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AIR GASIFICATION OF 50% - 50% RICE HUSK- COIR PITH - SAWDUST BIOMASS MIXTURE IN SELF CIRCULATING FLUIDIZED BED GASIFIER

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ABSTRACT

Synthesis gas can be generated from Biomass through thermo chemical conversion process. In this study rice husk, coir pith and saw dust mixture were selected in 50%-50% by mass and gasification process was carried out for synthesis gas generation in a self circulating fluidized bed Gasifier. Synthesis gas composition was analyzed for various equivalence ratios of 0.3, 0.4 and 0.5 for the period of 10 minute time interval and the effect on gas constituents was studied. Key parameters i.e Gas yield, gas heating value, overall carbon conversion and cold gas efficiency were used to evaluate performance of the gasification system. The result indicate that combustible gas generation are high at lower ER. With increase in ER the gas yield increases and HHV of the gas decreases. Optimum ER is considered to be 0.3 for syngas generation.

Keywords: Self circulating FBG, Equivalence ratio, gas yield, dry gas HHV, gas composition, overall carbon conversion, cold gas efficiency

1. INTRODUCTION

Biomass can be converted into different forms of energy by thermochemical and bio chemical conversion method. Gasification of biomass through thermo chemical conversion process is one of the promising method for Syngas generation in which the feedstock reacts with gasifying medium such as air, steam or a combination of both. The producer gas consists of mainly carbon monoxide, hydrogen and methane which can be utilized for applications like, thermal, power generation and industrial applications **[1]**. 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 **[2]**. designed and fabricated Fluidized bed gasifier for rice husk 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 rice husk and concluded that the performance of gasifiers depends mainly on equivalence ratio range 0.2 to 0.35 on volumetric yield and also compared the result form pilot model with experimental data to validate proposed mathematical model.

[3] carried out experimentation in selected granular biomaterials like coir pith, rice husk and saw dust in fluidized bed gasifier for syn gas generation. They analyzed gas yield, gas compositions for the equivalence ratios of 0.3,0.4 and 0.5.The maximum gas yield for the product gas reached 3.7 Nm^3/Kg during saw dust gasification and the percentage of carbon monoxide and carbon dioxide was in the range of 8.24–19.55 and 10.21–17.14 respectively. Gasification technologies for energy production from biomass was reviewed by **[4]** and concluded that biomass properties and pretreatment are the key parameters in gasification process. **[5]** conducted experiments in a downdraft gasifier for hydrogen production from biomass using air and oxygen/steam gasification and observed that the use of steam/oxygen improved the hydrogen yield compared to air gasification. Heating value reached its maximum value of 11.11 MJ/Nm^3 for biomass oxygen/steam gasification and the maximum hydrogen yield reached its value of 45.16 gH_2/kg biomass. **[6]** Discussed about the development of fluidized bed gasifier for smaller particles biomass gasification over fixed bed gasifiers. They also observed that heating value of the gas increased about 20% in fluidized bed gasifiers using silica sand and calcined limestone as bed materials. **[7]** Determined the bulk density, coefficient of friction and particle density of coir pith with the biomass moisture content varies from 10.1% to 60.2% by weight and developed correlations to explain the effect of physical properties. **[8]** Studied the feasibility of using coir pith in powder form to gassify since briquetting consumes huge amount of energy. **[9]** Conducted simulation of biomass mixtures of 100 g with rice husk, sawdust and bamboo dust mixtures for the operating parameters of equivalence ratio, temperature and composition of biomass mixtures. It was found that for all biomass mixtures the optimum equivalence ratio was 0.3 with gasification temperature of 800^{0}C. **[10]** Conducted experiments on coir pith gasification using air as gasifying agent. They observed that maximum yield of hydrogen 11.2 % is obtained at a temperature of 1028.6^{0}C and discussed the effect of temperature on gas composition during gasification.

[11] Conducted experiments in atmospheric and bubbling fluidized bed gasifier using air, steam and steam- O_2 mixture as gasifying agent and concluded that hydrogen yield increases when steam is used as gasifying agent compared to O_2.

2. BIOMASS AND INERT BED MATERIALS

In this study rice husk, coir pith and saw dust were collected in sengipatti near trichy where plenty of agricultural residue are available which can be used for syngas production in the proposed self circulating fluidized bed gasifier. Sand is used as inert material in the bed and its particle size was selected as 0.375 mm by sieve analysis. **[12]** Conducted sieve analysis to predict particle size distribution of biomass materials having a size up to 3mm. **[13]** conducted particle size distribution in a set of standard sieves. Proximate analysis was carried out in muffle furnace and percentage of moisture content, volatile matter, ash content and fixed carbon was determined by ASTM procedures and shown in **Table 1**.

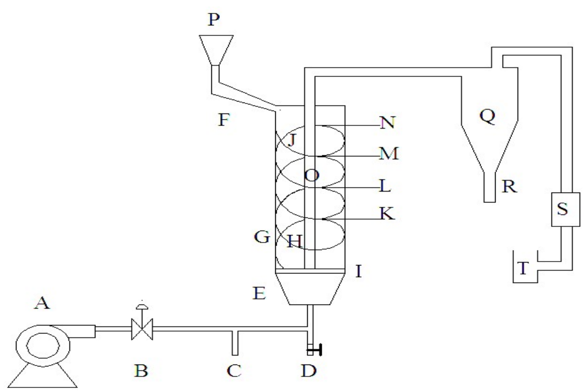
Table 1: Proximate Analysis

S. No.	Proximate analysis (in %)	Rice Husk + Coir Pith	Coir Pith + Saw dust	Saw dust + Rice husk
1	Moisture content at 110^{0}C	10.5	8.5	6.5
2	Volatile matter at 925^{0}C	60	70.5	74.5
3	Ash content at 750^{0}C	13.5	9	9
4	Fixed Carbon	16	12	10
	Total	100	100	100

3. EXPERIMENTAL SETUP AND PROCEDURE

3.1 System Description

The experimental setup consists of self circulating fluidized bed gasifier, air distributor plate, riser column, rotameter, pressure tapping, temperature tapping and cyclone separator. A control valve regulates the air from the blower to the gasification system. The flow rate of air is measured by pressure tapping which is connected to U tube manometer. The pressure tapping is also done at different location above and below the air distributor. Temperature tapping is provided at different location in the riser column. K type thermocouples are provided along the height of gasifier to measure the temperature in gasifier which are connected to temperature indicator. A rotameter with a capacity of 100 cc/min is fixed at the end of the cyclone separator for measuring the flow rate of the producer gas. The schematic diagram of experimental setup of a self circulating fluidized bed Gasifier is shown in **Figure 1**.



A -BLOWER
B -CONTROLVALVE
C -PRESSURE TAPPING
D -DRAIN 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 -ROTAMETER
T -BURNER

Figure 1: Fluidized Bed Gasifier- Self Circulating Setup

3.2 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 in a muffle furnace.

The photographic view of experimental set up is shown in **Figure 2**.

Figure 2: Photographic view of experimental set-up

A systematic procedure is adopted for gasification of biomass mixture in 50% Rice husk and 50% Coir pith, 50% Coir pith and 50% Saw dust, 50% Saw dust and 50% Rice husk combination by mass is selected and gasified in the self circulating fluidized bed gasifier.A sample of biomass mixture is first pretreated using sieve analysis to remove unwanted materials present in rice husk and coir pith in order to get the required size prior to experimentation.

Initially the biomass mixture of 50% rice husk and 50% Coir pith is charged through the hopper which is kept at the top of the gasifier. The charged biomass mixture eaches the bottom of the gasifier through a self circulating set up without the aid of fuel feeding subsystem by gravity. Sand is used as inert material during gasification of biomass. Sand is mixed with biomass mixture of suitable quantity depending upon the biomass used during gasification in fluidized bed. Initially the biomass is heated by dipping charcoal in kerosene and burnt inside the gasifier in order to sustain the temperature inside the system in order to attain stable temperature. The temperature is monitored by thermocouples located along the riser column. Similarly the same procedure is followed for 50% Coir pith and50% Saw dust, 50% Saw dust and 50% Rice husk biomass mixture.

Gasification process started by feeding rice husk and coir pith mixture mixed with sand and reaches the bottom of the reactor over the grate through the self circulating set up. Rice husk coir pith mixture is pre heated when it passes through self circulating set up fixed around the riser column. Air is passed from the bottom of the grate through the distributor plate which takes the rice husk and coir pith in the riser column. Synthesis gas along with sand and unburnt rice husk coir pith mixture passes through riser column and reaches the cyclone separator. The gas is collected at the top of cyclone separator and the remaining solid particles reach the bottom of the cyclone which can be recirculated into the reaction chamber again. During this process temperature is monitored at different locations at regular intervals. The flow rate of producer gas is recorded by rotometer and gas composition is analyzed by gas chromatography for every 10 min.

3.3 Data Collection

The air flow rate is measured by making tapping in the pipe coming from blower which is connected to the U tube manometer. Two Pressure tapping is provided above and below the air distributor for measuring the pressure difference in the riser column connected to U tube Manometer. Four temperature probes (T1 to T4) are located at different height along the riser column for measuring the temperature of the gasifier reactor. K-type thermocouples are used to measure the temperature of the reactor. Gas flow rate is measured by using rotameter with a capacity of 100 cc/min. Gas constituents of producer gas are analyzed by gas chromatography.

4. 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, gas yield, dry gas HHV, overall carbon conversion and cold gas thermal efficiency are studied and the results are given below.

4.1 Fluidized bed reactor 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. Once the temperature reaches stability as observed by **[14]**. 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 maximum temperature attained for an ER of 0.3 during rice husk and coir pith mixture gasification was around 824^{o}C. For ER of 0.4 and 0.5 the temperature attained was around 875^{o}C and 930 ^{o}C. With increase in equivalence ratio, reaction temperature also increased due to more air supply [15]. observed linear increase of reaction temperature with increase in equivalence ratio. Similar trend was observed during 50% Coir pith and 50% Saw dust and 50% Saw dust and 50% Rice husk in the reactor. The effect of equivalence ratio on reactor temperature for 50%-50% rice husk, coir pith and saw dust mixture gasification is shown in **Figure 3, Figure 4 and Figure 5**.

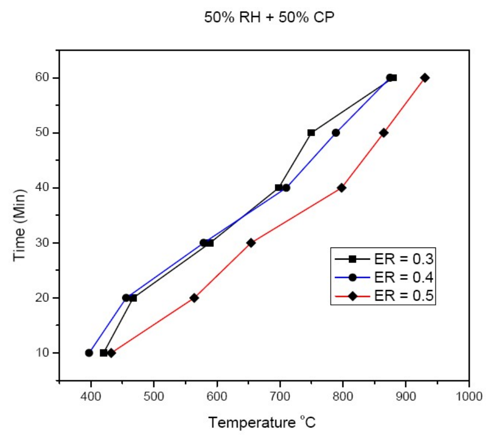


Figure 3: Effect of Equivalence Ratio on Reactor Temperature

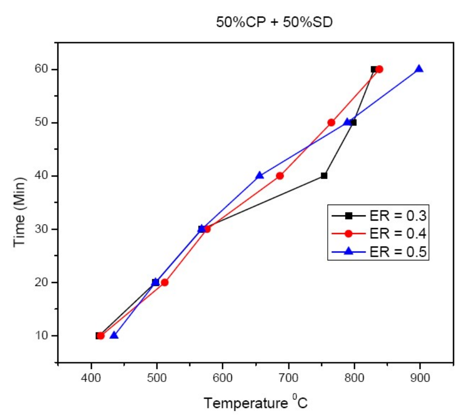


Figure 4: Effect of Equivalence Ratio on Reactor Temperature

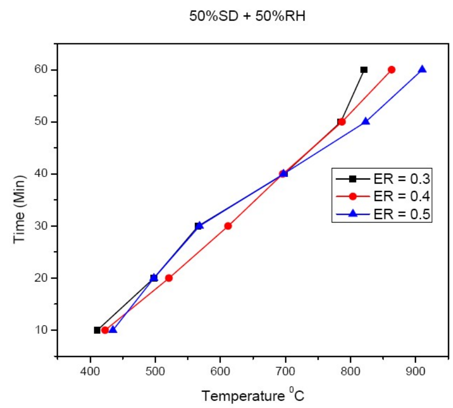


Figure 5: Effect of Equivalence Ratio on Reactor Temperature

4.2 Gas composition

The gas composition of synthesis gas such as carbon monoxide, carbon dioxide, methane and hydrogen were observed for every 10 min for the equivalence ratio of 0.3, 0.4 and 0.5. From the observed data that carbon monoxide content decreases with increase in equivalence ratio. Carbon monoxide value was in the range of 10 - 17.7% for 50%-50% Rice husk and Coir pith biomass mixture. During 50%-50% Coir pith and Saw dust gasification carbon monoxide content reached its maximum value of 14% at the ER = 0.3 when the reaction temperature was at 830°C. Data on 50%-50% Saw dust and Rice husk mixture gasification revealed that carbon monoxide content reached its maximum value of 14% at the ER = 0.3.

Experimental results 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 12.4% was observed at ER of 0.5 during 50% saw dust and 50% rice husk gasification trial. The results are compared with **[16]** findings for individual biomass and are close to the experimental value. During fluidized bed gasification of biomass it was observed the percentage of carbon monoxide decreases with increase in ER and the carbon dioxide content increases with increase in ER .The quantity of hydrogen gas generated dropped from 9.3% to 8.5% during 50% rice husk and 50% coir pith mixture gasification. The same trend was observed by **[3]** with a decrease CO and hydrogen for higher ER in fluidized bed biomass gasification for individual biomass. Similar results were obtained for 50% - 50%Coir pith, Saw dust mixture and 50%-50% Saw dust, rice husk mixture. Methane level generation was found to be low for all biomass mixture with equivalence ratio The influence of ER on gas composition is shown in **Figure 6, Figure 7 and Figure 8**.

4.3 Gas yield and Gas heating value

From the gas flow rate and gas composition of synthesis gas the gas yield was calculated. The result showed during gasification with increase in equivalence ratio the gas production rate also increased from 1.72 – 2.12 Nm^3/kg for 50%-50% Rice husk – coir pith biomass mixture. The present data was compared with the result obtained by **[17]** in a circulating fluidized bed gasification and the gas yield was in the range of 1.63 – 2.13 Nm^3/Kg, which indicates the present study is in good agreement. Similar trend was observed for Coir pith-Saw dust mixture and Saw dust - rice husk mixture. The gas heating value were analyzed form gas composition and it was found to be in the range of 3.34 - 4.61MJ/Nm^3 during 50% rice husk and 50% coir pith mixture gasification. The influence of ER on gas yield and gas heating value, for all biomass mixture are shown in **Figure 9, Figure 10 and Figure 11**.

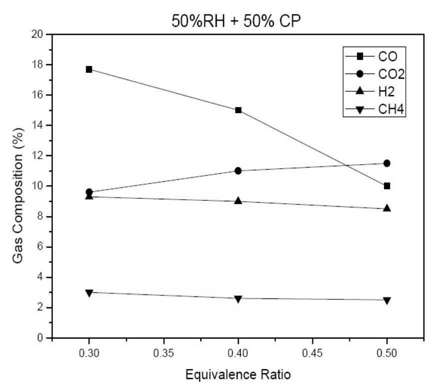


Figure 6: Influence of Equivalence Ratio on Gas Composition

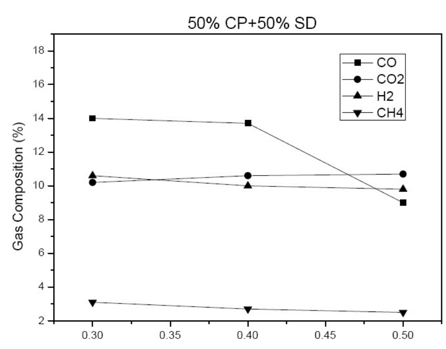


Figure 7: Influence of Equivalence Ratio on Gas Composition

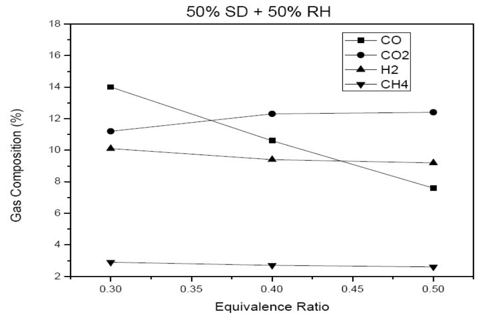


Figure 8: Influence of Equivalence Ratio on Gas Composition

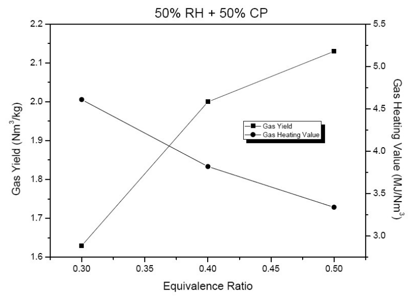


Figure 9: Influence of Equivalence Ratio on Gas Yield And Gas Heating Value

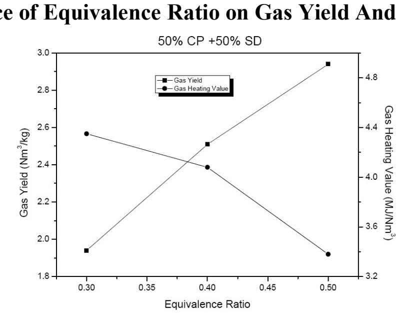


Figure 10: Influence of Equivalence Ratio on Gas Yield And Gas Heating Value

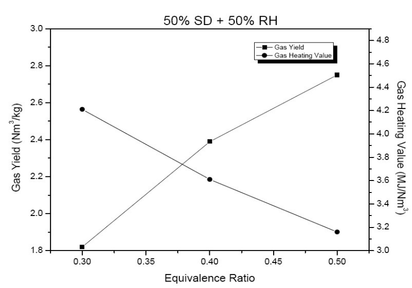


Figure 11: Influence Of Equivalence Ratio On Gas Yield And Gas Heating Value

4.4 Cold gas thermal efficiency and overall carbon conversion

Overall carbon conversion during gasification reached its maximum value of 93.16% at ER = 0.5 for 50%-50% Coir pith and Saw dust mixture and Cold gas thermal efficiency reached its maximum value of 78% at the equivalence ratio of 0.4 when the reaction temperature was at

838 ^{0}C, during Coir pith and Saw dust mixture gasification. Carbon conversion reached its maximum value of 91.2% at an equivalence ratio of 0.4 for Saw dust–Rice husk mixture and maximum cold gas efficiency of 69.56% was obtained during gasification at ER= 0.5 for Saw dust- Rice husk mixture. The influence of ER on overall carbon conversion and cold gas thermal efficiency for all biomass mixture are shown in **Figure 12, Figure 13 and Figure 14**.

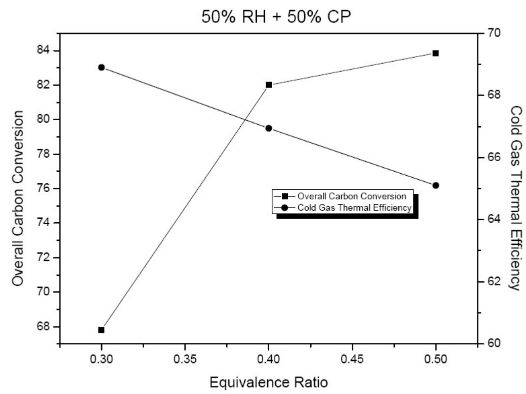


Figure 12: Influence of Equivalence Ratio on Carbon Conversion And Cold Gas Efficiency

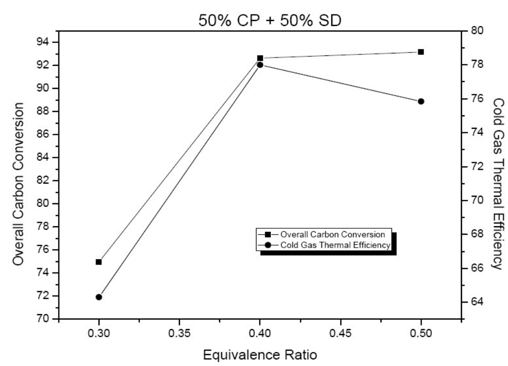


Figure 13: Influence of Equivalence Ratio on Carbon Conversion And Cold Gas Efficiency

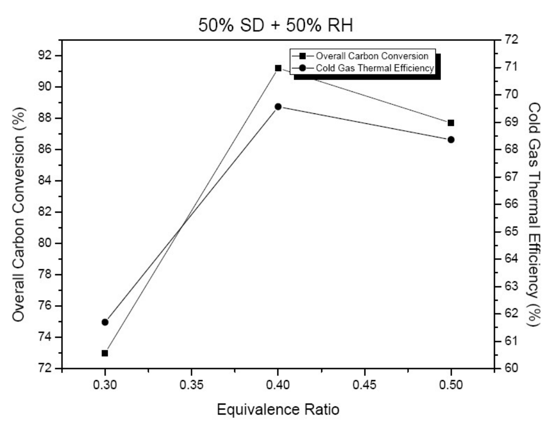


Figure 14: Influence of Equivalence Ratio on Carbon Conversion And Cold Gas Efficiency

5. CONCLUSION

Rice husk, coir pith and sawdust mixture in 50%-50% by mass 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 gasification, it is found that increase in ER favored the linear increase in temperature for all the biomass mixtures. The highest temperature attained was around 930°C at an ER of 0.5 for rice husk-coir pith mixture. The highest hydrogen composition obtained in this study was 10.6 % for coir pith -saw dust mixture at ER of 0.3. It is observed that the gas heating value decreases with ER. The self circulating fluidized bed gasifier is useful for thermal application and power generation in rural applications.

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