# MASS AND HEAT BALANCE OF STEELMAKING IN BOF AS COMPARED TO EAF PROCESSES

M.M.LOTFY[1], H.A.AHMED[2] AND F.A.ELREFAIE[3]

## ABSTRACT

Mass and energy balance equations are applied on top blowing BOF and EAF steelmaking processes to detect the energy profile of production one ton steel by both processes. An experimental data of known streams was used while the unknown were estimated. The calculated amount of scrap should be added to BOF is compared to that actually added based on experimental measurements in HADISOLB, while the calculated thermal efficiency of EAF is compared to that calculated by Pfeifer and kirschen as a check. [1,2]. The mass and energy of input and output streams of BOF are shown schematically versus EAF.

KEYWORDS: BOF, EAF, Steelmaking, Liquid Steel, Slag, Offgas, Scrap, Mass Balance, Energy Balance.

## 1. INTRODUCTION

Takeshi et.al developed a mathematical model to control the steelmaking process in EAF by computer. Their developed model depends on a specific procedure which implies monitoring the position of electrodes and the temperature of the wall of the furnace to judge the meltdown of scrap accurately, estimating decarburization and temperature increase by applying a set of equations and calculating the amount of blown oxygen, electric power by a developed control models [3].

Johanes et.al, used the principles of thermodynamics in combination with empirical equations to derive a set of equations which used to create a model simulates the EAF steelmaking process [4].

DebRoy and Robertson calculated the compositions at different depths in the melt using a model which had been developed by them [5], later they compared the prediction data which they calculate for the refining of the whole converter against experimental heat data and found a good agreement. They used a heat balance to describe the temperature of the process [6].

Wei and Zhu [7, 8] had a series of researches on both side and mixed blown converters to study the influence of the temperature of the process on decarburization implying calculating the temperature increase during the blowing time. Firstly they developed a mathematical model using heat balance to calculate the temperature increase of the process of a side blown converter [7]. Secondly they made an investigation of a reaction model for a combined top and side blown converter and concluded that the temperature approach used in the side blown converters was not suitable for application on the combined top and side blown converter [8].

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[1] Teaching assistant, Department of Metallurgy, Faculty of Engineering, Cairo University.

[2] Professor, Department of Metallurgy, Faculty of Engineering, Cairo University.

[3] Professor, Department of Metallurgy, Faculty of Engineering, Cairo University.

Memoli et.al used supersonic injection system to simulate both of decarburization and oxygen penetration in EAF [9].

Logar et.al, created two models, the first estimated the heat and mass transfer in EAF steelmaking process [10] while the second was for thermo chemistry of EAF steelmaking and they used the values predicted by their first model [11].

The purpose of this work is to develop a mathematical model to calculate the material balance and energy balance of BOF and EAF steelmaking processes, and to have a comparison between the results obtained by this model and the data available in literature which might be obtained experimentally or by using other models; this is to have the main features which leads to efficient utilization of materials and energy.

# 2. CALCULATIONS

## 2.1 Mass Balance

Calculations based on static mass balance equations are carried out on steelmaking processes of BOF and EAF steelmaking processes as a first step to estimate the unknown output streams, thereafter calculating the energy profile and drawing Sankey diagram.

### 2.1.1 Mass Balance for BOF Steelmaking

The chemical compositions of the input hot metal, the liquid steel produced at the end of oxygen blowing, and the molten slag, based on experimental measurements in the Egyptian Iron and Steel Company (HADISOLB), are tabulated in tables (1)&(2). The mass of burnt lime charged was 93.34 kg per ton hot metal, containing 75% CaO averagely [1].

Table (1). The Chemical Compositions of Hot Metal and Liquid Steel in (BOF).

| Element | Weight Percentage of Input Hot Metal | Weight Percentage of Produced Liquid Steel |
|---|---|---|
| C | 4.07 | 0.17 |
| Si | 0.77 | 0.0 |
| Mn | 2.0 | 0.34 |
| P | 0.35 | 0.05 |
| S | 0.047 | 0.02 |
| Fe | 92.763 | 99.42 |
| Total | 100 | 100 |

Table (2). The Chemical Composition of Molten Slag in (BOF).

| Compound | Weight Percentage |
|---|---|
| CaO | 44.04 |
| $SiO_2$ | 10.66 |
| MnO | 11.52 |
| $P_2O_5$ | 3.89 |
| $Fe_2O_3$ | 7.9 |
| FeO | 17.34 |
| MgO | 1.5 |
| Total | 100 |

- **Elemental Mass Balance**

Elemental mass balance has been done by applying Eq. (1) on each constituent. The calculated value of $W_{M\,(bal)}$ should be zero but if it was negative this means that this value should be added to the furnace.

$$W_{M\,(bal)} = W_{M(h)} + W_{M\,(add)} - W_{M(ST)} - W_{M(SL)} - W_{M(off)} \qquad (1)$$

- **Estimating the Mass and Composition of Offgas**

The volume and composition of offgas are calculated by applying Eq. (2) on carbon. Carbon monoxide is the solitary product due to carbon oxidation according to the thermodynamical conditions of the operation .

$$W_{CO\,(off)} = W_{C\,(oxi)}/M.Wt_{C}*M.Wt_{CO} \qquad (2)$$

### 2.1.2 Mass Balance for EAF Steelmaking

The data of both known and unknown both input and output streams of the EAF steelmaking process are shown in tables (3)&(4). The elemental Mass balance equation shown in Eq. (3) is applied on each element.

$$N_{M(scr)} + N_{M(I)} + N_{M(injO)} + N_{M(injG)} + N_{M(add)} + N_{M(cok)} = N_{M(ST)} + N_{M(SL)} + N_{M(DL)} + N_{M(offgas)} \qquad (3)$$

Table (3): The Amounts and Compositions of the Inputs of EAF

| **140 ton Steel scrap** | **40 ton DRI + 40 ton HBI 80 ton** | **5500 m$^3$ $O_2$ at P = 12 bar T = 219 K** | **500m$^3$ $CH_4$ at P = 2 bar T = 297K** | **Additions 9 ton Lime** | **Coke 5.3 ton** |
|---|---|---|---|---|---|
| Fe=98.32%<br>Al = 0.01%<br>Cu = 0.2%<br>K = 0.03%<br>C = 0.15%<br>Mn=0.55%<br>Si = 0.16%<br>P = 0.05%<br>S = 0.04%<br>Cr= 0.38%<br>Ti= 0.06%<br>V = 0.02%<br>Na= 0.04% | 93.5 % Fe<br>1.5% C<br>1.5% $SiO_2$<br>1.75%$Al_2O_3$<br>1.2% CaO<br>0.55% MgO | | | 0.508% $SO_3$<br>91.33% CaO<br>5.33% MgO<br>0.43% $SiO_2$<br>0.02% $Al_2O_3$<br>**+ 1.5 ton MgO** | 10%$SiO_2$<br>85%C |

Table (4): The Amounts and Compositions of the Outputs of EAF.

| **ML (steel) 185 ton** | **SL (slag) $X_1$ ton** | **DL (dust) $X_2$ ton** | **Off gas $X_3$ Nm$^3$** |
|---|---|---|---|
| 0.0326% C<br>0.0062% Si<br>0.0288% Mn<br>0.0081% P<br>0.15% Cu<br>0.04% S<br>1000 PPm O<br>99.74% Fe | 27.9 % CaO<br>6.7% $SiO_2$<br>56.5% FeO<br>5.9% MgO<br>3.7% $Al_2O_3$<br>2% MnO<br>0.27% $Cr_2O_3$<br>0.27% $P_2O_5$<br>0.04 $Na_2O$<br>0.04 $K_2O$<br>0.4 % $TiO_2$<br>0.15% $V_2O_5$ | | CO<br>$CO_2$<br>$N_2$<br>$O_2$<br>$H_2O$ |

### – Estimating the Mass of Molten Slag

The number of moles of calcium oxide in molten slag is calculated by applying Eq. (3) on calcium, considering that all the input calcium exists in molten slag only. The weight of slag is then calculated by applying Eq. (4). The weight of every compound is calculated by applying Eq.(5), while the number of moles of each element in molten slag is calculated by applying Eq.(6).

$$W_{(SL)} = N_{Ca\ (SL)} * M.Wt_{CaO} / \mu_{CaO\ (SL)} \quad (4)$$

$$W_{MxOy\ (SL)} = \mu_{MxOy\ (SL)} * W_{(SL)} \quad (5)$$

$$N_{M\ (SL)} = x * (W_{MxOy\ (SL)} / (x*M.Wt_{M} + y* M.Wt_{O})) \quad (6)$$

- **Estimating the Mass and Composition of Offgas**

The offgas contains carbon monoxide, carbon dioxide and water vapor. The numbers of moles of offgases are calculated by applying Eq. (3) on carbon and hydrogen. Assume that 80% of carbon in offgas exists as carbon monoxide while the balance exists as carbon dioxide. The normal volume of offgas is calculated by applying Eqs. (7 – 9).

$$V_{CO\ (offgas)} = 0.8\ N_{C\ (offgas)} *22.4 \quad (7)$$

$$V_{CO2\ (offgas)} = 0.2\ N_{C\ (offgas)} *22.4 \quad (8)$$

$$V_{H2O\ (offgas)} = 0.5\ N_{H\ (offgas)} *22.4 \quad (9)$$

- **Estimating the Mass and Composition of Dust**

The number of moles of each oxide exists in dust is calculated by applying Eq.(3) on each element. The weight of each oxide is calculated by applying Eq. (10) while the total weight of dust is the summation of all of weights of dust oxides.

$$W_{MxOy\ (DL)}= N_{M\ (DL)} * M.Wt_{MxOy} / x \quad (10)$$

## 2.2 Heat Balance

Static energy balance calculations are carried out on BOF and EAF steelmaking processes. The main purpose is estimating the energy profile for both of BOF and EAF besides estimating the temperature of the liquid steel in BOF at the end of the blow and the amount of scrap should be added to BOF to cool the path.

### 2.2.1 Heat Balance for BOF

The reference temperature of the system is taken as the temperature of the input hot metal which is 1256$^{o}$C. All the heats of oxidation reactions and heat capacities at constant pressure ($C_p$) are assumed to be constant and independent on temperature. All thermodynamical data is taken from Ref. [12]&[13].

- **Calculating the Total Heat Input**

The total heat input is calculated by applying Eqs. (11 – 13) on reactions (1B – 14B) using values which were previously calculated by means of mass balance calculations at the end of the blow.

$$\Delta H^{o}_{(react)} = W_{Si(oxi)}* \Delta H^{o}_{(react)(Si)} + W_{Mn(oxi)}* \Delta H^{o}_{(react)(Mn)} + W_{C(oxi)}* \Delta H^{o}_{(react)(C)}+$$

$$W_{P(oxi)}* \Delta H^{o}_{(react)(P)} + W_{Fe(oxi)}* \Delta H^{o}_{(react)(Fe)}+ W_{MnO(red)} * \Delta H^{o}_{(10)}+ W_{FeO(red)} * \Delta H^{o}_{(11)} \quad (11)$$

$$\Delta H^{o}_{(sl)} = W_{SiO2\ (sl)} * \Delta H^{o}_{(8)} + W_{P2O5\ (sl)} * \Delta H^{o}_{(9)} \quad (12)$$

$$\Delta H^o_{in} = (\Delta H^o_{(react)} + \Delta H^o_{(SL)}) \tag{13}$$

- **Calculating the Sensible Heat of Liquid Steel and Molten Slag**

The sensible heat of liquid steel and molten slag is calculated by applying Eqs. (14 – 18) using values, which were previously calculated by means of mass balance calculations, at the end of the blow.

$$\Delta H^o_{in} + \Delta H^o_{out} + \Delta H^o_{loss} = 0.0 \tag{14}$$

$$\Delta H^o_{(lime)} = \Delta H^o_{MgO\ (heating)} + \Delta H^o_{CaO\ (heating)} \tag{15}$$

$$\Delta H^o_{(offgas)} = W_{CO2\ (offgas)} * \Delta H^o_{CO2\ (offgas)} + W_{CO\ (offgas)} * \Delta H^o_{CO\ (offgas)} \tag{16}$$

$$\Delta H^o_{(O2)} = W_{(O2)} * \Delta H^o_{(O2)\ (heating)} \tag{17}$$

$$\Delta H^o_{(st)} + \Delta H^o_{(sl)} = \Delta H^o_{out} - (\Delta H^o_{(offgas)} + \Delta H^o_{(lime)} + \Delta H^o_{(O2)} + \Delta H^o_{loss}) \tag{18}$$

- **Calculating the Mass of Scrap should be added**

$$\Delta H_{(red)} = \Delta T_{(red)} * (Cp_{(st)} * W_{(st)} + C_{p\ (sl)} * W_{(sl)}) \tag{19}$$

$$\Delta T_{(red)} = T_{(st)} - T_{(tap)} \tag{20}$$

$$W_{(scr)} = \Delta H_{(red)} / (C_{P\ (scr)} * (T_{(tap)} - 25)) \tag{21}$$

### 2.2.2 Heat Balance for EAF

Energy balance calculations are carried out on EAF steelmaking process using the values have been calculated by applying mass balance equations in the previous section. The reference temperature is taken as 298k, the tapping temperature of both steel and slag is taken as 1913k and the output temperature of dust and offgas is taken as 1300k. All thermodynamical data is taken from Ref. [12]&[13].

- **Calculating the input chemical energy**

The input chemical energy is calculated by summing the values of heat of reactions (1E – 9E) as shown in Eq. (22).

$$R_{tot} = \sum_{\iota=1}^{\iota=11} (N_M * R_M) \tag{22}$$

| | |
|---|---|
| $\langle Al\rangle + 0.75\{O_2\} = 0.5\langle Al_2O_3\rangle$ | $\Delta H^o_{(298K)} = -0.84$ MJ/ mol Al (1E) |
| $\langle Si\rangle + \{O_2\} = \langle SiO_2\rangle$<br>$[\underline{Si}] + \{O_2\} = (SiO_2)$ | $\Delta H^o_{(298K)} = -0.91$ MJ/ mol Si (2E)<br>$\Delta H^o_{(298K)} = -32.2$ MJ/ kg Si (2B) |
| $\langle Mn\rangle + 0.5\{O_2\} = \langle MnO\rangle$<br>$[\underline{Mn}] + 0.5\{O_2\} = (MnO)$ | $\Delta H^o_{(298K)} = -0.385$MJ/ mol Mn (3E)<br>$\Delta H^o_{(298K)} = -4.25$MJ/ kg Mn (3B) |
| $\langle Cr\rangle + 0.75\{O_2\} = 0.5\langle Cr_2O_3\rangle$ | $\Delta H^o_{(298K)} = -0.565$MJ/ mol Cr (4E) |

| | |
|---|---|
| $<V> + 1.25\{O_2\} = 0.5<V_2O_5>$ | $\Delta H^o_{(298K)}$= -0.775MJ/ mol V (5E) |
| $<Fe>+ 0.75\{O_2\} = 0.5<Fe_2O_3>$ | $\Delta H^o_{(298K)}$= - 0.41 MJ/ mol Fe (6E) |
| $<Fe>+ 0.5\{O_2\} = <FeO>$<br>$[\underline{Fe}]+ 0.5\{O_2\} = (FeO)$ | $\Delta H^o_{(298K)}$= -0.264MJ/ mol Fe (7E)<br>$\Delta H^o_{(298K)}$= -4.42MJ/ kg Fe (7B) |
| $<C>+ \{O_2\} = \{CO_2\}$<br>$\{CO\}+0.5\{O_2\} = \{CO_2\}$ | $\Delta H^o_{(298K)}$= -0.393MJ/ mol C (8E)<br>$\Delta H^o_{(298K)}$= -0.283MJ/ mol CO (8.1E) |
| $<C>+ 0.5\{O_2\} = \{CO\}$<br>$[\underline{C}]+ 0.5\{O_2\} = \{CO\}$ | $\Delta H^o_{(298K)}$= -0.11 MJ/ mol C (9E)<br>$\Delta H^o_{(298K)}$= -10.84 MJ/ kg C (9B) |
| $(MnO)+ <C>= [\underline{Mn}] + \{CO\}$ | $\Delta H^o_{(298K)}$= 3.863 MJ/ kg $MnO_{(red)}$ (10B&E) |
| $(FeO)+ <C>= [\underline{Fe}] + \{CO\}$<br>$(FeO)+ \{CO\} = [\underline{Fe}] + \{CO_2\}$ | $\Delta H^o_{(298K)}$= 2.14 MJ/ kg $FeO_{(red)}$ (11B&E)<br>$\Delta H^o_{(298K)}$= -0.5 MJ/ kg $FeO_{(red)}$ (11.1E) |
| $[\underline{P}]+ 1.25\{O_2\} = 0.5(P_2O_5)$ | $\Delta H^o_{(298K)}$= - 6.0 MJ/ kg P (12B) |
| $<CaO> + < SiO_2> = <CaSiO_3>$ | $\Delta H^o_{(298K)}$= -1.38 MJ/ kg $SiO_{2(SL)}$ (13B) |
| $3<CaO> + \{P_2O_5\} = <Ca_3P_2O_8>$ | $\Delta H^o_{(298K)}$= -11.95MJ/ kg $P_2O_{5(SL)}$ (14B) |

- **Calculating the Sensible Heat of Outputs**

The sensible heat of output streams are calculated by applying Eq. (23) or Eq. (24) on each stream. The lower limit of the integration is taken as the reference temperature (298k) while the upper limit is taken as the output temperature.

$$\Delta H_{(stream)} = N_M \int CP\,(M)dT \tag{23}$$

$$\Delta H_{(stream)} = N_{MxOy} \int CP\,(\,MxOy)dT \tag{24}$$

- **Calculating the Thermal Efficiency of EAF**

The thermal efficiency of EAF is calculated by applying Eq.(25).

$$\eta_{EAF} = \frac{\text{Enthalpy }(St+Sl)}{\text{Energy input}} \tag{25}$$

# 3. RESULTS AND DISCUSSION

## 3.1 Mass Balance

### 3.1.1 The Results of Mass Balance of BOF

The results of applying the elemental mass balance on each constituent in all input and output streams based on the experimentally measured data are shown in table (5). It is logical, based on the nature of additions, that the miss balance masses of iron, manganese, carbon and phosphorous might be added to the converter as constituents of scrap, while the miss balance masses of silicon, calcium and magnesium might be added as silicon oxide, unburned calcium carbonate and magnesium oxide as constituents of the added dolomitic lime. The corrected mass and composition of dolomitic lime might be added are shown in tables (6).

Table (5). The Miss Balance Masses of the Constituents per ton Hot Metal (BOF).

| Element | The miss Balance Mass (kg/ton Hot Metal) |
|---|---|
| Fe | – 198.87 |
| Mn | – 0.516 |
| C | – 0.37 |
| Si | – 1.65 |
| Ca | – 9.18 |
| Mg | – 1.7 |
| P | – 0.245 |

Table (6). The Corrected Mass and Composition of dolomitic lime (BOF).

| Compound | Weight (kg/ton Hot Metal) | Weight Percentage Composition |
|---|---|---|
| CaO | 70 | 70.5 |
| $CaCO_3$ | 22.95 | 23.1 |
| $SiO_2$ | 3.54 | 3.56 |
| MgO | 2.82 | 2.84 |
| Total | 99.31 | 100 |

The calculated volume of oxygen blown, based on mathematical calculations, is 57.17 $Nm^3$ per ton hot metal, while the experimentally measured volume of oxygen blown was approximately 60.6 $Nm^3$ per ton hot metal which means an error equals 5.6%. This error may be due to the following reasons: error in weighing or converter lining profile due to wear. The calculated volume of carbon monoxide produced due to carbon oxidation is 72.5 $Nm^3$/ton hot metal, while the volume of carbon dioxide formed due to the decomposition of unburned calcium carbonate added is 5.14 $Nm^3$/ton hot metal. The volume and composition of offgas is shown in table (7). The percentage of carbon dioxide would be increased due to post combustion but unfortunately it would be out of area of interest belongs our thermodynamical system [1].

Table (7). The Calculated volume and composition of offgases (BOF).

| Compound | Volume ($Nm^3$/ton Hot Metal) | Volume Percentage |
|---|---|---|
| CO | 72.5 | 93.38 |
| $CO_2$ | 5.14 | 6.62 |
| Total | 77.64 | 100 |

### 3.1.2 The Results of Mass Balance of EAF

The calculated amounts and compositions of molten slag, offgas and dust based on mass balance are shown in tables (8) and (9) respectively. The calculated masses of slag, offgas and dust based on our mathematical model are 178.4, 228.6 and 11.16kg per ton steel produced which are within range as compared to Pfeifer and Kirschen `s results [2]. The amounts of input and output streams of BOF as compared to EAF are shown schematically in Fig.1.

Table (8): The Volume and Composition of Offgas in (EAF) .

| Offgas Compound | Volume ($Nm^3$) (EAF) | Percentage Composition (EAF) |
|---|---|---|
| CO | 9143.68 | 27.8% |
| $CO_2$ | 2284.8 | 7% |
| $N_2$ | 20451.2 | 62.2% |
| $H_2O$ | 1000 | 3% |
| Total | 32879.68 | 100% |
|  | (177.7 $Nm^3$/ ton steel produced) |  |

Table (9): The Amount and Percentage Composition of Dust (EAF).

| Dust Compounds | Weight (kg) | Percentage Composition |
|---|---|---|
| FeO | 257.47 | 12.47% |
| $Fe_2O_3$ | 71.52 | 3.46% |
| $Al_2O_3$ | 204 | 9.88% |
| MnO | 263 | 12.73% |
| $Cr_2O_3$ | 689 | 33.36% |
| MgO | 452 | 21.88% |
| $Na_2p$ | 77 | 3.73% |
| $K_2O$ | 39 | 1.88% |
| $TiO_2$ | 3 | 0.145% |
| $V_2O_5$ | 9 | 0.435% |
| Total | 2065 | 100% |
| Weight of Dust per ton Steel Produced | 11.16 kg/ ton Steel Produced | |

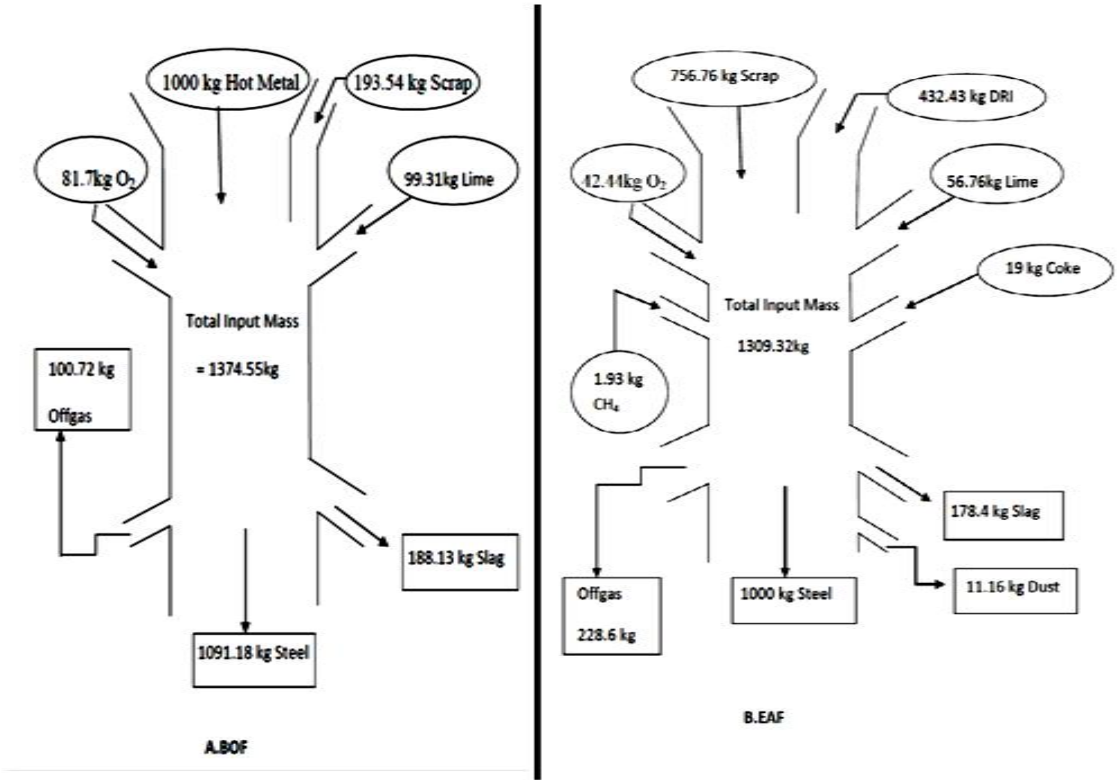

Fig.1. Schematic Diagram shows the Masses of Input and Output Streams of (A.BOF&B.EAF)

## 3.2 Heat Balance

### 3.2.1 The Results of Heat Balance of BOF

The energy profile of the top blown BOF is shown schematically in Fig.2. The temperature of liquid steel without adding scrap is calculated to be 1757.82 $^{o}$C, while the tapping temperature based on the experimental measurements was 1620$^{o}$C, hence 137.82$^{o}$C should be reduced to cool the path and in the same time to melt scrap to use that energy and enhance the metallic yield. The calculated mass of scrap to be added is 193.54 kg/ton hot metal while the amount of the scrap added based on the experimental measurements was 200 kg/ ton hot metal, so the error is 3.23% which may be due to error in weighing, effect of size of scrap and extent of mixing within the phases and between the phases. The calculated amount and composition of liquid steel with taking in consideration the calculated amount of scrap is shown in table (10) [1].

Table (10):The Composition of Liquid Steel Produced after adding Scrap (BOF).

| Element | Weight (kg) | Weight percentage |
|---|---|---|
| Fe | 1084.3 | 99.37 |
| C | 1.86 | 0.17 |
| Mn | 4.25 | 0.39 |
| P | 0.55 | 0.05 |
| S | 0.22 | 0.02 |
| Total | 1091.18 kg/ ton Hot Metal | 100 |

### 3.2.2 The Results of Heat Balance of EAF

The energy profile of EAF is shown schematically in Fig.2.The calculated thermal efficiency based on our mathematical model is 66% which is larger than the range of thermal efficiencies calculated by Pfeifer and Kirschen this difference may be due to that the measured input electrical energy in our experiment was less than the range of input electrical energies in their work; which may be due to measuring errors or the different types of electrodes used [2].

### 3.2.3 The Results of Heat Balance of BOF as Compared to EAF

The calculated total heat input is 959.28 MJ / ton steel in BOF steelmaking while the total input energy in EAF steelmaking is 2,590.77 MJ / ton steel. It is acceptable difference because the energy required in BOF is for refining only while in EAF is for melting scrap and refining besides the nature of the process carried out in EAF is more complicated than that in BOF. The chemical energy due to oxidation is the only energy source in BOF, while it represents 35.4% of the total input energy in EAF and the balance is electrical energy.

The heat lost in heating offgas formed in BOF is 172 MJ/ton steel while the heat lost in heating offgas formed in EAF is 466.2 MJ/ ton and this difference is due to the difference of reference temperatures used in calculations which is 1256$^{o}$C for BOF and 25$^{o}$C for EAF. The heat lost in heating dust formed in EAF is 9.5 MJ/ ton steel produced and it is clear that it can be neglected as compared to the total input energy.

The sensible heat of liquid steel and slag in BOF is 515 MJ/ton steel while the sensible heat of liquid steel and slag in EAF is 1,712.45 MJ/ton steel, this difference may be due to that the sensible heat is calculated based on the useful energy of melting the solid scrap, mixing ,and heating the liquid steel and slag formed. The heat lost due to cooling process in EAF is 336.4 MJ/ton steel which represents about 13% of the total input energy. Sankey diagram is drawn schematically for both of energy inputs and outputs of BOF and EAF as shown in Fig.2.

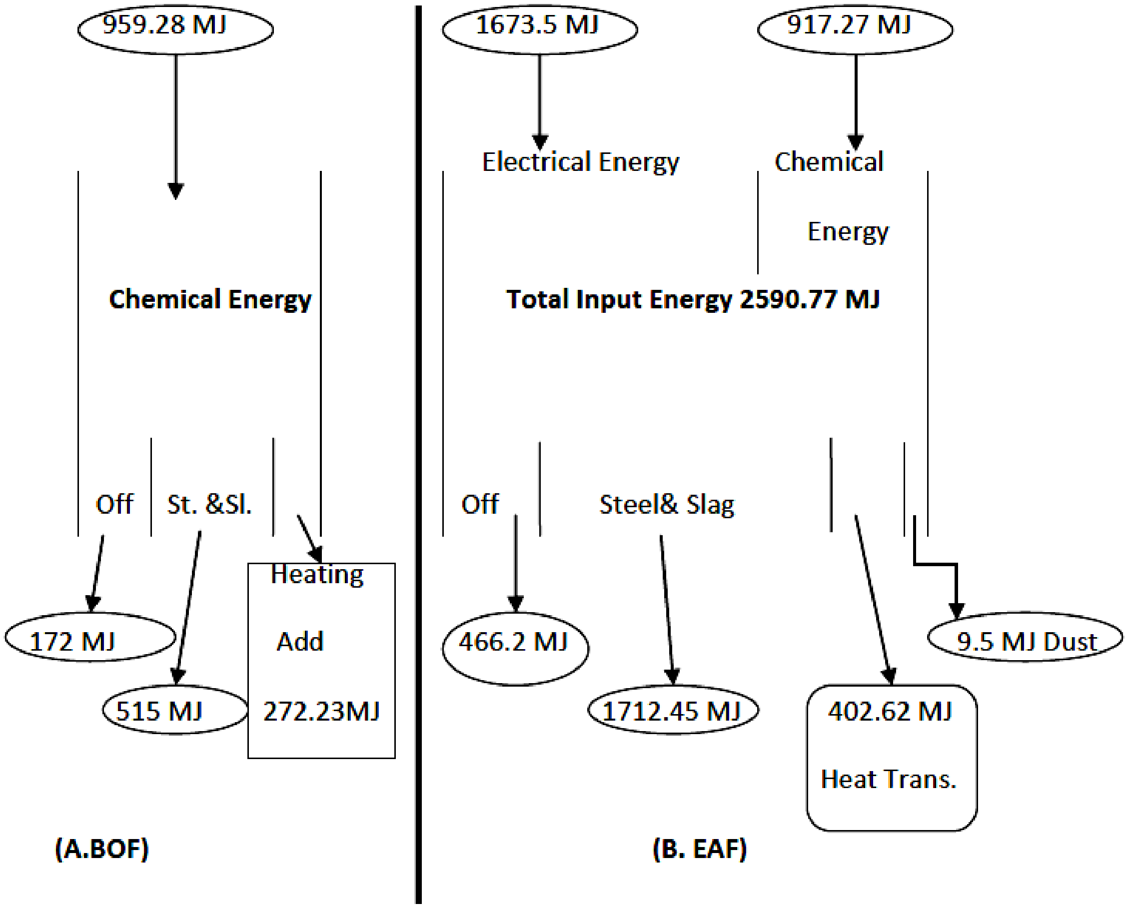

Fig.2. Sankey Diagram Shows the Input and Output Energies per ton Steel for (A.BOF&B.EAF).

## 4. CONCLUSION

Mass balance and energy balance are applied on both of top blowing BOF and EAF steelmaking processes to calculate the energy requirements for producing 1 ton steel and compare the results.

The calculated amount of scrap should be added to BOF was 193.54 kg/ton steel produced while the amount of the scrap added based on the experimental measurements was 200 kg/ ton hot metal, so the error is 3.23% which may be due to error in weighing, effect of size of scrap and extent of mixing within the phases and between the phases[1].

The calculated thermal efficiency of EAF based on our mathematical model is 66% which is larger than the range of thermal efficiencies calculated by Pfeifer and Kirschen this difference may be due to that the measured input electrical energy in our experiment was less than the range of input electrical energies in their work; which may be due to measuring errors or the different types of electrodes used [2].

The amount of slag formed per ton steel produced in EAF more slightly larger than that formed in BOF. The injected oxygen per ton steel produced in BOF is 1.76 times that injected in EAF.

The total energy required to produced 1 ton steel by BOF steelmaking process represents 37% of that required in EAF steelmaking process. The sensible heat of steel and slag in BOF steelmaking represents 30% of the sensible heat of steel and slag in EAF steelmaking process. The heat lost in heating dust is minor so it can be neglected. The total heat lost in the BOF steelmaking process represents one half of that lost in EAF steelmaking Process.

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Table (11): List of Symbols

| Symbol | Meaning | Symbol | Meaning | Symbol | Meaning |
|---|---|---|---|---|---|
| ST | Steel | M | Element M | SL | Slag |
| add | Additions to BOF or EAF | $M_xO_y$ | The oxide of element M | M.Wt | The molecular weight |
| N | No.(kmoles) | inijO2 | Injected oxygen | K | Degree Kelvin |
| h | Hot Metal | scr | Scrap | W | Weight (kg) |
| inijNG | Injected N.G | $\Delta H^o$ | Sensible Heat (MJ) | DL | Dust |
| V | Volume ($Nm^3$) | $\Delta H^o{}_R$ | Heat of Reaction (R) (kw.h/ ton steel) | μ | Fraction of an oxide in slag |
| I | DRI &HBI | Stream | Input or Output stream | $C_P$ | Heat Capacity at constant pressure |