International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Performance Of Four Stroke Compression Ignition Engine Operated On Dual Fuel Mode With Producer Gas And Diesel

K. C. Keerthivasan, S. Vivekanandan, R. Suresh

Abstract*: We intensify our probe on waste biomass found in South India namely Prosopis Juliflora, because of its forceful growth in uncultivated agricultural landfills. To depose the Prosopis Juliflora, biomass gasification is the sufficient thermo-chemical reaction to excerpt useful energy from waste biomass. The fluidized bed gasifier (FBG) was used to gasify the waste biomass Prosopis Juliflora with a feed rate capacity from 5 to 20kg/hr and temperature is in the range of 650 - 950 ℃ with an equivalence ratio of 0.24 - 0.44 was maintained. When the gasifier is operated alone, the flame temperature is lower so that the conversion rate of heat energy will also be lower. If the gasifier is operated with accessories the flame temperature got increased by 40%, the conversion rate of heat energy will also be high in the compression ignition (CI) engine. The brake thermal efficiency of compression ignition engine for both (diesel) single fuel and (producer gas + diesel) dual fuel modes at four different producer gas mass flow rate has been shown and specific fuel consumption(SFC) has improved slightly due to addition of calorific value in the producer gas to the supply to the engine from the gasifier.

Keywords: **Biomass gasification, Fluidized bed gasifier, Prosopis Juliflora, Flame temperature, Brake thermal efficiency, Specific fuel consumption.**

I. INTRODUCTION

Among the renewable sources of energy, biomass is third among the renewable in nature after fossil fuels like coal; oil and petroleum products [1 - 4]. Due to its vast accessibility in environment, renewable, portable in associated to global warming [5, 6]. Waste biomass is recognized as promising renewable sources of energy. Conversion of solid fuels to gaseous fuels is named as gasification. It is a thermo-chemical process will lead to convertion of organic fuel based carbonaceous substantial into CO, H_2 and CO_2. Gasification is the more desirable secondary fuel in India for numerous reasons: a) availability in nature and uniform allocation of biomasses in India, b) it is accessible all over the year at cheaper cost, c) initial investments of small scale gasifier, duel fuel producer gas alternator, quality improvement accessories are quite less, and d) gasification technology is simplest and unskillful labors should be used for operation purpose and maintenance of the gasifier plant [7 - 9].

Today, gasification is have the ability to furnish the solution to diminish environmen pollution and also health problems rises due to feeble cooking and householding method maintained in rural area of villages in India. It fulfils the electricity concern of the rural villages by contributing them a convenient and sustainable sources of energy from agricultural biomass waste. Gaseous fuel can be generated from the solid biomass fuel, the convertion process is known as gasification and gas obtained from this process is called producer gas. It justifies that successful option for chemical waste, waste management and non-conventional feed management such as agricultural, poultry, municipal waste and wastewater [10]. Biomass was partially comdustion in the gasifier and producer gas was generated and it was used as secondary fuel for CI engine. Diesel engine cannot be operated without injecting the diesel as primary fuel because of syn gas or producer gas calorific value was low, so it will not allow the diesel engine to take place the ignition. The compression ignition diesel engine have been dual fueled with two different phases of liquid and gaseous fuels. The producer gas quality and quantity will generally have an effect on performance study and emissions characterization of an CI engine. Therefore, the aspect improvement of producer gas can be enhanced by cooling and cleaning the producer gas by using scrubber and dehumidifier. The fuel combination of the syn or producer gas which was developed on or after the gasifier may count from the sample biomass as feed stock material for gasification process in the FBG [11 - 13]. Dual fuel mode operation of CI engine with diesel and producer or syn gas initiates more detailed study, as it is fewer investigated. Hence, in this study to run the compression ignition engine by improvement of the syn gas quality which has been derived from Prosopis Juliflora in a FBG.

A. Gasification process

Biomass is a organic material which stores any form of energy from photosynthesis process in the habitation of sun-light. Gasification process regularly contains the reaction related in various areas such as drying or moisture removing zone, pyrolysis or without oxygen zone, oxidation or combustion zone and reduction reaction zone. The moisture content of the biomass has been removed in the drying zone.

Manuscript published on 30 September 2019.
***Correspondence Author(s)**
K.C.Keerthivasan, Department of Mechanical Enineering, Annamalai University, Annamalai Nagar, Chidambaram, India.
S.Vivekanandan, Department of Mechanical Enineering, Annamalai University, Annamalai Nagar, Chidambaram, India.
R.Suresh, Department of Mechanical Enineering, Annamalai University, Annamalai Nagar, Chidambaram, India.

It occurs at 90–180°C in addition to reduces the wet moisture of sample as below 5% to 10%. In the pyrolysis zone, decomposition by thermal heating of a concern biomass is takes place from the nonexistence of atmospheric air or oxygen. The volatile matter of biomass was diminished, as the result the hydrocarbon present in the producer gas from the biomass was diminished to strong charcoal. Oxidation layer is the response zone between strong biomass and oxygen noticeable all around bringing about arrangement of CO_2. Water was oxidized from the hydrogen present in the biomass. Lot of heat was dissipated with the combustion or oxidation of carbon and hydrogen. Vacancy of air or oxygen, a lot of reduction process occurs in the temperature range of 780– 980°C [14]. Reactions are mostly endo-thermic reactions. The major reactions in the form of groups as follows are (1) oxidation reaction, (2) water gas reaction, (3) hydro gasification reaction, (4) boudourd reaction and (5) water-gas shift reaction.

$$C + O_2 \rightarrow CO_2 + 406\ \text{kJ/g. mol} \quad (1)$$

$$C + H_2O \rightarrow CO + H_2 \ -131.4\ \text{kJ/g. mol} \quad (2)$$

$$C + 2H_2 \rightarrow CH_4 + 75\ \text{kJ/g. mol} \quad (3)$$

$$C + CO_2 \rightarrow 2\,CO \ -172.6\ \text{kJ/g. mol} \quad (4)$$

$$CO + H_2O \rightarrow CO_2 + H_2 + 42.3\ \text{kJ/g. mol} \quad (5)$$

B. Gasifier

Various types of gasifier are presently available for the commercial applications. They are fixed and fluidized bed gasifier. But we have chosen fluidized bed gasifier, because of its lower ash and semi-solid waste (tar) present in syn or producer gas and efficient within nature compare with other types of gasifier.

C. Fluidized bed gasifier

FBG is very successful intended for operating engines since of its semi-solid waste (tar) present in the producer or syn gas when compare to updraft and cross-draft type gasifier. In the FBG, primary fuel as atmospheric air is initiated as gasification agent at below the oxidation or combustion zone in the FBG gasifier. An external electrical heater was fitted in the oxidation zone to increase and maintain the combustion temperature in the reactor core [15, 16]. The producer gas is sent out from the top of the reactor, so that fuel and gas move in opposite direction.

D. Cooling and cleaning system

Scrubber are the distinct root of control device for air pollution that can be used to take away the semi-solid waste (tar) particles present in the syn or producer gas from the exhaust gas from FBG. Habitually, scrubbers are assigned for removing the tar content that uses liquid or water to “scrub” undesirable pollution from the producer gas. Now-a-days, the scrubber is used to characterize system to inert the dry testing agent into uncleaned fatigue gas to “scrub out” the unwanted acidic gas [17]. Scrubber are the most important primary device for controlling gaseous pollution, exclusively acidic gas.

Wet scrubbering is the description of the concept of characterize a various types of devices that uses liquid to clear away pollutanting agent. In wet scrubber, contaminated steam is import into direct contact with scrubbing (water) liquid by showering with the help of sprayer with liquid [18]. A wet scrubbing has an ability to remove the low size particles is often direct proportion to the power input. A spraying towers are used to collect the particulate size more than 5µm which was the low energy level devices. Removal of 1µm particulate size normally requires the high energy content level devices such as augmented device are used to attain high efficiency of the scrubbing system.

E. Dual fuel operation

CI engine can be run with producer gas as secondary fuel, without alteration of engine. Be that as it may, it can't substitute the diesel entirely. In dual fuel operation diesel fuel substitute up to 60–80% has been accomplished without modification of engine. Lower ignition qualities of producer or syn gas, diesel is necessary to begin starting ignition of engine [19]. Then again engine will get more load, brake thermal efficiency of the engine will reduces drastically in dual fuel operation. While CI will emit some excess smoke in dual fuel operation. This means that incomplete ignition of fuel. Every one of the emanations, in dual fuel mode little bit more emission like CO, HC, NO_x and CO_2 will have higher when compare with diesel.

II. EXPERIMENTAL PROCEDURE AND MATERIALS

The schematic layout of fluidized bed gasifier setup includes of 10.8 cm inner diameter with stainless steel material surround with cotton wool with a height of 140 cm is shown in figure 1. A screw feeder was used with a capacity of 5 – 20 kg/hr to continuously feeding to the fluidized bed gasifier above the stainless steel distributor from a pressurized hopper. To recognize the density and particle size of the feeding material for the function of screw feeder, rotation speed of auger was calibrated for the nominal feed rate for each run of operation. An external electrical heater was worn with a capacity of 1 – 60 °C/min for gasification purpose. Each trial was started with heating coil by heating up the gasifier containing of silica sand to the gasification temperature 750 °C under atmospheric air. Then, at this temperature continuous fuel feed injection and air flow was started. Feed rate and air supply time for each experiment was 98 min. Temperature and pressure were measured every 10 min from the fluidized bed gasifier with thermocouple and pressure drop sensor.

Table- I: Engine Specifications

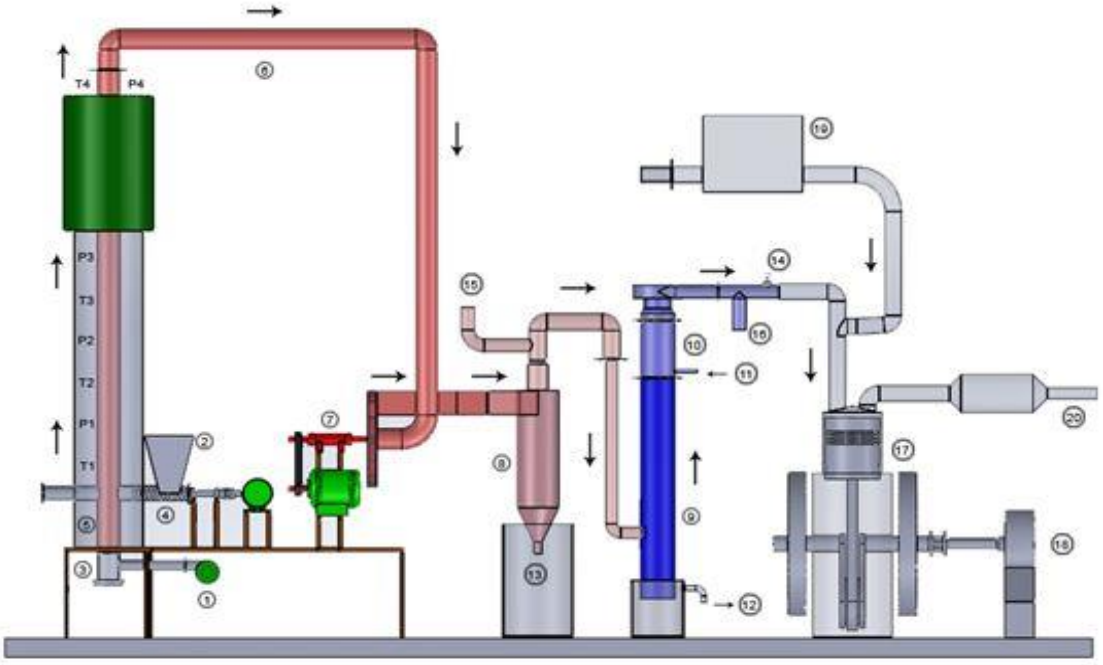
Parameters	Values
Manufacturer	Kirloskar
Type	4-stroke, single cylinder
Rated power	3.5 kW @ 1500 rpm
Combustion system	Direct injection
Bore diameter	87.5 mm
Stroke length	110 mm
Compression ratio (CR)	16.5:1
Type of cooling	Water

Waste wood was used as feeding material to generate producer gas from the fluidized bed gasifier heating coil is used for burning the fuel with a capacity of 1 – 60°C/min. The cyclone separator will receive the producer gas with the help of suction blower which was around 100-200°C sent by the pipeline was attached.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Cyclone-separator will take away the fine dust elements, and the cleaned producer or syn gas is burnt in Bunsen burner in first trial. In second trial outlet of the cyclone separator is fed to water scrubber for exclusion of CO_2 and also reduce the temperature to 35-50°C now the producer gas is burnt in Bunsen burner. After the experiment, it was noticed the quality of producer or syn gas was improved by removing its semi-solid waste (tar) content present in the producer or syn gas. Gasifier was operated and measured the producer gas temperature at scrubber exit temperature and flame range temperature of syn or product gas at the burner. The producer or syn gas flame temperature has got increased by removing moisture from producer gas as 250 – 300 ºC. While flame temperature got increased, the combustion catch place in the I.C. engine will also get good performed. After the experiment, it was pragmatic that the excellence of producer or syn gas has improved by removing its semi-solid waste (tar) content present in the producer or syn gas. Then the producer or syn gas (secondary fuel) was sent to the I.C. engine for replacement of diesel, specification of engine was shown in table 1.

The internal combustion engine head was modified and the T-Section manifold was attached in the air suction for sending the producer gas with proper measuring device. The experiment was conducted in diesel mode separately and Diesel+producer gas was sent with 20, 40, 60 and 80 % respectively.



1. Air blower
2. Biomass hopper
3. Distribution plate
4. Screw feeder with motor
5. Heating coil
6. Gasifier outlet pipeline
7. Suction blower
8. Cyclone separator
9. Water scrubber
10. Packed bed scrubber
11. Water In
12. Water Out
13. Dust particle storage
14. Producer gas exit
15. Flare
16. Flare 2
17. I.C. Engine
18. Loading device
19. Air tank
20. Exhaust gas

Fig. 1.Schematic layout of fluidized bed gasifier.

III. RESULT AND DISCUSSION

A. Properties of Biomass

Prosopis Juliflora is the waste wood grown in agricultural area which was unwanted growth in cultivated lands. We collected samples from the agricultural landfills and it was squashed and pulverized to avoid limitation of heat and mass transfer to less than 300µm.

Prosopis Juliflora's proximate analysis (ASTM D5142), ultimate analysis (ASTM D3176), and calorific values (ASTM D3523) are existing in Table 2. The calorific value of Prosopis Juliflora is more than that of normal agricultural residual and consequently more suitable for fuel processing expertise. In the ultimate analysis hydrogen has a high than carbon content [20], signifying that a higher concentration of hydrogen developed from the partial combustion or gasification of Prosopis Juliflora must be higher than the processing of coal gasification.

Table- II: Properties of biomass

Proximate Analysis (wt%, as received)		Ultimate Analysis (wt%, daf)	
Bulk density (kg/m^3)	407	C (%)	47.16
Moisture content (%wb)	8.81	H (%)	5.81
Volatile matter (%db)	83.23	N (%)	0.42
Ash content (%db)	1.07	O (%)	46.41
Fixed carbon (%db)	15.70	S (%)	0.20
Calorific value (MJ/kg)	16.82		

B. Variations of flame temperature in gasification process

The producer gas's flame temperature shows good role in the combustion part of the I.C. engine [20 - 22]. The producer gas's flame temperature was estimated at three extraordinary feeding rate of Prosopis Juliflora with 5, 10 and 15 kg/hr respectively. From the figure 2. shows the flame temperature at gasifier exit without any cooling and cleaning process of producer gas at various feeding rate of biomass. It is practical that the flame temperature of the producer gas at gasifier exit of 10 kg/hr of biomass as feed stock has gradually increased due to its feeding rate at the gasifier.

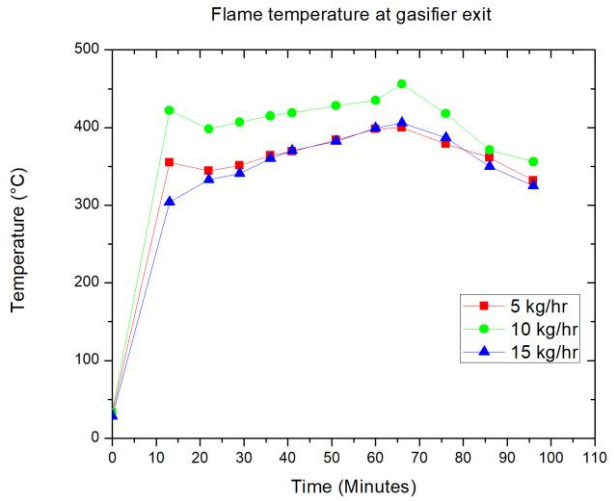


Fig. 2.Flame temperature at gasifier exit.

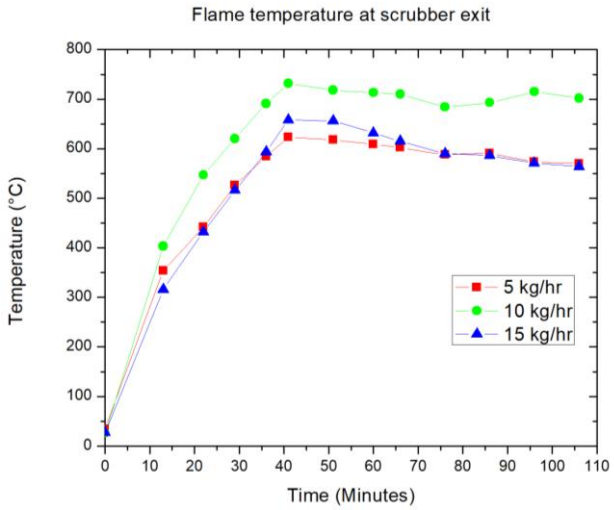


Fig. 3.Flame temperature at Scrubber exit

The equivalence ratio of gasification system will vary depends upon the biomass feeding rate [24, 25]. From the figure 3, states that the producer gas was cleaned and cooled by using cyclone separator, water scrubber and packed bed scrubber. After the cooling and cleaning process, the quality of producer gas got increased by hiring the flame temperature by 400 ºC to 700 ºC. Three different feeding rate of biomass was feuded to the gasifier. From the three different feeding rate, 10 kg/hr of biomass feeding rate has got increased the flame temperature by 20% compare to 5 and 15 kg/hr of biomass. From this we conclude that 10 kg / hr of biomass is better suited to accommodate the producer gas to the I.C. engine for the fluidized bed gasifier.

From the figure 4, it is clear that in every trial there is at least a little change in producer gas temperature. In first trial only gasifier is used so the temperature of gas is high and the flame temperature is low [26]. Flame temperature is low in this trial, there are various reasons but main causes can be moisture content present in the fuel (i.e) wood, oxygen content in the fuel. In second trial when wet scrubber is used flame temperature has been increased about 83% than the first trial. When the producer or syn gas is permitted to pass in the wet scrubber, producer or syn gas oxygen content has been increased. Because of the moisture has been fully removed, producer gas oxygen content has been increased more and also removed TAR content, it is evident that water contamination at the end of the trial was completely black.

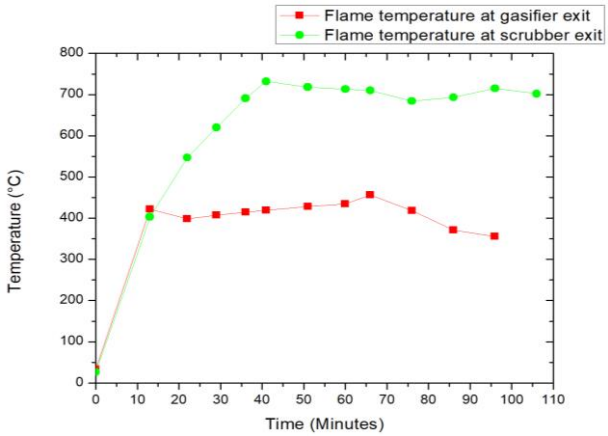


Fig. 4.Time Vs Temperature

C. Producer gas composition

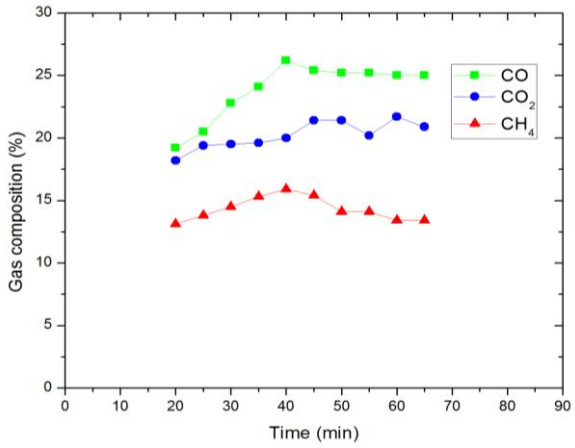


Fig. 5.Gas composition of producer gas

Experiment was conducted with different feed rate and it was observed that only 10 kg/hr of biomass feed rate has a higher flame temperature to achieve better combustion in ignition of engine. Producer gas used as a secondary fuel for engine application. Gas composition acting a major contribution in the combustion of I.C. engine[27]. Figure 5 shows the gas composition of syn or producer gas at after starting of experiment 20 to 70 minutes. At the starting of experiment the biomass did not ignitie properly so, the quality of producer gas will also be low after it attain the combustion rate of biomass.

Retrieval Number: J99520881019/19©BEIESP
DOI: 10.35940/ijitee.J9952.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The gas composition was achieved for the combustion in the I.C. Engine.

D. Engine performance

a) Brake thermal efficiency

Engine operation was done on both diesel fuel and dual mode operation at four different flow rate of producer gas. [28, 29] It has been noted that the whole control range on dual fuel mode function at a low brake thermal efficiency for all flow rate of producer or syn gas as shown in figure 6. This may appropriate to the occurrence of producer or syn gas in dual fuel operation and also appropriate to lower heating rate of producer or syn gas. The brake thermal efficiency of CI engine in dual fuel mode at diesel, D+PG20%, D+PG40%, D+PG60% and D+PG80% is 36.98%, 35.67%, 33.99%, 32.47% and 29.72% respectively.

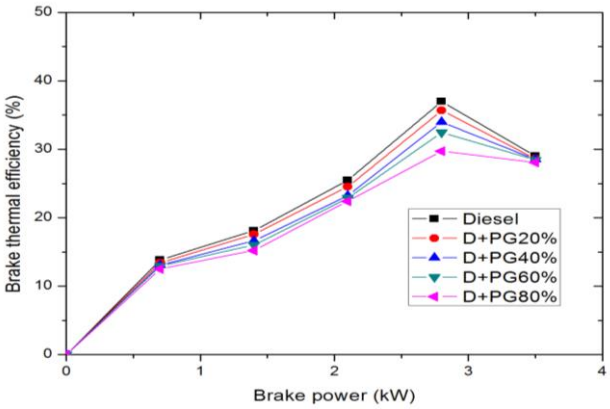


Fig. 6.Brake thermal efficiency with different brake power

b) Specific fuel consumption

SFC is certifiably not an entirely solid output to look at the dual fuelling will have diverse calorific values and density, SFC is liked to think about the exhibition of CI engine. SFC in dual-fuel mode is determined from the amount of fuel utilization of diesel and also producer gas from the gasifier [30]. SFC of the engine is almost high up to some possible extant at some part of loading condition regardless of the fuel utilized shown in figure 7. SFC in dual-fuel mode is somewhat high than diesel mode at various loading setting.

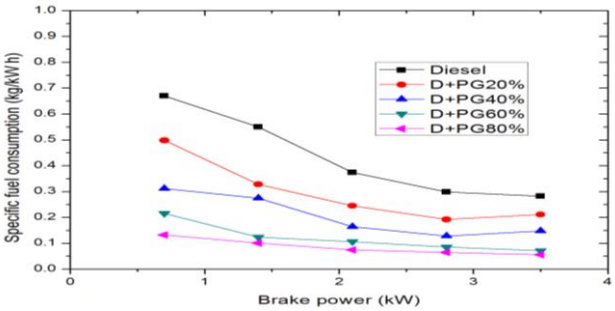


Fig. 7.Specific fuel consumption with different brake power

IV. CONCLUSION

From the above discussion we came to a conclusion that gasifier should not operate without the accessories (cyclone separator, water scrubber, wet scrubber, etc…). When the gasifier is operated alone the flame temperature is less so the heat energy conversion rate will also be less. When running the gasifier with the accessories flame temperature is high so the heat energy conversion rate will also be high at the biomass feeding rate at 10 kg/hr. Producer gas composition are Carbon Monoxide (CO) as 18 – 21 %, Carbon-di-oxide as 16 – 22 % and Methane as 11 – 16 %. The brake thermal efficiency of compression ignition engine on dual fuel operation at diesel, D+PG20%, D+PG40%, D+PG60% and D+PG80% is 36.98%, 35.67%, 33.99%, 32.47% and 29.72% respectively. The specific fuel consumption has got increased by 30-40% when compared with diesel and D+PG80% respectively.

ACKNOWLEDGMENT

We would like to gratefully acknowledge Steam laboratory, Department of Mechanical Engineering at Annamalai University.

REFERENCES

1. Werther, J., Saenger, M., Hartge, E. U., Ogada, T., & Siagi, Z. “Combustion of agricultural residues. Progress”, Energy and Combustion Science, 26(1), 2000, pp.1–27.
2. Bharath, M., Raghavan, V., Prasad, B. V. S. S. S., & Chakravarthy, S. R. “Co-gasification of Indian rice husk and Indian coal with high-ash in bubbling fluidized bed gasification reactor”, Applied Thermal Engineering, 137, 2018, pp.608–615.
3. Hernández, J. J., Aranda-almansa, G., & Bula, A. “Gasification of biomass wastes in an entrained flow gasifier : Effect of the particle size and the residence time”, Fuel Processing Technology, 91, 2010, pp.681–692.
4. Sánchez, C., Arenas, E., Chejne, F., Londoño, C. A., Cisneros, S., & Quintana, J. C. “A new model for coal gasification on pressurized bubbling fluidized bed gasifiers”, Energy Conversion and Management, 126, 2016, pp.717–723.
5. Abbas, T., Costen, P. G., & Lockwood, F. C. “Solid fuel utilization: From coal to biomass”, Symposium (International) on Combustion, 26(2), 1996, pp.3041–3058.
6. Vivekanandan.S., & Keerthivasan.K.C., “An Attempt to Reduce Prosopis Juliflora from Agricultural Land by using Gasification Process”, Indian Journal of Environmental Protection, 39(2), 2019, pp. 167–172.
7. Buragohain, B., P. Mahanta, and V.S. Moholkar. “Biomass gasification for decentralized power generation: The Indian perspective”, Renewable and Sustainable Energy Reviews. 14(1), 2010, pp. p. 73-92.
8. 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 and Bioenergy, 26(2), 2004, pp. 171–193.
9. Gil, J., Corella, J., Aznar, M. P., & Caballero, M. A. “Biomass gasification in atmospheric and bubbling fluidized bed: Effect of the type of gasifying agent on the product distribution”, Biomass and Bioenergy, 17(5), 1999, pp.389-403.
10. Patra, T.K. and P.N. Sheth, “Biomass gasification models for downdraft gasifier: A state-of-the-art review”, Renewable and Sustainable Energy Reviews, 2015, pp.583-593.
11. Bhoi, P. R. Ã., Singh, R. N., Sharma, A. M., & Patel, S. R.. “Performance evaluation of open core gasifier on multi-fuels”. *Biomass and Bioenergy*, *30*, 2006, pp.575–579.
12. Sethusundaram, P.P. & Keerthivasan, K.C. “A Comparative study of downdraft gasifier with effect of de-humidifier”, *International Journal of Applied Engineering*, 10(85), 2015, pp.477-482.
13. Cross, P., Kulkarni, A., Nam, H., Adhikari, S., & Fasina, O. “Bubbling fluidized bed gasification of short rotation Eucalyptus: Effect of harvesting age and bark”, Biomass and Bioenergy, 110(January), 2018, pp.98–104.
14. Buragohain, B., Mahanta, P., & Moholkar, V. S. “Biomass gasification for decentralized power generation: The Indian perspective”, Renewable and Sustainable Energy Reviews, 14(1), 2010, pp.73–92.
15. Arena, U., Zaccariello, L., & Laura, M. “Fluidized bed gasification of waste-derived fuels”, Waste Management, 30(7), 2010, pp. 1212–1219.

16. Yan, L., Cao, Y., Li, X., & He, B. "Characterization of a dual fluidized bed gasifier with blended biomass/coal as feedstock", Bioresource Technology, 254(January), 2018, pp.97–106.
17. Ku, X., Jin, H., & Lin, J. "Comparison of gasification performances between raw and torrefied biomasses in an air-blown fluidized-bed gasifier", Chemical Engineering Science, 168, 2017, pp.235–249.
18. Karatas, H., & Akgun, F. "Experimental results of gasification of walnut shell and pistachio shell in a bubbling fluidized bed gasifier under air and steam atmospheres", Fuel, 214, 2018, pp.285–292.
19. Gadge, R & N Madansure, V. "Liberation of Carbon Monoxide Through Gasifier-IC Engine System". I.E. (I) Journal I.D. 2003, 84.
20. Hong, Y. C., Lee, S. J., Shin, D. H., Kim, Y. J., Lee, B. J., Cho, S. Y., & Chang, H. S. "Syngas production from gasification of brown coal in a microwave torch plasma", Energy, 47(1), 2012, pp.36–40.
21. Panwar, N.L., Rathore, N.S., & Kurchania, A.K. "Experimental investigation of open core downdraft biomass gasifier for food processing industry", Mitig Adapt Strateg Glob Change, 2009, pp.547–556.
22. Sánchez, C., Arenas, E., Chejne, F., Londoño, C. A., Cisneros, S., & Quintana, J. C. (2016). A new model for coal gasification on pressurized bubbling fluidized bed gasifiers. Energy Conversion and Management, *126*, 717–723.
23. Lapuerta, M., Hernández, J. J., Pazo, A., & López, J. "Gasification and co-gasification of biomass wastes: Effect of the biomass origin and the gasifier operating conditions", Fuel processing technology, 9, 2008, pp.1–10.
24. Bhoi, P.R.A, Singh, R.N., Sharma, A.M, & Patel, S.R. "Performance evaluation of open core gasifier on multi-fuels", Biomass and Bioenergy, 30,(2006, pp. 575–579.
25. Chen, C., Jin, Y., Yan, J., & Chi, Y. "Simulation of municipal solid waste gasification in two different types of fixed bed reactors", Fuel, 103, 2013, pp.58–63.
26. Arena, U., Zaccariello, L., Laura, M. "Fluidized bed gasification of waste-derived fuels", Waste Management, 30(7), (2010) 1212–1219.
27. Patel, V. R., Patel, D., Varia, N. S., & Patel, R. N. "Co-gasification of lignite and waste wood in a pilot-scale (10 kW) downdraft gasifier". Energy, 2016, pp.1–11.
28. Singh, R. N. Ã., Singh, S. P., & Pathak, B. S. "Investigations on operation of CI engine using producer gas and rice bran oil in mixed fuel mode". *Renewable Energy*, *32*, 2007, pp. 1565–1580.
29. Deshmukh, S. J., Bhuyar, L. B., & Thakre, S. B. "Investigation on Performance and Emission Characteristics of CI Engine Fuelled with Producer Gas and Esters of Hingan (Balanites) Oil in Dual Fuel Mode". *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, *2*(2), 2008, pp. 206–211.
30. Banapurmath, N. R., Tewari, P. G., & Hosmath, R. S. "Experimental investigations of a four-stroke single cylinder direct injection diesel engine operated on dual fuel mode with producer gas as inducted fuel and Honge oil and its methyl ester (HOME) as injected fuels". *Renewable Energy*, *33*(2008), 2018, pp.2007–2018.

AUTHORS PROFILE

K.C.Keerthivasan received his Bachelor's degree in Mechanical Engineering from Annamalai University, Chidambaram and Masters degree in Energy Technology in Pondicherry Engineering College, Pondicherry University, Puducherry. The author has published around 4 International journals with ISSN number. He is currently pursuing his Ph.D. in Mechanical Engineering in Annamalai University, Chidambaram. His area of interest is biomass gasification and its applications.

S.Vivekanandan, Professor in the Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamil Nadu, India. He received his Doctor of Philosophy from Annamalai University, Chidambaram. He guided around 6 Ph.D. scholars under his supervisions. The author has published around 33 International journals with ISSN number. His area of specialization is biogas generation and biomass gasification from agricultural and industrial waste.

R.Suresh, Assistant Professor in the Department of Mechanical Engineering, Annamalai University, Annamalai Nagar, Tamil Nadu, India. He received his Doctor of Philosophy from Annamalai University, Chidambaram. The author has published around 3 International journals with ISSN number. His area of specialization is biogas generation and biomass gasification.