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Comparative investigations on performance parameters of insulateddiesel engine and conventional diesel engine with biogas

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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 vegetable 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 petrochemical industry receives the vast majority of India's alcohol production. Since biodiesel has a moderate viscosity and oxygen in its molecular makeup, it is made from vegetable oils. However, LHR engines are required for these biodiesels because of their high heat release rate and rapid combustion rate, making them ideal for fuels with a low calorific value and a high viscosity. The various benefits of gaseous fuels over liquid fuels include lower pollution levels and higher calorific values, making them a safer alternative. Several techniques exist for inducting gaseous fuels, including port injection, carburetion technique, and injection at the end of the compression stroke, among others. Biogas gas was pumped into the engine via the port, and traditional methods of injecting cottonseed biodiesel were also used in the investigations. The LHR engine's combustion chamber was a cylinder head covered with ceramic. At full load, the highest intake of biogas in a CE engine was 35% and in an LHR engine it was 45% of the total mass of biodiesel. The following performance metrics were studied: volumetric efficiency, coolant load, exhaust gas temperature (EGT), brake specific energy consumption (BSEC), and brake thermal efficiency (BTE) at varying levels ofconventional engine (CE) and low-speed rotation (LHR) engine braking power (BP) with maximal biogas induction. The LHR engine outperformed the CE in almost every performance metric when the biogas induction was set to its maximum.

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. As a result, the number of automobiles on the road is growing at an alarming pace, putting pressure on the government to spend a lot of money importing crude oil to power all those cars. cars powered by fossil fuels are contributing significantly to air pollution.

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and this problem is becoming worse as the number of cars on the road rises. While efficient fuel utilization has long been a focus of engine makers, consumers, and researchers engaged in combustion and alternative fuel studies, the rapid depletion of fossil fuels, coupled with the high demand for diesel fuel in the transportation and agricultural sectors, has made the search for alternative fuels all the more pressing.

1. Rudolph Diesel tried using peanut oil and powdered coal as fuels in his experiments with the engine that was named after him [1].Several studies using conventional engines (CE) and biodiesel found that performance was somewhat better and particle emissions were lower. paragraphs 2–8. Nevertheless, it was mentioned that while using biodiesel on CE, NOx emissions were somewhat more than when using pure diesel.Insulation throughout the coolant flow channel is fundamental to the LHR engine's design philosophy, which aims to minimise heat loss to the coolant. Low grade insulated engines (LHR-1), medium grade insulated engines (LHR-2), and high grade insulated engines (LHR-3), are the three levels of insulation that LHR engines may be classed into. 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.Diesel operation with an LHR-1 engine enhanced performance and decreased particulate levels, according to experiments done on low-grade LHR engines with diesel [9–11]. Nevertheless, levels of nitrogen oxide (NOx) were elevated.Research using biodiesel in low-grade LHR engines found that the engines' performance was increased and particle emissions were lowered.Tables [12–14]. Nevertheless, their levels of NOx were elevated.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. For all engine loads, the peak pressure and heat release rate in dual fuel mode were marginally higher than in diesel and biodiesel modes of operation. [16].Research was conducted using conventional engines running on biogas, diesel-methane, and clean diesel [17]. When comparing diesel and brake modes under heavy loads, they found that the former had better thermal efficiency. While the volumetric efficiency of diesel and diesel-CH4 dual modes was almost same, 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.According to [17].NOx levels are very sensitive to regional temperature changes. At maximum load, they found that the compression ignition engine's NOx and soot emissions decreased while using a gas-fuel combination rather than diesel fuel alone, and that the engine's speed remained constant at 1500 r/min [18].Nevertheless, there was a lack of information about the performance metrics associated with LHR engines running on biogas and biodiesel. Therefore, writers have done work along these lines. This

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.

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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

1.1. Experimental Set-up

Table.1 gives the details of the engine.

Table.1

Details of the Engine

Fig.1 shows that the test engine (1) and the details of the CRDi engine are given in Table.1 It was located at Applied Thermo Dynamics Laboratory of MED, CBIT, Hyderabad. The engine was connected to power measuring device (2). The engine had computerized test bed. There was facility of loading the engine by means of variable rheostat. (3). Outlet jacket water temperature was indicated with temperature sensor (4). The flow of the coolant was measured with flow meter (5). The temperature of the exhaust gas was indicated with exhaustgas temperature sensor (6). The particulate levels were determined with AVL Smoke meter at full load operation. The pollutants of CO and UBHC were determined by Netel Chromatograph multi gas analyzer (8) at full load operation. The range and accuracy of the analyzers in multi gas analyzer are shown in Tabl.2. EGR (9) system was employed in the system to reduce NO_x emissions. Air flow was measured with air flow sensor (10). Biodieseltank (11), burette (12) and three way valve (13) were used to induct biodiesel into the engine in conventional injection system. Bypass system was provided for EGR system. Air box arrangement (14) along with water manometer was employed to measure air flow rate from atmosphere. Directional valves (15) were provided for bypass system b p Biogas clean fromCO2 was stored in a gas cylinder (16). Pressure regulator (17) was incorporated in the system. The pressure of the gas was noted in gas pressure sensor (18). The mass flow rate of the gas was noted by means of a rotometer (19). The flame arrestor (20) was employed in the gas circuit to ensure safety. Cam position senor was used to measure injection timing. Crankposition sensor was used to determine the speed of the engine. Fuel temperature was determined with fuel temperature sensor. Gas was injected through gas injector. 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	Infra red absorption spectrograph	0-10%	± 0.1%
3	Netel Chromatograph UBHC analyzer	NDIR	0-1000 ppm	±5 ppm
4	Netel Chromatograph NO_x analyzer	Chemiluminiscence	0-5000ppm	±5 ppm

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1. 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

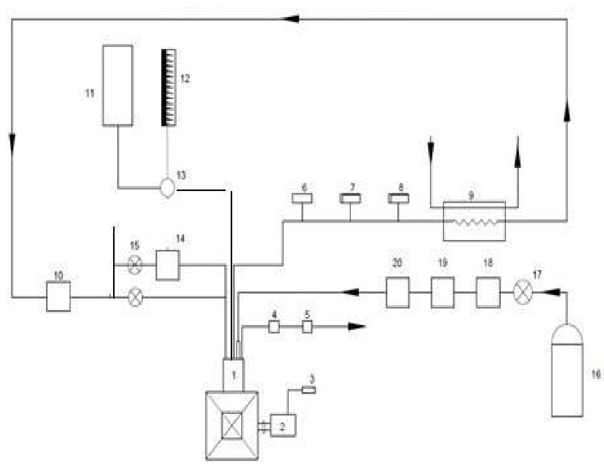

Fig.1. Schematic diagram of experimental set up

The engine was provided with gravity lubrication system. Biogas was inducted through portinjectionat the near end of compression stroke of the engine. There was facility to increase injection pressure by means of sensor.

The test fuels of the investigations were i) neat diesel and ii) biogas and biodiesel. The configurations or the versions of the engine were normal or base engine and insulated engine. Performance parameters were determined at different values of brake power of the engine with test fuels.

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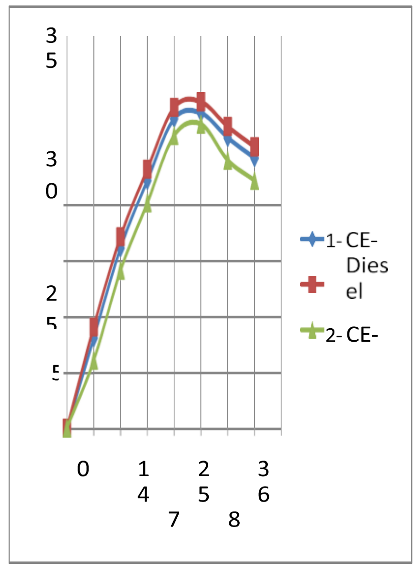
3. RESULTS AND DISCUSSION

Fig.2 shows the variation of brake thermal efficiency (BTE) with brake power (BP) with conventional engine (CE) with various percentages of biogas induction along with diesel 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 of fuel conversion efficiency and mechanical efficiency up to 80% of the full load causing increase of BTE. However, 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 CH_4 in biogas and O_2 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.



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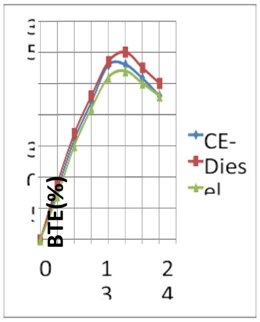
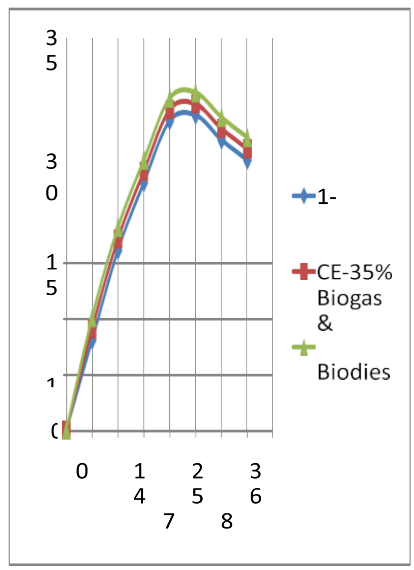


Fig.3. Variation of BTE with BP with diesel and biogas operation in insulated engine.

Fig.4 Variation of BTE with BP in both versions of the engine.

Variation of BTE with BP with biogas and biodiesel of LHR engine followed similar trends with 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 inLHR 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.



BTE (%)

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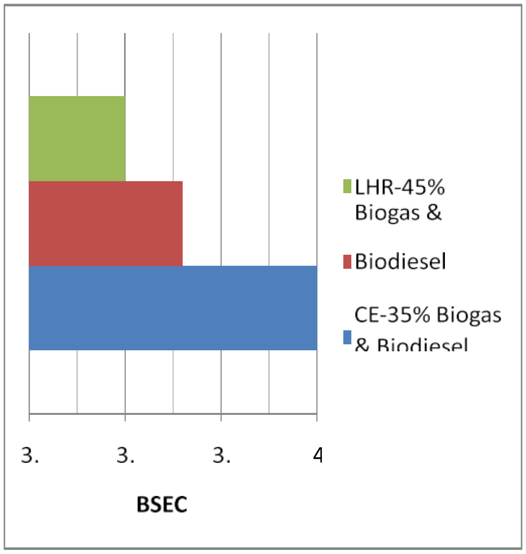

As mentioned earlier, LHR engine showed improved performance than CE with biogas operation. This is due to improved heat release rates and faster rate of combustion with LHR engine. This is also because of LHR engine could absorb more quantity of biogas, in comparison with CE, leading to improve combustion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

EGT (° C)

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 neatdiesel operation on CE. This confirmed that performance improved with induction of biogas with both versions of the engine, as 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, asthere 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

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LHR engine.

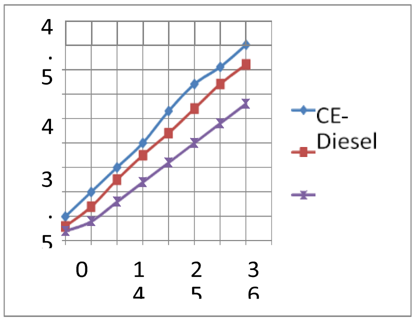

Fig.6. Variation of EGT with BP with both versions of the engine.

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

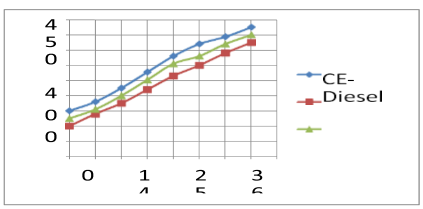

Fig.8. Variation of volumetric efficiency with BP with both versions of the engine.

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 and the 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 of the 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.

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

4. CONCLUSIONS

The maximum induction of biogas in conventional engine was 35%, while with LHR engine, it was 45% of total mass of biodiesel at full load operation. LHR engine improved all performance paramters except volumetric efficient

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