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Bagasse based gasification system for thermal application

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Abstract: A commercial scale (1240 MJ h^{-1}) gasification system using bagasse and its briquettes for thermal application was developed. The system was tested at different airflow rates from 50 - 250 m^3 h^{-1} (0.11 - 0.54 equivalence ratio). The biomass cosumption rate varied from 60 - 180 kg h^{-1}. The calorific value of the bagasse and its briquettes ranged between 17.8 and 18.0 MJ kg^{-1} and calorific value of gas was 4.44 MJ m^{-3}. The maximum gas production rate was 186 - 257 m^3 h^{-1}. The efficiency reached a maximum of 63.34% for 30 mm briquettes at 200 m^3 h^{-1} airflow rate at a consumption rate of 100 kg h^{-1}.

Key words : Bagasse gasifier, Calorific value, Hot gas efficiency.

Introduction

Among the non-conventional forms of energy, agro-residues have very good potential as energy source. India produces large quantity of agro-residues but they are used inefficiently causing extensive pollution to the environment. Out of 260 million tonnes of agro-residues generated in India per year about 100 million tonnes remain unutilized (Mishra *et al.* 1995). Bagasse is one of the major residues produced from sugarcane crop as surplus in sugar mills after being sent to paper mills. In a typical Indian sugar factory, 100 tonnes of cane produces 30 tonnes of bagasse, of which 26 tonnes is used as captive fuel and 4 tonnes remain as surplus (Anon, 1985). It has a potential to produce 1500 kWh of electricity. In India, 31 million tonnes of bagasse is produced per annum (Gopinath, 1997). The bagasse after milling is in a disintegrated fibre size from few millimeters to few centimeters.

At present bagasse is used as fuel for boiling sugarcane juice to manufacture jaggery. Various types of furnace are currently being used for this purpose. The overall heat utilization efficiency of these furnaces is merely 15%, which is too low (Rajvanshi *et al.* 1993). Hence, there is an urgent need to improve combustion and heat utilization efficiency of these bagasse furnaces. In this context, gasifier systems with high efficiency have shown adequate and immediate promise for thermal application. Use of commercial scale 1240 MJ h^{-1} gasifiers for such thermal applications can lead to increase in efficiency upto 30% (Rajvanshi *et al.* 1993 and Jain, 1997). This paper reports on the development of a suitable bagasse based gasifier to generate producer gas for concentrating juice

Materials and Methods

Gasification system design

A gasifier with a thermal output of 1240 MJ h^{-1} was developed (Sada Siva Rao, 2000) at Tamil Nadu Agrcultural University, Coimbatore, India. It comprised of a double walled reactor, grate, lid and a biomass feeding system (Fig. 1). The gasifier was a downdraft, throatless, double walled cylindrical reactor for gas generation with an internal diameter of 0.7 m. The diameter of the outer shell was 0.8 m to give ample clearance for the air flow and to act as a heat exchanger to preheat the incoming air. The height of the reactor was 2.2 m. A 0.75 hp blower was used for admitting air into the system. A surge hopper was fitted on the top of the reactor for conveying additional feed stock whenever needed. The outer surface of the reactor was covered with 2.5 cm thick ceramic wool to minimize the heat loss from the outer shell. The reactor assembly was mounted on a channel frame. The gasifier was simple to operate within an initial starting time of 10 to 15 min, while subsequent starting was effected in less than 5 min. During operation, air delivered by the blower was allowed to pass through the annular space, being forced from bottom to the top of the reactor. The air was heated up during the process and entered inside the reactor near the top of the inner shell. A limited supply of air was allowed for gasification reactions to occur. The gas produced was taken out of the reactor through the grate and a mesh and delivered to the burner.

Table 1. Bagasse and bagasse briquette characteristics

Feed stock	Moisture content % (wb)	Bulk density kg m^{-3}	True density kg m^{-3}	Elemental composition, %				Calorific value MJ kg^{-1}	Proximate composition, %		
				C	H	N	O		Fixed carbon	Volatile matter	Ash content
Bagasse	12.00	61.40	–	48.25	6.00	0.19	39.16	17.98	15.00	83.00	2.00
Bagasse briquette	9.33	–	1000	48.40	5.93	0.56	38.60	18.03	17.00	80.00	3.00

Table 2. Heat output at different air flow rates

Airflow rate	Air equi-valence ratio	Bagasse					Bagasse briquette 15 mm length				
		Biomass consump-tion	Average gas production	Average calorific value of gas	Heat output	Hot gas efficiency	Biomass consump-tion	Average gas production	Average calorific value of gas	Heat output	Hot gas efficiency
m^3 h^{-1}		kg h^{-1}	m^3 h^{-1}	MJ m^{-3}	MJ kg^{-1}	%	kg h^{-1}	m^3 h^{-1}	MJ m^{-3}	MJ kg^{-1}	%
50	0.11	111.20	114.49	3.77	3.90	21.70	61.86	120.63	4.18	8.15	15.20
100	0.22	105.00	185.36	4.02	7.10	39.49	60.00	84.56	4.93	6.95	38.55
150	0.32	180.00	171.60	3.72	3.55	19.74	109.10	172.99	5.29	8.39	46.53
200	0.43	151.30	231.78	4.74	7.26	40.38	84.51	170.36	5.40	10.89	60.40
250	0.51	134.06	236.67	5.24	9.25	51.45	88.24	186.62	4.58	9.69	63.74

Airflow rate	Air equi-valence ratio	Bagasse briquette 30 mm width					Bagasse briquette 45 mm width				
		Biomass consump-tion	Average gas production	Average calorific value of gas	Heat output	Hot gas efficiency	Biomass consump-tion	Average gas production	Average calorific value of gas	Heat output	Hot gas efficiency
m^3 h^{-1}		kg h^{-1}	m^3 h^{-1}	MJ m^{-3}	MJ kg^{-1}	%	kg h^{-1}	m^3 h^{-1}	MJ m^{-3}	MJ kg^{-1}	%
50	0.11	70.59	124.49	4.61	8.13	45.09	92.31	87.19	3.39	3.20	17.75
100	0.22	63.16	91.97	2.52	5.13	28.45	88.49	85.62	3.48	3.37	18.69
150	0.32	103.45	224.88	4.38	9.52	52.80	120.00	117.23	5.08	4.96	27.51
200	0.43	100.00	257.14	4.44	11.42	63.34	66.67	144.37	2.91	6.30	34.94
250	0.54	100.00	184.31	4.38	8.07	44.76	80.00	195.42	4.44	10.85	60.18

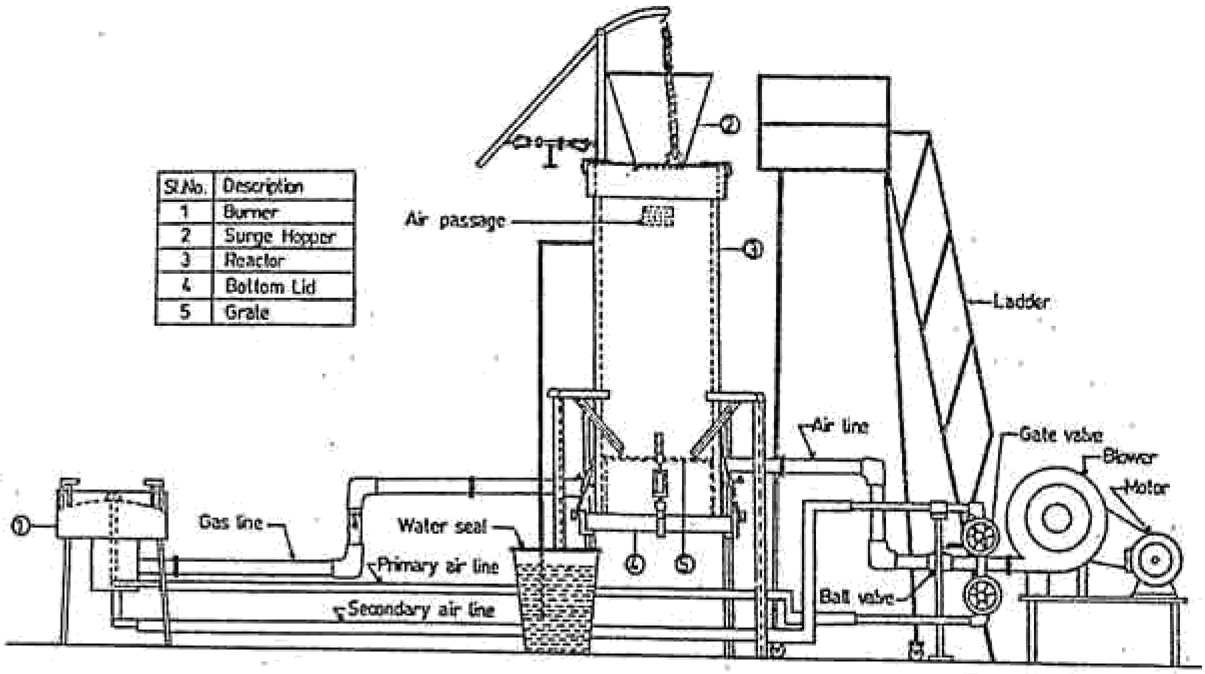

Fig.1. Bagasse based gasification system for thermal applications

Fuel Characteristics

The gasification system was successfully tested on sugarcane bagasse and its briquettes during 1997 to 2000. The briquettes were of 60 mm diameter and 15, 30 and 45 mm length. The properties of sugarcane bagasse and its briquettes are given in Table 1. The physical properties control the flow behaviour, while the chemical properties are important to understand how the reactions proceed. The physical properties namely moisture content, bulk density and true density were measured as suggested by Browning (1967). The chemical properties such as proximate and elemental composition were measured by the standard methods (Grover, 1998). Using the physical and chemical properties the gasification air requirement and reactor size were calculated (Pathak *et al.* 1986).

Results and Discussion

The gasification system was operated at different equivalence ratios and the feed stock consumption rate was studied. The performance of the system is given in Table 2. The biomass consumption rate varied between 60-180 kg h^{-1} depending on the air flow rate used. The output was in the range of 296-1240 MJ h^{-1} (thermal). No condensation and accumulation of tar and particulate matter were noticed in the equipment and piping even after two hours of operation.

The hot gas efficiency of the system was dependent on air flow rate (Table 2). The efficiency was maximum at an airflow rate of 200 to 250 m^3 h^{-1}. The efficiency reached a maximum of 51% at 250 m^3 h^{-1} airflow rate 60% for 60 mm diameter, 45 mm length briquette at 250 m^3 h^{-1} airflow rate 63% for 15 mm and 30 mm briquettes at 250 and 200 m^3 h^{-1} airflow rates respectively. The air equivalence ratio at the highest efficiency was observed as 0.43 to 0.54. This is in conformity with the results reported by Manurung and Beenackers (1985) and Jain and Goss (2000) for throatless gasifiers. To obtain maximum hot gas efficiency, the consumption of 30 mm bagasse briquette was 100 kg h^{-1}, 15 mm briquette was 84.5 kgh^{-1}, bagasse was 134.06 kg h^{-1} and 45 mm briquette was 80 kg h^{-1}. The maximum gas production rate ranged between 186 and 257 m^3 h^{-1}.

The economic analysis of the system was carried out and compared to the conventional process at their respective rated capacities. The analysis of fuel requirement and its saving show that 200 kg of bagasse and 265 kg of briquettes are saved per batch compared to coventional method. The study also indicate that the system is economically attractive and the cost of operation is Rs.550 as against Rs.850 per batch in the conventional method. Also three batches can be completed in a day as against only two in the conventional method.

Conclusions

The present study clearly demonstrated that sugarcane bagasse / bagasse briquettes can be used for gasification for thermal applications. The fuel requirement is nearly half (1.8 to 2.3 kg kg^{-1} of jaggery) when gasifier is employed as compared to conventional method (3.85 kg kg^{-1} of jaggery made).

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