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Using Oxygen Reaction as Electricity Saving in Electric Arc Furnace Steel Making

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Abstract: Reaction of Oxygen with Carbon, Silicon, Iron and many other elements is exothermic. The heat of released from these kind of reactions could help to decrease the electricity needed for fusion of iron and steel for metallurgical purposes in the electrical arc furnaces. So, we can reduce the consumption of electricity and save cost by blowing oxygen into the furnace. But, there are many problems in the procedure of the oxygen blowing. The author had a technological project for Machine Sazi Arak Company and it was also set up an oxygen blowing system and it's controlling on the 20 tons arc electrical furnace of metallurgy department. This process reduced the consumption of electricity up to 20%, by using of this theory. It increased the rate of process and the amount of production also. In this paper, the theoretical aspect of the oxygen blowing and its process in the arc electric furnaces are investigated.

Key words: Oxygen in Steel, Electric Arc Furnace, Electricity in EAF, EAF Steel Making, Steel Making

Introduction

Electric Arc Furnace (EAF) is one of the most common methods of steel making which is used in casting and rolling of steels industry. The first EAF was made in the beginning of 20th century. The major cost for steel making with EAF is electricity (About one KW/KG steel). In EAF about 60% of energy is electricity drawn. Any practical way that can make heat and help to melt steel, is useful and can reduce electricity consumption. In the last 20 years some methods are developed to reduce the cost of casting and electricity[1] .

Blowing Oxygen in molten steel releases heat, because the reaction of oxygen with carbon, silicon, iron and other metals in the melt sample is exothermic and heat will be produced. At these conditions, time of melting will be reduced and the productivity will increase. Because of heat release, the consumption of electricity will decrease as well as the electrode consumption along with refractory ware. It is very important in financial benefit when the stable capital for steel making industry has been considered. Iron and steel industry are the major users of oxygen[2]. For example the use of oxygen for steel making in EAF during 1990 to 1995 in USA has jumped twice[3,10] .Over the past 20 years, the use of oxygen in EAF steelmaking has grown considerably[3,11]. In the past when oxygen consumption of less than 300 cubic feet per ton of steel were common, lancing operations were carried out manually using a consumable pipe lance. Most modern operations now use automatic lances and most facilities now use a non-consumable, water-cooled lance for injecting oxygen into the steel. Many of these lances also have the capability to inject carbon as well[4,12].

In some European countries oxygen consumption is about 52 m^3 per each ton of steel produced[5] . In 1990-1999, the productivity of EAF world wide increased from 61 to 94 metric tons per hours. The International Iron and Steel Institute (IISI) reports, electrical-energy consumption decreased from 450 to 392 kWh/mt (kilo watts hours per metric tons). EAF tap weights rose from 86 to 110 mt. [6] .

Table 1: Oxygen requirements per NTHM [13]

REACTION	#/NTHM	% OF TOTAL
C —>CO	120	66
Si—>SiO2	17	9
Fe—>FeO (SLAG)	16	9
CO—>CO2	12	7
Fe—>FeO (FUME)	8	4
Mn, P—>MnO,P2O5	7	4
DISSOLVED OXYGEN	1	1
	181	100

Figures and Tables

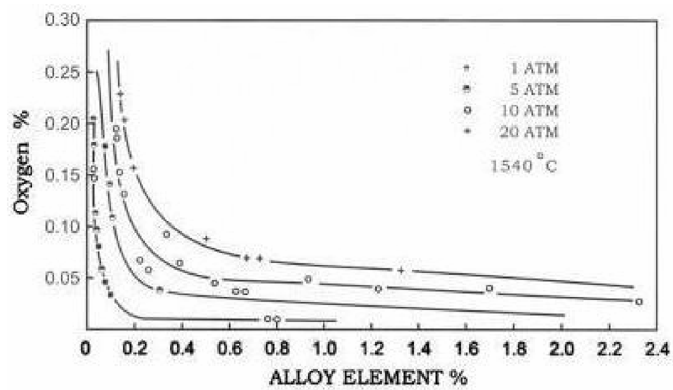

Figure 1: Oxygen- Carbon equilibrium diagram at Different partial pressure of oxygen [1]

Table 2: Heat balance per net ton of hot metal (75% hot metal in charge) [14]

HEAT AVAILABLE	Btu (000's)	HEAT REQUIRED	Btu (000's)
C —> CO	366	H.M 2400—>2900 F	220
Si —> SiO2	204	FLUXES —>2900 F	110
Mn —> MnO	60	O2 —>2900 F	120
P —>P2O5	10	HEAT LOSSES	50
Fe—>FeO	110	SCRAP —>2900 F	415
CO—>CO2	130		
SLAG FORMATION	35		
TOTAL	915		915

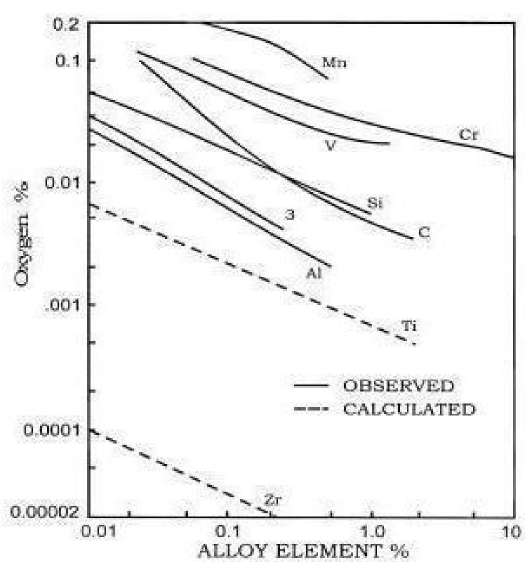

Figure 2: Deoxygenating capacity of different element [1]

Experimental :Theory

Oxygen in steel industry is important, because it has a considerable effect on the quality of cast steel parts. Solubility of oxygen in steel will in relation with the carbon content. The equilibrium oxygen and carbon at 1540 °C at different partial pressure of carbon monoxide is shown in Figure 1. This figure shows that steel with low percent of carbon has a higher solubility of oxygen[1]. Adding oxygen to molten steel can be done at a suitable temperature and percentage of oxygen since low temperatures will cause over oxidation. In this situation oxygen will react with oxygen of element, when the casting steel is in process[7].

$C + FeO = Fe + CO$

Carbon monoxide makes bubble gasses in the casting of steel. To reduce this problem, more oxygen can be added to react with carbon in the furnace. This is a good practical way to prevent reactions of making CO gasses in cast steel parts[1].

Steel at 1540 °C is completely molten but only when the flame color is yellow and the temperature is about 1595-1620 °C, the conditions are suitable for oxygen blowing.

When the temperature increases by 5 to 10 °C, oxygen blowing is stopped. At this stage a natural and final boiling (foaming) happens and at this temperature oxygen and carbon will be in equilibrium[8] .

If foaming of carbon is very high this can be controlled by adding ferromanganese. At low temperature molten metal, however in high carbon content, too much oxidation can occur. In such cases, if the temperature increases, severe foaming takes place in an uncontrollable way. Hence, slag and molten metal spark outside of furnace. Consequently the controlling of foaming is very important and can be done with the following way[9]:

1. Reaching equilibrium in the furnace that can produce clean steel[9].
2. Removing hydrogen and nitrogen gasses by carbon monoxide[9].

Deoxygenating must be considered in the process of steelmaking to stop the generation of CO, CO_2 and H_2O gasses, witch make bubbles in casting parts. This process happens according to the following reactions:

$C + 1/2\ O_2 = CO \qquad H_2 + 1/2\ O_2 = H_2O$

Deoxygenating should be completed before beginning of solidification. A high deoxygenating element is suitable for making a stable oxide in order to reduce the oxygen content of molten steel. The capacity of oxygen reduction can be determined by the amount of oxygen that element absorb. The capacity of oxygen absorbent of some elements is shown in Figure 2. In the furnaces deoxygenating is done usually by using weaker elements such as Mn and Si[1].

Control of the metallic constituents in the bath is important as it determines the properties of the final product. Usually, the melter will aim at lower levels in the bath than are specified for the final product. Oxygen reacts with aluminum, silicon and manganese to form metallic oxides, which are slag components. These metallic ions tend to react with oxygen before the carbon. They will also react with FeO resulting in a recovery of iron units to the bath. For example:

Mn + FeO = MnO + Fe[4] .

Manganese will typically be lowered to about 0.06 % in the bath[4].

Blowing oxygen into the furnace to a foam slag alleviates the problem that creates bubbles of CO2, which percolate up into foam. The arc is down in the foamy slag. Therefore, the heat is absorbed by the slag instead of moving out to the walls of the vessel and the slag heat is transferred to the molten metal[5].

The reaction of carbon with oxygen in the bath to produce CO is important as it supplies a less expensive form of energy to the bath, and performs several important refining reactions. In modern EAF operations, the combination of oxygen with carbon can supply between 30 and 40 % of the net heat input to the furnace. Evolution of carbon monoxide is very important for slag foaming. Coupled with a basic slag, CO bubbles are tapped in the slag causing it to "foam" and helping to bury the arc. This gives greatly improved thermal efficiency and allows the furnace to operate at high arc voltages even after a flat bath has been achieved. Burying the arc also helps to prevent nitrogen from being exposed to the arc where it can dissociate and enter into the steel[4].

One of the reasons of oxygen blowing into EAF is producing heat for heating or melting scrap, decarburizing of steel foaming slag and burning of carbon monoxide (CO). Other important reasons are producing chemical energy to decrease the time of melting and the electricity consumption. An increase of the use of high carbon raw materials such as pig iron, carbide etc. helps to increase productivity[3].

Various purity of oxygen is used in the steelmaking industry. For example 99.5% oxygen is used mostly in the open heart furnace and EAF. Oxygen of 95% purity is used in welding, cutting and blast furnace. In EAF, usually oxygen is used to reduce the content of P, Cr, Si, and especially carbon[9] .

The oxygen required per heat is shown in Table 1, as #/NTHM and as a percentage for the various reactions. 181 #/NTHM corresponds to about 18.6 tons per heat or 1800 scf per tapped ton. Oxygen consumption increases if end-point control is poor and reblows are necessary. Table 2 illustrates the heat balance per ton of hot metal[13].

Experimental : Procedure

In addition to theoretical study and research for this project, it is carried out in an industrial scale for 12-tons EAF at Machine Sazi Arak Company.

During the project design, manufacture, install and operation all of the tools and machines of Oxygen blowing system was, such as the oxygen line, camera system for controlling and view the surface of melt in the furnace with a monitor as well as the controllable caring oxygen blowing lance, a flow meter and controlling flow systems with display and control panel.

Result and Discussion

To reduce the carbon content of molten steel oxygen gas is blown with a lance in most of the EAF. However in this project, the main purpose is to produce heat with adding more coke to the molten steels and burned that extra coke with more oxygen. Blowing oxygen into the furnace to a foam slag alleviates the problem that creates bubbles of CO2, which percolate up into foam. The arc is down in the foamy slag. Therefore, the heat is absorbed by the slag instead of moving out to the walls of the vessel and the slag heat is transferred to the molten metal. Table 3 shows the electric power consumption in MWh for 12 tons EAF in Machine Sazi Arak Co. without extra Oxygen blowing.

After the operation and Oxygen blowing in a 12-ton EAF at Machine Sazi Arak Company, the results of electric power consumption are obtained and given in Table 4.

Table 3: Electric consumption for melting (MWh) of 12 tons EAF in Machine Sazi Arak Company, without oxygen blowing

Sample	Tap number	(MWh) Electric Consumption
1	14363	6.460
2	14361	7.370
3	14359	8.500
4	14358	9.470
5	14379	9.330
	Average	8.226

Table 4: Electric consumption (MWh) of 12 tons EAF in Machine Sazi Arak Company, with oxygen blowing

sample	Tap number	(MWh) Electric Consumptio n	M3 Oxygen consumption
1	14373	6.200	40
2	14378	6.790	40
3	14374	5.820	40
4	14383	6.330	35
5	14376	6.900	38
	Average	6.408	39

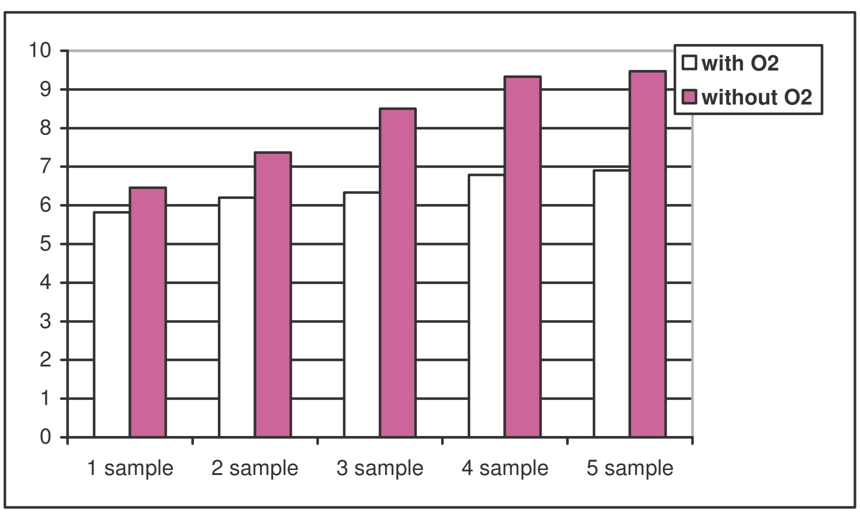

Figure 3: Electric consumption (MWh) in EAF of Machine Sazi Arak Company

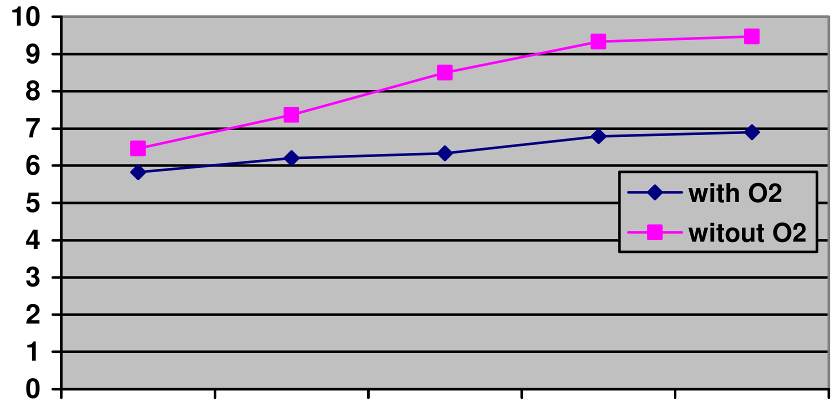

Figure 4: Electric consumption (MWh) in EAF of Machine Sazi Arak Company

Conclusion

The data of steel making melting electric power consumption in the 12-ton EAF at Machine Sazi Arak Company from table 3 and 4 are compared in Figure 3 and 4. It is obvious that, the average electric power is reduced from 8.226 MWh to 6.40 MWh or 22 %. This result conclude that it can reduce the electric power consumption of steel making in Electric Arc Furnace up to 22per cent by adding coke and oxygen bellowing to the furnace. It will save the fee of energy.

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