Experimental Investigation of Down Draft Fixed Bed Gasifier

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Abstract- *Gasification is one of the technology used to convert solid biomass into syngas of high calorific value. Although the main objective of gasification is to achieve high quality syngas production and to minimize tar formation, the performance of different feedstock in the gasifier has to be studied. In this project work, the performance of biomass such as coconut shells and casuarina wood and its gasification feasibility for closed top fixed-bed downdraft gasifier were studied. It was observed that gasifier performs best at equivalence ratio of 0.35 for coconut shell and 0.3 for casuarina wood with negligible clinker formation and cold gas efficiency is found to be around 72% for casuarina wood and 75% for coconut shells.*

Keywords- downdraft gasifier; equivalence ratio; casuarina wood; coconut shell.

I. INTRODUCTION

Renewable energy is the fastest-growing alternative energy source accounting for 40% increase in primary energy [1]. It is forecasted that share of renewable energy for total power generation will increases from 7% in 2018 to around 25% by 2040. In India, agricultural residues is estimated to produce biomass resources of 656 million tons/year associated with power potential of 18729.9 MWe respectively and forest/wasteland residues is estimated to produce biomass resources of 259 million tons/year associated with power potential of 14561.5 MWe respectively [3]. Currently India is third largest producer of coconuts with a yield of 11.93 million tons per year. Three mechanisms namely Thermo chemical, Biochemical and Physiochemical can be used to generate energy from biomass feedstock. Comparing these technologies gasification accounts to be best choice owing to minimum space requirement and fuel flexibility [4]. This paper investigates the gasification performance of Casuarina Wood and Coconut Shell as a feedstock in a downdraft gasifier fixed bed gasifier.

II. EXPERIMENTAL SECTION

To use biomass as a feedstock for gasification, it has to confirm with certain physical and chemical characterization so as to confirm its quality & quantitative energy content [5] available. Proximate and ultimate analysis of casuarina wood and coconut shell is provided in table 1.

Table 1. Proximate and Ultimate Analysis

	Weight (%)	Casuarina Wood	Coconut Shell
Proximate analysis	Fixed Carbon	18.5	23.7
	Volatile Matter	67	64
	Moisture	12.2	10.5
	Ash	2.3	1.8
Ultimate analysis			
	Carbon	47.5	54.4
	Oxygen	42.5	37.4
	Hydrogen	5.9	5.6
	Nitrogen	2.1	1.5
	Sulphur	0.05	0.03
Other properties			
	Calorific	16.32	18.73
	Angle of	40	37
	Bulk density	430	325

Based on the literature [6], [7], [8], Parameters obtained in proximate and ultimate analysis holds goods and are within the range. Hence above mentioned biomass can be used as feedstock in gasification process.

III. INSTRUMENTATION SET UP

The experimental setup consists of centrifugal blower, downdraft gasifier, flare pipe, cyclone separator, dust filter and gas cooler. Air to the gasifier is supplied by motorized centrifugal blower and its flow rate is controlled by a butterfly valve. A feeding port for feeding feedstock is at the top of gasifier. The feeding port is closed throughout operation of gasifier and it is opened solely at the time of feeding biomass. The cylindrical gasifier shell is lined inside with medium density castable refractory in order to withstand high temperature. Eight chromel-alumel thermocouples are provided at regular intervals along the gasifier height to measure the bed temperatures inside the gasifier. A specially designed levelling rod is used to agitate biomass bed in the gasifier chamber periodically. Ash chamber is provided at the bottom of gasifier chamber to collect the residual char and ash falling from the grate. A Siemens made online gas analyzer were used to establish gas composition. A sample of Producer gas was collected prior to cyclone separator for measuring tar & particulates.

Figure 1 Photographic view of experimental setup

A cyclone separator is used to remove coarser dust particles from producer gas after it exit the gasifying chamber. For hot gas cleaning (300°C) producer gas is sent to a dust filter which can retain dust particles greater than 152-micron size. A shell and tube heat exchanger is used as gas cooler to cool the dry cleaned, hot Producer gas. The condensed water and tar formed is drained out periodically from the bottom of the gas cooler. An orifice meter is use to measure the flow rate of producer gas. To ignite the Producer gas emanating from the flare pipe, a fire torch is used. figure 1 shows photographic view of experimental setup.

IV. EXPERIMENTAL PROCESS

Batches of Coconut shell weighing approximately 25 kgs, were placed near the system. Gasification of Coconut shell was commenced by opening the gas valve, followed by operation of the unidirectional blower and holding a flame near the air tuyere. The flame was drawn into the system because of the suction created by the blower. For gasification process to be stable, it takes sixty to ninety min which can be ensured by inferring a constant temperature in the raw gas and therefore the reduction zone. By refueling the gasifier on a periodic basis and by filling the gasifier volume to a marked level at the top of the gasifier fuel consumption rate was measured. The ash that had accumulated on the grate is removed at regular intervals by operating ash door provided at the bottom of gasifier. The major influential parameters in the performance of gasification system are equivalence ratio, the bed temperature and the bed pressure drop. Equivalence ratio was changed by varying the air supplied to the gasifier bed. The gasifier's performance for Casuarina Wood & Coconut Shell as feedstocks was compared by varying the equivalence ratio, the optimum operating condition that yields maximum efficiency was determined.

V. RESULTS AND DISCUSSION

Equivalence ratio (ER) is defined as the ratio of actual air supplied in the chamber to stoichiometric air requirement for a given fuel. Here Butterfly valve can be used to control the air flow rate inside the gasification chamber so that Equivalence ratio can be changed accordingly.

5.1 Influence of Equivalence Ratio on H_2

Figure 2 shows that H_2 increases first at lower value of ER & decreases at higher value. Uniform increase in H_2 is due increase in gasification temperature at starting stage of gasification. Whereas at higher Equivalence Ratio, oxygen percentage increases leading to increase in oxidation reaction rate converting H_2 to H_2O thereby leading to drop in H_2 percentage. Maximum yield percentage of H_2 is found to be 14.8% for Casuarina Wood and 13.8 % Coconut Shell.

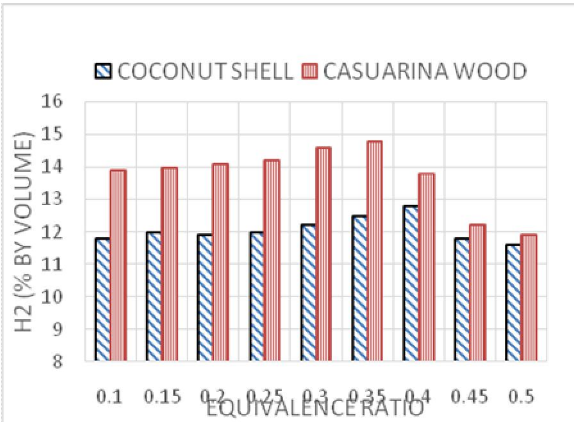

Figure 2 Influence of ER on H_2 for different feedstock

5.2 Influence of Equivalence Ratio on CH_4

Figure 3 shows that, CH_4 decrease for increase in ER. At high temperature zone, CH_4 reacts with water vapour and gets converted to CO, CO_2& H_2.

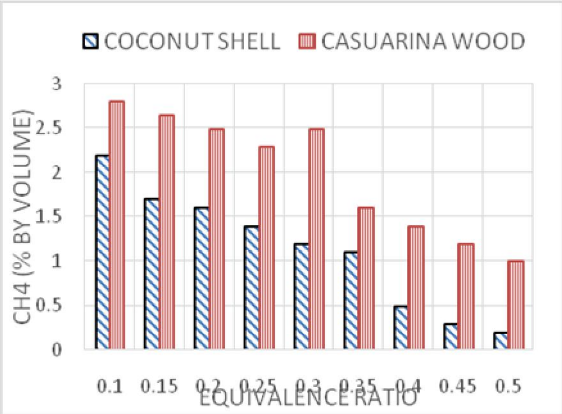

Figure 3 Influence of ER on CH_4 for different feedstock

5.3 Influence of Equivalence Ratio on CO_2/CO

Figure 4 shows the variation of CO_2/CO ratio for different ER. It is inferred that better conversion of biomass feedstock into syngas takes place for minimum value of CO_2/CO ratio [16-20]. For Casuarina Wood, CO_2/CO value is less than one for ER of 0.25 to 0.35 and for Coconut Shell, CO_2/CO lies below one for ER of 0.1 to 0.5. For all the biomass feedstock, the best operating point for attaining higher HHV of producer gas and the highest efficiency coincides with the least value of CO_2/CO. hence the best operating point for Casuarina Wood is at ER of 0.30 and for Coconut Shell is at ER of 0.35.

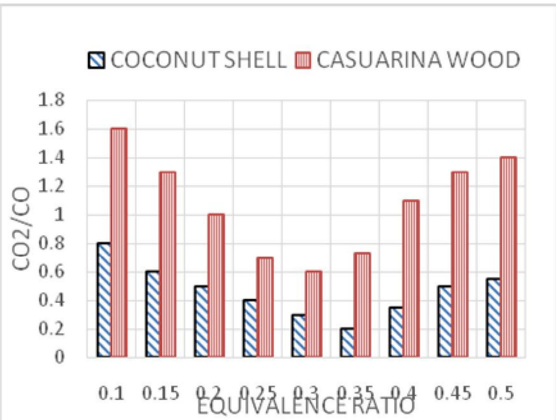

Figure4Effect of ER on CO_2/CO for different feedstock

5.4 Influence of Equivalence Ratio on HHV of Producer Gas

Figure 5 shows that variation of HHV with ER. HHV of gas obtained from Casuarina Wood & Coconut Shell gasification increase until best operating point and falls thereafter. At its best operating point, HHV of gas obtained for Casuarina Wood & Coconut Shell gasification is 4.852 MJm^{-3}& 4.253 MJm^{-3} respectively.

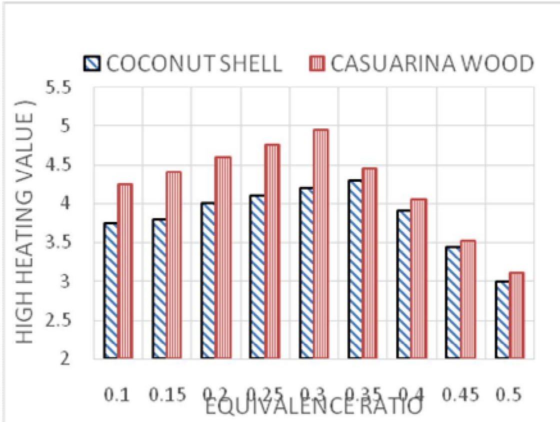

Figure5HHV of producer gas Vs ER for different feedstock

5.5Influence of Equivalence Ratio on Specific Gas Generation

Figure 6 shows that with increase in ER, Specific gas generation increases. This uniform increase in SGG with ER might be due to increased reactivity caused by high carbon content and higher gasification temperature.

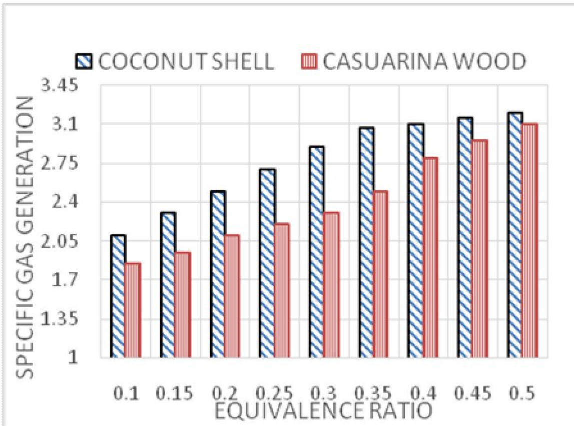

Figure 6 Variation of SGG Vs ER for different feedstock

5.6Gasification Efficiency Vs Equivalence Ratio

Effect of Cold gas efficiency depends on Specific gas generation and HHV of producer gas.

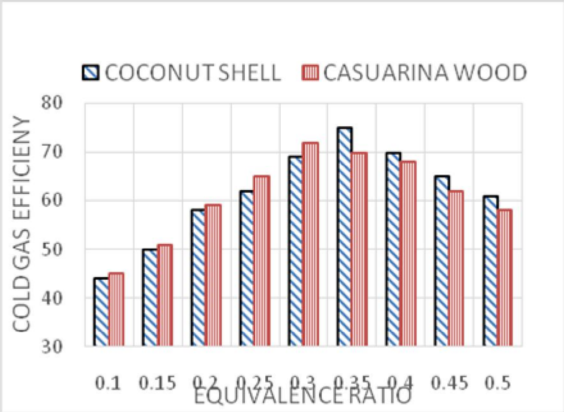

Figure 7 Variation of cold gas efficiency Vs ER for different feedstock

Figure 7 shows the variation of cold gas efficiency increases till the operating point and decreases with respect to ER. This ascending trend is due to rise in percentage combustible gases H_2, CH_4 and CO with increase in ER up to the best operating point.

5.7Particulates and tar content:

It was decided to find the tar and particulate matter at the best operating condition (ER of 0.3 for CW and 0.35 for CS) as tar sampling and analysis is a laborious and time consuming.

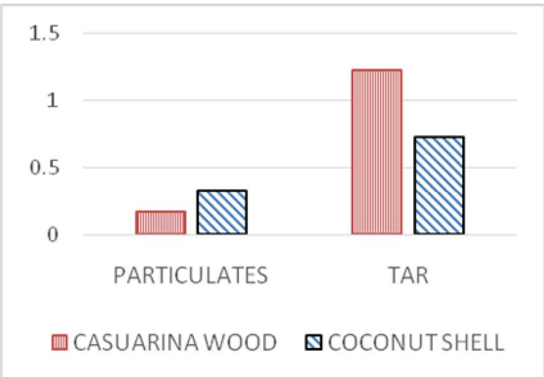

Figure 8 Particulates and Tar content in Casuarina Wood and Coconut Shell

Figure 8 shows that Tar of 1.232 gm^{-3} & 0.723 gm^{-3} and particulates of 0.168 gm^{-3} & 0.325 gm^{-3} are estimated for Casuarina Wood & Coconut Shell gasification respectively. Owing to higher temperature at throat zone due to higher carbon content leads to effective tar cracking. Tar content of producer gas from Coconut shell gasification is observed to be half of Casuarina wood gasification. Based on the literature review [22], [23], tar and particulates obtained in this study are within the range.

VI. CONCLUSION

A fixed bed closed top downdraft gasifier had been used to analyze and compare the gasification of Casuarina Wood and Coconut Shell with air as gasifying medium. By varying ER from 0.1 to 0.5, HHV of gas, SGG, Gas composition and gasifier efficiency were studied. From the studies, it is found that best operating point for Casuarina Wood is at ER = 0.3 and for Coconut Shell is at ER = 0.35 for deriving highest efficiency. The results of gasification at its best operating point (ER of 0.30 for Casuarina Wood and ER of 0.35 for Coconut Shell) for both the feedstocks are tabulated below in table 2.

Table 2. Optimum parameters

Parameters	**Casuarina Wood**	**Coconut Shell**
ER (Best Operating Point)	0.3	0.35
CH_4 (% by volume)	2.5	1.1
H_2 (% by volume)	14.6	12.5
CO_2/CO	0.625	0.255
SGG (m^3kg^{-1})	2.3	3.07
HHV (MJ/m^3)	4.956	4.286
Cold gas efficiency (%)	72.45	75.25
Particulates (m^3kg^{-1})	0.168	0.325
Tar (m^3kg^{-1})	1.232	0.723

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