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Investigating the Role of Fatty Acid Methyl Ester Composition on Engine Performance and Emission Characteristics

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ABSTRACT:

This experimental study is focused on the significance of Fatty Acid Methyl Ester (FAME) composition for usage of biodiesel in diesel engines. Karanja Oil Methyl Esters (KOME) from two different feed stocks were selected for the study. FAME composition was analysed by gas chromatography and physical, chemical properties were evaluated. KOME 30% blends with diesel were analysed for performance and Emission characteristics. The present work predicted that H30 sample 1 with higher unsaturation has resulted in higher peak pressure, higher NO_x emissions, as compared to H30 sample 2 with lower unsaturation fatty acid methyl ester composition.

KEYWORDS:

Fatty Acid Methyl Ester; Peroxide Value; Acid Value; Engine performance

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1. Introduction

Biodiesel is a mono alkyl ester of elongated chain fatty acids resultant from trans esterification of edible and non-edible oils [7]. Many investigators have studied on the Fatty Acid Methyl Ester (FAME) composition for evaluating different biodiesel properties [1, 8]. The dependence of fuel properties on FAME and its optimization for enhancing biodiesel properties was studied extensively [4-5]. Some of the studies concluded that there is no effect of biodiesel feedstock on the engine power but it has an effect on the combustion and emission characteristics [10]. Effect of unsaturation for different oils was studied for a single cylinder diesel engine. The study predicted that unsaturation in biodiesel causes an escalation in NO_x and lowers thermal efficiency for different oils [3]. Degradation of biodiesel was observed when it was stored above 40°C with the exposure of air and traces of water. Degradation was owing to the existence of water content which has caused hydrolysis of biodiesel which increased the unsaturation of fatty acids. [6]. The purpose of the present work is to study the effect of Karanja Oil Methyl Esters (KOME) from two different feed stocks with respect to the FAME composition on the emission and engine performance. 30% Karanja blended with diesel was used for the analysis.

2. Test setup

A constant speed, variable load test, four stroke single cylinder direct injection diesel engine was used for the experiment. Fig. 1 shows the schematic setup of the engine. The test engine was fixed to an eddy current dynamometer. The specifications of the engine are listed in Table 1. The air flow was measured with a conventional manometer and a differential pressure transducer. Emissions were measured by a five gas analyser Indus PEA205 with a non-dispersive infra-red sensor for measuring HC, CO, CO_2 emission, and an electrochemical sensor for O_2 and NO_x. The accuracy of each emission measurements was as follows: CO: ±0.06%, CO_2: ±0.5%, HC: ±12 ppm.

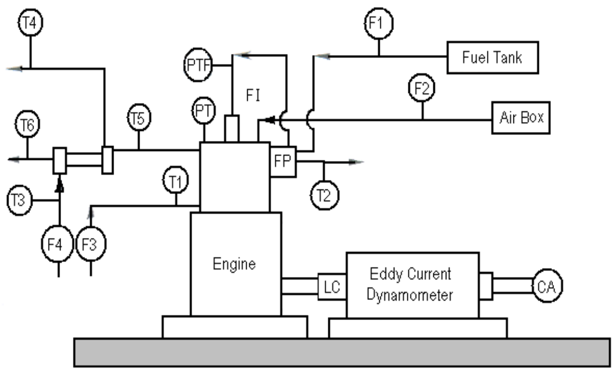

Fig. 1: Schematic setup of engine test rig

PT - Combustion chamber pressure sensor, PTF - Fuel injection pressure sensor, FI - Fuel injector, FP - Fuel pump, T1 - Jacket water inlet temperature, T2 - Jacket water outlet temperature, T3 - Calorimeter water inlet temperature, T4 - Calorimeter water outlet temperature, T5 - Exhaust gas temperature before calorimeter, T6 - Exhaust gas temperature after calorimeter, F1 - Liquid fuel flow rate, F2 - Air flow rate, F3 - Jacket water flow, F4 - Calorimeter water flow rate, LC - Load cell, CA - Crank angle encoder, EGC - Exhaust gas calorimeter

Table 1: Engine specification

Parameters	Description
Power	5.2 kW @ 1500 rpm
Cubic capacity	661 cc
Bore diameter	87.5 mm
Stroke	110 mm
Compression ratio	17.5: 1
Fuel injection pressure	200 bar

3. Testing procedure and properties

Neat KOME is designated as H100 and 30% KOME blend with diesel is designated as H30. The properties for H100 biodiesel are listed in Table 2 and the properties for H30 and diesel is listed in Table 3. Procedure for acid value measurement was suggested by Leung et al [6]. Peroxide value has been measured as suggested by Atinafu and Bedemo [2]. Iodine value was determined by using the procedure as suggested by Rushkar Alam [9]. Neat Karanja oil sample 1 was purchased from Gandhi Krishi Vignan Kendra, Bangalore and neat Karanja oil sample 2 was purchased from Siddaganga Institute of Technology, Tumkur. Both the samples were prepared by transesterification using methanol and NaOH as catalyst maintained at 65°C at a reaction time of 1.5 hours. The H30 blend sample 1 and sample 2 with diesel are tested at 80% load condition for peak pressure analysis. The emission characteristics of the samples are tested with 20%, 40%, 60% and 80% load respectively. The FAME composition of sample 1 and sample 2 was measured by gas chromatography at M/s Bangalore Test House. The FAME composition for both the biodiesel samples is listed in Table 4. The term unsaturation is defined as the percentage of double bonds in FAME (C18:1 + C18:2 + C18:3 + C20:4).

Table 2: Fuel properties evaluation for H100

Property	H100 Sample 1	H100 Sample 2
Acid value (mg KOH/g)	4.28	2.776
Peroxide Value (meq/kg ester)	63.4	38
Iodine Value (I_2/100 g)	74.3	79.2
Kinematic viscosity @26°C (mm^2/s)	9.384	5.808
Density @ 15°C (kg/m^3)	900	800
Higher Calorific Value (kJ/kg)	40695.0	39104.72

Table 3: Fuel properties for H30 and diesel

Property	H30 sample 1	H30 sample 2	Diesel
Density @ 15°C (kg/m^3)	857.3	854.3	839
Higher Calorific Value (kJ/kg)	41931.5	41438.9	44300
Kinematic visc. @ 26°C (mm^2/s)	5.315	4.8626	4.169

Table 4: FAME compositions (%) details

FAME	H100 Sample 1 (%)	H100 Sample 2 (%)
Palmitic (C16:0)	10.74	8.38
Stearic (C18:0)	6.8	5.32
Oleic (C18:1)	50.24	40.54
Linoleic (C18:2)	17.21	14.91
Linolenic (C18:3)	3.47	2.84
Arachidonic (C20:4)	1.28	1.07
Behenic (C22:0)	0.24	2.03
Unsaturation	72.2	59.36

4. Results and discussion

The results concerning the performance characteristics like pressure crank angle diagram, brake thermal efficiency (BTE), brake power (B.P), brake specific fuel consumption (BFSC), emission characteristics like carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbon (HC), and nitrous oxide (NO_x) are compared and discussed for the sample 1 and sample 2 respectively with diesel. Fig. 2 shows the pressure crank angle comparison for diesel, H30 sample 1 and H30 sample 2. Ignition delay for diesel, H30 sample 1 and H30 sample 2 are 22º, 16º and 20º respectively. Lesser ignition delay has caused an increase in peak pressure for H30 sample 1 as compared to H30 sample 2. Fig. 3 shows the BTE vs. BP for the samples. Due to the higher calorific value and lesser density, diesel has higher efficiency compared to H30 sample 1 and H30 sample 2 respectively. Fig. 4 shows the BSFC vs. BP for the samples. The higher calorific value has reduced BSFC for diesel compared to H30 sample 1 and 2 respectively. The peroxide value of H30 sample 1 is higher than H30 sample 2. Hence BSFC of H30 sample 1 is lesser than H30 sample 2.

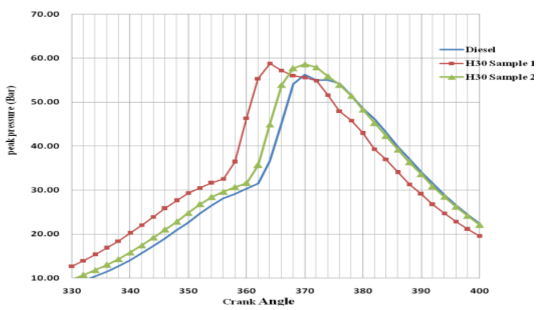

Fig. 2: Pressure - crank angle comparison for 80% load condition

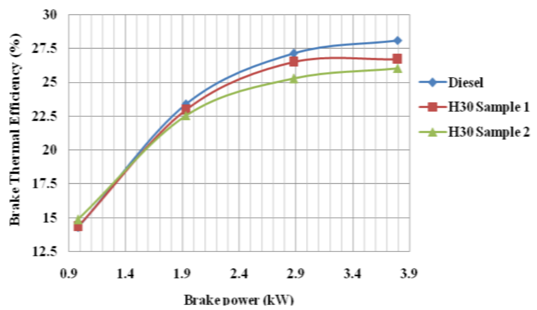

Fig. 3: BTE vs. BP

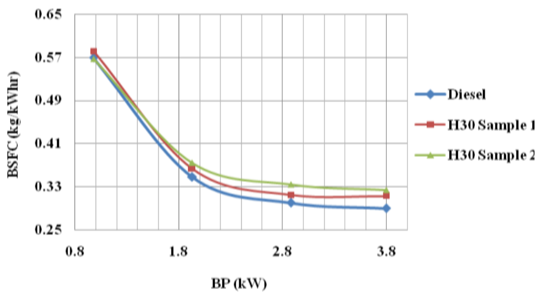

Fig. 4: BSFC vs. BP

Fig. 5 shows the CO emissions vs. Load for the samples. CO emissions of H30 sample is lesser due to better combustion and higher peroxide value, which has resulted from biodiesel oxidation as compared to H30 sample 2 and diesel. Fig. 6 shows the CO_2 vs. Load for the samples. The CO_2 emissions are higher for H30 Sample 1 due to complete combustion and lesser ignition delay as compared to H30 sample 2 and diesel. Fig. 7 shows the HC emissions vs. Load. The HC emissions are higher for diesel and lesser for biodiesel blends. The H30 sample 1 has lesser HC emissions due to higher unsaturation and higher peroxide value as compared to H30 sample 2 Fig. 8 shows the NO_x vs. Load for the samples. Due to shorter ignition delay and better combustion, the NO_x emissions are higher for H30 sample 1 as compared to H30 sample 2 and diesel. H30 sample 1 has higher unsaturation in the FAME composition as compared to H30 sample 2.

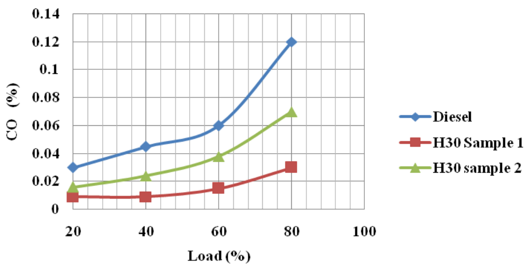

Fig. 5: CO emissions vs. Load

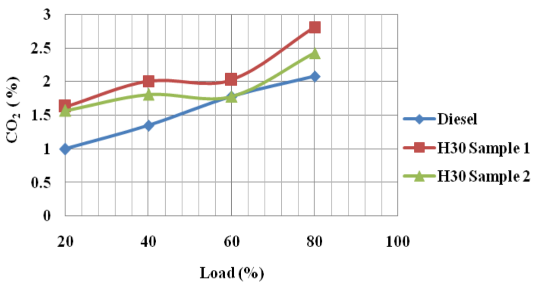

Fig. 6: CO_2 emissions vs. Load

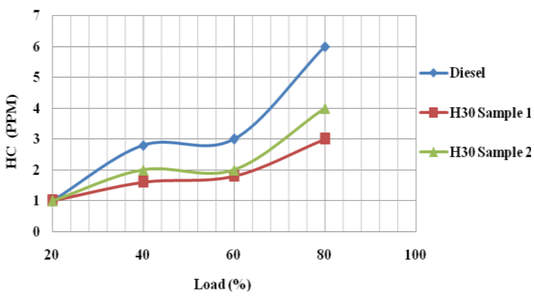

Fig. 7: HC emissions vs. Load

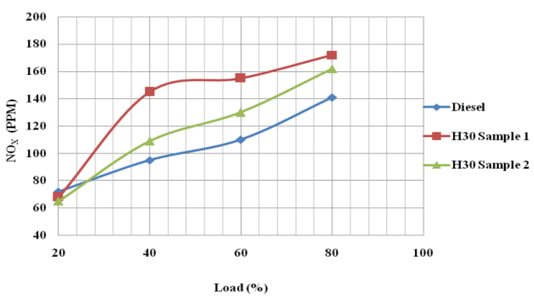

Fig. 8: NO_x emissions vs. Load

5. Conclusions

Experimental investigation of H30 samples on engine performance and emission characteristics was undertaken in this work. H30 sample 1 has lesser ignition delay, higher peroxide value, better combustion, and lesser BSFC than H30 sample 2. H30 sample 1 produced higher NO_x, lesser CO, CO_2 and HC emissions as compared to H30 sample 2. The reasons are H30 sample 1 has higher peroxide value, lower iodine value, and higher acid value, which is due to unsaturation resulting from biodiesel degradation or oxidation. The unsaturation (double bond) percentage is higher for H30 sample 1 as compared to H30 sample 2.

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