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Experimental and Theoretical Investigation of Biomass Gasification Using Circulating Fluidised Bed Gasifier

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--ABSTRACT---
The gasification of juliflora chip is investigated experimentally and the effect of equivalence ratio and temperature on gas composition, gas heating value, gas yield and Gasification efficiency. Equivalence ratio is maintained at 0.2-0.3 for experimental set up having 0.156m internal diameter and height of 5m.Gas composition has been found theoretically using equilibrium gas composition for the temperature range of 700-900°C.Gas composition of experimental data is compared with the theoretical result. The concentration of CO2 increases whereas CO decreases with increase in temperature. With increasing equivalence ratio the concentration of CO2 increases and the gas heating value decreases.

KEYWORDS : *Biomass, Circulating fluidized bed, Equivalence ratio; Gasification, Modelling*

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I. INTRODUCTION

The paper reports on an improved concept for fuel gas production from juliflora chip using CFB technology. With the acceptance of wide variety of biomass-feeds, CFB conversion of biomass for fuel gas will be promising [1]. At higher equivalence ratio more amount of air is introduced into the gasifier resulting in exothermic reaction of thermal decomposition leading to complete combustion process. The product gas composition depends primarily on the air ratio. The system operates at 1100 to 1300K with air ratio of 0.15-0.25 to produce hydrogen rich gas at atmospheric pressure [2].Pressure balance is to ensure the separation of the flue gas and the product gas, which is optimised.It is feasible to produce hydrogen and syn gas with medium calorific value from the low calorific solid fuel [3]. It is very well known how thermo chemical gasification produces a valuable gas, a mixture of H2,CO,CO2,CH4,C2Hn etc., with some tar and other impurities by using a gasifying agent and an organic feedstock (biomass,coal,residues,etc.). Circulating fluidised bed reactors are promising gasifiers because of their very high throughputs, which in the case of biomass range between 1500 and 4000kg biomass fed/h m2 of cross sectional area of the gasifier [4].The purpose of present study is to analyses the effect of operating parameter on CFB gasification of Juliflora chip.

II. EXPERIMENT AND DISCUSSION

In order to study the gasification characteristics of biomass, a CFB gasifier consisting of 0.156 m inner diameter and 5 m height consisting of 5 segments each of 1.0 m high. A locally available Juliflora wood chip was used as feedstock. Experiments were carried out using silica sand with mean particle size of 200 µm. The riser is made of 316 stainless-steel material with a refractory-lined of 0.6 cm thickness. The fuel feeding system consists of a fuel hopper with a screw feeder driven by an electric motor. The exit of the CFB gasifier riser was connected with primary cyclone in which the hot product gas with particulates coming out from the riser passed through and then passes through the secondary cyclone where the ash got separated and collected in the ash drum. The experimental condition in Table-1.

Feed stock	Juliflora wood chips
Fuel feed rate	5 – 65 kg/h
Bed material	Silica sand of mean diameter 256 µm
Gasification medium	Air
Fluidization velocity	0.14 – 4 m/s
Gasification temp.	700 – 900ºC
Equivalence ratio	0.2 – 0.3

Table -1 Experimental condition

The primary air required for gasification was supplied through a multiorifice type distributor plate at the bottom of the riser from an air blower. Air was supplied to CFB gasifier from a two stage centrifugal blower. The gasifier is preheated to 400-500°C to maintain desired bed temperature before feeding the biomass fuel. Cyclone separator, ceramic filter and water scrubber was used to clean the producer gas. The hot producer gas passes through first and second cyclone where the coarser particle and ash gets separated respectively. The producer gas concentration were analysed using gas chromatograph. The result shows that the equivalence ratio significantly affect the gas composition. Table 2 provides the effect of equivalence ratio on gas composition and heating value.

Equivalence ratio	**Producer gas composition (%)**					Gas heating value (kJ/Nm^3)
	CO	**CO_2**	**H_2**	**CH_4**	**N_2**	
0.20	25.80	7.14	9.81	2.91	54.2	5558.13
0.22	25.37	8.70	9.72	2.70	53.35	5413.81
0.24	24.16	11.82	9.21	2.25	52.39	5031.23
0.26	23.85	13.90	8.97	1.96	51.12	4863.57
0.28	22.62	16.46	8.42	1.81	50.50	4577.77
0.30	21.81	19.10	7.80	1.76	49.32	4383.67

Table 2 typical gas compositions and heating values
(*Juliflora* chips)

The gas yield and gasification efficiency were determined by the correlation suggested by Yijun Zhao [6] and the values are tabulated as shown in Table 3.

Test	**Mass of fuel (kg/hr)**	**Mass of air (kg/hr)**	**Q air (Nm3/hr)**	**Gas yield (Nm3/kg)**	**Efficiency of gas (%)**
1	32	43.37	35.30	1.28	50
2	39.92	54.56	44.41	1.64	62
3	46.88	74.82	60.76	1.95	68
4	52.92	84.67	68.92	2.01	68.16
5	54.48	87.05	70.86	2.03	64
6	62.06	99.83	81.26	2.09	64.01

Table 3 Gas yield and gasification efficiency

III. THEORETICAL APPROACH

Modeling is an important means for scale-up of a gasifier. It also helps the design of a unit based on result obtained from another gasifier operating on different feedstock. A good model will help in identifying the sensitivity of the performance of a gasifier to variation in different operating and design parameters. The models developed generally belongs to one of the following categories: Kinetic, Equilibrium.The kinetic model predicts the progress and product composition at different position along a reactor. A non-stoichiometric model for CFB, predicts that the product gas composition depends primarily on the air ratio [5]. The experimental data suggests that real gasification process deviate from chemical equilibrium. The calculated thermodynamic equilibrium constant for a number of gasification reaction using standard JANAF thermodynamic data [6].

Estimating Equilibrium gas composition

1.866FXc =VCo + VCo2 + VCH4

1.24FS + (11.21FXH +1.24FW) = VH2 + VH2O + 2VCH4

.623(FS+FW) + .701(FXo+ FAO a) = .5Vco +Vco2+.5VH2o

.8FXN+.8FANa = VN2

Vco+Vco2+VH2+VcH4+VH2O+ VN2 = 1

To estimate the values of seven unknowns; Vco, Vco2, VH2, VH2o, VN2, VcH4 and F we need total of seven equations. The following are four major gasification reactions;
Water gas reaction

C+H2=H2+CO

Boudouard reaction;
The carbon dioxide present in the gasifier reacts with char to produce CO according to the following endothermic reaction
CO_2+C=2CO
Shift conversion
The heating value of hydrogen is higher than that of carbon monoxide.
CO+H_2 O=CO_2+H_2
This endothermic reaction, known as water gas shift, results in the increase in the ratio of hydrogen to carbon monoxide in the gas.
For the boudouard -reaction equilibrium constant is K $K_{pb} = (V_{co})^2 P / V_{co2}$

Similarly, for the water gas reaction $K_{pw} = P_{H2} P_{co}/P_{H2o} = V_{H2} V_{co} P / V_{H2o}$ [7].

IV. RESULTS AND DISCUSSION

Figure The results of gas composition with respect to temperature is shown in figure 1 to figure 5.An increase in concentration of CO2 and decrease in concentration of CO is shown in figure5 and figure 3 with respect to temperature. Due to the dilution of the gas by the nitrogen used as gasification agent contained in the air and due to increase in carbon dioxide, the heating value decreases with an increasing equivalence ratio. Experimental result obtained in this work indicate that the gas heating value dropped from 5.5 MJ/Nm3 to 4.3 MJ/Nm3.

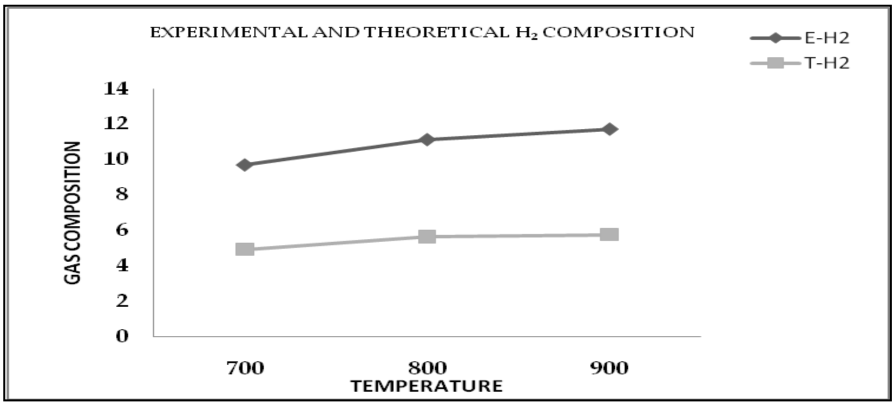

Figure 1

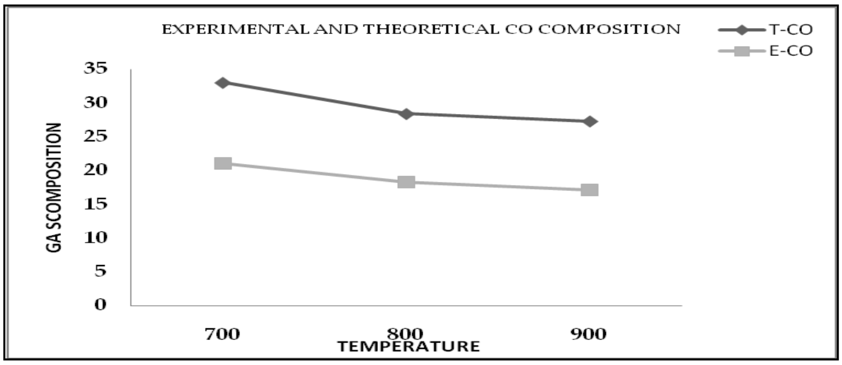

Figure 2

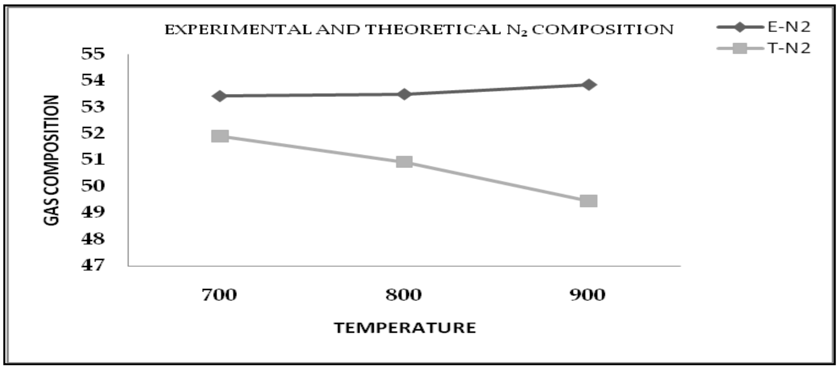

Figure 3

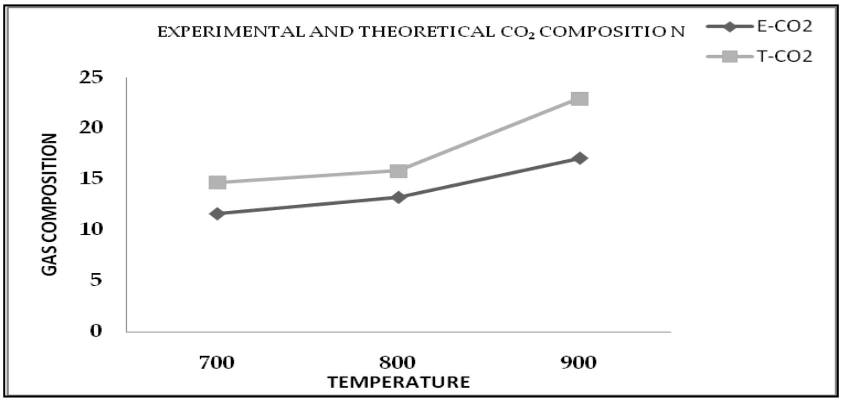

Figure 4

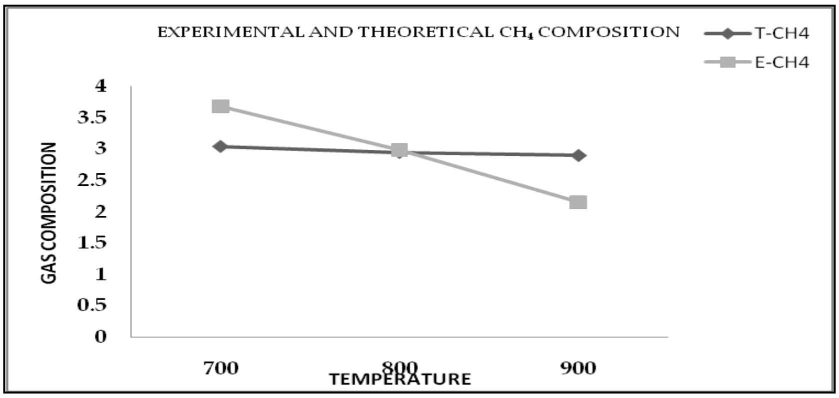

Figure 5

V. CONCLUSION

On the one hand experimental evidence is provided demonstrating that real gasification process predicts gas composition, product heating value, and gas yield, gasification efficiency. Experiment shows that how the gas composition, gas heating value, gasification efficiency is influenced by equivalence ratio and temperature. On the other hand the theoretical result predicts product gas composition in good agreement with experimental data. Gas composition of H2 and CO2 increases with increasing bed temperature but CO and CH4 composition in gas is decreased but the composition of CH4 decreases very less theoretically. This is because of improved carbon conversion at higher temperature [8].

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BIOGRAPHIES

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