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Experimental investigation on a CI engine fuelled with bio gas and rice straw additives

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ABSTRACT

Biogas is a new source of fuel for mechanisation of agriculture and village industries. It can be used for running diesel and petrol engines. The objective of the present work is to run a CI engine through biogas and biogas with rice straw as an additive and to analyse its performance through a load test. The experiments in the study consist of three phases. Diesel, diesel and biogas (DF) and with adding an additive (rice straw) to the biogas. The rice straw was dried and pulverised into fine pieces of maximum 1 inch in size and mixed with diesel and biogas with a weight ratio of 20–40% for the experimental purpose. The results show good performance characteristics of biogas in the tested CI engine.

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KEYWORDS
Biogas; CI engine; rice straw; additive; performance

1. Introduction

Biogas production technology is based on the phenomenon of biological decomposition of organic materials in the absence of oxygen the organic materials are obtained from cattle dung and agricultural residues (Von Mitzlaff and Mkumbwa 1984). Biogas is an excellent and economic fuel for both petrol and diesel engines. Even electricity can be generated from it. The cost involved is low which leads to greater acceptability (Demirbas 2000; Gavrilescu and Chisti 2005). However, the power obtained is less than that obtained when liquid fuel alone is used. As engines using biogas become hotter than those on liquid fuels, they need to be cooled to be kept in good condition. Petrol engines can be run 100% on biogas except that little petrol is consumed for starting up. Diesel engines are modified to dual-fuel engines which use both biogas and diesel oil (Mckendry 2001; Ali, Habib, and Malik 2015). Biogas is introduced into the inlet pipe after it passes through the air filter. Gas inlet devices are designed to suit different engine designs and inlet pipes in order to give the proper biogas/air mixture (Karekezi and Kimani 2002).

2. Load test

The main aim of the study was to run the engine through biogas and to calculate its performance through a load test. The experiment was done on three phases, the first phase is with diesel only, the second phase is mixture of diesel and bio gas (DF) and the third phase is by adding an additive of rice straw on weight basis. The straw was dried and cut into small pieces of and then was mixed with slurry on weight ratios of about 20% and 40%. The experiment was conducted on a Kirloskar single cylinder engine. The biogas used in this test was from cow dung which is commonly known as Gobar gas in India. The biogas unit is a floating drum type and it produces 30 m^3 volume of gas every day.

3. Experimental procedure

The experiment is conducted by varying the load applied to the engine in the form of ratio of the rated power. The speed is maintained at 1500 rpm. The experimental test rig consists of electrical loading, i.e. the indirect loading method. The engine is connected to the generator by means of flexible coupling, and the output is given to the loading device. Certain modifications were made in order to conduct the tests which are explained in the next sections.

3.1. Fuel flow modification

The measurement of diesel flow is measured by using a burette. The time taken for each trial is noted and flow of the engine can be modified according to the requirement. A special type of inlet passage to the fuel filter has been designed to feed the fuel through the burette by means of the siphon method.

3.2. Modification of air inlet

Since the engine requires both biogas and air as mixture to run, air and biogas are need to be mixed before air filter. An air filter hose is connected with a T type connector by using a reducer. One end of the 'T' connector is fed to the atmosphere and the other end is connected to the biogas pipe at the outlet of the gas flow meter.

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3.3. *Maintaining of the speed*

The speed is maintained constant by means of adjusting the throttle and checking the rpm by means of a mechanical tachometer.

4. Loading device

The loading device uses the principles of electrical discharge in water. The loading devices consist of two-iron rod connected to a wooden bar; the wooden bar is raised or lowered. By rotating the V clamp which is connected to the wooden bar either in clockwise (or) anti clockwise turns to raise or lower the iron rod. The water is used as the charge-dissipating medium. Sodium chloride is mixed with water to increase the rate of charge dissipation. About 0.25 kg of sodium chloride is mixed with 5 L of water. When the iron rod is immersed into the water the power gets dissipated. The amount of power dissipation depends upon the length of the iron rod immersed and the product of voltmeter and ammeter reading obtained.

5. Measuring the gas flow

A gas flow meter is used to measure the flow of gas into the engine. The gas from the digester is connected to the input of the flow meter, and the output is connected to one end of the 'T' connector.

6. Experimental procedure

Observations were made using the diesel available in the local market. The specific gravity of the diesel tested in the study is 0.85 kg/m^3 with a gross calorific value of 42,000 kJ/kg. The biogas used had a specific gravity of 0.55 kg/m^3 and a calorific value of 22,500 kJ/kg and 23,200 kJ/kg for the biogas with 40% additive. The details of the engine test rig used in this study and the details of the loading device are depicted in Table 1.

7. Results and discussions

The results computed through the observations made from the experiments conducted are discussed in the section.

7.1. *Fuel consumption*

The rate of fuel consumption against the per cent of load for diesel, blend of diesel with biogas (DF), blend of diesel and biogas with 20% rice straw (DF 20% RS) and 40% rice straw additive (DF 20% RS) are presented in Figure 1. From the results, it is clearly understood that the dual-fuel mixture with and without additives are consumed more by the engine due to less calorific values of the respective fuels. The dual fuel with 40% rice straw additive has produced more fuel consumption values per hour than the other tested fuels.

Table 1. Engine details and loading device.

Kirloskar single cylinder	
Type of cooling	Air cooling
Fuel used	Diesel
Speed	1500 rpm
Power	4.4 kW
Capacity	550 cc
Generator power rating	5 kVA
Speed	1500 rpm
Output voltage	230 v
Output current	20 amp
Power factor	8

7.2. *Brake power*

The brake power developed in the engine against the per cent of load for diesel, blend of diesel with biogas (DF), blend of diesel and biogas with 20% rice straw (DF 20% RS) and 40% rice straw additive (DF 20% RS) are presented in Figure 2. From the graph it is evident that the brake power developed by the engine with the tested fuels increases with an increase in the engine load. There is not much difference between these values of the fuels in all the loads. The brake power of all the tested fuel types maintained a similar pattern.

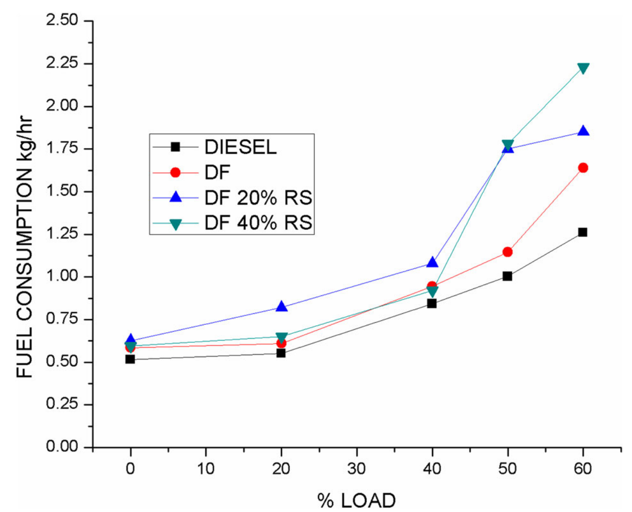

Figure 1. Fuel consumption in kg/h versus % of load.

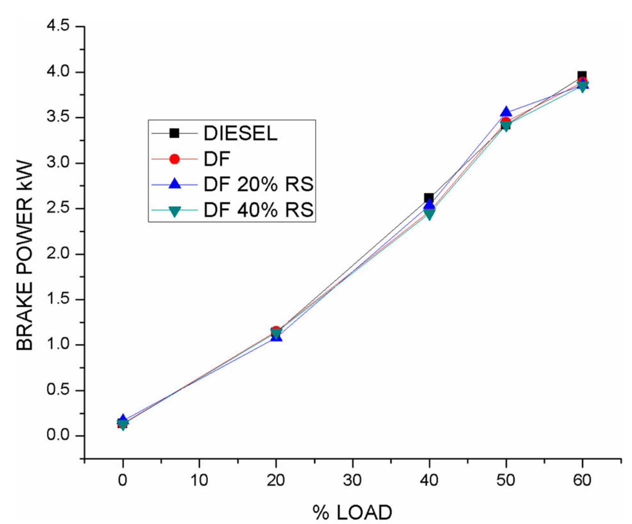

Figure 2. Brake power in kW versus % of load.

7.3. Specific fuel consumption

The brake-specific fuel consumption during the test against the per cent of load for diesel, blend of diesel with biogas (DF), blend of diesel and biogas with 20% rice straw (DF 20% RS) and 40% rice straw additive (DF 20% RS) are presented in Figure 3. The specific fuel consumption values of all the tested fuels increases with a decrease in the engine load. As the biogas has a lesser calorific fuel the biogas combination with and without additives are consumed heavily by the engine.

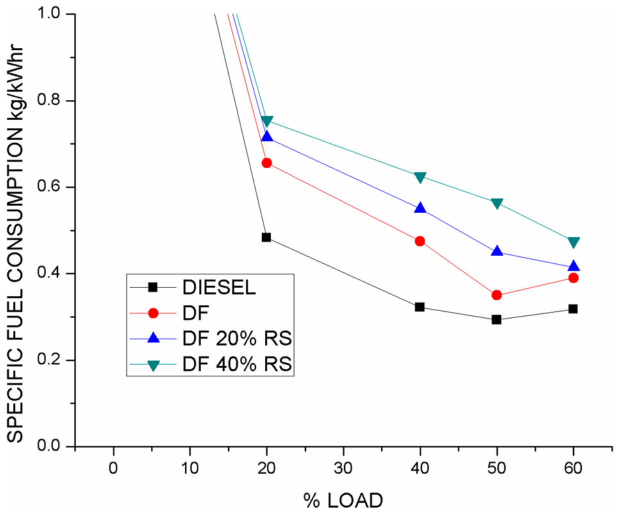

Figure 3. Specific fuel consumption in kg/kW-h versus % of load.

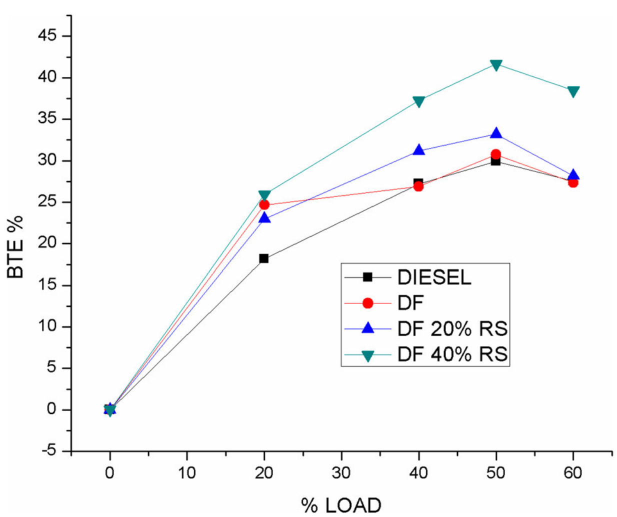

Figure 4. Brake thermal efficiency in % versus % of load.

7.4. Brake thermal efficiency

The brake thermal efficiency values computed from the observations made during the test against the per cent of load for diesel, blend of diesel with biogas (DF), blend of diesel and biogas with 20% rice straw (DF 20% RS) and 40% rice straw additive (DF 20% RS) are presented in Figure 4. The BTE values of all the tested fuels increases up to 50% load and decreases thereafter. The bio gas combination fuel types produced slightly higher BTE values than diesel. The reason for this effect may be due to the homogeneous mixture formation of biogas with the inducted air attaining complete combustion which in turn increased the BTE values.

8. Conclusion

The engines performance was increased during the trial of the dual-fuel mode with 40% of additive. When the engine was made to run on the dual-flow mode; the engines rated speed was not achieved by excess addition of biogas. In order to get the engine speed up to the rated rpm only diesel can be used. The vibration was more when the engine was used under the dual-fuel mode. When the engine was made to run on biogas and with little amount of diesel in it, the exhaust gas was clean when compared to that of diesel alone. The maximum attained speed using biogas alone was 660 rpm. Though the engine was made to run under a maximum dual-fuel ratio of 70% biogas and 30% diesel, the rated speed and maximum power were not achieved.

Disclosure statement

No potential conflict of interest was reported by the authors.

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