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Performance evaluation of a 15 kW_{th} biomass gasifier in downdraft and updraft operating modes: an experimental study

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Abstract: Biomass gasifiers are equipment's that can generate producer gas which is a renewable, alternate source of energy that can be employed for power generation and thermal applications. In this experimental study the gasifier is tested in updraft and downdraft modes and performance analysis was carried out. For both the studies, casuarina wood and ambient air were used as feed stock and gasification agent respectively. From the experimental analysis it was inferred that the performance of the biomass gasifier was higher in downdraft mode than updraft mode.

1 Introduction

Amongst the viable alternative technologies available for power generation, biomass gasification technology is a highly viable option that can cater to the requirements of current energy scenario [1-3]. Biomass gasification is a thermochemical process by which the raw wood is converted into a burnable gas termed as producer gas. Furthermore this process is a highly suitable technology for decentralized locations such as villages that couldn't be connected by normal electrical grids [4-6]. Moreover this technology operates on feed material such as wood stock that is available in the vicinity of the villages. This technology can be operated by employing available atmospheric air as the gasification agent. These gasifiers capacity can range from few kW to multiple MWs. Adoption of this technology can reduce the incurring running cost, can create job opportunities in villages, spur the economic activities in villages directly and indirectly, apart from providing electrical power to villages. Based on the economic point of view these gasifiers can be fabricated at cheaper cost, rather than coal based centralized power plants that require quantum of expenditure.

In addition the gasifiers create lesser pollution in contrast to the centralized power plants. On the nut shell this gasification technology is a boon to the remote locations in the country that are still to be electrified.This gas can be used for thermal applications or can be used for operating internal combustion (IC) engines or can be used for power generation [7-9]. The producer gas consists of CO (18-22)%, CO_2 (9-12)%, H_2 (13-19) %, CH_4 (1-5)%, N_2 (45-55)%.

Based on the movement of fuel, air and producer gas the gasifiers are named as updraft, downdraft and cross draft gasifiers. In downdraft gasifiers both the feed material and ambient air moves from top of gasifier to its bottom and the producer gas exits from bottom of the gasifier. In updraft gasifier the wood moves from top to bottom, but the air and producer gas moves from bottom of gasifier to its top. The downdraft gasifiers finds application in power generation as it contains least tar. The updraft gasifier is employed for thermal applications as it contains sizeable quantity of tar [10-12].

In this experimental study an attempt is made to study the performance of 15 kW_{th} biomass gasifier in updraft and downdraft modes.

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2. Experimental and Instrumentation setup

The experimental setup comprises of biomass gasifier comprising of top and bottom shell. The shell is made of mild steel material of 5 mm thick and is coated with refractory cement for 1 cm to repel the heat to the interiors of the gasifier. The gasifier has a throat at the middle region. The throat region consists of convergent – divergent region and the meeting region of both is termed as throat. The grate is located below the throat. The grate is the region where the biomass is combusted. The ash collection tray is available below the grate by which the formed ash is removed periodically.

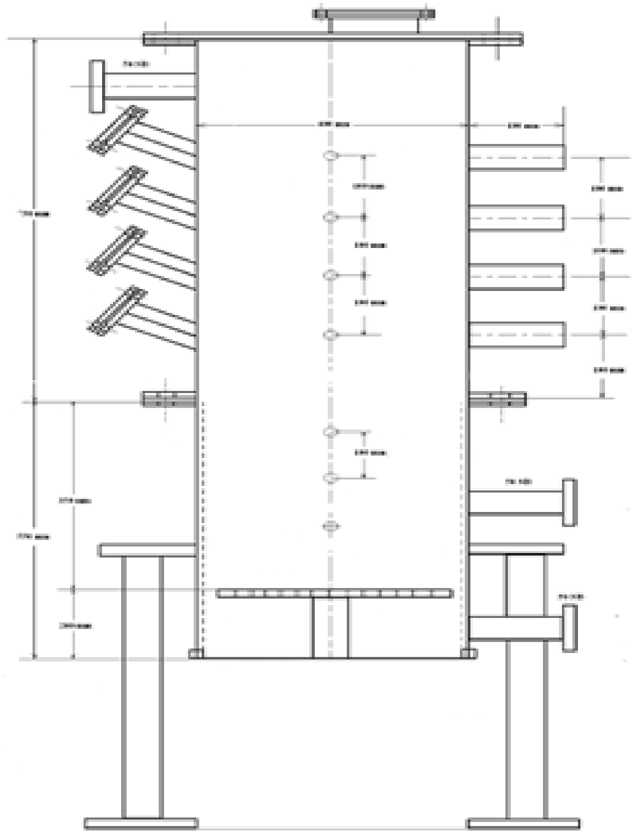

Fig. 1(a). Schematic of the updraft gasifier

The gasifier is located on stand so that it can be operated comfortably. The biomass inlet port is located at the top of the gasifier, through which the biomass is fed into the gasifier. The air is supplied into the gasifier by employing a suitable centrifugal blower ahead of the gasifier. The air supplied by the gasifier is controlled by a gate valve. The producer gas formed in the gasifier is flared through a firing port or flare duct. The updraft and downdraft gasifier diagram is depicted vide Figure 1(a) and (b).

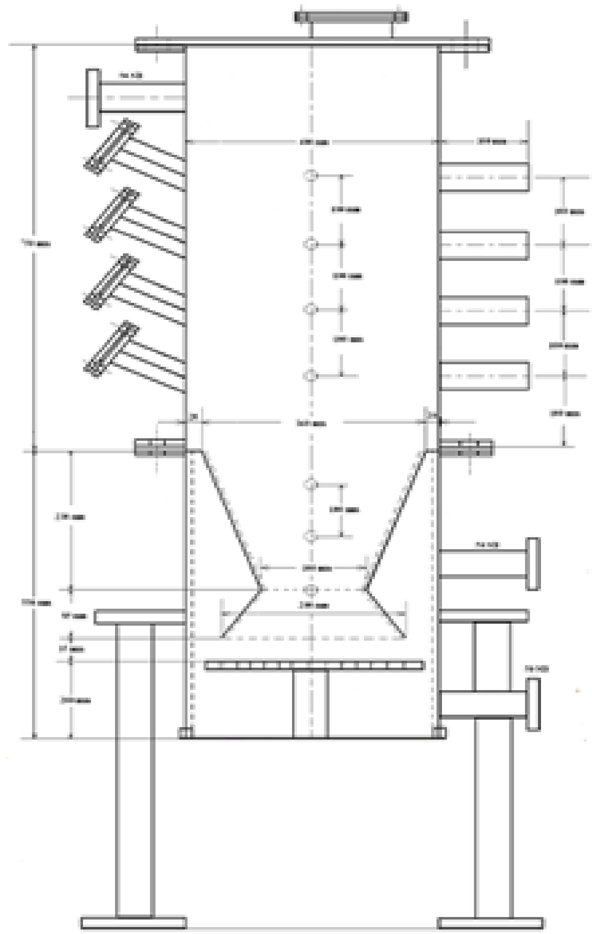

Fig. 1(b). Schematic of the downdraft gasifier

The instrumentation employed in the gasifier is useful to measure the critical operating parameters such as temperature, pressure, air flow rate, producer gas flow rate, producer gas composition and tar formed in the gasifier. The temperature formed in the gasifier is detected by deploying “K” type thermocouples. The pressure in the gasifier is measured by employing the “U” tube manometers. The air flow rate is measured using a orifice meter. The producer gas flow rate is measured using the venturimeter. The producer gas composition is measured using a suitable gas analyzer. A tar sampling set up is used for sampling the tar in the producer gas. The collected samples are then analyzed to estimate the tar formed during the gasification process.

3 Results and discussion

The feed stock used in this experimentation is casuarina wood. Figure 2 depicts the photograph of casuarina wood feed stock.

Fig. 2. Photograph of Casuarina wood feed stock

The characterization findings of this feed stock are tabulated in Table 1.The moisture content of 12.5% is in agreement of the range denoted by Peter et al (2002) ie lesser than 30 %. The required ash content should be lesser than 5%. The tabulated value is 2% which lies in this range. The volatile content of 67.5% indicates the possibility for formation of more tar during gasification process. That indicates the need for gas cleaning technologies such as physical, thermal method or catalytic tar mitigation methods. The gasifier is operated first in downdraft and then in updraft mode and the key findings are tabulated in Table 2.

Table 1. Characterization of feed stock

Feed material	Proximate analysis % by weight				Ultimate analysis % by weight			
	Ash	FC	VM	M	C	H	O	N
Casuarina wood	2	18	67.5	12.5	47.5	5.9	42.5	2.1

Table 2. Gasification parameters at Updraft and downdraft operating modes

Operating modes	Average Values of producer gas composition					Average Values of CV (MJ/Nm^3)
	CH_4 (% Vol.)	CO (% Vol.)	H_2 (% Vol.)	CO_2 (% Vol.)	N_2 (% Vol.)	
Updraft	1.58	10.42	10.62	12.56	64.82	3.03
Downdraft throat	1.45	14.70	13.82	11.22	58.79	3.87

The temperature distribution in the gasifier is depicted vide Figure 3.

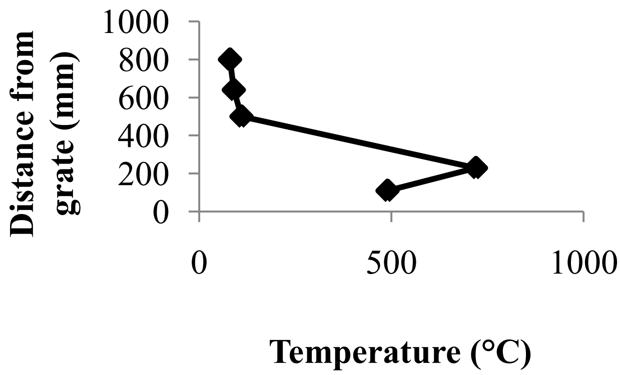

Fig. 3. Temperature distribution across the gasifier

The temperature distribution curve indicates a temperature of 750ºC in the throat region. At this existing temperature condition the gasification parameters for updraft and downdraft modes are analyzed as indicated in Table 2. From the Table it is inferred that the downdraft mode of operation yields better performance than updraft mode, due to the reason that the downdraft mode has generated a producer gas with a calorific value of 3.87 MJ/Nm^3, whereas the updraft mode has generated a lesser caloric value producer gas of 3.03 MJ/Nm^3. This is due to the generation of 13.82 vol % of H_2 in downdraft mode which is higher than 10.62 vol% in updraft mode. Similarly another important component which contributed to the higher calorific value was the formation of 14.7 vol% of CO which was higher than 10.42vol% in updraft mode. On the contrary the CH4 content during downdraft mode was 1.45 vol% which was lesser than 1.58 vol% in updraft mode. The CO_2 content and N_2 content in downdraft mode is lower than updraft mode.

The better performance of downdraft mode of operation than updraft mode has generated higher caloric value of gas in downdraft mode predominantly due to larger cracking of tar in downdraft mode, based on the fact that due to presence of narrowed throat region, higher temperature has occurred, enhancing water - gas, water – shift, Boudard and tar reforming reactions which has cracked the hydrocarbons in the tar into Hydrogen and carbon mon Oxide gas. Furthermore the cracking of CH_4 has increased the formation of CO and H_2 gas composition which is evident from Table 2.On the contrary the temperature distribution in a updraft gasifier will be lesser due to the non availability of throat, which has resulted in lesser cracking of tar. This has resulted in formation of lesser vol% of CO and H_2 and lesser calorific gas.

4 Conclusions

From the above experimentation the following conclusions were derived.

1. The performance of the downdraft gasifier is better than updraft gasifier.
2. The calorific value of producer gas from a downdraft gasifier is higher than updraft mode gasifier.
3. The Vol% of CO and H_2 in downdraft mode was higher than updraft mode
4. The higher performance of downdraft gasifier is due to the reason that higher temperature in the throat region has favored the water gas, water shift, boudard and tar cracking reactions that has increased the formation more vol% of CO and H_2 and higher caloric value of gas than updraft mode of operation.

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