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Performance Evaluation of Single Cylinder Diesel Engine in Dual Fuel Mode with Biogas as Primary Fuel and Diesel and Biodiesel as Pilot Fuel

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Abstract- *In whole world energy demand is increasing day by day. It is very difficult to meet this high energy demand with coal and petroleum based fuels. The environmental pollution and global warming caused by fossil fuels consuming at faster rate, the energy focus now shifting toward nuclear energy and renewable source of energy but nuclear energy required careful handling raw and waste material, so only option is left that is renewable source of energy. Biogas and Biodiesel are best alternative fuel. The fuel can be directly used in diesel engines with/without any modification in the existing engine. In the proposed work experiments will be performed on Kirloskar (AV1 model) 4 stroke single cylinder diesel engine. The primary fuel, biogas was mixed with diesel and Biodiesel pilot fuel. The experiment were performed to measure various parameters like brake power, energy conversion efficiency, and emission such as percentage of CO, CO₂, HC particulate matter and NO_x in exhaust gas. The effect of diesel replacement on emissions was also studied*

Keywords: Dual fuel, biogas, biodiesel, diesel.

1. Introduction

In India 75% of population is engaged in agriculture related activities. This population is living in rural area, some at very remote areas. Over past many years there has been phenomenal increase in the use of diesel engines in rural areas. Diesel engines are commonly used in power generation in rural applications, viz. tractors, irrigation pumps, generate sets chaff-cutters, crushers, mills etc., the demand for conventional fuel-diesel is increasing even at rural areas. On the other hand, the global huge pressure on energy issues and environmental pollution and global warming caused by burning fossil fuels has driven researchers as well as industrialists and governments to look for the other energy sources. This made essential that the electricity be introduced to rural areas in sustainable and environmentally sound way. Local production of fuel and generation of electricity is a sustainable option for rural electrification, which only can contribute to economic development and poverty reduction of rural areas. The diesel engines are most reliable and efficient combustion device, there is a growing need to adopt/modify such diesel engines for efficient and trouble free operation with biomass based gaseous fuels. Since biomass is available in huge amount in rural areas, it could be helpful to generate these fuels at the local sites; and using them to operate diesel engines. These fuels are also environment friendly because it increases renewable fuel consumption. These fuels can be used directly in the

diesel engine with no/minimal modification in the engine, which is most advantages part of system. In the Present scenario, diesel engines are being extensively used for variety of applications in villages, while petrol engines or petrol operated generator sets are almost nil.

The invention and thermal efficiency in the second case was increased by 8% in second case. In second stage the by keeping the biogas flow rate fixed and reducing the pilot flow rate, it was noticed that the pilot quantity can be reduced to as low as 10%. This also resulted in lower exhaust gas temperature with turbocharger system. Better thermal efficiency in the experiment with turbocharger was probably due to better mixing of biogas with air. HC emissions were reduced notably with the system having longer mixing length. It showed a good mixing of air and biogas results in lower emissions and also with increased thermal efficiency (PisarnSombatwong et al. 2013) The Study of a diesel engine performance with exhaust gas recirculation (EGR) system fuelled with palm biodiesel. Experimental works using a multi-cylinder diesel engine with EGR and using Diesel-RK were performed at a constant engine speed of 2500 rpm in full load condition. On the basis of results the experimental works, palm biodiesel significantly increased fuel consumption increased NO_x and slightly decreases in other emissions including CO₂, CO, and unburned hydrocarbon (UHC). However, the use of EGR showed a significant reduction in the NO_x emission and exhaust temperature with increases in fuel economy, CO, CO₂,

and UHC emissions (MohdHafizil Mat Yasin et al. 2017) The effects of varying composition of biogas on performance and emission characteristics of compression ignition engine using exergy analysis carried out by (SaketVerma et al. 2017). It was found that the peak cylinder pressures with biogas dual fuel modes were always higher than that for diesel fuel mode. Peak in-cylinder pressure for diesel fuel mode was found 64.73 bar; and that for dual fuel modes: BG93, BG84 and BG75, it was found to be 71.56 bar, 70.15 bar and 68.84 bar respectively. It was concluded that the high methane fraction in biogas equitable performance can be obtained in dual fuel operation without any major engine modifications. However, for improved performance with high CO₂ concentration in biogas, significant changes in operating parameters are suggested. By increasing compression ratio in improvement in BTE was observed by (Bhaskor J. Bora et al. 2014) This, in turn, increases the probability of more amount of biogas to undergo complete combustion. The effects of CO₂ content was studied in biogas on the fuel consumption and NO_x emission. Thermal efficiency improved and NO_x reduced with using a lean burn strategy. He concluded that a significant reduction in NO_x emissions is expected using biogases containing CO₂; however, an increase in fuel consumption appears unavoidable. A lean burn strategy was effective for reducing both fuel consumption and NO_x emissions; however, the use of biogas with the stoichiometric air-fuel ratio (which can better handle transient operating conditions) appears effective in reducing NO_x emissions and can improve the fuel economy at higher loads (Yungjin Kim et al. 2016)

2. Objectives

The objective of this work is to study engine performance

- a. Using diesel fuel,
- b. Using biodiesel fuel,
- c. Using Bio gas in dual fuel mode with diesel and biodiesel

The parameters in this work are under,

- 1. Variation in break power
- 2. Brake specific fuel consumption
- 3. Thermal efficiency
- 4. Mechanical efficiency
- 5. Volumetric efficiency

The engine performance was compared with on Diesel and Biodiesel fuel performance against Bio Gas Diesel or Biogas Biodiesel fuel performance.

3. Experimental Setup

Table -1: Technical specifications for Kirloskar TV1 engine

Make	Kirloskar Oil Engines
Type	Compression Ignition, Constant speed, Four Stroke, Water cooled,
No. of cylinder	One
Bore X stroke	87.5 mm X 110 mm
Cubic capacity	0.661 litres
Compression ratio	17.5:1
Peak pressure	77.5 kg/cm ²
Maximum speed	2000 rpm
Min. idle speed	750 rpm
Operating speed	1500 rpm

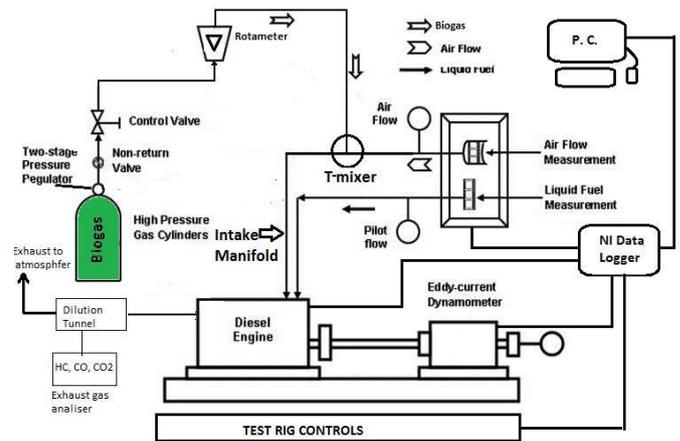


Fig.1 Block diagram of test setup

4 Results and Discussion

From figure 2 and 3 it is observed that, pressure rise is maximum for Biodiesel and diesel mode in both cases. The pressure rise is decreasing with increasing portion of biogas when engine is run in dual fuel mode.

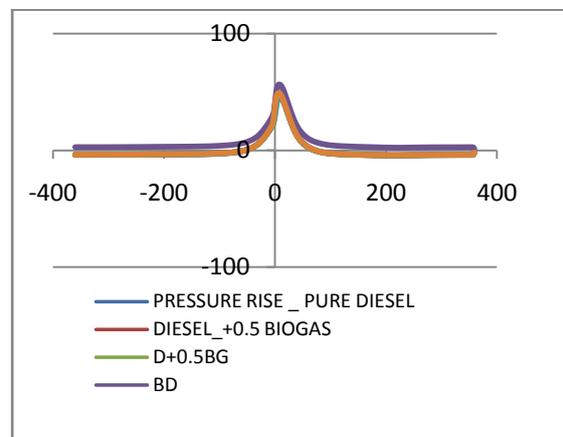


Fig. 2 comparison of ICP vs CA (1.7 k W, 1500 rpm)

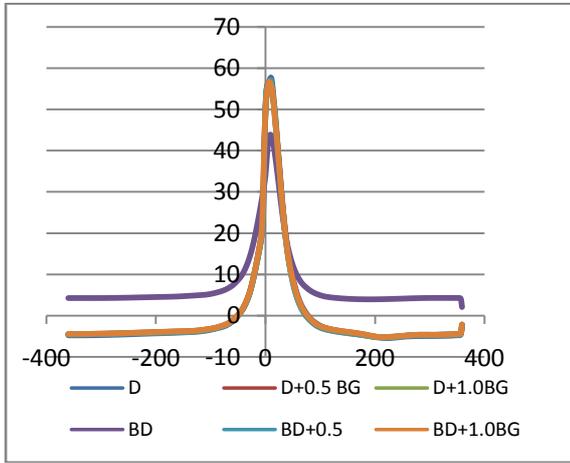


Fig. 3 comparison of ICP vs CA (3.5 kW, 1500 rpm)

Brake power

Variation of brake power with % of full load is shown in fig 4. It is observed that the dual fuel mode develops a brake power equivalent to the diesel dual only mode. At lower loads the power developed in different modes of operation is nearly the same. At higher loads it is seen that the dual fuel mode develops somewhat higher power than that of diesel being the difference very small.

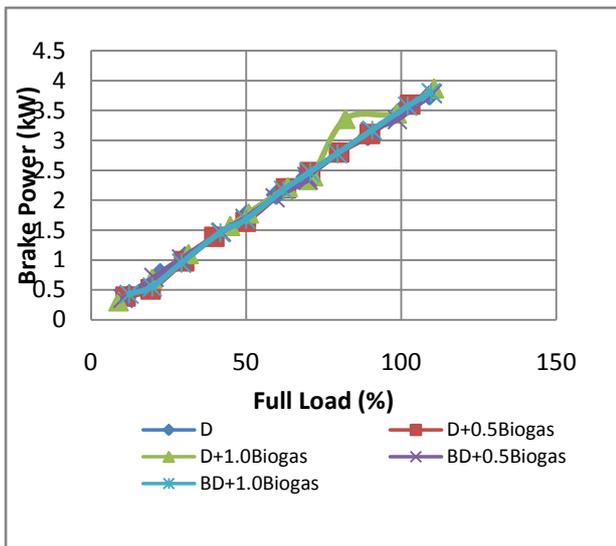


Fig.4.Variation of Brake power with % full load

Mechanical Efficiency

The variation of mechanical efficiency of the engine with % of full load is shown in fig 5. The engine was operated on diesel and dual fuel mode. In dual fuel mode, the engine develops an equivalent amount of power as developed in diesel mode. A keen observation shows that the mechanical efficiency is slightly higher than diesel except at a few points. A maximum mechanical efficiency of 70.61% was obtained at a slightly overloaded condition.

Brake Thermal Efficiency (%)

The variation of brake thermal efficiency of the engine with % of full load is shown in fig 6. The engine was operated on diesel and dual fuel mode. The maximum brake

thermal efficiency was found at 90% of full load in dual fuel mode.

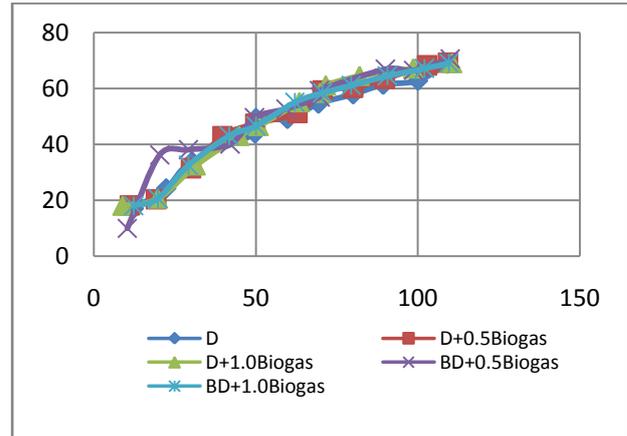


Fig.5 Variation of Mechanical Efficiency (%) with % full load

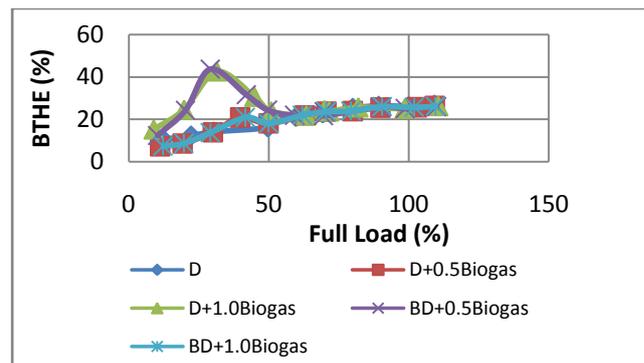


Fig. 6 Variation of BTHE (%) with % full load

The flow rate for this particular case was 1.0m³/hr. This is achieved because of the biogas which is having 95% methane. Brake thermal efficiency in dual fuel mode is higher than that in diesel only mode at all the points. This is the advantage of methane present in biogas. It is clean fuel, and burns completely. This is in accordance with all engines operating in dual fuel mode with a gas as primary fuel.

Volumetric efficiency

The variation of volumetric efficiency of the engine with % of full load is shown in fig 7. The engine was operated on diesel and dual fuel mode. In all cases it decreases with increase in the load. For both modes of operation, i.e. diesel only mode as well as dual fuel mode, the volumetric efficiency is decreasing with increase in load. For a biogas flow rate of 0.5m³/hr, it is minimum. This is because of the nature of biogas induction method. For a biogas flow rate of 0.5m³/hr, it is minimum. This is because of the nature of biogas induction method. As biogas is directly fumigated into the induction manifold using a T-joint mixer, it directly replaces/displaces the amount of air that is supposed to enter in the cylinder. This may affect other parameters like emissions, maximum peak pressure, and indicated work as the amount of air required for complete combustion may decrease.

Hydrocarbon (HC) emissions

The variation of HC emission of the engine with brake power is show in fig 8 was operated on diesel and dual fuel mode. Unburnt hydrocarbons are the result of incomplete combustion. The figure shows that unburnt HC emissions are lowest in diesel only operation, and increases with higher flow rates of biogas. As biogas has methane as its main and only constituent, it is obvious that the unburnt part of the fuel will be more methanous in nature. A biogas flow rate of 1.0 m³/hr records maximum HC emissions.

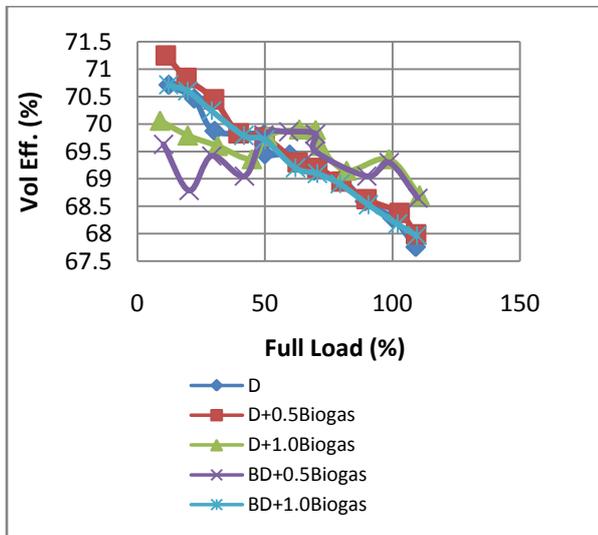


Fig. 7 Variation of Vol eff. (%) with % full load

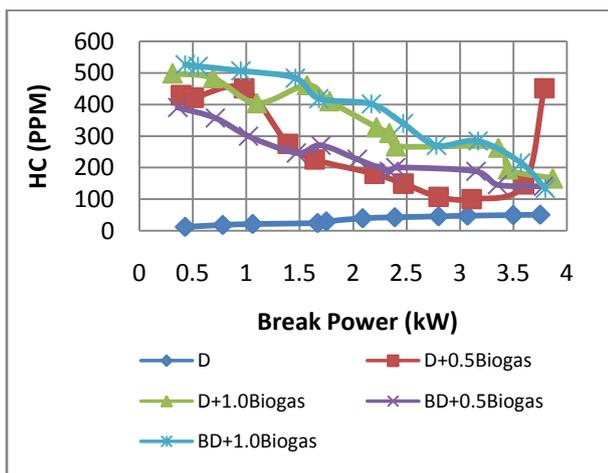


Fig. 8 Variation of HC with Break power

Carbon monoxide (CO) emissions

The variation of CO emission of the engine with brake power is show in fig 9 was operated on diesel and dual fuel mode. There are two major causes of formation of CO emissions. The first one is the incomplete combustion due to insufficient supply of oxygen to combustion chamber and second one is the poor mixture formation.

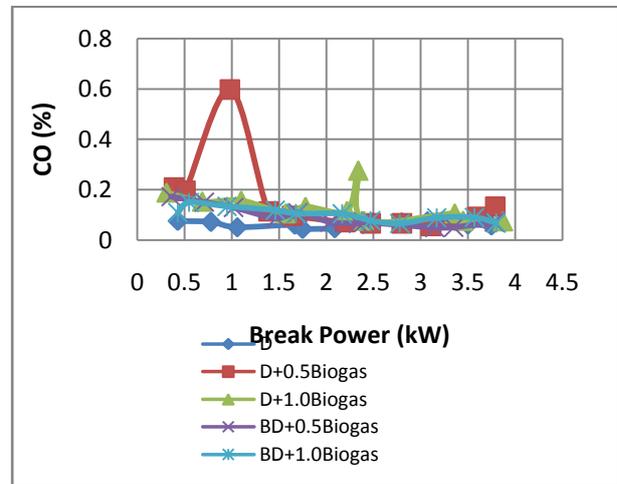


Fig. 9 Variation of CO with Break power

Carbon dioxide (CO₂) emissions

The variation of CO₂ emission of the engine with brake power is show in fig 10 was operated on diesel and dual fuel mode. Figure shows the biogas flow rate of 1.0m³/hr shows a reduced level of CO₂ emissions. However, under this mode, the performance of engine was noisy, harsh, and intermittent. For other flow rates of biogas, the CO₂ level is higher in the emissions. This is because the biogas contains CO₂, and the same is found in the emissions also.

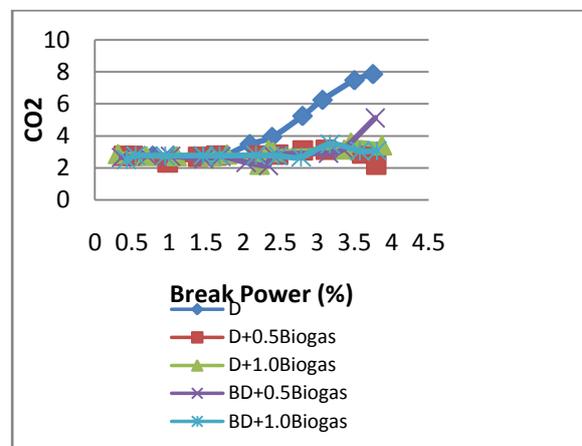


Fig. 10 Variation of CO₂ with Break power

Conclusions

The objective of this work was to study the performance of a single cylinder diesel engine when operated in biogas diesel dual fuel mode. It was studied by observing different parameters of diesel engine, following pars reports the short pres conclusions of this work.

It was found that the engine when operated on biogas-diesel and biogas-biodiesel dual fuel mode develops nearly same power as that of when operated on neat diesel mode. Near full load condition, the brake power developed in dual fuel mode is same as that of developed by neat diesel operation.

Mechanical efficiency the engine was also tested. It was noted that the biogas-diesel and biogas-biodiesel dual fuel mode has same as the mechanical

efficiency over neat diesel mode. This trend is similar for part load as well as full load operation.

Volumetric efficiency of the engine was found decreasing with increasing loads. It further decreased in fuel mode as biogas is introduced into the induction manifold direct and is replacing some amount of air being sucked.

Thermal efficiency of engine was higher in diesel dual fuel mode as compared to neat diesel mode. This is due to the methane from biogas, which has good combustion characteristics. Biogas forms a homogeneous mixture before entering the combustion chamber. This is helpful for achieving near complete combustion of the charge. This is major advantage of this system.

Emission measurements were noted for neat diesel mode and biogas-diesel and biogas-biodiesel dual fuel mode. Neat diesel operation has a record minimum and fairly constant value throughout the operating range. Subsequently, biogas-diesel and biogas-biodiesel dual fuel mode represents reducing nature of HC emission with increasing loads. CO emissions have a similar trend. A like HC emissions CO emissions are also notably less for neat diesel operation, where in they decreases initially and then rises near full load. For biogas-diesel and biogas-biodiesel dual fuel mode, the trend shows that HC emissions reduce with increasing loads. For other flow rate of biogas CO₂ emissions are greater than neat diesel operation. This is because biogas inheritable contains 2 as one its constituents, which is found in the exhaust emissions also.

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