Lecture 22: Synthetic slag practice

Contents:

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Introduction

Synthetic slag practice is employed to obtain clean steels and to desulphurize molten steel. Synthetic slag practice is adopted to meet the following objectives

i)   To cover molten steel for cutting down heat losses.

ii)   To avoid reoxidation of steel from atmospheric oxygen because the molten steel transfer operations are done under atmospheric condition.

iii)   To remove inclusions from molten steel.

iv)   Using slag of desired basicity and sulphide capacity, deoxidized steel can be desulphurized to as low as 0.005%

v)   Synthetic slag practice is attractive due to low capital cost on equipment.

Desulphurization of steel

Synthetic slag practice can desulphurize steel up to 50% to 60% of original sulphur in steel. The following properties are desirable in synthetic slag:

i)   Slag should have high sulphide capacity

ii)   Basic slag is required

iii)   Slag should be fluid to obtain faster reaction rates.

iv)   Slag should not cause excessive refractory wear.

For efficient desulphurization , steel should be deoxidized and slag carry-over should be minimized. Fireclay ladles are not suitable if low sulphur steel is to be produced. Instead, dolomite or other basic refractory lined materials should be used. Argon bubbling is done.

Design of synthetic slag

The synthetic slag contains $CaO, Ca\,F_2, Al_2O_3$ and with small amount ofSiO_2. The principle component of synthetic slag is lime. Calcium fluoride increases the sulphide capacity of slag and helps fluidizing the slag. Often Al is present to deoxidize the molten steel since transfer of sulphur from molten steel to slag is followed by transfer of oxygen from slag to steel. Therefore deoxidation of steel is must for efficient

desulphurization. Typically, slag contains $45 - 55\% CaO$, $10 - 20\%\ Ca\ F_2$, $5 - 16\%\ Al$ and $0 - 5\% SiO_2$. This slag is pre fused in solid state.

Special synthetic slag can be designed for a specific purpose. For removal of oxide inclusions, a neutral slag with $CaO/SiO_2 = 1$ or 1.2 can be used, when no desulphurization is needed.

Issues related to synthetic slag practice.

Synthetic slag practice appears to be simple and not much capital investment is needed. Certain issues are:

   i.   Desulphurization may vary from one heat to other if slag carry- over from BOF/EOF is not controlled. Oxygen content of steel should be same for consistent results.
   ii. CaO is the main component. It is hygroscopic and leads to hydrogen pick up
   iii.   Argon bubbling is done to stir the bath. Temperature drop could be of the order of $10°C$ to $25°C$ for $150 - 250$ ton heat. The temperature drop is resulting from radiation heat loss from surface and heat transfer due to argon bubbling.
   iv.   The slag attacks the ladle refractory. Excessive amount of $Ca\ F_2$ results in refractory wear. Higher tap temperature increases refractory wear.

Alternative synthetic slag

A pre melted slag based on CaO and Al_2O_3 with small amount of $Ca\ F_2$ can alleviate the problem of refractory wear and hydrogen pick. Composition of CaO and Al_2O_3 can be selected so as to melt at $1400 - 1450°C$. Small amount of $Ca\ F_2$ may be added. A synthetic slag consisting of $70\%(50\% CaO + 50\%\ Al_2O_3)$, $25\%\ CaO$ and $5\% Ca\ F_2$ could be used. This remelted slag, when used for desulphurization, has been found to reduce the problems associated with pre fused slag.

Characterization of synthetic slag

An important parameter to characterize synthetic slag for its suitability to desulphurize molten steel is sulphide capacity of slag. On the basis of ionic theory, a modified sulphide capacity of slag is

$$C_s^1 = \frac{(W_s)[h_o]}{h_s} \qquad\qquad (1)$$

Where (W_s) is % sulphur in slag and h_o and h_s are henrian activity of oxygen and sulphur in steel. In terms of property of slag sulphide capacity C_s is

$$C_s = (W_s) \times \sqrt{\frac{pO_2}{pS_2}} \qquad\qquad (2)$$

Where W_s is weight percent of sulphur in slag with a gas having partial pressure of oxygen p_{O2} and p_{S2}. For a given slag, higher is the value of C_s, better is for desulphurization. C_s and C_s^1 are related with

$$\log C_s = \log C_s^1 + \frac{936}{T} - 1.375 \qquad\qquad (3)$$

At $T = 1823$ K and 1873 K, $\frac{C_s}{C_s^1} = 0.137$ and 0.133 respectively. Within the temperature range of desulphurization the ratio C_s/C_s^1 does not depend significantly on temperature. Alternatively C_s can be calculated by

$$\log C_s = 3.44(X_{CaO} + 0.1\, X_{MgO} - 0.8 X_{Al_2O_3} - X_{SiO_2}) - \frac{9894}{T} + 2.05 \qquad (4)$$

For a slag with $X_{CaO} = 0.6$ and $X_{SiO_2} = 0.4$; C_s according to equation 4 is 2.87×10^{-3} at 1873 K.

Another important parameter is partition coefficient of S at equilibrium; it is defined as

$$K_s = \frac{(W_s)}{[W_s]} = \frac{C_s^i}{[h_o]} \qquad (5)$$

h_o is activity of oxygen in steel and is determined by the amount of deoxidizer. Extent of desulphurization depends on extent of deoxidation. An aluminum killed steel can desulphurize steel much effectively that that when either $FeMn$ or $Fe\,Si$ is used to deoxidize steel

Large value of K_s ensures efficient desulphurization, also large value of K_s requires low value of h_o and high value of C_s as well. By equation 5

$$\log K_s = \log C_s^i - \log h\,[o] \qquad (6)$$

$$\log K_s = \log C_s - \frac{936}{T} + 1.375 - \log h\,[o] \qquad (7)$$

If aluminum is used to deoxidize steel, h_o in steel can be determined by

$$\log h_o = \frac{1}{3}\left[-\frac{64000}{T} + 20.57 - 2\log W_{al} + \log(a_{Al_2O_3})\right] \qquad (8)$$

Combining equations 7 and 8 we get.

$$\log K_s = \log C_s + \frac{20397}{T} + \frac{2}{3}\log[W_{Al}] + \frac{1}{3}\log(a_{Al_2O_3}) - 5.482 \qquad (9)$$

Consider a slag with $X_{CaO} = 0.65$ and $X_{Al_2O_3} = 0.35$ which is used to desulphurized steel at 1873 K. Steel has 0.01 wt % Al dissolved. Activity of Al_2O_3 is 0.38 in slag

Let us calculate K_s by equation 9.

$\log C_s$ by equation 4 $= -1.96$

$\therefore \log K_s$ by equation 9 $= 97$

References:

A.Ghosh: Secondary Steelmaking