EFFECT OF SAFFLOWER OIL BIO-DIESEL ON PERFORMANCE AND EMISSION CHARACTERISTICS OF SINGLE CYLINDER DIESEL ENGINE

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Abstract*—Safflower seed oil was chemically treated by the alkaline transesterification reaction in methyl alcohol environment with potassium hydroxide (KOH) to produce biodiesel at JSPM's charak college of Pharmacy laboratory. The produced biodiesel was blended with diesel fuel by 20% (B20) and 40% (B40) volumetrically. Some of important physical and chemical fuel properties of blend fuels, pure biodiesel and diesel fuel were determined. Performance and emission tests were carried out on a 4 stroke single cylinder diesel engine to compare biodiesel blends with petroleum diesel fuel. The engine used for the purpose of investigation is of variable compression ratio mechanism. Experiments were carried out for different load i.e. at 0kg, 3kg, 6kg and 9kg. The entire test was carried for compression ratio 17:1 and 18:1. Brake thermal efficiency was increased to 14% at 17:1 compression ratio for blend B40 running at full load as compared from pure diesel. Blend B40 shows minimum fuel consumption as compared from blend B20 and B40. On an average CO2 emissions reduced by 48%, NOX emissions reduced by 68% and HC emissions reduced by 60% at all load conditions. It can be concluded that the use of safflower oil biodiesel has beneficial effects both in terms of emission reductions and alternative petroleum diesel fuel.

***Index Terms*—safflower oil methyl ester, compression ratio, trans esterification, specific fuel consumption.**

I. INTRODUCTION

Increasing rate of petroleum products in India has led to a significant problem to find some alternative source which can fulfill the need of petrol and diesel. For sustainable development of India Energy, fuels and pollution are the major issues to tackle with. Energy sector is highly reliable on imports of petroleum products. Petroleum products import have increased by 170% in quantity and 363% by value from 2004-05 to 2011-12. [1] Mostly for a developing country like India, energy consumptions are directly linked with the use of diesel engine which are used in a various fields like Transport, Agriculture, Constructions, passenger cars, etc. Agricultural sector is highly depends on diesel engine used in tractors. Due to increasing rate of diesel prices, it is not proving economical for the farmers [2]. But at the same time exhaust of diesel engine are rich source of air pollutants like SPM and NOx. Use of alternative technology and alternate fuels is a solution to overcome these issues. [3]Again the feasibility of this type of fuels should be checked, then only it can be produced on a mass scale for commercial use making its price affordable for end users. The potential alternative fuels available are Liquefied Petroleum Gas (LPG), Alcohols (Methanol and Ethanol), Compressed Natural Gas (CNG), Hydrogen and Vegetable oils. Out of these alternatives, vegetable oil is one of the most important choices because of its properties to mix with diesel. The use of vegetable oils as engine fuels can help to reduce the environmental hazards of fossil fuels. Vegetable oils have good ignition characteristics but they also comes with some demerits like carbon deposits, high density, more molecular weight, high viscosity, lower calorific value and poor combustion. These problems lead to poor thermal efficiency. But these can be rectified by using techniques like Dilution (blending), Pyrolysis (cracking) ,Micro-emulsification and transestrification which reduces the viscosity of vegetable oils [4]. Biodiesel is fuel derived from renewable biological resources for use in diesel engines. It is a liquid fuel with similar combustion properties to petrol or diesel. This is why biodiesel is considered as an alternative source of energy that is produced from vegetable oils, animal fats and even used waste cooking oil. It can be made from the oils of vegetable products such as soybean, canola, sunflower, safflower and cotton, and also animal fat. Variation in compression ratio gives nearly the same result on engine running with diesel, blend of diesel and bio-diesel and bio-diesel. Increasing compression ratio within a certain range gives us positive result like increase in brake thermal efficiency, decrease in brake specific fuel consumption, reduces smoke-CO emissions etc. [5]. In this work biodiesel is prepared by using safflower oil through transesterificationprocess. Safflower oil methyl ester blended with diesel is used as a fuel for single cylinder diesel engine. Blend of 20% and 40% at compression ratio 17 and 18 are checked for the analysis of performance and emission of engine. A comparison has been made with the blend of biodiesel and diesel and pure diesel.

II. MATERIALS AND METHODS

Safflower oil used in this work was purchased from sarda oil mill near kadamwasti, Pune. While all the chemicals used in this work was taken from pharmacy lab of Charak College of pharmacy, wagholi. Biodiesel was also prepared in that laboratory.Experiments were carried out in Engine Test Laboratory of JSPM's RajshriSahu College of engineering and research, tathwade, Pune.

A) PREPARATION OF BIODIESEL

The Trans esterification process of safflower oil to produce biodiesel is presented by the steps below:

- The oil was heated to 55 °C in a 500 ml vessel. It was kept at this stable temperature. To obtain a homogenous mixture of reactants, a magnetic stirrer was used. The mixture of oil and alcohol catalyzer was stirred at 1000 rev/min. in the vessel.
- The heated safflower oil was filled into a beaker. An amount of methyl alcohol equal to 40% of prepared oil was mixed with 0.4% KOH, volumetrically. The mixture was heated and then stirred between 30 and 40 °C until the KOH was completely dissolved and

liquefied in the alcohol. Then the mixture of alcohol and KOH was added to the cap containing safflower oil.

- The mixture of oil-alcohol catalyzer was heated at permanent temperature of 55–65 °C and it was stirred simultaneously at about 1000 rev/min. in the reaction beaker for 2 h.
- After 2 h of reaction time, the products were filled into a washingand separation funnel. The reaction products were separated intotwo layers, the top one was biodiesel and the bottom one wasglycerol. The biodiesel was separated from glycerol.
- The biodiesel was then washed with equal amount of water toseparate the probably remained alcohol or catalyst from biodiesel.It was then kept for 4 h in the beaker to separate the water. Finally, thebiodiesel was heated above 100 °C to remove the remaining waterfrom biodiesel fuel.
- The obtained fuel, biodiesel, was added to petroleum diesel fuel volumetrically by 20% and 40%. The fuel mixtures that obtained from the addition of 20% and 40% of biodiesel were named here as B20 and B40 respectively. The fuel properties of purebiodiesel and raw safflower oil are presented in the Table1.

Table 1Properties of safflower oil and its blends

Property	Diesel	B20	B40
Kinematic Viscosity	3.6663	3.3764	3.9876
Density(kg/m^3)	810.7	818.4	833.2
Calorific value(kj/kg)	42000	37000	34000
Specific gravity	0.805	0.8129	0.8325
Flash point in° c	54	75	83
FIRE POINT IN° C	58	82	87

B) ENGINE Testing

Engine testing was done on a single cylinder, 4 stroke and variable compression ratio engine at IC engine lab. The specification of engine used is given below in the table 2.

Table 2 Specification of engine

Engine Type	Four stroke diesel engine
No of cylinders	1
Rated Power	3.5 kw@1500rpm
Cylinder diameter	87.5mm
Stroke length	110mm
Connecting rod length	234mm
Compression ratio vary	12 to 18
Cylinder diameter	20mm
Cooling	Water cooled

Fig.1 Variable compression ratio diesel engine

III. RESULTS AND DISCUSSIONS

A) Performance Parameters

Performance Characteristics of the Engine like Specific Fuel Consumption (SFC) and Brake Thermal Efficiency (BTE) for each blend and effect of variation in Compression Ratio are calculated and plotted on graph.

The fuel consumption characteristics of an engine are expressed in terms of specific fuel consumption in kilograms of fuel per kilowatt- hour. It reveals how good the engine performance is.

- **Specific Fuel Consumption (SFC)**

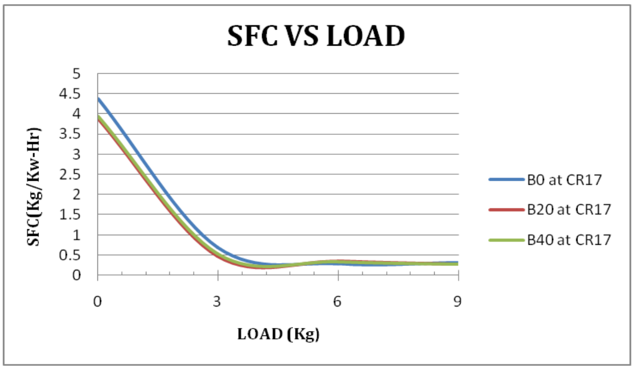

Fig.2 Variation of specific fuel consumption with loadat CR17

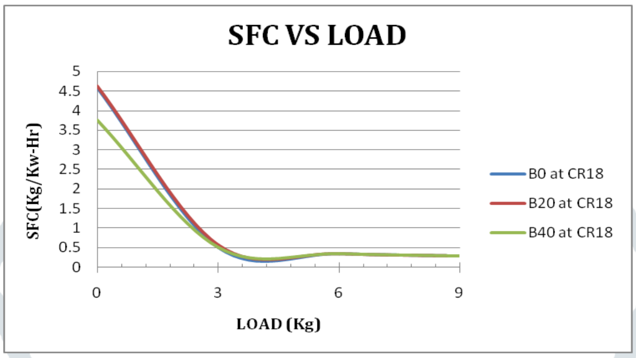

Fig.3 Variation of specific fuel consumption with load at CR18

From above figures it can be observed that, at compression ratio 17:1 specific fuel consumption (SFC) for blend B20 is less as compared from other blend and diesel. While at compression Ratio 18:1 specific fuel consumption (SFC) for blend B40 is minimum as compared from other blend and diesel. At no load condition, SFC reduces by 18%. This advantage is significant at part loads and diminishes as the engine is run at full load and above**.**

- **Brake Thermal Efficiency**

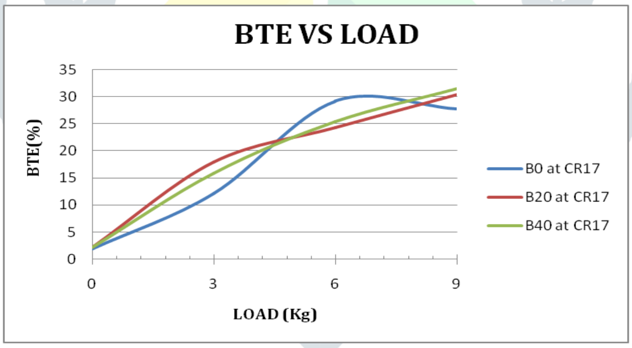

Fig.4 Variation of Brake Thermal Efficiency with load at CR17

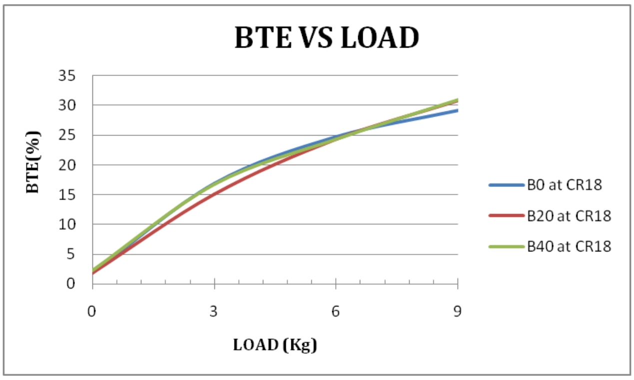

Fig.5 Variation of Brake Thermal Efficiency with load at CR17

From the figure 4 it can be observed that at compression ratio 17:1 brake thermal efficiency (BTE)of B20 and B40 is better than diesel. BTE increases by approx. 6% while running at half load condition. From the figure 5 it can be observed that at compression ratio 18:1 brake thermal efficiency of B40 is better than other blends and diesel. This change is marginal at all load condition.

B) Emissions

Emissions like carbon dioxide, carbon mono-oxide, nitrogen oxide etc. are very harmful for the environment. Therefore it is very necessary to check the emission characteristics of engine when fuelled with safflower oil biodiesel blends**.** So emissions from both the blends and diesel were recorded using exhaust gas analyzer and a comparison has been made using graphical method under different load Condition.

- **CO_2 Emissions**

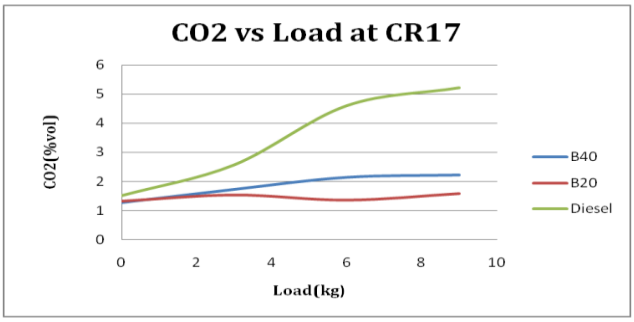

Fig.6 Variation of $CO_2$with load at CR17

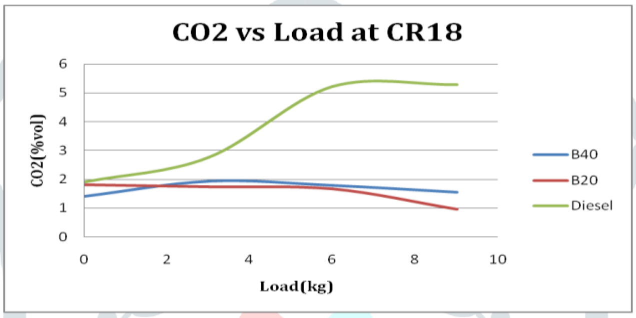

Fig.7 Variation of $CO_2$with load at CR18

At compression ratio 17:1, higher CO_2 emissions are observed for diesel. At all the load conditions, all the blends have lesser CO_2 emissions than that of diesel. At full load, CO_2 emission reduces by 70% from diesel in case of blend B20. In the operating range, CO_2 emissions are more for blend B40.This may due to the complete oxidation of carbon particles present in the fuel. At compression ratio 18:1 also higher CO_2 emissions are observed for diesel. At all the load conditions, all the blends have lesser CO_2 emissions than that of diesel. At full load condition, CO_2 emissions reduce by 82% from diesel in case of blend B20. In the operating range, CO_2 emissions are more for blend B40. This may be also due to the complete oxidation of carbon particles present in the fuel.

- **NOx Emissions**

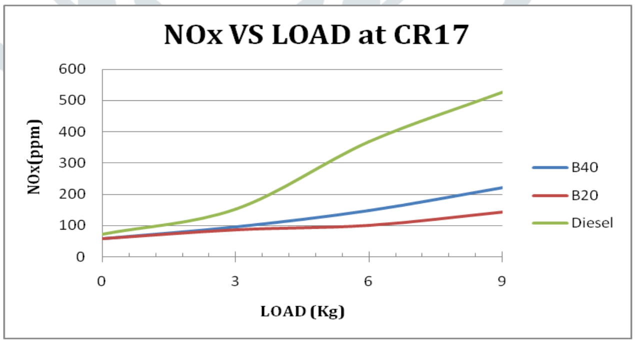

Fig.8 Variation of NOx with load at CR17

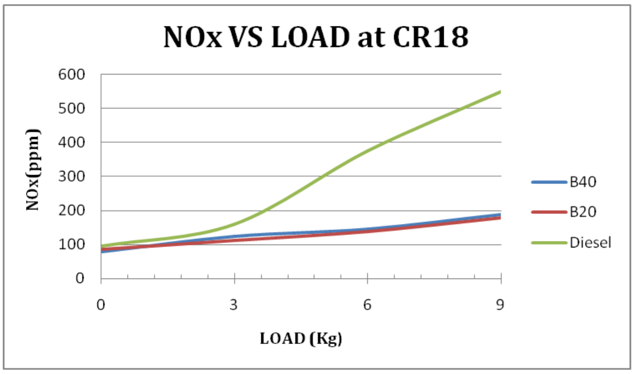

Fig.9 Variation of NOx with load at CR18

At compression ratio 17:1 Higher NOx emissions are observed for diesel. At all the load conditions, all the blends have lesser NOx emissions than that of diesel. In fact it reduces by almost 73% at full load condition for blend B20. In the operating range, NOx emissions are more for blend B40. At compression ratio 18:1 also higher NOx emissions are observed for diesel. At all the load conditions, all the blends have lesser NOx emissions than that of diesel. In this case NOx emissions reduce by almost 68% at full load condition for blend B20. In the operating range, NOx emissions are more for blend B40. This may due to the increase in temperature inside the engine cylinder because of complete combustion of fuel**.**

- **CO Emissions**

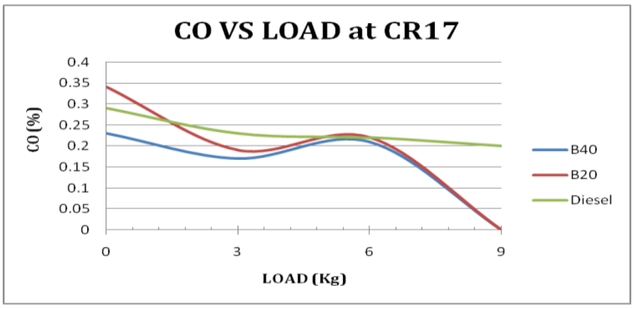

Fig.10 Variation of CO with load at CR17

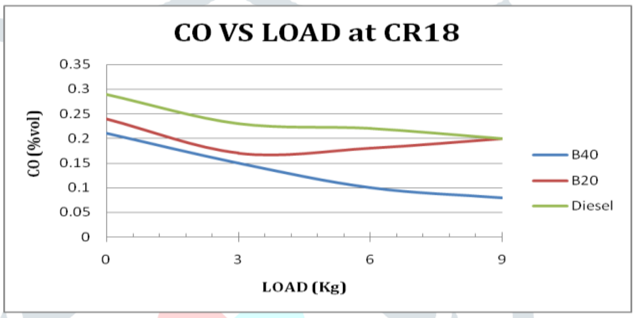

Fig.11 Variation of CO with load at CR18

From figure10 and figure 11 it can be observed that, at compression ratio 17:1, higher CO emissions are observed for diesel. At no load condition blend B20 has more emissions than diesel while at half load and full load it reduces by big margin for both the blends. This may due to more availability of oxygen for complete combustion of fuel particles. At compression ratio 18:1, both the blends show less CO emissions than diesel. It reduces by 60% for blend B40 at half load condition. This also may be due to more availability of oxygen for complete combustion of fuel particles.

- **Hydrocarbon Emissions**

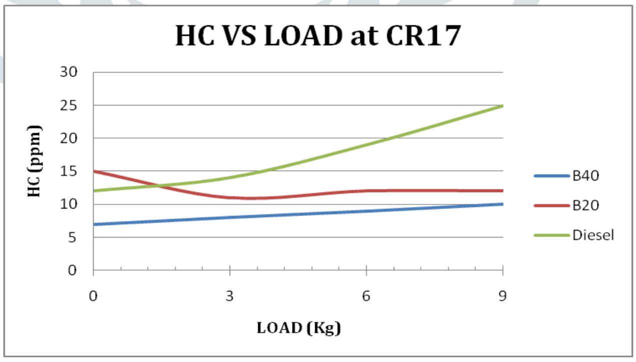

Fig.12 Variation of HC with load at CR17

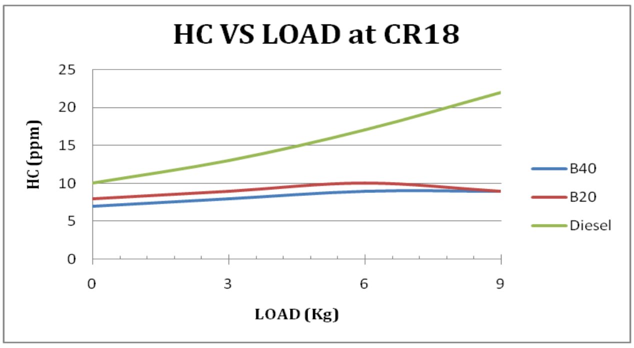

Fig.13 Variation of HC with load at CR17

At compression ratio 17:1, higher HC emissions are observed for diesel. At all the load conditions, all the blends have lesser HC emissions than that of diesel except for blend B20 which shows more ppm than diesel. At full load condition HC emission reduces by 60 % for blend B40. At compression ratio 18:1, also all the blends have less HC emissions than diesel. At full load it reduces by 59% for blend B40. This may be due to an increase in residual gas temperature within the cylinder and decrease in flame quenching thickness at higher loads in the engine.

IV. CONCLUSIONS

From the above results and discussions it can be concluded that:

- Specific fuel consumption (SFC) for blend B40 at compression ratio 18:1 is marginally less than blend B20 and Pure diesel. Also it reduces to 18 % from diesel at no load condition.
- At all load conditions, brake thermal efficiency for blend B40 at compression ratio 18:1 and 17:1 is better than blend B20 and Pure Diesel. In fact it increases by 14% running at full load at compression ratio 17:1
- At all load conditions, CO_2 emission for diesel is more than other blends. At compression ratio 18:1, emissions for blend B20 reduce by 82% at full load.
- At all the load conditions, all the blends have lesser NOx emissions than that of diesel. Blend B20 has the lowest emissions of Nitrogen Oxide gas**.**It reduces by 68% while operating at 18:1 compression ratio.
- Almost at all the load conditions, all the blends have lesser CO emissions than that of diesel. At full load condition HC emission reduces by 60 % for blend B40 at 18:1 compression ratio.
- At compression ratio 17:1 and 18:1 higher HC emissions are observed for diesel at all load condition. At full load condition HC emission reduces by 60 % for blend B40.

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