Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

Air Gasification of 75% - 25% Rice Husk- Coir Pith - Sawdust Biomass Mixture in Self Circulating Fluidized Bed Gasifier

Ganesh R[1], Saraswathy N[2], Renuka Devi P[3]

[1]Department of Mechanical Engineering, Parisutham Institute of Technology and Science Thanjavur-613006, Tamil Nadu, India

[2]Department of Humanities and science, Parisutham Institute of Technology and Science Thanjavur-613006, Tamil Nadu, India

[3]Department of Mechanical Engineering, Parisutham Institute of Technology and Science Thanjavur-613006, Tamil Nadu, India

Corresponding Auther: R.Ganesh , E-mail: rganeshmech1978@gmail.com
N.Saraswathy. E-mail:saraswathyrajam@gmail.com
P.Renuka Devi E-mail:prrenu13@gmail.com

***Abstract** :Thermo chemical conversion process is well proven technology for synthesis gas production. Mixture of biomass with various ratios is a new approach and the same has been experimented in fluidized bed gasification. A self circulating fluidized bed gasifier is designed and experimented by combination of above biomass with mixture ratio of 75%-25% for an equivalence ratio of 0.3,0.4and 0.5.The overall performance of gasification system has been evaluated by the key parameters such as gas yield, gas heating value, carbon conversion and cold gas efficiency.*

***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 thermo chemical 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.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. J.J.Ramirez et al.(2007) 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.

P.Subramanian et al. (2011) 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 McKendry (2002) and concluded that biomass properties and pretreatment are the key parameters in gasification process. Lv et al. (2007) 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

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

biomass oxygen/steam gasification and the maximum hydrogen yield reached its value of 45.16 gH_2/kg biomass. Bingyan et al. (1985) 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. Manickam and Subramanian (2006) 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.physical properties. Subramanian et al. (2004) studied the feasibility of using coir pith in powder form to gassify since briquetting consumes huge amount of energy. Buljit Buragohain et al. (2011) 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 800^0C.Sheeba et al.(2009) 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 1028.6^0C and discussed the effect of temperature on gas composition during gasification.

Gil et al. (1999b) 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. The dependency of individual biomass for power generation can be substantially reduced when it is operated under Biomass mixtures of different combinations. Thanh et.al(2012) investigated gas and particles hydrodynamic behaviors in a pilot scale cold-mode riser and bubbling fluidized bed gasifier by means of experiment and computational fluid dynamics (CFD).They concluded that the cold-bed simulation can be used to predict the solid circulation rate for the hot-bed operation of the DFB gasifier.

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 of particle size 0.375 mm is selected as inert bed material. 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

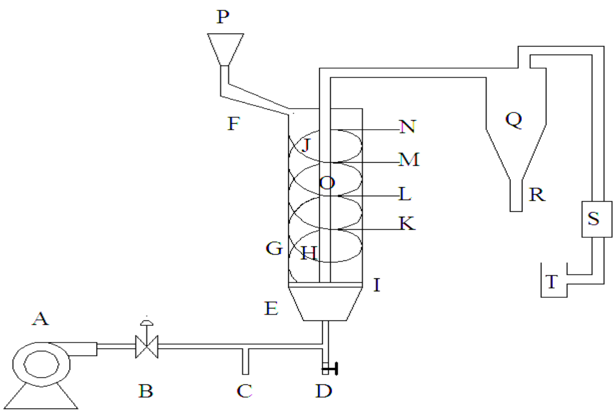
S. No.	Proximate analysis (in %)	Rice Husk + Coir	Coir Pith + Saw	Saw dust + Rice
1	Moisture content at 110^0C	10.5	8.5	6.5
2	Volatile matter at 925^0C	60	70.5	74.5
3	Ash content at 7500C	13.5	9	9
4	Fixed Carbon	16	12	10
	Total	100	100	100

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)
Volume7-Issue2, January 2024
Paper: 9

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 and temperature tappings are placed in different locations in air distributor and riser column respectively. Temperature tapping is provided at different locations 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 self circulating fluidized bed Gasifier is shown in Fig.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

FIG. 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

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

and Technology.

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

FIG.2.PHOTOGRAPHIC VIEW OF EXPERIMENTAL SET-UP

A systematic procedure is adopted for gasification of biomass mixture in 75% Rice husk and 25% Coir pith,75% Coir pith and 25% Saw dust , 75% Saw dust and 25% Rice husk combination by mass is selected and gasified in the self circulating fluidized bed gasifier.

Initially the biomass mixture of 75% rice husk and 25% Coir pith is charged through the hopper which is kept at the top of the gasifier.The charged biomass mixture reaches the bottom of the gasifier by gravity through a self circulating set up without the aid of fuel feeding subsystem. 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 75% Coir pith and 25% Saw dust, 75% Saw dust and 25% 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 carries 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 synthesis gas is recorded by rotameter and gas composition is analyzed by gas chromatography for every 10 min.

3.3 Data Collection

The air flow rate is measured by providing tapping in the pipe after the 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 synthesis gas are

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)
Volume7-Issue2, January 2024
Paper: 9

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 stabilizes as observed by Czernik et al. (1992), 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 and the gas produced after passing through 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 806^oC. For ER of 0.4 and 0.5 the temperature attained was around 859^oC and 896 ^oC respectively. With increase in equivalence ratio, reaction temperature also increased due to more air supply. Mathieu et al.(1999) observed linear increase of reaction temperature with increase in equivalence ratio. Similar trend was observed during 75% Coir pith and 25% Saw dust and 75% Saw dust and 25% Rice husk in the reactor.

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.It is observed data that carbon monoxide content decreases with increase in equivalence ratio. Carbon monoxide value was in the range of 11 - 20.4 for 75%-25% Rice husk and Coir pith biomass mixture. During 75%-25% Coir pith and Saw dust gasification carbon monoxide content reached its maximum value of 14% at ER = 0.3 when the reaction temperature was at 790^oC. Data on 75%-25% Saw dust and Rice husk mixture gasification revealed that carbon monoxide content reached its maximum value of 18.5% 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 12.2% was observed at ER of 0.5 during 75% coir pith and 25% saw dust gasification. The results are compared with Mansaray et al.(1999) for individual biomass 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 quantity of hydrogen gas generated dropped from 9.1% to 8.1% during 75% rice husk and 25% coir pith 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 for individual biomass. Similar results were obtained for 75% - 25%Coir pith , Saw dust mixture and 75%-25% Saw dust, rice husk mixture. When gasifying with air as the medium,the results showed that the yield of gaseous product is higher due to the enhanced cracking and catalytic action of biomass. Final gas composition duringgasification in the fluidised bed reactor depends on the cracking reactions. During fluidized bed gasification of biomass it is observed that the percentage of carbon monoxide decreases with increase in ER and the carbon dioxide content increases with increase in ER and this reduction in level of carbon monoxide was due to high air flow rate. Hydrogen generation during gasification of all biomasses showed a decreasing trend for higher ER. Methane level generation was found to be low for all biomass mixture with

Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

equivalence ratio. The influence of ER on gas composition is as shown in Fig 3, Fig 4 and Fig 5.

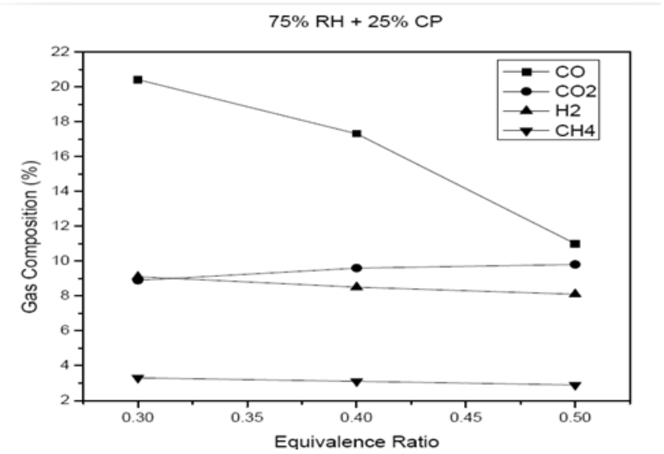


FIG. 3. INFLUENCE OF EQUIVALENCE RATIO ON GAS COMPOSITION 75%RH+25% CP

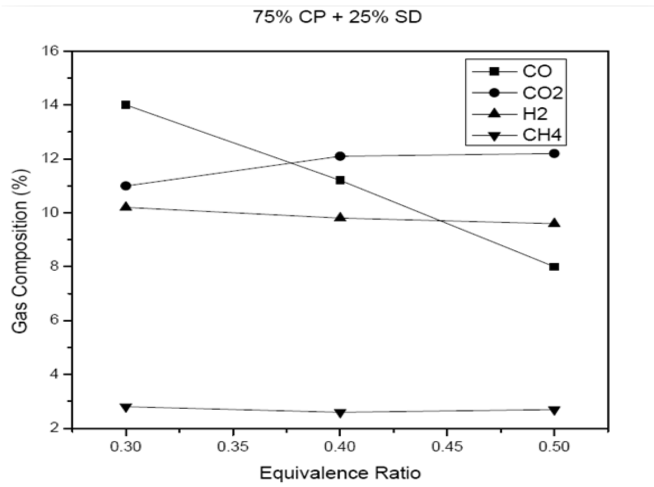


FIG. 4. INFLUENCE OF EQUIVALENCE RATIO ON GAS COMPOSITION 75%CP+25% SD

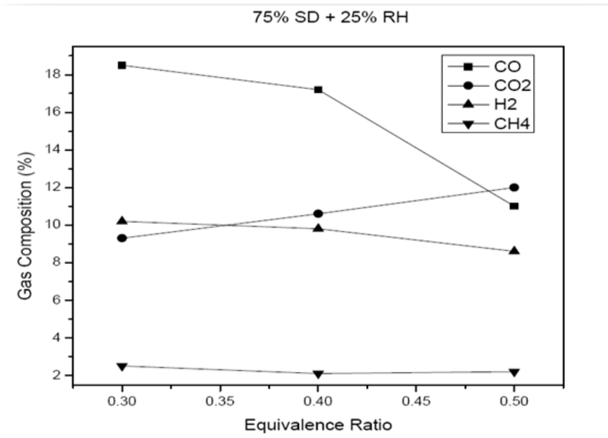


FIG. 5. INFLUENCE OF EQUIVALENCE RATIO ON GAS COMPOSITION 75%SD+25% RH

Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

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 1.69 – 2.34 Nm^3/kg for 75%-25% Rice husk – coir pith biomass mixture. 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 1.63 – 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 3.57 -5 MJ/Nm^3 during 75% rice husk and 25% coir pith mixture gasification. As the temperature increases, more of the solid fuel is converted into gaseous products thereby increasing the product gas yield.Gas heating value for all biomass showed a decreasing trend withincrease in ER due to dilution of produced gas by nitrogen gas present in air at higher ER. The influence of ER on gas yield and gas heating value, for all biomass mixture are shown in Fig 6, Fig 7 and Fig 8.

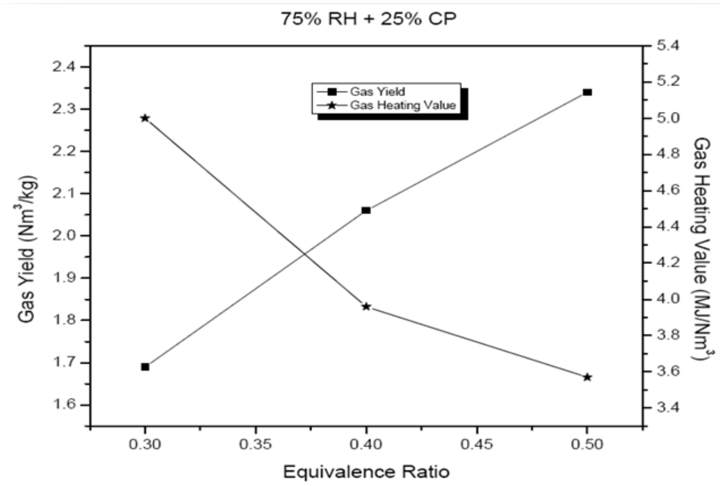


FIG. 6. INFLUENCE OF EQUIVALENCE RATIO ON GAS YIELD AND GAS HEATING VALUE 75%RH+25% CP

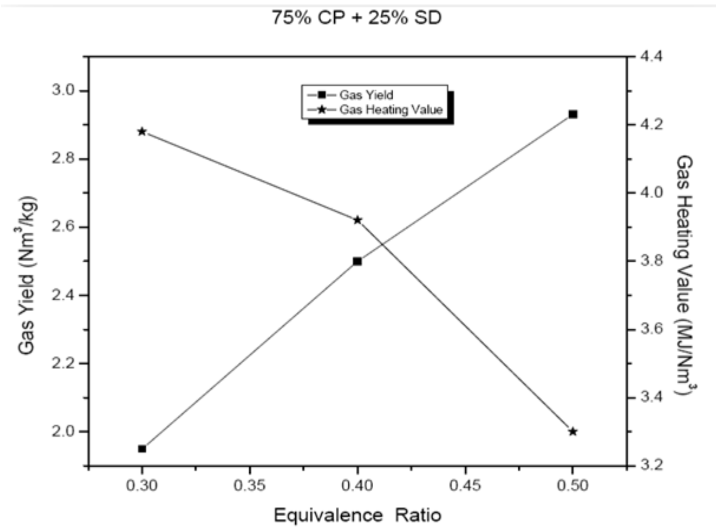


FIG. 7. INFLUENCE OF EQUIVALENCE RATIO ON GAS YIELD AND GAS HEATING VALUE

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

75%CP+25% SD

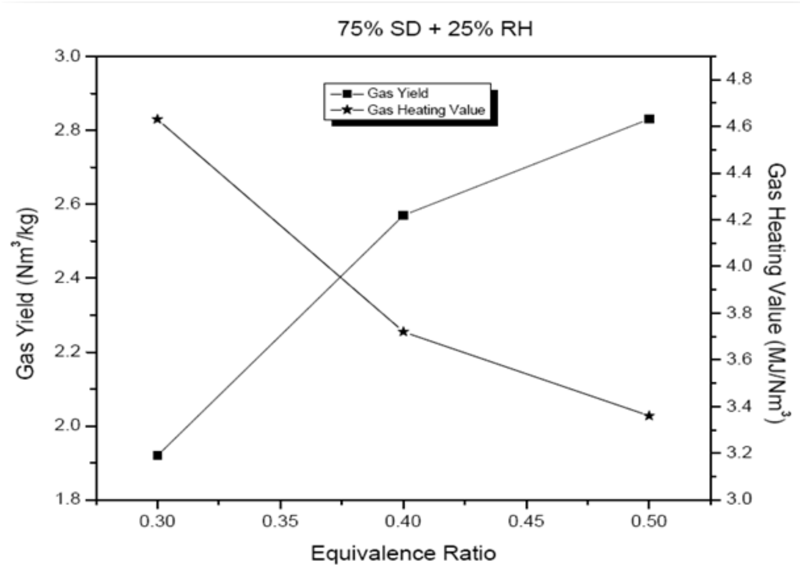


FIG. 8. INFLUENCE OF EQUIVALENCE RATIO ON GAS YIELD AND GAS HEATING VALUE 75%SD+25% RH

4.4 Cold gas thermal efficiency and overall carbon conversion .

Overall carbon conversion during gasification reached its maximum value of 94.15% at ER = 0.5 for 75%-255% Saw dust and rice husk mixture and Cold gas thermal efficiency reached its maximum value of 69.6% at the equivalence ratio of 0.4 when the reaction temperature was at 859 ^{0}C, during Rice husk and Coir pith mixture gasification. Cold gas thermal efficiency increases with increase in equivalence ratio up to ER=0.4 and decreases thereafter due to change over from gasification to combustion process beyond ER =0.5. Carbon conversion increases with increase in ER due to more supply of air during gasification. The influence of ER on overall carbon conversion and cold gas thermal efficiency for all biomass mixture are shown in Fig 9, Fig 10 and Fig 11.

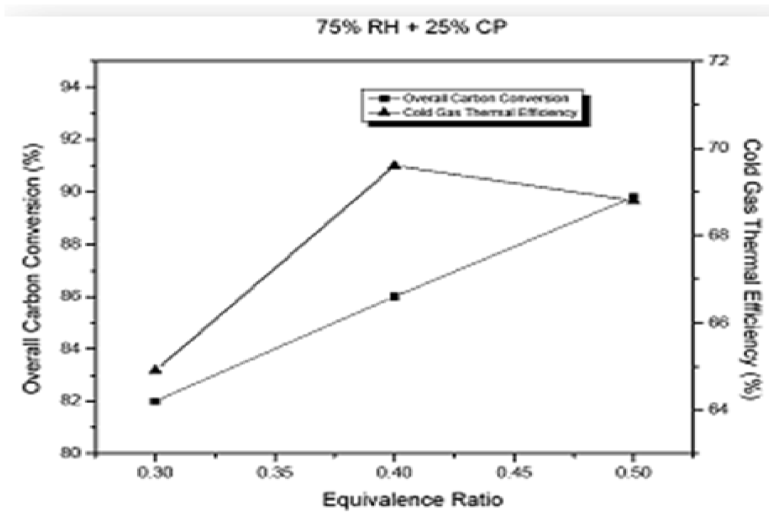


FIG.9. INFLUENCE OF EQUIVALENCE RATIO ON CARBON CONVERSION AND COLD GAS EFFICIENCY 75%RH+25% CP

Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

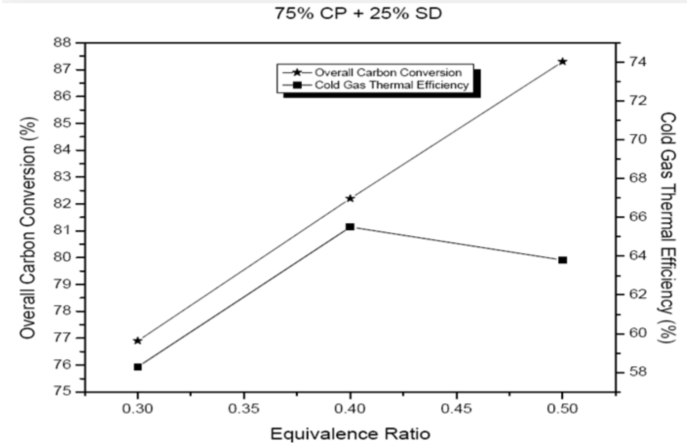


FIG.10. INFLUENCE OF EQUIVALENCE RATIO ON CARBON CONVERSION AND COLD GAS EFFICIENCY 75%CP+25% SD

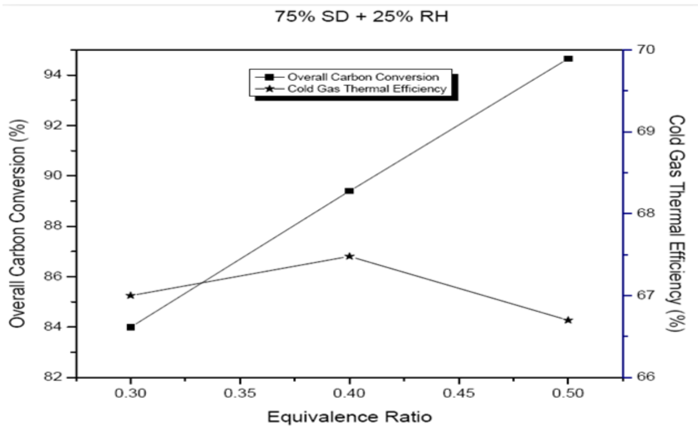


FIG.11. INFLUENCE OF EQUIVALENCE RATIO ON CARBON CONVERSION AND COLD GAS EFFICIENCY 75%SD+25% RH

4.5 CFD analysis validation.

Simulation of a fluidised bed biomass Gasifier with self circulating using computational fluid dynamics, geometry creation, mesh building and boundary conditions have been carried out by CFD analysis. The results obtained from the simulation are compared with the experimental values and the results are validated. The percentage of each constituent in the raiser column after gasification of each of the raw materials of rice husk, coir pith and saw dust mixtures in 75% - 25%combinations for various equivalence ratios and its comparison to the experimental results are shown in Fig. 12,13 and 14. The experimental data is verified with CFD analysis and deviation falls ± 10%

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN: 2581 - 611X)

Volume7-Issue2, January 2024
Paper: 9

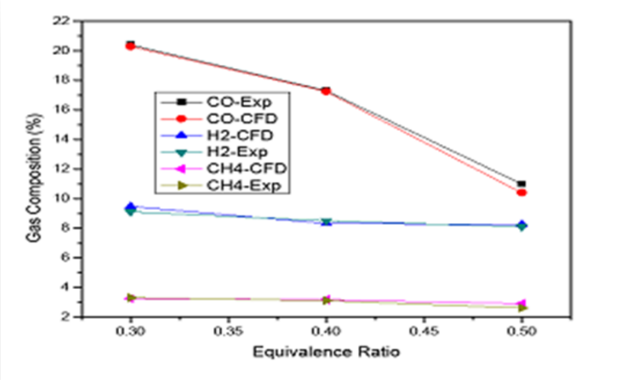


FIG. 12.COMPARISON OF EXPERIMENTAL RESULTS WITH CFD ANALYSIS75% RH + 25% CP

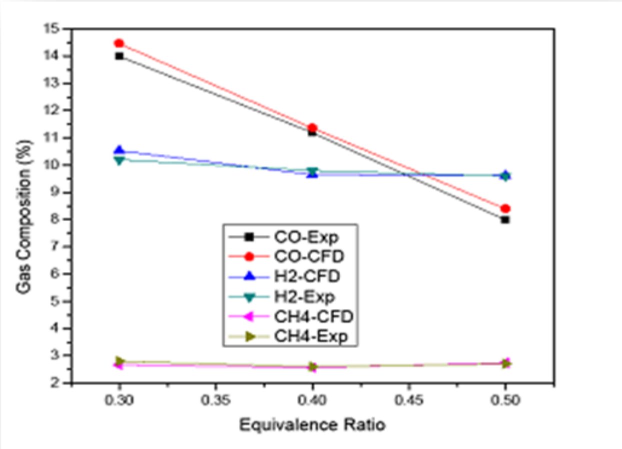


FIG.13.COMPARISON OF EXPERIMENTAL RESULTS WITH CFD ANALYSIS 75% CP + 25% SD

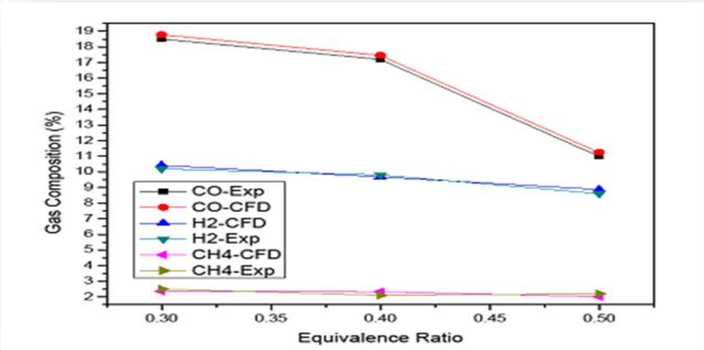


FIG.14.COMPARISON OF EXPERIMENTAL RESULTS WITH CFD ANALYSIS 75% SD + 25% RH

5. CONCLUSION

Rice husk, coir pith and sawdust mixture in 75%-25% 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 910^oC at an ER of 0.5 for saw dust- rice husk mixture. The highest hydrogen composition obtained in this study was 10.2 % 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.

6.REFERENCES

[1] Bingya X, Flaingan V, Sitton O, Huan E.W. Design and Operation of a 6inch Fluidised Gasifier for Rice Hulls. Energy from Biomass and Wastes IX 1985: Orlando. USA.

[2] Buragohain, Pinakeswar Mahanta , Vijayanand S, Moholkar. “Investigations in gasification of biomass mixtures using thermodynamic equilibrium and semi – equilibrium models”. Journal of Energy and Environment 2011 : 2: 551-578.

[3] Czernik S, Koeberle P.G, Jollez P, Bilodeau J.F, Chornet E. “Gasification of residual biomass via the biosyn fluidized bed technology”. Biomass Energy 1992 Ind. X 423: 37.

[4] Gil J, Corella JM, Aznar MP, Caballero MA, “Biomass gasification in atmospheric and bubbling fluidized bed: effect of the type of gasifying agent on the product distribution”. Biomass Bioenergy 1999b: 17:389–403.

[5] Henderson S.M, Perry R.L. “Size reduction in agricultural process Engineering”. 2nd ed. AVI Pub. 1966: USA : 128–153.

[6] Li X.T, Grace J.R, Lim C.J, Watkinson A.P, Chen H.P, Kim J.R. “Biomass gasification in a circulating fluidized bed”. Biomass Bioenergy 2004: 26(2): 171–193.

[7] Lin C.L, Wey M.L, You S.D. “The effect of particle size distribution on minimum fluidization velocity at high temperature”. Powder Technol. 2002: 126 : 297– 301.

[8] Lv P, Yuan Z, Ma L, Wu C, Chen Y, Zhu J. “Hydrogen-rich gas production from biomass air and oxygen/steam gasification in a downdraft gasifier”. Renew. Energ. 2007:32: 2173–85.

[9] Manickam N, Subramanian P. “Study of physical properties of coir pith”. Int. J. Green Energ. 2006: 3:397–406.

[10] Mansaray K.G, Ghaly A.E, Al-Taweel, A.M., Hadullahpur F, Ugursal. “Airgasification of rice husk in a dual distributor type fluidised bed gasifier”. Biomass Bioenergy. 1999:17: 315–332.

[11] Mathieu P, Dubuisson R. “Performance analysis of a biomass gasifier”. Energy Convers. Manage. 2002: 43: 1291–1299.

[12] McKendry P. “Energy production from biomass (part 3): gasification technologies”. Bioresour. Technol. 2002: 83:55–63.

[13] Rajiv varshney J.L, Bhagoria , Mehta . “Small scale biomass gasification technology in India – An overview” , Journal of Engineering, science and management education .2010: 3: 33-40.

[14] Ramirez J.J, Martinez J.D, Petro L. “Basic design of a fluidized bed gasifier for rice husk on a pilot scale Latin American Applied Research. 2007: 37: 299-306.

[15] Sheeba K.N, Sarat Chandra Babu J, Jaisankar S. “Gasification characteristics of coir pith in a circulating fluidized bed gasifier”. Energy for sustainable development.2009: 13: 166-173.

[16] Subramanian P, Sampatharajan A, Venkatachalam P.V. “Fluidized bed gasification of select granular biomaterials”. Bioresource Technology. 2011: 102: 1914 – 1920

[17] Subramanian P, Premalatha M, Sekar T. “Determination of angle of internal friction for biomass”, Biomass Research and Development. 2004 : Bioproducts opportu-nities report,

[18] Thanh D.B. Nguyen, Myung Won Seo, Young-Il Lim, Byung-Ho Song and Sang-Done Kimb. “CFD simulation with experiments in a dual circulating fluidized bed gasifier”.Computers and Chemical Engineering.2012:36: 48-56