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Producer Gas Production from Cotton Stalk and Sugarcane Bagasse in a Downdraft Gasifier: Composition and Higher Heating Value Investigation

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Abstract—*Biomass is one of the most important sources of renewable energy. Presently, various forms of biomass available and exist in large quantity in many areas of the world. The objective of this study is to evaluate the composition of producer gas that can be used for various purposes. In the present study, a process of conversion of solid fuel (biomass) into a useful combustible gas by partial combustion known as gasification is done. The resulting combustible gas is known as producer gas, which mainly consists of carbon monoxide (CO) and hydrogen (H_2) gas and some traces of methane (CH_4), carbon dioxide (CO_2) and nitrogen (N_2). In this experiment, a downdraft gasifier available in the Thapar University is used to carry out the gasification process with waste generated by cotton stalk plant and sugarcane. The main biomass fuels used are cotton stalk and sugarcane bagasse. Results were expressed in terms of producer gas composition and were compared. Results show the composition by volume of CO and H_2 for cotton stalk were 13.5% and 10.3%, for sugarcane bagasse CO and H_2 were found to be 11.1% and 9.45%.*

Keywords*: Biomass; Gasification; Proximate analysis; Producer gas; Downdraft gasifier.*

1. INTRODUCTION

Energy demand in the world continues to increase with increase in population and economic development. To meet this increased demand, renewable energy sources must be used. Biomass is one of the most promising renewable energy sources which are available in wide quantity in almost every part of the world [1]. Biomass is considered a CO_2-neutral fuel because biomass consumes the same amount of CO_2 from the atmosphere during Growth and combustion [2]. As an alternative fuel it has attracted much attention worldwide in the recent year. At present, biomass is converted into heat and electricity most often by combustion. Biomass includes all matter that is produced biologically and is the name given to all the living matter on earth [3]. Biomass energy can be obtained from the plant sources, wastes from natural forests, agricultural, industrial, animal wastes. All the biomass decomposes to its molecules with the release of heat which is termed as anaerobic digestion. It is the combustion of biomass that initiates the anaerobic digestion process. Biomass is a carbon neutral fuel therefore it does not add carbon dioxide to the atmosphere as in the case of fossil fuels [4]. In nature, biomass is spread in wide area and is not concentrated at a particular area or place, and so, the use this biomass requires transportation, which increases the cost and reduces the net energy production. Also partial combustion of biomass may produce organic particulate matter, carbon monoxide and other harmful organic gases, which are a concern among the environmentalist. If high temperature combustion is used, oxides of nitrogen would be produced. All above discussed gases and particulate matter give rise to health concerns and increase in pollution, especially in developing countries, where fuel wood is burnt inefficiently in open fires for domestic cooking and space heating [5].

The conversion technologies for utilizing biomass can be separated into four basic categories: direct combustion processes, thermo-chemical processes, biochemical processes and agro-chemical processes [3]. Out of the four processes the thermo-chemical conversion of biomass is considered in this study, which includes pyrolysis, gasification and combustion. It is a unique renewable form of energy with many ecological advantages. In the thermo-chemical conversion process, biomass gasification is the method which offers higher efficiencies in comparison to combustion and pyrolysis. Gasification is a process of conversion of solid carbonaceous fuel into combustible gas by partial combustion [6].

The resulting gas which is known as producer gas is a mixture of number of gases such as carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), nitrogen (N_2) and methane (CH_4). The producer gas is more efficient in its use than the solid biomass. This producer gas is used to generate process heat and steam or find a scope in gas turbines to generate electricity

[7-8]. The fuels such as sawdust, rice straw, corncobs, nut shells, wood chips, etc. which have low-value wastes, are used in the biomass gasifier to produce a gas having high calorific value (producer gas). The gas that is produced by downdraft gasifier is considered tar-free and is used directly to drive most of the internal combustion engines [9]. In [9], according to author analysis of cotton stalk shows the moisture content of the cotton stalk is 13.63 percent on dry basis, which represented the suitability of fuel for gasification in downdraft gasification systems, high moisture content not only gives rise to low gas heating values, but also leads to low temperature in the reaction zone, which in turn to insufficient tar-converting capability, that is low grade gas, so moisture content should be less than 15 percent. In [10], the author used chir pine needle (leaf) as a biomass fuel and shows an increase in the moisture content reduces the biomass consumption rate. Also biomass moisture content greatly effects both the operation of the gasifier and the quality of the product gas. In [11], the author reported a biomass gasification system having low-density biomass such as bajra stalks, sorghum stalks, crushed sugarcane leaves, and bagasse for thermal applications. In [12], the author carried out gasification studies using hazelnut shell as a biomass. Hazelnut shell is an agricultural waste and abundantly available in Turkey. By **[**13**]** a downdraft biomass gasifier is used to carry out the gasification experiments with the waste generated while making furniture in the carpentry section of the institute's workshop. Dalbergia sisoo, generally known as sesame wood or rose wood is mainly used in the furniture and wastage of the same is used as a biomass material in the present gasification studies.

In the present study, gasification experiments are carried out with the cotton stalk and sugarcane bagasse as a biomass material in a downdraft biomass gasifier. The biomass used in the present study is the waste generated on extracting cotton from cotton stalk plant and bagasse is collected on crushing the sugarcane. These biomass materials when burnt in the atmosphere results in enormous amount of ash content and particulate matter in the emission [14]. These emissions can be reduced using biomass gasification process. The producer gas thus generated from the downdraft biomass gasifier is mostly tar-free and therefore can be used in an engine for the generation of electricity.

2. EXPERIMENTAL SETUP AND PROCEDURE

2.1. Experimental setup

In this experiment a downdraft gasifier is used. It has four distinct reaction zones: (1) drying, (2) pyrolysis, (3) oxidation and (4) reduction. A downdraft biomass gasifier is the one, which has throated combustion zone and different diameter for pyrolysis and reduction zone, unlike stratified downdraft biomass gasifier in which gasifier diameter is uniform throughout the gasifier [15]. As the name suggests in downdraft gasifier, pyrolyzed gas along with the moisture generated in pyrolysis and drying zone, respectively flow downwards. This pyrolyzed gas passes through a combustion zone followed by a hot bed of char which is supported by a grate. Biomass is fed to the gasifier from the top and oxidized in the zone where continuous air is supplied from two air nozzles. The heat generated in the combustion zone is transferred to the pyrolysis and drying zone. This released heat from the biomass combustion raises the temperature of the biomass particles resting above the oxidation zone and thus they get pyrolyzed.

The biomass particles are decomposed into volatiles and charcoal in the pyrolysis zone. These volatiles from the biomass particles flow in the downward direction and reached packed pyrolysis bed. The rate of these volatiles release is a function of particle size and temperature to the core of single particle. The reason for low tar is the high temperature of the combustion zone which helps in cracking the tar into non-condensable gases and water vapors. This cracked pyrolyzed gas mixes with the carbon dioxide produced during combustion and the inert N_2 present in the air. This mixture of various gases passes over the hot bed of charcoal and releases heat (endothermic reduction reactions). Water seal is provided at the top of the gasifier to maintain the downward flow.

A moving grate is present at the bottom of the gasifier which supports the charcoal in the reduction zone. Correspondingly the ash is removed by this rotating grate using the lever arrangement which provide unclogging of the grate. By moving the grate, as discussed above grate clogging can be prevented and also bridging of the biomass can be avoided thereby causing higher amounts of biomass to undergo gasification.

2.2. Experimental Procedure

At the bottom or some times on the side of the gasifier a water filled container is placed and this water circulates at the top of the gasifier which acts as sealant and hence prevents the gas from escaping out of the downdraft biomass gasifier. Cotton stalk and sugarcane bagasse is fed into the hopper separately. As the biomass moves downward it gets pyrolyzed and converted into charcoal. Biomass then travelled to the oxidation zone of the biomass gasifier and for its oxidation air is introduced in the biomass gasifier through side nozzles, around 25 ml of diesel is poured to enhance the combustion of biomass. Once combustion starts properly and covers the whole oxidation zone, which generally takes about 3–4 min, additional biomass is fed inside the gasifier from the top and is closed from the top by cover. Due to the volatility and good temperature of the oxidation zone the combustion starts properly and biomass is burnt with good rate.

The samples of this producer gas exiting from the gas burner are collected in the syringes. Sampled gas is analyzed with a gas chromatograph (NUCON 5900) with two thermal conductivity detectors and one flame ionization detector. Each experimental run is carried out for 20 min. At the end of the experiment any leftover biomass and charcoal are removed from the gasifier.

3. RESULTS AND DISCUSSIONS

3.1. Biomass Characteristics

The cotton stalk from cotton stalk plant and bagasse from sugarcane is used as a biomass in the present gasification studies. Table 1lists the proximate analyses of the cotton stalk and bagasse. Higher heating value (HHV) is calculated using the empirical formula given by Eq. (1) reported in the literature [16].

HHV (MJ/Kg) = 0.3536 FC + 0.1559 VM – 0.0078 ASH (1)

Table 1: Proximate analysis (% wt. dry basis) and higher heating values of biomass samples.

Sample	Moisture (%)	Volatile matter (%)	Ash (%)	Fixed carbon (%)	Higher heating value (MJ/Kg)
Cotton stalk	9.45	68.65	2.5	19.40	17.54
Sugarcane bagasse	8.48	76.58	2.92	12.00	16.16

3.2. Producer gas composition

The gas composition of producer gas for test 1 and test 2 during gasification experiments is found using gas chromatograph (NUCON 5900) with two thermal conductivity detectors and one flame ionization detector. The gas composition for each experimental run is shown in the graphs below:

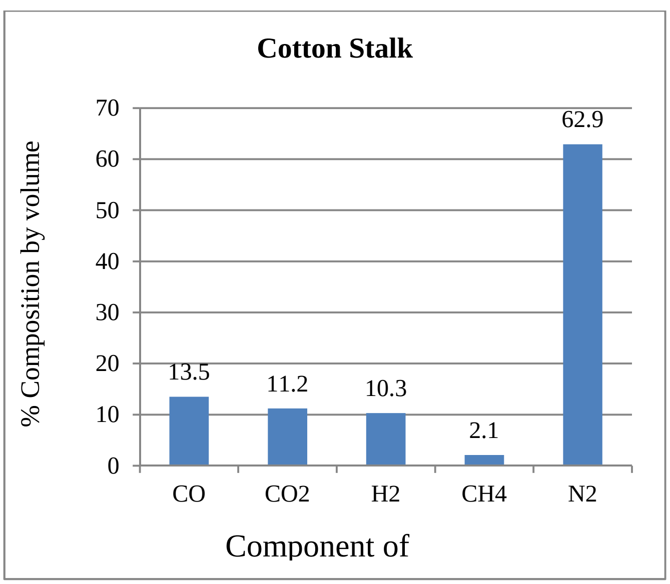

Fig. 1: Producer gas composition of cotton stalk in (% volume)

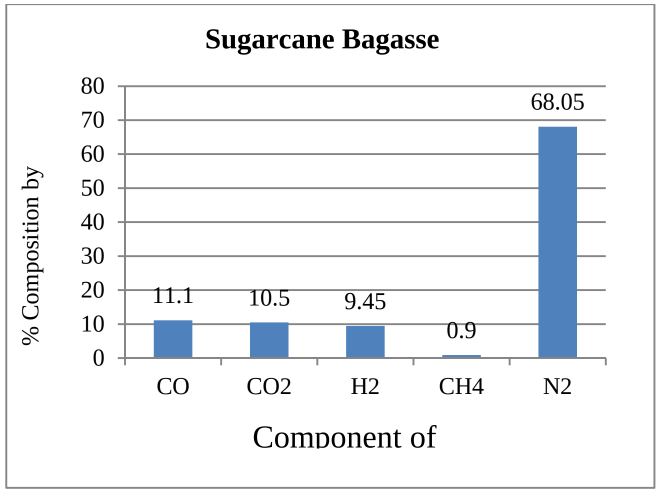

Fig. 2: Producer gas composition of sugarcane bagasse in (% volume)

4. CONCLUSIONS

The experiment was successfully performed on downdraft biomass gasifier. The feeding of biomass is smooth. Based on the results of this study, the conclusions drawn are:

- Producer gas composition (in % volume) for cotton stalk gives CO 13.5%, CO_2 11.2%, H_2 10.3% and N_2 62.9% with small traces of methane.
- Results of composition (in % volume) of producer gas for sugarcane bagasse gives CO 11.1%, CO_2 10.5%, H_2 9.45% and N_2 68.05% with small traces of methane.
- Also the higher calorific values of producer gas from cotton stalk and sugarcane bagasse are found to be 17.54 MJ/Kg and 16.16 MJ/Kg.

REFERENCES

[1] Mythili R., and Venkatachalam, P., "Briquetting of Agro-residues", *Biomass Bioenergy*, 72, 2013, pp. 58-61.

[2] Liu, Y., Wang, X., Xiong, Y., Tan, H., and Niu, Y., "Study of briquetted biomass co-firing mode in power plants ", *Applied Thermal Engineering*, 63 (1), 2014, pp. 266-271.

[3] Babu, B.V., "Biomass pyrolysis: a state-of-the-art review", +*Biofuels, Bioproducts and Biorefining*, 2(5), 2008, pp. 393-414.

[4] Twidell, J., "Biomass energy", *Renewable Energy World*, 1(3), 1998, pp. 38-39.

[5] Demirbas, A., "Biomass resource facilities and biomass conversion processing for fuels and chemicals", *Energy conversion and Management*, 42(11), 2001, pp. 1357-1378.

[6] Basu, P., Combustion and gasification in fluidized beds.*CRC press, 2006.*

[7] Babu, B.V., and Sheth, P.N., "Modeling and simulation of reduction zone of downdraft biomass gasifier: effect of char reactivity factor", *Energy Conversion and Management*, 47 (15), 2006, pp. 2602-2611.

[8] Sheth, P.N., and Babu, B.V., "Differential evolution approach for obtaining kinetic parameters in non-isothermal pyrolysis of biomass", *Materials and Manufacturing Processes*,24(1), 2008, pp. 47-52.

[9] Demirbas, A., "Biomass resources for energy and chemical industry", *Energy Education and Science Technology*, 5(1), 2000, pp. 21-45.

[10] Kumar, A., and Randa, R., "Experimental Analysis of a Producer Gas Generated by a Chir Pine Needle (Leaf) in a Downdraft Biomass Gasifier", *International journal of engineering research and applications*, 4, 2014, pp. 122-130.

[11] Jorapur, R., and Rajvanshi, A.K., "Sugarcane leaf-bagasse gasifiers for industrial heating applications", *Biomass and bio-energy*, 13, 1997, pp. 141-146.

[12] Dogru, M., Howarth, C.R., Akay, G., Keskinler, B., and Malik, A.A., "Gasification of hazelnut shells in a downdraft gasifier", *Energy*, 27(5), 2002, pp. 415-427.

[13] Umesh, D., Sarsavadiya, P., Vaja, K., and Mahadeo, K., "Physio-chemical Properties of Cotton Stalk Biomass from aricultural Residues", *Current World Environment*, 10(1), 2015, pp. 343-349.

[14] Noyes, R., Pollution Prevention Technology Handbook. *William Andrew Inc. New York*, 1993.

[15] Reed, T., and Das, A., "Handbook of biomass downdraft gasifier engine systems", *Biomass Energy Foundation*, 1988.

[16] Parikh, J., Channiwala, S.A., and Ghosal, G.K., "A correlation for calculating HHV from proximate analysis of solid fuels", *Fuel*, 84(5), 2005, pp. 487-494.