International Journal of Scientific & Engineering Research Volume 10, Issue 4, April-2019
ISSN 2229-5518

Analysis of Emission on Variable Compression Engine with using Biogas as a Fuel

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Abstract: - In this paper an experimental investigation is done to use biogas in stationary duel fuel compression engine as a substitute for diesel. Biogas is introduced in the engine through inlet manifold along with the atmospheric air and diesel is injected into the engine through fuel injector. Performance and Emission characteristics is plotted under different compression ratio with varying load on engine. The Biogas used was produced by using cow dung. The result shows that the emission characteristics were greatly improved and the flow-rate of 1.8 kg/hr was found to be best. The results also show that the performance was not affected and biogas emerges as an epitome of the substitution. Hence this work tries to tell the effect of compression ratio on combustion and emission characteristics of a DFDE run on raw biogas. For setting of same CR, there is rise of nitrogen oxides and carbon -dioxide emission. In various tests, hydrocarbon and carbon monoxides emissions under DFDE was found to be greater than that of diesel mode due to reduction of volumetric efficiency. Hence looking up at all the experiments suggests that operating on (DFDE) has higher CR.

Index Terms—Biogas, Cow Dung, Compression Ratio, Diesel, Dual fuel stationary engine, Emission Analysis,

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1. Introduction

In today's world everything that is automated or trying to be automated requires energy. This energy is generated from various kinds of fossil fuels. But since these fuels are depleting at a very faster rate hence the cost of production also increases. So demand of time is to use some of their replacement. In this way our precious fuels can be saved and also the attention can be diverted towards other renewable resources. Biogas is a renewable source of energy which is formed by anaerobic fermentation of carbon contained matter like animal waste, vegetable waste etc. Biogas composition generally consist of 52–77%, Methane 27–45%, Carbon dioxide 0–1%, Hydrogen 2-10%, Nitrogen .1-0.5% of Hydrogen Sulfide. Pollution is a major concern regarding the use of conventional energy sources and also the non-renewable sources will not last forever, therefore the use of biogas is a smart choice. Earlier the use of biogas was limited to cooking and heating but with the advancement of technology it is also used as a transport fuel and to generate electricity.

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Use of fossil fuel in any form either direct or indirect results in pollution in the end and major source of is caused by the transportation system so its high time to reduce our usage of fossil fuel and work on alternative fuel like biogas in the IC (internal combustion)

The setup helps in analyzing various parameters of VCR engine performance for indicated power, frictional power, BMEP, IMEP, mechanical efficiencies, A/F ratio, Heat balance and combustion analysis [9] The software that is used for online engine performance evaluation is Lab view based Engine Performance Analysis software package "Engine soft".[10]

The engine consists of single cylinder, multifuel, four stroke engine connected to dynamometer (eddy current type) for loading. The mode of operation is variable from ECU Petrol to Diesel mode from Diesel to ECU Petrol. In these given ways the CR can change without any change in the geometry of combustion chamber or without any stoppage in the engine.

NOMENCLATURE TABLE

Terms	Symbols
Indicated power	I.P
Torque	T
Heat Addition	H.A
Applied Mass	M
Mass flow rate	m
Speed (RPM)	N
Calorific Value	C.V
Mean Effective Pressure	Pm
Mass of air Consumed	m_a
Area of Piston	A
Air Density	A_{den}
Dual Fuel Diesel Engine	DFDE
Diameter	D
Compression Ratio	CR
Length of Stroke	L

engine Debnath et al ; Jindal et al. [1-2]. For this purpose a Dual fueled diesel engine is used where diesel act as a pilot fuel while biogas act as a primary fuel. By using biogas in the dual fuel engine the emission characteristics is improved Chandra et al [3]. S. K. Mahla et al [4] in his experiment used the equal proportion of organic kitchen inlet where diesel act as pilot fuel while biogas in the dual fuel engine waste and cow dung for the biogas production. On the basis of engine of performance of engine and emission characteristics the optimum flow rate was 2.2kg/hr. Karen Cacua et al [5] found that adding the small amount of oxygen increases the stability of combustion, in the intake combustion fueled stationary engine on emission characteristics. It is formed from organic wastes that biodegrades in anaerobic environment with the help of bacteria .Biogas is used as dual fuel mode in these engines. Here temperature at end of the stroke (compression) is even higher than 550 K . Self ignition temperature of biogas is 1085 K. The process is carried out at a general temperature of 40°C/104°F (mesophilic) or 50°C/122°F (thermophilic) in plant's digester. Both the waste and the manure get mix in plant's receiving tank. It is then heated and pumped to CI engine is modified into DFDE by connecting the chamber of gas mixer with the inlet manifold and also installing the mechanism of fuel control with it. VCR is a technology which is used to set the CR of IC engine while it is in working stage . It is done in regards to increase the fuel efficiency when under changing loads. VCR Engines allow the volume above piston at TDC to get changed. Higher loads use low compression ratios to increase power and vice versa. For automobiles requirement this needs to be done as engine runs in regard to the load and the driving demands. In addition to this, VCR also allows free use of various fuels other than petrol e.g. LPG or ethanol.VCR Engine can produce any ratio ranging from 8:1 to 14:1. Maximum torque is achieved at a ratio of 8:1, giving highest acceleration, while the best gas mileage is at a ratio of 14:1. Electronic engine controller responds as per the pressure on the gas pedals, in real-time situation, changing the compression ratio without any hurdles. Though this engine has an inline four engine, it do not use the weights (for eg balance shafts to remove the secondary vibrations). It is balanced by some mechanical linkages.

2.PRESENT WORK

In today's time because of fuel crisis, biogas usage can easily take place of other nonrenewable resources. Hence in order to make it energy conservative, a proper study about the various effect of compression ratio on the performance and on emission characteristics need to be performed. Hence the main aim behind this research is for using DFDE in power generation in rural areas.

3.EXPERIMENTAL SETUP

The setup consists of four stroke,water cooled, single cylinder 3.5 KW Kirloskar engine. It connects with eddies curent and dynamometer cooled by water for crankshaft loading with the help of EMF. Cylinder's arrangement is designed for variable Compression ratio with-out disturbing its speed and with-out change its combustion chamber's (heating) geometry. Controller is fixed on panel for varying electric current for variation in load. Rotameter and calorimeter are provided for constant supply of water to the engine. Engine specification in table1. Two piezo-type sensors are used for measuring the combustion pressure on cylinder's head and also on fuel injector and also used to measure the pressure of fuel line. Sensor of optical crank angle measures every degree of rotation of crankshaft and transmit the signal to the computer screen for RPM measurement purpose. In this setup we are using six thermocouples for measuring the temperature value of exhaust gases and cooled water

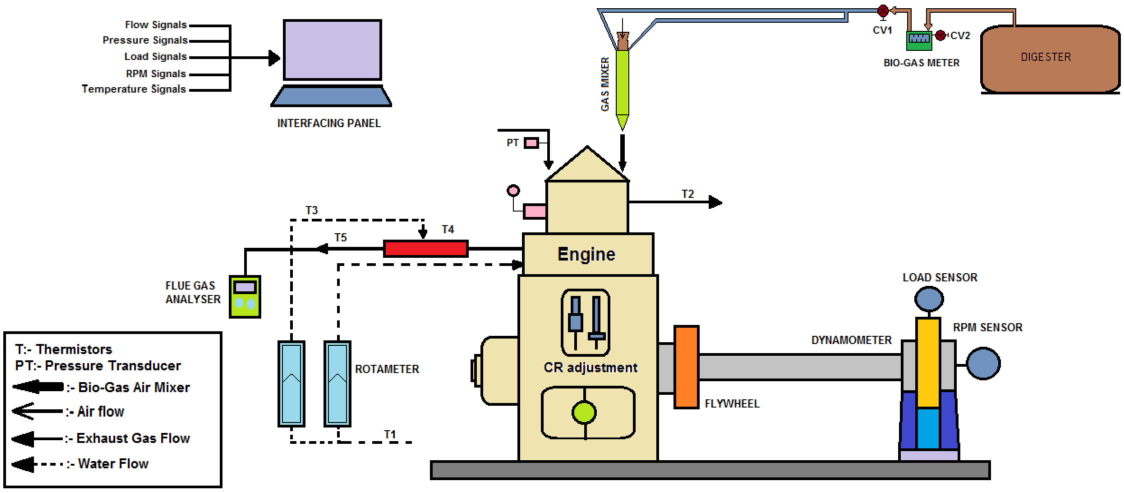


Fig 1: Schematic diagram of Experimental Setup

3.1 ENGINE SPECIFICATION

Parameters	**specification**
Exhaust Opens	ATDC 35.5deg
Exhaust closes	ATDC 4.5deg
Compression ratio	12-18
Connecting rod length	234 mm
Cooling System	Water Cooled
Maximum Power	3.5 KW
Valve Timing Inlet Opens	BTDC 4.5 deg
Inlet Closes	ATDC 35.5 deg
Displacement volume	661cc
Number of cylinders	1
Engine (make and model)	Kirloskar,240 PE

4. EXPERIMENT PROCEDURE

Firstly, Engine is running with diesel at standard diesel specifications. Initially, engine is running at zero load for quick overview so that heating condition can reached for proper burning of fuel. At the time of experiment procedure, we have different load conditions like 25% , 40% , 65% and 100%. As we increase load, engine's speed gets reduce. For maintaining the constant brake power more fuel consumption take place which results to increase the heat release rate hence cylinder inside temperature increases. This increases temperature of cold water and also exhaust gases respectively. At any single load condition , engine should run for a while and monitor temperature value of exhaust gases and cold water and AIO screen until it reaches up to optimum values. This state indicates the steady condition of the engine as well as engine ready for data acquisition. Initially, RPM of the engine has noted and then slowly opened the supply of the bio gas. As we starts the supply of the bio gas then the RPM of the engine gets increases this is because of the additional combustion energy of the bio gas in the engine cylinder. After some increment of the biogas value we saw there was no further change in engine RPM. At this point we start reducing the diesel flow rate by using fuel control mechanism. this mechanism is to be done for achieving the actual value of the engine RPM. At that condition we made to run the engine for several minute, thus note the value of biogas by biogas flow metre's usage. Same procedure needs to be follow for various load conditions and various compression ratios.

5. Properties

	Diesel	Biogas
Chemical Composition	$C_{12}H_{24}$	60% CH_4 and 40% CO_2
Lower Calorific value	42	20.67
Cetane Number	45-55	---
Auto ignition temp.	483K	873K
Stoichiometric air fuel ratio	14.92	10

6. Performance and Combustion Analysis Equation

1. Indicated thermal efficiency (ηt): It is defined as the ratio of energy in the indicated power to the heat addition in fuel energy.

$\eta t = I.P/H.A$

H.A=Mass flow rate*Calorific Value

$$\eta t\ \% = \frac{I.P\ (KW) \times 3600 \times 100}{m(kg/hr) \times C.V\ (KJ/kg)}$$

2. Brake thermal efficiency (ηbth): Overall efficiency of the engine is measured through the brake thermal efficiency. Brake thermal efficiency is defined as the ratio of brake power energy to the Heat addition in fuel energy.

$\eta bth = B.P/H.A$

$$\eta bth\% = \frac{B.P(KW) \times 3600 \times 100}{m(kg/hr) \times C.V\ (KJ/kg)}$$

3. Mechanical efficiency (ηm): Mechanical efficiency is defined as the ratio of Brake Power to the Indicated Power.

$\eta m = B.P/I.P$

Frictional Power = Indicated Power-Brake Power

4. Volumetric efficiency -It is an indication of the 'breathing' ability of the engine and is defined as the ratio of air actually induced at ambient conditions to the swept volume of the engine.

$$\eta v(\%) = \frac{\text{Mass of air consumed}}{\text{mass of flow of air at swept volume}}$$

$$\eta v(\%) = \frac{ma(Kg/Hr) \times 100}{(\pi/4 \times D2 \times L(m3) \times N(rpm)/n \times \text{no of cyl.} \times Aden(Kg/m3) \times 60)}$$

Where n=1 for 2 stroke engine and n=2 for 4 stroke engine

5. Air flow: Box with orifice is used for air consumption measurement.

$$\text{Air Flow (Kg/Hr)} = Cd \times \pi/4 \times d2 \times \sqrt{2g \times h_{water} \times \frac{W_{den}}{A_{den}}} \times A_{den} \times 3600$$

Where Cd = Coefficient of discharge of orifice
d = Orifice dia in 'm'
g = Acceleration due to gravity (m/s2) = 9.81 m/s2
h = Differential head across orifice (m of water)
Wden = Water density (kg/m3) =1000 kg/m3

Wair = Air density at working conditions (kg/m3) = p/RT
Where p= Atmospheric pressure at kgf/m2

(1 Standard atm. = 1.0332×104 kgf/m2)

R=gas constant= 29.27 kgfm/kg k

T= Atmospheric temperature in °k

6.Power and Mechanical efficiency: Power is defined as the rate of doing work and equal to the product of force and linear velocity.

The power developed by the engine at the output shaft is called brake power and is given by

Power = N×T/60,000(kW)

Where T (Nm) =W×R

W=9.81×M

R=Radius in meter

7.Mean effective pressure and torque: Mean effective pressure is defined as the hypothetical pressure, which is thought to be acting on the piston throughout the power stroke.

Power in kW = (Pm×L×A×N/n 100)/60 in bar

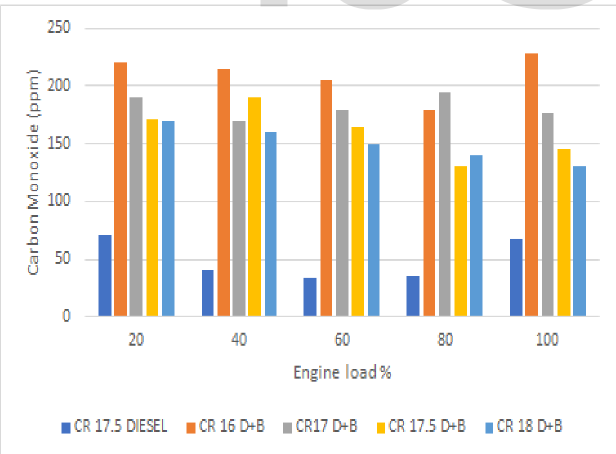
Where Pm= mean effective pressure

n= number of revolutions required to complete one engine cycle

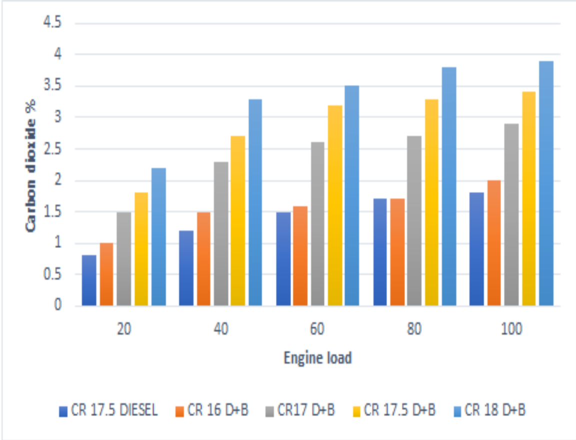
n = 1 (for two stoke engine)

n = 2 (for four stroke engine)

7.Result and Discussion



From the above graph we can predict that at a particular engine load as the CR of the blend increases the % of carbon monoxide also decreases.



From the above graph we can predict that at a particular engine load as the CR of the blend increases the % of carbon dioxide also increases. With increase of the engine load and CR, the CO_2 also increases

8.Conclusion

A trial examination was done to study the impact of CR on the emission, ignition and performance of a dual fuel diesel engine using biogas as a fuel. The investigations were carried out in a single cylinder chamber, DI, water cooled VCR diesel engine. With respect to emission, there is a decrease in CO just as hydrocarbon emission mode. Nonetheless, there is an increment in NOx. On the basis of the aftereffects of this examination, it very well may be presumed that the emission parameters and discharge of a DFDE which uses biogas as a fuel are observed to be an function of CR. However, more CR should be investigated to touch optimum level of performance of the biogas run dual fuel diesel engine[8]. Providing CO_2 in biogas suppress the high heat discharge. The high self-ignition temperature of methane helps delay the ignition procedure to favourable crank angles[6]. The diesel option was eradicated at higher pilot fuel(diesel) amount, it might be because of the blend being more richer at high pilot diesel amount and engine loads.The productivity of the engine can be improved by increasing the pilot fuel amount. The CO emissions can be decreased by increasing the pilot fuel quantity.[7]

9. ACKNOWLEGMENT

The authors wish to thank college, friends, relatives , parents and well wishers without their support this paper has not been possible.

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