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Experimental Investigations on the Engine Performance and Characteristics of Compression Ignition (CI) Engine Using Dual Bio – Fuel Methyl Ester As Alternate Fuel With Exhaust Gas Recirculation

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Abstract
Petroleum products and resources are limited and their consumption is increasing very fast with globalization and high technology development since last decade. The emissions from the petroleum products polluting the environment considerably. Bio-fuels can be produced from diverse sources, which are subject to local geography, topology and climatology. Hence, every nation will have its own choice of a source. Duel bio-fuel represents an untapped resource of energy easily available in India. This study investigates the potential substitution of duel bio-fuel methyl ester blends for diesel as fuel for automobiles and other industrial purposes. This study is concerned with the analysis of the performance and emission characteristics of the duel bio-fuel methyl esters and comparing with petroleum diesel. The fuels used were neat methyl ester, diesel and different blends of the methyl ester with diesel. The tests were carried out on a 4.4 KW, single cylinder, direct injection, air-cooled diesel engine. The fuels used were neat duel bio-fuel methyl ester, diesel and different blends of the methyl ester with diesel. The experimental result shows that 20% of blend shows better performance with reduced pollution. This analysis shows that duel bio-fuel methyl ester and its blends are a potential substitute for diesel.
Keywords— Dual biofuel methyl ester,CI engine, exhaust gas recirculation, Animal Palm Diesel (APD)

I. INTRODUCTION

The tremendous growth of vehicular pollution and industrialization of the world has led to steep rise in the demand for petroleum products. The high consumption of diesel fuels and limited sources of the others are reasons for an enormous rise in prices of petroleum fuels [1]. It has been found that biodiesel hold special promise in this regard, since it can be produced from plants like Jatropha, Mahua, Neem, Cotton seed, Rape seed, Palm, Karanja etc. Biodiesel is a completely natural, clean burning, renewable, non- toxic, biodegradable and eco friendly fuel. Even though Diesel is a part of its name, there is no petroleum or other fossil fuels in biodiesel. Biodiesel is 100% vegetable oil based [2]. Biodiesel is one of the renewable alternative fuels that actually reduce major green house gas components in the atmosphere. Any substance that can be used as fuel other than conventional fuel is called alternate fuel. The alternate fuels are available in three forms i.e. solid, liquid and gaseous. CI engine is the most efficient and versatile prime mover when compared with SI engine, therefore manufacturers have come out with CI engines in personal transportation. CI engines are used both for mobile and stationary electric generating plants of varying capacities.

Bio-diesel is a domestic, renewable fuel for diesel engines derived from natural oils like vegetable oils. Bio-diesels can be used in any concentration with petroleum based diesel fuel in existing diesel engines with little or no modification. Bio-diesel is not the same thing as raw vegetable oil. It is produced by a chemical process, which removes glycerol from the oil. Chemically, it is a fuel comprised of a mix of mono-alkyl esters of long chain fatty acids. A lipid transesterification production process is used to convert the base oil to the desired esters and remove free fatty acids. After this processing, unlike straight vegetable oil, bio-diesel has very similar combustion properties to petroleum diesel, and can replace it in most current uses.

TRANS-ESTERIFICATION is the process of exchanging the alkoxy group of esters by another alcohol. The most important variables that influence trans-esterification reaction time and conversion are reaction temperature, ratio of alcohol to oil, Catalyst type and concentration, Mixing intensity, purity of reactants.

Base catalysis is also one of the method used for the manufacturing of bio-disel. The steps involved in this process are as follows.

- Weight 6 kg of crude oil (refined oil) and pour it into the reactor for preliminary heating to temperature of about 60-70^{0}C.
- In separate container, dissolve 22.8 grams of NAOH (3.8 grams per liter of oil) in 1.2L methanol (200 ml per liter) add the NAOH slowly. This combined mixture makes sodium methoxide.
- Add this to crude oil. Provide rigorous mixing with the use of stirrer.
- The cloudy looking free fatty acids, called glycerin, will sink to the bottom and the methyl ester translucent liquid, will remain on the top.
- When the separation appears not to be advancing any more, stop mixing.
- Let the mixture settle overnight.
- The liquid on the top is methyl ester, but before using it any remaining soaps or salts which could cause engine damage have to be removed.

II. DUAL BIO-FUEL AS BIO DIESEL

Duel bio-fuel means it is an exact mixture of two bio-fuels (palm oil + animal fat oil).The proportions of dual bio-fuel are

FUEL	FLASH POINT (Deg)	FIRE POINT (Deg)	DENSITY (Kg/m^3)	CALORIFIC VALUE(Kj/kg)
Diesel	56	62	827	43000
20(APD)	66	74	835.6	41854
40(APD)	74	85	844.2	40708
60(APD)	80	97	852.8	39562
80(APD)	110	128	861.4	38416
100(APD)	162	178	870	37270

III. EXPERIMENTATION

CI ENGINE: The engine used is four stroke vertical single cylinder diesel engine. The panel board is provided with 3 way cock, digital temperature indicator with selector switch, digital RPM indicator and U-tube manometer. The experimental procedure is as follows:

1. The fuel level and lubrications oil levels are checked and three way cock is opened so that the fuel flows to the engine.
2. The electrical power is supplied to the panel instrumentation.
3. The engine is de-compressed by decompression lever provided on the top of the engine head.
4. The engine is unloaded by removing the weights from the hanger.
5. The engine is started by cranking.
6. The experiment is repeated for different loads.
   The readings are noted are:

- Time taken for 10cc fuel consumption in seconds (t).
- Manometer reading (hw).
  The above steps 5 & 6 are repeated for different blends of fuels.

For the measurement of exhaust emission exhaust gas analyzer was used. A microprocessor controlled exhaust gas analyzer (AVL Five Gas Analyzer) was utilized to measure the composition of exhaust gas. The specifications of the system are given in Appendix E. It works on Non-Destructive Infra-Red (NDIR) techniques. This unit measures carbon monoxide, carbon dioxide, nitrogen oxides and hydrocarbons. A further channel is provided employing electrochemical measurement of oxygen.

For the measurement of smoke, smoke meter was used. The smoke meter samples a volume of exhaust gas, which is freely definable by the operator within the generous limits by means of probe in the exhaust gas line and sucks it through a clean piece of filter paper.

IV. EXPERIMENTAL RESULTS

A. Performance and Emissions of CI Engine For 20% APD:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	4.4	14.9	26	38.2	50.4
I (amp)	0	4.5	9	13.5	18
T (sec)	65	47	37	31	25
m_f	0.463	0.64	0.813	0.97	1.203
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.582	0.37	0.294	0.273
η_{bth}	0	14.78	23.3	29.26	31.5
η_{mech}	0	43.1	60.2	69.4	75.2

B. Emissions of 20% APD:

BP(kw)	0	1.1	2.2	3.3	4.4
CO(%)	0.07	0.06	0.06	0.05	0.08
CO_2(%)	2.00	3.00	4.30	5.40	6.90
HC(ppm)	23	21	19	18	21
NO_x(ppm)	152	426	749	1039	12.88
O_2(%)	17.63	16.17	14.42	12.88	10.77

C. Performance and Emissions of CI Engine For 40% APD:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.0	14.6	25.8	37.4	49.3
I (amp)	0	4.5	9	13.5	18
T (sec)	76	51	38	30	25
m_f	0.40	0.596	08	1.01	1.216
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.54	0.364	0.307	0.276
η_{bth}	0	16.32	24.13	28.89	32
η_{mech}	0	43.1	60.2	69.4	75.2

D. Emissions of 40% APD:

BP (kw)	0	1.1	2.2	3.3	4.4
CO (%)	0.08	0.06	0.04	0.04	0.06
CO_2 (%)	1.90	3.10	4.10	5.50	7.00
HC (ppm)	163	486	829	1172	1399
NO_x(ppm)	19	19	19	16	23
O_2 (%)	17.91	16.23	14.80	12.83	10.72

E. Performance and Emissions of CI Engine For 60% APD:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.4	14.8	25.9	37.8	49.4
I (amp)	0	4.5	9	13.5	18
T (sec)	78	51	38	31	25
m_f	0.394	0.602	0.81	0.99	1.228
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.547	0.367	0.31	0.279
η_{bth}	0	16.6	24.7	30.33	69.4
η_{mech}	0	43.1	60.2	69.4	75.2

F. Emissions of 60% APD:

BP (kw)	0	1.1	2.2	3.3	4.4
CO (%)	0.08	0.06	0.04	0.04	0.06
CO_2 (%)	1.90	3.10	4.10	5.50	7.00
HC(ppm)	163	486	829	1172	1399
NO_x(ppm)	19	19	19	16	23
O_2 (%)	17.91	16.23	14.80	12.83	10.72

G. Performance and Emissions of CI Engine For 80% APD:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.6	14.1	26	37.7	49.4
I (amp)	0	4.5	9	13.5	18
T (sec)	77	51	38	30	25
m_f	0.40	0.61	0.82	1.03	1.24
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.55	0.37	0.31	0.28
η_{bth}	0	16.9	25.3	30	33.3
η_{mech}	0	43.1	60.2	69.4	75.2

H. Emissions of 80% APD:

BP(kw)	0	1.1	2.2	3.3	4.4
CO (%)	0.07	0.06	0.05	0.04	0.07
CO_2 (%)	1.80	2.90	4.20	5.50	7.10
HC(ppm)	18	20	18	17	18
NO_x(ppm)	173	428	817	1166	1385
O_2 (%)	17.98	16.41	14.68	12.88	10.76

I. Performance and Emissions of CI Engine For 80% APD:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.6	14.1	26	37.7	49.4
I (amp)	0	4.5	9	13.5	18
T (sec)	77	51	38	30	25
m_f	0.40	0.61	0.82	1.03	1.24
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.55	0.37	0.31	0.28
η_{bth}	0	16.9	25.3	30	33.3
η_{mech}	0	43.1	60.2	69.4	75.2

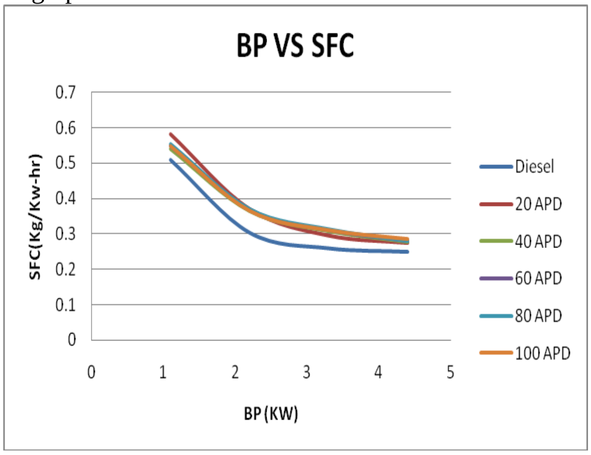
J. Performance and Emissions of CI Engine For 100% APD:

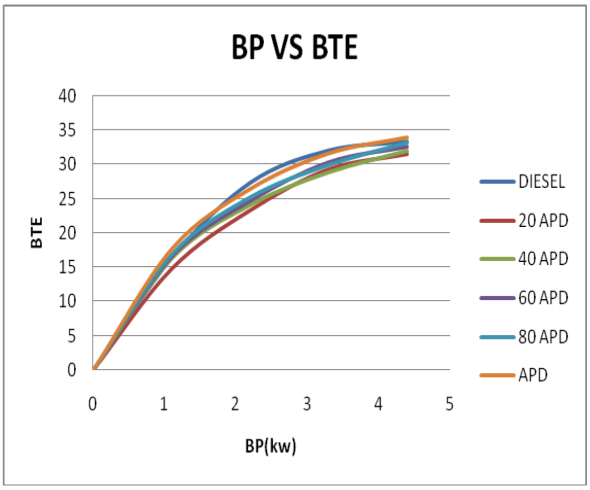
N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.4	14.8	25.9	37.8	49.4
I (amp)	0	4.5	9	13.5	18
T (sec)	78	51	38	31	25
m_f	0.394	0.602	0.81	0.99	1.228
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.547	0.367	0.31	0.279
η_{bth}	0	16.6	24.7	30.33	32.6
η_{mech}	0	43.1	60.2	69.4	75.2

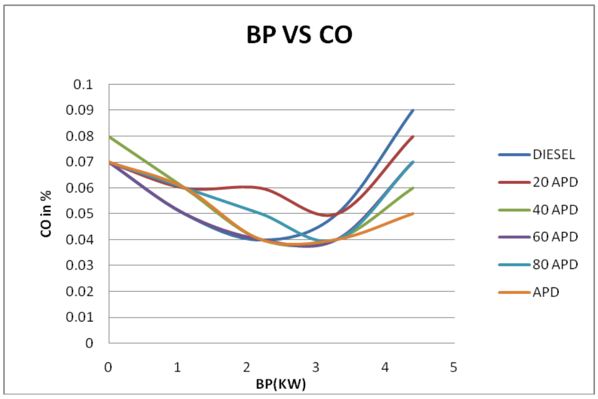
V. RESULTS AND DISCUSSIONS

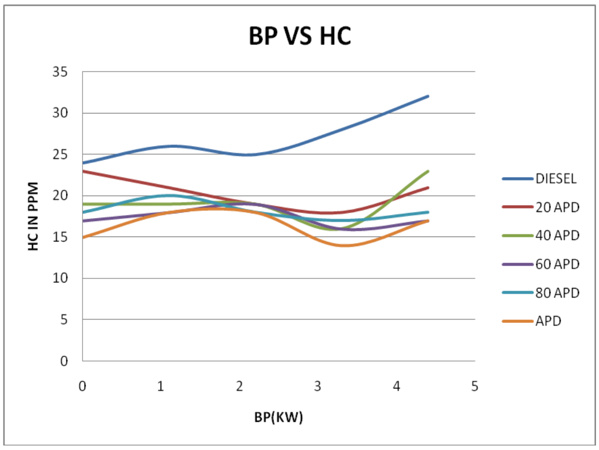
Performance properties are slightly lesser for biodiesel compared to diesel. Accordingly they improve injection process and ensure better atomization of the fuel in the combustion chamber. Biodiesel can be blended in any ratio for better performance and the increased lubricity makes for a better running of vehicle.

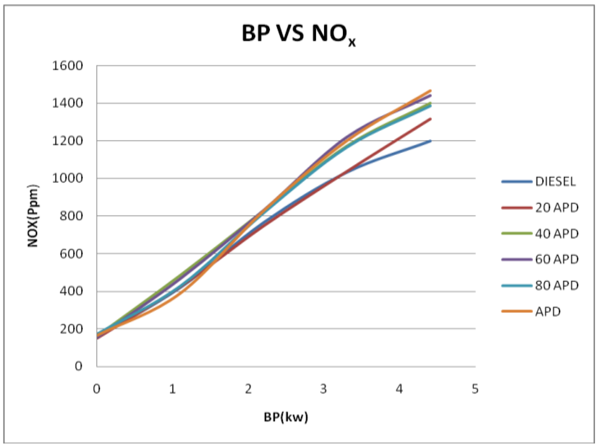
We analyzed the performance properties of duel bio-fuel methyl esters. Results of the experiments in the form of brake power, brake thermal efficiency, specific fuel consumption for different load conditions for various blends of duel bio-fuel methyl esters compare with the petroleum diesel in the form of graphs.

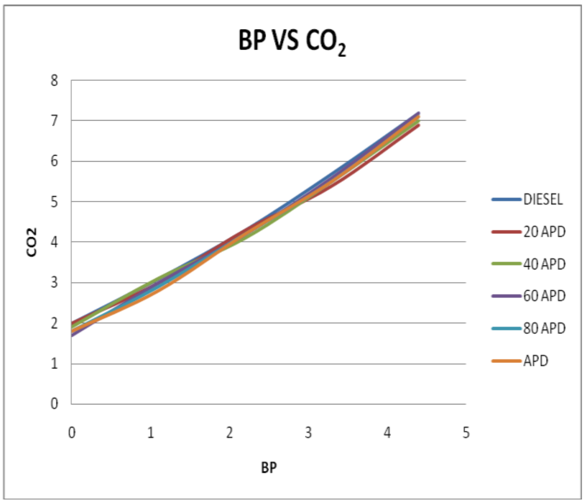












VI. EXHAUST GAS RECURCULATION

When a small percentage of exhaust gas is introduced into the combustion air, the oxygen purity of the combustion air is reduced leading to lower NO_x emissions.

The layout of the experimental setup requires the following equipments:

- Temperature indicator–exhaust gas temperature.
- Flexible pipe (connects exhaust to the pulse reducer).
- Pulse reducer.
- By-pass line (re-circulation line).
- Gate valves.
- Orifice on the exhaust line.

The first step in the testing procedure is to ensure that the valve on by-pass line is completely closed (0% EGR). Then the load is kept at zero and then the engine is cranked. The engine is then allowed to stabilize for some time and then the manometer depression is noted down. This value is taken as 100% atmospheric air or no EGR. At this condition various parameters such as Fuel flow rate, Composition of exhaust gas were noted using a 5-gas analyzer. After all the parameters are noted the gate valve on the exhaust line is partially opened to create back pressure. The gate valve in the by-pass line is opened or closed depending on the manometer depression (i.e.) say if we need 5% EGR then the manometer depression is adjusted to 0.95times of the 0% EGR value and the measurements were taken as before similarly for 10%, 15%, 20% and 30% re-circulation, the same procedure is followed.

Then the load is increased and the same procedure is repeated. The loads used are 0%, 25%, 50%, 75% and 100% of the full load.

A. Emission Readings for 0% EGR:

LOAD	0	25	50	75	100
CO(% vol)	0.07	0.06	0.06	0.05	0.08
CO_2(% vol)	2.00	3.00	4.30	5.40	6.90
NO_X (ppm)	152	426	749	1039	1317
HC(ppm)	23	21	19	18	21
O_2(vol)	17.63	16.17	14.42	12.88	10.77

B. Emission Readings for 10% EGR:

LOAD	0	25	50	75	100
CO(% vol)	0.08	0.06	0.05	0.05	0.12
CO_2(% vol)	2.40	3.60	5.10	6.70	8.70
NO_X (ppm)	80	217	330	525	660
HC(ppm)	25	35	34	30	34
O_2(vol)	17.18	15.47	13.33	11.32	8.52

C. Emission Readings for 20% EGR:

LOAD	0	25	50	75	100
CO(% vol)	0.08	0.07	0.06	0.06	0.12
CO_2(% vol)	2.40	3.70	5.10	6.90	8.90
NO_X (ppm)	42	110	167	265	333
HC(ppm)	25	31	35	37	39
O_2(vol)	17.07	15.25	13.29	10.96	8.08

D. Performance Readings without EGR:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	4.4	14.9	26	38.2	50.4
I (amp)	0	4.5	9	13.5	18
T (sec)	65	47	37	31	25
m_f	0.463	0.64	0.813	0.97	1.203
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.582	0.37	0.294	0.273
η_{bth}	0	14.78	23.33	29.26	69.4
η_{mech}	0	43.1	60.2	69.4	75.2

E. Performance Readings with 10% EGR:

N (rpm)	1500	1500	1500	1500	1500
Load (kg)	3.8	14	25.8	37.2	49.8
I (amp)	0	4.5	9	13.5	18
T (sec)	74	53	40	32	26
m_f	0.407	0.567	0.75	0.94	1.156
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.515	0.341	0.285	0.267
η_{bth}	0	16.68	25.23	30.2	32.74
η_{mech}	0	43.1	60.2	69.4	75.2

F. Performance Readings with 20% EGR:

N (rpm)	1500	150 0	1500	1500	1500
Load (kg)	5.1	14.1	25.7	37.5	49.6
I (amp)	0	4.5	9	13.5	18
T (sec)	78	57	41	31	26
m_f	0.386	0.52 8	0.73 4	0.97	1.15 7
BP	0	1.1	2.2	3.3	4.4
FP	1.5	1.5	1.5	1.5	1.5
IP	1.45	2.55	3.65	4.75	5.85
SFC	0	0.48	0.33 4	0.294	0.26 3
η_{bth}	0	17.9	25.8 4	29.26	32.7
η_{mech}	0	43.1	60.2	69.4	75.2

VII. CONCLUSIONS

Experiment has been done by blending biodiesel in different volumes with diesel. The engine performance indicating parameters like brake power, indicated power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency, etc., have been observed for various blends at different loads.

It is clear that, at 20% blending of biodiesel the engine performance is found to be very appreciable. At this blending trial particularly at full load and half load conditions the specific fuel consumption and indicated thermal efficiency are very closer to the values obtained without blending.

From the experiments conducted, it is concluded that biodiesel and its blends as a fuel for diesel engine have better emission characteristics compared with diesel.

The NOx emissions are high due to presence of oxygen content in the fuel.

The HC and CO emissions are less compared with diesel. Thus biodiesel may be the promising fuel for the future.

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