International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 3, May - 2012

Application of Wood Chip Producer Gas and Bio-diesel Blends In CI Engine

Prof. Sharad P. Bargat
DES'S COET, Dhamangaon Rly.
Amravati-444709(M.S.)INDIA

Prof. Pravin S. Wagh,
DES'S COET, Dhamangaon Rly.
Amravati-400709(M.S.)INDIA

Prof. Uday A. Kakde
DES'S COET, Dhamangaon Rly.
Amravati-444709(M.S.)INDIA

Abstract

In order to meet the energy requirements, there has been growing interest in alternative fuels like biodiesels, methyl alcohol, ethyl alcohol, biogas, hydrogen and producer gas to provide a suitable diesel substitute for internal combustion engines

The performance of the CI engine was investigated for Dual Fuel Mode and mixed fuel mode operation in terms of brake thermal efficiency, specific energy consumption and compared with the base line performance of the engine.

The specific energy consumption is found to be minimum in the tune of 13.8 MJ/kw-hr and the exhaust gas temperature is observed higher in the range of 427^{o}C. The increment in load on the engine increases the brake thermal efficiency, exhaust gas temperature, liquid fuel replacement and lowered the specific energy consumption. The maximum liquid fuel replacement in the tune of 46.73% is possible with the use of mixed fuel

1. Introduction

Now-a-day alternative fuels have been interesting for everyone in country due to fuel crisis occurred. In order to meet the energy requirements, there has been growing interest in alternative fuels like biodiesels, methyl alcohol, ethyl alcohol, biogas, hydrogen and producer gas to provide a suitable diesel substitute for internal combustion engines. Gasification is a very efficient method for extracting energy from many different types of organic materials and also has applications as a clean waste disposal technique. Gasification is a process in which solid biomass is converted into a mixture of combustible gases, which complete their combustion in C.I engine. Hence, producer gas can act as a promising alternative fuel, especially for diesel engines by substituting considerable amount of diesel fuels.

There are many alternative fuels in India for example gas fuel, Bio-diesel, and others. One of them is the producer gas acquired from bio-mass such as wastes from agricultural products. Mostly, the producer gas is used as the fuel for the electricity generation system. This system is operated by the dual fuel diesel engine in which the diesel is main fuel while producer gas is the secondary fuel. By using the dual fuel system, in this experiment, downdraft gasifier is used to produce the producer gas and wood chips as biomass feedstock for downdraft gasifier [1].

The producer gas generated through the process of gasification from bio-mass such as wastes from agricultural products, wood chips, coconut shells, groundnut shell, etc can be considered as alternative fuel for IC engines. Gasification is a process that converts carbonaceous materials, such biomass into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen. The resulting gas mixture is called producer gas and is itself a fuel. Gasification is a very efficient method for extracting energy from many different types of organic materials, and also has applications as a clean waste disposal technique [2].

In order to meet the energy requirements, there has been growing interest in alternative fuels like biodiesels, methyl alcohol, ethyl alcohol, biogas, hydrogen and producer gas to provide a suitable diesel oil substitute for internal combustion engines. Vegetable oils present a very promising alternative to diesel oil since they are renewable and have similar properties. Vegetable oils offer almost the same power output with slightly lower thermal efficiency when used in diesel engine. Research in this direction with edible oils have yielded encouraging results, but their use as fuel for diesel engines has limited applications due to higher domestic requirement[3].

Internal combustion Engines have proved its utility in transportation, agriculture and power sector of India. These engines also help in developing decentralized systems energy for rural electrification. However, the concerns about long term availability of petroleum diesel and strict environmental norms have mandated that renewable alternative to diesel fuel should be expedite explored to overcome these problems. Vegetable oils have always been considered as a good alternative to diesel for last many years and oil derived from Jatropha cruces plant has been considered as a sustainable substitute to diesel fuel.

Compression ignition (CI) engine could be operated with following fuels either alone or in the form of mixture. Use of diesel in CI engine is a well-proven technology. In India, a large variety of biomass feedstock is available in huge amounts. As these are available locally, biomass gasifier-based power generation may be an appropriate option for decentralized power generation in many parts of the country [4]. Biomass gasifier-based system capable of producing power from a few kilowatts up to several hundred kilowatts has been successfully developed indigenously. The utilization of producer gas in the diesel engine in dual fuel operation is an established technology for conservation of Diesel. Producer gas could be used in CI engine, without any modification in the engine. However, it cannot replace the diesel completely. Diesel replacements up to 70–90% have been achieved in the dual fuel mode. Because of its poor ignition/delay ignition characteristics some minimum amount of Diesel is required to start the ignition. On the other hand, the use of plant oil as fuel for CI engine is not new. The all properties of plant oils were close to diesel except viscosity and volatility. Various methods were adopted to overcome these problems. It included blending of oils with diesel, heating of plant oils before injecting into the combustion chamber of engine and esterification of plant oils [2].

2. Overview of producer gas

What to expect from a wood gasifier system?

Operation of modern spark ignition or compression ignition stationary engines with gasoline or diesel fuel is generally characterized by high reliability and minor efforts from the operator. Under normal circumstances the operator's role is limited to refueling and maintenance. There is little need for action and virtually no risk of getting dirty. Start and operation can in fact be made fully automatic.

Anybody expecting something similar for wood gas operation of engines will be disappointed. Preparation of the system for starting can require half an hour or more. The fuel is bulky and difficult to handle. Frequent feeding of fuel is often required and this limit the time the engine can run unattended. Taking care of residues such as ashes, soot and tarry condensates is time-consuming and dirty.

It is a common mistake to assume that any type of biomass which fits into the opening of the refueling lid can be used as fuel. Many of the operational difficulties which face inexperienced users of gasifiers are caused by the use of unsuitable fuels. In order to avoid bridging in the fuel bunker, reduced power output because of large pressure losses, or "weak" gas, slag cakes, tar in the engine and damage to the gasifier caused by overheating, it is necessary for most designs that the fuel properties are kept within fairly narrow ranges. This is not necessarily a more serious limitation than the need to use gasoline of super grade for high compression spark ignition engines rather than regular gasoline or diesel fuel. But in the case of gasifier operation, more of the responsibility for quality control of the fuel rests with the operator. The need for strict fuel specifications is well documented in the experiences reported from the Second World War [2, 5].

Operation of wood gas engines can also be dangerous if the operator violates the safety rules or neglects the maintenance of the system. Poisoning accidents, explosions and fires have been caused by unsafe designs or careless handling of the equipment. It may be assumed that modern systems are designed according to the best safety standards, but it is still necessary to handle the equipment in a responsible manner [5].

3. Fuelling Of Engines by Producer Gas

Producer gas, the gas generated when wood, charcoal or coal is gasified with air, consists of some 40 per cent combustible gases, mainly carbon monoxide, hydrogen and some methane. The rest are non-combustible and consists mainly of nitrogen, carbon dioxide and water vapor.

The gas also contains condensable tar, acids and dust. These impurities may lead to operational problems and abnormal engine wear. The main problem of gasifier system design is to generate a gas with a high proportion of combustible components and a minimum of impurities [5].

4. Possibilities of Using Producer Gas with Different Types of Engines

Spark ignition engines, normally used with petrol-or kerosene, can be run on producer gas alone. Diesel engines can be converted to full producer gas operation by lowering the compression ratio and the installation of a spark ignition system. Another possibility is to run a normal unconverted diesel engine in a "dual fuel" mode, whereby the engine draws anything between 0 and 90 per cent of its power output from producer gas , the remaining diesel oil being necessary for ignition of the combustible gas/air mixture. The advantage of the latter system lies in its flexibility: in case of malfunctioning of the gasifier or lack of biomass fuel, an immediate change to full diesel operation is generally possible.

However, not all types of diesel engines can be converted to the above mode of operation. Compression ratios of ante-chamber and turbulence chamber diesel engines are too high for satisfactory dual fuel operation and use of producer gas in those engines leads to knocking caused by too high pressures combined with delayed ignition. Direct injection diesel engines have lower compression ratios and can generally be successfully converted [5].

5. Theory of Gasification

The production of producer gas called gasification, is partial combustion of solid fuel (biomass) and takes place at temperatures of about 1000 °C. The reactor is called a gasifier. The combustion products from complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen. However in gasification where there is a surplus of solid fuel (incomplete combustion) the products of combustion are combustible gases like Carbon monoxide (CO), Hydrogen (H2) and traces of Methane and no useful products like tar and dust. The production of these gases is by reaction of water vapor and carbon dioxide through a glowing layer of charcoal. Thus the key to gasifier design is to create conditions such that a) biomass is reduced to charcoal and, b) charcoal is converted at suitable temperature to produce CO and H2.

Since there is an interaction of air or oxygen and biomass in the gasifier, they are classified according to the way air or oxygen is introduced in it. There are three types of gasifiers (Figure II-I); Downdraft, Updraft and Crossdraft.

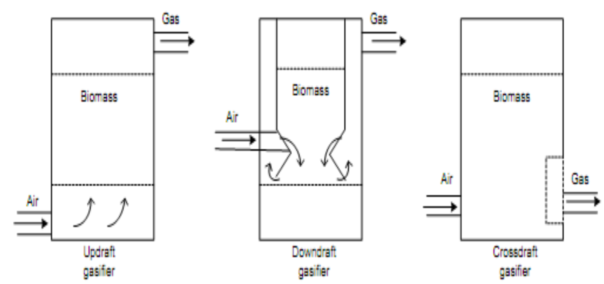

Fig. II-I Schematic view of various types gasifier[5].

Table II-I show the advantages and disadvantages of different types of gasifier set up used for generating the producer gas from the woody bio-mass[5].

6. Test methodology

A. Parameters Selection:

The selections of appropriate parameters were essential for engine calculations and set-up available. The main parameters desired from the engine are listed below.

1. Power produced by the engines
2. Specific energy consumption
3. Brake thermal efficiency
4. Fuel consumption
5. Speed of the engine

B. Parameters Calculation:

With a view to calculate the parameters mentioned above, it was essential to pick up the following signals from the test bench.

1. RPM of the engine
2. Load on engine
3. Fuel consumption rate
4. Producer gas consumption rate
5. Voltage generated by the alternator
6. Current generated by the alternator

Once the parameters were selected, the essential instruments required for sensing these parameters were installed at the appropriate points in the experimental set-up.

TABLE II-I

AVANTAGES AND DISADVANTEGES OF DIFFERENT TYPES OF GASIFIER UNIT

No	Gasifier type	Advantages	Disadvantages
1	Updraft	➢ Small pressure drop, good thermal efficiency ➢ Little tendency towards slag formation	➢ Great sensitivity to tar and moisture and moisture content of fuel ➢ Relatively long time required for start up of IC engine ➢ Poor reaction capability with heavy gas load
2	Downdraft	➢ Flexible adaptation of gas production to load ➢ Low sensitivity to charcoal dust and tar content of fuel	➢ Design tends to be tall ➢ Not feasible for very small particle size of fuel
3	Crossdraft	➢ Short design height ➢ Very fast response time to load ➢ Flexible gas production	➢ Very high sensitivity to slag ➢ High pressure drop

7. Experimental setup

A. Details of Engine Specification:

'Field Marshal' make diesel engine was used. Detailed specification of the engine given in table IV-I:

TABLE IV-I
ENGINE SPECIFICATION

Sr. No.	Item	Technical Data
1	Method of Cooling	Water
2	No. of Cylinder	1
3	Rated Power - B. H. P. / kW	10.0/7.4
4	Bore (mm)	102.0
5	Stroke (mm)	116.0
6	Rated R. P. M.	1500
7	Swept Volume (CC)	948
8	Compression Ratio	18.8:1
9	Bearing Type	Bush
10	Method of Starting	Cold Starting with the help of Starting Handle
11	Engine Rotation	Standard Rotation clockwise facing Flywheel
12	Fuel Tank Capacity	11.0 Lts.
13	Sp. Fuel Consumption gms / bhp - hr	185
14	Sp. Fuel Consumption gms / Kwhr	251
15	Lubrication System	Plunger Pump
16	Lub. Oil Sump Capacity (Lts.)	3.500
17	Crank Shaft Height (mm)	203
18	Engine Net Weight (kg)	165

B. Details of Gasifier Specification:

A Downdraft wood waste gasifier, Associated Engineering Work (AEW) make having the technical collaboration with SPRERI was used for generation of producer gas from wood chips as an input feed stock.

TABLE IV-II
GASIFIER SPECIFICATION

Gasifier Unit	
Type Of Gasifier	Downdraft, batch feeding
Model	GM 55
Material Of construction	Generally M.S. except hearth and air Nozzles where S.S. is used
Rated capacity	10 to 12 m^3/hour
Air Nozzles	4 Nos.
Hopper capacity	60 kg
Fuel used	Waste woody biomass
Size of fuel	Chips of 25 mm, 10mm
Gas cooling medium	Water
Gas Clean Up Unit	
Scrubber	Direct contact, co-current water jet
Filter Media	Pebble, cotton yarn waste etc.
Scrubber water flow rate	600 Lit/hrs.
Pressure drop	45 mm of water column
Gas Temperature	Ambient [after cooling]
Tar and Soot in gas	Negligible

A. Experimental Test Rig:

The main components of the experimental setup are Engine two fuel tanks (Diesel and Jatropha blend), Gasifier unit, gas flow meter, fuel consumption measuring unit, Electrical resistance loading arrangement, voltmeter, ammeter and digital tachometer meter. Fig. IV-I shows the schematic diagram of the experimental setup used for experimentation.

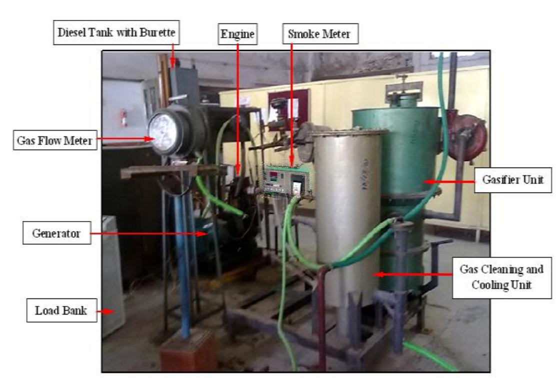

Fig. IV-I Schematic diagram of experimental test rig

The engine was started with diesel for at least 30 minutes and once the engine warms up, it is switched over to Jatropha biodiesel blend. For switching the engine from diesel to Jatropha biodiesel blend, a two way valve was provided on the control panel. Both the fuels from the two tanks can be feed to the engine through this valve separately. One end of the valve is connected to Jatropha biodiesel blend tank and the other end is connected to diesel. The fuel from the valve enters into the engine through this fuel measuring unit. With the help of this fuel measuring unit, Fig. IV-II shows the schematic layout of the experimental setup.

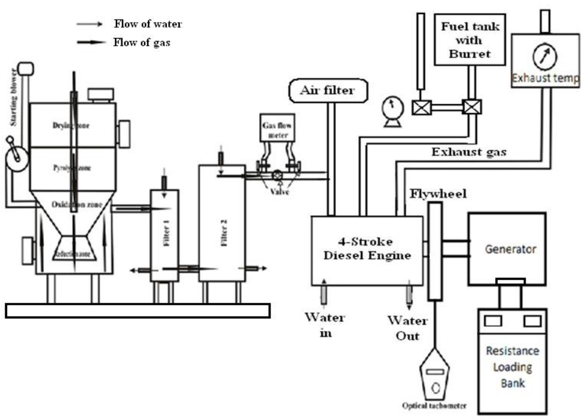

Fig. IV-II Layout of experimental test rig

8. Results:

The main objective of the work was to fuel the diesel engine with blend of Jatropha bio-diesel and wood chip producer gas and performance was studied on different blending % of Jatropha bio-diesel at different loading condition and compared with baseline data. The engine performance was test on various loads as 1kw, 2kw, 3kw and 4kw. The results of this experiment are presented in brake thermal efficiency and specific energy consumption.

A. Brake Thermal Efficiency

The brake thermal efficiency of the engine is one of the most important criteria for evaluating the performance of the engine. It indicates the combustion behavior of the engine to a great extent.

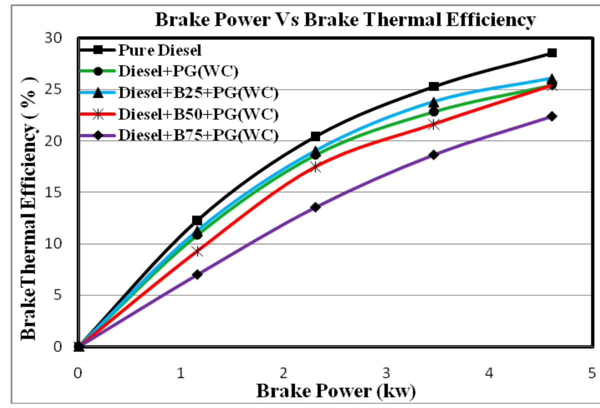

Fig. V-I Brake thermal efficiency with brake power

Figure-V-I shows the variations in brake thermal efficiency of the engine for different combination of fuel blends. The brake thermal efficiency with diesel + wood chips producer gas was found to be slightly lower than that of diesel + B25 + Producer gas in mixed fuel mode fuel at tested load conditions. There was no difference between the diesel + B25 + Producer gas and diesel + producer gas on efficiencies at the lower load but at the higher loading condition the engine give the maximum brake thermal efficiency with diesel + B25 + Producer gas . The brake thermal efficiencies of engine, operating with diesel + B25 + Producer gas in mixed fuel mode were 11.25, 19.03, 23.8 and 26.08 per cent at 1kw, 2kw, 3kw and 4kw load conditions respectively. It was observed that detonation or knocking occurred when the engine was operated with a large fraction of the fuel energy from producer gas particularly at high load. In order to reduce detonation, the intake of producer gas was reduced resulting in a low liquid fuel replacement at high load.

B. Specific Energy Consumption

The brake specific energy consumption was preferred to compare the performance of CI engine at different loading condition for mixture of diesel + producer gas in dual fuel mode and diesel+ blend of Jatropha bio-diesel + Producer gas. Specific energy consumption in dual fuel mode (diesel and producer gas) was calculated from the fuel consumption and calorific value of diesel and producer gas. Figure-V-II shows the variations in specific energy consumption of the engine for different combination of fuel in dual fuel mode and in mixed fuel mode.

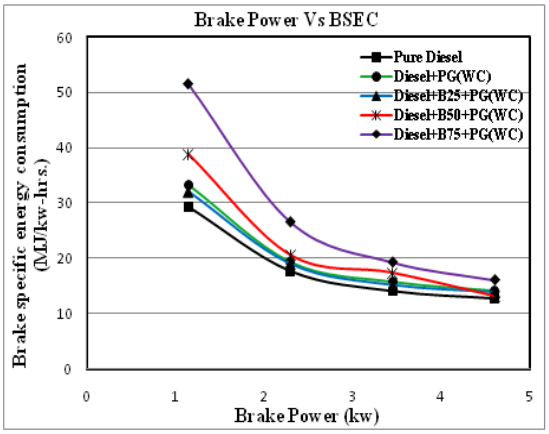

Fig. V-II Specific Energy Consumption with brake power

With increased percentage of Jatropha bio-diesel in the blends, specific energy consumption increased. The decrease in specific energy consumption may be attributed to the more energy content with increased gas flow rate of wood chips producer gas in the combustion chamber. Form the Fig. V-I and Fig. V-II it was observed that, the diesel + B25 + Producer gas in mixed fuel mode shows the better performance than other combination of fuel.

Conclusion

From the experimentation on the engine the following conclusions were drawn and the best combination of fuel is found for the minimum consumption of the diesel.

- In dual fuel mode operation the engine performance decreases, with increased smoke density at all load conditions.
- In the dual fuel mode of operation, while using wood chips, higher liquid fuel savings is achieved at part load conditions.
- The maximum Brake thermal efficiency is observed to be 26.08 % in mixed fuel mode(Diesel+ 25% Jatropha bio-diesel +PG) at higher load
- Specific energy consumption is found to be minimum in mixed fuel mode in the tune of 13.8 MJ/kw-hr
- It is observed that, the increment in load on the engine increases the BTE and lowered SEC for the existing engine set up.
- The exhaust gas temperature is observed higher in the range of 427^{o}C
- The best combination of fuel found to be Diesel 75 % + Jatropha Bio-Diesel 25% + Producer Gas for Constant engine Speed of 1500 RPM. The Brake thermal efficiency
- observed 26.08 % Specific Energy Consumption found to be 13.8 MJ/kw-hr

References

[1] N.R. Banapurmath et al "Combustion characteristics of a 4-stroke CI engine operated on Honge oil, Neem and Rice Bran oils when directly injected and dual fuelled with producer gas induction". *Renewable Energy 34 (2009) 1877–1884*.

[2] A.S. Ramadhas et al "Dual fuel mode operation in diesel engines using renewable fuels: Rubber seed oil and coir-pith producer gas". *Renewable Energy 33 (2008) 2077–2083*.

[3] N.R. Banapurmath and P.G. Tewari "Comparative performance studies of a 4-stroke CI engine operated on dual fuel mode with producer gas and Honge oil and its methyl ester (HOME) with and without carburetor". *Renewable Energy 34 (2009) 1009–1015*.

[4] Samir J. Deshmukh et al "Investigation on performance and emission characteristics of CI engine fuelled with producer gas and esters of higan (Balanites) oil in dual fuel mode" *International journal of aerospace and mechanical engineering 2:3 2008*

[5] Book of Wood Gas As Gngine Fuel, Food And Agriculture Organization Of The United Nation, M-38 ISBN 92-5-102436

[6] N.R. Banapurmath et al "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) 2007–2018*.

[7] R.N. Singh et al "Investigations on operation of CI engine using producer gas and rice bran oil in mixed fuel mode". *Renewable Energy 32 (2007) 1565–1580*.

[8] M. Ghazikhani et al "Experimental investigation of the Exhaust Gas Recirculation effects on reversibility and Brake Specific Fuel Consumption of indirect injection diesel engines". *Applied Thermal Engineering 30 (2010) 1711-1718*.

[9] Md. Nurun Nabi et al "Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions". *Applied Thermal Engineering 29 (2009) 2265–2270*.

[10] M. Baratieri et al "The use of biomass syngas in IC engines and CCGT plants: A comparative analysis". *Applied Thermal Engineering 29 (2009) 3309–3318*.

[11] David Brown et al "Thermo-economic analysis for the optimal conceptual design of biomass gasification energy conversion systems" *Applied Thermal Engineering 29 (2009) 2137–2152*.

[12] Avdhesh Kr. Sharma "Experimental study on 75 kW downdraft (biomass) gasifier system". Renewable Energy 34 (2009) 1726–1733.

[13] K. Pramanik, "Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine". Renewable Energy 28 (2003) 239–248.

[14] F.K. Forson et al "Performance of jatropha oil blends in a diesel engine", *Renewable Energy 29 (2004) 1135–1145*.

[15] R. N. Singh et al "Feasibility study of cashew nut shells as an open core gasifier feedstock". *Renewable Energy 31 (2006) 481–487*

[16] J. B. Kandpal and Mira Madan "Jatropha curcus : a renewable source of energy for meeting future energy needs". *Renewable Energy, Vol. 6, No. 2, pp. 159-160, 1995*

[17] Ch .S. Naga Prasad et al "Performance and emission characteristics of a diesel engine with castor oil" *Indian Journal of Science and Technology, Vol.2 No.10 (Oct 2009)*

[18] Thana Phuphuakrat et al "Tar removal from biomass pyrolysis gas in two-step function of decomposition and adsorption" *Applied Energy 87 (2010) 2203–2211*.