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Combustion, Performance and Emission Analysis of Diesel Engine Fuelled with Methyl Esters of Fish oil

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ABSTRACT

The methyl esters of vegetable oils, known as biodiesel are becoming increasingly popular because of their low environmental impact and potential as a green alternative fuel for diesel engine and they would not require significant modification of existing engine hardware. Methyl ester of Fish oil (FME) is derived through transesterification process. Experimental investigations have been carried out to examine properties, performance and emissions of different blends (B00, B20, B40, B60, B80, and B100) of FME comparison to diesel. A Computer assisted Single cylinder constant speed water cooled four stroke direct diesel engine (5 H.P) which is commonly used in the agricultural sector for driving the pumps and small electrical generators is selected for the experimental investigation. The performance, emissions and combustion characteristics are analyzed. The combustion parameters considered for this analysis are cylinder pressure and rate of heat release. The brake thermal efficiency is slightly reduced and hydrocarbon, carbon monoxide and smoke emissions in the exhaust are reduced when fueled with methyl esters compared to diesel. But the NOx emissions are high when fueled with methyl esters compared to diesel.

Keywords: *Bio-diesel, Fish oil, Transesterification, Methyl Esters*

1. INTRODUCTION

Energy is considered as a critical factor for economic growth, social development and human welfare. Since their exploration, the fossil fuels continued as the major conventional energy source with increasing trend of modernization and industrialization, the world energy demand is also growing at faster rate. To cope up the increasing energy demand, majority of the developing countries import crude oil apart from their indigenous production. This puts extra burden on their home economy. Hence, it is utmost important that the options for substitution of petroleum fuels be explored to control this burgeoning import bill. India has very vas coastline and fisheries industry well developed. All along the coastal line there is no dearth of fish and fish oil which are easily available and also the cost of production of bio-diesel from fish oil is quite economical other land based tree bearing oils. There are also instances in the Gujarat and Maharashtra coastal area where the fish oil is drained back into the sea just because there is no viable and economical use for it. A number of industries and entrepreneurs are using fish oil to produce biodiesel at an economical cost as compared to other non-edible oils sources. Fish oil can be transesterified just like any other oil to give a clear, yellowish colour bio-diesel which can be used in any biodiesel engine.

The Use of vegetable oils and animal fats as diesel fuel has been studied extensively.[1] Alternate fuels like ethanol, biodiesel, LPG, CNG, etc., have been already commercialised in the transport sector. [3] Increase in energy demand, stringent emission norms and depletion of oil resources led the researchers to find alternative fuels for internal combustion engines, Usability of cotton oil soapstock biodiesel–diesel fuel blends as an alternative fuel for diesel engines were also studied [11-12] The effects of biodiesel (rapeseed methyl ester, RME) and different diesel/RME blends on the diesel engine NOx emissions, smoke, fuel consumption, engine efficiency, cylinder pressure and net heat release rate are analysed. [13] The performance of biodiesel obtained from mahua oil and its blend with high speed diesel in a Ricardo E6 engine has been studied together with some of its fuel properties. [14] Tall oil methyl ester was produced by reacting tall oil fatty acids with methyl alcohol under optimum conditions and is used as alternate fuel for diesel engine. [4] Tobacco seeds are a by product of tobacco leaves production. Tobacco leaves, tobacco seeds are not collected from fields and are not commercial products. However, tobacco seeds contain significant amounts of oil. Although tobacco seed oil is a non-edible vegetable oil, it can be utilized for biodiesel production as a new renewable alternative diesel engine fuel. [6]

Vegetable oils are produced from numerous oil seed crops. While all vegetable oils have high-energy content, most require some processing to assure safe use in internal combustion engines. Some of these oils already have been evaluated as substitutes for diesel fuels. With the exception of rape seed oil which is the principal raw material for biodiesel fatty acid methyl esters, sunflower oil, corn oil and olive oil, which are abundant in Southern Europe, along with some wastes, such as used frying oils, appear to be attractive candidates for biodiesel production. [5]

By reviewing these literatures on biodiesel, most of the researches were emphasis on the different alternate fuels for diesel engine. However, the researches related to the methyl esters of fish oil, the combustion characteristics of methyl esters of are rare. Therefore more researches are required to understand the methyl esters fish oil as a fuel in diesel engine.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

Fish oil was selected for this study and transesterified to fish oil methyl ester (FME). FME was used as one of the test fuels in the engine experiments. In transesterification reaction, the molar ratio of methanol to fish oil was 6:1 and 1% mass of KOH to ground nut oil was used. The reactions were taken for two hours at reaction temperature 60˚C. After the end of the reaction, the mixtures were kept at the ambient temperature for eight hours and then the settled glycerin layer was drained off. At last the residual methanol in methyl ester mixtures was evaporated. Then the finished product is ground nut oil biodiesel or FME. The ester conversion rate of FME was over 95%. From fatty acid composition, FME can be said a saturated fatty acid type biodiesel. The FAME composition of FME measured by gas chromatograph and the properties of FME are expressed in table 2.1 and 2.2.

From the fuel properties of FME; the viscosity of was measured according to IS: 1448(P25) by using Constant temperature Viscosity Bath and Redwood viscosity meter. The density was measured according to IS: 1448(P16) by using a hydrometer. Flash Point & Fire Point was measured according to IS: 1448(P66) by Pensky Marten flash point apparatus. Total Acid No was measured according to ASTM D974 by Indicator Titration method Carbon Residue was measured according to 1448(P8) by Ramsbottom carbon residue apparatus The Fatty acid Profile was measured according by Gas Chromatograph

The pour point was measured according to 1448(P10) by using a Test tube & Thermometer rapid pour point tester. A Computer assisted Single cylinder constant speed water cooled four stroke direct diesel engine (5 H.P) which is commonly used in the agricultural sector for driving the pumps and small electrical generators is selected for the experimental investigation. Exhaust emissions such as NOx, UBHC, CO, CO2 were measured with a QRO-401(5GAS) 5 gas exhaust gas analyzer, and smoke opacity using an AVL 437C smoke meter.

TABLE 2.1 FAME COMPOSITION OF FME

Fatty acid	C:N	Content (%)
Caprylic	8:0	nil
Capric	10:0	nil
Lauric	12:0	0.16
Myristic	14:0	15.88
Palmitic	16:0	36.33
Stearic	18:0	6.95
Oleic	18:1	14.33
Linoleic	18:2	2.48
Linolenic	18:3	0.29
Others	-	23.58

TABLE 2.2 PROPERTIES OF FME

Properties		FME
Cetane number		54
Net calorific value	(Cal/gm)	8321.0
Density@288K	(gm/ml)	0.920
Kinematic viscosity@313K	cSt	6.1
Flash point	°C (open cup)	159.0
Fire Point	°C	166
Total acid number	Mg KOH/gm	3.5
Carbon Residue (Rams bottom)	% W/W	0.025
Pour Point	°C	-4

Table 2.3 Test engine specifications

Make	Kirlosker(AV1 MODEL)
Number of cylinders	1
Combustion chamber	Direct injection
Valve arrangement	OHV
No. of stroke per cycle	4
Cooling system	Water-cooled
Compression ratio	16. 5
Bore x stroke	110mm×106mm
Max. power (at 1500rpm)	5HP (3.5kW)
Swept volume	562cc

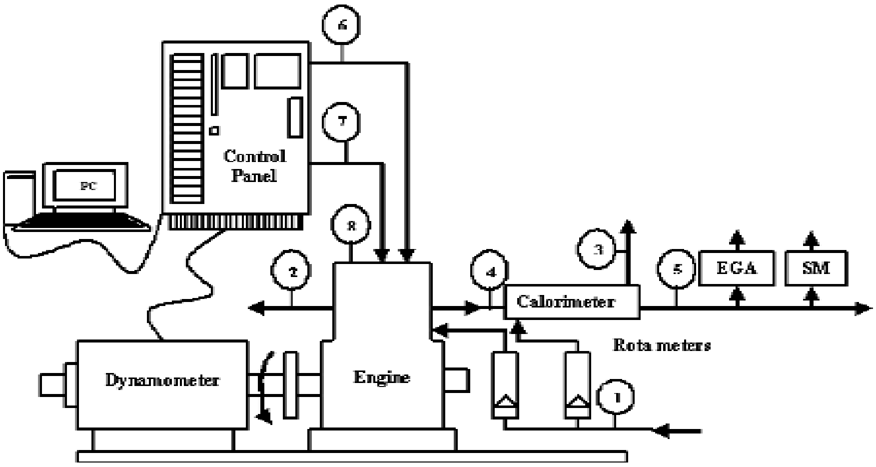

Figure 2.1 shows test engine and measurement devices set-up.

1. Water inlet to the calorimeter and engine ($T_1{}^0C$)
2. Water outlet from the engine jacket ($T_2{}^0C$)
3. Water outlet from the calorimeter ($T_3{}^0C$)
4. Exhaust gas inlet to the calorimeter ($T_4{}^0C$)
5. Exhaust gas out let from the calorimeter ($T_5{}^0C$)
6. Atmospheric air temperature (($T_6{}^0C$)
7. Fuel flow
8. Pressure Transducer

EGA: Exhaust gas Analyzer
SM: Smoke Meter
PC: Personal Computer

3. RESULTS AND DISCUSSIONS

The experimental investigation was carried out for different blends of Fish oil methyl esters (biodiesel) and the combustion, performance and emissions were evaluated and compared with diesel.

1. In Figure3.1, shows the brake thermal variations of various test fuels at various loads. The brake thermal efficiency increases with increase in load for all the test fuels. Brake thermal efficiency is slightly lower for methyl esters and their blends compared to diesel at all brake powers.
2. Figure 3.2, shows the exhaust gas temperature variations for methyl esters and its blends with load. It is observed that the exhaust gas temperature increases with load as more fuel is burnt at higher loads to meet the power requirements. It is also observed that the

exhaust gas temperature increases with percentage of methyl ester in the fuel for all the loads. This may be due to the oxygen content of the methyl esters, which improves combustion. Also the poor fuel atomization and vaporization due to higher viscosity of the methyl esters and their blends results in late burning of injected fuel and higher exhaust gas temperature.

3. Variation of CO emissions for various ester and their blends at different loads is shown in figure3.3. Formulation of CO emissions is due to the insufficient oxygen and time in the combustion chamber during the combustion process. In general the CO emissions are low for diesel engines as they are operated under lean mixture. It is observed that all esters and their blends show lesser CO emissions than diesel at all loads. Due to intrinsic oxygen content in the esters, the oxygen availability for oxidation of CO is more in esters and their blends compared to diesel which results in reduced CO emissions.
4. The variation of HC emissions with load for various blends of methyl esters are shown in figure3.4. It can be seen that there is increase in HC emissions for all test fuels as load increases. This is perhaps due to the presence of fuel rich mixture at higher loads. There is significant reduction in HC emissions for methyl esters and their blends at all loads compared to diesel. Adding methyl esters to diesel increases oxygen content resulting in better combustion and this result in lower HC emissions. Increase the percentage of the methyl esters in the fuels drastically reduces HC emissions.
5. The variation of NOx emissions with load for methyl esters and their blends are compared with those of diesel in figure3.5. It is observed that the NOx emissions increase with increase in load for all the test fuels. This is due to the increase in the amount of fuel burned with load, which results in increase in combustion temperature. At any load a gradual increase in the emissions of nitrogen oxides with increase in percentage of methyl ester in the fuel is observed. Methyl esters with their lower stoichio metric air-fuel ratio relative to diesel can burn with less air requirement for combustion. This results in higher combustion temperatures. As methyl esters are oxygenated fuels more oxygen is available for the formation of NOx compared to diesel. Hence the NOx emission increases with increase in percentage of methyl esters in the blend.
6. Most of the smoke results from incomplete combustion of fuel hydrocarbons and some is contributed by the lubricating oil. They are highly undesirable as they reduce the visibility. The variation of Smoke (%) at various loads is shown in figure3.6 for blends of different methyl esters. From these figures, it is clear that smoke emissions decreases with increase in methyl esters in the fuel blend. The smoke emission reducing effect of methyl esters can be attributed to their lower aromatic and short chin paraffin hydrocarbons and higher oxygen content.
7. The variation of cylinder pressure with crank angle for various fules is shown in figure3.7. It can be seen that all the test fuels shows the same trend except for slight changes in values of pressure at various crank angle.
8. The comparison of heat release rate variations for methyl esters and their blends with diesel as shown in figure3.8. It can be seen that the heat release rate curves of the diesel, methyl ester of fish oil and its blends shows similar pattern. The peak heat release rates of methyl ester of fish oil and its blends are lower than that of diesel.

4. CONCLUSIONS

From the investigation of the use of methyl ester of fish oil and its blend as an alternative fuel for diesel engine, the fallowing conclusions are derived

Methyl ester and its blend s record slightly lower values of peak pressure compared to diesel. Peak pressure occurs slightly away from TDC for the methyl ester and its blends. The magnitude of maximum rate of heat release decreases with increase in percentage of methyl ester in the fuel. The occurrence of maximum rate of heat release advances with increase in percentage of methyl ester in the fuel.

Fish oil methyl ester and its blends shows slightly lower brake thermal efficiency compared to diesel. The HC emissions, CO emissions and smoke in the exhaust decreases with increase in percentage of methyl ester in the fuel while the exhaust gas temperature and nitrogen oxide emissions increases.

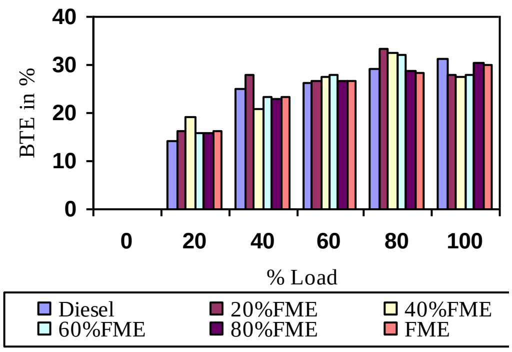

Figure3.1 Brake Thermal Efficiency of Test Fuels

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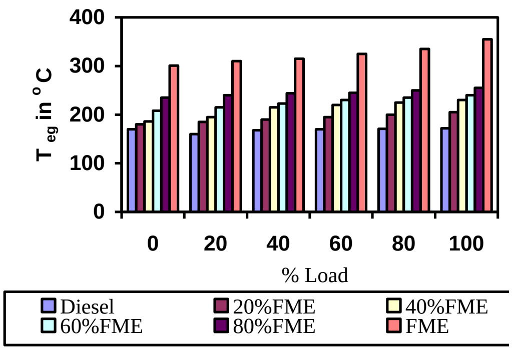

Figure 3.2 Exhaust Temperatures of Test Fuels

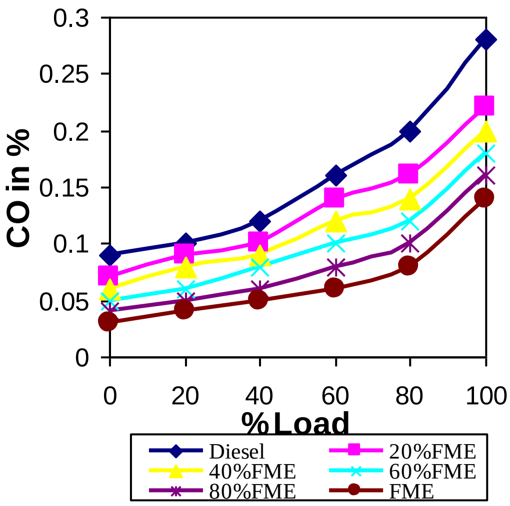

Figure3.3 CO emissions of Test Fuels

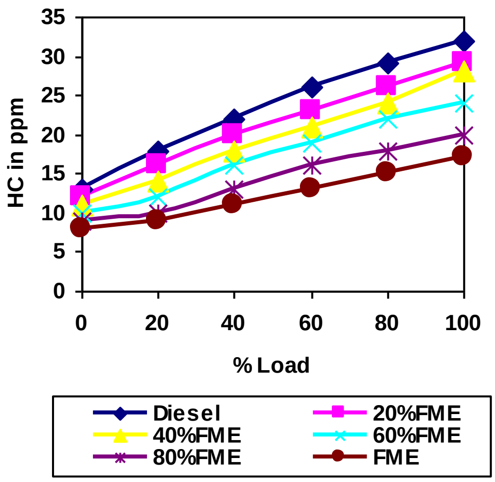

Figure3.4 HC Emissions of Test Fuels

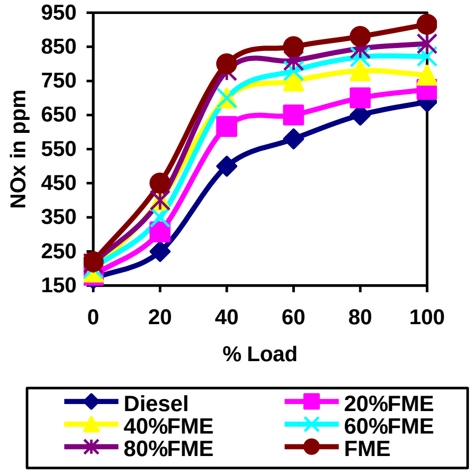

Figure3.5 NOx Emissions of Test Fuels

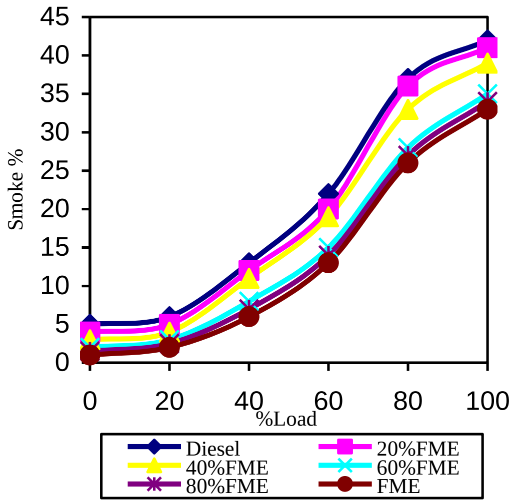

Figure3.6 Smoke of the Test fuels

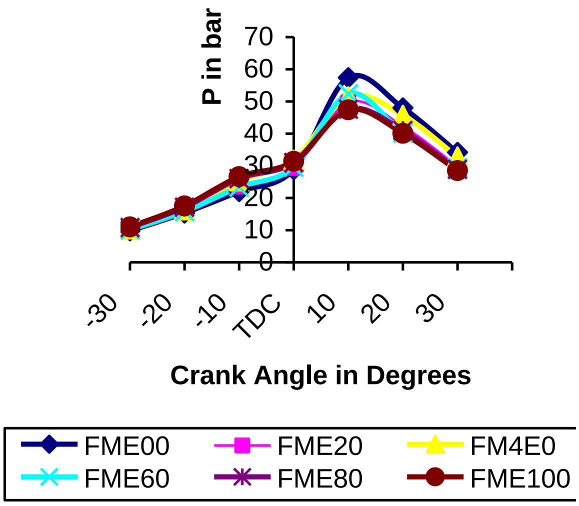

Figure3.7 Pressure Variation in the cylinder for Test Fuels

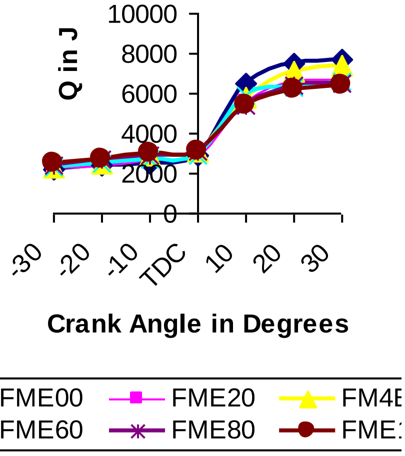

Figure3.8 Heat release in cylinder for Test fuels

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