A Comprehensive Assessment and Analysis of a Direct Reduced Iron Process

Pratyusha Nanda[1], Alok Sahai[2]

[1]Department of Management Studies, Sri Sri University, Bidyadharpur, Arilo, Ward No. 3, Cuttack, Odisha, India – 754 006
Email: *pr_nanda[at]yahoo.com*

[2]Department of Management Studies, Sri Sri University, Bidyadharpur, Arilo, Ward No. 3, Cuttack, Odisha, India – 754 006
Email: *alok.s[at]srisriuniversity.edu.in*

Abstract: ***This particular study has been undertaken to quantity the Mass of material input to the rotary kiln of the Direct Reduced Iron process and the mass of output and energy associated with it. The various studies undertaken in the field reveals that the considerable quantum of mass and associated energy in the form of heat energy is not getting utilized and wasted. Today the energy market is so much volatile due to recent Ukrain war and is the need of the hour to increase focus on small improvements in improving efficiency of such processes, based on the energy assessment of the plant. This is a systematic way of assessment for taking suitable action for optimizing use of natural resources. This study is done based on real-time data analysis captured online for ensuring data quality and authenticity. For conducting such an analysis, the detailed study of the DRI process, co-relationships with all variables, energy content of various forms of coal, electricity, heat energy and power generation process was done. Further, study of accretion formation, temperature profile of the Kiln shell, dynamics of iron ore and their physical and chemical properties including the physical and chemical properties of coal, dolomite were conducted.***

Keywords: DRI, Sponge Iron, Mass balance, Heat Balance, Energy Balance etc

1. Introduction

As per the Organisation for Economic Cooperation and Development (OECD), there is a gap between the Steel production and consumption in the market, which is also continuously getting widened. Data shows that the International steelmaking capacity increased to 2452.71 Million Metric Ton in 2020, while the actual steel production decreased to 1829.11Million Metric Ton [3].Lots of actions are being initiated by Government of India by supporting the steel production either through policy intervention or through investment and subsidy to the sector. Indian National Steel Policy - 2017 envisage per capita steel consumption to be increased to 160 Kg from the then figure of about 60 Kg, by the year 2030. This is possible if the capacity is increased to 300 Mn Metric Ton. This capacity is expected to be increased not only from blast furnace route but by all the possible ways of steel making. As per the report about 80 Mn Metric Ton to be produced from DRI route alone [2]. So this indicates there exists a potential for the sector as a whole.Indian Steel Policy 2017 while aiming at projected steel capacity by 2030, also aims at reduction of CO2 reduction by 2030 from 2005 levels as per COP-25. Government India, Ministry of Steel in it's INDC (i.e. Intended Nationally Determined Contributions)envisaged reduction of CO2 emission by about 2.4 tonnes per tonne of steel in Primary steel making route and about 2.7 tonnes per tonne of steel in Secondary steel making route by the year of 2030 [2].

Induction furnace and Electric Arc furnace route of steel making through use of Sponge Iron is popular in India due to low capital cost. As per Ministry of Steel, about 60% of steel production capacity of India is from EAX and IF route, as shown in Figure 1.1.

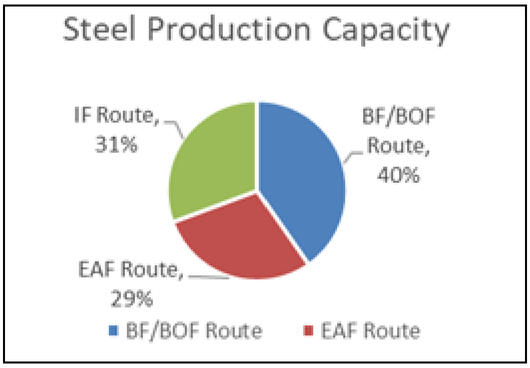

Figure 1.1: Steel Capacity as per National Steel Policy: 2017

Sponge Iron is produced when Iron Ore along with other feed materials like dolomite and coal are fed inside the DRI Kiln at a high temperature of about 1070° C [4] [1]. Here Coal serves the purpose of enhancing the temperature inside the Kiln to allow exothermic reactions to happen. The sections of the Kiln shell are termed as inlet side, pre reducing zone, reducing zone based on the steps of reactions takes place.

Coal and Air in the form of Oxygen reacts with the Iron oxides as given below [4]:

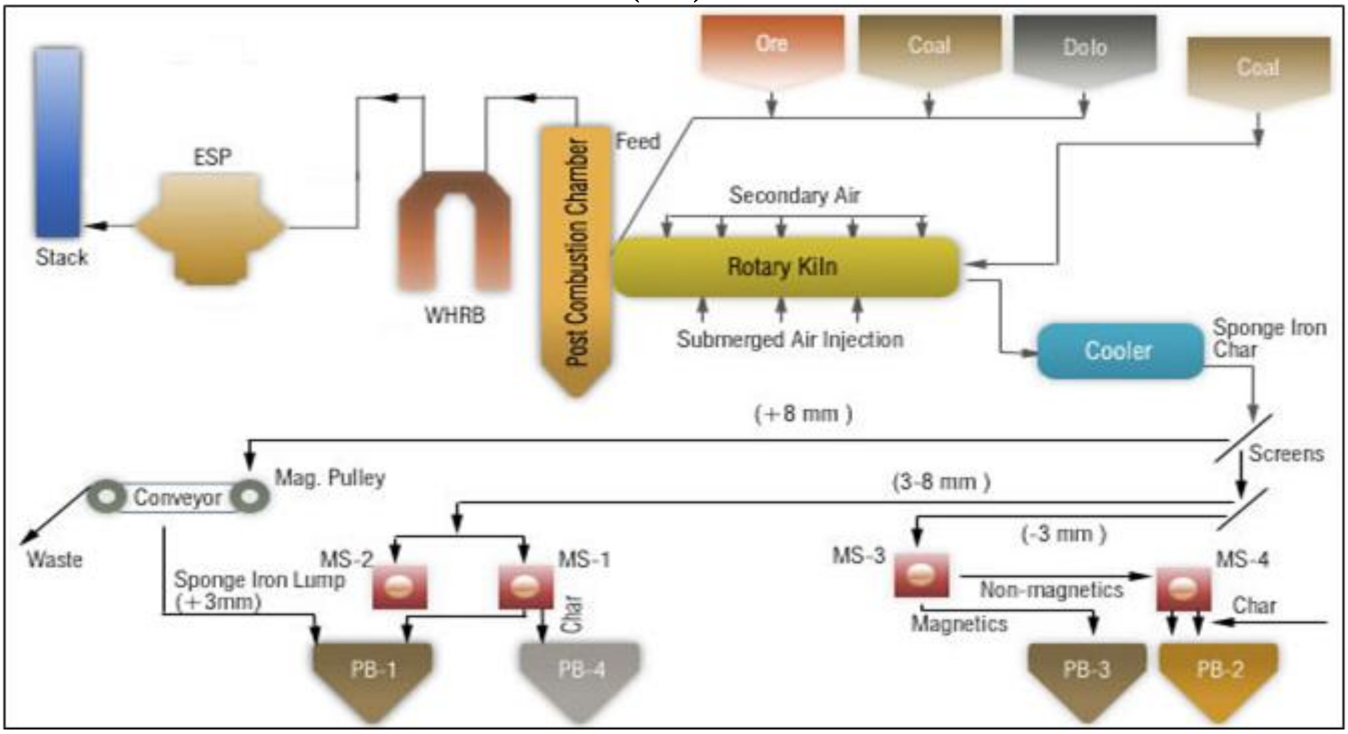

Figure 1.2 Major Equipment Layout and Process Flow in a Typical Rotary DRI Plant

$C+O_2=CO_2$ (1)
$CO2+C=2CO$ (2)
$3Fe2O3+CO=2Fe3O4+CO2$ (3)
$Fe3O4+CO=3FeO+CO2$ (4)
$FeO+CO=Fe+CO2$ (5)

The process flow diagram of any horizontal DRI plant is given in Figure 1.2. Various researchhave been made to understand factors responsible tomaintain a conducing environment for producing quality sponge iron consistently by use of multi linear regression and changing the dependent variables as per the regression derived [4].

2. Controlling Parameters

In any DRI process, the majority of the Energy consumption is from Coal only [6]. The typical DRI process has many controllable parameters for control over the quality while maintaining optimum energy usage. Control of Air flow, coal input are major factors for proper reduction of iron ore and reduce the losses in the system [4].

3. Data Collection

The data for all the input and output parameters were captured and the proximate analysis of the same were made, which are given below in Table1 to Table 4 below:

Table 1: Input and Output Materials

Iron Ore Feed Rate (T/Hr.)	Feed Coal (T/Hr.)	Inj. Coal (T/Hr.)	Dolo (T/Hr.)	Sponge Iron Product (T/Hr.)	Dola Char (T/Hr.)
27.17	6.32	9.0	5.76	16.85	3.12

Table 2 (a): Temperature Profile

TC1	TC2	TC3	TC4	TC5	TC6
899	924	994	990	1004	902

Table-2 (b): Temperature Profile

TC7	TC8	TC9	TC10	TC11
1068	1090	926	1043	971

Table-3 (a): Surface Temperature of Kiln in Deg.Cen

Part1	Part-2	Part-3	Part-4	Part-5
250.1	259	249	275	307

Table-3 (b): Surface Temperature of Kiln in Deg.Cen

Part -6	Part -7	Part -8	Part -9	Part 10	Part -11
300	279	313	259	241	249

Table 4 (a): Coal and Iron Ore Analysis (%)

Feed Coal				Injection Coal
Water Content	VM	Ash Content	F.C	Water Content
7.70	27.33	19.42	53.24	7.70

Table 4 (b): Coal and Iron Ore Analysis (%)

VM	Ash Content	F.C	FeM	FeT
25.86	18.25	55.89	83.03	88.70

4. Studies and Finding

The analysis of measured parameters shows the balance between mass and energy as given below:

4.1 Total Mass Input to the Kiln in the form of Iron Ore, Coal and Dolomite- 31592 KG/ Hr

The result of the analysis for Iron Ore balance are given below in Figure-4.1

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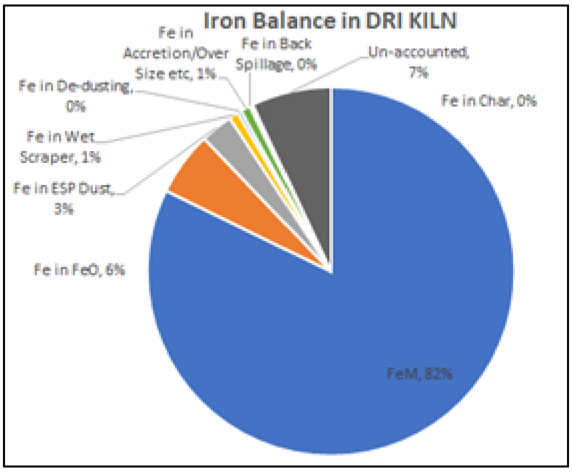

Figure 4.2: Carbon Balance

Similarly, the Carbon balance is shown in following Figure 4.2:

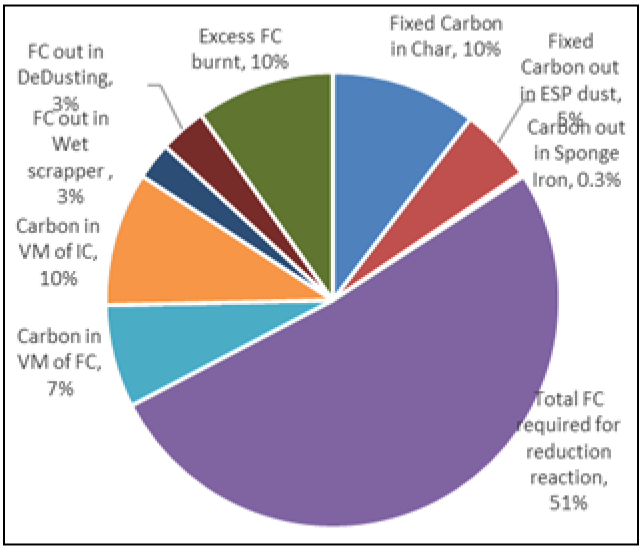

Figure 4.2: Carbon Balance

4.2 The Energy balance assessment shows the following:

Input:
Energy Input to the Kiln from Coal (Injection) - 51.75 G Cal/ Hr.
Energy Input to the Kiln from Coal (Feed) - 36.34 G Cal/ Hr.
Energy Input from Power to Kiln drives - 1.20 G Cal/ Hr
Total Energy Input - 89.29 G Cal/ Hr.

Heat Utilised and Output:
Heat utilized in the Kiln for reduction & other - 51.64 G Cal/ Hr
Heat Loss through the sensible heat of the Char - 8.29 G Cal/ Hr
Heat Loss through un-burnt Coal V.M - 16.27 G Cal/Hr
Heat lost through Flue Dust and Others - 9.50 G Cal/Hr
Un-accounted heat - 3.59 G Cal/Hr

The analysis of measured parameters shows that there is a considerable quantum of loss of heat energy in the form of radiation from Kiln shelli.e.2.94G Cal/ Hr, which is about 3%. Further the most prominent areas/ constituents of loss are through un-burnt coal VM, which is about 16.27 G Cal/ Hr, which is about 18% of the total input.

If we further analyse the data and find out the total heat energy input to Kiln and the output heat, the percentage of heat that is usefully utilised is about 58% only as shown in Figure 4.3, thereby a net loss of about 42%, which needs attention of researchers for further efficiency improvement. Considering the major loss area of unburnt carbon, research should be made for improvement to reduce such losses.

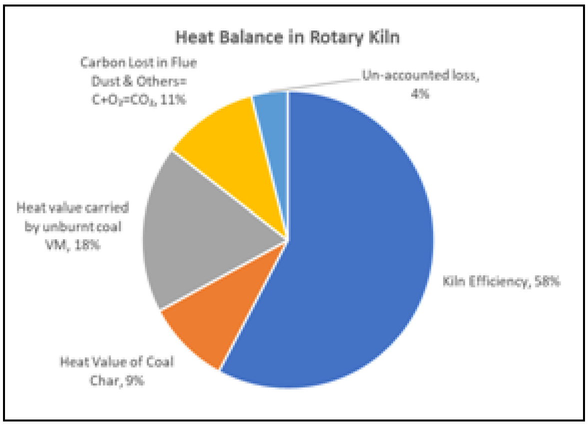

Figure 4.2: Heat/Energy Balance of DRI Process

5. Results and Discussion

The analysis shows a considerable quantity of heat energy is lost till we take up some interventions for efficiency improvement. The components of losses indicate that there is further scope available to contain the losses under (i) Heat lost through Coal Char and (ii) Total lost through unburnt carbon. Also, the focus should be there to find out more on un-accounted losses of heat, which are mostly because of leakages through Slip Seal areas and to contain them. Various researchhas been made w.r.t tapping the heat energy of the flue gas for pre-heating of the coal by using suitable heat exchanger [8], other suitable heat exchanger by tapping the heat from the stack in a integrated manner for DRI process [9], process integration, for efficiency improvement in water intake and waste gas generation [7]. There can't be any universal energy and mass balance model to arrive at the efficiency of the process [6]. Suitable mechanismare also experimented to reduce coal consumption by binding coal fines to make briquettes. Few other initiatives/experiments include power consumption reduction by optimizing aircontrol through speed control of secondary air blowers as per requirement of air at various zones rather than control of air through damper control.

6. Conclusion and Recommendations

Focus should be there to optimise coal consumption and reduction of unburnt carbon which are coming out of the Kiln in the form of ESP carbon, char in product etc.

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