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Original Research Article

Effect of mixing chamber or carburetor type on the performance of diesel engine operated on biodiesel and producer gas induction

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Abstract

Biodiesel-producer gas fueled dual fuel engine suffers from lower brake thermal efficiency (BTE) with higher unburned hydrocarbon (HC) and carbon monoxide (CO) emissions at all loads. In this present work, to harness energy from producer gas and ensure air and producer gas mixing quality, different mixing chambers (carburetors) have been developed. In the first phase of the work, mixing chambers were analyzed for its mixing performance using experimental approach. Different carburetors were drawn from Y– shape having 45, 60, 90^0 gas entries as well as with parallel flow gas entry. Based on the results obtained, it was found that parallel flow gas entry carburetor resulted in better mixing of air and producer gas. In the next phase of the work, experimental investigations were conducted to study the effect of air-producer gas mixture quality on the performance, combustion and emission characteristics of single cylinder, four strokes direct injection diesel engine developing 3.7 kW at 1500 rpm operated on dual fuel mode with Honge oil methyl ester (HOME) and producer gas induction. Experimental investigation showed that all carburetors except parallel flow gas entry carburetor resulted in lower performance. Dual fuel engine with parallel flow gas entry carburetor showed 5 to 8 % increased BTE with reduced smoke, HC and CO emission levels compared to other carburetors tested. Based on the study, it is concluded that this area still requires more research with long term engine operation.

Key Words: Honge oil Methyl ester, Biomass gasification, Producer gas, Mixing chamber, Emissions, Sustainability, energy security

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1. Introduction

Increasing cost of electricity is a key issue for India and is same for rest of the world. This factor has created lot of attention for researchers. The main reason for this is due to growing population with increasing life quality, government policies and development of new technologies in engines. The harmful effects on human health caused by the degradation of environment due to emission of greenhouse gas (GHG) emissions, decreasing reserve of crude petroleum in the earth crust, and increasing cost of crude oil have been realized in the present energy scenario. In addition, India is now experiencing high and volatile energy prices as well as issues of national security against energy. Therefore, the need for sustainable and environmentally benign sources of energy for power generation and industrial growth has become necessary in recent years. In this regard, researchers are putting their sincere efforts on the engine research using alternative fuels. In this direction researchers have identified biomass as a main future fuel for energy applications. Researchers have estimated that about 620 million tonnes of biomass reserve in the country during 2004–2005 and was 700 million tonnes during 2010–2011. In addition, it may increase to 1200 million tonnes during end of 2025. India is producing about 450-500 million tonnes of biomass per year including sugarcane, bagasse and leaves. Biomass provides 32% of all the primary energy use in the country at present. About half of the surplus residues are burnt in the fields causing serious air pollution. The potential for additional generation of woody biomass in the country has been estimated to be about 255 million tonne. Out of this, forest wastelands are estimated to contribute 171 million tonne and the marginal crop land to contribute the remaining 84 million tons. Even though, India is still dependent on non-commercial fuel sources such as cow dung, firewood, agricultural waste and biofuels to the extent of 30–35%. India had planned to produce 288 metric tonnes of biodiesel by the end of 2012, which was supplemented about 41.14% of the total demand of diesel fuel consumption [1, 2, 3, 4, and 5].

In this context, researchers have reported effect of biodiesel properties on the performance and emission characteristics of diesel engine [6, 7]. India has implemented many facilitating policies and programmes on biomass gasifier-based power units with as high as megawatt-level grid-connected plants that operate on a dual-fuel mode and 100% producer gas-run engines [5]. Dual-fuelling of a diesel engine needs liquid fuel for initiating the combustion because the producer gas will not ignite under the prevailing conditions of temperature and pressure. In addition, dual fueling offers fuel flexibility, 70-90% fuel saving, lowers emissions, acceptable efficiency and easy conversion of existing diesel engines. Several investigators have reported that use of advanced injection timing, increased compression ratio (CR) and addition of hydrogen resulted in increased thermal efficiency [8, 9, 10, and 11]. Reduced brake-specific fuel consumption, BTE and HC and CO emission levels have been reported in previous literatures [9, 10, and 12]. Power generation using biomass gasifier based projects and financial evaluation has been reported [13, 14]. Several investigators have extensively investigated gasifier – engine systems for rural and urban power generation and agricultural applications [9, 12-17]. Dual fuel operation with producer gas favors higher compression ratio as it has high octane number and self-ignition temperature, but it suffers from 20-30% power derating [10, 11]. Many researchers have generated producer gas using biomass feedstock of different origin and investigated performance and emission characteristics of diesel engine operated on diesel/biodiesel and producer gas combinations [10-12, 15, and 18]. In the case of a producer gas-fuelled dual-fuel engine, the performance was found to be lower than as acceptable. This could be due to improper air-producer gas mixing, hence a suitable mixing chamber or carburetor must be designed. Shridhar et al 2005 have developed a carburetor for producer gas fueled engine

(Spark ignited engine). A suitable mixing chamber provides a mixture of appropriate predefined air-to-fuel ratios to the engine over the entire range of engine operation [9, 11].

Major attention and interest is given to enhance the thermal efficiency of a producer gas-operated dual-fuel engine with decreased emission levels. The use of biodiesel and producer gas-based power generation will create new industries, addresses energy security and bring increased economic activity. In this context, the present study aims to develop various mixing chambers and investigation of mixing performance through experiments. Further, the present study was extended to investigate the performance combustion and emission characteristics of a water-cooled, single-cylinder, direct injection (DI) compression ignition (CI) engine operated under a dual-fuel mode with HOME and producer gas induction. Further, the results were compared with diesel–producer gas operation.

2. Producer gas supply system

Ensuring uniform supply of quality gas and stoichiometric air-producer gas mixture to the dual fueled engine is quite difficult as this would depend on the gasifier design and operating conditions, mechanism of reactions taking place and flow conditions occurring through the gasifier system. Carburetor used for mixing air and producer gas mainly consists of individual fluid inlets with single outlet, which is attached to the intake manifold of an engine. Carburetor developed must have an ability to maintain the required air-fuel ratio (1.2 to 1.3) with varying load and pulsating gas flow conditions [12, 19, 20]. The carburetor was developed to operate in conjunction with a calibrated venturimeter designed for the producer gas flow measurement. Figure 1 shows the producer gas supply system with Y –shaped carburetor, venturimeter and digital gas flow meter. During the engine operation, appropriate mixture of producer gas and air were supplied to the engine. The supply of producer gas was adjusted manually to obtain maximum substitution of producer gas. The air and producer gas flow rates were measured individually over a range of engine operating conditions. The air-producer gas (A/F) ratio was reasonably constant beyond a specified mixture flow rate, with relatively rich mixture at low flow rates. Rich mixture for engine start-up and no-load operations and relatively leaner mixture during part load operations [12, 20, and 21].

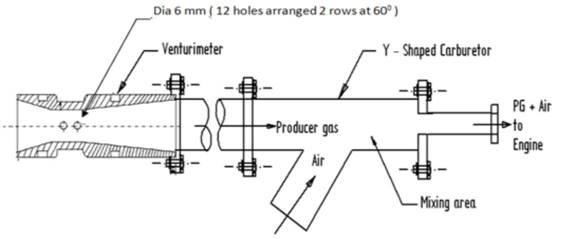


Fig. 1 Schematic diagram of producer gas supply system with Y – shaped carburetor

3. Characterization of fuels used

HOME was derived from Honge seeds and producer gas by partial combustion of woody biomass in a down draft gasifier. Producer gas composition involves CO, H_2, CO_2, Nitrogen and Methane. The laminar burning velocity for producer gas (at 0.1 MPa, 300 K) was about 0.5 m/s, which is about 30% higher than methane [9]. The properties of the fuels were determined in the laboratory. Table 1 shows the properties of liquid fuels and proximate and ultimate analysis of biomass feed stock used in the present study. Composition of producer gas derived from babul wood was checked two times at different timings during the test and averaged out values are shown in Table 2.

4. Experimental setup

Experimental investigations were conducted on four-stroke, single cylinder, direct injection water cooled compression ignition engine as shown in Figure 2 (a) and (b). The specification of the gasifier- engine system is given in Table 3. The engine was always operated at a rated speed of 1500 rev/min. The engine had conventional fuel injection system. The injection nozzle had three holes of 0.3 mm diameter with a spray angle of 120^0. The injector opening pressure and the static injection timing as specified by the engine manufacturer for diesel operation were 205 bar and 23^0 before top dead centre (bTDC), respectively. However, for the present study, the injection timing and injection pressures of 27^0 bTDC and 230 bar were used with dual fuel operation as these were optimized in the earlier work reported by authors [9-11]. The engine is provided with a hemispherical combustion chamber with overhead valves operated through push rods. The engine was cooled by circulating water through the jackets of the engine block and cylinder head. In this present work, the air and producer gas flow rates were measured using air box method and venturimeter connected with digital indicator respectively. Roussos et al., [21] reported fuel-air equivalence ratio and its effect on the for dual fuel operation.

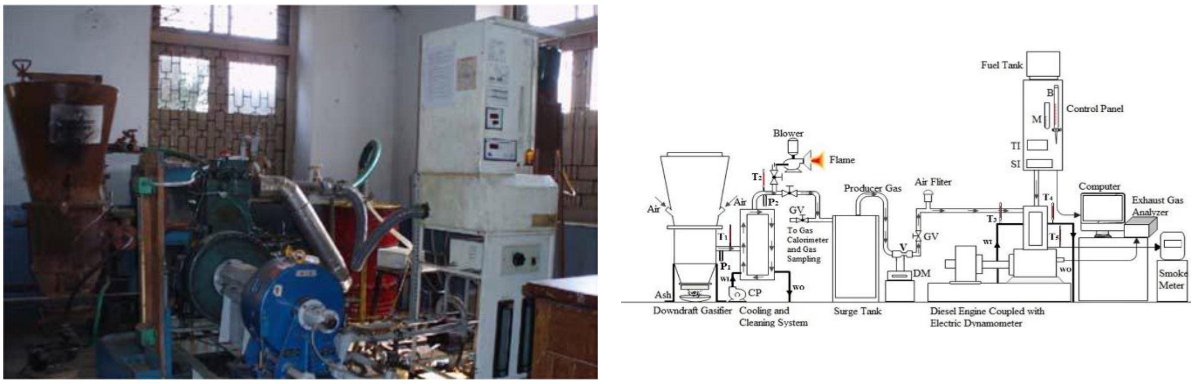
Figures 3, 4, 5 and 6 shows Y – shaped, 60^0, 90^0 and parallel flow gas entry carburetors. The cylinder pressure was measured with piezo electric transducer fitted in the cylinder head. Exhaust gas analyzer and Hartridge smoke meter were used to measure HC, CO, CO_2, NO_X and smoke emissions. All the readings were repeated for five times and average readings were used for analysis.

Table 1 Properties of liquid fuels and Proximate and ultimate analysis of biomass feed stocks

Type of wood	CO %	H_2 %	Methane %	HC %	N_2 %	Water Vapour %	CO_2 %	Calorific value kJ/m^3	Density kg/m^3
Babul wood	18-22%	15-19%	1-5 %	0.2-0.4%	4.5-5.5%	4	8 -10%	5200	360

Table 2 Composition of producer gas

S.N	Properties	Diesel	HOME	Description	Babul wood
1	Viscosity @ 40 ^{0}C (cst)	4.59 (Low)	5.6	Moisture Content, % wlw	10.3
2	Flash point ^{0}C	56	163	Ash Content, % wlw	0.79
3	Calorific value in kJ / kg	45000	36,010	Volatile Matter, % wlw	85.8
4	Specific gravity	0.830	0.870	Fixed Carbon % wlw	13.4
5	Density Kg / m3	830	890	Sulphur, % wlw	0.05
6	Type of oil	Fossil	Non edible	Nitrogen, as N % wlw	0.30
7	------	----	------	Gross Calorific value, Cal/g	5631.O
	------	-----	------	Gross Calorific value, kJ/ kg	23575.8
8	------	----	------	Density, kg/ m^3	380
9	------	-----	------	Phosphorus % w/w	---
10	------	----	------	Potassium	---



(a) Photographic view of Experimental Setup (b) Schematic diagram of Experimental Setup

Fig. 2 Overall view of Experimental Setup

5. Results and discussions

Experimental investigations have been conducted in two phases. In the first phase of the work, air-producer gas mixing performance has been studied and better carburetor type for dual fuel operation was identified. In the phase of the present work, effect of air-producer gas mixture quality on the performance, combustion and emission characteristics have been carried out using different mixing chambers or carburetors. Further, the results obtained with HOME-producer gas combination were compared with diesel-producer gas operation.

Table 3 Shows specification of experimental test rig and down draft gasifier

SN	Compression ignition engine		Down draft gasifier	
	Parameters	**Specification**	**Parameters**	**Specification**
1	Machine Supplier	Apex Innovations Pvt Ltd, Sangli. Maharastra State.	Rated capacity	15000kcal/hr
2	Engine Type	Single cylinder four stroke water cooled direct injection TV1 compression ignition engine with a displacement volume of 662 cc, compression ratio of 17:1, developing 5.2 kW at 1500 rev/min TV1 (Kirolsker make)	Rated gas flow	15Nm^3/hr
3	Software used	Engine Soft	Average gas calorific value	1000kcal/m^3
4	Nozzle opening pressure	200 – 225 bar	Rated woody biomass consumption	5-6kg/hr
5	Governor type	Mechanical centrifugal type	Hopper capacity	40kg
6	Cylinder diameter (Bore)	0.0875 mtr	Biomass size	10mm (Minimum) 50mm (Maximum)
7	Stroke length	0.11 mtr	Moisture content (DB)	5 to 20%
8	Combustion camber	Open Chamber (Direct Injection) with hemispherical cavity	Typical conversion efficiency	70-75%
9	Eddy current dynamometer:	Model :AG – 10, 7.5 KW at 1500 to 3000 RPM and Water flows through dynamometer during the use		

Fig. **3** Y- shaped carburetor

Fig. **4** 60^0 gas entry carburetor

Fig. **5** 90^0 gas entry carburetor

Fig. **6** Parallel flow gas entry carburetor

5.2 Optimization of carburetor for dual fuel operation: Experimental approach

Figure 7 presents the fuel-air equivalence ratio obtained for different carburetor or mixing chambers. Reduced equivalence ratio has been obtained for Y-shape, 60^0 and 90^0 carburetor compared to parallel flow gas entry carburetor. Parallel flow gas entry carburetor resulted in better mixing performance. It could be due to better mixture of air and producer gas and turbulence. During the experimentation, it is observed that, the flow rate of producer gas was not constant. In addition, the fuel-air equivalence ratio was greatly affected by variation in gas flow rate and its composition. Hence minimum five reading were recorded at different timings and averaged out value was used for the analysis. Influencing factors such as variations in gas quality, improper gas flow rates and flow friction due to bends in the pipe lines significantly affect the air-producer gas mixing. Mixing chambers are developed in such a way that they should supply an air-producer gas mixture at an excess air ratio. However, flow rate of the air-producer gas mixture can be well controlled using an integrated mechanical valve. It is evident from the Figure 7 that the mixing chamber used in this present work provides an air-producer gas mixture quality based on its development. Frictional resistance and inadequate turbulence may be responsible for lower mixing performance with Y-shape, 60^0 and 90^0 carburetors. The air-producer gas equivalence ratio for Y-shape, 60^0 and 90^0 carburetors were found to be 0.44, 0.49 and 0.58 compared to 0.62 for parallel flow gas entry carburetor.

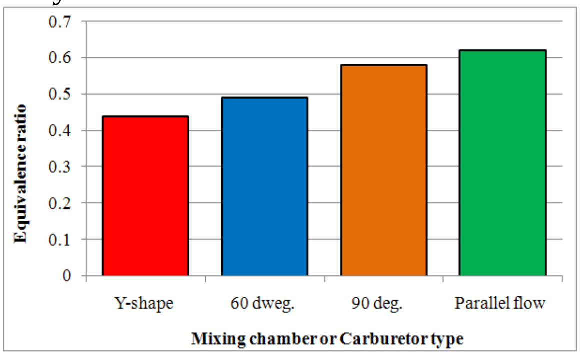


Fig. 7 Effect of carburetor design on the equivalence ratio

5. 3 Effect of mixing chamber type on the performance, combustion and emissions of dual fuel operation

This section presents the effect of mixing chamber type on the overall performance of diesel engine operated on a dual fuel mode using HOME and producer gas induction. During the experimentation, the producer gas flow rate was maintained constant and engine speed was maintained at 1500 rpm. Injection timing of 27^0 bTDC, injection pressure of 230 bar and compression ratio of 17.5 are maintained constant throughout the study. Results and discussions on the performance of dual fuel engine operated on HOME–producer gas combination have been presented in subsequent paragraph.

5.3.1 Performance characteristics

The variation of BTE with various carburetors or mixing chambers at 80% engine load has been presented in Figure 8. The BTE was found to be higher for diesel-producer gas dual fuel mode of operation compared to HOME-producer gas operation. Producer gas being common, properties of the injected fuel has a major effect on the engine performance. The lower BTE with biodiesel injected fuel could be due to reduced equivalence ratio and higher viscosity which makes atomization difficult and lower adiabatic flame temperature of producer gas. However, the performance of HOME-producer gas operation can be improved to some extent if air-producer gas was mixed at nearly stoichiometric ratio. Of all the carburetors tested, parallel flow gas entry carburetor resulted in better performance compared with Y and 60^0 and 90^0 gas entry carburetors. This could be attributed to better turbulence and air-producer gas mixing. In addition, parallel flow gas entry carburetor provides a homogeneous mixture of air and producer gas and varying mixture flow according to load. The BTE values at 80% load with HOME – producer gas operation and Y, 60^0, 90^0 degree and parallel flow gas entry carburetors were found to be 13.65, 14.41, 15.25 and 16.18 % and 20.25 % for Diesel–

producer gas operation with parallel flow gas entry carburetor respectively.

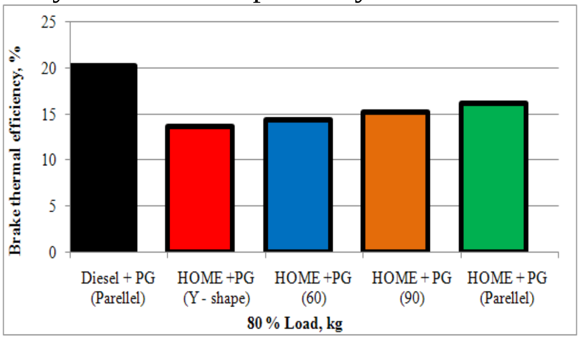


Fig. 8 Variation of BTE at 80% load

Exhaust gas temperature at 80% load during dual fuel mode of operation is presented in Figure 9. The Exhaust gas temperature was found to be higher for HOME-producer gas compared to Diesel-producer gas operation. This could be due to the incomplete combustion of gaseous fuel with the injected biodiesel inside combustion chamber with most of the fuel burning during expansion stroke. Results showed that the parallel flow gas entry carburetor gives lower exhaust gas temperature compared with other carburetors tested. Improved combustion caused by the better mixing of air-producer gas is responsible for this observed trend. However, air-producer gas was mixed nearly at stoichiometric when parallel flow gas entry carburetor was used. The exhaust gas temperature values at 80 % load with HOME – producer gas operation and Y, 60°, 90° and parallel flow gas entry carburetors were found to be 540, 525, 510 and 495 °C and 385 °C for Diesel-producer gas operation with parallel flow gas entry carburetor respectively.

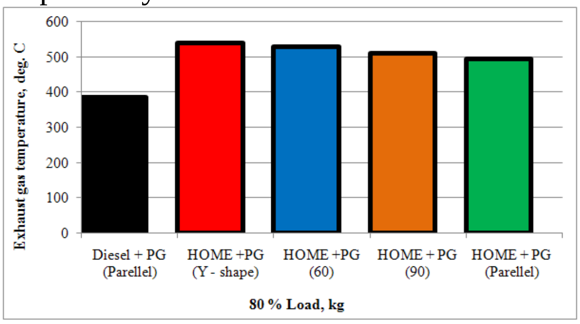


Fig. 9 Variation of EGT at 80% load

5.3.2 Emission characteristics

Emission Characteristics of engine are important as far as environmental aspect is concerned. The emission levels with producer gas operation under dual fuel mode were measured under steady state conditions, using well calibrated instruments. The different emission measurements for the dual fuel mode operation at 80% load are discussed below.

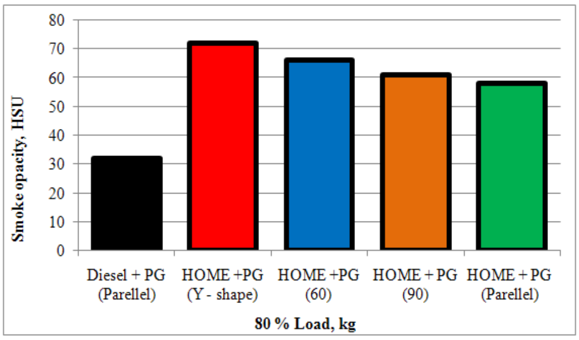


Fig. 10 Variation of smoke opacity at 80% load

Results related to smoke opacity at 80% engine load is presented in Figure 10. The smoke opacity was lower for diesel- Producer gas dual fuel operations compared to HOME - Producer gas over the entire load range. Improper air-fuel mixing rates due to presence of free fatty acid and heavier molecular structure of the injected bio-diesel compared to diesel resulted in higher smoke levels. Of all the carburetors, parallel flow gas entry gives lower smoke emissions compared to Y, 60^0, and 90^0 gas entry carburetors. The improved air and gas mixing in parallel gas entry carburetor as evident from CFD analysis (Figure 14) resulted into complete combustion of gaseous fuel. The smoke opacity values at 80% load with HOME – producer gas operation and Y, 60^0, 90^0 and parallel flow gas entry carburetors were found to be 72, 66, 61 and 58 HSU and 32 HSU for Diesel –producer gas operation with parallel flow gas entry carburetor respectively.

The variation of HC emission levels at 80% load is shown in Figure 11. The lower BTE associated with bio-diesel compared to diesel, resulted into higher HC emissions with higher wall wetting observed in the former case. Parallel flow gas entry carburetor nearly ensures stoichiometric mixture of air and producer gas compared to other carburetors tested and this further supported by improved combustion. HC emissions were observed in the range of 65 to 73 ppm for neat Diesel–producer gas operation and 46 to 64 ppm for HOME-Producer gas dual fuel operation throughout the load range at the optimum parameters. At lower loads, HC level were found to be higher and decreased at higher loads. The HC emission values at 80% load with HOME–producer gas operation and Y, 60^0, 90^0 and parallel flow gas entry carburetors were found to be 69, 61, 58 and 54 ppm and 38 ppm for Diesel–producer gas operation with parallel flow gas entry carburetor respectively.

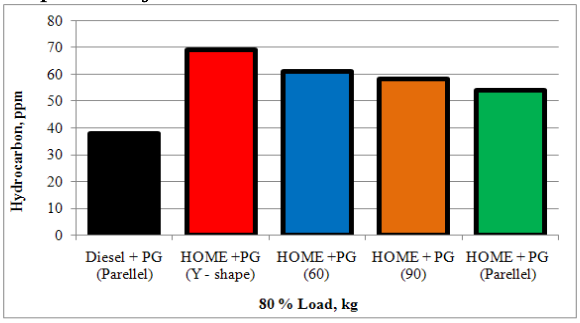


Fig. 11 Variation of HC emission at 80% load

The effect of brake power on CO emissions for Diesel-producer gas and HOME–producer gas, dual fuel operation is shown in Figure 12. Higher concentration of CO in the exhaust is a clear indication of incomplete combustion of the pre-mixed mixture. The CO levels were higher for dual-fuel operation due to the presence of CO in the producer gas and combustion inefficiencies. It may also be due to the improper mixture of producer gas-air flow to the engine with reduced amount of oxygen required for complete combustion and this provides incomplete combustion and increased CO emission levels. At lower loads, the mixture being leaner, results in greater extent of incomplete combustion and hence higher CO concentration. This puts a lower load limit for the dual fuel operation. At higher loads, the CO levels in the exhaust may slightly be reduced to lower extent compared to lower loads because of increased combustion temperature. Higher emission of CO levels in the exhaust could be attributed to lower heating value of producer gas, lower adiabatic flame temperature and lower mean effective pressures. However, the CO emission levels were found to be lower with parallel flow carburetor compared to other carburetors tested. This could be due to better mixing of gaseous fuel with air as is evident from the Figure 14 and leads to slightly improved combustion. The CO emission values at 80% load with HOME–producer gas operation and Y, 60^0, 90^0 and parallel flow gas entry carburetors were found to be 0.78%, 0.67%, 0.58%, 0.47% and 0.31% for Diesel–producer gas operation with parallel flow gas entry carburetor respectively.

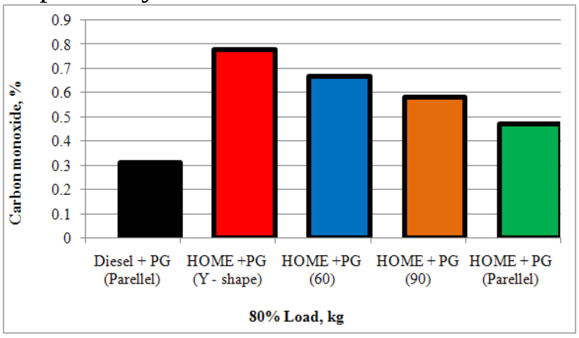


Fig. 12 Variation of CO emission at 80% load

Nitric oxide (NOx) emission levels for the tested fuel combinations at 80% engine load are presented in Figure 13. The NOx emissions were found to be higher for Diesel-producer gas dual fuel operations compared to HOME-producer gas over the entire load range. Diesel- producer gas operation resulted in higher BTE associated with higher NOx emissions as it is evident from higher heat release rate during premixed combustion as shown in Figure 26. Lower adiabatic flame temperature of producer gas and absence of organic nitrogen in producer gas could also be responsible for the observed trend. Results indicate that the parallel flow gas entry carburetor gives higher NOx compared with other carburetors tested because of higher heat release rates during premixed combustion. The NOx emission values at 80% load with HOME-producer gas operation and Y, 60^0, 90^0 and parallel flow gas entry carburetors were found to be 61 ppm, 68 ppm, 74 ppm and 78 ppm and 110 ppm for Diesel–producer gas operation with parallel flow gas entry carburetor respectively.

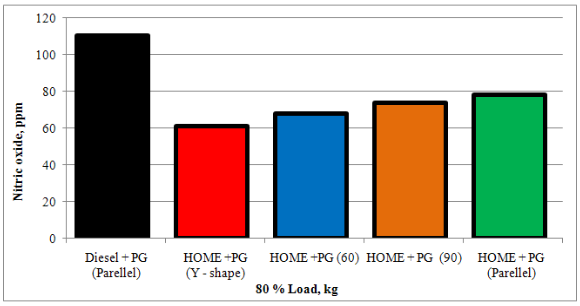


Fig. 13 Variation of NOx at 80% load

5.3.3 Fuel substitution

Figure 14 presents the fuel substitution for dual fuel operation at 80% load. Fuel substitution values were higher for Diesel-producer gas operation compared to HOME-producer gas combinations. Injected fuel properties such as cetane number, viscosity and calorific value may be considered as responsible for the observed trend. Substitution was higher at lower loads and found to decrease with increased load. The fuel substitution at 80% load with HOME-producer gas operation and Y, 60^0, 90^0 and parallel flow gas entry carburetors were found to be 45%, 53%, 49% and 57% and 61% for Diesel-producer gas operation with parallel low gas entry carburetor respectively.

5.3.4 Combustion analysis

The combustion in a diesel engine differs when gaseous fuels are used and it depends on the air–fuel mixture quality. Different combustion characteristics are discussed below:

Variation of ignition delay with different carburetors at 80% load is shown in Figure 15.

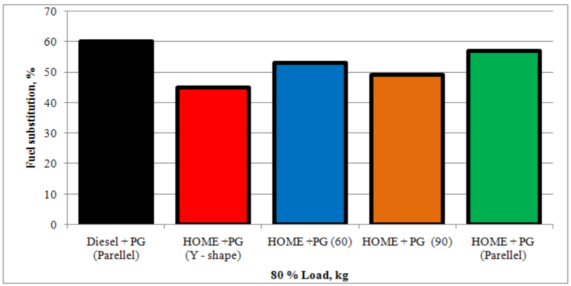


Fig 14 Variation of fuel substituted at 80% load

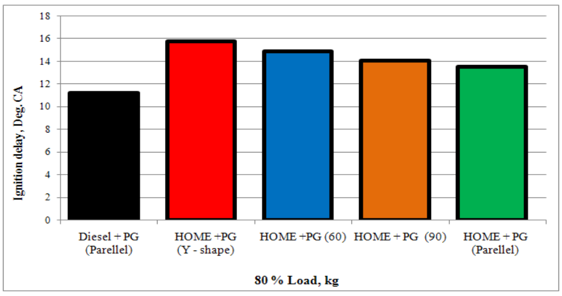


Fig. 15 Variation of ignition delay at 80% load

The ignition delay is calculated based on the static injection timing. Dual fuel operation with HOME-producer gas showed longer ignition delays compared to Diesel-producer gas operation. The injected fuel had the influence on the results indicated. Variations in the air–producer gas mixture in different carburetors lead to difference in the air–fuel ratio and improper burning of fuel with producer gas, which affects the combustion. Longer ignition delay was observed for HOME-producer gas operation and it is mainly because of improper mixing of fuel combination during ignition delay caused by higher viscosity and density and reduced volatility of HOME compared to diesel along with lower burning nature of producer gas. The HOME-producer gas (parallel flow gas entry carburetor) operation gives slightly lower ignition delay compared to HOME-producer gas operation with other carburetors used. This is because parallel flow gas entry carburetor results in nearly stoichiometric mixture and it may be due to turbulent flow resulted in air and producer gas flow-pipes of the carburetor. Values of the ignition delay at 80% load were 19.82, 18.93, 18.01 deg. CA for HOME- producer gas (Y – shape), HOME-producer gas (60), HOME-producer gas (90) and HOME- producer gas (parallel flow gas entry) operation respectively, compared to 13.65 ^{o} CA for Diesel-producer gas (parallel flow gas entry) operation at 80% load.

Variation of combustion duration with different carburetors at 80% load is shown in Figure 16. It was calculated based on the duration between the start of combustion and 90% cumulative heat release. The combustion duration increases with increase in the power output with all the fuels. This is due to increase in the quantity of fuel injected. Higher combustion duration is observed with HOME-producer gas compared to Diesel-producer gas. It could be due to improper air–fuel mixing, longer time required for mixing and leading to incomplete combustion and longer diffusion combustion phase. However, from the Figure, it is observed that the combustion duration was reduced and improved with the HOME–producer gas (parallel flow gas entry) operation. This could be due to improper mixing of air–producer gas in the respective carburetor. Also reduced heat release rate was obtained with HOME-producer gas (Y–shape, 60^0, 90^0) and HOME– producer gas and (parallel flow gas entry) operation compared to diesel–Producer gas dual fuel operation. This may also be due to higher viscosity of HOME and reduction of air-fuel mixing rates along with slow-burning producer gas. This leads to less fuel being prepared for rapid combustion with HOME-producer gas operation after the ignition delay. Therefore more burning occurs in the diffusion phase rather than in the premixed phase with HOME- producer gas operation. Significantly higher combustion rates during the later stages with HOME- Producer gas operation leads to higher exhaust temperatures and lower thermal efficiency. However, HOME-producer gas (parallel flow gas entry) operation shows improvement in heat release rate compared to HOME-producer gas operation with other carburetors tested. Values of the combustion duration at 80% load were 53.65, 48.01, 45.12 and 40.15 deg. CA for HOME-producer gas (Y–shape), HOME-producer gas (60^o), HOME-producer gas ($90\,^o$) and HOME-producer gas (parallel flow gas entry) operation respectively, compared to 36^o CA for Diesel-producer gas (parallel flow gas entry) operation at 80% load.

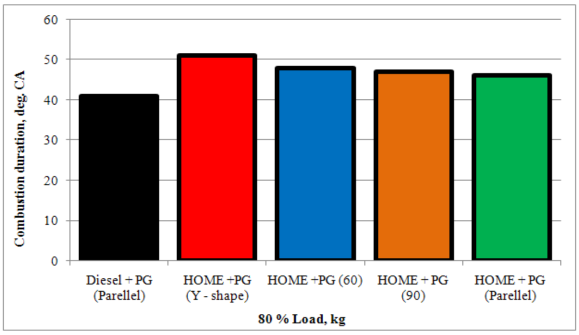


Fig. 16 Variation of combustion duration at 80% load

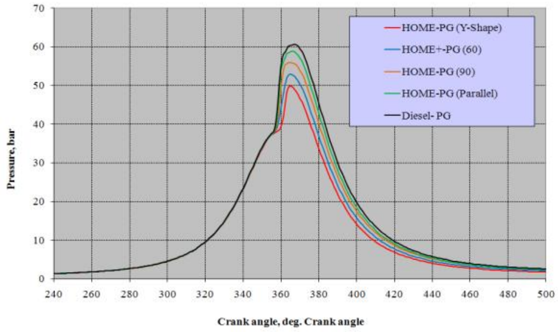


Fig. 17 In-cylinder pressure versus crank angle for HOME-producer gas combinations with different carburetor at 80% load.

Figure 17 shows in-cylinder pressure versus crank angle for different HOME-producer gas and Diesel–producer gas combinations at 80% load. The peak pressure depends on the combustion rate and the amount of fuel taking part in rapid combustion period. The uncontrolled combustion phase is governed by the ignition delay period and by the mixture preparation during the delay period. Therefore, mixture preparation and slow burning nature of producer gas during the ignition delay period were responsible for this trend of peak pressure and maximum rate of pressure rise. Results showed that diesel-Producer gas results in higher peak pressure compared to HOME–producer gas with different carburetors. It may be due to higher viscosity and lower volatility of HOME. The lower peak pressure was observed for the HOME–producer gas (Y–shape, 60^0, 90^0) compared to HOME–producer gas (parallel flow gas entry) operation. Carburetor type influences the nature of the pressure crank angle variation.

Figure 18 shows rate of heat release versus crank angle for HOME-producer gas and Diesel – producer gas combinations at 80% load using different carburetors. Results showed that Diesel-producer gas results in higher heat release rate compared to HOME–producer gas with different carburetors. It may be due to higher viscosity and lower volatility, cetane number and calorific value of HOME. The lower heat release rate was observed for the HOME–producer gas (Y–shape, 60^0, 90^0) compared to HOME–producer gas (parallel flow gas entry) operation. Carburetor type influences the nature of the heat release rate.

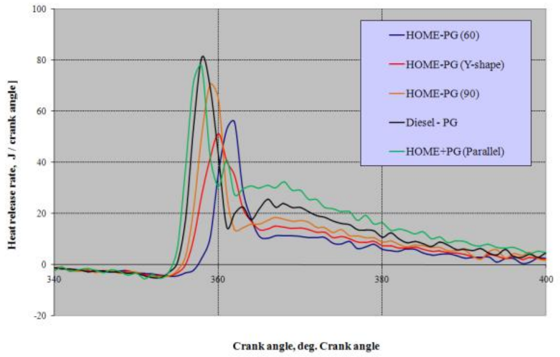


Fig. 18 Rate of heat release versus crank angle for HOME-producer gas combinations with different carburetor at 80% load

7. Estimation of uncertainty

Errors in all experimental data were bound to occur that ultimately affect the accuracy of measured value and also limit the conclusions of the present work. Random errors and systematic errors were minimized by the proper calibration of the measuring instruments. The uncertainties of different quantities were determined and were 1.95, 14.56, 8.65, 6.28, 14.28 and 5.45% for BTE, EGT, smoke opacity, CO, NOx and fuel substitution, respectively.

8. Conclusions

The following conclusions are made from the present study.

- Experimental analysis using different carburetors showed that parallel flow gas entry carburetor resulted in better mixing performance compared to Y-shape, 60^0 and 90^0 gas entry carburetor.
- Operating the Gasifier–engine system with carburetor on HOME and producer gas makes the system completely independent from the use of fossil fuels.
- Dual fuel operation with HOME-producer gas combination resulted in lower performance with increased emission levels compared to Diesel-producer gas operation.
- On an average, for HOME–producer gas operation with parallel flow gas entry carburetor, the BTE was increased by 15.3%, 10.67% and 5.4% compared to the operation with Y shape, 60^0, and 90^0 gas entry carburetors. But it was decreased by 20.4% compared to Diesel-producer gas operation.
- The smoke opacity for HOME–producer gas operation with parallel flow gas entry carburetor was reduced 24.34%, 9.08% and 4.9% compared to the operation with Y shape, 60^0, and 90^0 gas entry carburetors. Similarly, HC and CO emissions were lowered significantly with parallel flow gas entry carburetor compared with other carburetors tested. However, it could be compromised with 27.4%, 14.65% and 5.4% increased NOx emission levels compared to Y shape, 60^0, and 90^0 gas entry carburetor operations.
- For HOME–producer gas operation with parallel flow gas entry carburetor, the peak pressure was decreased by 14.4%, 8.32% and 4.6% compared to the operation with Y shape, 60^0, and 90^0 gas entry carburetors.
- Studies on the gasifier-engine system showed that, several new policies towards commercialization and marketization are still necessary, even though India has implemented many policies in renewable energy sector. Some of the reasons for the slow commercialization and marketization are mainly due to high cost of debt. This is the biggest issue facing in renewable energy technology. Hence, to promote Gasifier-Engine system for power production using renewable and alternative fuels, the nation should adopt attractive price setting and good policy. Some of the problems encountered in the implementation of this system and policies can be reduced if government and NGOs initiate the emission reduction and energy plantation programs adequately.

On the whole, it is seen that dual fuel mode of operation with the selected alternative fuel combination and with different carburetors resulted in lower performance compared to diesel-producer gas operation and smooth engine operation was observed. Among the selected carburetors, HOME–producer gas operation with parallel flow gas entry carburetor resulted in slightly improved performance and decreased smoke, HC and CO levels compared to the operation with other carburetors tested. Gasifier-Engine systems using renewable fuels with advanced technology are convenient and economically viable. This can serve the future energy needs for transport and agricultural applications.

9. References

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