

Performance and Emission Characteristics of a Diesel Engine Running on Biodiesel

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ABSTRACT: Alternative fuels have received much attention due to the depletion of world petroleum reserves and increased environmental concerns. The desire to reach higher efficiencies, lower specific fuel consumption and reduced emissions in modern engines has become the primary focus of engine researchers and manufacturers over the past three decades. Thus processed form of waste cooking oil (Biodiesel) offers attractive green alternative fuels to compression ignition engines. Biodiesel used in the experiment is a methyl ester of free fatty acid made from waste cooking oil (WCO). The fuel properties of biodiesel are very similar to the diesel fuel, so it can work in existing infrastructure of conventional diesel engine without any modification in the engine. The present work investigates and compares the engine performance parameters such as brake power and brake specific fuel consumption and emission characteristics such as CO, CO₂, HC and NO_x emissions of direct injection Kirloskar diesel engine using various blends of waste cooking oil biodiesel and diesel. The biodiesel blends B10, B15, B20, B25, B35, B50, B75 and B100 were tested and B20 was found as the optimum blend based on the experimental results as it had properties comparable to diesel and lower emissions than diesel. From the results of investigation it was found that, there has been a decrease in brake power with an increase in brake specific fuel consumption for all blends of biodiesel over the entire load range when compared to the diesel fuel. In the case of engine exhaust gas emissions; lower HC, CO and higher CO₂ and NO_x emissions have been found for all biodiesel blends when compared to diesel. Moreover, reductions in sound level for all biodiesel blends have been observed when compared to diesel. B20 was found as the best fuel as it showed lower emissions, better properties and economy than diesel.

KEYWORDS: Biodiesel, Blends, Waste Cooking Oil, Performance, Emissions.

I. INTRODUCTION

Diesel engines are the most efficient prime movers. Now a days the cost of petroleum based fuels are shooting up and also the demand for them are increasing. From the point of view of protecting global environment and concerns for long-term energy security, it becomes necessary to develop the possibilities of using alternative fuels with properties comparable to petroleum based fuels. Unlike the rest of the world, India's demand for diesel fuels is roughly six times that of gasoline, hence seeking alternative to mineral diesel is a natural choice. The rapid depletion of petroleum reserves and rising oil prices has led to the search for alternative fuels. Non edible oils are promising fuels for agricultural applications. Vegetable oils have properties comparable to diesel and can be used to run C.I engine with some modifications. Usage of biodiesel will allow a balance to be sought between agriculture, economic development and the environment.

In this century in order to meet the emergent energy needs as a consequence of spiraling demand and diminishing supply, alternative energy sources predominantly bio-fuels are receiving more attention. The invention of internal combustion engine and subsequent developments in engine technology led to extensive exploitation of the petroleum reserves which were being depleted at a rapid rate. It is very common for all articles based on biodiesel to start claiming that Rudolf Diesel fuelled one of his early engines with peanut oil at the Paris Exhibition in 1900. The first known report of using esters of vegetable oils as a motor fuel was described in a Belgian patent granted to G. Chavanne in

1927 [1]. In 1930s and 1940s vegetable oils were used as diesel fuels, but only in emergency situations [2, 3]. With the increased availability of petroleum in the 1940s, research into vegetable oils decreased. Certainly, the petroleum crisis exploded in the late 1970s and early 1980s and the petroleum products became very scarce and expensive. Since then, research interest has expanded in the area of alternative fuels which are comparable to conventional fuels. In 1979 research into the use of transesterified sunflower oil and its refining to the diesel fuel standard was initiated in South Africa. By 1983 superior quality biodiesel suitable for engines was prepared and tested [4].

In this work the biodiesel produced from waste cooking oil (WCO) through Transesterification reaction is investigated for its performance as a diesel engine fuel. Performance parameters like brake power and brake specific fuel consumption and emission characteristics such as CO, CO₂, HC & NO_x emissions of various biodiesel blends and diesel were determined separately by conducting the Load test in a diesel engine. The performance and emission characteristics of various blends of biodiesel were compared with diesel and the optimum blend was identified based on the test results in a four stroke single cylinder Kirloskar engine.

II. DETERMINATION OF FUEL PROPERTIES

Important fuel properties such as Flash point, Fire point, Kinematic Viscosity, Density, Calorific value and Time for consuming 10cc of fuel were measured. Biodiesel had higher Density, Kinematic Viscosity, Flash point, Fire point, Time for consuming 10cc of fuel and lower Calorific value. The comparison between physical and chemical properties of various blends of Biodiesel and Diesel determined are as follows:

FUELS	DENSITY	VISCOSITY	FLASH POINT	FIRE POINT	TIME FOR CONSUMING 10cc OF FUEL	CALORIFIC VALUE
DIESEL	820 kg/m ³	2.95 cst	50°C	56°C	72 sec	46401 kJ/kg
B10	839 kg/m ³	3.37 cst	52°C	59°C	72.5 sec	44162 kJ/kg
B20	844 kg/m ³	3.78 cst	53°C	68°C	73 sec	42709 kJ/kg
B25	855 kg/m ³	4.50 cst	59°C	80°C	74.2 sec	41455 kJ/kg
B50	862 kg/m ³	4.97 cst	72°C	98°C	75 sec	40665 kJ/kg
B75	890 kg/m ³	5.80 cst	125°C	133°C	76 sec	38279 kJ/kg
B100	897 kg/m ³	6.46 cst	135°C	140°C	77.5 sec	37177 kJ/kg

Table 1: Comparison between properties of various Blends of Biodiesel and Diesel.

III. EXPERIMENTAL SET UP

The project work was done using various blends of biodiesel and diesel in a single cylinder four stroke Kirloskar diesel engine. An experimental set up was configured with necessary instruments to evaluate the emission and combustion parameters of the compression ignition engine at different operating loads. Here the diesel engine was operated separately with diesel and biodiesel blends i.e; B10, B15, B20, B25, B35, B50, B75 and B100.



Fig 1.1: Kirloskar Engine with Mechanical rope brake drum dynamometer.

IV. PERFORMANCE TEST

BRAKE POWER V/S LOAD:

Present work investigates and compares the engine performance parameters such as brake power and brake specific fuel consumption of waste cooking oil biodiesel blends with diesel based on the tests conducted in a direct injection Kirloskar diesel engine. The biodiesel blends used for optimization were B10, B15, B20, B25 and B35. It was found that the use of biodiesel leads to imperceptible power loss and increase in fuel consumption.

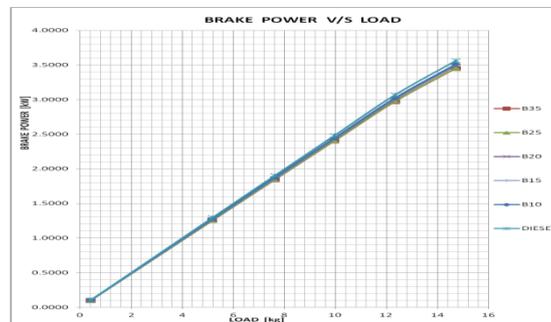


Fig 1.2: Variation of BRAKE POWER V/S LOAD.

In general, although maximum power values of both fuels were very close, all blends of Biodiesel showed power values lower than that of diesel fuel. This lower engine Brake Power (B.P) obtained for Biodiesel could be due to the fuel flow problems. The higher density, higher viscosity and decreasing combustion efficiency will be due to the bad fuel injection atomization and lower thermal efficiency of Biodiesel than diesel fuel.

BRAKE SPECIFIC FUEL CONSUMPTION V/S LOAD:

The bsfc is estimated from the brake power output of the engine and the mass flow rate of the fuel. It can be seen from the figure that the bsfc decreases as the engine speed increases, reaches it's minimum and then increases at higher engine speeds. Average brake specific fuel consumption for usage of Biodiesel was higher than that of diesel. One possible explanation for this increase could be due to lower heating value, higher viscosity and density when compared to the diesel fuel.

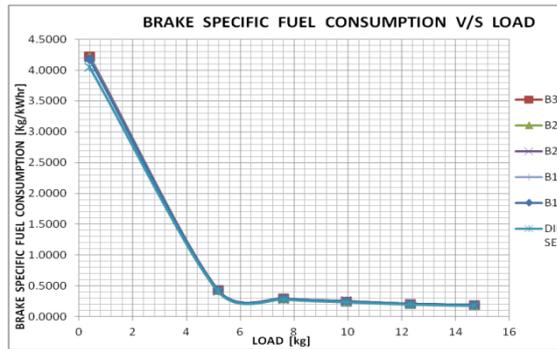


Fig 1.3: Variation of BRAKE SPECIFIC FUEL CONSUMPTION V/S LOAD.

v. EMISSION TEST

The main exhaust emission parameters of waste cooking oil (WCO) biodiesel blends and diesel measured for optimization are CO, CO₂, HC and NO_x emissions. The results were obtained by conducting tests separately for each fuel in a single cylinder four stroke direct injection Kirloskar diesel engine.

CARBON MONOXIDE (CO)EMISSIONV/S LOAD:

It was observed that generally CO emissions increased with increase in engine load. The lower CO emission of all blends of biodiesel when compared to diesel is likely due to the oxygen content inherently present in biodiesel which helps in the more complete oxidation of the fuel.

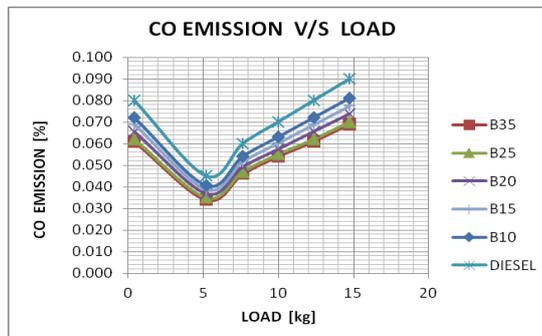


Fig 1.4: Variation of CARBON MONOXIDE (CO)EMISSIONV/S LOAD.

CARBON DIOXIDE (CO₂) EMISSION V/S LOAD:

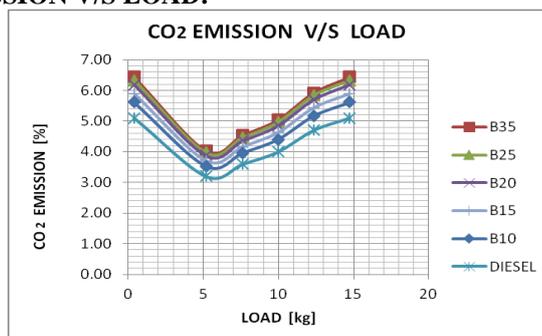


Fig 1.5: Variation of CARBON DIOXIDE (CO₂) EMISSION V/S LOAD.

CO₂ emissions for all the biodiesel blends were found to be higher than that of the diesel fuel. This may be attributed to the oxygen content in biodiesel which reacts with unburned carbon atoms during the combustion and increases the formation of CO₂. More amount of CO₂ in exhaust emission indicates the complete combustion of the fuel [8].

NITROGEN OXIDE (NO_x)EMISSION V/S LOAD:

The NO_x emissions for all blends of Biodiesel were found to be higher than that of diesel. It has been reported that formation of NO_x emissions are strongly dependent upon the equivalence ratio, oxygen concentration and burned gas temperature. According to Mishra et al. [6] and Song et al. [5] increased oxygen levels in Biodiesel increase the maximum temperature during the combustion and thus increase NO_x formation. It is also agreed that in the production of NO_x, the fuel born oxygen is more effective than the external oxygen supplied with the air [9].

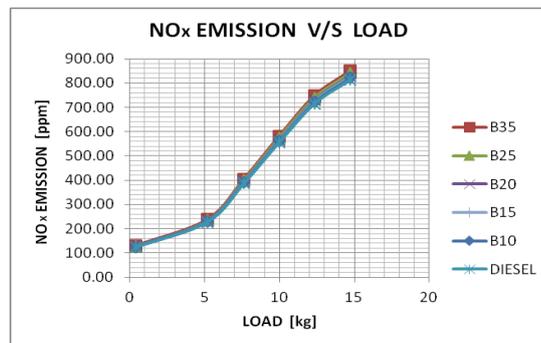


Fig 1.6: Variation of NITROGEN OXIDE (NO_x)EMISSION V/S LOAD.

This can be explained on the basis that at higher engine loads the volumetric efficiency and gas flow motion within the combustion cylinders are found to increase and this in turn leads to a faster mixing between air and fuel which results in the minimization of the ignition delay [4]. The reduction of ignition delay minimizes the reaction time of the free nitrogen and oxygen gas in the combustion chamber which is the main mechanism of NO_x formation.

HYDROCARBON (HC)EMISSION V/S LOAD:

The emissions of unburnt hydrocarbon for biodiesel blends was found to be lower than that of diesel fuel due to the increased gas temperature and higher cetane number of biodiesel. Higher temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon thus reducing unburnt HC.

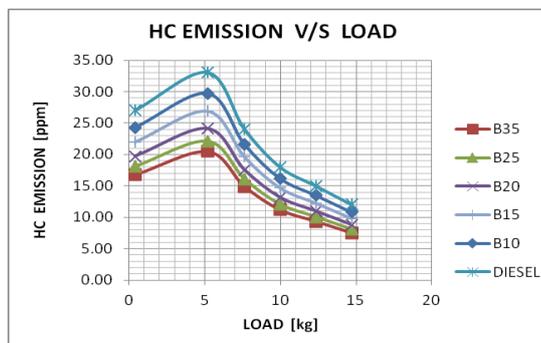


Fig 1.7: Variation of HYDROCARBON (HC)EMISSION V/S LOAD.

FUELS	B.P	B.S.F.C	CO	CO ₂	HC	No _x	COST
DIESEL	.1012 kW	4.1 Kg kWhr	0.08 %	5.1 %	27 ppm	124 ppm	Rs.57
B10	-1.4 %	+ 3.1 %	- 10 %	+ 10 %	- 10 %	+ 1 %	Rs.53.3
B15	-1.75 %	+ 3.43 %	- 14 %	+ 16 %	- 18.5 %	+ 1.5 %	Rs.51.5
B20	- 2.1 %	+ 3.75 %	- 18 %	+ 21 %	- 27 %	+ 2 %	Rs.49.6
B25	- 2.9 %	+ 4.1 %	- 22 %	+ 24 %	- 33 %	+ 3.5 %	Rs.47.8
B35	- 3.1 %	+ 4.3 %	- 24 %	+ 26 %	- 38 %	+ 4.5 %	Rs.44.1

Table 3: Optimization of parameters of various Blends of Biodiesel and Diesel.

VI. CONCLUSIONS

The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel when compared to diesel and it results in the increase in biodiesel fuel consumption. From the experimental results it can be concluded that NOx emissions increase while using biodiesel. This increase is mainly due to the higher oxygen content of biodiesel. Moreover, the cetane number and different injection characteristics also have an impact on NOx emissions of biodiesel. It is accepted commonly that CO emissions reduce while using biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel than diesel. It is predominant viewpoint that HC emissions reduce when biodiesel is fuelled instead of diesel which is mainly contributed by the higher oxygen content of biodiesel. Thermal barrier coatings help to overcome the limitations possessed by biodiesel due to its lower heating value when compared to diesel [7]. The optimum Blend found based on the experimental results was B20 as it had properties comparable to diesel than other blends and lower emissions and cost of preparation than diesel. Thus it can be said that B20 Biodiesel obtained from waste cooking oil (WCO) can be used as an alternative fuel for diesel engine without any complex modification in the engine. So it can be said that waste cooking oil (WCO) methyl ester biodiesel will immediately replace diesel.

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