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Study on applicability of biomass in iron ore sintering process

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A B S T R A C T

India as a developing economic power, has to rely much on its energy sector for growth and development. The growth is largely interlinked with the availability of energy and its judicious utilization. Also involved is the question whether the available energy is environmentally acceptable and technically viable. With the growth of country's economy, per capita power consumption has also increased resulting greater demands for power. India's power sector is mainly dependent on conventional or fossil fuels i.e., coal (60.1%) and gas (8.7%) (2015). India has around 10% of the world's coal reserves that will last for about another 30–40 years at the present consumption rate. The use of conventional fossil fuels has a negative impact on the environment due to the emission of harmful greenhouse gases. On the other hand, according to the Ministry of New and Renewable Energy (MNRE), Government of India, the country has untapped source of renewable energies such as, wind, solar power, nuclear energy and biomass. Globally, depletion of conventional fuel resources, is increasingly turning the focus on non-conventional sources of energy. The present paper is a review of biomass energy, its sources and its energy efficiency. Even though sources of biomass fuels are widely available all across India, these are still largely underutilized. According to the available statistics, in India the share of renewable energy has increased from 7.8% to 12.3% during 2012-13 and to 12.95% as on 31st March 2014, this paper also highlights the challenges and advantages of biomass energy over conventional fuels as well as utilization and applicability of biomass in sintering process as a replacement for coke.

1. Introduction

India is the fifth largest power producer in the world [1–3]. Production of energy in India has rapidly increased to 263.66 GW (as on march 2015) from 223 GW (2012-13) and 98 GW (1997-98) [1,2]. The main source of energy in India is coal and gas with a share of 60.1% and 8.7% respectively [2]. With an increasing requirement of coal from power and steel sector, load over coal production and utilization has significantly increased sharply enhancing the level of greenhouse gas emissions, thereby adversely affecting the environment. Increased production of coal is fast depleting the coal resources as well [4–54]. To overcome this ensuing crisis, the fast exhausting coal (fossil fuel) stock has to be replaced completely or partially with alternative or renewable energy sources [51]. The need of replacement has shifted focus to the search for development of a sustainable technology by utilizing renewable sources. Biomass availability in India is estimated to be about 500 MT/year [1,13,32]. According to the MNRE, currently 18 GW of energy values are getting generated from agricultural residues [13,32]. Below detailed statistics of state-wise estimated potential and installed capacity of biomass are provided in Table 1 and Fig. 1.

Biomass as a replacement for the conventional fossil fuel is gaining much attention because it is renewable and a clean source of energy [4–52]. Despite its neutrality or reasonably environment friendly nature, biomass energy has certain drawbacks as well, such as high moisture and H content, contaminated and low quality sources, low energy density, low calorific value, varying composition and properties and availability of sources etc. In order to find suitable source for generation of power, different types of biomass are characterized on the basis of their structure and chemical composition. [18]. A number of peer reviewed journal [4–54] have highlighted the efficacy of using biomass as a replacement for coal. So far, studies on the feasibility of biomass energy and availability of literature on this subject have been limited. However, in general, it is believed that biomass can optimally replace 20% of coal by sintering process. The present study focuses on utilizing biomass as a fuel source and replacing coal by carrying out sintering process on metallurgical coke as a fuel source.

Frohlichova et al., [4] and Lu et al., [5] proposed conversion to renewable energy sources like biomass and carried out a number of studies to suggest replacement of coke with biomass. For investigations, a number of biomass sources were collected. These were characterized by means of proximate and ultimate analysis as well as GCV (gross calorific value). It has been found that biomass of 1 mm-size is the most preferable, Zandi et al., [6]. Subsequently, suitability of

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Table 1
State-wise estimated and installed power generation capacity of biomass [1,32].

State	Estimated potential (MW)	Installed capacity (MW)
Uttar Pradesh	2867	776.50
Maharashtra	3137	756.90
Tamil Nadu	1520	538.70
Karnataka	1581	491.38
Andhra Pradesh	878	380.75
Chhattisgarh	236	249.90
Punjab	3472	124.50
Rajasthan	1039	91.30
Haryana	1683	45.30
Bihar	919	43.30
Gujarat	1571	30.50
West Bengal	396	26.00
Odisha	246	20.00
Madhya Pradesh	1364	16.00
Uttarakhand	24	10.00
Others	1606	NA
All India	22,539	3601

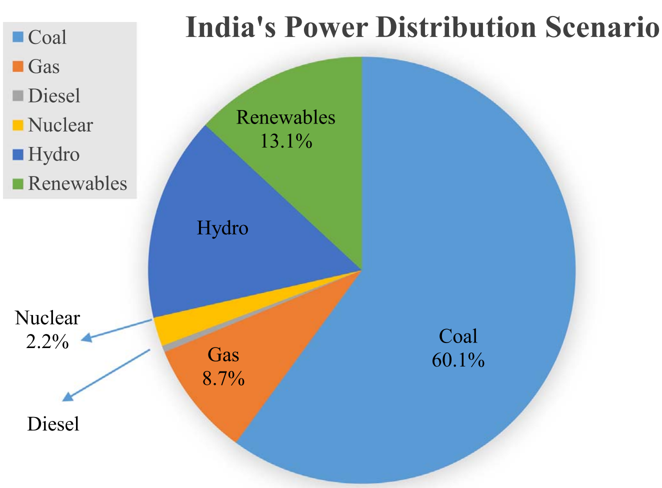

Fig. 1. Present power distribution diagram of India [2].

sources is selected on the basis of its energy value and chemical composition. That particular fuel is used in sintering experiments. The temperature profile for biomass as well as coke is achieved almost in the same process. The SO_x emission is significantly reduced in case of biomass but no reduction can be noticed as far as the NO_x emission is concerned. Ooi et al., [7] carried out the same investigation by using sunflower seed husk as a replacement for coal in the sintering process. The impact of the sintering process on the environment from the operational point of view was investigated by Abreu et al., [8] a new technique was introduced by Min et al., [9]. They used biomass in a process involving flue gas recirculation over sinter layer to minimize the heat loss. Furthermore, Ooi et al., [10] carried out sinter experiments using charcoal as a fuel to study the sintering performance. It was found that 20% charcoal with coke breeze can provide same amount of energy. Vassilev et al., [11] combined findings of various investigations on composition and properties of biomass to find out advantages and limitations of biomass. Yang et al., [12] and Lu et al., [13] studied the level of emissions (Polychlorinated dibenzo-p-dioxins and dibenzofurans) originating from the sinter plants while Ooi et al., [14] suggested remedies for mitigation of emissions.

Sintering is an energy-intensive [6,36,37,41], complex and parallel process where a number of parameters have to be taken into account. A small change in any of the parameters affect the quality of sintering. As it is a pre-processing step for charge preparation in blast furnace smelting operations [50], it should match with the overall process too. Partial replacement of coal by biomass should maintain a consistency with other parameters, such as, sinter productivity, sinter strength, fines generation, chemical composition and proper energy values.

The following challenges have to be overcome for developing biomass energy as a sustainable alternative to fossil fuels [4]:

There have to be sustainable methods to utilise renewable sources of energies and iron ore fines as well as concentrates.

A technology has to be developed which can meet the demands of iron/steel production through sintering.

A process for sintering has to be developed which is technically viable and sound as well as environmentally and economically acceptable.

The biomass energy, thus produced, has to have good quality and be available in feasible quantity. The paper is a review about the work done so far on using biomass as a fuel for iron ore sintering process. The idea is to develop a relationship between the conventional and renewable sources to optimize environmental and technological benefits.

2. Materials and methods

Biomass is a hydrocarbon material which consists of carbon, hydrogen, nitrogen, oxygen and a certain amounts of sulphur too. It also contains certain amounts of mineral matters that eventually generate ash. Biomass can be considered as a carbon- neutral source [4,11,40]. The term neutrality refers to the simultaneous formation of CO_2 through smelting and absorption by biomass.

2.1. Description of sintering process

In the process of sintering, iron ore fines convert into lumpy porous mass by incipient fusion. The term incipient fusion is used because the process takes place by partial combustion of ore with a fuel within the mass itself. The produced sinter possesses strength, permeability and fluxing agents that are beneficial to steel-making operations. It is a pre-processing step for blast furnace smelting operations. The process starts with proportioning in which raw materials (Iron values, flux and fuel) are blended carefully in a fixed proportion [9]. Usually metallurgical-grade coke is used as a fuel with a weightage of 4–5%. The proportioned material is then sent to mixing drums for granulation. Granulation [37] takes place in one or two mixing drums with addition of water and steam to help in mixing. The granulated micro-pellets are then fed to a sinter machine. Sinter machine is typically a continuous car-type furnace where each end corresponds to feeding and discharge, respectively [37]. The car consists of grates or strands connected through a belt and has a depth of 0.4–0.7 m and width of 1 m. typically, it moves at a speed of 2–3 m/min [7]. Granulated material is fed into those strands and are heated through a series of gas burners (at start point) generating carbon content to combust and derive heat from the process. Atmospheric oxygen helps in exothermal combustion resulting in heat that allows the peak temperature to reach 1300 °C [8]. A series of wind boxes are also connected with each strand that provides suction. The sinter car moves horizontally and the process takes place vertically. A process of suction draws hot air and transmits heat to downward layers of the sinter bed.

Sintering provides heat only to combust the upper layer of the sinter bed. The rest of the layers are sintered with the heat provided by suction. Suction is powered by induction draught fan connected to an electrostatic separator [10]. The waste flue gas is sucked through the draught fan and released free. At the end point, sinter cake falls from the strand through a roll breaker to annular cooler. The sintered product is cooled [41] and then transferred to the screening section where it is classified by size fraction. While −5 mm material is transferred back to the proportioning Section, +5–40 mm material is forwarded to the blast furnace operations. A schematic diagram of the sintering furnace is shown in Fig. 2.