American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-11, pp-150-154
www.ajer.org
Research Paper Open Access

Use of Coke Oven Gas during shutdown period of Direct Reduced Iron Plant for Steam Generation: Experimentation and Optimization

Harish C. Dalai[1], Dr. N.C.Nayak[2]

[1]*M Tech Scholar, Department of Mechanical Engineering, Indira Gandhi Institute of Technology, Sarang. India-759146,*

[2]*Reader, Department of Mechanical Engineering, Indira Gandhi Institute of Technology, Sarang. India-759146,*

Abstract: *Development of any country is largely based on its magnitude of industrial growth. Steel industries in India took a leading role in the world after mid-sixties. During the last five decades, the steel industries all over the world made considerable developments in new methods for reducing iron ore directly to metallic iron for use as commercial scrap substitute in the manufacture of steels. BSL has been producing steel and other products over last two decades and the above process is used in BSL for one decade. Direct reduction is a process, which extracts high metallic solid iron by removing oxygen from iron ore or any other iron oxides without passing through molten stage, i.e. solid state reduction. The product, so formed is known as directly reduced tron (DRI) or Sponge Iron. Due to shortage of raw material or any other problem in DRI sections, the DRI section undergoes a temporary short down. During the shutdown period the equipments tend to be idle. To keep the equipment ready for operation as well as to maintain the plants economy an alternate methodology is used in this research. Various operations are: CO gas from Coke Oven, DRI, Steam Generation, and Power Generation.*

Key words: *Coal base, direct reduced iron, alloy, coke oven gas, steam generation*

I. Introduction

Steel is an alloy of iron with varying amounts of carbon and some other elements such as Manganese, Chromium, Nickel, Molybdenum, Zirconium, Vanadium, Tungsten and so on. Currently there are over 3000 catalogued grades of steel available [1]. The global steel production touched 109. Million tons in the year 2007 making an increase of 7.6% compared with 2006.The largest steel producing countries are China, Japan and United States. The largest consumers are Singapore (1,200kg), Taiwan (over 970kg) and Korea (830kg) per capita [2]. India's steel production ranked 7th in the world in the year 2012 up from 9th in the year 2013. A look at the past production figures over the last century attests a significant shift in the geography of Steel making. In 1990, USA was producing 37% of the world steel as against 14% at present [3]. With post war industrial development Asian production now accounts for almost 40%, Europe (including the former Soviet Union) for 36% and North America for 14.5%.Since the late 1960s there has been a leveling off of the rate of growth in steel production, which is partly attributable to greater efficiency in the use of steel and less wastage [4]. Progress in steel making is also indicated from the uses of Bessemer converter at the turn of the 19th century to the introduction of oxygen conversion processes in the 1950s and continuous casting in the 1960s. Steel is one of the most recycled non-expendable industrial materials recycled. Material is used in all steel production [5]. Even after decades of use, steel is salvaged and over 40% of steel production is based on recycled material including scraps.

1.1Objectives of research

i. Efficient use of shut down kiln to avoid it's ideal condition of equipments for further operation.
ii. Use of by product gas from recovery coke oven plant to generate steam for power generation.
iii. To generate steam, it requires lesser investment and one time investment. It has less maintenance cost in future.
iv. To generate steam, no high skilled labour is required. Semi skilled labour can operate easily which is easily available.

v. To generate steam, this is the most pollution free method using by product gas of recovery coke oven plant.

vi. To generate steam, this is only one method which can continue during shout down of recovery coke oven plant, by using coke oven gas from gas holder.

II. Review of literature

Direct Reduced Iron, also called Sponge Iron, is produced by direct reduction of iron ore by a reducing gas produced from coal or natural gas. This gas is mainly Carbon Monoxide gas. The process is known as direct reduction because iron ore is reduced in solid state itself. Iron ore doesn't melt [6]. The conventional route for making steel consists of sintering or pelletization plants, coke ovens, blast furnaces, and basic oxygen furnaces. Such plants require high capital expenses and raw materials of stringent specifications. Coking coal is needed to make a coke strong enough to support the burden in the blast furnace [7]. Integrated steel plants of less than one million tons annual capacity are generally not economically viable. The coke ovens and sintering plants in an integrated steel plant are polluting and expensive units. Direct reduction, an alternative route of iron making, has been developed to overcome some of these difficulties of conventional blast furnaces [8]. DRI is successfully manufactured in various parts of the world through either natural gas or coal-based technology. Iron ore is reduced in solid state at 800 to 1,050 °C (1,472 to 1,922 °F) by coal. The specific investment and operating costs of direct reduction plants are low compared to integrated steel plants and are more suitable for many developing countries where supplies of coking coal are limited [9]. Hence, it is concluded that:-

The direct reduction is a process, which extracts high metallic solid iron by removing oxygen from iron ore or any other iron oxides without going through molten stage. It is a solid state reduction process [10]. The product, so formed is known as Directly Reduced Iron or Sponge Iron. The progressive stages of reduction of iron ore to produce Sponge Iron are as follows:

$Fe_2O_3 \longrightarrow Fe_3O_4 \longrightarrow FeO \longrightarrow Fe \longrightarrow$

Fe_2O_3 - Hematite

Fe_3O_4 -Magnetite

FeO -Wustite

III. Theory and Methodology

3.1 Bhushan Steel Plant (BSL): An Overview

Bhushan Steel Plant, biggest plant is in Odisha, it has signed an agreement with the Government of Odisha for setting up of a three million tons capacity steel plant at Meramandali in Dhenkanal district, and as part of its total integration of the steel value chain, Bhushan Steel is in the process of setting up a power plant and an advanced hot rolling plant on 3,200 acres (13 km^2) at Meramandali in Dhenkanal district near Angul, at a cost of 52 billion and its subsequent backward integration and expansion to 4 million tons.

3.2 Present financial & management status

Gross sales of Bhushan Steel grew from Rs.5 billion in 2001 to Rs.40 billion in 2007. It earned net profits of Rs.3.13 billion in 2007 and exported goods worth Rs.12.57 billion. Its exports include steel for both the automotive and white goods industry and the list of countries it is exporting to includes several developed countries.

The Khopoli plant in Maharashtra was commissioned in 2004 and has been producing colour coated sheets, high tensile steel strappings, hardened and (aluminium and zinc coated sheet) for the first time in India, along with CRCA steel to cater the need of Automobile Industry. At its Sahibabad plant in Ghaziabad, Uttar Pradesh, it has a 1700 mm mill, which produces the widest sheets in India for the automotive industry. It has highly automated systems.

At its Meramandali, Dhenkanal plant in Odisha, Bhushan Steel produces hot rolled coils and has mills for hot rolling. Construction of the first phase and second phase is completed. Bhushan Power and Steel Limited have seven plants at four locations – Chandigarh, Derabassi in Punjab, Bangihatti, near Dankuni in West Bengal, and Thelkoloi in Odisha.

IV. Data collection

Coal based Direct reduction process is classified based on the reducing agent namely solid. Most solid reduction process use non-coking coal as reducing agent due to abundantly available non-coking coal. The process proposed to be adopted is the rotary kiln proposes using Non-coking coal and iron ore [11]. Iron are undergoes the following reduction reaction in all the processes:

Fe_2O_3+ 2 CO = 2 Fe + 3 Co2

As shown in above reactions, carbon monoxide is reducing gases. These reducing gases can be obtained by controlled combustion of coal, according the boudouard reaction produces carbon monoxide.

C + O2 -- > CO2

C + Co2 --> 2CO

As maintained earlier direct reduction is the conversion of oxide feedstock to the metallic state with such conversion taking place entirely in the solid state (at no time does the material become molten). The carbon monoxide (co) produced as above reduces iron oxide to metallic iron [12].

Fe_2O_3 + 2 CO = 2 Fe + 3 Co2

However, the reduction form oxide to metal does not occur in one step, but by gradual removal of oxygen giving, rise to various intermediary oxides.

The reduction sequence can be expressed as follows:

3 Fe_2O_3 -> 2 Fe2o4 -> 6 FeO -> 6 Fe

Hematite, magnetite, wustite iron

V. Result and discussion

5.1Use of CO gas during shutdown of D.R.I.

Generally rotary Kiln is heated up by LDO (Low density oil) Firing. LDO firing system is inserted through the CB (Central Burner) Pipe. When the LDO firing system is started, LDO is burnt and give coal firing temperature. The temperature is maintained at 500-600 deg Cel. at the Kiln outlet. After attaining the temperature mentioned above the injection fines coal is started from Kiln outlet side. Then after 1-2 Hours of time the Coarse Coal is started according to temperature. It is continued according to the schedule to reach the prescribed temperature. At last feed coal is started from Kiln inlet side up to maintain the feeding temperature. Then feeding of iron ore is started and continued. LDO is firing is continuing for some hour which depends upon the experience of engineers to maintain the temperature of outlet.

All the above work which is done by LDO is can be totally replaced by CO gas in the same procedure which is an ultimate product of Coke Oven. The only change in arrangements is the diameter of CO Gas pipe will be more than the diameter of LDO pipe.

During shutdown period the raw materials i.e. the iron ore, coal & dolomite etc. are not provided to us. So the operation of rotary Kiln is stopped according to schedule for maintenance work of the equipments for few days. If the shut down period is extended for a long period of time it may hamper the smooth condition of the equipment as well as the plant’s economy. Keeping it in sight the following experimental projects can be applied.

Experimental Data:

The data is recorded for the Month of December, 2014 and provided as below:

Table 1: Recorded data for the Month of December, 2014

Date	Avg.CO gas flow (M^3/H)	Avg. Kiln outlet Temp (ºC)	Avg. Kiln inlet Temp (ºC)	Elbow duct Temp (ºC)	WHRB Temp (ºC)	Steam Generation (Ton/Hour)	Cost Benefit (Rupees) Rs.= 650x 1Ton steam
1	9800	27	27	1008	968	33	21450
2	9700	27	27	955	918	30	19500
3	9400	27	27	1008	968	33	21450
4	9500	27	27	978	938	30	19500
5	7000	27	27	965	945	32	20800
6	9700	27	27	1010	970	34	22100
7	9700	27	27	955	915	30	19500
8	9800	27	27	962	922	34	22100
9	7000	27	27	958	918	34	22100
10	9700	27	27	1008	968	33	21450
11	9600	27	27	960	920	30	19500
12	7000	27	27	990	950	31	20150
13	7000	27	27	1010	970	34	22100
14	7000	27	27	970	930	31	20150
15	9500	27	27	980	940	32	20800
16	9800	27	27	1000	960	31	20150
17	9900	27	27	1010	970	34	22100

18	10000	27	27	998	958	35	22750
19	9900	27	27	980	940	32	20800
20	9800	27	27	1010	970	34	22100
21	7000	27	27	1008	968	33	21450
22	9700	27	27	970	930	31	20150
23	10000	27	27	1000	960	35	22750
24	9900	27	27	980	940	32	20800
25	9700	27	27	1000	960	32	20800
26	7000	27	27	1010	970	34	22100
27	9900	27	27	1005	965	33	21450
28	9900	27	27	1010	970	34	22100
29	9800	27	27	1000	960	32	20800
30	9900	27	27	1008	968	33	21450
31	9900	27	27	1010	970	34	22100

Inferences from the above data table are made and shown in figure as follows:

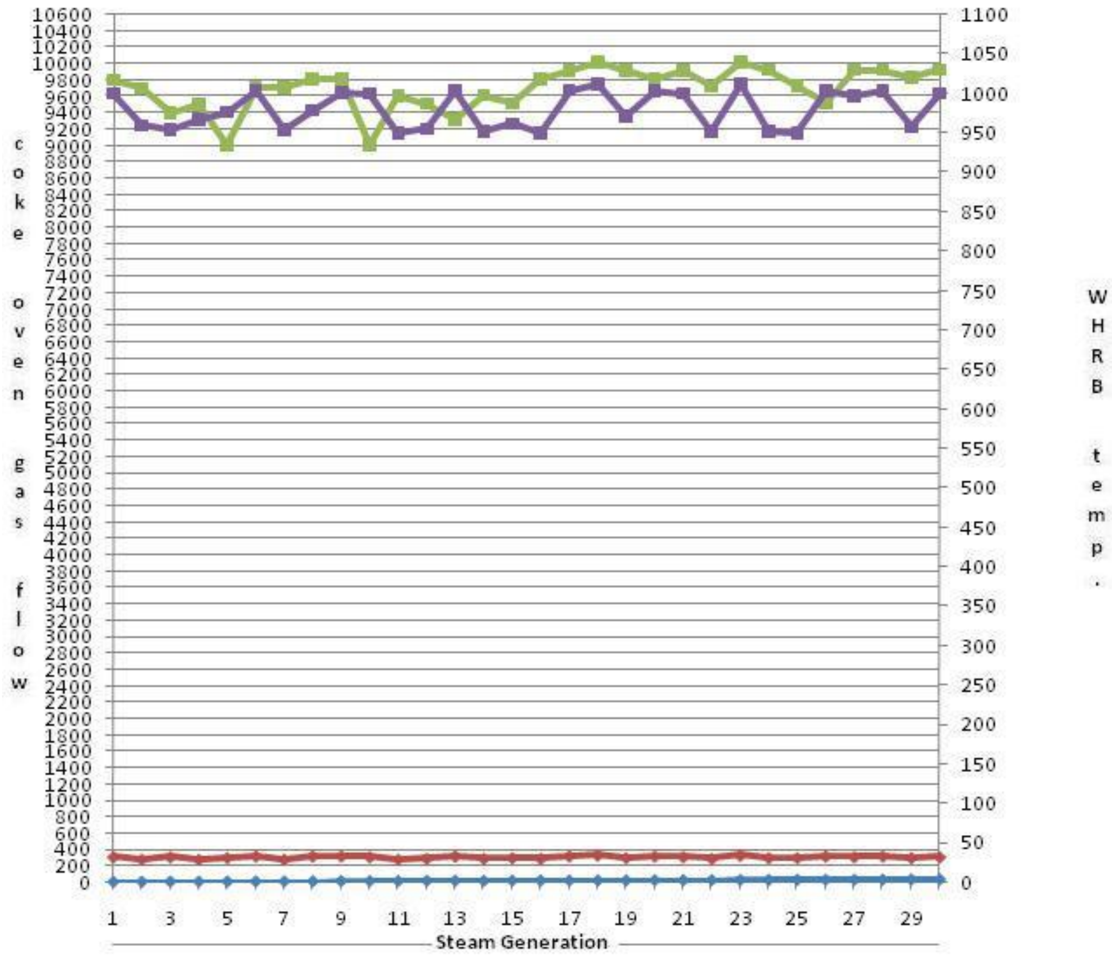

Figure 1: WHRB Temperature, CO gas flow, and steam generation for the above data table

VI. Conclusion & Scope for future work

6.1 Conclusion

From the above data it is concluded that the CO gas that we are providing in this suitable arrangement is much profitable as it is desired for the plant's economy. Thus, the above methodology fulfils the targeted objectives [13].

While summarizing the end effects it has been observed possessing the following characteristics:

i. Steam as well as power generation is possible.

ii. It is a continuous process.
iii. Zero pollution.
iv. Less manpower is required.
v. Less equipment is required.
vi. One time investment.
vii. Less maintenance is required.

6.2 Scope for future work

i. Using cold ESP dust in ABC area, the temperature may be increased in WHRB as well as steam generation.
ii. Using char (the waste or by-product of sponge iron plant), the temperature may be increased in WHRB as well as steam generation.

References

[1] Bandyopadhyay A., Ray A. K., Srivastava M. P., Subba Rao S. V. B., Prasad K. K., Bandyopadhyay P. K., Haque R. and Choudhary B. R., Selection of Coals for Rotary Kiln Sponge Iron Plant, Trans. Indian Institute of Metals, 40, (3), p. 209-218, 1987.

[2] Biswas D. K., Asthana S. R. and Rau V. G., Some Studies on Energy Savings in Sponge Iron Plants, Trans. of ASME, 125, p. 228-237, 2003.

[3] Elsenheimer G., and Serbent H., The Current Position of the SL/RN Process, Taking into Account Conditions in India, Int. Conf. on Alternative Routes on Iron and Steel under Indian Conditions, Jamshedpur, India, vol. 2, p. 105-110, 1988.

[4] Jena S. C., Patnaik N. K. and Sarangi A., Heat and Mass Balance in Rotary Kiln Sponge Iron Making, Int. Conf. Alternative Routes on Iron and Steel under Indian Conditions, Jamshedpur, Jan. 11-13, p. 59-64, 1996.

[5] P. John and B. Richelieu, "Carbon deposits: Formation, nature and characterisation," presented at the COMA/CRF Meeting, United Kingdom, 2006.

[6] V. Zymla and F. Honnart, "Coke oven carbon deposits growth and their burning off," *ISIJ International*, vol. 47, pp. 1422-1431, 2007.

[7] S. R. Turns, *An introduction to combustion concepts and applications*, 3rd ed. New York: McGraw Hill, 2012.

[8] H. S. Caram and N. R. Amundson, "Diffusion and reaction in a stagnant boundary layer about a carbon particle," *Ind. Eng. Chem., Fundam,* vol. 16, pp. 171-181, 1977.

[9] F. Yi, J. Fan, D. Li, S. Lu, and K. Luo, "Three dimensional time dependent numerical simulation of a quisecent carbon combustion in air," *J. Fuel*, vol. 90, pp. 1522-1528, 2012.

[10] T. H. Shih, W. W. Liou, A. Shabbir, Z. Yang, and J. Zhu, "A new k-e eddy-viscosity model for high reynolds number turbulent flows – model development and validation," *Computer Fluids*, vol. 23, pp. 227-238, 2012.

[11] K. K. Kuo, *Principle of combustion*. New York: John Wiley and Sons, 1986.

[12] P. Cheng, "Two-dimensional radiating gas flow by a moment method," *AIAA Journal*, vol. 2, pp. 1662-1664, 1964.

[13] T. F. Smith, Z. F. Shen, and J. N. Friedman, "Evaluation of coefficients for the weighted sum of gray gases model," *J. Heat Transfer*,vol. 104, pp. 602-608, 1982.

Harish C. Dalai is presently serving as Manager, Quality Control Department at Bhusan Steels Ltd, India. He obtained his master's degree in Mechanical Engineering from Biju Patnaik University of Technology, India. He has more than 12 years of research & industry experience in India. His research interest includes quality and performance measurement.

Dr. N C Nayak obtained his Ph. D in the department of Industrial Engineering and Management and Master's degree in Mechanical Engineering both from Indian Institute of Technology, Kharagpur. He has over 22 years of teaching, research and industry experience in India. Presently he is serving as Associate Professor of Mechanical Engineering Dept. at IGIT Saranga. He has published a number of research papers in International and National Journals and Conferences. His research interest includes operations management, industrial engineering, composites and supply chain management.