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Performance and Emission Analysis of Mamey Sapote Biodiesel with SC 5D Polymer Additive

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ABSTRACT

Biodiesel with diesel additives have been attaining increased attention from engine researchers in the point of the energy crisis and growing environmental issues. The present work is aimed at experimental investigation of polymer based additive are mixed in different proportions with B15 (15% of Mamey Sapote oil + 85% of diesel) bio diesel. Experiments were done on a 4-Stroke single cylinder variable compression ratio ignition engine by varying percentage by volume of SC 5D additives in diesel-biodiesel blends. Their emissions and performance results are compared with base fuel B15 bio diesel. By mixing of this additive, it is observed that cetane index number is increased. The tests conducted at full load and varying speed conditions. At full load for B15 with 2500: 5 ml blend shows that the results of HC, NOx, C0 & smoke density are reduced by 10%, 24%, 16% & 11.12% respectively. Brake power is increased 2.19% whereas brake specific fuel consumption is decreased by 9.09% and for B15 with 2000:3 brake thermal efficiency increased by 4.16%.

Introduction

Fossil fuels play a major role in development of any country in the present scenario. Petroleum derived products are the critical sources of energy for fuelling of automobiles for the entire world. But fossil fuels are depleting day by day and they are non renewable. At the present and future projected consumption of petroleum products, it is assessed that these sources will be depleted in a certain period of time and it is not possible to meet the requirements. It is estimated that world petroleum fuels utilization in 2004 is 83 million barrels per day and the same may increase to 118 million barrels per day in 2030. The automobile engines consumes two third of the estimated increase of the fuel. In the next coming years petroleum fuels have huge demand in the transportation sector than in any other sectors. India’s fuel consumption in the transportation sector may grow an average rate of 3.3% per year when compared with world average of 1.7% per year. Diesel fuel is consumed in any country in the major sectors are agriculture, industrial and transpiration. The cost of any consumable product depends on the cost of the diesel fuel .Any country’s economic growth is linked with the availability of petroleum fuels for power generation and transportation. Thus developing country like India has a challenge to meet the requirement of the high demand of fuel energy which is growing very rapidly. Hence there is a need for development of renewable energy sources to meet the requirement of fossil fuels. It is essential to explore the reasonable substitution of diesel with alternative fuel within the country on a massive production for commercial usage. In the past few years Alcohols (methanol/ethanol), liquefied petroleum gas (LPG), compressed natural gas (CNG), Hydrogen, fruit & Vegetable seed oils have been tested for suitability on diesel engines. Liquid fuels are suitable than other fuels because of their high calorific value per unit mass and ease of storing, distribution and handling. The major alternative fuels are alcohols and fruit & vegetable seed oils and both the fuels are renewable energy sources. But alcohols have low cetane number when compared to seed oils hence they are not suitable for direct use in diesel engines. The seed oils having properties very close to diesel fuel , so they can use directly without any modifications of the diesel engine. The major constituents in the seed oils are larger molecules with carbon, oxygen and hydrogen. They have similar chemical structure, but different in type of bond which leads to high viscosity and higher molecular mass. Due to high viscosity it is intricate to inject vegetable oils in diesel engines and it is not possible to break them into fine droplets. They have more carbon residue when compared with the diesel, this leads to a black smoky exhaust form diesel engine. The stoichiometric air fuel ratio is high in vegetable oil mixture because of oxygen content in the fuel and it is free from sulphur. The calorific value of these oils is almost 90% of the diesel fuel. Vegetable oils are costly than diesel oils in the present market, this is a major drawback for usage in the diesel engine. But it can be overcome within a period of time by developing agricultural methods and innovative oil extraction techniques. The viscosity is also one of the serious drawback associated with vegetable oils, this can be reduced by various methods. Those are transesterification, preheating, blending with alcohols /diesel, duel fuelling with liquid and gaseous fuels and use of additives.

Now a day’s improvement of petroleum fuels high quality is an important challenge to minimize engine emissions to protect the environment. The cetane number of the diesel fuels can be improved by blending different kind of additives without modification of the engine. The diesel engine provides

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better fuel economy and high brake power when compared with the petrol engines. Samarjeet Bagri *et al.[1] studied the effects of SC 5D in different proportions with diesel .Their emissions and performance results are compared with diesel.

Z.H. Huang a *et al. [2], investigated that the combustion characteristics and heat release for various proportions of blending DMM (Dimethoxy methane) in diesel fuel and found adequate results on emission reduction. .Shahabuddin et al. [3] researched the experimental investigation of various parameter of a Turbocharged (IDI) Diesel engine exhaust emissions though operating along with POME mixed anti-corrosion additive as fuels. This particular study aimed on the major effects of additive on POME-Diesel blended fuels especially for B20+1% (20% biodiesel + 80% diesel + 1% additive). The additive utilized in this experiment is IRGANOR NPA (Product name) as a corrosion inhibitor for fuels. Results suggested that the bio diesel powered together with a number of ingredients (B20+1%) indicates best overall performance

Ruijun Zhua,b et al. [4], analyzed controlled and uncontrolled emissions from diesel engine mixed fuel with diethyl adipate, showed by using this additive better combustion is attained . Xiangang Wanga et al. [5], researched the mixing of diesel-ethanol, diesel-biodiesel and diesel-DGM (diethylene glycol dimethyl ether) or perhaps known as diglyme and observed that using ethanol blended fuels HC, CO, NOX and NO2 emissions are improves but DGM blended fuels minimizes HC,CO NOX and NO2 emissions. PM emission is also decreases by using DGM as compare to diesel. By using biodiesel mixed fuels noted that the HC, CO, NOX, and NO2 emissions, situated among ethanol and DGM mixed fuels. Ruijun Zhu a et al. [6], investigated that the combustion and emission characteristics regarding Compression ignition engine by using DMM combinations and got acceptable decrease of HC, CO, NOX, smoke and PM emission. W.M. Yang* et al. [7], Has utilized nano-organic additives and studied that when engine speed enhances the HC, CO and NOX emissions lowers. Wang Yinga,*et al.[8], blending oxygenated DME (dimethyl ether) in diesel fuel and examined the engine performance and emission analysis of CI engine. He noticed that by blending DME in diesel fuel, the cetane number enhance as compare to pure diesel. The end results confirmed that engine performance enhances and emission characteristics decrease. F.K. Forson et al. [9], studied that the performance of diesel engine by utilizing jatropha oil blends. Right here it is observed that pure jotropha, pure diesel and jatropha plus diesel oil presented similar results under various working conditions, but blending of jatropha oil in diesel fuel the exhaust gas temperature is decreased. Yakup Icingur et al. [10], studied the engine performance and emission characteristics of diesel engine by utilizing various fuel cetane numbers. He noticed that using various cetane numbers of fuel NOX, SO2, emission are decreased at various speed. Here from the literature review it reviles that the additive plays an important role in enhancing the performance and minimizing the emissions.

Objective of the Study

The objective of present study is to carry out the experimental analysis, to observe the effect of SC5D additive on diesel engine. The SC5D additive compare to other additives cost wise very cheap as well as quality like mileage, performance, power, and reliability are good. The additive manufactured by Suma Fine Chemicals Ltd Pune. The company tested diesel cetane index and smoke density in CIRT PUNE with SC5D additive and compare these results with pure diesel. Here it is noted that by adding this additive, the cetane index increases and smoke density reduces. But we utilized this additive in different proportion of bio-diesel B15[Mamey Sapota 15% + 85% Diesel] and analyze the engine performance as well as emission characteristics and their results compare with pure B15 bio-diesel.

Table 2.1. The physical and chemical properties of SC5D additive as follows

Chemical properties		
S.No	**Property**	**Value**
1.	Density at 29 ℃	0.795 Kg/m3
2.	Boiling Point	180 ℃
3.	Flash point	30 ℃
4.	Ignition Temperature	210 ℃
5.	Vapor Pressure	3.9 mbar
Physical properties		
1	Appearance	liquid
2.	Color	Radish yellow liquid
3.	Odor	Aromatic
4.	Solubility	soluble in hydrocarbons

Table 2.2. Fuel properties of B15 (diesel 85% + Mamey Sapote Oil 15%)and mixing with additive used for experimental analysis

S. No	Fuel type	Density @ 15 °C kg/m3	Degree of API Gravity	Aniline point °C	Flash point °C	Cetane Number
1.	D0(Pure diesel)	835.13	36.80	52	56	51
2.	B1(000:1) ml	841	38.26	53	72.12	52.63
3.	B2(1500:2) ml	840.20	37.98	54	73.28	54.40
4.	B3(2000:3) ml	838.35	37.74	56	74.95	56.68
5.	B4(2500:5) ml	834.45	37.46	58	75.86	58.91
6.	B5(3000:7) ml	828.34	39.71	60	78.52	60.66

Experimental Set-Up

The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to eddy current type dynamometer for loading. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package "Engine Soft" is provided for on line engine performance evaluation.

Engine Software

The 'Engine Soft' is Lab view based software package developed by Apex Innovations Pvt. Ltd. for engine performance monitoring system. Engine Soft can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates power, efficiencies, fuel consumption and heat release. Various graphs are obtained at different operating condition. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats. The data in excel format can be used for further analysis

Instrumentation

Product is supplied with best quality instruments. The eddy current dynamometer is SAJ, Pune make. The components like Open ECU (PE USA), Combustion pressure sensor (PCB Piezotronics, USA), Crankangle sensor(Kubler,Germany),Fuel flow transmitter(Yokogawa, Japan), Pressure transmitter (Wika, Germany), High speed data acquisition device (National instruments, USA) are of MNC grades.

Table 3.1. Engine Specifications

Make and Model	Research Engine Test setup code 240 PE Apex innovations pvt.Ltd.
Type of Engine	Multi fuel
Number of Cylinders	Single cylinder, Four Stroke
Cooling Media	water cooled,
Rated Capacity	3.5 KW @ 1500 rpm,
Cylinder diameter	87.5 mm
Stroke length	110 mm,
Compression ratio range	12-18
Injection variation	0- 25 ^{o} BTDC
Dynamometer	Eddy current Dynamometer
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Table 3.2. AVL Five Exhaust Gas Analyzer

Exhaust gas	Measurement range	Resolution	Accuracy
CO	0-10% vol.	0.01% vol.	<0.6%vol.:± .03%, ≥0.6%vol.:± 5% of ind. val
HC	0-20000 ppm	≤2000:1ppmvol.>2000:10 ppm vol.	<2000ppmvol.:± 10 ppm≥2000ppm vol:± 5% of ind. val.
CO_2	0-20%vol.	0.1 % vol. .	<10%vol.:±0.5%vol. ≥10% vol.:± 0.5% of ind. val.
O_2	0-22%vol.	0.01% vol.	<2%vol.:±0.1%vol.≥ 2% vol.:± 5%of ind. val
NO_X	0-5000 ppm	1 ppm vol.	<500 ppm vol.:± 50 ppm.≥500 ppm vol:± 10% of ind. val

Result and Discussion

Load Vs Brake thermal efficiency

Brake thermal efficiency of the diesel engine increases with the increase in load on the engine. From fig: 4.1 it observed that at full load B 15 (15%Mamey Sapote Oil +85% Diesel) with SC 5D polymer based diesel additive in the proportion of 2000:3 ml has the highest brake thermal efficiency which is 27.28%.This is 4.16% higher than the base line engine without the additive.

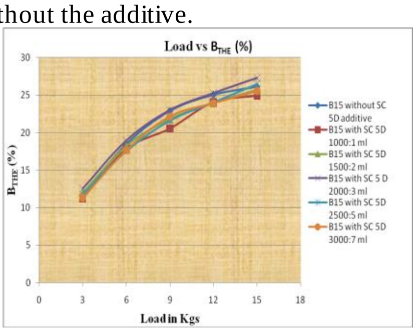

Figure 4.1. Variation of brake thermal efficiency with variation of load

Load Vs Brake Power: Brake power of the engine increases with the increase in load on the engine. Brake power is the function of calorific value and the torque applied. Diesel has more calorific value than the biodiesel, hence to increase the cetane number we are blending B15(15% MSO+85% Diesel) with SC 5D polymer additive at different proportions. From Fig 4.2 the brake power is increased by 2.19% for 2500:5 when compared with without polymer based additive.

All most all blends are closely showing the same brake power of pure diesel. It can also be seen that as we increase the load, torque increases

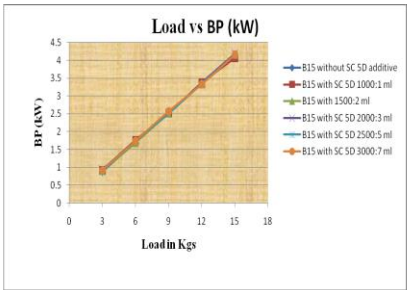

Figure 4.2. Variation of brake Power with variation of load

Load Vs Brake Specific fuel consumption

The variation in brake specific fuel consumption (BSFC) for various engine loads for all test fuels is shown in Figure 4.3 Brake specific fuel consumption of the engine decreases with the increase in load on the engine. It can be seen that the BSFC for all test conditions gradually decreases with an increase in load because of improved combustion rates at higher load.. Hence the amount of heat released is more, so that the fuel consumption is less for the all the blends when compared to without blending.Fig:4.3 illustrates that at full load the B15 with 2000:3 blend consumes less fuel i.e 0.3 kg/kw-hr. It is observed at this blend there is a decrease of 9.09 % specific fuel consumption at full load when compared with the base line engine without additive.

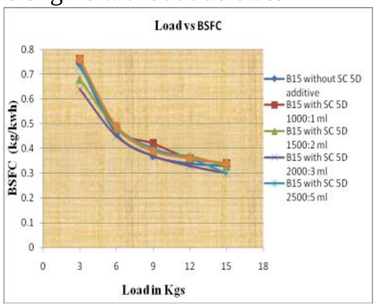

Figure 4.2. Variation of brake specific fuel consumption with variation of load

Load vs Hydro Carbons

The biodiesel blends have more oxygen content than that of standard diesel. So, it involves in complete combustion process. The hydrocarbon emissions of the biodiesel blends are lower than the standard diesel due to complete combustion process. When percentage of blends of biodiesel increases, hydrocarbon decreases. Fig: 4.4 illustrate that, at full load B15 (15% Mamey Sapote+85% Diesel) with 2500:5 ml Polymer SC5D additve, the HC emissions are less i.e 20 ppm, which is 10% less when compared with the base line engine without diesel additive.

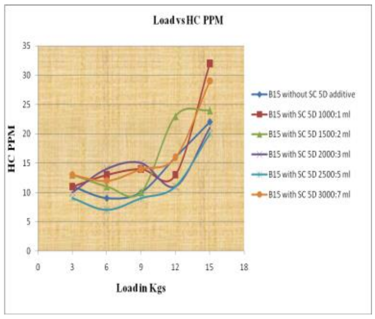

Figure 4.3. Variation of Hydrocarbons with variation of load

Load Vs Carbon monoxide (CO)

The major reason to the CO formation is insufficient time and oxygen for oxidation of CO to CO_2. The carbon monoxide emission depends upon the oxygen content and cetane number of the fuel. By blending the polymer based SC5D additive its Cetane number is further improved. As biodiesel has more oxygen content than the diesel fuel the biodiesel blends are involved in complete combustion process. Fig: 4.5 shows that at full load B15(15 % MSO+85% Diesel) with 2500:5 ml SC 5D additive emits low carbon monoxide (0.05% in volume), which is 16% lower than the base line engine without diesel additive. The carbon dioxide emission depends upon the complete combustion of the fuel.

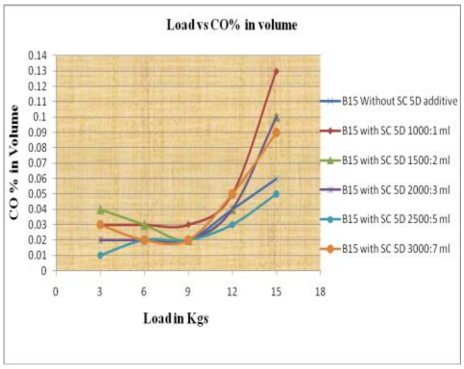

Figure 4.5. Variation of Carbon monoxides with variation of load

Load Vs Carbon dioxide (CO_2)

The carbon dioxide emission depends upon the oxygen content and cetane number of the fuel. The biodiesel has more oxygen content than the diesel fuel and its value is further improved by adding polymer based SC5D additive. So the biodiesel blends are involved in complete combustion process. The maximum carbon monoxide emission was observed at full brake power of the engine.

The biodiesel blends have the 11.5% oxygen content, resulting in complete combustion. Due to the complete combustion of the biodiesel blends, carbon dioxide emission also increases. The carbon dioxide emission using diesel fuel is lower because of the incomplete combustion. The combustion of biodiesel also produced more carbon dioxide but crops are focused to readily absorb carbon dioxide and hence these levels are kept in balance.

Fig: 4.6 illustrate that at full load B15 with 1000:1 ml blend the carbon dioxide emissions are more (3.6 % volume), which is 24.13% higher than the base line engine (B15 15% Mamey Sapote+85% Diesel) without diesel additive.

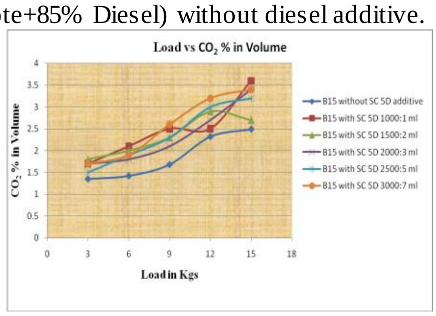

Figure 4.6. Variation of Carbon dioxide with variation of load

Load Vs NOx

Nitrogen and oxygen react relatively at high temperature. Therefore high temperature and availability of oxygen are the two main reasons for formation of NOx. When the more amount of oxygen is available, the higher the peak combustion temperature the more is NOx formed. Fig: 4.6 shows that at peak load B15 with 2500:5 ml SC5D additive emits low NOx i.e 421 ppm, which is 24% lower than the base line engine without diesel additive.

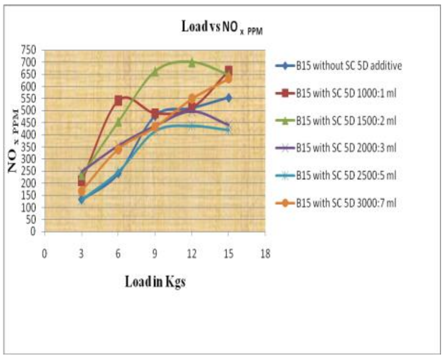

Figure 4.7. Variation of NOx with variation of load

Load Vs Smoke Opacity: Any volume in which fuel is burned at relative fuel-air ratio greater than 1.5 and at pressure developed in diesel engine produces soot. The amount of soot formed depends upon the fuel ratio and type of fuel. If this soot, once formed finds sufficient oxygen it will burn completely. If soot is not burned in combustion cycle, it will pass through the exhaust, and it will become visible. The size of the soot particles affects the appearance of smoke. Black smoke largely depends upon the air fuel ratio and increases rapidly as the load is increased and available air is depleted. Black smoke largely depends upon the air fuel ratio and increases rapidly as the load is increased and available air is opacity for the B15 with SC5D additive comparable with that of B15 without diesel additive for all loads. For over load the smoke opacity is maximum, which is due to incomplete combustion. Fig: 4.8 shows that at peak load B15 with 2500:5 ml diesel additive emits less smoke which is 11.2% lower than the base line engine without additive.

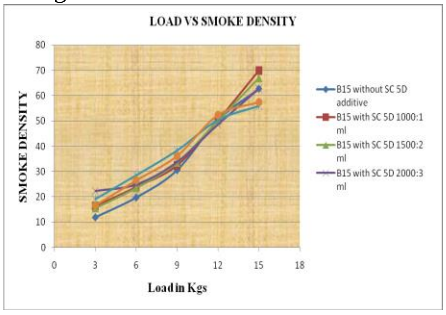

Figure 4.8. Variation of Smoke densities with variation of load

Conclusions

Assessments pertaining to performance and emission characteristics have been carried out about the single cylinder, 4-stroke, uniform speed diesel engine at a Compression ratio of 18. The combustion along with performance and emission characteristics of single cylinder DI diesel engine fuelled with Mamey Sapote (MSO) biodiesel B15 and its SC 5D Polymer based blends have been analyzed and compared the same with the standard base line engine B15 without Diesel additive. Based on the experimental results, the following conclusions are drawn.

- It was observed that at full load B 15 (15%Mamey Sapote Oil +85% Diesel) with SC 5D polymer based diesel additive in the proportion of 2000:3 ml has the highest brake thermal efficiency which is 27.28%.This is 4.16% higher than the base line engine without the additive.

- At full load the brake power is increased by 2.19% for B15 with 2500:5ml SC5D blend when compared with without additive.
- At full load the Brake Specific fuel consumption for B15 with 2000:3 blends consumes less fuel i.e 0.3 kg/kw-hr. which is 9.09 % lower than the base line engine without additive.
- At full load B15 (15% Mamey Sapote+85% Diesel) with 2500:5 ml Polymer SC5D additve, the HC emissions are less i.e 20 ppm, which is 10% less when compared with the base line engine without diesel additive.
- At full load B15 with 2500:5 ml SC 5D additive emits low carbon monoxide (0.05% in volume), which is 16% lower than the base line engine without diesel additive.
- At full load B15 with 1000:1 ml blend the carbon dioxide emissions are more (3.6 % volume), which is 24.13% higher than the base line engine without diesel additive.
- At peak load B15 with 2500:5 ml SC5D additive emits low NOx i.e 421 ppm, which is 24% lower than the base line engine without diesel additive.
- At peak load B15 with 2500:5 ml diesel additive emits less smoke which is 11.2% lower than the base line engine without additive

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depleted. It can be observed from the figure that smoke