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Performance Study of Dual Fuel Engine Using Producer Gas as Secondary Fuel

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Abstract: In the present paper, development of producer gas fuelled 4 stroke diesel engine has been investigated. Producer gas from biomass has been examined and successfully operated with 4 stroke diesel engine. The effects of higher and lower loads were investigated on the dual fuel mode. The experimental investigations revealed that at lower loads dual fuel operation with producer gas shows lower efficiency due to lower combustion rate cause by low calorific value of the producer gas. Beyond 40% load the brake thermal efficiency of dual fuel operation improved due to faster combustion rate of producer gas and higher level of premixing. It can be observed that at lower load and 20% opening of producer gas the gaseous fuel substitution found to be 56% whereas at 100% opening of producer gas it reaches 78% substitution. The CO_2 emission increased at high producer gas opening and high load because at 100% producer gas maximum atoms of carbons were there and at high load condition the diesel use increased. At 80% load and producer gas varying from 20% to 100. Power output was almost comparable to diesel power with marginal higher efficiency. Producer gas is one such technology which is environmentally benign and holds large promise for future.

Keywords: Dual fuel engine; Bio fuels; Producer gas

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1 Introduction: Energy consumption of any country shows standard of living. The advantages of renewable energy sources are well known for its secure and long term sustainability. Government of India's National Program on Biomass aims at optimum utilization of variety of biomass materials such as agro-based residues and dedicated energy plantations for power generation through the adaptation of efficient and state-of-the-art conversion technologies which includes gasification, pyrolysis and combustion. Diesel engines are widely used in Indian agricultural farms for a variety of stationary and mobile operations. The usual approach of producer gas utilization in diesel engines consists of operating existing compression ignition engines on producer gas cum diesel dual-fuel mode. A Performance Study of a Diesel Engine by using producer gas from Selected Agricultural Residues on Dual-Fuel Mode of Diesel-cum-Producer gas was done **[1]**.

Experimental investigation **[2]** on Dual fuel mode operation in diesel engines using renewable fuels Rubber seed oil and coir-pith producer gas was done. Dual fuel mode operation using partial combustion of biomass in the gasifier generates producer gas that can be used as supplementary or sole fuel for internal combustion engines. Dual fuel mode operation using coir-pith derived producer gas and rubber seed oil as pilot fuel was analyzed for various producer gas–air flow ratios and at different load conditions. Investigations **[3, 4]** on Characterization of biomass producer gas as fuel for stationary gas engines in combined heat and power production. This study was done in order to analyse and characterise the utilisation of biomass producer gas as a fuel for stationary gas engines in heat and power production. Study in Gasification and power generation characteristics of rice husk and rice husk pellet using a downdraft fixed-bed gasifier by, [5] Using rice husk and rice husk pellet a downdraft fixed-bed gasifier was applied under an air supply as a gasification agent. Gasification was conducted under a temperature range of 600-850 ^{0}C, and an excess air ratio of 0.45-0.6 for rice husk and 0.2-0.32 for rice husk pellet gasification. In the case of rice husk gasification, synthetic gas composition shows about 13.6%, 14.9%, 12.9%, and 2.3% for H_2, CO, CO_2, and CH_4. High CH_4 content was observed, typical of gasification of biomass. The heating value of the synthetic gas was moderate at 1084 kcal/Nm^3. For rice husk pellet gasification, synthetic gas composition shows about 18.6%, 20.2%, 8.1%, and 1.5% for H_2, CO, CO_2, and CH_4. The heating value of the synthetic gas shows higher value of 1314 kcal/Nm^3 than the synthetic gas produced from rice husk gasification. The cold gas efficiency was calculated to be more than 60% and 70% for rice husk and rice husk pellet gasification, respectively. Finally, it was found that the optimum excess air ratio for gasification of rice husk and rice husk pellet is about 0.6 and 0.3. To make power generation, the CD800L reciprocating engine designed to basically use LPG fuel was conducted by supplying synthetic gas generated in this downdraft gasifier. It was confirmed that stable power generation of 10 kW was achieved. This shows the possibility of stable power generation using synthetic gas from rice husk and rice husk pellet gasification with atmospheric air as a gasification agent.

In this paper, performance of a dual fuel engine using producer gas as secondary fuel is presented. Producer gas was analyzed and produced through gasification process. Down draft fixed bed bio gasifier was used for gasification process to generate producer gas with lower tar concentration, the gas produced filtered to remove impurities and to make it suitable for power generation from engine system. Gaseous fuel was directly connected to the engine system. The engine used in this experiment was 4 cylindered four stroke diesel engine with rated speed of 1500 rpm and its rated power was 62.5 KW. This investigation was done on both duel fuel and diesel mode.in; examples of the type styles are provided throughout this document and are identified in italic type, within parentheses, following the example. Some components, such as multi-leveled equations, graphics, and tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

Nomenclature:

°C	Degree centigrade
IC	Internal Combustion
SI	Spark Ignition
CI	Compression Ignition
NO_X	Oxides of Nitrogen
CO	Carbon Monoxide
HC/UHC/UBHC	Unburnt Hydrocarbon
CH_4	Methane
CO_2	Carbon Dioxide
KW	Kilowatt
HP	Horse Power
MJ	Mega Joule
Kg	Kilogram
CSt	Centi stokes
CR	Compression Ratio
Hz	Hertz
PPM	Part Per Million
mm	millimetre
RPM	Revolutions Per Minute

cc	Cubic Centimetre
BTDC	Before Top Dead Centre
K	Kelvin
AVR	Automatic Voltage Regulator
IP	Indicated Power
BP	Brake Power
FP	Frictional Power
Bmep	Brake mean effective pressure
FIP	Fuel Injection pump
NTP	Normal Temperature & Pressure
BSFC	Brake Specific Fuel Consumption
BSEC	Brake specific energy consumption
FC	Fuel Consumption
PG	Producer Gas
TDC	Top Dead Centre

2. EXPERIMENTAL SET-UP

Bio gasifier inspected and developed to generate producer gas, and dual fuel engine was also checked and developed for the experiment. Modified engine set up connected with various filters for receiving purified produced gas. The instruments used were properly checked and calibrated to minimize possible errors.

2.1. Bio gasifier:

The experimental setup used in this work consists of a Bio-gasifier mainly thought for agricultural or wood biomass. The gasifier used is an open top downdraft fixed bed reactor. The reactor and filter work in a blower-generated depression. After the blower, the gas passes through the flow rate measurement device. Producer gas fuels an internal combustion engine, before fuelling engine it get filtered through various filters such as cyclone, reformer, scrubber and dust filters. Gas temperature measurements were taken by thermocouples in different points in particular at the reactor outlet, at the filter inlet and outlet, near the flow rate measurement device and at the producer gas sampling spot. Pressure measurements are not considered to be relevant as the system is not pressurized. Thus the small pressure drops along the lines are neglected and in calculations pressure is assumed to be at its atmospheric value.

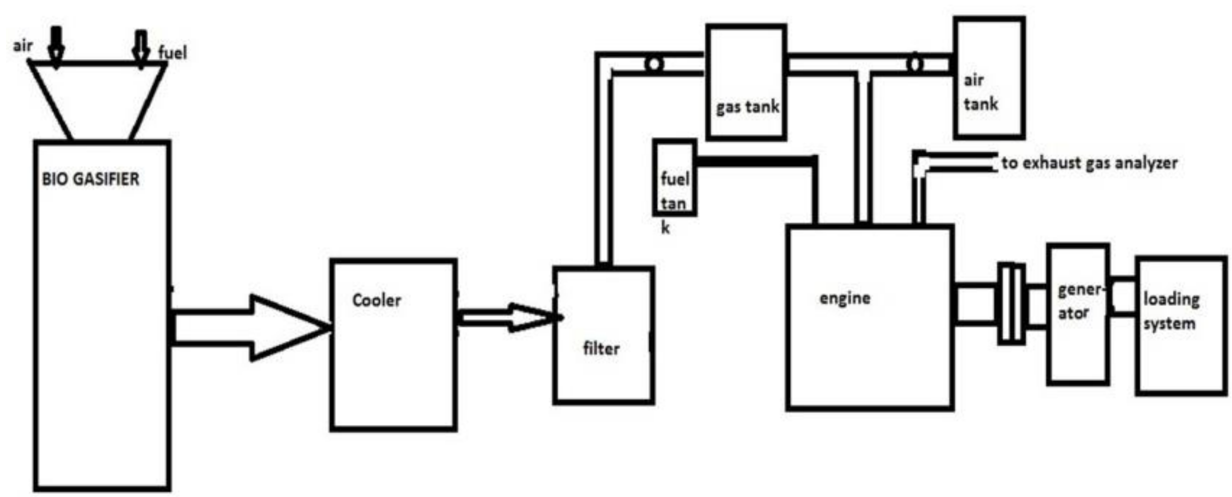

Figure 2.1 Experimental setup

2.1.2 Diesel Engine Set-up

A 4 cylindered four stroke diesel engine with rated speed of 1500 rpm and rated power 62.5 KW used. This investigation was done on both dual fuel and diesel mode. The engine system was connected with a computerized diesel engine rig equipped with software's taking data of crank angle and pressure. Engine was supplied with diesel through the diesel tank. Engine tested at constant rated speed throughout its power range with diesel-only and dual fuel operations. Three separate meter systems were used to measure the flow rates of air, diesel and producer gas. Major specification of engine given in Table 2.1. Direct injecting engine with water cooling system was used. The engine was turbo charged coupled with an alternator. Initially engine starts through a battery. Diesel consumption was measured in a 1000cc burette.

Table 2.1

Sl . No.	Parameter	Specification
1	Make and model	Ashok Leyland ALU WO4CT Turbocharged, intercooler, gen-set
2	General details	Four stroke, compression ignition, constant speed, vertical, water-cooled, direct injection, turbo charger, intercooler, gen-set
3	No. of cylinder	4
4	Bore (mm)	104
5	. Stroke (mm)	113
6	Rated speed (rpm)	1500
7	Swept volume (cc)	3839.67
8	Clearance volume (cc)	84.90
9	Compression ratio	17.5:1
10	Injection pressure (bar)	260
11	Injection timing BTDC(°)	16
12	Rated power kW at 1500rpm	62.5
13	Inlet pressure (bar)	1.06
14	Inlet temperature (K)	313
15	Nozzle diameter (mm)	0.285

2.1.3 **Emission measurements:** Exhaust gas emissions namely CO, CO_2, NO_x, O_2, and unburnt hydrocarbons (UHC) were measured by automotive emission analyzer.

3. Experimental Procedure:

Rice husk was the biomass used to generate producer gas from bio gasifier, rice husk was fed to the gasifier through its top opening. Air enters at the combustion zone of gasifier and producer gas generated leaves near its bottom. Hot producer gas passes through cooler where its temperature reduces to atmospheric, cooled gas with impurities then passed through various filters such as pebble bed filter, bubble cap filter column, cyclone, reformer, scrubber for fine filtering. A valve at the outlet of filter pipe controls the gas flow. An orifice connected to the surge tank used to measure the producer gas flow rate.

Producer gas and air were mixed in the intake pipe and the mixture enters into the engine. Quantity of gas and air flow to the engine were measured separately with the help of two venture sections provided in the T-section, U-tube manometers were connected to the venture section with polythene tube to measure the pressure drop across them.

Engine was investigated on 20%, 40%, 60%, 80% and 100% openings of valves at each opening producer gas was supplied to the engine and finally at 100% i.e. at full opening of the valve full producer gas was supplied. At first only 20% of the valve was opened and five readings were taken for five loads 1 kw, 6 kw, 18 kw, 30 kw, and 42 kw. Similarly at every opening five readings were taken for each load finally at 100% opening of the valve five reading were taken successfully. The dual fuel mode uses compressed Producer gas and quantities of pilot fuel for ignition. Engine was tested on diesel as well as on dual fuel mode at speed 1500 rpm and five loads, engine was started with diesel fuel, later the diesel was reduced and producer gas was supplied to the intake manifold.

Gasifier was connected to blower provided with a venturimeter to measure gaseous fuel pressure through which mass flow rate of producer gas was calculated, pressure of air was measured by manometer connected to engine cylinder. Flow rate of diesel was measured by a 1000 cc burette which shows the consumption of 100 ml diesel with time and time was measured with the help of stop watch. Engine exhaust was connected to a long iron pipe which exhales the exhaust produced. Exhaust analyzer was used to measure the particulates such as CO, CO_2, HC, O_2 and NO_x. Probe of exhaust analyzer was kept inside iron pipe for few minutes for measuring the emission of particulates.

Composition of producer gas was tested in biotech lab through Gas chromatography test.

4. Results and Discussion

The experimental results at rated speed of 1500 rpm, injection pressure 260 bar and injection timing 16^0 BTDC are presented for different load conditions. Full load has not been taken into consideration due to knocking problem. Results thus produced by different substitution of gaseous fuels have been analyzed in association with that of pure diesel operation.

4.1. Performances

The engine performance characteristics by Producer Gas substitution were evaluated on the basis of variation in load conditions and different Producer gas substitutions on brake thermal efficiency, brake specific energy consumption.

The effect of brake thermal efficiency at different compositions and different loads are shown in graph Figure 4.1. At lower loads dual fuel operation with producer gas shows lower efficiency, due to lower combustion rate cause by low calorific value of producer gas. Again at these loads pilot fuel leads to poor ignition and combustion of lean air-gas mixture. Therefore a minor influence of producer gas on thermal efficiency at part loads observed. However beyond 40% load the brake thermal efficiency of dual fuel operation is improved. This is due to faster combustion rate of producer gas and higher level of premixing.

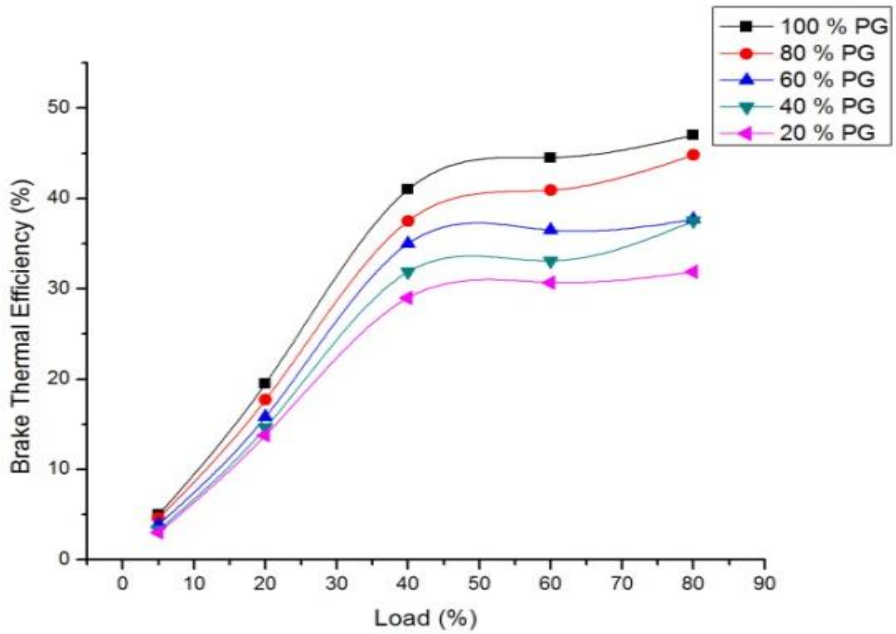

Figure 4.1: Brake Thermal Efficiency vs Load.

Graph Figure 4.2 shows the variation of BSEC with load for different opening of producer gas. It can be observed that the BSEC increase from 70800 kj/kwh to 119000 kj/kwh at 5% load and producer gas opening is 20% to 100%. Further at 20% load it decreases in the range of 15000-25000 kj/kwh and finally at full load it reaches the level of 7000 kj/kwh to 10000 kj/kwh. This is due to the better mixing of producer gas and air and complete combustion. The incomplete combustion at low load condition leads to high BSEC.

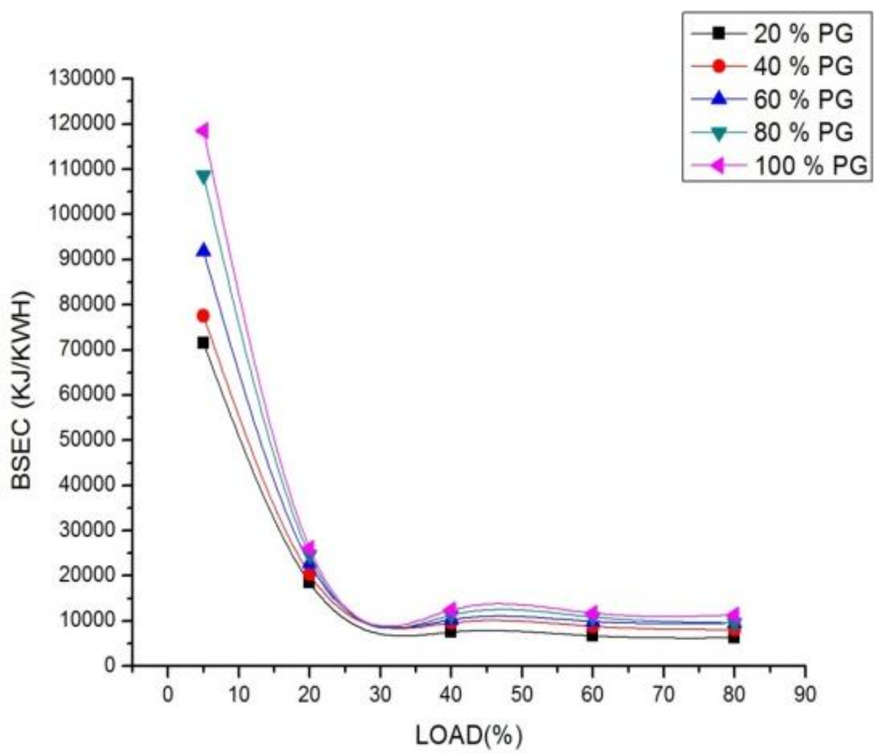

Figure 4.2: Brake specific energy consumption vs Load

Graph of Figure 4.3 shows the gaseous fuel substitution rate vs load. It can be observed that at lower load and 20% opening of producer gas the gaseous fuel substitution found to be 56% where as at 100% opening of producer gas it reaches 78% substitution. Maximum 92% substitution occurred at 80% load condition and 100% opening of producer gas. Increase in the fuel substitution is due to the sufficient gas flow at high load but at lower load fuel substitution rate decreases as there is insufficient oxygen to complete the combustion.

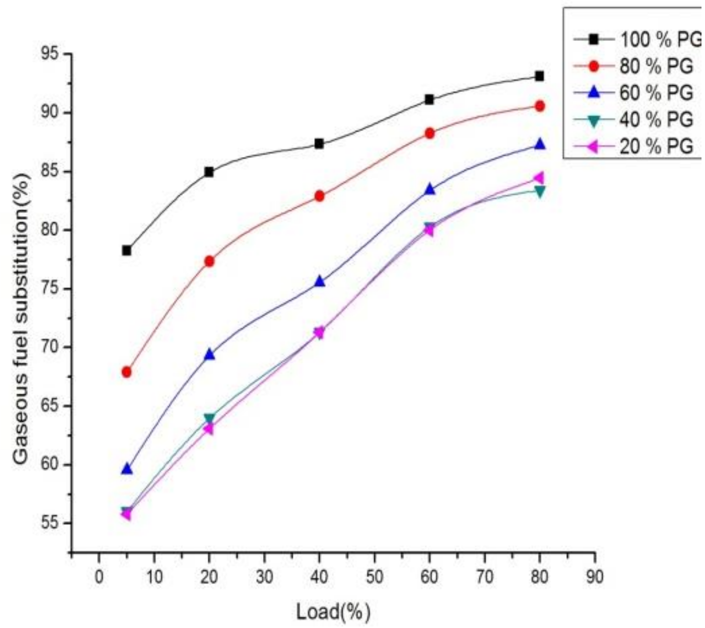

Figure 4.3: Gaseous fuel substitution vs Load

Figure 4.4 shows the variation of volumetric efficiency with load. The volumetric efficiency obtained for 100% opening of producer gas was very low i.e. 32% at 5% load and 35% at 80% load condition. The volumetric efficiency at 20% opening of producer gas and at 5% load is found as 54% and 58% at 80% load conditions. As the producer gas increases the volumetric efficiency is decreases because increasing producer gas displaces the portion of incoming air and results in reduction in volumetric efficiency. Thus restriction of fresh charge decreases the volumetric efficiency.

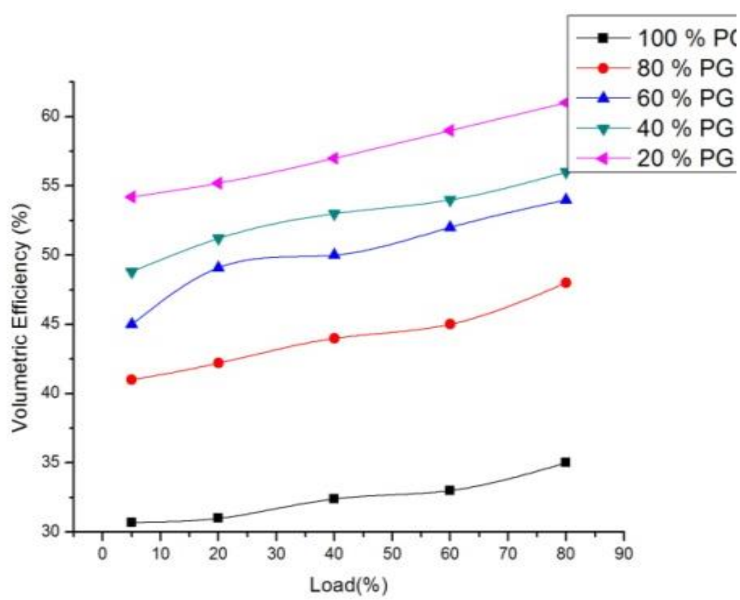

Figure 4.4: Volumetric Efficiency vs Load.

5. CONCLUSIONS:

Experiments were performed on 4 cylinder turbocharged, intercooled with 62.5 kw gen-set diesel engine by using Producer Gas as secondary fuel. The main objective of this study was to find the performance of a dual fuel engine by using Producer Gas. This study also yielded some basic information on the environmental aspects of power generation system with Producer Gas in dual fuel mode. The various openings of the Producer Gas were investigated on the engine performance, and emission characteristics. The present investigations were resulted and discussed. On the basis of result and discussion presented following conclusions are made:

1. Use of PG as a secondary fuel enhances brake thermal efficiency at high load but shows adverse effect at low load conditions.
2. The study shows a higher gaseous fuel substitution of 95%.
3. The volumetric efficiency gets reduced at all loads for dual fuel operation due to displacement of sucked air by PG.
4. Smooth and knock free engine operation resulted from the use of Producer gas.
5. A maximum of 22% of diesel is replaced by producer gas.

5.1. Suggestions for Future Work:

1. There is a need to develop suitable gas kits for gaseous fuels and so as to optimize the engine performances over the complete range of operation. These kits have to be simple and rough so that existing diesel engines may be easily adapted for dual fuel operation.
2. A good quality raw material should be used for production of producer gas so as to improve the quality of gaseous fuel which will help reducing ignition time.

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