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INVESTIGATION ON PERFORMANCE AND EMISSION OF A DI DIESEL ENGINE USING BLENDS OF JATROPHA OIL AND ITS BIODIESEL IN DUAL FUEL MODE WITH PRODUCER GAS

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ABSTRACT

The objective of the present work is to analyze the effects of Jatropha oil and Jatropha biodiesel blends in dual fuel mode using producer gas in a stationary diesel engine. The purpose of this investigation is to reduce the use of fossil diesel in CI engines by using suitable alternate fuels. A twin cylinder direct injection stationary diesel engine is used in dual fuel mode for experimentation. Producer gas is used as primary fuel and Jatropha oil and Jatropha biodiesel blends with diesel are used as pilot fuels during engine operation. Producer gas is introduced into the engine in premixed mode with air through the intake manifold. Jatropha oil and Jatropha biodiesel are blended with diesel in 50% volume proportions and used as test fuels. A downdraft gasifier is used to generate producer gas which used babul wood pieces as biomass. The gas flow rate is kept constant at 21.41 kg/hr. Three different dual fuel runs are performed using producer gas and other liquid fuels at varying loads. Engine performance and emission parameters are measured using the above test procedure. Results showed higher thermal efficiency obtained for diesel based dual fuel and lowest for Jatropha oil based dual fuel. The Brake specific energy consumption is found lowest for diesel-producer gas and highest for Jatropha oil-producer gas dual mode. CO and HC emissions are highest for diesel-producer gas and lowest for biodiesel-producer gas dual mode. NO emission is found highest in biodiesel-producer gas and lowest in diesel-producer gas dual mode.

Keywords: - *Direct Injection Diesel Engine, Downdraft gasifier, Jatropha, Producer gas, Twin cylinder.*

I. INTRODUCTION

In order to meet the growing demand for energy due to rapid industrialization and significant increase in the number of automobiles, there is a fast growing interest in alternative fuels for engines like biodiesel, methanol, ethanol, biogas, hydrogen and producer gas for providing a suitable substitute for diesel fuel in internal combustion engines.

Non-edible vegetable oils like Jatropha, Karanja, mahua, Neem etc. and their derivative products can also be used as alternate fuels in compression ignition (CI) engines. These bio-fuels are quite familiar to be used in CI engines because of close fuel properties with diesel, plenty availability and being renewable and eco-friendly in nature. As these fuels are high in viscosity and density, may cause flow problem when used in a CI engine. To reduce the viscosity of fuel and to enhance the engine performance these oils are preferably blended with diesel in various volume proportions before use in CI engines [1]. The attractive features of biodiesel include higher cetane number, non-toxic emissions, bio-degradability, absence of sulphur and aromatic compounds and excellent lubricity. Biodiesel use in a CI engine reduces carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), particulate matter (PM) emissions but on the other hand increases nitrogen oxide (NO_x) emissions [2]. In this context biomass is one of the leading sources for alternative fuels as it is composed of carbon, hydrogen and oxygen. Solid biomass through the process of gasification can be converted into a mixture of combustible gases and subsequently utilized for combustion in internal combustion engines [3]. Biomass is available in various forms as forest residues, agricultural residues, plant residues, animal waste, industrial waste and municipal solid waste. Biomass energy conversion technologies are gaining momentum due to low cost energy, renewable in nature and lower emissions [4].

Producer gas is generated from biomass in a thermo-chemical process. Gasification is a process by which solid biomass is converted into clean gaseous form in a solid bio-residue gasifier. In this process the solid biomass is subject to partial combustion under sub-stoichiometric conditions in presence of air followed by reduction process subsequently resulting in the formation of a gas mixture of CH_4, H_2, CO, CO_2 and N_2 commonly known as producer gas [5].

Dual fuelling a diesel engine with various liquid and gaseous fuels saves fossil fuel, increases power output and efficiency and produces lower emissions. Dual fuel operation in a CI engine is achieved by injecting a small quantity of diesel primarily to provide ignition to the lean mixture of gaseous fuel and air. Another method of dual fuelling can be achieved with addition of gaseous fuel into air of a fully operational diesel engine. In dual fuel methods there is a need of optimum pilot fuel (diesel) quantity variation in contrast with the primary fuel (gas) supply, in order to obtain maximum performance [5].

II. THE PRESENT WORK

In the present investigation diesel (D), neat Jatropha oil (JO), Jatropha biodiesel (JBD) are used as pilot fuels and producer gas (PG) is used as primary gaseous fuel with air in a dual fuel diesel engine. The specific objective of the present investigation is to minimize the use of fossil diesel in a CI engine, to enhance the engine performance and to lower the engine emissions. The fuel properties of the liquid test fuels, the composition of **producer** gas and the properties of producer gas are given in Table 1, Table 2 and Table 3 respectively.

Table 1 Properties of test fuels

Property	Diesel	JO	JBD	ASTM methods
Density (kg/m^3)	830	981	880	D1298
Kinematic viscosity at 40^{o}C (cSt)	2.5	37	5.65	D445
Calorific value(kJ/kg)	42,200	37,500	38,450	D240
Cetane No.	45-55	45	50	D613
Cloud point (^{o}C)	-12	9	-	D2500
Oxygen (%,w/w)	0.31	12.52	-	-
Flash point (^{o}C)	70	238	170	D93
Pour point (^{o}C)	-17	4	-	-
Carbon (%, w/w)	86.71	77.21	-	-

Table 2 Composition of producer gas [4, 7]

Constituents	Percentage (%)
Carbon monoxide	19±3
Hydrogen	18±2
Carbon dioxide	10±2
Nitrogen	50
Methane	Up to 3

Table 3 Properties of producer gas [6, 7]

Sl. No.	Parameter	Value
1	Gas calorific value ratio	5.6 MJ/m^3
2	Stoichiometric air/fuel ratio	1.12:1
3	Adiabatic flame temperature	1546±25K
4	Laminar burning velocity	0.5±0.05 m/s
5	Energy density	2.6 MJ/m^3

III. MATERIALS AND METHODOLOGY

TYPE OF TEST FUELS

During the present investigation the sources of fuels used are diesel, neat Jatropha oil and Jatropha biodiesel. Two different fuel blends are prepared along with diesel for use as test fuels. The first fuel blend used is 50% diesel and 50% neat Jatropha oil (J50) where as the second fuel blend used is 50% diesel and 50% Jatropha biodiesel (B50). The fuel blends are prepared on a volume basis. The fuel properties are estimated for all the three fuels as per ASTM standards.

TYPE OF BIOMASS

The present experimental investigation used woody biomass for producer gas generation as it is having higher heating value and low ash content. Babul tree wood pieces of size 25 mm length and 25 mm diameter are used as gasifier feedstock for producer gas generation. The moisture content of the woody biomass is kept below 20% for obtaining higher calorific value of the gas.

IV. EXPERIMENTAL SET UP

The present experimental set up consists of a twin cylinder four-stroke diesel engine with electrical generator and bulb loading devices, a downdraft type biomass gasifier, gas cooler and gas filter. The schematic diagram of the experimental set up is shown in figure 1. The detailed specifications of the test engine and the woody biomass gasifier are given in Table 4 and Table 5 respectively.

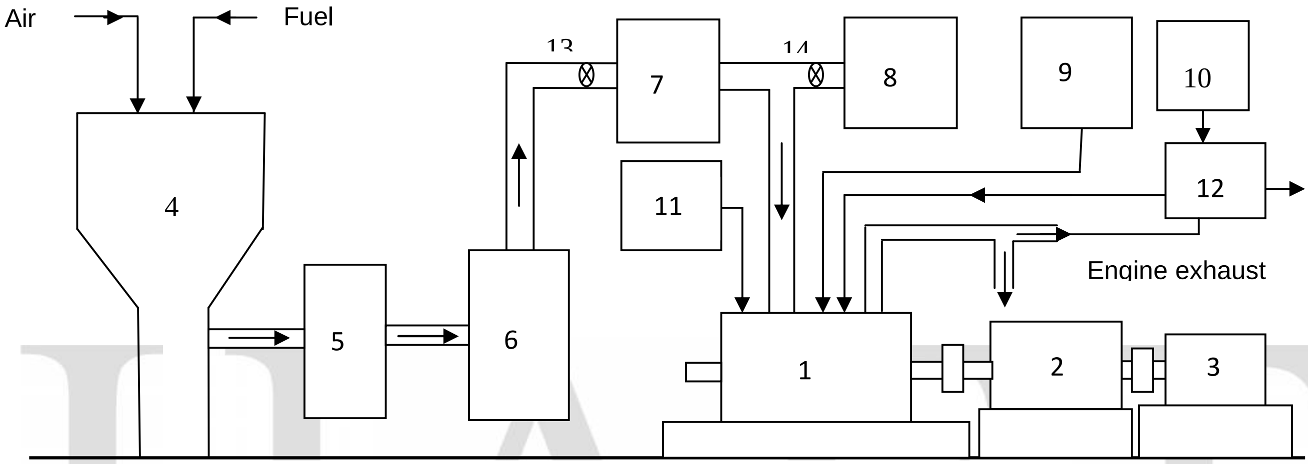

Fig. 1 Schematic diagram of the experimental set up

1. Engine, 2. Generator, 3. Loading unit, 4. Gasifier, 5. Cooler, 6. Filter, 7. Producer gas tank, 8. Air tank, 9. Diesel tank, 10. J50 tank, 11. B50 tank, 12. Heat exchanger, 13,14. Control valves.

Table 4. Test engine specification

	Parameters	Specification
	Make	Prakash Udyog Ltd., Agra, India
	No. of cylinders	Two
	No of strokes	4-Stroke
	Rated power Bore	14 HP 114 mm
	Stroke length	110 mm
	Compression ratio	16:1
	Rated speed Injection pressure Injection angle Alternator capacity	1500 rpm 220 bar 23^{o}bTDC 10.3 kW

Table 5. Specifications of the gasifier

Parameter	Specification
Machine supplier	Ankur Scientific Energy Technologies Pvt. Ltd. Vadodara, India
Model Gasifier	WBG-10 in scrubbed, clean gas model Downdraft type
Gasification temperature	1050 – 1100 ^{o} C
Rated gas flow Average gas calorific value Fuel Storage Capacity	25 Nm^3/hr 1000 kcal/Nm^3 100kg
Rated hourly consumption	8 – 9 kg.
Fuel type and size	Wood/woody waste with maximum dimension not exceeding 25 mm in diameter and length
Typical conversion efficiency	>75%

Permissible moisture Content in biomass Ash removal	Less than 20% (wet basis) Manually (dry ash discharge)

EXPERIMENTAL PROCEDURE

The biomass is loaded from the top of the gasifier and ash is removed continuously in regular interval. The partial combustion of biomass in the gasifier produces high temperature producer gas which enters into the gas cooling unit. The moisture, grease and the dust particles are removed by passing through a two set filter. A mechanical valve is provided for controlling the gas flow rate at the outlet of the filter pipe. An orifice meter is connected to the surge tank for measuring the gas flow rate. The intake manifold of the engine is modified using a T-section to introduce the mixture of producer gas and air into the engine cylinder. Separate fuel tanks are attached to the engine for supplying the three liquid fuels. To reduce the viscosity of the J50 blend it is passed through a heat exchanger operated by the exhaust gas of the engine before its supply to the fuel pump. The tests are conducted using the three test fuels diesel, J50 and B50 in dual fuel mode with producer gas at a const. gas flow rate of 21.41 kg/hr at different loads. The engine is operated at a rated speed of 1500 rpm, injection timing maintained 23^o before top dead centre (bTDC) and injection pressure maintained at 220 bar. An AVL 5-gas analyzer (Model-AVL Digas 444) is used for measuring the emission parameters. A mechanical type thermocouple is used to measure the exhaust gas temperature.

V. RESULTS AND DISCUSSION

BRAKE THERMAL EFFICIENCY (BTE)

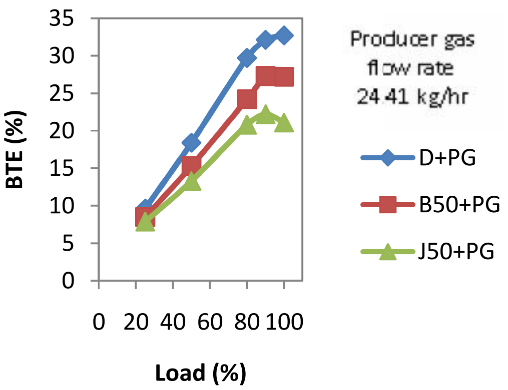

Fig. 2 Variation in BTE with load

Figure 2 explains the variation in BTE with load of the three test fuels when operated in dual fuel mode with producer gas. Results show a continuous increase in BTE for all test fuels in dual fuel mode up to 85% load and then decrease. This is due to higher charge temperature resulting in better combustion efficiency with increase in load. At highest load BTE decreases due to lack of oxygen [1]. The highest BTE obtained are 34.6%, 31.3% and 27.2% for diesel, B50 and J50 respectively with PG at 90% load. Lower BTE with bio-fuels may be attributed towards their lower calorific value and higher viscosity.

BRAKE SPECIFIC ENERGY CONSUMPTION (BSEC)

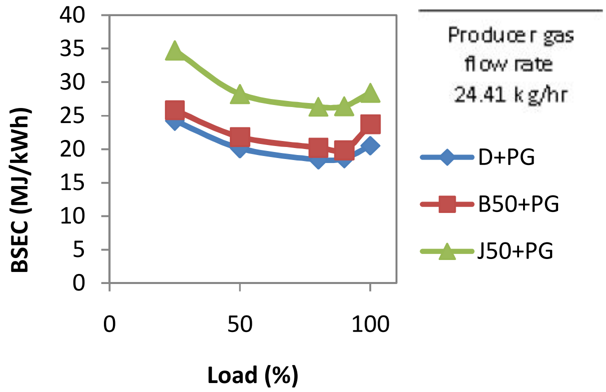

Fig. 3 Variation in BSEC with load

The BSEC is calculated based on fuel consumption and calorific value to the brake power. In dual fuel operation the BSEC is found to be more compared to diesel mode under all operating conditions [8]. From figure 3 it is seen that BSEC increases up to 85% load and then increases under dual fuel operation for all test fuels. This decrease in BSEC can be attributed to the increase in thermal efficiency in the same range. Diesel-PG dual operation produced the lowest and J50-PG dual operation produced the highest BSEC at all loads. This is as a result of lower calorific value of PG and bio-fuels as compared to diesel [1].

CARBON MONOXIDE (CO)

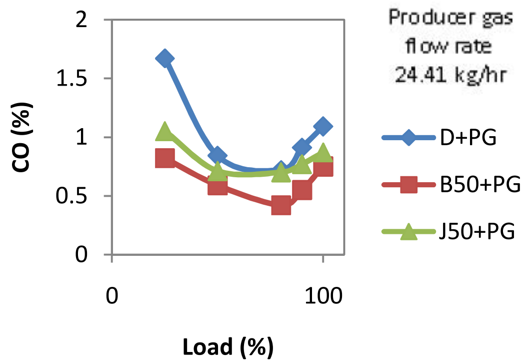

Fig. 4 Variation in CO emission with load

Figure 4 shows the variation in CO emission with load. Higher CO emission in the exhaust completely indicates combustion inefficiency. Presence of PG in the engine cylinder reduces the quantity of oxygen in the cylinder and creates incomplete combustion and higher CO emissions [9]. Result shown indicates that CO emission decreases up to 85% load and then increases for all test runs. Lower CO emission obtained for B50-PG and J50-PG dual mode operations as compared to diesel-PG. This may be due to the fact that higher oxygen content of bio-fuels compensates the requirement of oxygen in the engine cylinder, hence combustion inefficiency is minimized. The lowest CO emission is found to be 0.42% for B50-PG at 80% load.

HYDROCARBONS (HC)

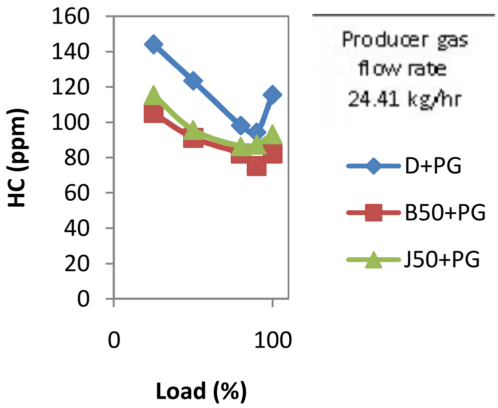

Fig. 5 Variation in HC emission with load

Figure 5 indicates that the HC emission decreases up to 85% load and then increases for all test fuels operating in dual mode with PG. This is because at very high loads availability of more fuel in the combustion chamber tends to incomplete combustion [10]. HC emission is found to be less in B50-PG and J50-PG dual mode as compared to diesel-PG dual operation at all loads. This is attributed towards higher oxygen content in bio-fuels compensates the slow burning rate in dual fuel operation with PG and reduces the HC emission [10]. Lowest HC emission is obtained as 71 ppm for B50-PG at 90% load.

NITROGEN OXIDE (NO)

Figure 6 shows the variation in NO emission with load for all dual fuel test runs. It is observed that, NO emission is much higher in bio-fuel and Pg dual mode as compared to diesel-PG operation. Also the trend shows a continuous increase in NO with load. NO_x emission is higher in CI engines because of higher in cylinder temperature. Availability of more oxygen in bio-fuels increases combustion efficiency and results in higher combustion temperature increasing NO_x emission [10]. With increase in load the NO_x emission also increases due to increased energy input in dual mode operation [1, 10]. The highest NO emission is found to be 544 ppm for B50-PG dual mode at highest load.

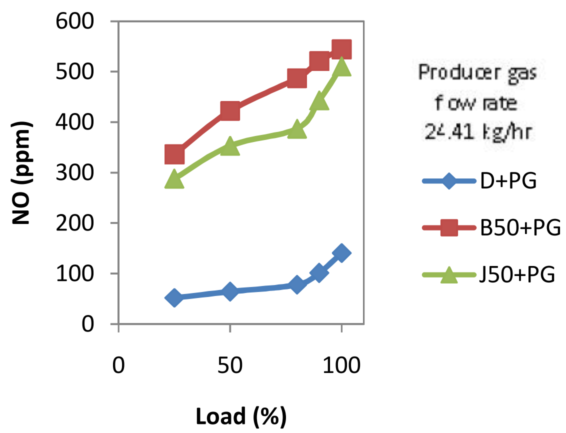

Fig. 6 Variation in NO emission with load

VI. CONCLUSION

The primary objectives of the present investigation is to examine the effectiveness of Jatropha oil, Jatropha biodiesel in dual mode with producer gas in a CI engine for minimizing the use of fossil diesel and to closely study the behaviour of engine performance and emission characteristics with these fuels.

The main findings of the present experimental investigation are as follows.

1. The BTE is found to be highest for diesel-PG dual fuel as compared to other test fuels. The BSEC is found to be lowest in case of diesel-PG dual fuel and higher for other test fuels.
2. CO and HC emissions are highest for diesel-PG dual fuel and lowest for B50-PG dual fuel.
3. The NO emission is found to be highest in case of B50-PG dual fuel and lowest for diesel-PG dual fuel for entire range of loads.

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