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Research comparing insulated diesel engines with regular diesel engines powered by biogas in terms of performance metrics

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ABSTRACT

Fossil fuels are depleting at an alarming rate as a result of increased demand in the transportation and agricultural sectors , skyrocketing fuel prices in the international oil market that divert funds from vital areas like healthcare, education, poverty alleviation, and defense, and a host of environmental issues like climate change and the greenhouse effect caused by internal combustion engines. As a result, the hunt for alternative fuels is more important than ever. The renewable nature of vegetabl e oils and alcohols makes them viable alternatives to diesel fuels. Nevertheless, diesel engines encounter combustion issues due to the disadvantages linked to alcohols (low cetane number {measure of combustion quality} and calorific value) and vegetable oils (high viscosity and low volatility). The majority of India's alcohol production is redirected to the petrochemical sector. Since biodiesel has a moderate viscosity and oxygen in its molecular makeup, it is made from vegetable oils. But, low heat rejection (LHR) engines are required for these biodiesels because of the rapid heat release rate and quicker combustion rate that these engines provide, making them ideal for fuels with a low calorific value and a high viscosity. For numerous reasons, including lower pollution levels and higher calorific values, gaseous fuels are preferable to their liquid counterparts. Several techniques exist for inducting gaseous fuels, including port injection, carburetion technique, and injection at the end of th e compression stroke, among others. The experiments used biogas gas as the main fuel, pumped into the engine via the port, and traditional injection of cottonseed biodiesel as the secondary fuel. The ceramic-coated cylinder head served as the LHR engine's combustion chamber. While the LHR engine's maximum induction of biogas at full load was 45% of the entire mass of biodiesel, the CE engine's maximum induction was 35%. Brake thermal efficiency (BTE), brake specific energy consumption (BSEC), exhaust gas temperature (EGT), coolant load, and volumetric efficiency were measured at various values of brake power (BP) in conventional engines (CE) and low-speed hybrid (LHR) engines with maximum biogas induction. Compared to CE, LHR engine performance metrics were much better with maximal induction of biogas.

Key words: Diesel, biodiesel, CE, LHR engine, Performance parameters.

1. INTRODUCTION

The number of cars on a country's roads has become a proxy for the level of development in that nation's society. Cities are growing at an unprecedented pace due to the massive population increase, and the average person now has to travel great distances to accomplish even the most basic of tasks. The government is under increasing pressure to spend vast sums of foreign currency on importing crude petroleum to fulfill the fuel demands of the automotive vehicles, which is leading to an alarming growth in the population of automobiles.

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cars powered by fossil fuels are contributing significantly to air pollution, and this problem is becoming worse as the number of cars on the road rises. Apart from efficient fuel utilization, which has been a focus of engine manufacturers, users, and researchers engaged in combustion and alternative fuel research, the search for alternative fuels has become pertinent due to the fast depletion of fossil fuels and the heavy consumption of diesel fuel in the transportation and agricultural sectors.The engine's namesake creator, Rudolph Diesel, tried using peanut oil and powdered coal as fuels [1].Several studies on biodiesel in conventional engines (CE) found that it reduced particle emissions and somewhat enhanced performance. from two to eight. On the other hand, they found that while running on biodiesel instead of plain diesel on CE, NOx emissions were somewhat greater.Insulation throughout the coolant flow channel is fundamental to the LHR engine's design philosophy, which aims to minimise heat loss to the coolant. There are three levels of insulation for LHR engines: low grade (LHR-1), medium grade (LHR-2), and high grade (LHR-3). Low grade LHR engines are made using ceramic coatings on the piston, liner, and cylinder head; medium grade LHR engines are made with low-thermal conductivity materials (superni, cast iron, mild steel, etc.) and an air gap between the piston and other parts; and high grade LHR-3 engines are a hybrid of the two types.Results showed that running the LHR-1 engine on diesel enhanced performance and decreased particulate levels in experiments using low-grade LHR engines [9–11]. On the other hand, their levels of nitrogen oxide (NOx) rose.

Research using biodiesel in low-grade LHR engines found that the engines' performance was increased and particle emissions were lowered.on pages 12–14. On the other hand, their levels of NOx rose.

Biogas in a conventional engine was used for the investigations. Lower peak values of heat release rate were observed in the dual fuel mode. Additionally, they found that in-cylinder pressure was lowered and ignition delay was enhanced when exhaust gas recirculation (EGR) was applied to the dual fuel mode. [15]. When compared to other fuel modes, dual fuel mode emitted less nitrogen oxides and smoke opacity but significantly more HC and CO. Across the board, the engine's peak pressure and heat release rate were somewhat greater while operating in dual fuel mode as opposed to diesel or biodiesel. [16].The use of biogas, diesel-methane, and clean diesel in conventional engines was the subject of investigations [17]. At heavy loads, they found that the brake thermal efficiency were better than diesel mode. The volumetric efficiency of diesel and diesel-CH4 dual modes was almost same, however the temperatures of the exhaust gas were highest in the diesel-biogas mode, next in the diesel-methane mode, and finally in the diesel mode.on page 17.NOx levels are very sensitive to regional temperature changes. They found that compared to using only diesel fuel, the energy content rates in gas-fuel mixtures were lower in compression ignition engines operating at a constant speed of 1500 r/min under full load, and that both NOx and soot missions were eliminated [18].

The performance characteristics of LHR engines running on biogas or biodiesel were, however, scarcely documented. Therefore, writers have done work along these lines. This study compared data from a CE engine running on biogas with those of an LHR engine using biogas and cottonseed biodiesel in an effort to identify the performance characteristics of the former.

MATERIALS AND METHODS

Experimental Set-up

Table.1 gives the details of the engine.

Description	Specification
Make	Mahindra & Mahindra
Number of cylinders	01
Number of Strokes	04
Ratio of bore to stroke	93 mm/92 mm
Power	6.6 kW (9 HP) at the rated speed of 3000rpm
Compression Ratio	18:1
Type of cooling Arrangement	Water cooling
Recommended Injection Pressure	190 bar
Recommended Injection Timing	27 degrees before top dead centre
Maximum Torque	30 Nm at 1800 rpm.

Table.1
Details of the Engine

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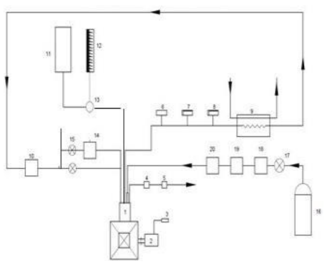
Fig.1 Table provides facts about the CRDi engine and the test engine (1).1 Applied Thermo Dynamics Laboratory of MED, CBIT, Hyderabad was its location. A power measurement device was attached to the engine (2). There was a computerized test bed for the engine. The engine could be loaded with ease using the variable rheostat. (3). A temperature sensor (4) was used to indicate the water temperature of the outlet



jacket. Use of a flow meter allowed for the measurement of the coolant's flow rate (5). A sensor that measures the temperature of exhaust gas was installed (6). Under full load conditions, the AVL Smoke meter (7) was used to measure the particle levels. Under full load conditions, the CO and UBHC pollutants were detected using a Netel Chromatograph multi gas analyzer (8). In Table 2, we can see the multi gas analyzer's range and accuracy. The system used an EGR (9) system to lower NOx emissions. An air flow sensor was used to measure the airflow (10). In a traditional injection system, biodiesel was introduced into the engine using a biodiesel tank (11), a burette (12), and a three-way valve (13). The EGR system was equipped with a bypass system. To measure the air flow rate from the atmosphere, a water manometer and an air box arrangement (14) were used. The bypass system b p was equipped with directional valves (15). Sixteen gas cylinders of CO2-free biogas were stored. An integrated pressure regulator (17) was part of the setup. The gas pressure sensor recorded the gas pressure (18). The gas's mass flow rate was measured using a rotometer (19). To make sure everyone was safe, the gas circuit used the flame arrestor (20). To measure the injection time, a cam position sensor was used. The engine's speed was determined using a crank position sensor. A fuel temperature sensor was used to ascertain the fuel's temperature. A gas injector was used to inject gas.

Table.2
Range and accuracy of Analyzers

S.No	Name of the Analyzer	Principle adopted	Range	Accuracy
1	AVL Smoke Analyzer	Opacity	0-100 HSU (Hartridge Smoke Unit)	±1 HSU
2	Netel Chromatograph CO analyzer	Infrared absorption spectrograph	0-10%	± 0.1%
3	Netel Chromatograph UBHC analyzer	NDIR	0-1000 ppm	±5 ppm
4	Netel Chromatograph NO_x analyzer	Chemiluminiscence	0-5000pm	±5 ppm

Engine, 2.Electical Dynamometer, 3.Load Box, 4. Outlet jacket water temperature indicator, 5.Outlet-jacket water flow meter Orifice meter, 6.Exhaust gas temperature indicator, 7 AVL Smoke meter, 8.Netel Chromatograph multi-gas analyzer 9. . Heat exchanger , 10. Air flow sensor, 11.Biodiesel tank, 12.Burette, 13.Three-way valve, 14.Air box with manometer arrangement, 15.Directional valve, 16.Gas cylinder, 17. Pressure regulator,18. Gas pressure sensor, 19.Flame arrestor and 20Rotometer

Fig.1. Schematic diagram of experimental set up

The engine came with a mechanism that uses gravity to keep it oiled. Biogas was introduced into the engine by port injection when the compression stroke was coming to a close. It was possible to use a sensor to raise the injection pressure.

Investigational fuels included (i) pure diesel and (ii) a combination of biogas and biodiesel. A standard, or base, engine and an insulated engine were the available combinations or versions. The performance metrics were calculated using test fuels and various engine braking power settings.

3. ANALYSIS AND DEBATE

A conventional engine (CE) with varying percentages of biogas induction and diesel is shown in Fig. 2 as is the fluctuation of brake thermal efficiency (BTE) with braking power (BP).

operation. BTE increased with an increase of BP up to 80% of the full load and beyond that load, it decreased with different percentages of induction of biogas. This is due to increase offuel conversion efficiency and mechanical efficiency up to 80% of the full load causing increase of BTE. However,

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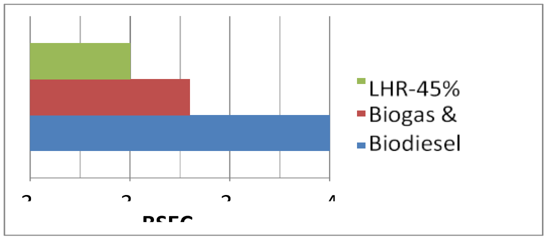


beyond 80% of the full load, decrease of fuel conversion efficiency and oxygen-fuel ratio made reduction of BTE. At all load, BTE increased with increase of induction of biogas up to 35%. This is due to improved oxidation reaction of CH4in biogas and O2 in the combustion chamber. However, beyond 35% induction of biogas, BTE decreased at all load when compared with neat diesel operation on CE. This is due to reduction of ignition delay with biogas causing to produce peak pressure at an early stage. Hence the optimum induction of biogas was limited up to 35% of total consumption of biodiesel by mass basis along with diesel operation. ‘’

Fig.2. Variation of BTE with BP with diesel and biogas operation in Conventional Engine(CE).

Fig.3 shows the variation of brake thermal efficiency (BTE) with brake power (BP) with LHE engine with various percentages of biogas induction along with biodiesel operation.

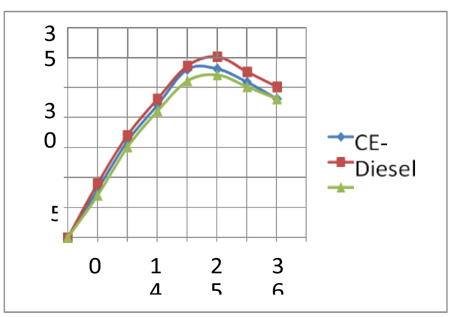
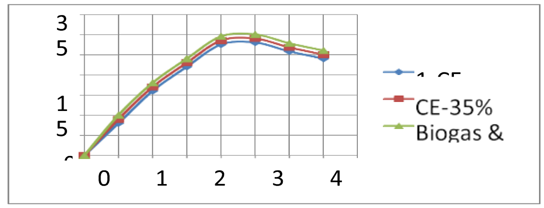


Fig.3. Variation of BTE with BP with diesel and biogas operation in insulated engine.

Variation of BTE with BP with biogas and biodiesel of LHR engine followed similar trendswith CE. However, the maximum or peak BTE was higher with LHR engine with biogas. This is due to improved oxidation reaction of CH4 with oxygen present in the biodiesel. Thisis also due to improved heat release rate and faster rate of burning of biogas and biodiesel in LHR engine. However, the optimum induction of biogas was limited up to 45% by mass basis with biodiesel operation in LHR engine.

Fig.4 shows the variation of BTE with BP with both versions of the engine with the maximum induction of biogas..4 Variation of BTE with BP in both versions of the engine.



As mentioned earlier, LHR engine showed improved performance than CE with biogas operation. This is due to improved heat release rates and faster rate of combustion with LHR engine**.** This is also because of LHR engine could absorb more quantity of biogas, in comparison with CE, leading to improve combustion with LHR engine.

Fig.5 presents the bar chart showing the variation of brake specific energy consumption (BSEC) at full load with different versions of the engine with maximum induction of biogas.BSCE at full load was lower with LHR engine in comparison with CE with maximum induction of biogas. Since, LHR engine could absorb higher quantity of biogas than CE, combustion improved with LHR engine due to high calorific value of methane, present in the biogas. Biodiesel has high cetane number and contains oxygen in its molecular composition, leading to improve the combustion with biodiesel.

Fig.5 Bar chart showing the variation of BSEC at full load

Fig.6 shows the variation of exhaust gas temperature (EGT) with brake power (BP) with both versions of the engine with the maximum induction of biogas. EGT increased with an increase of BP with both versions of the engine. This is due to increased mass flow rate of fuel with the load. EGT decreased with both versions of the engine in comparison with neat diesel operation on CE. This confirmed that performance improved with induction of biogaswith both versions of the engine, as

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ISSN 2347–3657
Volume 2, Issue 2, April 2014

the quantity of heat rejection was reduced and converted into actual work with induction of biogas. The oxidation reaction of CH4 present in biogas and oxygen present in biodiesel improved combustion and thus reduced heat rejection with induction of biogas. Reduction of combustion chamber deposits is also one of reasons to
reduce EGT. Combustion is clean with induction of biogas causing reduction of EGT with induction of biogas. LHR engine showed marginally higher EGT in comparison with CE, as there was heat release rate with LHR engine, hot gases are confined to combustion chamber with the provision of insulation with LHR engine causing increase of EGT with LHR engine.

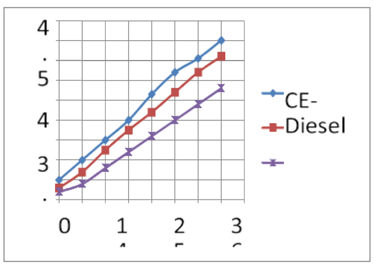

Fig.6. Variation of EGT with BP with both versions of the engine.

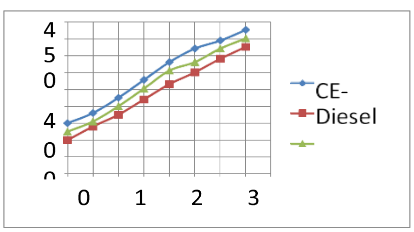

Fig.7 shows the variation of coolant load with brake power (BP) with both versions of the engine with the maximum induction of biogas.

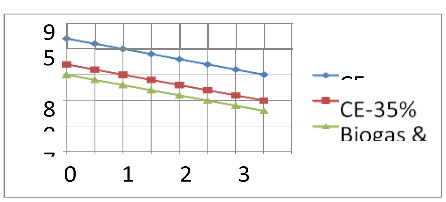

Fig.7. Variation of coolant load with BP with both versions of the engine.
Coolant load increased with an increase of BP with both versions of the engine with maximum induction of biogas. Coolant load decreased with induction of biogas due to reduction of un-burnt fuel concentration at the combustion chamber walls with induction of
biogas with improved combustion. Coolant load was lower with LHR engine due to the provision of thermal insulation in the path of heat flow to the coolant. EGTs were lower andthe temperatures of combustion chamber walls were lower with induction of biogas leadingto reduce coolant load..

Fig.8 shows the variation of volumetric efficiency with brake power (BP) with both versions of the engine with the maximum induction of biogas. Volumetric efficiency decreased with an increase of load with both versions of the engine due to reduction of air-fuel ratios. Volumetric efficiencies were lowered with induction of biogas with both versions of the engine due to the replacement of air with biogas. Volumetric efficiency depends on speed ofthe engine, air-fuel ratio, valve overlap, accumulation of un-burnt fuel concentration at combustion chamber walls. There was much reduction of un-burnt fuel concentration with induction of biogas with both versions of the engine. But air fuel ratio dominates this factor leading to reduce volumetric efficiency with the induction of biogas.

CONCLUSIONS

In a traditional engine, biogas induction may reach 35% at full load, but in an LHR engine, it reached 45% of the entire biodiesel mass. Every performance statistic, with the exception of volumetric efficiency, was enhanced with the LHR engine.

Fig.8. Variation of volumetric efficiency with BP with both versions of the engine.REFERENCES

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