Case Studies in Thermal Engineering 6 (2015) 1–15

Contents lists available at ScienceDirect

Case Studies in Thermal Engineering

journal homepage: www.elsevier.com/locate/csite

Energy survey of the coal based sponge iron industry

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ARTICLE INFO

Article history:
Received 10 February 2015
Received in revised form
31 March 2015
Accepted 16 April 2015
Available online 20 April 2015

Keywords:
Sponge iron
Rotary kiln
Energy efficiency
Exhaust
Energy survey
Energy balance

ABSTRACT

A survey is made on a typical coal based Indian sponge iron plant of capacity 500 t/d in order to identify the largest energy losses and find ways to increase the efficiency. The required data are obtained by measurements or taken from production industries. The process efficiency is about 51.31%. The energy balances of the process show that the gap between theoretical and actual energy consumption is 45.2% and the exhausts make up the largest loss of 43.5%. A huge amount of waste gas is generated during operation and substantial part of it associated with the waste gas, remains unutilized. The energy content in the exhaust gases which is found at useful temperature can be used in three different ways: by internal use; by external energy supply; or by power generation. The four possible potential areas are identified where energy is being lost and untapped. The largest improvements would be made by design modifications adopting a novel energy conservation scenario by process integration and thereby decreasing the coal and water consumption and by decreasing the cold fresh air.

1. Introduction

Sponge iron is a metallic mass with honeycomb structure. It is produced by direct reduction of iron ore in the presence of coal and air. Since last few years, sponge iron has emerged as an alternate raw material for steel making. The Indian Government has recognized sponge iron as a vital sector for growth of Indian steel industries. At present, India is largest producer of sponge iron with a largest number of coal based sponge iron plant of total capacity around 12.8 million ton. Sponge iron manufacturing units looked profitable since beginning of the nineties. However, with the increase in the input cost of raw materials and decrease in the selling price, the industry is struggling for its survival. The lack of infusion of modern technology has also added further dimensions to the impasse. In the present situation, even though, the condition has improved considerably, sponge iron industry is passing through several problems like lack of proper integration of heat energy, obsolete technology, non-optimal operation of equipment, etc. which are making it a less profitable venture. Thus, there exists a large scope to apply modern technology to this industry and to make it more competitive by cutting down its internal losses. The present study utilizes the above opportunity effectively and puts forward suggestions to improve the energy effectiveness of the industry through design modifications.

Jena et al. [1] focused on very useful information on different parameters like waste gas, gas composition, dust loss, other losses and the thermal efficiency of the sponge iron operation The authors are in favor of the loss of heat in the waste gas can be recaptured by waste heat recovery boiler (WHRB) to generate steam to produce electricity.

Agarwal and Sood [2] proposed to utilize the untapped energy of waste gas by installing a waste heat recovery boiler

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http://dx.doi.org/10.1016/j.csite.2015.04.001
2214-157X/

Nomenclature

h_r	heat transfer coefficient from outer surface of rotary kiln to outside atmosphere, kJ/h m^2
D	diameter, m
L	length, m
m	mass flow rate, kg/h
T	temperature, °C
Q	heat load, kJ/h
C_p	specific heat capacity, J/kg K

Subscripts

m	moisture
s	iron ore
a	air
i	inlet
p	process/reaction condition
c	coal

Greek letters

Δ	difference between two parameters
λ	latent heat of vaporization, kJ/kg

(WHRB) to generate steam. The above way of heat recovery has some inherent problems such as (1) kiln operation is governed by process parameters and metallization of sponge iron and is not dependent on the quality of steam to be generated, (2) during startup the steam quality is not suitable for turbine application, (3) any interruption of kiln operation due to accretion formation, shut down or unavailability of feedstock disturbs the waste gas generation which in turn affects or stops steam generation and (4) kiln waste gas contains 35–40 g/mm^3 of dust particles. Due to the above problems WHRB were not successful in India.

Misra and Ipicol [3,4] examined the sponge iron manufacturing process and observed that a large quantity of heat is produced during operation and substantial amount of it is associated with the waste gas that remains unutilized.

According to Ruifeng et al. [5] the generating capacity of the waste heat recovery system is 4.9 MW. The overall CO_2 removal rate was as high as 78.5%.

Kumar and Khanam [6] suggested that 21.6 t/h waste gas generated during sponge iron production process.

Prasad et al. [7] suggested that by applying process integration in sponge iron process which reduces coal and water consumption by 30.5% and 72.6%, respectively resulting releases minimum waste gas to the atmosphere.

It has also been reported that significant improvements in the reduction of energy consumption were achieved in gas based processes. However, for coal based processes such savings, which can be certainly achieved, are not reported with supporting facts derived from simulation. Although, many plants have acquired workable level of operational efficiency, but from an energy point of view, a large number of such units are operating below optimum limits.

In the sponge iron process concentrated and finely divided iron ore is reduced in solid phase into sponge iron at high temperatures in rotary kiln. The process is very energy demanding. In order to identify the largest losses and to find ways to increase the efficiency, an energy survey of the sponge iron plant was carried out for a number of different production rates.

The energy usage in processing industries can be reduced by changing the process or by utilizing the surplus heat. The latter can be done in three different ways; by internal use, by external energy supply, or by power generation. The survey will be used when evaluating, for instance, whether heat content in the exhausts can be used for internal use for design modification or external energy supply or by power generation.

To estimate the fuel requirement and to find out the kiln efficiency and general thermal study of the process, a material and mass balance was made based on the data of a plant of capacity 500 t/d using SL/RN process, selected for the present investigations.

2. Process description

The process flow diagram (PFD) of a conventional coal based sponge iron plant is shown in Fig. 1. Different streams in the PFD are assigned individual number and henceforth each stream will be referred through its respective number. The stream-wise data (stream number, temperature, pressure, energy content, mass flow rate of stream and its composition) are presented in Table 1. These data are obtained directly from the plant. The kiln data were taken at production of sponge iron of capacity 453.875 t/d. The length of the kiln is 80 m and its internal and external diameters are 4.55 m and 5 m, respectively. Temperature of the solids inside the kiln is maintained at 1020 °C. Waste gas temperature at the feed end and discharge end of the kiln is 900 °C and 1170 °C. The feed rate and discharge rate of the materials are shown in Table 1 and chemistry of the materials is described through Sections 3.2.1–3.2.6. In other words these data are a priory to material and energy balance data generated through computation.

The actual process of the coal based sponge iron production is based on SL/RN process (jointly developed by the **S**teel Company of Canada, **L**urgi Chemie, **R**epublic Steel Company and **N**ational Lead Corporation in 1964), which works on direct reduction of ore. This process is adopted by worldwide conventional sponge iron industries. The production of sponge iron in the plant undertaken is started in the financial year 1988–1989. For better visualization of the process the longitudinal