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Prospects of Bagasse Gasification Technology for Electricity Generation in Sugar Industries in Bangladesh

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Abstract

Bangladesh is facing severe power crisis all over the country. This acute electricity crisis along with the conventional fuel crisis is affecting every sector of the country and economy is being crippled. Bagasse gasification in the sugar industries in Bangladesh could be an alternative option for electricity generation. Bagasse is the fiber left over after the juice has been squeezed out of sugarcane stalks and accounts 25% of sugar cane production. Bagasse, being a by-product of sugar production as well as of biomass origin seems to be a suitable candidate for sustainable energy production. There are 15 sugar mills in Bangladesh and sugar cane production in the fiscal year 2010-2011 was about 4.67 million tonnes and bagasse production was around 1.167 million tonnes. The potential of power generation from bagasse by gasification is around 100MWe in Bangladesh over the year. In this regards, in sugar industries, bagasse gasification for power generation for its own consumption could be an alternative option in Bangladesh and the surplus could be exported to the national grid. In this paper the prospects of bagasse gasification for power generation and the technological aspects of the gasification process as well as environmental effects have been studied.

Keywords: Bagasse, sustainable energy, gasification, sugar industry, power generation

1. Introduction

The present electricity access to people is approximately 49% in Bangladesh [1]. The major part of this electricity is delivered from natural gas. The reserve of this natural gas however is currently under threat. Government is therefore becoming desperate to think of alternatives of natural gas. In the recent years the government is allowing to produce electricity from heavy fuel oil (i.e. furnace oil) which is imported at a high rate. The installed capacity in Bangladesh as increased by roughly 3,415MW between 2009-2012 and is now about 8,535MW (December 2012) [2]. Over 70% of total primary energy consumption is covered by biomass, mainly agricultural waste and wood. Only about 6% of the entire population has access to natural gas, primarily in urban areas. Biomass fuels, such as wood, cow dung and agricultural residues are collected mainly from the local environment and have become a traded commodity as cooking fuel [3].

Biomass provides a clean renewable energy source that could dramatically improve our environment; economy and energy security [4].Biomass can be converted into gaseous and liquid fuels [5]. In Bangladesh, researchers evaluated the rate of biomass energy potential for electricity generation produced from agricultural residues. They found that the assessment of available biomass supply can vary in the range of biomass energy consumption [6].Bangladesh has strong potential for biomass gasification based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse etc. This technology can be disseminated on a larger scale for electricity generation. Bangladesh has a 15 sugar mills and most of them are situated in the north-west region where they face severe electricity crisis for production. Sugarcane is one of the largest biomass resources that can be crop residues base for electric energy. Residues from the sugarcane can be divided into three main parts: juice, fiber residues (bagasse) and sugarcane agriculture residues (tops and leaves). Sugarcane bagasse and sugarcane tops and leaves can be utilized as principal feedstock for electricity production. Some sugar factories were fitted with biomass gasifier-combined cycle systems, which can produce about 15–30 kWh per ton of sugarcane [7].

2. Bagasse in Bangladesh

Bangladesh is an agricultural country and it's economy largely depends on agriculture. About 70% people earn their livelihood by agriculture and agro-based industry. Total area of Bangladesh is about 147570 km², where the total agricultural land is about 90500km² which is 62.8% of the total area. Total arable land is 79700km² and is 55.3% of the total area [8]. Crop residues represent the non-edible plant parts which are left in the field after harvest and/or remain as byproducts after crop processing e.g. extraction or milling [9]. Crop residues are generated by agriculture production. Agricultural residues contribute significantly to the biomass sector of Bangladesh. The quantities of residues have been estimated by applying a residual factor from several studies for different agricultural crops. Straws are typically produced around 50% of the total crops production whereas rice husk produce 20% of paddy production and bagasse are produced 36% of the total sugarcane production [10].Sugarcane harvested in the year of 2011 was 116175 hector and the sugarcane production was 4.67million tones [11]. So, bagasse production counted around 1.68 million tones.

3. Characteristics of Bagasse

Proximate analysis gives information about feedstock suitability in terms of moisture content, volatile matter content and fixed carbon content. Chemical compositions of the bagasse are identified by the determination of elemental contents in the sample such as Carbon, Nitrogen, Sulfur and Hydrogen. Table 1 shows the proximate and ultimate analysis of bagasse [12].

Table 1: Proximate analysis of sugarcane bagasse

Proximate analysis	
Contents	wt%
Moisture	9.51
Volatile Matter	74.98
Fixed Carbon	13.57
Ash	1.94
Ultimate analysis	
Elements	wt%
C	43.77
H	6.83
N	-
S	-
O	47.46
Bulk density	177.65 kg/m^3
Calorific value	16.81 MJ/kg

The higher heating value (HHV) indicates the energy content of a given biomass. The typical HHV of agricultural residue ranges between 15 MJ/kg and 17 MJ/kg. Feedstock needs suitable sized 15~75 mm and dried before loading.

4. Gasification overview

Biomass gasification is a thermo-chemical conversion process in which a solid biomass fuel e.g. wood, husk, bagasse is converted into a combustible gas. In a biomass gasifier, biomass is burned in a limited amount of air. The amount of air supplied is less than the amount of air required for complete burning. This converts the biomass (which consists of carbon, hydrogen, oxygen, etc) into an inflammable mixture of gases known as producer gas/ wood gas. The producer gas consists of carbon monoxide (CO), hydrogen (H_2), and methane (CH_4), along with carbon dioxide (CO_2) and nitrogen (N_2). The nitrogen is not combustible; however, it does occupy volume & dilutes the syngas as it enters & burns in an engine. A generalized reaction describing biomass gasification is as follows [13]:

Biomass + air (or H_2O) → CO, CO_2, H_2O, H_2, CH_4 and N + tars + particulates

Gasifiers can differ in either their system construction or bio-fuels used, but generally not in the chemical reactions. Regardless of gasifier type, the bio-fuels must undergo drying, pyrolysis, oxidation, and reduction steps to convert the fuel from a solid phase into a gas phase. The gasification reaction mechanism is shown in figure 1. Classification of biomass gasifiers based on the density factor (ratio of dense biomass phase to total reactor volume) is a simple and effective method of classification. The gasifiers can be classified into a) dense phase gasifiers b) lean phase gasifiers. In lean phase gasifiers e.g. fluidized bed, the biomass occupies very little reactor volume i.e. 0.05 -0.2. Most of the gasifiers employed for decentralized applications in developing countries are dense phase reactors, mostly fixed bed reactors, they have typical density factor of 0.3 -.08 [9].

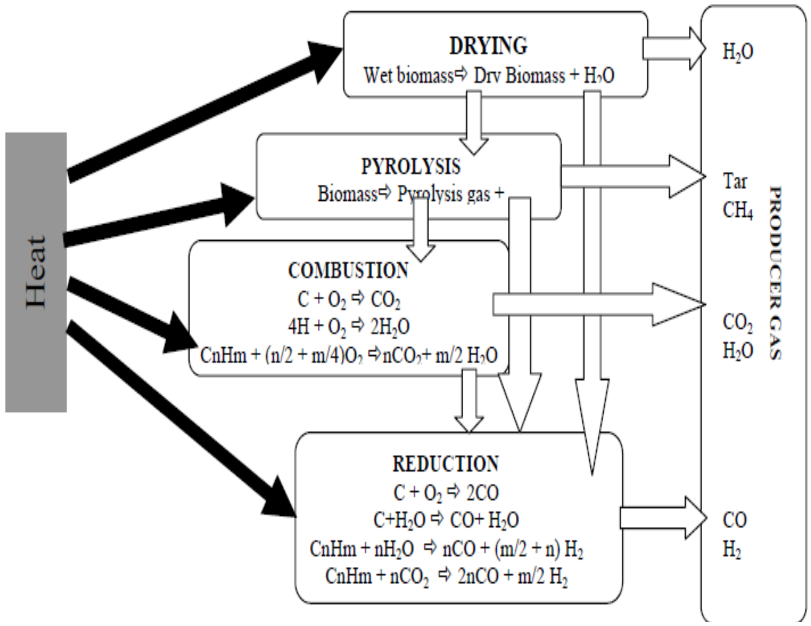


Figure 1. The reaction mechanism of biomass gasification process [14].

Fixed bed gasifier

Fixed bed gasifiers typically have a grate to support the feed material and maintain a stationary reaction zone. They are relatively easy to design and operate, and are therefore useful for small and medium scale power and thermal energy uses. The two primary types of fixed bed gasifiers are updraft and downdraft.

In a downdraft gasifier, air is introduced into a downward flowing packed bed or solid fuel stream and gas is drawn off at the bottom. The air/oxygen and fuel enter the reaction zone from above decomposing the combustion gases and burning most of the tars. Downdraft gasifier is suitable for bagasse gasification for small scale power generation for its simplicity and cost effectiveness.

In an updraft gasifier, the fuel is also fed at the top of the gasifier but the airflow is in the upward direction. As the fuel flows downward through the vessel it dries, pyrolyzes, gasifies and combusts. The main use of updraft gasifiers has been with direct use of the gas in a closely coupled boiler or furnace. Because the gas leaves this gasifier at relatively low temperatures, the process has a high thermal efficiency and, as a result, wet MSW containing 50% moisture can be gasified without any pre-drying of the waste.

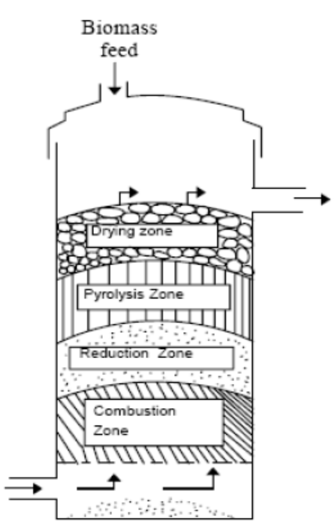


Figure 2: Updraft gasifier

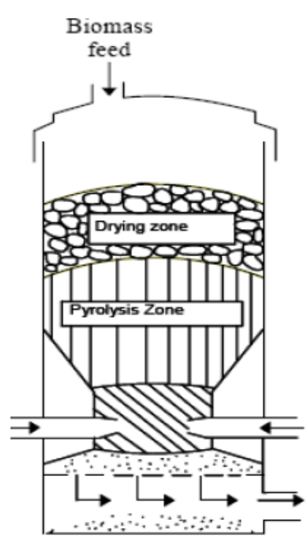


Figure 3: Downdraft gasifier

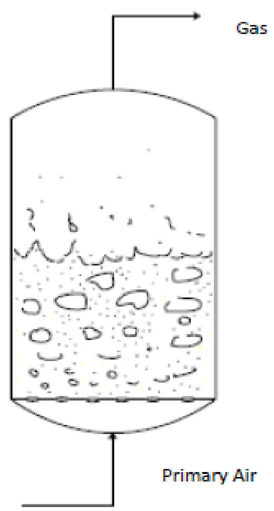
Figure 4: Cross draft gasifier

Fluidized bed gasifier

Fluidized beds are an attractive proposition for the gasification of biomass. In a fluidized bed boiler, a stream of gas (typically air or steam) is passed upward through a bed of solid fuel and material (such as coarse sand or limestone). The gas acts as the fluidizing medium and also provides the oxidant for combustion and tar cracking. Waste is introduced either on top of the bed through a feed chute or into the bed through an auger. Fluidized-beds have the advantage of extremely good mixing and high heat transfer, resulting in very uniform bed conditions and efficient reactions. Fluidized bed technology is more suitable for generators with capacities greater than 10 MW because it can be used with different fuels, requires relatively compact combustion chambers and allows for good operational control. The two main types of fluidized beds for power generation are bubbling and circulating fluidized beds.

In a Bubbling Fluidized Bed (BFB), the gas velocity must be high enough so that the solid particles, comprising the bed material, are lifted, thus expanding the bed and causing it to bubble like a liquid. As waste is introduced into the bed, most of the organics vaporize pyrolytically and are partially combusted in the bed. Typical desired operating temperatures range from 900° to 1000 °C.

A circulating fluidized bed (CFB) is differentiated from a bubbling fluid bed in that there is no distinct separation between the dense solids zone and the dilute solids zone. The capacity to process different feedstock with varying compositions and moisture contents is a major advantage in such systems



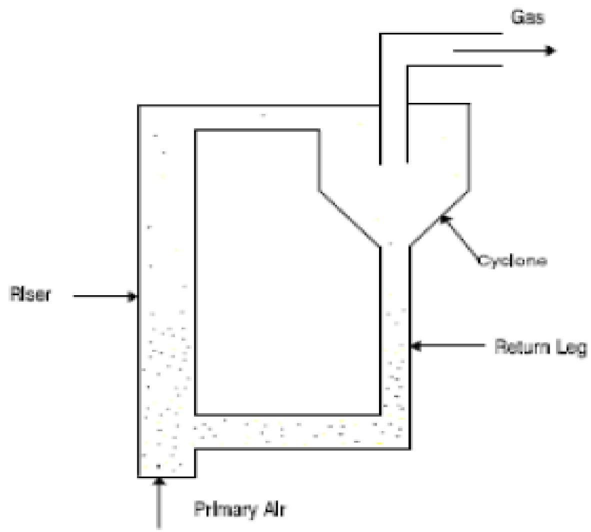


Figure 5: Bubbling fluidized bed

Figure 6: Circulating fluidized bed

Figure 2, figure 3 and figure 4 show the different type fixed bed gasifier whereas figure 5 and figure 6 present the fluidized bed gasifier [15]. Downdraft gasifier system can be chosen for developing countries perspective due to their simplicity in construction and cost competitive. Down draft gasifier produces very small amount of tar and with little treatment it can directly use to the internal combustion engine. Also, the technologies of these systems are quite matured in the world. Based on the above comparative discussions, however, a downdraft gasifier is better than an updraft gasifier system in many aspects. This gasifier has some unique advantages like suitability to small scale production (50-150kW), minimum operating labor required, exhaust type (particularly % of tar content), and easy as well as less maintenance required [15].

5. Power generation potential from bagasse in Bangladesh

Electricity generation from bagasse depends on the availability of raw materials and technology for conversion of bagasse to electricity. Gasification converts a traditional, low quality fuel to a modern day energy carrier i.e. combustible gas. Such conversion occurs at relatively high efficiencies and results in total convenience and process control. The process can be applied over a very wide range of output ratings (a few kilowatts to tens of megawatts) with only a small variation in overall efficiency and investment. Gasifiers with individual units being capable of supporting power generation at upto 500-800 kWe level; larger outputs need paralleling of more than one unit. Complete power generation systems including gasifiers, gensets, fuel handling sub-systems and grid paralleling sub-systems, as needed and effluent treatment.

Bangladesh, having about 15 sugar mills, produced around 1.68 million tons of bagasse in the year 2011 which is sufficient to produce power with minimum investment. In the north-western region, which is starved for energy, the sugar mills would be a great energy resource. This is also an advantage as all the 15 sugar-producing units were installed in the region. Gasification process is equally applicable for electricity generation and a variety of thermal applications. Raw material availability is also a concern for larger plants. The process is equally applicable for stand-alone utility and grid feeding. Almost all environmental pollution associated with biomass use can be eliminated. Various researcher shows that the downdraft gasifier is suitable for small scale bagasse gasification base power plant [15, 16]. For gasification based power plant consumption of bagasse is 2kg per kWh electricity generation [17]. On the basis of the bagasse available in Bangladesh and assuming a small fraction (~50% availability) of bagasse is available for generation in sugar industries, the possible power potential is about 50 MW.

6. Conclusion

In response to meeting the energy demand from sustainable sources, green energy technology implementation is essential. Bangladesh has a good potential form power generation from bagasse gasification and the current study indicates in 2011 the total potential of power generation from bagasse gasification has estimated around 50 MWe. There are seasonal, geographical distribution and other variations in the availability of this potential. This could help the sugar industries to be self sufficient of power generation and be able to expedite the sugar production as well. Establishment of bagasse based power plants in sugar industries will be led to an enormous change in the sugar production and rest of power to be supplied to national grid and to the local communities.

7. References

[1] http://www.energybangla.com/. Accessed on 27 May, 2013

[2] BPDB- Bangladesh Power Development Board, "Key Statistics", December, 2012, http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=5&Itemid=6, accessed on 25/04/2013.

[3] Population and housing census, 2011, http://www.bbs.gov.bd/WebTestApplication/userfiles/Image/BBS BBS/Socio_Economic.pdf

[4] Demirbas, A. Importance of biomass. *Energy sources*, 26, pp. 361-366,2004a.

[5] Bala, B. K. Renewable Energy. Agrotech *Publishing Academy*, India,2003.

[6] A.K. Hossain and O. Badr: Prospects of renewable energy utilisation for electricity generation in Bangladesh. *Journal of renewable and sustainable energy reviews*. 11: 1617–1649,2007.

[7] A.M. Omer: Biomass energy potential and future prospect in Sudan. *Journal of renewable and sustainable energy reviews*. 9: 1–27, 2005.

[8] Bangladesh Bureau of Statistics (BBS), 2010a. Statistical yearbook of Bangladesh 2009. Planning Division, Ministry of Planning Government of People's Republic of Bangladesh.

[9] Bernard F., Prieur A. Biofuel market and carbon modeling to analyse French biofuel policy. *Energy Policy* 35:5991-6002, 2007.

[10] Hossain S.M.I, Zaman M.A., Huq M.M., and Abdullah M. Potential of sugarcane as a renewable source of energy in Bangladesh. J. Agril. Mach. & Mech. 1(1):47-52, 1994.

[11] FAO FAOSTAT Statistics Database, 2011.AgroSTAT. Available at http://www.faostat.fao.org Accessed: 21 May, 2013.

[12] Islam, M.R.,Islam, M.N. and Islam, M.N," Fixed bed pyrolysis of sugarcane bagasse for liquid fuel production", *Proc. of 5th Int. Conf. on Mechanical Engineering (ICME2003)*, Bangladesh, 2003.

[13] Wei, L. "Experimental study on the effects of operational parameters of a downdraft gasifier." 2005.

[14] N. L. Panwar, Design and performance evaluation of energy efficient biomass gasifier based cook stove on multi fuels, Springer Science + Business Media , 2009.

[15] Environmental Protection Agency Combined Heat and Power Partnership (EPA-CHP), Biomass conversion technologies in biomass combined heat and power catalog of technologies, Environmental Protection Agency, United States, 2007.

[16] Bhattacharya, S. C., Salam, P. A., A review of selected biomass energy technologies, *Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC)*,Asian Institute of Technology (AIT), Thailand, 2006.

[17]Singh. R.I, Combustion of Biomass in an Atmospheric Fbc: An Experience and Study. *Paper presented at the International Conference in Advances on Energy Research* Indian Institute of Technology Bombay, December, 12-15, 2007.