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EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF NONPREHEATED AND PREHEATED BIOGAS ADDITION IN THE SINGLE CYLINDER COMPRESSION IGNITION ENGINE

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Abstract— **With decrease in non-renewable fuels, the need for renewable fuels has gathered great momentum. The energy crisis has started to grow rapidly due to the increase in use of vehicles. To provide energy for the next generation lot of research work is going on alternative fuels. This paper deals with the use of biogas as a renewable fuel, from anaerobic digestion of animal manure waste. Here a 4- stroke single cylinder compression ignition water cooled resistive loaded diesel engine is fuelled using non-preheated biogas and preheated biogas with diesel as pilot fuel. The various controlled amount of biogas is mixed with air and is fed into the intake manifold of the engine. The amount of biogas input to the engine is controlled by the electronic flow control valve. Preheating of biogas is done by electronic heater for the temperatures of 50^0c, 60^0c, 70^0c and 80^0c and investigations are done. The temperature of the biogas is maintained at constant value by controlling the current in the heater using the controller unit. A temperature sensor is used to measure the temperature of biogas. The non-preheatedand preheated biogas is mixed with air using blower and supplied to the engine through its inlet manifold. The total fuel consumption (TFC), specific fuel consumption (SFC), brake thermal efficiency (BTE), carbon monoxide (CO) emission, hydro carbon (HC) emission, carbon dioxide (CO_2) emission, oxygen (O_2) emission, nitric oxides (NO_x) emissions and smoke are measured by varying load using resistive loading arrangement. From the experiment, it is observed that total fuel consumption is reduced for non-preheated biogas diesel fuel mixture when compared with diesel fuel and it is further reduced when the preheating of biogas is used. The specific fuel consumption is also less for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is further reduced when the preheating of biogas is used. The brake thermal efficiency is higher or non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is further increased when preheating of biogas is used. The carbon monoxide emission is higher for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is reduced when heating of biogas is used. The hydro carbon emission is higher for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is reduced when heating of biogas is used. The carbon dioxide emission is higher for biogas diesel fuel mixture when compared to diesel fuel and it is reduced when heating of biogas is used. The oxygen emission is slightly higher for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it further increased when preheating is done on biogas. The nitric oxides emission is less for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is reduced when heating of biogas is used. The smoke emission is less for non-preheated biogas diesel fuel mixture when compared to diesel fuel and it is further reduced when heating of biogas is used. From the results it is concluded that usage of biogas in addition to diesel improves fuel consumption, efficiency and emissions.**

Keywords— non-renewable fuels, brake thermal efficiency, oxygen (O_2) emission, biogas.

I. INTRODUCTION

Today energy crisis exist worldwide because conventional forms of energy supply and consumption are causing serious economical as well as environmental problems. Country like India is now facing the grim scenario of excessive dependence on international sources for crude oil and natural gas requirements, as natural gas and crude reserves in the known and established wells are getting depleted day by day. This means that Indian petrochemical industries are severely vulnerable to the international supply and price fluctuations. The truth is that the country has built large petrochemical capacities without ensuring the supply of basic feedstock from dependable sources. In India consumption of petroleum products is increasing day-by-day resulting in huge gap of demand and supply. India currently imports about seventy percent of its petroleum need by paying 1, 27,000 cores of rupees every year. Imports of crude oil and petroleum products were 57.8 and 16.6 million tons respectively during 1999-2000. The demand is about 120 million tons for 2006-2007. Our domestic production of crude oil and natural gas is around 34 mT during 2006-2007. The current consumption of diesel in India is approximately 40 mT forming about 40% of the total petroleum products consumption

There are many petrochemicals that can be produced more profitably and in an environmentally superior way from agro and natural resources that are plentifully available in the country. Such areas have to be quickly short-listed and focused to achieve tangible and overall benefits. For example, the molasses and derivatives, pongamia and jatropha based vegetable oil/ fuel, setting up of edible oil industry and large scale cultivation of edible crops, important chemicals that can be produced from sea water and brine and large capacity creation of nuclear power projects, setting up of coal bed methane gas projects are a few of many non-petrochemical possibilities, where national efforts have still not been focused to the extent required. There are several alternative sources of fuels, some of them being biogas, producer gas, natural gas, hydrogen, alcohols (methanol and ethanol), fuel cells and biodiesel- all renewable in nature

This paper deals with the use of biogas in CI engine. Biogas is generated from organic materials under anaerobic conditions. Feedstocks for biogas generation include cow dung, poultry droppings, pig manure, kitchen waste, grass faecal matter and algae. Animal manure from farms can produce biogas after anaerobic treatment, the main components of which are methane (CH4) and carbon dioxide (CO2), with relatively small amounts of nitrogen (N2), hydrogen (H2), ammonia (NH3), hydrogen sulfide (H2S), and organic compounds. Because methane is a flammable fuel, a biogas containing methane can be used as a renewable fuel.

In this paper the performance and emission characteristics are studied on single cylinder compression ignition engine using diesel, diesel with non-preheated biogas and diesel with preheated biogas. Biogas is heated to different temperatures such as 50^0c, 60^0c, 70^0c and 80^0c and the performance and emission characteristics of the engine are determined. The methane concentration of biogas can be affected by heat treatment of biogas.

II. LITERATURE REVIEW

Tippayawong et al. [1] used a mixture of biogas and diesel fuel to feed a small diesel engine and then examined its endurance over 2000 h. The results showed that the engine had a 7% increase in power output and higher efficiency compared to that of normal diesel operation.

Abd-Alla et al. [2] operated a high-speed, indirect-injection, dual-fuel engine, using methane or propane as the main fuel and diesel fuel as the pilot fuel. The presence of inert gases such as CO_2 and N_2 in the primary fuel increases the negative effects at part load operation due to its influence in burning rate inhibition. The results showed that the admission of diluents reduces NOx emissions.

Tsung-Han Lee et al. [3] stated that power generation for biogas with 73% CH4 is higher than for biogas with 60% CH4, except in the region where $\lambda < 0.85$. However, thermal efficiency increases with the increasing methane concentration only in the region of $\lambda > 0.95$.

The investigation was conducted on a four stroke, four-cylinder, indirect injection (IDI), turbocharged diesel engine by Can Cinar et al. [4] using CO_2 as a diluent in the intake manifold and found that NOx is reduced.

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An experimental setup was developed to evaluate the effects of mixing system and the pilot fuel quality on a stationary dual fuel engine performance using biogas as primary fuel by IvánDaríoBedoya et al. [5] The results showed that full diesel substitution is attainable using palm oil biodiesel as pilot fuel on biogas dual fuel engine. The combination of a supercharger and Kenics mixer in the inlet system of biogas dual fuel engines can be applied as a strategy to increase thermal efficiency and substitution level of pilot fuel as well as to reduce methane emissions at part load.

At low engine loads, the lower rate of premixed controlled combustion of the gaseous fuel resulted in lower charge temperature inside the combustion chamber compared to normal diesel operation, hence resulting in the lower NOx emission. At higher engine loads, apart from the lower charge temperature effect, the low oxygen concentration in the charge due to the higher level of gaseous fuel inducted reduced NOx formation even further. Nonetheless, it was shown that too high gaseous fuel concentration at high engine loads led to an increase in the rate of energy released and consequently increased the NOx formation due to higher in-cylinder maximum temperature and these were studied by Deepak Agarwal [6].

The formation of UHC emissions are influenced by the quality of engine combustion process. At low engine load, the lower charge temperature and excess air/fuel ratio (AFR, λ) caused the suppression of turbulent flame propagation from ignition regions of pilot, allowing small quantities of gaseous fuel to escape the combustion process [7]. In addition, the higher ignition delay for dual fuel operation also caused an increase in UHC emissions [8].

It was also shown by Bari [9] that the dissociation of carbon dioxide into carbon monoxide and oxygen is possible at high temperature conditions, leading to the high CO emissions during both dual fuel operations.

2.1 Biogas

The properties of biogas are shown in Table 1.

Table 1- Biogas Properties

Methane (%, by vol.)	60-70
Carbon dioxide (%, by vol.)	20-40
Hydrogen (%, by vol.)	1-3
Oxygen (%, by vol.)	0-5
Density (kg/m3)	0.65-0.91
Auto-ignition temperature (°C)	632-813
Lower heating value (MJ/kg)	26.17

III. EXPERIMENTAL SETUP AND TESTING

In the present investigation kirloskar single cylinder four stroke naturally aspirated water cooled diesel engine is used for comparing the performance and emission characteristics of diesel, diesel with non-preheated biogas and diesel with preheated biogas. The schematic diagram of the experimental set-up and the photograph of the experimental set-up are shown in figure 1 and 2 respectively. The specification of the tested engine is shown in Table 2.

Bio-gas is admitted into the engine along with air during suction stroke. Bio-gas is also compressed along with air during compression stroke. At the end of compression stroke, small quantity of diesel is injected as pilot fuel which initiates combustion of bio-gas. The biogas enters the engine as gaseous fuel. It displaces the intake air which results in a lower volumetric efficiency. As the gas mixes uniformly with air, there is no starting problem. Blower is used to mix the gas and air. At initial stage only diesel is used as fuel.

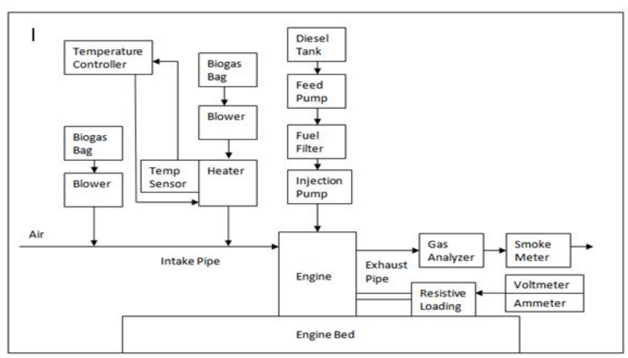

Fig1 : Schematic Diagram

The flow rate of biogas was controlled using electronic controller. The fuel flow rate is measured on volumetric basis using burette and stop watch. AnAVL make gas analyzer and smoke meter were used to measure exhaust gas emissions and

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smoke. The experiment was conducted at constant speed of 1500 rpm. A temperature controller is used to maintain the temperature of biogas by controlling the supply to the 500W heater. Using the panel buttons the temperature of biogas can be set as required. The temperature of the biogas is fed to the controller with the help of J-type thermocouple sensor.

Based on the output of the sensor the controller maintains the constant temperature of biogas as it is set initially. This gas then combines with the air using a blower of 0.09 HP. Now the biogas and air mixture is sent to the engine through the inlet manifold.

Fig 2 : Photograph of the Experimental Setup

Table 2. Engine Specification

Type	Vertical Engine
Type of Cooling	Water
Speed	1500 rpm
Brake Power	3.7 KW
Bore Diameter	80 mm
Stroke Length	110 mm
Make	Kirloskar engine
Loading Method	Resistive loading

During testing, first diesel is used as fuel and the engine is run for different loads, second biogas is mixed with inlet air with diesel as pilot fuel for ignition and third preheated biogas is mixed with inlet air with diesel as pilot fuel for ignition.

IV. RESULT AND DISCUSSIONS

In this research work an attempt has been made to compare the performance and emission characteristics of a CI diesel engine when operated with diesel (D), non-preheated biogas diesel mixture (D+B), preheated biogas diesel mixture at 50^{o}C (D+B@50), preheated biogas diesel mixture at 60^{o}C (D+B@60), preheated biogas diesel mixture at 70^{o}C (D+B@70)and preheated biogas diesel mixture at 80^{o}C (D+B@50). Electrical loading arrangement is used to apply loads to the engine. The burette setup is used to find the time taken for 10CC consumption of diesel. Five gas analyzer and smoke meter are used to find CO, CO2, NOx, O2, HC and smoke.

The Fig 3 shows the variation of carbon monoxide with increase in load. From this figure it is observed that the carbon monoxide emission value is increased for all the mixtures when compared with diesel up to 60% load and it is decreased for all mixtures except diesel with non-preheated biogas at higher loads.

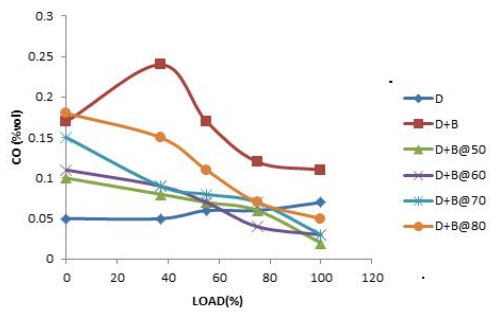

Fig 3 : CO Vs LOAD

The Fig4 shows the variation of hydro carbon with increase in load. From this figure it is observed that the hydro carbon monoxide emission value is increased for all the mixtures when compared with diesel up to 60% load and it is decreased for all mixtures except diesel with non-preheated biogas at higher loads.

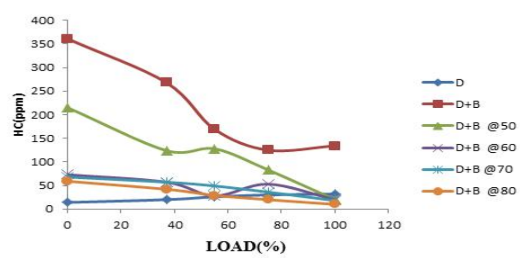

Fig 4 : HC Vs LOAD

The Fig5 shows the variation of carbon dioxide emission with increase in load. From this figure it is observed that the carbon dioxide emission value is increased for all the mixtures and it

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is higher for non preheated biogas diesel mixture at all loads. The diesel fuel is then having higher value and when heating temperature is decreased carbon dioxide value is also decreased for all loads.

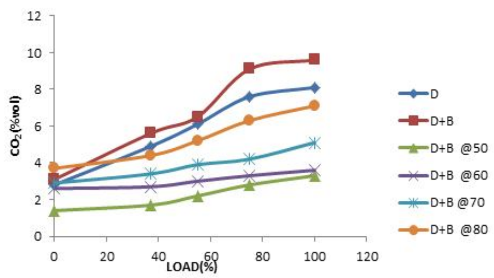

Fig 5 : CO2 vs LOAD

The Fig6 shows the variation of oxygen emission with increase in load. From this figure it is observed that the oxygen value is decreased for all the mixtures at all loads and it is lower for non diesel fuel at all loads. The non preheatedbiogas diesel fuel is then having lower value and when heating temperature is decreased oxygen value is also increased for all loads.

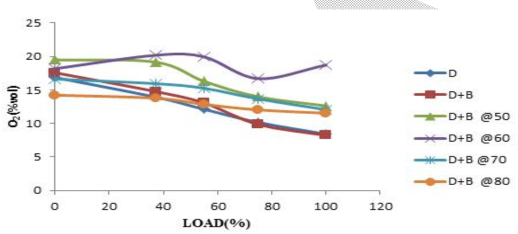

Fig 6 : O2 Vs LOAD

The Fig 7 shows the variation of nitric oxides emission with increase in load. From this figure it is observed that the nitric oxides emission value is increased for all the mixtures and it is higher for diesel fuel at all loads. The non preheated biogas diesel fuel is then having higher value and when heating temperature is increased nitric oxides value is also decreased for all loads.

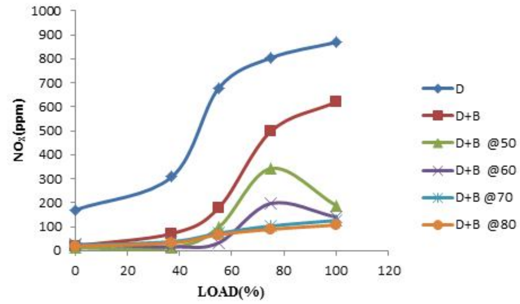

Fig 7 : NOxvs LOAD

The Fig8 shows the variation of smoke emission with increase in load. From this figure it is observed that the smoke emission value is increased for all the mixtures and it is higher for diesel fuel at all loads.

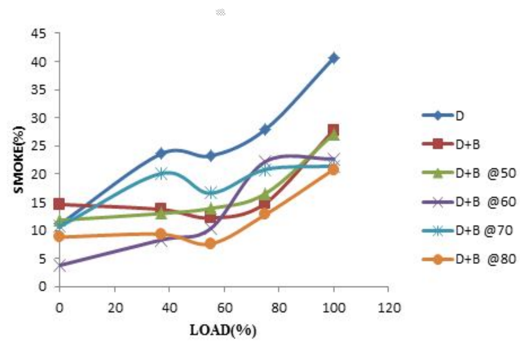

Fig 8 : SMOKE vs LOAD

The Fig 9 shows the variation of specific fuel consumption with increase in load. From this figure it is observed that specific fuel consumption is decreased for all the mixtures and it is higher for diesel fuel at all loads. The non preheated biogas diesel fuel is then having higher value and when heating temperature is increased specific fuel consumption value is also decreased for all loads.

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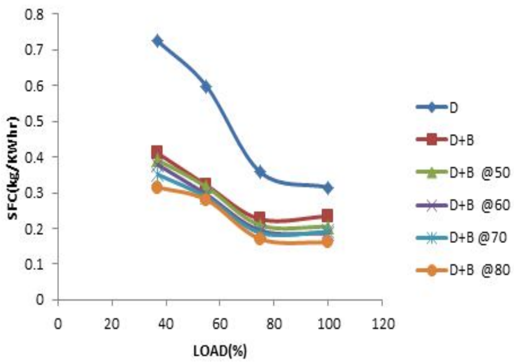

Fig 9 : SFC Vs LOAD

The Fig 10 shows the variation of brake thermal efficiency with increase in load. From this figure it is observed that the brake thermal efficiency value is increased for all the mixtures and it is higher for preheated biogas diesel mixture @ 80 at all loads. When the temperature of biogas is increased, the brake thermal efficiency in increased. The non preheated biogas diesel fuel is having lower value and then diesel fuel is having very low value.

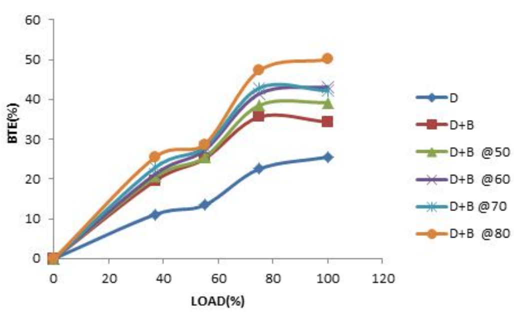

Fig 10: BTE Vs LOAD

The Fig 11 shows the variation of brake thermal efficiency with increase in load. From this figure it is observed that the brake thermal efficiency value is increased for all the mixtures and it is higher for preheated biogas diesel mixture @ 80 at all loads. When the temperature of biogas is increased, the brake thermal efficiency in increased. The non preheated biogas diesel fuel is having lower value and then diesel fuel is having very low value.

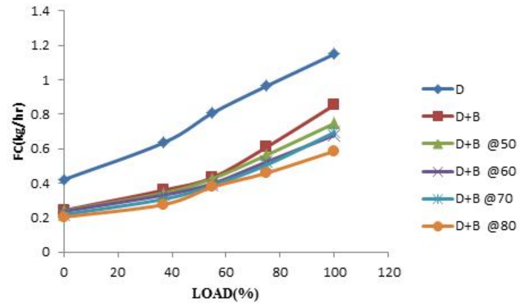

Fig 11 : FC Vs LOAD

V. CONCLUSION

In the present experimental investigation the tests were carried out in a four stroke, single cylinder, naturally aspirated, water cooled and direct injection diesel engine at same engine speeds under different load conditions. The diesel fuel, non preheated biogas diesel mixture and preheated biogas diesel fuel mixture at temperatures of 50^oC, 60^oC, 70^oC and 80^oC are used as fuel. The engine performance and emission testing are done using dynamometer, burette setup, gas analyzer and smoke meter. The use of biogas resulted in improved engine performance and reduction in emissions particularly NO_x and smoke. Usage of biogas with diesel was found to be one of good way to conserve energy and reduce pollution. Emissions were found to be reduced when the biogas is heated. Specific fuel consumption was less for the biogas with 80^0c whereas brake thermal efficiency was improved for biogas at 80^0c. Emissions such as NO_X, Smoke and HC were found to be less for biogas with the temperature of 80^0c. Increase in temperature of biogas reduces the emissions and improves the performance of the engine.

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