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Effect of Equivalence Ratio on Reaction Bed Temperature in Coir Pith and Groundnut Shell Biomass Mixture Gasification in Self Circulating Fluidized Bed Biomass Gasifier

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***Abstract* - Biomass energy conversion through thermo chemical conversion process yield producer gas having hydrogen, carbon monoxide and carbon dioxide as major constituents. Air is used as gasifying agent for producer gas generation. In this study proximate analysis was carried out for coir pith and groundnut shell mixture in muffle furnace for fixed carbon determination. Temperature of the reactor and Gas composition have been analyzed for equivalence ratios of 0.3, 0.4 and 0.5 for 10 minute time interval and its effect on gas constituents has been studied. The maximum temperature attained during gasification process was around 980°C for an equivalence ratio of 0.5. The gas yield has been found to be in the range of 1.8 - 2.9 Nm^3/Kg. The study has been carried out in a pilot model Gasifier.**

Keywords: Self circulating fluidized bed gasifier, Equivalence ratio, biomass Mixture, Proximate Analysis, Pilot Model Gasifier.

I. INTRODUCTION

The demand for energy in India is growing at an alarming rate with major contribution comes only through conventional energy sources like coal, petroleum and gas, moreover the prices of coal, petroleum and gas are highly volatile which affects our Indian economy on large scale. The exhaustive nature of conventional energy sources making a way for us to go for renewable energy sources like solar, biomass and wind, as the availability for such energy sources in India is abundant.

Gasification process is the thermo chemical conversion of biomass fuel into a product called syngas or producer gas in which atmospheric air is normally used as gasification agent. Energy from biomass can substantially reduce the burden on fossil fuels in countries like India through power generation and process heat application on medium and small scale application. Producer gas or Syngas generation by Thermo chemical conversion process involves Air, CO_2, steam and O_2 as gasification agents. The performance of the gasifier is influenced by several parameters like gasifier dimension, feed property and operating parameters. The producer gas consists of mainly Carbon monoxide, Hydrogen and oxygen which can be used for heating purpose or for generation of motive power either in diesel engine or dual fuel engine with some modification. Rajiv Varshney et al (2010) reviewed the potential and status of biomass gasification technology used in india for thermal application and power generation with capacity ranges from 5-500 KW gasifier.

J.J.Ramirez et al (2007) designed and fabricated Fluidized bed gasifier for coir pith on a pilot scale and analyzed various parameters like minimum fluidization velocity during gasification, air flow rate, energy balance of gasification process, cold gas efficiency and equivalence ratio for coir pith and the result showed that the performance of gasifiers depends mainly on equivalence ratio range 0.2 to 0.5 on volumetric yield and also compared the result form pilot model with experimental data to validate proposed mathematical model. K.N.Sheeba et al (2009) conducted experiment on gasification of coir pith in a circulating fluidized bed gasifier using air as the gasifying medium and analyzed the effect of various parameters like Equivalance Ratio(ER), Temperature on gas yield, gas composition, carbon conversion, cold gas efficiency and overall thermal efficiency and concluded that highest hydrogen composition is found to be 11.2% at a temperature of 1020^0c at an ER of 0.18. They also observed that highest heating value of 5.31 MJ/Nm^3 for a temperature of 1020^0c at an ER of 0.31.

From the literature survey several research works have been carried out in converting biomass like coir pith, coir pith, saw dust, groundnut shell powder and bagasse to syngas generation using different design of biomass gasifiers. Tamilnadu is one among the top ten states in India producing agriculture residues, so there is a large scope of biomass conversion to useful energy. Subramanian et al (2011) carried out experimentation in selected granular biomaterials like coir pith, coir pith and saw dust in fluidized bed gasification for

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syn gas generation. They also analyzed gas yield, syn gas compositions and percentage of carbon monoxide and carbon dioxide in the equivalence ratio of 0.3 to 0.5.

Even though several research work have been carried out in thermo chemical biomass energy conversion the presence of moisture content in biomass and level of un burnt carbon particles coming out from cyclone separator affects the syn gas generation, gas composition, cold gas efficiency, carbon conversion efficiency and overall thermal efficiency. In the present study an attempt is made to design and develop a pilot model gasifier with self circulating setup in order to bring the biomass through gravity for eliminating fuel feeding subsystem and to reduce the level of un-burnt carbon particles coming out from cyclone separator.

II. EXPERIMENTAL SETUP AND PROCEDURE

2.1 Methodology

From the Literature review a pilot model gasifier was designed and fabricated in order conduct gasification process. Proximate analysis was carried out for individual biomass and then for Coir pith and groundnut shell combination.

2.2 Experimentation

The work is carried out at Department of Mechanical Engineering in Star Lion College of Engineering and Technology group of institutions, Thanjavur. Initially Proximate analysis was carried out for individual biomass and with different combination in a muffle furnace which is shown in Fig 1.

Table 1 and Table 2 shows the proximate analysis values for individual and biomass combination. The schematic diagram of experimental setup of a self circulating fluidized bed gasifier is shown in Fig. 2. The photographic view of experimental set up is shown in Fig. 4. Dimension of the gasifier are given in Table 3.

Figure 1: Photograph of Muffle Furnace

Table 1: Proximate Analysis – Individual Biomass

S. No	Proximate analysis	Rice Husk	Sugar cane Bagasse	Coir Pith	Ground	Saw Dust
1	% Moisture content at 110^{0}C	6	5.5	4	5	13.5
2	% Volatile matter at 925^{0}C	64.5	68.5	65	64	71
3	% Ash content at 750^{0}C	16	9	12.5	17.5	11.5
4	Fixed Carbon	13.5	17	18.5	13.5	4
5	Total	100	100	100	100	100

Table 2: Proximate Analysis – Biomass Mixtures

S. NO.	Proximate analysis	Coir pith + Groundnut shell
1	Moisture content at 1100c	10.5
2	Volatile matter at 9250c	63
3	Ash content at 7500c	13.5
4	Fixed carbon	13
5	Total	100

Table 3: Dimension of Gasifier

Parts	Description	Dimensions
Riser column	Diameter	100 mm
	Height	550 mm
Outer Chamber	Diameter	200 mm
	Height	350 mm
Cyclone separator	Height	400 mm
Tangential Inlet and circular Exit	Inlet diameter	100 mm
Distributor plate	Diameter	150mm

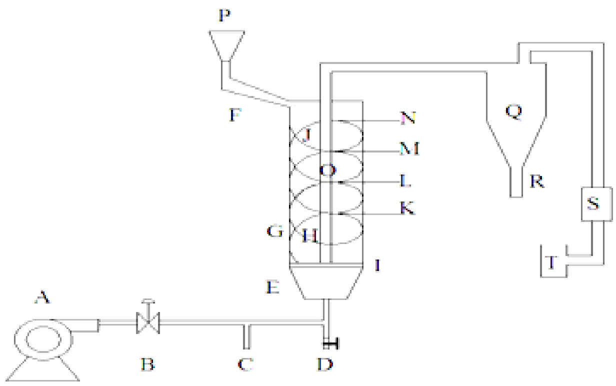

Figure 2: Fluidized bed gasifier- self circulating setup

A-Blower,

B–Control Valve,

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C-Pressure Tapping,
D-Rain Valve,
E-Pressure Tapping Lower End,
F-Pressure Tapping Upper End,
G-Reaction Chamber,
H-Riser Column,
I-Distributor Plate,
J-Self Circulating Setup,
K, L, M, N-Temperature Indicator,
O-Fluidizing Column,
P-Hopper,
Q-Cyclone Seperator,
R-Dust Collector,
S-Rota Meter,
T-Burner.

2.3 Experimental setup- reactor system

The gasifier consists of reaction chamber, riser column distributor plate, hooper and cyclone separator besides pressure and temperature tapping. The entire pilot model is made up of mild steel. A riser column with internal diameter of 10mm and with a thickness of 3mm for a height of 550 mm is selected. The riser column is kept inside the reaction chamber having an internal diameter of 200mm for a height of 350mm. The space between riser column and reaction chamber is fixed with self circulating setup which is also made up of mild steel through which the biomass reaches the bottom surface of reaction chamber by gravity. A blower is attached to the setup through which required air is supplied for supplying air for gasification. Pressure and temperature tapings are provided at different locations in the experimental setup. An air distributor plate is located at the bottom of the reactor with 200 holes of 2mm diameter. A suitable cyclone separator is attached at the end of riser column pipe. The cyclone separator has tangential inlet of circular type.

Figure 3: Photograph of experimental setup

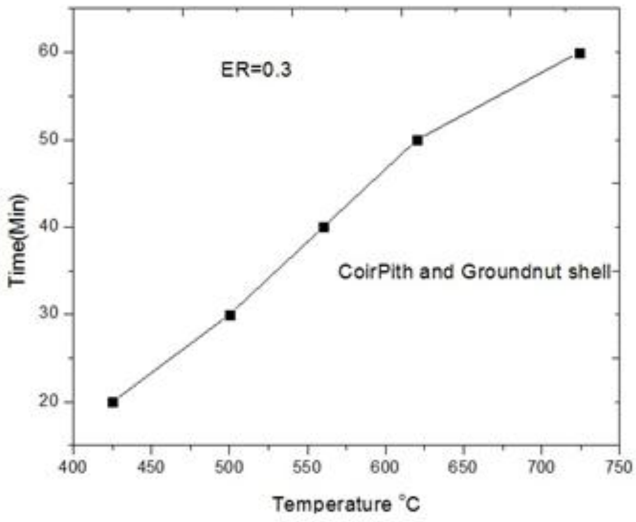
III. RESULTS AND DISCUSSION

In this study air is used as gasification agent. The effect of equivalence ratio (ER) on fluidized bed reactor temperature, gas composition and gas yield are studied and the results are given below.

3.1 Fluidized bed gasification and bed temperature

Initially the temperature of the reactor was increased gradually and it is done by heating the inert material along with burning the charcoal inside the reactor. The biomass material was fed into the reactor through hopper and air is allowed to pass through the distributor. The experiment was conducted for 1 hour run and the gas produced after passing the cyclone separator was measured and analyzed for various equivalence ratios of 0.3, 0.4 and 0.5. During gasification process the data were collected for every 10 min.

The fluidized bed reactor temperature increases sharply and reaches the maximum value at the end of 60th min of gasification. The maximum temperature attained for an ER of 0.3 during coir pith and groundnut shell gasification was around 705°C. For an ER of 0.4 and 0.5 the temperature attained was around 740°C and 980°C. With increase in equivalence ratio, reaction temperature also increased due to more air supply. Mathieu et al., (2002) observed linear increase of reaction temperature with increase in equivalence ratio. The effect of equivalence ratio on reactor temperature for coir pith and groundnut shell gasification, is shown in Fig. 4.



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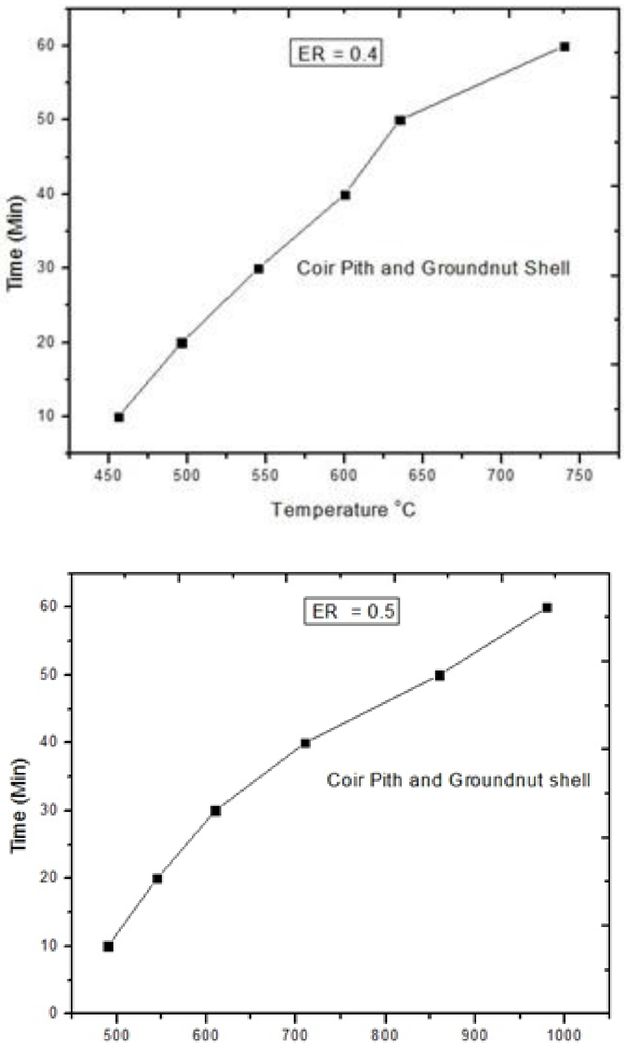

Figure 4: Effect of equivalence ratio on reactor temperature

3.2 Gas composition

During gasification trial, the gas composition of synthesis gas such as carbon monoxide, carbon dioxide, methane and hydrogen were observed for every 10 min while the equivalence ratio was varied from 0.3, 0.4 and 0.5. From the observed data carbon monoxide content increases with equivalence ratio. Carbon monoxide value was in the range of 17.4 - 18.35 for coir pith and groundnut shell mixture. Data on carbon dioxide revealed that increase in equivalence ratio during gasification increases the percentage of carbon dioxide content in the synthesis gas. A maximum value of 9% was observed at an ER of 0.5 and a minimum value of 8% at ER of 0.3 during gasification. The results are compared with Mansaray et al. (1999) findings and are close to the experimental value. During fluidized bed gasification of biomass it was observed that the percentage of carbon monoxide decreases with increase in ER and the carbon dioxide content increases with increase in ER .The same trend was noticed by Hanb et al. (2008). And this reduction in level of carbon monoxide was due to high air flow rate.

The level of hydrogen generation during gasification of all biomasses showed a decreasing trend for higher ER. The quantity of hydrogen gas generated dropped from 7.9% to 6.9% during coir pith and groundnut shell mixture gasification. The same trend was observed by Subramanian et al. (2011) with a decrease in CO and hydrogen for higher ER in fluidized bed biomass gasification.

During biomass gasification in the self circulating fluidized bed gasifier the methane level generation was found to be low and the range of methane content was 2.6- 3.6% for the biomasses during the trial. The influence of ER on gas composition is shown in Fig 5.

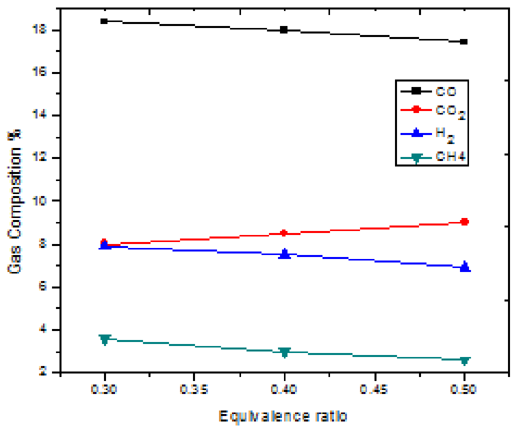

Figure 5: Influence of equivalence ratio on gas composition

3.3 Gas yield

From the gas flow rate and gas composition of synthesis gas the gas yield was calculated. The result showed that during gasification with increase in equivalence ratio the gas production rate also increased for coir pith and groundnut shell mixture. The gas yield was found to be in the range of 1.9 to 4 Nm^3/Kg during coir pith and groundnut shell mixture gasification, The present data was compared with the result obtained by Li et al., (2004) in a circulating fluidized bed gasification and the gas yield was in the range of 1.72 – 3.3 Nm^3/Kg, which indicates that the present study is in good agreement with literature. The gas heating value was analyzed form gas composition and it was found to be in the range of 1.9 - 3.9 MJ/Nm^3 for coir pith and groundnut shell mixture.

IV. CONCLUSION

Coir pith and groundnut shell mixture are gasified in the self circulating fluidized bed gasifier using air as the gasifying agent. Effect of ER on reactor temperature and gas composition and gas yield are studied. During biomass

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gasification, it is found that increase in ER favored the linear increase in temperature for all the biomasses. The highest temperature attained was around 980°C at an ER of 0.5. The highest hydrogen composition obtained in this study was 7.9 % at ER of 0.3. It is observed that the gas heating value increases with ER and reaches a maximum value of 3.9MJ/Nm^3 at an equivalence ratio of 0.5. The self circulating fluidized bed gasifier is useful for thermal application and power generation in small scale industries.

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