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RESEARCH ARTICLE

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Improve the operation of IC engine with 100% biogas as fuel

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ABSTRACT

World is facing energy crisis due to the increased industrialization coupled with rapid population growth. Limited reserved of fossil fuels, increasing use pattern of energy, fluctuating prices of petroleum products and the deteriorating environmental conditions are adversely affecting whole world. Hence, it must be necessitate concentrating our efforts to search for environmental friendly renewable fuels. Biogas is one of the ideal and clean energy rich fuel and can be used to produce heat, power and also used as vehicle fuel. A 5HP (3.7kW), Kirloskar diesel engine was modified to run on 100% biogas as fuel. The conversion kit used in the selected engine was provided by M/s Gas technologies India, New Delhi. The five different engine timings were selected for study. The engine parameters were studied to improve the operation of the engine on 100% biogas as fuel. The engine timing of 41^0bTDC gave optimized results for the selected engine.

Key words : Biogas, IC engine

INTRODUCTION

Biogas is the one of the potential energy source with multiple benefits. Now a day it is used to produce electricity by using modified IC engine. For generation of biogas only wastes are required. The biogas was never ending environmental friendly renewable energy source as long as human and animals exist on the earth. Amongst the renewable sources available in abundance of energy, biomass is one of the most potential energy sources. Under most circumstances methane is an ideal fuel, compared to other fuels, as it produces a few atmospheric pollutants and generates less carbon dioxide per unit energy (Chynoweth *et al.*, 2001). Also, biogas burning gives less concentration of particles and negligible dust. The technology helps to conserve forest, improves the health of rural people.

With the adoption of agricultural mechanization, the energy demand has increased many folds. Diesel and electricity are the main source of power supply to rural sector. The fluctuating prices of diesel and its unassured availability during peak seasons of agro-operations hamper the yield badly. Similarly, erratic power cut during the peak season of irrigation and threshing causes considerable stress to farmers and they are not able to take benefit of the technological developments. Hence, there is urgent need of a self-sustainable energy supply system to agro-catchments. Biogas technology could be one of the approaches.

Biogas can be used as a fuel in SI and CI engines with doing some required modifications. Biogas fueled duel fuel engines are available in the country but replacement of diesel in the tune of 70-80% is only possible through use of these engines (Ray,2007) but there is urgent need to develop biogas based engine genset system capable of running on 100% biogas.

MATERIALS AND METHODS

Engine modifications:

The capability of any fuel and engine is important factor for successful operation of the engine. Since, biogas is a lower calorific value fuel, it does not have good auto ignition properties, hence it can not be burnt directly in CI engines. So, some modifications in diesel engine are required to use 100% biogas fuel. Biogas is an alternative fuel for diesel engine. The 5HP Kirloskar make naturally aspirated modified diesel engine was used for the study. The modified engine was used to run on 100% biogas as fuel. The conversion kit was provided by M/s Gas Technologies India, New Delhi. The technical specifications of used test engine are given in (Table 1).

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Table 1 : Technical specifications of the test engine

Model	Kirloskar 5HP (3.7kW) engine
Manufactured by	Kirloskar Oil Engine LTD. Pune, India
Number of cylinders	1
Type	AV1
Governed speed (RPM)	1500
Specific fuel consumption	245 g/kW-h
Rated bhp	5
Cooling system	Water cooled
Compression ratio	20:1 changed to 11.2:1and 12.1:1and 12.4:1 for study
Stroke	110 mm
Bore	80 mm
Engine No.	10.1001/924403
Governing class	B1

The modifications incorporated in the engine for 100% biogas as fuel must be provided the biogas fuel metering system by removing the diesel fuel injection system. The compression ratio needs to be reduced compared to diesel. The compression ratio of the engine used for study was 11.2:1 by inserting the shims below cylinder head and the ignition timing needs to be optimized for proper combustion of biogas as fuel. Besides, the diesel injector needs to be replaced by suitable spark plug. Sparking is required for combustion of air biogas mixture.

A GI pipe of 0.043m diameter was connected to the air inlet to get entry of air into the biogas for proper amount of air fuel mixture. To control the required amount of air, air control valve was provided to control the proper amount of air flow.

Experimental technique:

The experimental set up consists of modified test engine (Fig. 1). Fig. 2 shows the view of biogas plants of KVIC type $6m^3$ and $4m^3$ capacity installed in the Energy Enclave of CIAE Bhopal was used for the study. The composition of biogas used as a fuel in the test engine contained 56-60% CH_4, 35-38% CO_2, 1-2% O_2 and traces of CO, H_2, H_2S indicating that the produce biogas was quite good for use in IC engine. The gas flow meter was used as a fuel measuring device. To measure the engine speed contact type tachometer was used. An AC generator of Kirloskar make was used for electricity generation by using 100% biogas as fuel. The AC generator was directly coupled with the flywheel of the engine. The hot wire anemometer was used for measuring the air velocity and inlet air temperature. Power meter was used to measure the voltage, current, frequency, power factor etc. Electric

Fig. 1 : Experimental set-up for testing the engine

Fig. 2 : Biogas plants used during experimentation

bulbs and heaters were used as loading device.

Test procedure of the modified engine:

– Biogas supply was assured and controlled in requisite amount.

– Airflow rate was adjusted for proper combustion of the mixture.

– Ignition switch was kept at on position.

– Engine coupled with AC generator was cranked using handle

– After starting of the engine, the speed was checked and adjusted to 1500 rpm by making adjustments in air-biogas supply.

– The engine was allowed to stabilize for 15 minutes.

– The engine was loaded in steps using electric bulbs and heater.

– Loading was continued till the engine tended to stall.

– The various performance parameters were recorded at each setting of compression ratio, engine ignition timing and loads.

RESULTS AND ANALYSIS

The performance of modified IC engine fueled with 100% biogas as fuel was evaluated at different loads, engine timings, and compression ratio. The engine was tested at the five engine timings and compression ratio was 11.2:1. The various performance data like time required to 20lit of biogas consumption, engine load, and power developed by the engine, exhaust gas temperature, air flow rate, air inlet temperature, were noted during the experimentation.

Effect of power developed by the engine on specific biogas consumption:

The maximum specific biogas consumption for power developed by the engine run on biogas at the different settings of engine timing position is shown in Fig. 3 *i.e.*36^{0}bTDC, 26^{0}bTDC, 31^{0}bTDC, 41^{0}bTDC, 46^{0}bTDC were 0.90m^3/kWh, 0.96 m^3/kWh, 1.55 m^3/kWh, 0.91m^3/kWh, and 0.99 m^3/kWh, respectively. At that time the maximum power developed by the engine at the respective for same set of engine timing positions given above were 2.18kW, 2.19kW, 0.82kW, 2.38kW and 2.01kW. The specific biogas consumption decreases with an increase in engine power development due to the fact that the engine develops more power with an increase in observed load on that engine (Bhattacharya *et al.*, 1988).

Effect of power development on engine efficiency:

The efficiency of the engine determined on fully biogas fueled engine indicated that the engine efficiency increased with increase in power developed by the engine. Fig. 4 shows graphical presentation of power developed vs engine efficiency. The maximum efficiencies on different settings of the engine timings position at 36^{0}bTDC, 26^{0}bTDC, 31^{0}bTDC, 41^{0}bTDC, 46^{0}bTDC were found out to be 16.39%, 15.45%, 9.56%, 17.66%, and 15.01%, respectively. The corresponding power developed was 2.18kW, 2.19kW, 0.82kW, 2.38kW, and 2.01kW. Thus, it is evident that the engine developed maximum efficiency at 41^{0}bTDC position of engine timing by using fully biogas as a fuel.

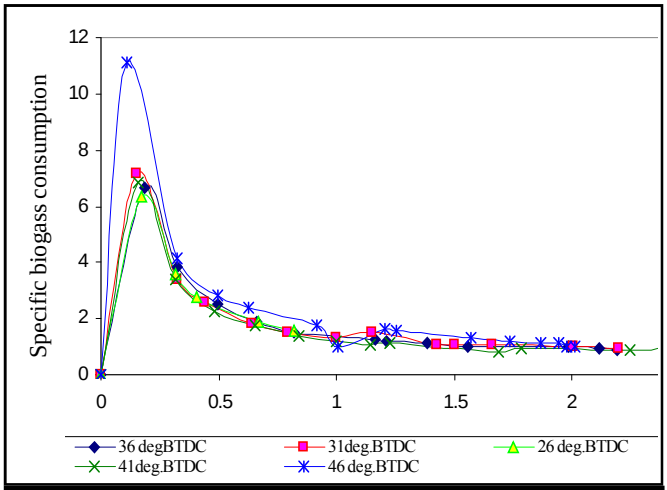

Fig. 3 : Effect of power developed on specific biogas consumption

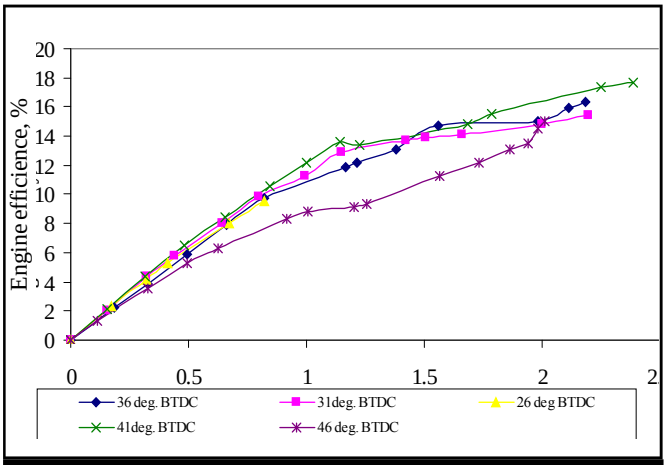

Fig. 4 : Effect of power developed on engine efficiency

Effect of power developed by the engine on air fuel ratio:

Tests were conducted to determine the quantity of air required for combustion by the engine while running on fully biogas as fuel. (Fig. 5) Shows the air fuel ratio of the engine when operating on biogas varied from 11.2:1 to 1.8:1, 9.8:1 to 0.6:1, 9.8:1 to 8.1:1, 12.8:1 to 8.34:1, and 10.4:1 to 2.6:1 at 36^{0}bTDC, 26^{0}bTDC, 31^{0}bTDC, 41^{0}bTDC, 46^{0}bTDC engine timing position. The reduction

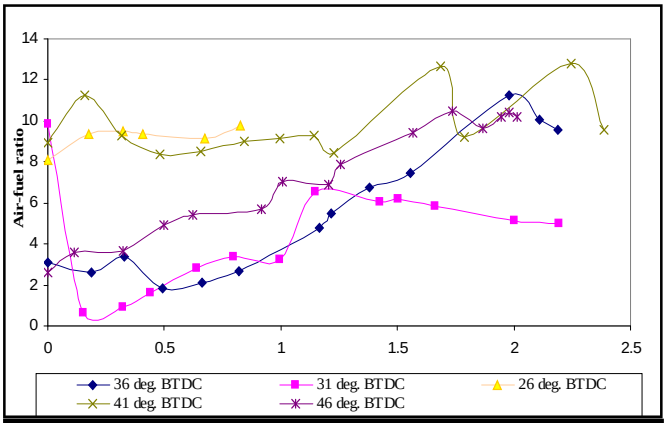

Fig. 5 : Effect of power developed on air fuel ratio

in air fuel ratio using biogas as fuel in engine operation may be due to biogas, being a low calorific value gas, needs less air for complete combustion. At first the air fuel ratio was increased with increase in power developed by the engine afterward it decreased. The air fuel ratio of 9.5:1 on biogas at a maximum engine output was observed at 41^{0}bTDC engine timing position. This has been found to be the best engine timing setting. Same trends was observed by Bhattacharya *et al.*,1988 and Bhattacharya and Darmora, 1984.

Effect of power developed on biogas consumption by the engine:

The biogas consumption increased with increase in power developed (Fig.6). The study was conducted at 36^{0}bTDC, 26^{0}bTDC, 31^{0}bTDC, 41^{0}bTDC, 46^{0}bTDC engine timing position at that time for each engine timing the compression ratio was 11.2:1. The biogas consumption at maximum power developed was 2.39m^3/h, 2.50 m^3/h, 1.55 m^3/h, 2.62 m^3/h, and 2.38 m^3/h, respectively. The corresponding power developed by the engine was 2.18kW, 2.19 kW, 0.82 kW, 2.38 kW, and 2.01 kW. The biogas consumption was maximum at 41^{0}bTDC engine timing position *i.e.* 2.62 m^3/h at that time the power developed was 2.38 kW.

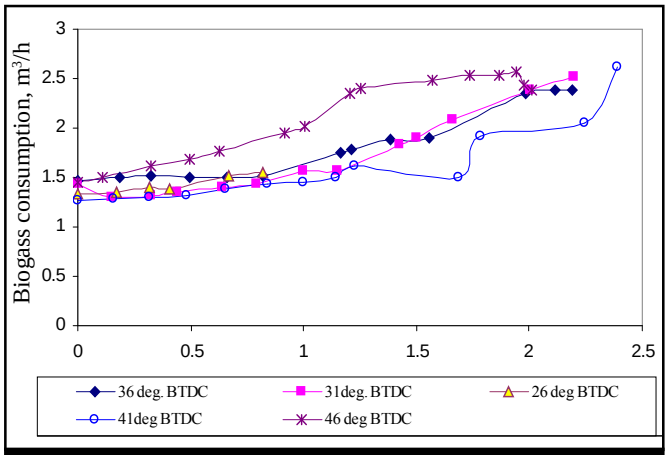

Fig. 6 : Effect of power developed by the engine on biogas consumption

Effect of power developed by engine on exhaust gas temperature at different engine timings:

The engine performance on different parameters used for study, one of them was exhaust gas temperature. The performance studied on different settings of engine timing presents in Fig. 7 which shows the variation in exhaust gas temperature of IC engine when operated on different loads. There was very little change in exhaust biogas temperature due to the different engine timings

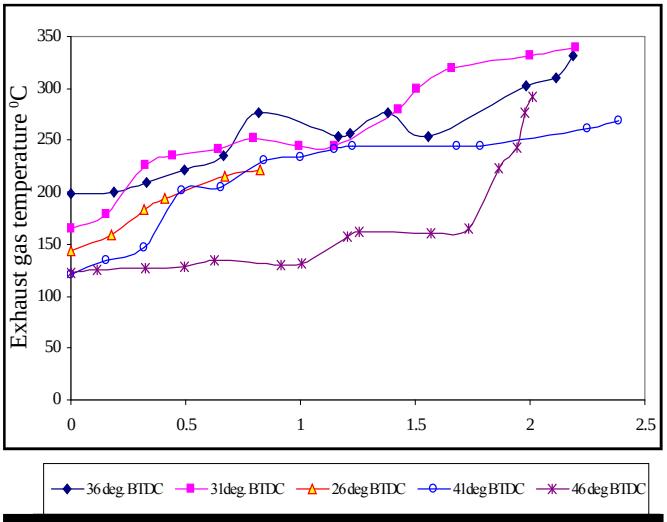

Fig. 7 : Effect of power developed by the engine on exhast gas temperature

used. The engine at 41^{0}bTDC position of engine timing developed maximum power 2.38kW and corresponding exhaust gas temperature was 269^{0}C. The temperature of exhaust gas increased with increase in power developed.

Conclusion:

If the diesel engine is required to run fully on biogas as fuel then the compression ratio, engine timing, ignition system, provision for entry of biogas in the inlet manifold, gas control apparatus, air control apparatus becomes the critical parameters of the engine.

– Biogas is a substitute for conventional engine fuels with little modifications in CI engine.

– The specific fuel consumption was decreased with increase in the power developed by the engine.

– The engine efficiency increased with increase in power developed by the engine.

– The temperature of exhaust gas increased with increase in power developed.

– The tests were conducted at 26^{0}bTDC, 31^{0}bTDC, 36^{0}bTDC, 41^{0}bTDC, 46^{0}bTDC at every engine timing compression ratio was 11.2:1. The optimum values of power developed, engine efficiency and biogas consumption was found at 41^{0}bTDC engine timing setting.

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