The important role of the oxygen gun in the oxygen furnace

Oxygen Blowing Guns and their Role in Basic Oxygen Furnaces

In Basic Oxygen Furnace (BOF) steelmaking， a water-cooled lance is used to inject a high velocity (supersonic) stream of oxygen into the liquid melt pool for refining. The speed or momentum of the oxygen injection results in the penetration of the liquid slag and metal to promote oxidation reactions in a relatively small area. The speed and penetration characteristics of the oxygen jet are a function of the nozzle (lance head) design.

The top blow gun oxygen jet of a blast furnace converter is the source of oxygen input and the source of energy for stirring the metal liquid in the molten pool. The main phenomena involving the BOF converter are the formation of cavities due to the physical interaction between the oxygen jet and the liquid metal， the stirring of the liquid metal， the generation of spit and dust， and the afterburning of CO gas produced by decarburization and reaction with oxygen. In order to optimize the operation of the converter and to control the above mentioned phenomena， different devices and improvements have been made in the design and operation of the top-blow lance. Examples of these include the use of Laval nozzles capable of efficiently converting pressure energy into jet flow energy to facilitate the stirring of liquid metal， and the use of multi-hole lances to enable high speed oxygen delivery while suppressing spitting and dust generation by dispersing the oxygen jet.

With the introduction of combined blowing in the BOF converter， the role of the top blowing lance jet as a source of energy for stirring the liquid metal iron was reduced and the flexibility of design and operation was significantly improved.

The primary reason for blowing oxygen into the liquid bath is to remove carbon from the bath to endpoint specifications. As a result of oxygen blowing， the primary reaction that results is the removal of carbon from the bath to CO. This is an exothermic reaction that adds heat to the system. Small amounts of carbon dioxide (usually less than 10%) are also produced as this carbon dioxide reacts with oxygen in the converter and burns (called afterburning). Other reactions that occur as a result of oxygen blowing are the oxidation of other elements such as silicon (Si)， manganese (Mn) and phosphorus (P). These elements are oxidized and absorbed into the slag layer. These reactions are also exothermic， further contributing to the heat required for the liquid bath and raising the temperature of the bath to the desired level. The oxidation of silicon is particularly important because it occurs early in the oxygen blowing process and the resulting silica combines with the added lime to form the liquid slag. The oxidation reactions that occur due to oxygen blowing are given below. The free energy change of the reaction (given in parentheses) at 1600 degrees C is given in kcal/mol.

$C + 0.5 O_2 = Co$ (- 66)

$2CO + O_2 = 2CO_2$ (- 57.4)

$Si + O_2 = SiO_2$ (-137.5)

$Mn + 0.5 O_2 = MnO$ (-58.5)

$2P + 2.5\ O_2 = P_2O_5$ (-148.5)

The oxidation reaction occurs in the impact zone of the oxygen jet. This impact zone is called the cavity and is created by the impact of oxygen. The depression in the liquid bath is a function of the momentum or thrust of the oxygen jet and is calculated by the following equation

$$F = W\ (Ve/g)$$

where F is the force， W is the mass flow rate， Ve is the exit velocity， and g is the acceleration of gravity. The jet thrust and impact angle were optimized by designing the nozzle of the oxygen gun to achieve the desired chemical reaction and bath agitation.

The nozzle of the oxygen gun is designed for a certain oxygen flow rate， usually in N cum/min， producing a certain exit velocity (Mach number) with the required jet profile and force to penetrate the liquid slag layer and react with the liquid metal bath in the cavity region.

The high-momentum oxygen jet leaves the Laval nozzle exit at approximately twice the speed of sound. The characteristic parameter is the Mach number， which represents the ratio between the local gas velocity and the speed of sound. Due to the expansion inside the nozzle， the oxygen cools to about -100 degrees Celsius on its way to the nozzle exit， thus concentrating the cooling of the nozzle in both water and oxygen.

A Laval nozzle consists of a convergent inlet and a divergent outlet duct. The term often used is convergent-divergent (CD) nozzle. Supersonic jets are generated with convergent/divergent (Laval) nozzles. A stagnant oxygen reservoir is held at pressure， Po. The oxygen accelerates in the converging section and reaches the speed of sound (Mach number = 1) in the cylindrical throat region. The oxygen then expands in the divergent section. The expansion reduces the temperature， density and pressure of the oxygen and the velocity increases to supersonic levels (over Mach 1).

As the oxygen jet leaves the nozzle and enters the BOF converter， it spreads and decays. A supersonic core remains at a certain distance from the nozzle. The supersonic jet spreads at