Many metal halides can also be reduced by other metals which form relatively more stable halides. Generally, magnesium, calcium, sodium etc. are used as the reducing agents. The reaction may be represented as:

  \[ M'X_n + M' = M'X_n + M \]

  Where, M and M' are metals, and X is a halogen, usually chlorine.

- Reduction of halides by magnesium is known as the **kroll's process**.

- The reaction for titanium production by this process is written as:

  \[ TiCl_4 + 2 \text{Mg} = 2\text{MgCl}_2 + \text{Ti} \]
DIRECT REDUCTION OF IRON ORE

This process can be divided roughly into two categories:

- Gas-based
- Coal-based

Direct reduction processes were developed to overcome the difficulties of conventional blast furnaces. It is comparatively energy efficient. The initial capital investment and operating costs of direct reduction plants are lower than integrated steel plant and are more suitable for developing countries where supplies of high-grade coking coal are limited.
DIRECT REDUCTION OF IRON ORE IN SHAFT FURNACE:
In a DR shaft furnace, a charge of pelletized or lump iron ore is loaded into the top of the furnace and is allowed to descend, by gravity, through a reducing gas. The reducing gas, comprised of hydrogen and carbon monoxide (syngas), and obtained by the catalytic reforming of natural gas, flows upwards, through the ore bed.

A section is of sufficient length to separate the reduction section from the cooling section, allowing an independent control of both sections.

The solid product, called direct reduced iron (DRI) or reduced sponge iron, is cooled in the lower part of the furnace, down to approximately 50 °C, prior to being discharged.

The model itself is two-dimensional, asymmetrical, and steady-state. It is based on the numerical solution of local
The reduction of hematite ore to iron occurs via two intermediate oxides, namely, magnetite and wüstite (considered as \( \text{Fe}_{0.95} \text{O} \)), and by two gaseous reactants, namely, \( \text{H}_2 \) and \( \text{CO} \). The following six reduction reactions were therefore considered:

\[
\begin{align*}
3\text{Fe}_2\text{O}_3(s) + \text{H}_2(g) & \rightarrow 2\text{Fe}_3\text{O}_4(s) + \text{H}_2\text{O}(g) \\
\text{Fe}_3\text{O}_4(s) + 16\text{H}_2(g) & \rightarrow 6\text{Fe}_{0.95}\text{O}(s) + 16\text{H}_2\text{O}(g) \\
\text{Fe}_{0.95}\text{O}(s) + \text{H}_2(g) & \rightarrow 0.95\text{Fe}(s) + \text{H}_2\text{O}(g) \\
3\text{Fe}_2\text{O}_3(s) + \text{CO}(g) & \rightarrow 2\text{Fe}_3\text{O}_4(s) + \text{CO}_2(g) \\
\text{Fe}_3\text{O}_4(s) + 16\text{CO}(g) & \rightarrow 6\text{Fe}_{0.95}\text{O}(s) + 16\text{CO}_2(g) \\
\text{Fe}_{0.95}\text{O}(s) + \text{CO}(g) & \rightarrow 0.95\text{Fe}(s) + \text{CO}_2(g)
\end{align*}
\]
Methane reforming and water gas shift reactions also occur in the gas phase, based on the composition of reduction gas and temperature, through the following reactions:

\[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + 3\text{H}_2(g) \]

\[ \text{CO}(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}_2(g) + \text{H}_2(g) \]

We also considered two other side reactions that could occur in the reactor, especially where an iron layer has formed:

Methane decomposition reaction:

\[ \text{CH}_4(g) \rightleftharpoons \text{C}(s) + 2\text{H}_2(g) \]

Carbon monoxide disproportionation (inverse Boudouard reaction):

\[ 2\text{CO}(g) \rightleftharpoons \text{C}(s) + \text{CO}_2(g) \]
PROCESS USED EARLIER

- Atmospheric air is introduced into the lower portion of the furnace.
- When charge material enters the gases, the coke is preheated when it reaches the lower...
• The reaction produces a reducing gas (CO) that ascends through the furnace.
• At the furnace the reducing gas CO is preheated and it reduces the iron oxide in the charge as it goes down the furnace.
INVENTION MADE WITH SHAFT FURNACE

Besides conventional smelting operation, the invention used in association with shaft furnace is preferable since it can produce cast iron or any other metal alloys in a cost effective manner.

- Allows conservation of fine materials from top gases in the form of oxides of metals and also permits the recovery and recycling of these metal and metal oxides.
ADVANTAGES OF THE INVENTION

Method of reducing metal oxide in accordance with the invention provides advantage

- A primary molten metal of the metal oxide and gas containing CO and an additional secondary metal and oxides are produced due to the reaction of charge of a metal oxide and a reductant.
- Gas is directed upwards in shaft furnace away from the charge.
- Temperature of gas may be controlled by varying height of the charge within the shaft furnace, it can also be controlled by using a burner to heat the gas.
The gas (essentially carbon dioxide and nitrogen) is removed from the furnace.

Charge may include iron ore... it can also include agglomerates that are self-reducing, self-fluxing or both.
Process and material flow diagram of shaft furnace roasting process
ADVANTAGES OF PYROMETALLURGY

• Pyrometallurgical methods are usually cheaper and suited for large scale production.

• Reaction rates are accelerated at high temperature, small units can achieve high production rates.

• Reactions which are not thermodynamically possible at low temperature becomes possible at high temperature.

• Physical separation of product metal from the gangue is easier because at high temperatures the products get melted or vaporized.
THANK YOU