Effect of Compression Ratio and Ignition Energy on Performance and Emission for Dedicated 4-Stroke S.I Engine Fuelled with BIOGAS – A Technical Review

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Abstract— The research on alternative fuels for internal combustion engine has become essential due to depletion of petroleum products and its major contribution for pollutants, where Natural gas is one of the most promising fuel alternatives for the future. Most of the BIOGAS fuelled vehicles in India are aftermarket retrofitted conversions from the existing SI engine vehicles. it is found that power produced by the BIOGAS engine is less compare to Gasoline engine. To increase the performance of the Bi-fuel engine there are many parameter which can be optimized. One of them is Compression Ration and Ignition energy. BIOGAS because of high ignition temperature and low flame speed compare to gasoline for complete combustion higher ignition energy is required. The objective of this research is to improve engine performance and emissions of BIOGAS fuelled SI engine by optimize ignition energy and compression ratio. The performance, emission and combustion characteristics with different Ignition Parameter with Compression Ratio are compared. It has been found from the results that the higher the compression ratio, the higher the brake thermal efficiency. The Performance and emission both decreased when engine was made to run on BIOGAS instead of Petrol. The review of this study can contribute important data for the design and optimization of Dedicated Biogas SI engine fuelled with BIOGAS for performance enhancement and emission reduction.

Key words: Alternative Fuel, Petrol, Biogas, Compression Ratio, Ignition Parameter etc

I. INTRODUCTION

The regular development of Internal Combustion Engine (ICE) changes direction in answer to changing requirement. In the 1970, the two most important problems determining the development trends of engines technology and in particular, their combustion against emission and noise and shortage of hydrocarbon fuels. The brief comparison of a variety of engine undertaken in what follows principally concerns specific fuel consumption, emissions and other technical and economic parameters[1]. Air pollution is fast becoming a serious urban as well as global with the increase pollution and its subsequent demands. This has resulted in an increase interest in using natural gas (NG) as fuel for internal combustion (IC) engines. NG resources are vast and widespread geographically and are not limited to politically sensitive location as is typical for crude oil. Base on current consumption rates the estimated total, recoverable gas, including proven reserve, is adequate for almost 200 years [2].Any researcher was researched about the compresses natural gas as alternative fuel motivated by the economic, emissions and strategic advantages of alternative fuels. Several alternative fuels have been recognized as having a significant potential for producing lower overall pollutant emissions compared to gasoline and diesel fuel. Reasons to used Biogas gas as a transportation application, first reason is availability, the second attraction reason of biogas is its environmental compatibility, the third attraction reason of natural gas is that it can be used in conventional diesel and gasoline engines [3] Reasons, where biogas powered vehicles theoretically have a significant advantage over petroleum-powered vehicles, the basis for this argument is the lower cost per energy unit of biogas as compared to petroleum. The difficulties with BIOGAS arise from vehicle range, fuel storage, infrastructure costs and ensuring sufficient supply in rural area. There are any problems for compressed natural gas applications such as onboard storage due to low energy volume ratio, knock at high loads and high emission of methane and carbon monoxide at light loads. However these can be overcome by the proper design, fuel management and exhaust treatment techniques. BIOGAS has been tested as an alternative fuel in a variety of engine configurations. The four main engine types include the traditional premixed charge spark ignition engine, the lean burn engine, the dual fuel/pilot injection engine, and the direct injection engine. There are basic types of engines used in vehicles- the spark ignition (SI) or gasoline engines and the compression ignition (CI) or diesel engine. To benefit from the use of BIOGAS in engines, it is necessary to understand its combustion under the appropriate condition and to study the effects of various parameters on it.

This review aims to prepare a concise state of art that provides an idea of various concerns related to employment of BIOGAS as a dedicated fuel for spark ignited petrol engine to improve the rapidly deteriorating air quality in urban region,

Energy security of nation, to reduce import cost of India and Reduce fiscal deficit.

II. BIOGAS AS AN ALTERNATIVE FUEL

Biogas is a mixture of methane and other gases produced from the decomposition of organic materials. It is produced naturally in landfills and from the processing of animal waste, sewage, cornhusks, leaves, crop waste, cellulosic and non-cellulosic crops. The major component of biogas is methane(CH_4) which is a significant greenhouse gas and is estimated to be 21 time as intense a greenhouse gas as carbon dioxide(CO_2).Biogas can be captured and flared which reduces the methane to carbon dioxide. But in doing so, its energy value is wasted. Biomass is an energy source, which is renewable in nature. When biomass is fermented in an anaerobic manner a gaseous fuel termed as biogas is obtained. The methane content varies from 50%- 60%

depending on the source. Biogas is produced by the anaerobic fermentation (oxygen free) process of organic matter. The production proceeds in three stages (hydrolysis, acid formation and methane fermentation) under the action of certain bacteria. This process of waste decomposition or biodegradation is natural and inevitable. The productions of biogas depend on many factors: kids of feedstock and its water content, temperature, pH etc. Fuel quality can be improved by removing traces of moisture and carbon dioxide. Approximately 67 m3 of gas can be produced from one tone of biomass. The energy of biomass is equivalent to two-thirds of natural gas and can be burned in IC engines. It is impractical to store biogas at lower pressure, as its volume is high. It is economical therefore to compress the gas and automobile fuel. When Biogas used to run IC Engine, changes in composition can have serious effects on performance.. BIOGAS is safer than gasoline in many respects and ignition temperature for BIOGAS is higher than gasoline and diesel fuel [1]. Additionally, natural gas is lighter than air, colorless, odorless, non-toxic, lower flammability. Biogas reducing CO2 NO_X emission, more complete and efficient burning with less unburned hydrocarbons present in the exhaust [2] compare to fossils fuel

Compound	Molecular Formula	Percentage
Methane	CH4	50-75
Carbon dioxide	CO2	25-50
Nitrogen	N2	0-10
Hydrogen	H2	0-1
Hydrogen sulphide	H2S	0-3
Oxygen	O2	0-0

Table 1: Typical Composition Of Biogas

It has also a wider flammability range than gasoline and diesel oil [1].The higher ignition temperature of gas compared with petroleum based fuel leads to reduced auto ignition delays. Due to the higher ignition temperature, BIOGAS is less hazardous than any other petroleum based fuel. The higher octane rating (130) for BIOGAS as compared to that of gasoline (89) allows a higher compression ratio (CR) (16:1) and consequently more efficient fuel consumption. Due to higher CR, CI engines can also use BIOGAS as a fuel, but since cetane rating for BIOGAS is poor, it cannot replace diesel totally like gasoline without modification [2].Maintenance cost for gaseous fuel is lower than that for gasoline or diesel engine, because gaseous fuel burn clean without carbon deposits. Furthermore, in gas engines, the fuel does not mix-up with the lubricants to dilute it or reduce its viscosity so that lubricant consumption is lower in gas engines than that of gasoline or diesel engines [2].

Fuel Property	Biogas	Gasoline
Molecular Weight	24-29	100-105
Density (kg/L, 15 ° C)	0.96-1.17	0.69-0.79
Specific Gravity (15 °C)	0.94-0.98	0.68-0.80
Boiling point, ° C	300	27-225
Specific Heat , kJ/Kg-k	1.6	2.0
Viscosity, mPs-S (20 °C)	11.2	0.37-0.44
Latent Heat of Vaporization, kJ/kg	481	349
Lower Heating Value, kJ/kg	21570	43500
Auto ignition Temperature, °C	617.86	257
Stoichiometric Air-Fuel Ratio, Weight	5.8	14.7
Upper Flammability Limit in Air (% vol.)	17	7.6
Lower Flammability Limit in Air (% vol.)	9	1.3
Octane Number	130	88-100
Cetane Number	0.7	8-10

Table 2: Important Properties of Biogas and Gasoline

III. EXPERIMENTAL SETUP

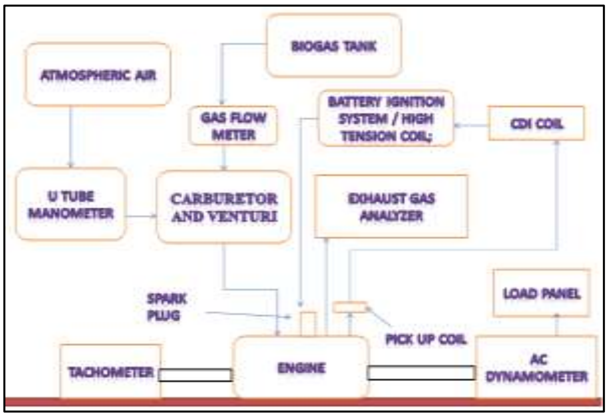
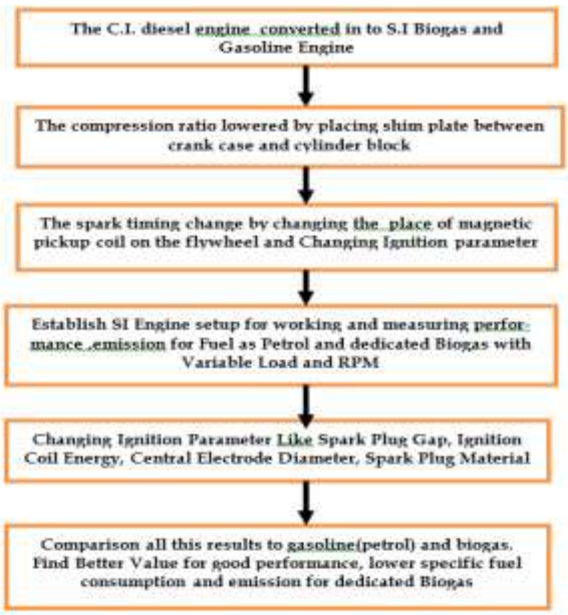


Fig. 1: Experimental Setup for Dedicated Biogas Engine

Make	Greaves Engine
Bore Diameter (mm)	86
Stroke Length (mm)	63
DisplacementVolume(cm3)	396
Compression Ratio	18.01
RPM	3600
Max. Torque- kgm	25@2200 rpm
Ignition	Electronic System
Capacity of oil sump in liter	1.2
HP(kw)	7.5

Table 3: Specification of engine

A. *Experimental Procedure*



The test has been carried out for both Gasoline and Biogas fuel. SI engine was converted into Bi-fuel engine with Biogas as second fuel. Performance and emission parameters are measured by using both ignition coil and both spark plug.

IV. MODIFICATION IN DIESEL ENGINE INTO DEDICATED BIOGAS

1) Changing the compression ratio
2) Modification in cylinder head
3) Installing ignition system
4) Venturi and Carburetor for supply of Biogas - Air mixture.
5) Modification in flywheel
6) Tappet screw adjustment
7) Spark ignition timing changed by changing sensor position

A. Method of Changing the Compression Ratio:

Fig. 2: Shim Plate

- Changing the compression ratio by inserting shim plate in between cylinder head and crankcase.
- This method is simple and less complicated than other methods.
- Thickness of shim plate which I have selected is 0.30 mm. So, by placing different numbers of shim plate we get different value of compression ratio, because clearance volume of combustion chamber will change by inserting shim plate.

B. Modification in Cylinder Head:

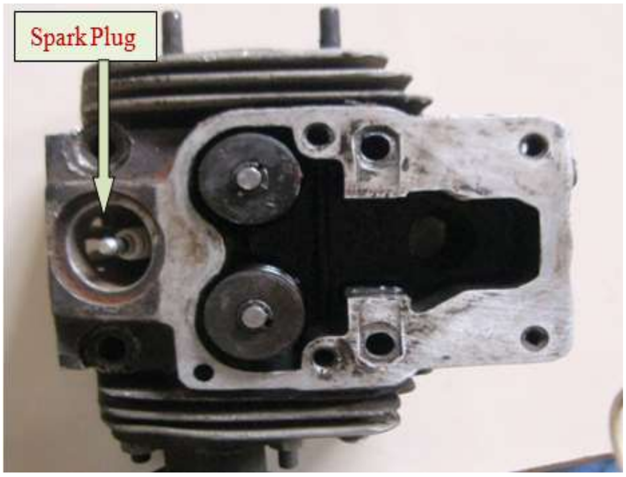


Fig. 3: Cylinder Head

C. Ignition System:

Fig. 4: Ignition System

D. CDI Coil & High Tension Coil:

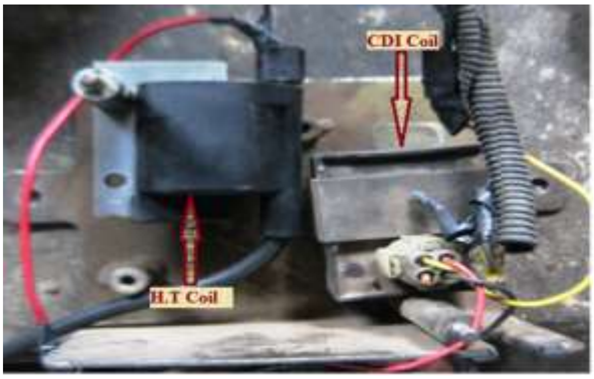


Fig. 5: CDI Coil & High Tension Coil

E. Venturi and Carburetor:

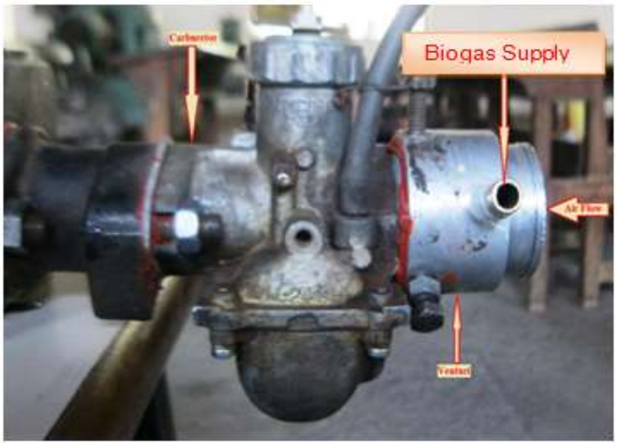


Fig. 6: Venturi and Carburetor

F. Modification in Flywheel:

Fig. 7: Modification in Flywheel

V. RESULTS AND DISCUSSION

The Experiment were carried out at 1800 rpm with 80 % load variation on Bi-fuel engine and performance parameters Brake power, Brake specific fuel Consumption, Brake Thermal efficiency, Volumetric efficiency, and emission parameter HC, CO and CO2 are measured.

A. *Brake Power:*

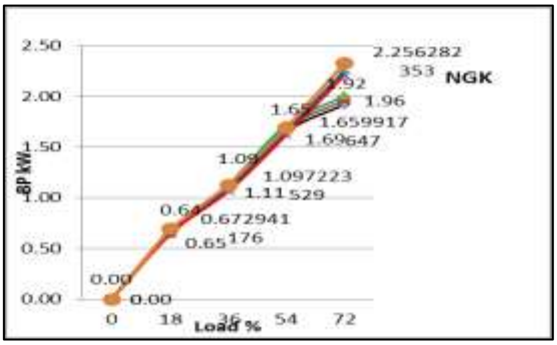


Fig. 8: Load vs Brake Power at 1800 rpm

Brake power for the gasoline and Biogas found increasing by increasing load on the engine. Maximum power produced by the engine is 3.12 kw and 3.30 kW at 80 % load on engine at 1800 rpm. When increasing spark plug gap and ignition coil energy BP value also increase.

B. *BSFC:*

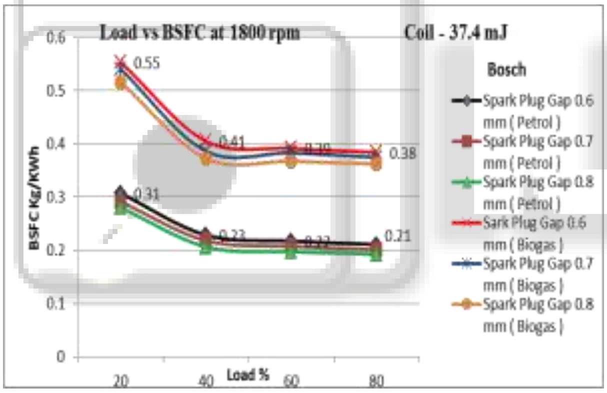


Fig. 9: Load Vs BSFC

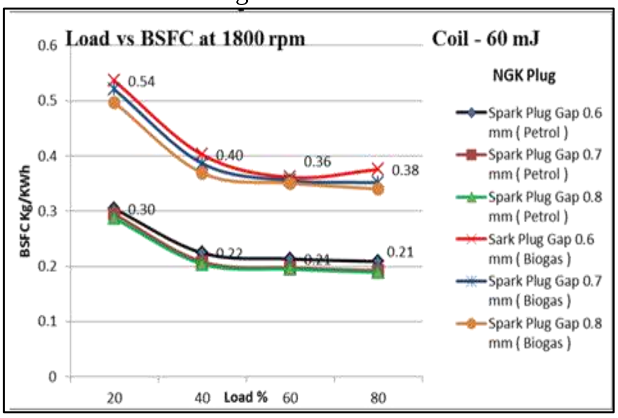


Fig. 10: Load Vs BSFC

Increasing Ignition coil Energy, increasing Spark Plug Gap, and change central electrode Diameter BSFC of Fuel is decreasing. Biogas is lower calorific gas so produced same power as petrol more amount of Biogas fuel required. BSFC for biogas higher than gasoline fuel.

C. *BTE:*

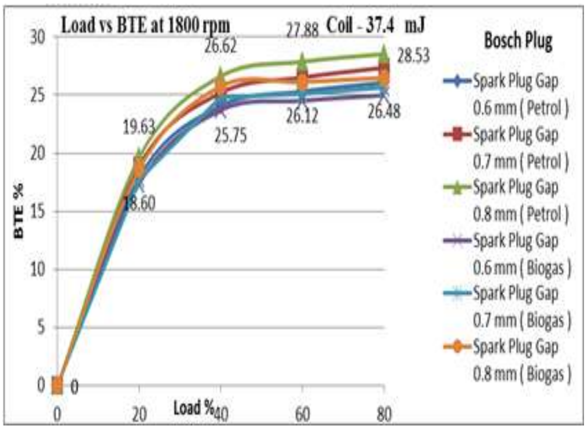


Fig. 11: Load vs. Bte

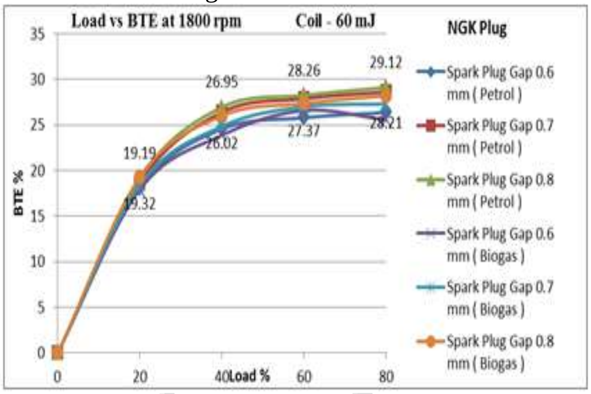


Fig. 12: Load vs. BTE

The Brake Thermal Efficiency decreases for Biogas compared to Petrol fuelled engine. The BTE of 29.12 % and 28.21 % for petrol and biogas at highest load and 1800 rpm for 0.8 mm Spark Plug Gap, Bosch (copper) with 60 mJ ignition coil energy of Bi-fuelled Engine. The BTE was a maximum of 26.64 % and 27.49 % for Petrol and Biogas at highest load and 1800 rpm for Iridium type plug with 60 mJ ignition coil Energy of Bi-fuelled Engine. Increase BTE 12.93 % and 11.74 % for comparing Bosch type plug with normal condition to NGK plug with 60 mJ ignition coil and 0.8 mm spark plug gap.

D. *Volumetric Efficiency:*

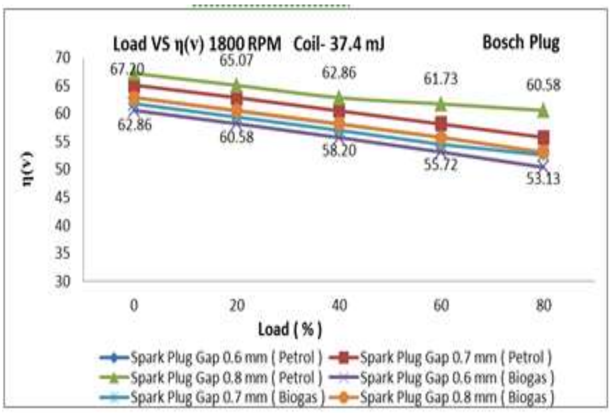


Fig. 13: Load vs. Volumetric Efficiency

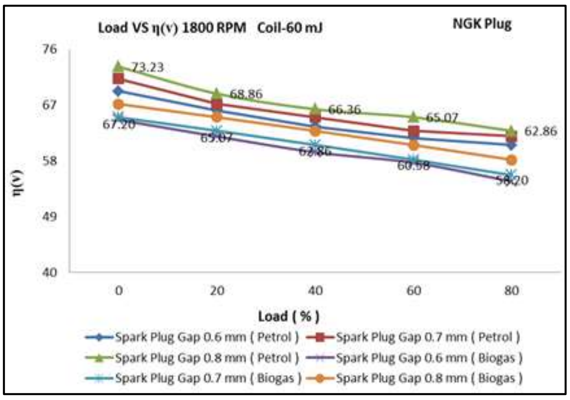


Fig. 14: Load vs. Volumetric Efficiency

The Volumetric Efficiency decreased significantly for Boigas Fuelled SI engine compared to Petrol. The Volumetric Efficiency decreasing 5.13 % and 4.64 % at 0.6 mm gap, 37.4 mJ and Bosch (Copper) type plug for 1800 rpm and full load comparing Petrol and Biogas. Volumetric Efficiency increased with increase in Spark Plug Gap and ignition coil energy. The Volumetric efficiency Variation 8.71 % and 4.72 % for both type plug, 0.8 mm gap and 60 mJ coil energy. For comparing normal condition 1 (37.4 mJ coil , 0.6 mm gap and Bosch (Copper) Plug) with Condition 2 (60 mJ coil , 0.8 mm gap and NGK (Iridium) Plug) increasing efficiency 5.13 %.

E. HC Emission:

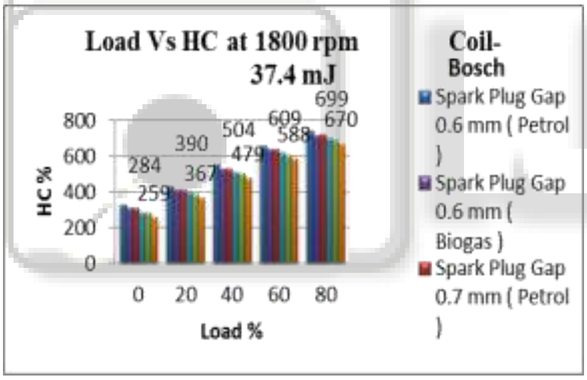


Fig. 15: Load vs. HC Emission

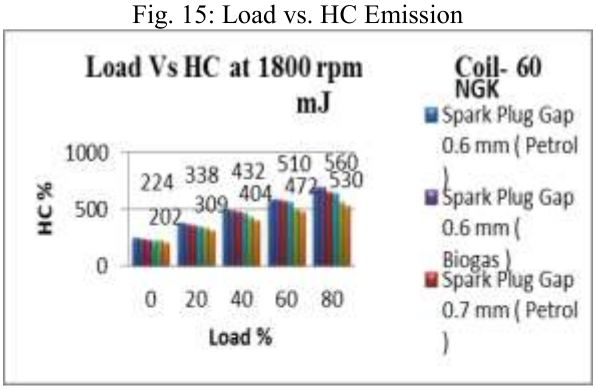


Fig. 16: Load vs. HC Emission

The highest emission for different Spark Plug Gaps were 742 ppm and 715 ppm at 0.6 mm, 724 and 701 ppm ppm at 0.7 mm, 699 ppm and 670 at 0.8 mm for the speed of 1800 rpm with full load for Petrol and Biogas. Maximum HC emission decreasing 17.56 % and 21.54 % for 0.8 mm gap,60 mJ coil for petrol and Biogas. Also decreasing emission 24.53 % and 25.88 % when comparing 0.6 mm gap, Bosch(Copper) plug to NGK (Iridium) at full load, 60 mJ energy for Petrol and Biogas.

F. CO Emission:

The CO emission decreased for Biogas when weighed against Petrol. The maximum CO emissions for Spark Plug gaps were 6.5 % vol and 2.4 % vol.at 0.6 mm, 5.88 % vol and 2.15 % vol.at 0.7 mm and 5.85 % vol and 2.11 % vol.at 0.8 mm for 1800 rpm, Bosch type plug, 37.4 mJ coil energy full load (80%). Increase Ignition coil energy, Central electrode diameter, change spark Plug gap CO emission decrease. CO emission decrease 7.69% and 16.67 % at 0.6 mm gap, 4.76 % and 18.60 % at 0.7mm gap, 15.38 % and 24.17 % at 0.8 mm gap for Bosch type and NGK plug 37.4 mJ coil energy, 80 % load and 1800 rpm. Comparing Normal condition (0.6 mm gap,37.4 mJ coil, Bosch plug) to modify Condition (0.8 mm gap, 60 mJ coil energy, NGK (Iridium) plug decreasing emission 28.46 % and 45.84 % for Petrol and Biogas at full load.

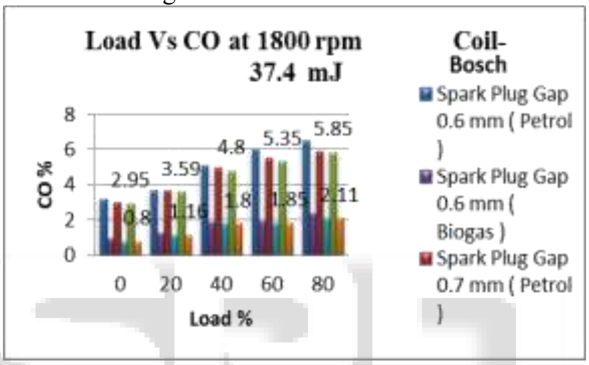


Fig. 17: Load vs. Co Emission

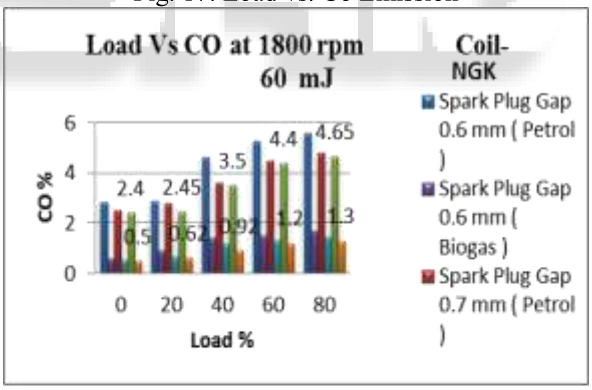


Fig. 18: Load vs. Co Emission

G. CO2 EMISSION:

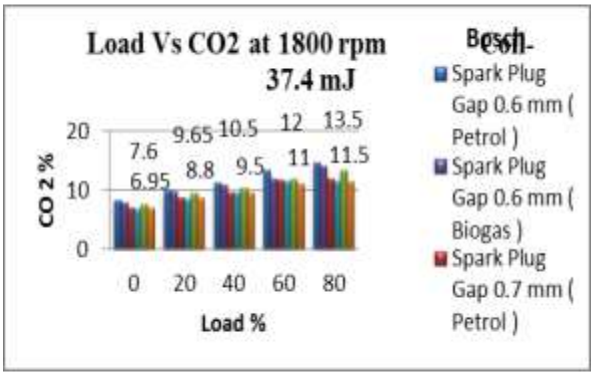


Fig. 19: Load vs. Co_2 Emission

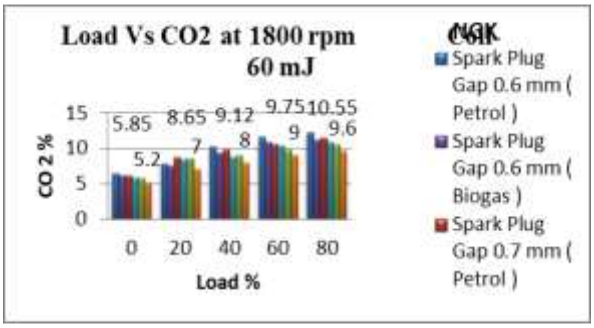


Fig. 20: Load vs. Co_2 Emission

CO_2 emission deceasing 11.23 % and 17.03 % at 0.6mm Gap, 15.75 % and 10.33 % at 0.7 mm Gap, 19.46 % and 21.31 % at 0.8 mm Gap when Comparing Bosch type plug and NGK type Plug for full load speed condition at 0.8 mm gap, 60 Coil Energy .Comparing Normal Bosch Plug Condition (0.6 mm gap, 37.4 mJ, Copper plug) to NGK (0.8 mm gap, 60 mJ coil, 1800 rpm) Condition CO2 emission decreasing 27.74 % and 31.91 % for Petrol and Biogas.

VI. CONCLUSION

The performance and emission was enhance in Bi-fuel Engine Biogas mode by using High energy ignition coil (60mJ) with iridium spark plug (0.6mm electrode diameter and 0.8 mm spark Gap) which increase the ignition energy for making complete combustion of Biogas for capability utilization of Biogas. BIOGAS is best alternative for the current IC engines. BIOGAS reduced emission like HC, CO2, and CO considerably. It is beneficial and less costly to convert SI engine compare to CI engine in to BIOGAS engine. However, majority of these kits are incapable of tapping the potential of BIOGAS as a spark ignition fuel.it is found that power produced by the BIOGAS less compare to petrol engine. To increase the performance compatible to petrol various parameters which affect the performance should be optimized.

1) Capacity utilization of BIOGAS fuel and reduce losses there should be modification done in engine like Compression ratio should increase, Inlet port Diameter increased, Spark advanced, spark energy increase.
2) Lean burn is an effective way to improve fuel efficiency and reduce NOx emissions. Lean burn limits are dependent on combustion chamber geometry, ignition timings, ignition energy and turbulence.
3) It is found that minimum spark energy required for methane ignition is 100 mJ to 120mJwhich is higher than the gasoline. So the conversion of an engine to BIOGAS engine requires higher performance ignition system.
4) Discharge energy can be increase various way by increasing the spark gap, by reducing the spark plug electrode, by changing the spark plug electrode material and by giving different shape to electrode, increasing capacity of ignition coil, using multiple spark plug,By increasing the ignition energy lean burn capacity of the fuel can be increase and performance of Bi-fuel engine in Biogas mode can be compatible with petrol mode performance and capability utilization of Biogas is possible.
5) Burning of Biogas in IC proper amount of compression ratio required. The lean misfire limit of combustion of biogas under actual engine operating conditions gets considerably extended with increase in compression ratio. Compression Ratio improves combustion of engine, improve performance and exhaust emission value. The peak pressure decreases, as the mixture becomes lean at all the compression ratios. The peak pressure is higher with higher compression ratio. Increase in compression ratio leads to high heat release rate. The reduction in the ignition delay and higher heat release rate with increase in compression ratio. There is an increase in HC and NO level with rise in compression ratio. There is an improvement in thermal efficiency and brake power output with increase in compression ratio.

The scope of this review is by changing the ignition energy by any method of above keeping other parameter optimum one can increase the performance of the BIOGAS in the Bi-fuel mode which compatible with petrol performance.

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