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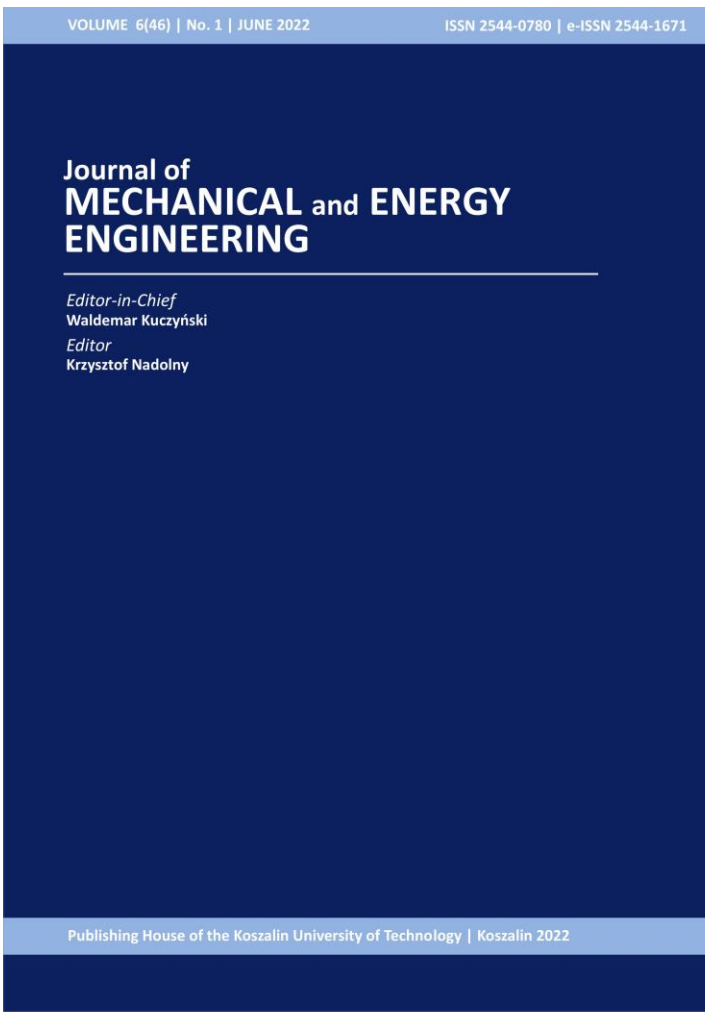
DOI: 10.30464/jmee.2022.6.1.67

Cite this article as:
Ingawale S. M.; Bagi J. S.; Nikam L. S. Comparative study of the performance of an internal combustion engine and its emission working on conventional fuel (Diesel) and alternative fuel (Bio-CNG). Journal of Mechanical and Energy Engineering, Vol. 6(46), No. 1, 2022, pp. 67-76.



Journal of Mechanical and Energy Engineering

Website: jmee.tu.koszalin.pl

ISSN (Print): 2544-0780
ISSN (Online): 2544-1671
Volume: 6(46)
Number: 1
Year: 2022
Pages: 67-76

Article Info:
Received 16 February 2022
Accepted 2 March 2022

Journal of
MECHANICAL and ENERGY
ENGINEERING

ISSN: 2544-0780 | e-ISSN: 2544-1671
Vol. 6(46) | No. 1 | June 2022 | pp. 67-76
DOI: 10.30464/jmee.2021.6.1.67

COMPARATIVE STUDY OF THE PERFORMANCE OF AN INTERNAL COMBUSTION ENGINE AND ITS EMISSION WORKING ON CONVENTIONAL FUEL (DIESEL) AND ALTERNATIVE FUEL (BIO-CNG)

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(Received 16 February 2022, Accepted 2 March 2022)

Abstract: Currently, the world is facing problems regarding environmental pollution due to the combustion of fossil fuels. Generally, the combustion of fossil fuels takes place in the Internal Combustion engine for power or electricity generation. The combustion of fossil fuels emits greenhouse gases that lead to the greenhouse effect. The main symptom of the greenhouse effect is increased earth surface temperature. Also, the resources of fossil fuels are depleting rapidly and can take thousands of years to reproduce, so the time has come to go for lesser polluting renewable fuels. In this research, Bio-CNG is considered as an alternative fuel to conventional fuel, i.e. Diesel. The performance test on four-stroke IC Engines working on Bio-CNG and Diesel fuel is conducted simultaneously. The performance parameters such as Brake Power, Indicated Power, Thermal Efficiencies, Mechanical, Volumetric efficiency for both fuels are compared. Along with the performance, the emission is also recorded and compared. The results have shown that Bio-CNG has slightly less performance ability for similar engines working on Diesel fuel. Yet, this study also shows that Bio-CNG possesses the ability to replace the conventional fuel with some engine and exhaust system modifications. The higher calorific value (47000 kJ/kg) and lower or negligible carbon emission make it the best sustainable fuel substitute to conventional fuel, i.e. Diesel.

Keywords: comparative study, biogas, bio-CNG, diesel, performance, efficiency, emission

1. INTRODUCTION

"Non-Renewable" is the word that pops up in our minds when we hear the word fossil fuel. Fossil fuels such as Coal, Crude Oil, and Natural Gas are fossil fuels that are used to produce commercial fuels like Diesel, Gasoline, and Kerosene. Millions of years are required to produce fossil fuels from organic matter that remained under the earth's crust from dead plants and animals.

The resources of fossil fuels are finite and they are exhausting rapidly; also, they are the largest climate change contributor. The potential of renewable energy resources in India is significant, especially Solar, Biomass, Wind, and Small Hydro Power Stations. Among these resources, Biomass demands special attention. Biomass can be derived from all living matter such as growing plants containing trees, crops, algae, and from animal manure . Digestion under anaerobic conditions by which organic matter, in the absence of oxygen is transformed into the mixture of methane (CH4) and carbon dioxide (CO_2) is usually known as Biogas. When Biogas is compressed and purified further, it is known as Bio-CNG. In 1939, the first experimentation on Biogas production was conducted by Mr. S.V. Desai, the pioneer of anaerobic digestion in India [1].

The methods used for the production of biogas are explained below.

1.1. Anaerobic Digesters

Plants, animals, and agricultural waste can be used to produce Biogas. Anaerobic digesters are used to process waste in the form of liquid or slurry combined with water. The main components of an anaerobic digester are a feedstock holder, a biogas recovery unit, a digestion tank, and heat exchangers utilized to maintain the optimum temperature for digestion. Household or Small-Scale digesters having a capacity of about 757 liters can be used to produce electric lighting or as cooking fuel in remote homes.

The temperature that is usually maintained in the digester is about 35°C for the optimum work of bacteria that decompose the organic matter into Bio-Gas. When the digester works efficiently, it can produce 200-400 m^3 of Biogas including 50-75% methane per ton of dry waste input [2].

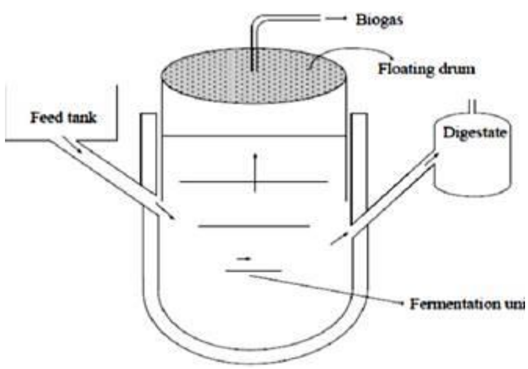

Fig. 1. Anaerobic biogas digester

1.2. Landfill gas

The decomposition of organic matter that occurred under landfills over many years and gas produced also called landfill gas which can be collected from the interconnections of pipes located at different depths across the landfill. Over the life span of the landfill, variations in the gas composition take place. Generally, in one year, the composition of gas contains about 60% methane and 40% carbon dioxide. The gas collection from the landfill varies with the age of the landfill facility and the percentage of organic waste. The average potential of energy contained in the landfill is about 2 GJ/ ton of waste (1,895,634 BTU).

The gas collection system under landfill is designed to prevent explosions due to the accumulation of methane gas inside the landfill area and to prevent or to minimize the release of methane into the atmosphere as a greenhouse gas. The landfill gas that is collected from the site can be combusted near the site in boilers or furnaces to generate heat but it is instead generally used as a fuel for IC Engines or to run the turbines which drive generators and produce electricity [2].

Biogas mainly consists of Methane (CH4, 55-65%) and Carbon Dioxide (CO_2, 35-45%) having a Calorific Value of about 19500 kJ/kg. Methane is an efficient carrier of energy including a wide range of applications; hence, it is considered as a valuable constituent of gas. The amount of Carbon Dioxide generated during the combustion of Biogas is very similar to the amount of Carbon Dioxide absorbed to produce Biomass which makes Carbon neutral. Along with methane and carbon dioxide, Biogas also contains some traces of water vapor, siloxanes, hydrocarbons, hydrogen sulfide, oxygen, nitrogen, and carbon monoxide. The amount of these trace components depends on the source of the collection of Biomass.

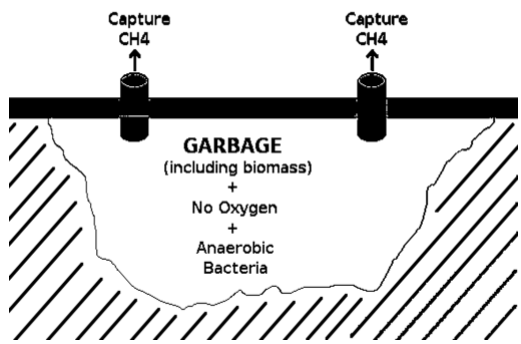

Fig. 2. Landfill anaerobic digester

If Biogas from the digester or the landfill is directly used in internal combustion engines as a fuel, it can lead to the erosion of metal parts which can significantly increase the cost and time of maintenance for the vehicles. Upgrading of Biogas can help to eliminate the problem of the corrosion of metallic parts in IC engines. Upgrading of Biogas means the purification of Biogas in which contaminants in raw Biogas are scrubbed or absorbed from the stream, leaving purer Biogas having more methane content per the unit volume of Biogas. The gas is obtained by the purification of raw Biogas is known as Bio-methane.

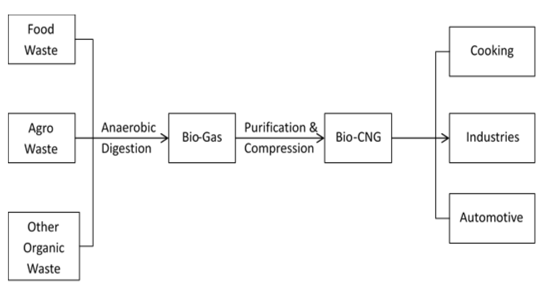

Fig. 3. Flow diagram of Biogas to Bio-CNG conversion process

The most widely adopted technologies for Biogas purification are Pressure Swing Absorption, Chemical and Membrane Scrubbing and Water Scrubbing. In a small scale, production water scrubbing and pressure swing absorption methods are the most suitable methods due to their easy maintenance and low cost. This purified Biogas can be compressed and bottled into cylinders and then it becomes Bio-Compressed Natural Gas (Bio-CNG or compressed Bio-Gas [1].

The commonly used biogas purification process is the water scrubbing method. In this method, pressurized water is used as an absorbent. This involves the direct absorption and regeneration of Carbon Dioxide (C02) and Hydrogen

Sulphide (H2S) in pressurized water. The absorption is carried out by releasing the water pressure with small temperature changes. After the compression, biogas is fed to the packed bed absorption unit from the bottom of the column and the spray of pressurized water is fed from the top of the column. Due to this counter current process of mixing along with the absorption takes place and hence H_2S and CO_2 are dissolved in water. Later, this water is collected from the bottom of the tower. The solubility of CO_2 in water increases with an increase in pressure and it decreases with an increase in temperature [3] {Journal Article}.

Currently, in India, 17 Bio-CNG plants are in operation having a combined capacity of about 46,178 kg/day. Bio-CNG plants are located in nine states of India. Among these states, Maharashtra has the highest production capacity of more than 16000 kg/day [1].

2. PERFORMANCE AND EMISSION ANALYSIS

2.1. Details of experimental setup

The following data is collected during the experimentation [4].

Engine details

- Power: 3.5 kW
- RPM: 1500
- No. of Cylinder: 1
- No. of Strokes: 4 Stroke
- Cooling Type: Water Cooled
- Speed Type: Constant
- Cylinder Bore Diameter: 87.50 mm
- Stroke Length: 110 mm
- Swept Volume: 661.45 cm^3
- Compression Ratio: 12-18 (18 for experiment)

Combustion parameters

- Specific Gas Constant: 1.00 kJ/kgK
- Air Density: 1.17 kg/m^2
- Adiabatic Index: 1.41
- Polytrophic Index: 1.09

Performance parameters

- Orifice Diameter: 20.00mm
- Orifice Coeff. Of Discharge: 0.60
- Dynamometer Arm Length: 185 mm
- Ambient Temperature: 27°C
- Fuels Used: Diesel and Bio- CNG
- Calorific Value for Diesel: 42000 kJ/kg
- Calorific Value for Bio-CNG: 47000 kJ/kg

Software used

- Name: IC EngineSoft
- Version: 9.0

2.2. Comparative study of performance and emission for IC engine working on bio-CNG and diesel fuel

The comparative study includes a comparison of similar quantities obtained during a performance and emission analysis for Diesel and Bio-CNG fuelled Engines. The quantities affecting the performance of the IC engine are considered for the comparative study and are listed below.

Indicated power, brake power, and frictional power

Tab. 1. Load (kg) vs power (kW)

For diesel fuel					
Sr. No.	Speed, rpm	Load, kg	IP, kW	BP, kW	FP, kW
1	1520	0.15	1.79	0.04	1.75
2	1520	3.08	1.63	0.89	0.74
3	1520	6.06	2.05	1.75	0.3
4	1524	9.11	2.57	2.64	-0.07
5	1527	12.15	4.89	3.53	1.36
For Bio-CNG fuel					
Sr. No.	Speed, rpm	Load, kg	IP, kW	BP, kW	FP, kW
1	1526	0.25	2.68	0.07	2.61
2	1567	3.13	1.92	0.93	0.99
3	1608	6.08	4.11	1.86	2.25
4	1592	9.2	5.07	2.78	2.29
5	1526	12.06	5.79	3.5	2.3

The possible reason for the negative frictional power is due to the indicated power recorded at other crank angles than power and compression strokes, which results in a smaller indicated power than the break power.

The above data shows that the maximum indicated power generated by the engine working on Bio-CNG is greater than that of the Diesel Engine. The brake power generated in the Diesel-fuelled engine is slightly greater than that of the Bio- CNG fuelled engine. The frictional power is also smaller in the Diesel-fuelled engine than that of the Bio-CNG fuelled engine. Due to this, the Diesel engine can produce more useful work than of the Bio-CNG Fuelled engine.

The data presented on Fig. 4 and 5 is obtained by varying the load from 0-12 kg. The graph shows that the Diesel engine has better energy conversion to useful work, i.e. to brake power as it has lesser wastage of power in friction.

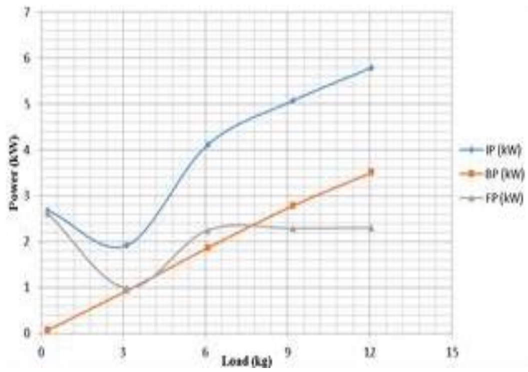

Fig. 4. Load (kg) vs power (kW) for diesel fueled engine

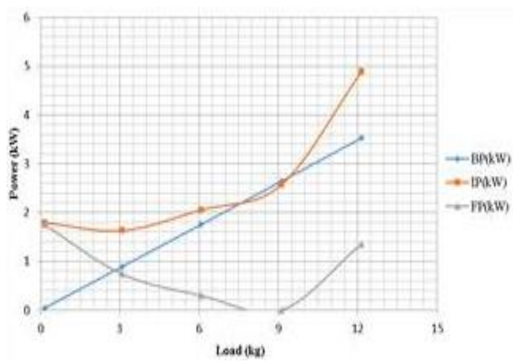

Fig. 5. Load (kg) vs power (kW) for Bio-CNG fueled engine

Mean effective pressure

The data in Table 2 shows that the maximum IMEP developed in the Bio-CNG fuelled engine is more than that of the Diesel-fueled Engine. The BMEP produced by both fuels is almost the same.

Tab. 2. Load vs mean effective pressure

Sr. No.	Speed, rpm	Load, kg	IMEP, bar	BMEP, bar	FMEP, bar
For diesel fuel					
1	1520	0.15	2.14	0.05	2.09
2	1520	3.08	1.94	1.06	0.88
3	1520	6.06	2.45	2.09	0.36
4	1524	9.11	3.05	3.14	-0.09
5	1527	12.15	5.81	4.19	1.62
For Bio-CNG fuel					
Sr. No.	Speed, rpm	Load, kg	IMEP, bar	BMEP, bar	FMEP, bar
1	1526	0.25	3.19	0.09	3.1
2	1567	3.13	2.22	1.04	1.14
3	1608	6.08	4.64	2.09	2.54
4	1592	9.2	5.78	3.13	2.6
5	1526	12.06	6.89	4.18	2.73

The FMEP is less in the Diesel-fuelled engine than that of the Bio-CNG fuelled engine. This shows that the frictional losses are greater in the Bio-CNG fuelled engine so that even if indicated power is greater it cannot produce more brake power.

Here, indicated mean effective pressure is calculated at crank angles other than compression or expansion strokes, which result in smaller IMEP than BMEP; hence, negative FMEP is recorded.

The graphs (Fig. 6 and 7) represent the behavior of IMEP, BMEP, and FMEP when the load is varied from 0-12kg. This demonstrates that the Diesel-fuelled engine has a similar brake mean effective pressure even if it has a lesser indicated mean effective pressure. This happens due to the lower values of the Frictional mean effective pressure in the Diesel-fuelled engine.

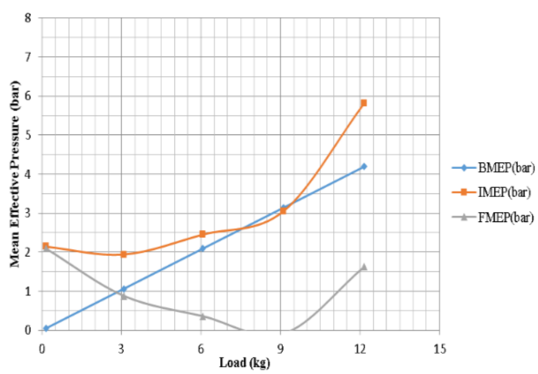

Fig. 6. Load vs mean effective pressure for diesel fueled engine

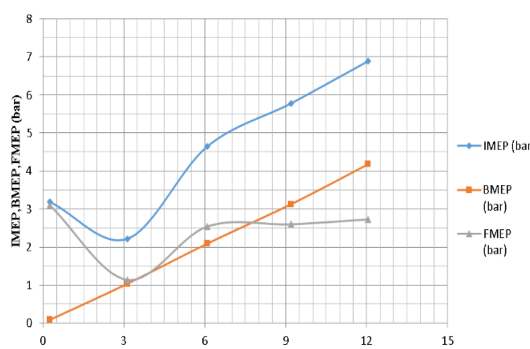

Fig. 7. Load vs mean effective pressure for Bio-CNG fuelled engine

Thermal efficiency

The data in Table 3 shows a representation for indicated thermal efficiency and brake thermal efficiency. The data is obtained by varying the load from 0-12kg, the engine speed is kept nearly constant. The data shows that indicated thermal efficiency is greater in the Diesel fuelled engine than that of the Bio-CNG fuelled engine. The brake thermal efficiency is also greater in the Diesel fuelled engine than in the Bio-CNG fuelled engine.

Tab. 3. Load vs thermal efficiencies

Sr. No.	Speed, rpm	Load, kg	ηIth, %	ηBth, %
For diesel fuel				
1	1520	0.15	51.38	1.25
2	1520	3.08	25.44	13.93
3	1520	6.06	22.05	18.84
4	1524	9.11	21.03	21.63
5	1527	12.15	36.59	26.39
For Bio-CNG fuel				
Sr. No.	Speed, rpm	Load, kg	ηIth, %	ηBth, %
1	1526	0.25	15.68	0.44
2	1567	3.13	11.23	5.83
3	1608	6.08	24.05	11.66
4	1592	9.2	29.66	17.43
5	1526	12.06	33.88	21.94

The graphs (Fig. 8 and 9) represent the data of thermal efficiencies vs load for diesel and Bio-CNG fuelled engines. The indicated and brake thermal efficiencies are greater for diesel fuelled engines.

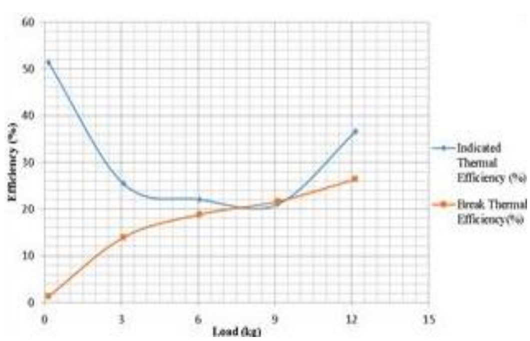

Fig. 8. Load vs thermal efficiencies for diesel fuelled engine

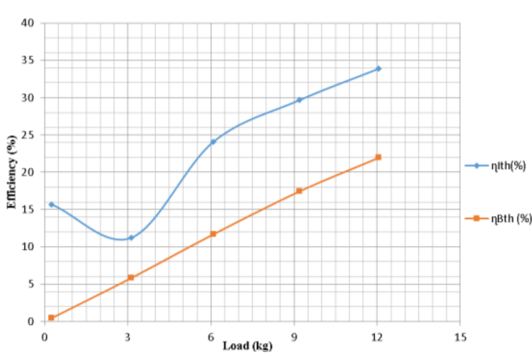

Fig. 9. Load vs thermal efficiencies for Bio-CNG fueled engine

Torque, mechanical and volumetric efficiency

The data in Table 4 shows a tabular representation for Indicated thermal efficiency and Brake Thermal Efficiency. The data is obtained by varying the load from 0-12kg, the engine speed is kept nearly constant. The data shows that Indicated thermal efficiency is greater in the Diesel- fuelled engine than that of the Bio-CNG fuelled engine. The brake thermal efficiency is also greater in the Diesel-fuelled engine than Bio-CNG fuelled engine.

Tab. 4. Load vs torque, mechanical volumetric efficiency

Sr. No.	Speed, rpm	Load, kg	Torque, Nm	η_{Mech}, %
For diesel fuel				
1	1520	0.15	0.27	2.44
2	1520	3.08	5.59	54.77
3	1520	6.06	11	85.44
4	1524	9.11	16.54	102.84
5	1527	12.15	22.05	72.12
For Bio-CNG fuel				
Sr. No.	Speed, rpm	Load, kg	Torque, Nm	η_{Mech}, %
1	1526	0.25	0.45	2.69
2	1567	3.13	5.68	48.59
3	1608	6.08	11.03	45.19
4	1592	9.2	16.7	54.91
5	1526	12.06	21.89	60.37

As discussed before, IP power is smaller than BP that results in Mechanical Efficiency being greater than 100%.

Heat balance sheet

The data in Table 5 is obtained during a performance analysis of the IC Engine working on Diesel and Bio-CNG fuels. This shows that the heat equivalent to the useful work (HBP) is greater in the Diesel-fuelled engine than in the Bio-CNG fuelled engine. The heat carried with cooling jacket water (HJW) is greater in the Diesel-fuelled engine is greater than that of the Bio-CNG fuelled engine. The heat carried with exhaust gases (HGas) is greater in the Bio-CNG fuelled engine than that of the Diesel-fuelled engine. Unaccounted heat is very high in the Bio-CNG fuelled engine than that of the Diesel-fuelled engine. The data shows that heat losses in Bio-CNG Fuelled engine are greater than that of Diesel-fuelled engine.

The graphs (Fig. 10 and 11) represent the variations in various heat expenses such as HBP, HJW, HGas and Unaccounted Heat when the load is varied from 0-12kg.

The Diesel-fuelled engine has better heat utilization for useful work than that of the Bio-CNG fuelled engine.

Tab. 5. Heat expenses vs load

For diesel fuel				
Sr. No.	Load, kg	HBP, %	HGas, %	HRad, %
1	0.15	1.25	57.14	25.54
2	3.08	13.93	37.94	18.28
3	6.06	18.84	35.94	16.41
4	9.11	21.63	37.34	15.65
5	12.15	26.39	32.13	15.53
For Bio-CNG fuel				
Sr. No.	Load, kg	HBP, %	HGas, %	HRad, %
1	0.25	0.07	18.11	15.42
2	3.13	0.93	18.13	17.3
3	6.08	1.86	19.37	19.57
4	9.2	2.78	20.88	19.83
5	12.06	3.5	22.64	17.88

Here, BP is heat equivalent to useful work or heat equivalent to break power. HJW stands for heat carried with jacket cooling water. HGas is heat carried with exhaust gases, and HRad is unaccounted heat.

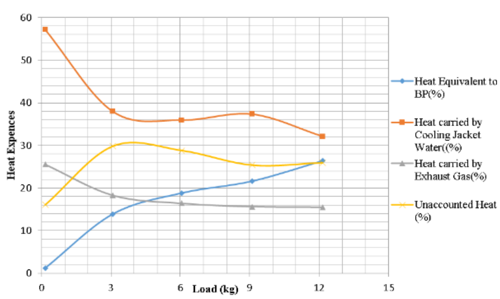

Fig. 10. Load vs heat expenses for diesel fuelled engine

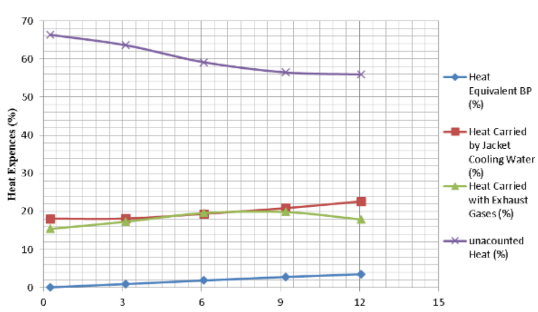

Fig. 11. Load vs heat expenses for Bio-CNG fuelled engine

Emission

The Table 6 shows the emission content of various components that are present in the exhaust gas. Gases like HC and NO are measured in ppm (parts per million by volume) and other gases like CO, CO_2, O_2 and Smoke are measured in percentage (%) by volume. The content of Carbon Mono-oxide in emission is much smaller in the Bio-CNG fuelled engine than that of the Diesel-fuelled engine. The content of hydrocarbon is very high in Bio-CNG fuelled engines. The emission of Carbon Dioxide is much smaller in Bio-CNG fuelled engines than that of Diesel-fuelled engines. The oxygen content in exhaust gases is greater for the Bio-CNG fuelled engine than for the Diesel fuelled engine. The Nitrogen Oxide content in the exhaust gas for Diesel engines is very high compared to that of the Bio-CNG fuelled engine. The content of Smoke in the exhaust gas for the Bio-CNG fuelled engine is almost zero but it is greater for the Diesel fuelled engine.

Tab. 6. Load vs emission

For diesel fuel						
Load, kg	CO, %	HC, ppm	CO_2, %	O_2, %	NO, ppm	Smoke, %
0.1	0	0	0	20.94	1	2.4
3.	0.02	0	0.7	19.84	45	9.3
6	0.03	1	1.7	18.29	156	8.7
9	0.03	8	2.7	16.89	265	8.4
12	0.07	17	4.1	14.86	365	9.2
For Bio-CNG fuel						
Load, kg	CO, %	HC, ppm	CO_2, %	O_2, %	NO, ppm	Smoke, %
0.2	0	4	0	20.57	6	0
3	0.03	255	0.3	18.62	5	0
6	0.03	193	0.5	18.52	6	0
9	0.02	105	0.5	18.69	8	0
12	0.02	79	0.4	18.77	27	0.4

Here, CO is Carbon Mono-Oxide in %, HC - Hydro Carbons in ppm (parts per million), CO_2 - Carbon Di-Oxide in %, O_2- Oxygen in %, NO - Nitrogen Oxide in ppm (parts per million).

The graphs (Fig. 12 and 13) show a graphical representation of various components in exhaust gases. CO, CO_2, and smoke contents are almost zero for Bio-CNG fuelled engines. The Bio-CNG fuel performed better while considered for emission than that of Diesel fuel.

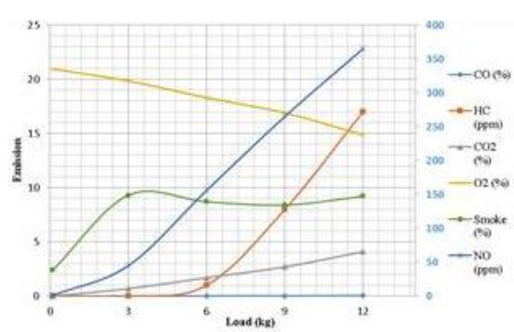

Fig. 12. Load vs emission for diesel fuelled engine

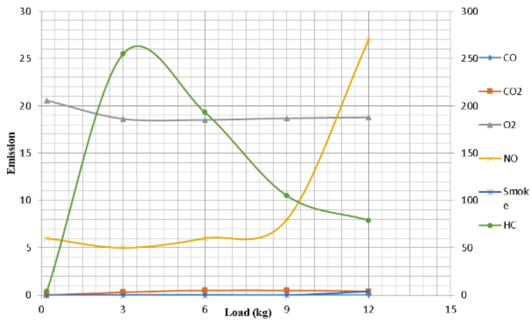

Fig. 13. Load vs emission for Bio-CNG fuelled engine

Temperatures observed

The tabular representation (Tab. 7) shows the temperatures at various sections during the performance evaluation. This data is obtained by varying the load from 0-12kg, the engine speed and compression are kept constant during the experimentation. The temperature of exhaust gases (T5) in the Bio-CNG fuelled engine is very high compared to that of the Diesel-fuelled engine.

Tab. 7. Observation table (temperatures)

For diesel fuel						
Load, kg	T_1, °C	T_2, °C	T_3, °C	T_4, °C	T_5, °C	T_6, °C
0.15	26.14	34.70	26.14	37.18	126.53	96.70
3.08	26.14	36.56	26.14	37.16	157.17	114.91
6.06	26.14	40.51	26.15	37.18	198.46	141.77
9.11	26.13	45.72	26.13	37.17	244.67	172.41
12.15	26.15	44.61	26.15	37.18	263.75	181.48
For Bio-CNG fuel						
Load, kg	T_1, °C	T_2, °C	T_3, °C	T_4, °C	T_5, °C	T_6, °C
0.25	26.36	39.67	26.36	37.32	307.14	210.84
3.13	26.39	39.72	26.40	37.32	341.42	231.78
6.08	26.36	40.60	26.36	37.34	373.32	259.03
9.20	26.65	42.00	26.66	37.35	383.02	271.69
12.06	26.83	43.47	26.83	37.35	361.73	261.82

Here, T1 - jacket cooling water inlet temp, T2 - jacket cooling water outlet temp, T3 - calorimeter water inlet temp, T4 - calorimeter water outlet temp, T5 - exhaust gas to calorimeter inlet temp, T6 - exhaust gas from calorimeter outlet temp.

3. RESULTS AND DISCUSSION

The following discussions are made based on the results above obtained during testing of the IC Engine.

3.1. Discussion

1. The maximum Brake Power generated by both fuels is almost the same.
2. The Indicated and frictional powers generated by Bio-CNG fuel are greater than that of diesel fuel as noted based on the observation data.
3. The maximum IMEP is greater in the Bio-CNG fuelled engine than that of the diesel-fuelled engine, BMEP is almost the same in both fuels, and FMEP is greater in the Bio-CNG fuelled Engine than that of the diesel-fuelled engine.
4. Brake thermal and indicated thermal efficiency is observed greater in the diesel-fuelled engine than that of the Bio-CNG fuelled engine.
5. The torque generated by both fuels is similar for all the loads, mechanical and volumetric efficiencies are higher in the diesel-fuelled engine than that of the Bio-CNG fuelled engine.
6. The heat equivalent to useful work (HBP) is very high in the diesel-fuelled engine compared to that of Bio-CNG fuel, heat carried with cooling jacket water (HJW) is greater in the diesel-fuelled engine, heat carried with exhaust gases (HGas) and unaccounted heat is greater in the Bio-CNG fuelled engine than that of the Diesel-fuelled engine.
7. The emissions of CO and CO_2 are much smaller in Bio-CNG fuelled engine, HC emission is much smaller in the Diesel-fuelled engine; similarly NO emissions are much smaller in Bio-CNG, smoke emission is much smaller in the Bio-CNG fuelled engine than that of the Diesel engine.
8. Economically, Bio-CNG is a more economic fuel than diesel fuel because the cost of Bio-CNG is 66Rs/kg and the Price of Diesel is 94Rs/kg (80Rs/lit).

3.2. Competitive results

Competitive results are presented in Table 8.

3.3. Challenges associated with Bio-CNG Technology:

1. The initial investment required for Bio-CNG conversion fuel is very high. It is estimated that it costs up to 1.65 crores to produce 400 kg/day, and to produce 5000 kg/day it costs about 16 crores [1].
2. The standards required for the maintenance, installation, and operations of new Bio-CNG plants are not pre-set in India.
3. Currently, the performance of Bio-CNG is lower than that of diesel fuel so the existing engine working on conventional fuels needs to be modified by considering Bio-CNG or other Bio-fuels as the primary fuel to improve the performance of the fuel.

4. CONCLUSIONS

The transportation sector plays a major role in the economy of every country in the world. The energy consumed for the transportation sector is mainly obtained by the combustion of fossil fuels. But the resources of fossil fuels are limited and they are being depleted rapidly; so the time has come to find an alternative fuel for transportation. An alternate fuel must underpin sustainable development because the combustion of fossil fuels produces a high amount of greenhouse gases which are adversely affecting the environment.

Tab. 8. Competitive results

Sr. No	Parameter	Diesel	Bio-CNG
1	Brake Power (kW)	✓	
2	Indicated power		✓
3	Frictional Power		✓
4	Brake Mean Effective Pressure	✓	
5	Indicated Mean Effective Pressure		✓
6	Frictional Mean Effective Pressure		✓
7	Brake Thermal Efficiency	✓	
8	Indicated Thermal Efficiency	✓	
9	Torque	✓	
10	Mechanical Efficiency	✓	
11	Volumetric Efficiency	✓	
	Overall Performance	✓	
12	**Heat Balance Sheet**		
	Heat Equivalent to Useful Work (HBP) %	✓	
	Heat Carried with Jacket Cooling Water (HJW) %	✓	
	Heat Carried With Exhaust Gases (HGas) %		✓
	Unaccounted Heat %		✓
13	**Emission**		
	Carbon Monoxide (CO)%	✓	
	Hydro Carbon (HC)ppm		✓
	Carbon Dioxide (CO_2)%	✓	
	Oxygen (O_2) %		✓
	Nitrogen Oxide (NO)ppm	✓	
	Smoke %	✓	
	Overall Emission	✓	
14	Economic		✓

In this research, we have used Bio-CNG as an alternative fuel. The results show that the engine working on the diesel fuel has performed better in most of the fields of performance but when as regards emissions, Bio-CNG has a very negligible greenhouse gas emission. On the other hand, diesel fuel emits a significant amount of greenhouse gases which need to be reduced for the purpose of sustainable development. The performance of IC Engines working on Bio-CNG can be improved by increasing the Compression ratio, upgrading the fuel injection system and making other improvements.

The competitive performance and a significantly lower emission of Bio-CNG fuelled engines make Bio-CNG an ideal alternative fuel for commercial fuels (Diesel).

Nomenclature

Symbols

T_1 – Jacket cooling water inlet Ttemp
T_2 – Jacket cooling water outlet emp
T_3 – Calorimeter water inlet temp
T_4 – Calorimeter water outlet temp
T_5 – Exhaust gas to calorimeter inlet temp
T_6 – Exhaust gas to calorimeter outlet temp

Acronyms

BMEP – Break Mean Effective Pressure
BP – Break Power
FMEP – Frictional Mean Effective Pressure
FP – Frictional Power
HBP – Heat Equivalent to Useful Work or Heat Equivalent to Break Power.
HGas – Heat Carried with Exhaust Gas
HJW – Heat Carried With Jacket Cooling Water
HRad – Unaccounted Heat or Heat Radiated to Surrounding
IMEP – Indicated Mean Effective Pressure
IP – Indicated Power
ηBth – Break Mean Effective Pressure
ηIth – Indicated Thermal Efficiency
ηMech – Mechanical Efficiency
ppm – Parts per Millions
RPM – Rotations per minute

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