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Potential Benefits of Diesel Aloe Vera Emulsified Fuel in A Non-Road Diesel Engine

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Abstract : In this paper, an experimental attempt has been made to improve the performance and emission of a non-road diesel engine using adiesel aloe vera emulsified fuel (A10). Two fuel samples such as neat diesel (D100) and diesel aloe vera emulsified fuel referred to as A10 (10% aloe vera, 89% diesel, 1% surfactant) was used to conduct the experiments and the obtained results were compared. The experiments were carried out on a single cylinder non-road Genset diesel engine at low load (BMEP 1.54 bar), mid load (BMEP 3.09 bar) and high load(BMEP 4.63 &6.18 bar) conditions.The experimental results show that the dieselaloe vera emulsified fuel resulted in reduced nitric oxide (NO) with increased brake thermal efficiency (BTE). overall, a 19.24% reduction in NO emission and a 9.82% increase in BTE was observed. Also, it was noticed that the A10 prolonged the ignition delay and improved the air-fuel mixing inside the combustion chamber.
Keywords: Non-road diesel engine, Aloe vera, Emulsified fuel, NO, BTE.

Introduction

The use of Non-road diesel engines to our society is largerespecially in anapplication such as agriculture, construction vehicles, power production, gas compression, and production of inert gas. Due to this, the non-road diesel engines also contributing to environmental pollution caused due to its exhaust emissions as well as on-road diesel engines[1].Intensive large-scale research on non-road diesel enginesbecomingmore important due to the government's emission norms on non-road diesel engines[2].The in-cylinder treatment techniques are the best feasible solution for better fuel economy and cleaner emissionsthan external treatment devices due to its high cost[3]. With this as a research motivation, in this research work, an effort had been taken to modify a diesel fuel using aloe vera to prepare adiesel aloe vera emulsified fuel. Few researchers showed an

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interest in using an aloe vera in a diesel engine along with nanoparticles and additives such as metal oxide and cerium oxide[4-6].Aloe vera contains both moisture and oxygen content. The use of aloe vera diesel blended fuel reduced NO emissions when 5% EGR was used[7]. To prepare and use the dieselaloe vera emulsified fuel in a compression ignition engine,aclear knowledge about the effect of emulsified fuels on a diesel engine is necessary. Hence a literature survey on emulsified fuels was made. Table 1 shows a summary of some of the existing literatures on emulsified fuels.This paper addresses an experimental effort made on a single cylinder Genset diesel engine to explore the potential outcomes of dieselaloe vera emulsified fuel without using the EGR system.

Table 1.Summary of some of the existing literatures on emulsified fuels (All results obtained from emulsified fuels compare to neat diesel).

Reference / Engine specification	Operating conditions	Performance/ Combustion results	Emission results
8/ HD diesel engine CC:2L; CR:17.25	Fuel: D/20-40%W Speed: 1800 rpm SOI: -2° CA a-TDC	ID:↑ SFC:↓ at low loads, ↑at high loads.	NO: ↓ Soot: ↓ at low loads, ↑at high loads.
9/ Single-cylinder diesel engine, CR:17. Four-cylinder diesel engine, CR: 17.	Fuel: D/10-30%W Speed:1000-1600rpm	ID: ↑ PCP: ↓ MHR: ↓ SFC: ↓ BTE: ↑	NO: ↓
10/ Turbocharged toyota diesel engine CC: 2.5L; CR: 18.5 RP:75kw @ 3600 rpm	Fuel: D/10%W Speed:800-3600rpm Load: 0-100%	ID: ↑ PCP: ↓ MHR:↑ at low loads ↓ at high loads SFC:↑ BTE:↓	NO: ↓ CO: ↑
11/ Single cylinder engine CC:0.638L; CR:17.7 RP:8.1kw@2400 rpm	Fuel: J/10%W SOI1: 23° b-TDC SOI2: 0,3,6° a-TDC Load: 3,4.5,6 kW Speed: 2000 rpm P_{inj}:1000 bar	ID: ↑ PCP: ↓ MHR: ↓ SFC:↑ BTE:↓	NO: ↓ HC: ↓ CO: ↑
12/ Four-Cylinder engine CC:1.45L, CR: 21.5	Fuel: D/5-30%W Speed:1000-3000rpm	ID: ↑ SFC:↑ BTE: ↑ for 5% emulsified fuel	NO: ↓ Soot: ↓
13/ Four-Cylinder turbocharged engine CC: 3.612L; CR:17.1 RP:80kw@3200 rpm	Fuel: D/0-30%W Speed: 2000rpm Oxygen supplied at intake manifold using oxygen cylinders. DWE+OE combustion mode	ID:↓ PCP: ↓ for DWEC PCP: ↑ for DWE/OEC MHR:↑ for DWEC MHR: ↓ for DWE/OEC SFC: ↓ BTE: ↑	NO: ↓ Soot: ↓
14/ Single cylinder engine CC: 0.406L, CR:19.3 RP: 4.2 kW	Fuel: D/5-20%W Load: 25-100% Speed: 3000 rpm SOI: 13° b-TDC P_{inj}: 200 bar	ID: ↑ PCP: ↓ MHR: ↓ SFC: ↓	NO: ↓ Soot: ↓ CO: ↑
15/ Renault F8Q 4-cylinder automotive diesel engine	Fuel: D/10%W Speed:2000-3500rpm Torque:11-105 N-m BMEP:0.75-7.05 bar	PCP: no change MHR: ↑ SFC: ↓ BTE: ↑	NO: ↓ Soot: ↓ HC: ↓

16/ Ford 4-cylinder automotive engine CC:1.8L, CR: 21.50 RP:45kw@4800 rpm	Fuel: D/5-15%W Speed:1000-5000rpm	SFC:↑ BTE:↓	NO: ↓ Soot: ↓ CO: ↓
Abbreviation: HD-Heavy duty; CC- Cubic centimeter; CR-Compression ratio; D-Diesel; W-Water; J-Jatropha; SOI-Start of injection; CA-Crank angle; a TDC-After top dead center; b TDC-Before top dead center; ID-Ignition delay; SFC-Specific fuel consumption; NO-Nitric oxide; rpm-revolution per minute; PCP-Peak cylinder pressure; MHR-Maximum heat release; BTE-Brake thermal efficiency; RP-Rated power; kW-kilowatt; CO-Carbon monoxide; HC-Hydro carbon; P_{inj}-Fuel injection pressure; DWEC-Diesel water emulsified combustion; OEC-Oxygen enrichment combustion; BMEP-Brake mean effective pressure; EGR-Exhaust gas recirculation			

Experimental Procedure

The experimental procedure consists of fuel preparation and followed by the selection of an experimental test engine.

(i) Fuel Preparation

The fuel preparation process was made by the four-step process as described below.

Step1: Transesterification process

The aloe vera gel from the raw aloe vera plant was collected separately. The methanol was added with the aloe vera gel in the ratio 1:5 (Methanol: Aloevera gel). The potassium hydroxide (KOH) catalyst of 0.5% weight was added to fasten the reaction. The temperature was maintained at 40°C for 30 minutes to complete the esterification. After 30 minutes the mixture was allowed for the sedimentation process for 24 hours. Then after the sedimentation process, the aloe vera methyl ester oil floats on top of the vessel were separated. The percentage of yielded pure aloe vera methyl ester oil was about 75%. Figure 1 and Figure 2 show the raw aloe vera plant and the aloevera methyl ester oil obtained after the transesterification process.

Figure 1. Raw Aloe vera plant

Figure 2. Aloe vera methyl ester oil

Table 2. Percentage composition of dieselaloe vera emulsified fuel

Raw materials	Composition (%)
Diesel	89%
Esterified aloe vera oil	10%
Span 80	0.5%
Tween 80	0.5%

Step 2: Emulsion preparation

Table 2 shows the Percentage composition of diesel aloevera emulsifiedfuel. The required composition (refer Table 2) to form a mixture was collected in the beaker. For efficient emulsion formation by reducing the interfacial tension between the diesel fuel and the esterified aloe vera oil the surfactant such as span 80 and tween 80 was used. The mixture was allowed to mix thoroughly for about 30 minutes using a magnetic stirrer. Figure 3 and Figure 4 shows the pictorial representation of magnetic stirrer and surfactants.

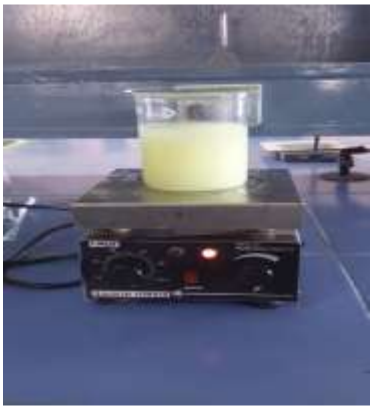

Figure 3. Magnetic Stirrer

Figure 4. Surfactants

Figure 5. Diesel aloe vera emulsified fuel(A10)

Step 3: Stability check and Calculation of HLB value

The Figure 5 shows the diesel aloe vera emulsified fuel (A10). The obtained fuel after the emulsion process calleddieselaloe vera emulsified fuel was kept separately and ideally to check its stability. It was observed that the emulsified mixture was able to be stable for 5 hours. Then again repeated three to four samples are tested for stability check for accuracy and showed stability for around 5 hours. Figure 6 shows the A10 fuel under stability check. The HLB (hydrophilic-lipophilic balance) value was calculated which was shown below.

$HLB_{resultant}$= (HLBvalue x weight percentage)$_{Span80}$ + (HLBvalue x weight percentage)$_{Tween80}$
= (4.3 x 0.5) + (15.6 x 0.5)
= 9.95

Figure 6. A10 fuel under Stability check

Step 4: Measurement of properties

The properties of the fuels are measured as per the American standard for testing and materials(ASTM) standards. Table 3 shows the properties of neat diesel (D100) and dieselaloe vera emulsified fuel (A10).

Table 3. Properties of neat diesel and diesel aloevera emulsified fuel.

Properties	**D100**	**A10**
Density, kg/m3	830	851
Calorific value, kJ/kg	41756	38330
Kinematic viscosity, cst	2.57	5.705
Flashpoint, °C	55	65
Fire point, °C	60	67

(ii) Selection of test engine set-up

The Kirloskar make TAF1 single cylinder naturally aspirated air-cooled compression ignition engine with a displacement volume of 662 cm^3 which produces a maximum power output of 4.42 kW at a constant speed of 1500 rpm has been used for experimentation. Table 4 shows the technical specifications of the test engine set-up. The schematic illustration of the test engine set-up was shown in Figure 7.The required instrumentations and measuring devices were provided with the test engine set-up to facilitate accurate fuel measurements and emission measurements.The swing filed (make-power stars) electrical dynamometer was used to load the engine.The fuel consumption was measured using a gravimetric fuel consumption unit.The engine lube oil, intake air temperature, and the exhaust gas temperature are measured using the K-type thermocouple.The AVL pressure transducer was used to precisely measure the in-cylinder pressure having a measuring range from 0 bar to 150 bar.The AVL crank angle encoder was used to measure the crank signal from the engine's crankshaft. The AVL combustion analyzer was used to measure the combustion parameters. The AVL gas analyzer was used to measure exhaust gas emissions.The uncertainty was calculated for the repeated three engine test data's and it was within the tolerance range. Hence the uncertainty will not affect the results.The uncertainty was calculated based on the detailed procedure given in the previous literature[17]. The uncertainty for the measured and the calculated parameters are shown in Table 5.

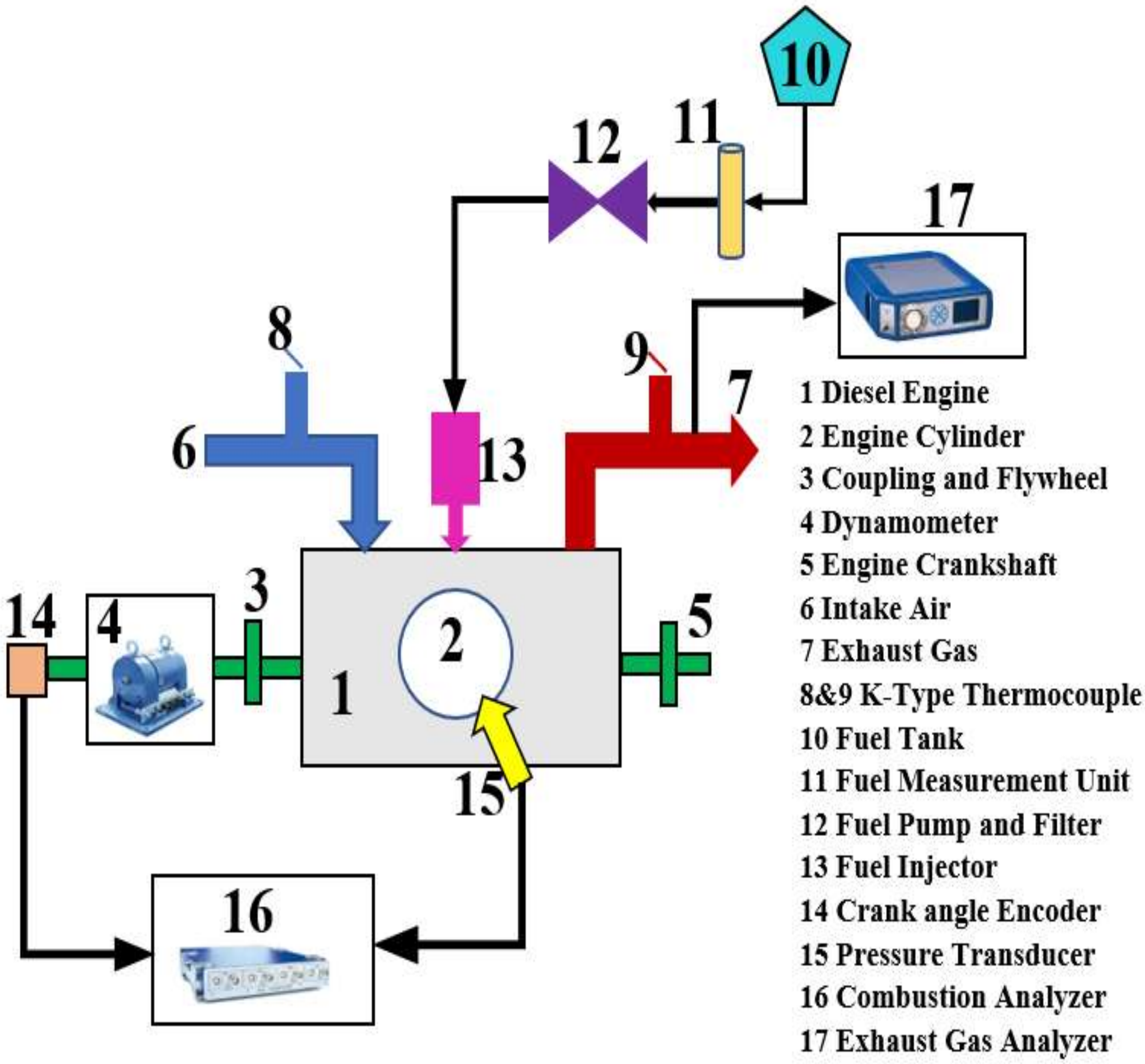

Figure 7. Schematic illustration of the test engine set-up

Table 4. Technical specifications of the test engine set-up

Model/ Type	**TAF1/ Vertical, Single cylinder, Four stroke, Air-cooled diesel engine**
Bore*stroke mm	87.5 & 110 mm
Displacement cc	662 cc
Rated power kW @ rpm	4.42 kW @ 1500 rpm
Compression ratio	17.5:1
Specific fuel consumption g/kWh	252 g/kWh
Fuel injection pressure bar	250 bar

Table 5. Uncertainty for the measured and the calculated parameters (Test condition: BMEP: 3.09 bar, Fuel: A10)

Parameters	Unit	Uncertainty (%)
Speed	rpm	0.1
Torque	N-m	0.4
Airflow rate	kg/h	0.2
Fuel flow rate	kg/h	0.6
NO	ppm	0.4
BTE	%	0.5

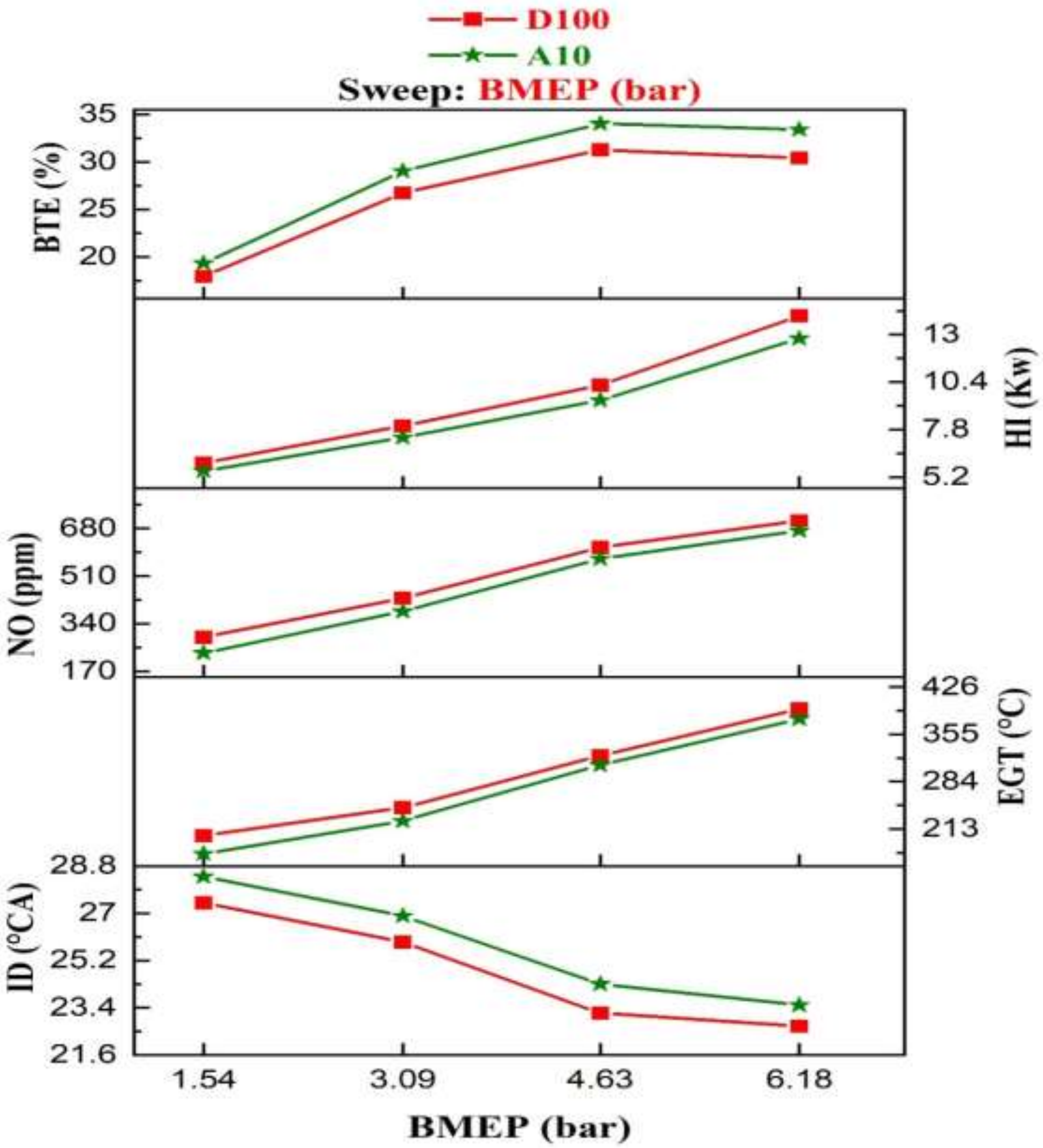

Figure 8.Effect of BMEP sweep on performance and emission of D100 and A10.

Results and Discussion

The experimental results obtained by fueling diesel aloe vera emulsified fuel (A10) in a single cylinder Genset diesel engine were analyzed and compared with the neat diesel (D100).

Figure 8 shows the effect of BMEP sweep in using dieselaloe vera emulsified fuel over neat diesel on Ignition delay (ID), Exhaust gas temperature (EGT), Nitric oxide (NO), Heat input (HI) and Brake thermal efficiency (BTE).

It can be seen from Figure 8that the ignition delay (ID) decreases with an increase in load for both D100 and A10. This could be due to an increased in-cylinder temperature which leads to the early start of ignition. The ID increases for A10 when compared to D100. This could be due to the addition of aloe vera methyl ester oil and an increase in moisture content.

It can be seen from Figure 8 that the exhaust gas temperature (EGT) increases with an increase in load for both D100 and A10. This could be due to the increased in-cylinder combustion temperature. The EGT decreases for A10 fuel compared to D100. This could be due to low in-cylinder temperature caused due to aloe vera addition.

It can be seen from Figure 8 that the Nitric oxide (NO) emission increased with an increase in engine load for both D100 and A10. This could be due to the high temperature and availability of oxygen content.The NO emission reduced for A10 compared to D100. This could be due to the reduction of combustion temperature caused by the addition of aloe vera.

It can be seen in Figure 8, the heat input (HI) increases with an increase in BMEPfor both D100 and A10. This could be due to the increased total fuel consumption needed for the engine to produce power. The HI reduced for A10 compared to D100 due to the lower calorific value of A10.

It can be seen from Figure 8 that the Brake thermal efficiency (BTE) increased with an increase in BMEPfor both D100 and A10. This could be due to the increased power output at the engine's crankshaft. The BTE increased for A10 compared to D100. This could be due to the reduced heat input, and reduced compression work caused due to prolonged ignition delay.

Conclusions

The following important conclusions were made based on the experimental work performed in a non-road diesel engine fueled with diesel aloe vera emulsified fuel (A10) when compared to neat diesel (D100).

1. The diesel aloe vera emulsified fuel (A10) serves as the best renewable fuel and alternative to diesel fuel.
2. The dieselaloe vera emulsified fuel was capable of reducing NO emission with increased brake thermal efficiency.
3. The ignition delay was increased for A10 at all load points compared to D100 which leadsto better mixing of air and fuel.
4. The compression work was reduced due to prolonged ignition delay for A10.
5. The maximum 19.24% reduction in NO was observed for A10 when compared to D100.
6. The maximum 9.82% increment in BTE was observed for A10 when compared to D100.

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