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Performance Characteristics Analysis of Madhuca Indica Mixed with Various Biodiesel

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Abstract:*-The increasing demand for renewable and sustainable energy sources has led to extensive research on biodiesel as an alternative fuel for internal combustion engines. Madhuca Indica (Mahua) oil is a promising non-edible feedstock for biodiesel production due to its high oil yield and adaptability to arid conditions. This study investigates the performance characteristics of Madhuca Indica biodiesel blends with various other biodiesel types, focusing on engine efficiency, fuel combustion, and emission characteristics.*

Experimental analysis is conducted using different blending ratios of Madhuca Indica biodiesel with soybean, Jatropha, pongamia, and palm biodiesel in a single-cylinder diesel engine. Key performance parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and cylinder pressure are measured. Additionally, exhaust emissions including CO, HC, NO_x, and smoke opacity are evaluated to determine the environmental impact of each blend.

The results indicate that blending Madhuca Indica biodiesel with other biodiesel types enhances combustion efficiency and reduces overall emissions while maintaining comparable engine performance. This research highlights the potential of multi-feedstock biodiesel blends as a sustainable and efficient alternative to conventional diesel, contributing to cleaner energy solutions and reduced dependency on fossil fuels.

I. INTRODUCTION

India is a home to over a billion people about one-fifth of the world's population. India is projected to become the largest consumer of transportation fuel in 2020, after USA and China with consumption growing at an annual rate of 6.8% from 1999 to 2020. India's economy has often unsettled by increasing in its fuel demand. The acid rain, global warming and health hazards are the results of the ill effects of the increased polluted gases like Sox, CO. The rising petroleum prices increasing threat to the environment from exhaust emissions and global warming have generated and intense international interest in developing non- petroleum fuels for engines. In recent years research has been directed to explore plant based fuels. Biodiesel is described as a fuel comprised of mono alkyl esters of long chain fatty acids derived from animal fat or vegetable fat. The use of non-edible oils compared to edible oils is very significant because of the increase in demand for edible oils as a food and they are too expensive as compared with diesel.

II. PRODUCTION OF BIODIESEL

Vegetable oils are chemically complex esters of fatty acids. These are the fats naturally present in the oil seeds on known as triglycerides of fatty acids. The molecular weight of these triglycerides would be order of 800 / 3 or more that because of the higher molecular weights. These fats have high viscosity causing major problems in the use as fuel in CI engines. These molecules have to split into simpler molecules so that they have viscosity and other properties comparable to standard diesel oils, Dilution and Transesterification among these Transesterification is the most commonly used in commercial process to produce clean and environment friendly light vegetable oil fuels i.e. Biodiesel

III. TRANSESTERIFICATION

The fatty acid triglycerides themselves are esters of fatty acids and the chemical splitting up of the heavy molecules giving rise to simpler esters is known as transesterification. The triglycerides are reacted with a suitable alcohol (methyl, ethyl or others) in the presence of the catalyst under a controlled temperature for a given length of time. The final product alkyl esters and glycerin. The alkyl esters, having a favorable properties has a fuel for use in CI engine are the main products and the glycerin is the byproduct. The chemical reaction triglycerides with methyl alcohol shown below with higher alcohol the chemical equation to change correspondingly

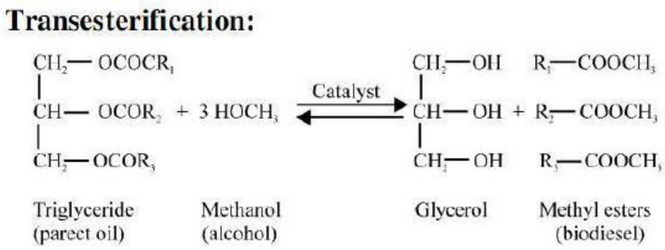

Fig 1.Transesterification reaction

IV. PROPERTIES OF BIODIESEL

The fuel properties of raw vegetable oil indicate that the kinematic viscosity of vegetable oil varies in the rangeof30-40CSTat38^0.The high viscosity of these oils is because of their large molecular mass in the range of 600-900kg/ ^{3}. This is about 20 times higher than that of diesel fuel. The flash point of vegetable oil is very high (above200^0). The heating values are in the range of39-40/ compared to 45 / for diesel. Heating values of various vegetable oils are nearly 90% of diesel fuel. The presence of chemically bound oxygen in vegetable oil lowers their heating values by about10%. The cetane numbers are in the range of 35-50 and is similar or close to that of diesel fuel. Long chain saturated, unbranched hydrocarbons are especially suitable for conventional diesel fuel. The long, unbranched hydrocarbon chains in the fatty acids meet this requirement. The above unique properties of vegetable oils help us to replace the conventional diesel fuel. The major disadvantage of vegetable oils is their inherent high viscosity. Modern diesel engines have fuel injection systems that are sensitive to viscosity change. A high viscosity may lead to poor atomization of the fuel, incomplete combustion, choking of the injectors, ring carbonization and accumulation of the fuel in the lubricating oils. A way to avoid these problems and to improve the performance of the fuel in an engine is to reduce the viscosity of vegetable oil. Methods that reduce the viscosity of vegetable oil include transesterification and fuel blending. These have advantages of improving the use of vegetable oil as fuel with minimum processing and engine modification.

The fuel properties of Mahua oil, Mahua methyl ester and its blends are compared with diesel in Table 5.1. It shows the effects of transesterification and blending on the properties of the fuel, Engines have fuel injection systems that are sensitive to viscosity change. A high viscosity may lead to poor atomization of the fuel, incomplete combustion, choking of the injectors, ring carbonization and accumulation of the fuel in the lubricating oils. A way

S.No	Fuel	Relative density	Kinematic viscosity	Calorific value	Flash point	Fire point
1	Mahua Oil(MOME)	0.920	6.10	41.84	131	180
2	B100	0.920	6.10	41.84	131	180
3	B75	0.884	4.96	42.50	110	125
4	B50	0.850	4.12	43.20	75	89
5	B25	0.841	3.44	43.92	75	76
6	Diesel	0.832	2.6	45.59	65	70

Table 1. Fuel properties of Mahua oil, Mahua methyl ester and its blends

to avoid these problems and to improve the performance of the fuel in an engine is to reduce the viscosity of vegetable oil. Methods that reduce the viscosity of vegetable oil include transesterification and fuel blending. These have the advantages of improving the use of vegetable oil as fuel with minimum processing and engine modification. The fuel properties of Mahua oil, Mahua methyl ester and its blends are compared with diesel in Table 1. The fuel properties of Mahua oil, Mahua methyl ester and its blends are compared with diesel in Table 2. It shows the effect of transesterification and blending on the properties of the fuel.

S.No	Properties	Diesel	MOME
1	Density( )	0.832	0.920
2	Calorific value( )	45.59	41.84
3	Viscosity	2.6	6.10
4	Cetane number	46	131
5	Flash point( )	65	131
6	Fire point( )	70	180

Table 2. Properties of diesel and Mahua oil methyl ester

V. EXPERIMENTAL SETUP AND METHODOLOGY

A typical 3.75 single cylinder, 4-stroke, constant speed (1500) diesel engine is used for investigation to study the performance and emissions. The engine was coupled to an eddy current dynamometer. The specifications of the engine are given in Table 3. Tests were conducted using diesel and biodiesel-diesel blends at no load and 50% of rated load of the engine at the rated speed of 1500 . A blend of 20% biodiesel and 80% diesel (by volume) is denoted byB20.

Exhaust gas composition was measured using AVI Digas Analyzer. The analyzer measures CO, HC, 2, 2, i the exhaust. The range and accuracy of the 5-ga analyzer is given in Table4

Manufacturer	Kirloskar oil Engines Limited
Model	AVL
Engine type	Vertical, single cylinder, water cooled, 4-stroke, Direct injection, compression ignition engine
Power(rated)	3.7at1500 *rpm*
Bore/Stroke	80 *mm*/110 *mm*
Displacement volume	553 *cc*
Compression ratio	16.5
BHP	5
Frequency	50
Amps	20 *A*
Voltage	230/430 *V*
Fuel Oil	High Speed Diesel
SFC	[illegible]

Table 3 Specifications of the Engine

Exhaust gas	Measurement range	Resolution
CO	0-10%	0.01% vol.
HC	0-20000 *ppm*	[illegible] vol. [illegible] vol.
	0-20%vol.	0.1% vol.
	0-22%vol.	0.01% vol.
	0-5000ppm	1 ppm vol.

Table 4 Emission Range

Initially, the biodiesels were prepared in Mahua seed by the method of transesterification process using NaOH as the catalyst. The properties like specific gravity, kinematic viscosity, flash point temperature, cetane number and calorific values for the test fuels, raw oils and diesel are analyzed using ASTM procedures.It is observed that the test fuels properties are within the range of biodiesel standards. The equipments like precision

Hydrometer, Redwood viscometer, Pensky Marten’s closed cup apparatus and digital Bomb calorimeter are used to find out the properties of the test fuels.The performance of fuels is analyzed in injection diesel engine. The engine is couple with an electrical dynamometer. Experiments are conducted with varying loads while engine speed was kept constant. Fuel flow rates are obtained with calibrated burette.The exhaust gas temperatures are measured using thermocouple. The smoke meter is utilized to find the smoke opacity of exhaust gas. The exhaust analyzer is used to measure the carbon monoxide (*CO*), carbon dioxide (2), Hydro carbon emission (*HC*) and Nitrogen Oxides ( ). The experimental setup is shown in fig 2

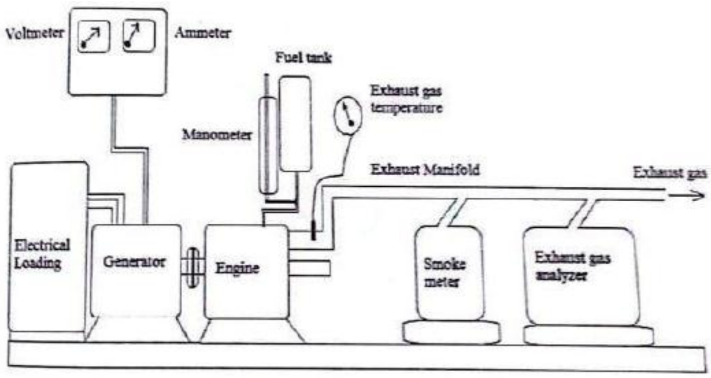

Fig 2 Schematic diagram of Experimental setup

VI. EMISSION CHARACTERISTICS

Carbon dioxide

2 is released into the atmosphere when Biodiesel is burned in an engine. However, this 2 is recycled into organic tissues during plant growth. Only about 40% or less of the organic matter is actually removed from farm fields for biodiesel production. The rest is returned to the soil as organic matter, increasing fertility and reducing soil erosion. With modern conservation farming practices, this soil organic-matter will build up, representing a net removal of 2 from the atmosphere. Biodiesel use in gasoline has tremendous potential for a net reduction in atmospheric 2 levels. Biodiesel is climate friendly, even when considered on a life-cycle basis. They have the lowest lifecycle greenhouse gas emissions. In fact, both emit larger quantities of 2 than conventional fuels, but as most of this is from renewable carbon stocks, that fraction is not counted towards the GHG emissions from the fuel. Table 2 shows fuel-cycle fossil fuel GHG emission (in 2 equivalent) from difference conventional and alternative fuels.

Carbon monoxide

CO is formed by the incomplete combustion of fuels, is produced most readily from petroleum fuels, which contain no oxygen in their molecular structure. Since biodiesel and other “oxygenated” compounds contain oxygen, their combustion in automobile engines is more complete. The result is a substantial reduction in CO emissions. Research shows that reductions range up to 30%. Depending on type and age of engine/vehicle, the emission control system used, and the atmospheric conditions in which the vehicle operates.

Hydrocarbons

Because of its high octane rating, adding biodiesel to gasoline leads to reduction or removal of aromatic HC’s and other hazardous high octane additives commonly used to replace ingasoline

Oxides of nitrogen

A clear trend of reduced HC and CO emissions and increased emissions were observed as the biodiesel concentration in the fuel increased from 0-20%. The standard vehicle was noted to operate at air/fuel ratios significantly richer than stoichiometric, with an average air/fuel ratio running on gasoline of approximately 12:21. For leaner base conditions, the trend could be the opposite, with HC emissions increasing and emissions reducing as the ethanol content of the fuel are increase.

VII. RESULTS AND DISCUSSION ENGINE EMISSION TEST GRAPH

The Performance and emission characteristics of the engine was studied using exhaust gas analyzer for Diesel, B25, B50, B75, B100. The various pollutants are tabulated below

BRAKE POWER VS BRAKE THERMAL EFFICIENCY

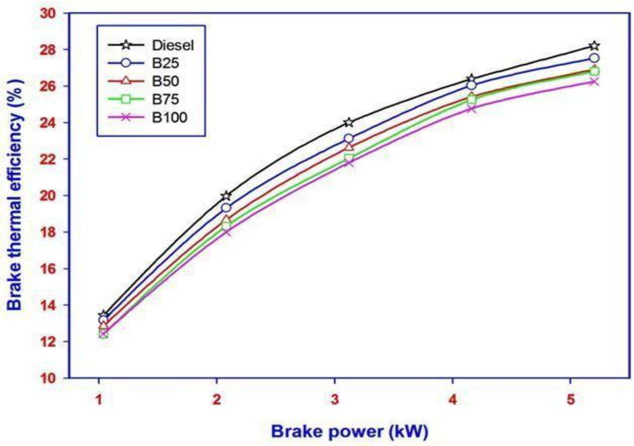

Fig 3.Variation of Brake Power with Brake Thermal Efficiency fordiesel and its blends

BRAKE POWER VS SPECIFIC FUEL CONSUMPTION

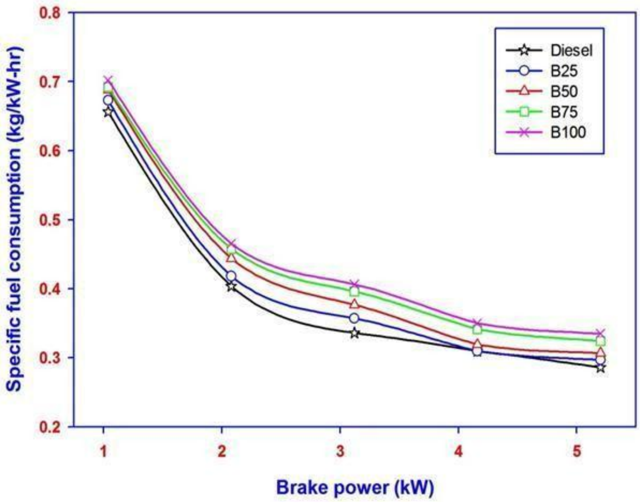

Fig 4.Variation of Brake Power with Specific Fuel Consumption for diesel and its blends

BRAKE POWER VS HYDROCARBON EMISSIONS

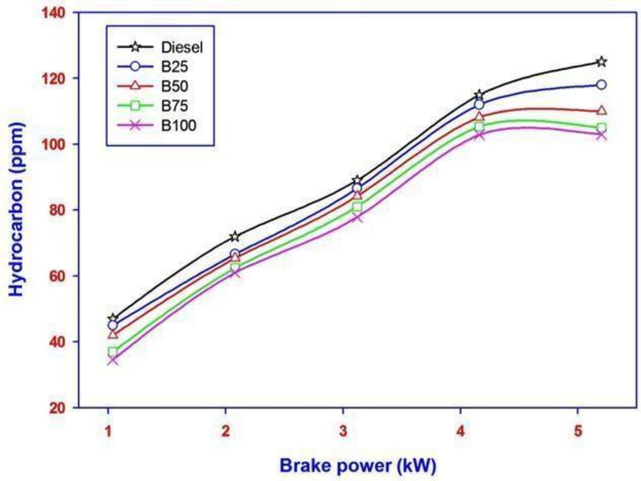

Fig 5. Variation of Brake Power with Hydrocarbon Emissions for diesel and its blends

BRAKE POWER VS CARBON MONOXIDE EMISSIONS

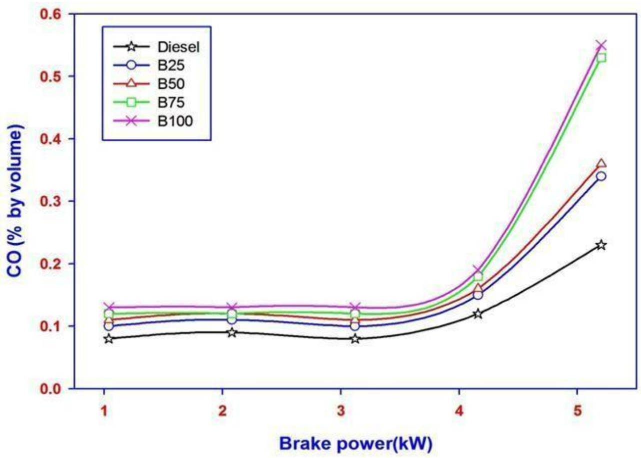

Fig 5. Variation of Brake Power with Carbon Monoxide Emissions for diesel and its blends

BRAKE POWER VS OXIDES OF NITROGEN

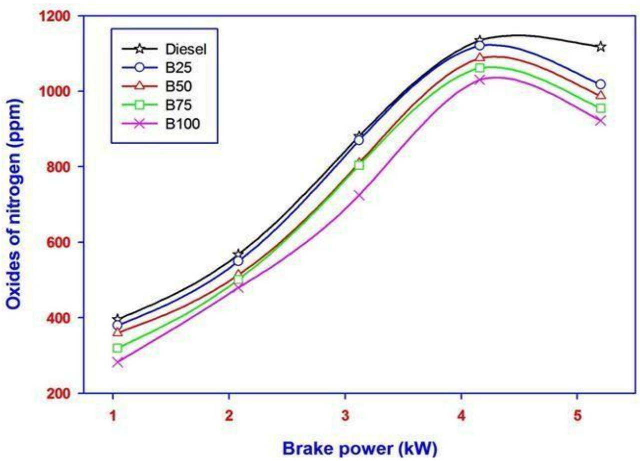

Fig 5. Variation of Brake Power with Oxides of Nitrogen for diesel and its blends

VIII. CONCLUSION

Performance and engine emission results of blends of transesterifiedMadhucaIndica biodiesel and diesel were compared with the results obtained with petrodiesel. Based on the above experimental investigations, it was found that blends of MadhucaIndica Methyl Ester and diesel could be successfully used in diesel engine without any modifications, with acceptable performance and better emissions. The following are the major conclusions that aredrawn.

(1) The blends of MadhucaIndica Methyl Ester with petrodiesel were compatible with diesel oil at higher loads from the perspective of engine performance.
(2) Physical and chemical properties tests revealed that the MadhucaIndica Methyl Ester have almost similar to the diesel, except the viscosity which is slightly higher than that of specified range ofdiesel.
(3) The results are in line with that reported in literature by different researchers using various biodiesel fuels and theirblends.
(4) Based on the engine performance the blend are comparable and better in some aspects than that of fossildiesels.

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