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Experimental Investigation of the Effect of Esterified Karanja Oil Biodiesel on Performance, Emission and Engine Wear of a Military 160hp Turbocharged CIDI Engine

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***Abstract*— Global warming due to engine emission and rapid depletion of petroleum reserves, has given us opportunity to find bio fuels. Biodiesel is an alternative diesel fuel that can be produced from renewable feedstock such as edible and non-edible vegetable oils, wasted frying oils and animal fats. Biodiesel is an oxygenated, sulphur free, non-toxic, bio gradable and renewable fuel. Use of Karanja oil methyl ester biodiesel in a CIDI engine was found highly compatible with engine performance along with lower exhaust emission as compared to diesel fuel but with slightly higher NOx emission and low wear characteristics. A Military 160hp, Turbo charged with intercooled, 06 cylinders CIDI engine was operated using Estrified Karanja oil biodiesel and diesel fuel respectively. Engine was subjected to 100 hours long term endurance test with both test fuels. Lubricating oil samples drawn from engine after a fixed interval of 20 hours were subjected to elemental analysis. Metal debris concentration analysis was done by atomic absorption spectroscopy. Wear of metals were found to be about 35% lower for bio-diesel operated engine. The additional lubricating property of biodiesel fuel due to higher viscosity as compared to diesel fuel resulted in lower wear of moving parts and thus improved the engine durability with a bio-diesel fuel.**

Index Terms— Diesel, Estrified Karanja oil biodiesel, military, metal wear, turbo charged

I. Introduction

The biodiesel has emerged as alternative for diesel fuel [1,5], due to renewable nature, better ignition quality, comparable energy content, higher density, better safety due to higher flash point [2,6,7,8]. It is sulphur free, non aromatics, non toxic, and oxygenated. These characteristics reduce the emission of carbon monoxide (CO), and hydrocarbon (HC) in the exhaust gas as compared with petroleum diesel. It is essential to evaluate engine wear characteristics, especially when the engine is to be operated on alternative biodiesel. Karanja oil biodiesel is having properties nearer to diesel (Table 1). Karanja plant can be grown in the wasteland and does not require too much care. It can be cultivated in all available wasteland to meet the total fuel requirement in future [10,11,12].

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TRANSESTERIFICATION OF KARANJA OIL

In the present study, the Karanja oil was used for making Karanja oil methyl ester biodiesel. Karanja oil was converted into methyl ester by the transesterification process. Its involves making the triglycerides of Karanja oil to react with methyl alcohol in the presence of a catalyst (KOH/ NaOH) to produce glycerol and fatty acid ester (3,14).

II. EXPERIMENTAL SETUP

In this research, a 118kW, 06 cylinder, four stroke, variable speed, and turbocharged with intercooled, Military CIDI diesel engine was tested. The engine was coupled to a 1125kW hydraulic dynamometer (SAJ). The basic specifications of the engine are given in Table 2**.** An electronic fuel meter was used to measure the fuel flow rate. For the measurement of the engine exhaust emission, Indus Automotive Exhaust Monitor, model PEA 205, gas analyzer (CO, HC, NOx) using electrochemical sensors was used to measure emissions on a dry basis, and the results were subsequently converted to a wet basis. In the gas analyzer, a probe is inserted into the exhaust pipe line and the other end is connected to the data acquisition system. A variable speed range from 1200-2400 engine rpm with full load condition was selected for performance test. Whereas a constant speed 1800 engine rpm with part load condition was maintained throughout the wear test for both the test fuels. The engine was operated for 100h with both test fuels. Samples of lubricating oil were collected through a one way valve connected to the crankcase sump at 10h intervals. The first sample was collected immediately after the engine had warmed up. The test was carried out with diesel fuel using new lubricating oil first. After100h operation, the fuel and lubricating oil were replaced with Karanja biodiesel and fresh lubricating oil and the same procedure was followed for both the test fuels. Immediately after collection, test samples were analyzed to obtain wear results. Atomic absorption spectroscopy (model: GBC, Avanta, Australia) with dry ash technique was used for extracting metals from the lubricating oil samples (10 ml).

TABLE1
PROPERTIES OF FUELS SELECTED FOR ENGINE EXPERIMENTS

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Fuel Properties	Diesel	Biodiesel (KOME)	Test Method
Relative Density at 15˚	829.6	922	ASTM D-4052
Kinematic Viscosity (cst) at 40˚	2.49	5.57	ASTM D-445
Calorific Value (MJ/Kg)	43080	39800	ASTM D-240
Flash Point (˚ C)	59	168	ASTM D-93
Cloud Point (˚ C)	-1	23	ASTM D-2500
Cetane No.	48	51	ASTM D-613
Carbon Content (wt%)	87	78	ASTM D-5291
Hydrogen Content (wt%)	12.4	11.5	ASTM D-5291
Sulfur Content (wt%)	0.0022	<0.01	ASTM D-4394
Water Content (wt%)	< 0.01	< 0.01	ASTM D-1796
Free glycerin	-	0.00	ASTM D-6584
Total glycerin	-	0.02	ASTM D-6584

TABLE 2
ENGINE SPECIFICATIONS

1	Make	W 06DT
2	Rated Brake Power (Kw) at 2400 rpm	118
3	Rated Torque (N-m) at 1600 rpm	495
4	Number of cylinder	06
5	Bore X Stroke (mm)	104 X 113
6	Displacement volume (cc)	5759
7	Compression ratio	18:1
8	Breathing	Turbo charged intercooled

III. ENGINE PERFORMANCE

The performance of engine was evaluated in terms of brake power. Pure Karanja biodiesel has a cetane rating higher than diesel fuel, slightly lower heating value, slightly higher viscosity as well as density, and also contains additional 10% oxygen. The lower heating value will cause a small loss in maximum power if engine fuel system is not recalibrated (Figure 1).

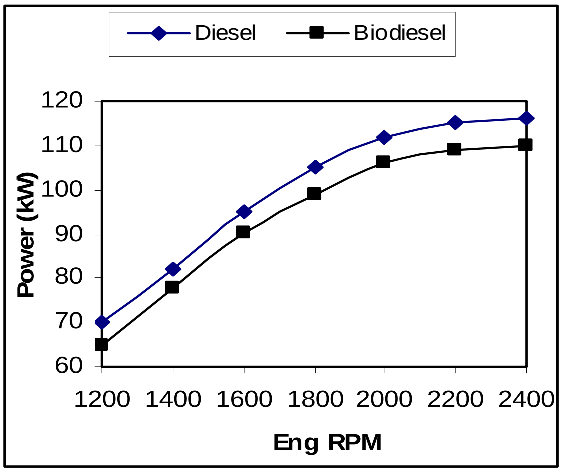

Fig.1. Power kW Vs rpm for diesel and Karanja biodiesel fuel.

ENGINE EMISSION

The exhaust emissions are compared for Karanja biodiesel and diesel fuel, at full load and the engine speed of 1400 to 2400 rpm. The measured exhaust emissions were CO, unburnt HC, and NOx.

A. CO EMISSION

In diesel engine, CO concentration in the exhaust increases steadily as the amount of excess fuel increases. The CO exhaust emissions of diesel and pure Karanja oil biodiesel are shown in Figure 2. The CO emissions were lesser for biodiesel fuel as compared with diesel fuel, the CO emission of biodiesel was reduced by 78% at full load. This is because biodiesel contain 10% additional oxygen, which leads to complete combustion of fuel. Other researchers (12) also found that biodiesel fuel has lower CO emissions compared with diesel, when the engine was running at full load condition.

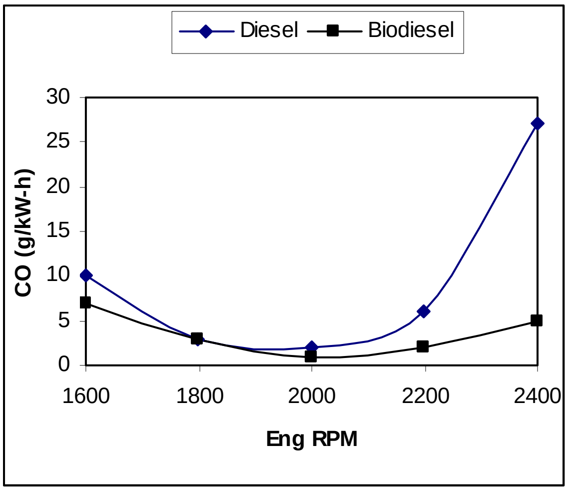

Fig.2. CO emissions for diesel and Karanja biodiesel fuel.

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B. *UNBURNT HC EMISSION*

The unburnt HC emission of diesel engine depends upon the engine operating conditions, the fuel spray characteristic, and the interaction of the fuel spray with the air in the combustion chamber. The HC exhaust emissions are shown in Figure 3. The HC emission was 40% lesser for pure Karanja biodiesel as compared to diesel fuel, at full load. Other researchers [9,12,13] also found significant HC reduction when blend of biodiesel with diesel was used in the diesel engine.

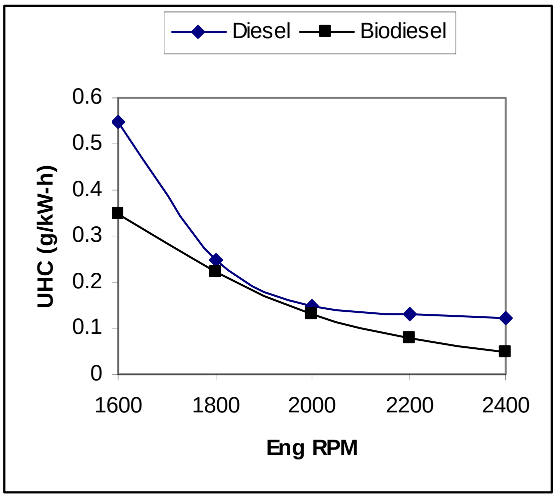

Fig.3. UBHC emissions for diesel and Karanja biodiesel fuel

C. NO_X EMISSION

NOx exhaust emissions are shown in Figure 4. The NOx emission was slightly higher for the pure biodiesel than for diesel fuel nearly by 6% at full load. The increase of NOx in the emissions may be associated with the oxygen content of the biodiesel, since the biodiesel fuel provided additional oxygen for NOx formation. Thus one of the main reasons for the formation of NOx is the higher availability of oxygen in the combustion chamber. Other researchers [7, 8, 10, 12, 13] also mentioned that NOx increased for the blend of biodiesel fuel.

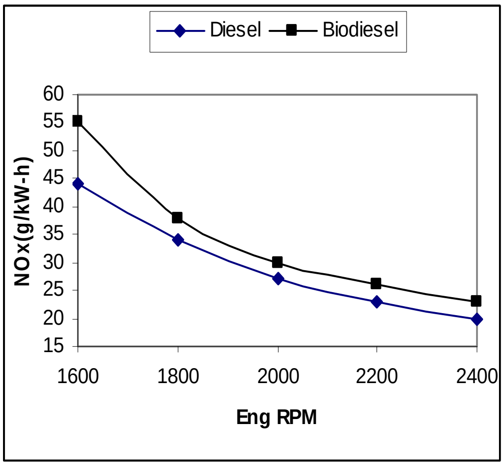

Fig. 4. NOx emissions for diesel and Karanja biodiesel fuel

ENGINE WEAR

Wear debris originate from various sliding and rotating component in engine and washed away by lubricants and finally get accumulated in the oil sump. The metallic wear debris, which originates from different parts, may have different composition depending on the origin. Hence metal analysis of lubricating oil gives a fair idea of wear of vital components of the engine. Various metals such as Iran (Fe), Copper (Cu), Chromium (Cr), Aluminum (Al), and Lead (Pb) were analyzed.

A. WEAR OF METALS

It has been observed that the wear debris of metals such as Fe, Cu, Cr, Al, Ni and Pb (Fig. 5 to 10) decrease up to 35% with pure Karanja oil biodiesel. One of the possible reasons for lower concentration may be the improved lubricating efficiency due to improved combustion and lower soot formation with biodiesel fuel. Other researchers [9, 15] have also found lower wear with blends of biodiesel.

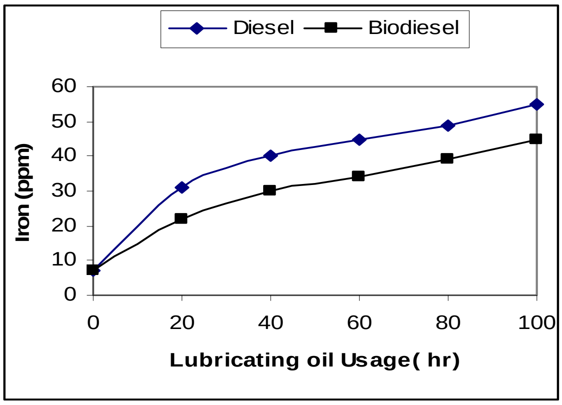

Fig.5. Fe concentration vs usage hours

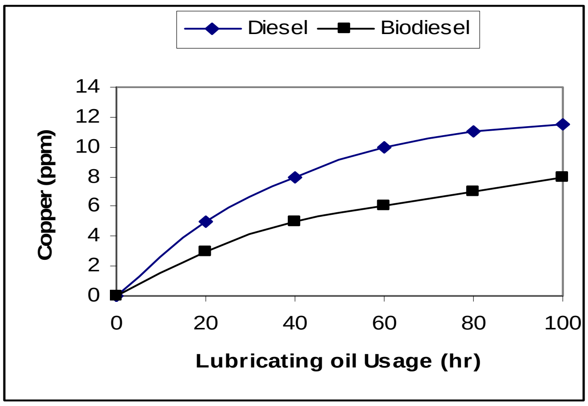

Fig.6. Cu concentration vs usage hours

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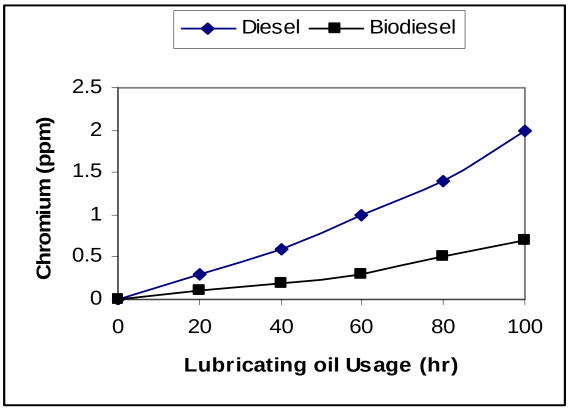

Fig.7. Cr concentration vs usage hours

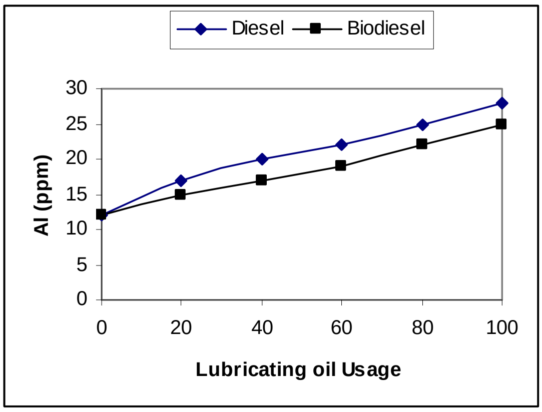

Fig.8. Al concentration vs usage hours

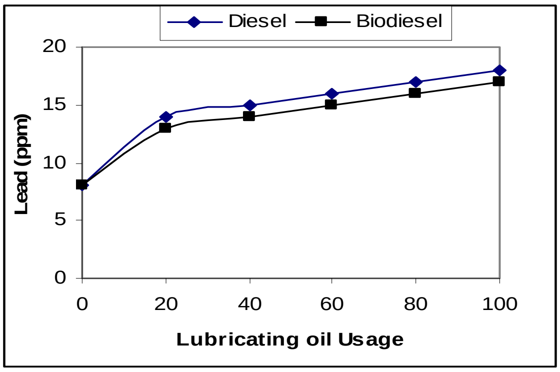

Fig.9. Pb concentration vs usage hours

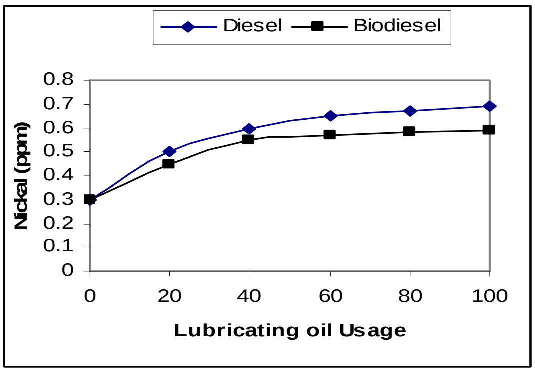

Fig.10. Ni concentration vs usage hours

IV. CONCLUSION

The effects of pure Karanja biodiesel fuel on performance, emission, and engine wear of a 118kW, 06 cylinders, CIDI engine have been investigated and compared with the baseline diesel fuel. The main observations are as follows:

1. The brake power of engine slightly decreases when diesel engine was fueled with pure Karanja oil biodiesel fuel.
2. CO emission decreases by 80% when diesel engine fuel is replaced with pure Karanja oil biodiesel fuel at full load condition.
3. The UHC decreases by 42% at full load condition with pure Karanja oil biodiesel.
4. NO_X emission increase by 10% with pure Karanja oil biodiesel in comparison with diesel fuel at full load condition.
5. The pure Karanja oil biodiesel fuelled engine shows up to 35% lower wear of metals (Fe, Cu, Al, Pb, Ni and Cr) as compared with diesel fuelled engine.

Therefore it can be concluded that pure Karanja biodiesel fuel can replace diesel fuel for running the military CIDI diesel engine, with prolonged engine life without compromising the engine performance.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

Symbol	Description
CA	Crank Angle
cc	Cubic Centimeter
CIDI	Compressed Ignition Diesel Engine
cSt	Centi Stoke
D	Diesel
^{o}C	Degree Centigrade
Eng	Engine
mg	Milligram
h	Hour
hp	Horse Power
IC	Internal Combustion
KOH	Potassium Hydroxide
KOME	Karanja Oil Methyl Ester
kW	Kilo Watt
kg	Kilogram
MJ	Mega Joule
NaOH	Sodium Hydroxide
No	Number
Pm	Particulate Matter
RPM	Revolution Per Minute
wt	weight

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