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Performance and Emission Characteristics of Diesel Engine using Alternative Fuels

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Abstract: ***The purpose of this study is to investigate the performance and emission characteristics of a diesel engine fuelled with diesel and its different blends with WCME biodiesel (15, 20, 25%). The experiment was performed on single cylinder, four stroke VCR diesel engine at different loads and a speed of 1500 rpm. The compression ratio was kept 18:1. Exhaust gas emissions were measured by AVL gas analyzer. The parameters used to measure engine performance were SFC, BTE and emission characteristics were CO, CO_2, HC and NOx. The results were compared among different biodiesel blends and also with pure diesel. The experimental results showed that the SFC of WCME biodiesel blends was higher than diesel. BTE of diesel was higher than biodiesel blends. CO and HC emissions decreases with addition of biodiesel blends in diesel. Diesel has lowest CO_2 emission. NOx emission increases with addition of biodiesel.***

Keywords: Performance, Emission, Diesel Engine, Alternative Fuels.

1. Introduction

1.1 Background

Energy is an essential basis of human activities. It is indeed the live wire of industrial, food and agricultural production, the fuel for transportation as well as for the generation of electricity in conventional thermal power plants. Petroleum is the largest contributing energy source to mankind, surpassing all other resources like; coal, nuclear, hydro, natural gas and wind [23].

The invention of CI engines and developments in engine technology has led to extensive use of the petroleum reserves which are being depleted at a rapid rate. CI engines are employed particularly in the field of heavy transportation and agriculture because of their higher thermal efficiency and durability. The demand of crude oil increases due to increase in vehicles on road every year. The vehicles run on conventional fuels like; petrol and diesel produces high exhaust emissions, thereby causing deterioration of the environment. Engine emissions primarily consist of NO_x, HC, CO, PM, N_2, CO_2, H_2O, H_2, and O_2. The harmful emissions of NO_x, HC, CO and PM are the emissions of most interest.

In India, the total consumption of petroleum products (excluding Refinery Boiler Fuel) increased considerably to 164.99 million tonnes in 2014-15 over the previous year which was 158.41. Imports of crude petroleum increased to 189.432 million tonnes in 2014-15, over the preceding year level of 189.238 million tonnes with a growth of 0.1%. Imports were mainly from Saudi Arabia, Iraq, Kuwait, Nigeria, UAE & Iran, and Venezuela [24].

The diesel engine is the most efficient power plant among all known types of IC engines. Heavy trucks, urban buses, and industrial equipment are powered almost exclusively by diesel engines all over the world and diesel powered passenger cars are increasingly popular. For the foreseeable future, the world's transportation needs will continue to rely on the diesel engine and its gasoline counter-part. However, both engine technologies are evolving at an ever increasing pace to meet two major challenges: lower emissions and increased energy efficiency. IC engines are significant contributors to air pollution that can be harmful to human health and the environment. In response, clean diesel technologies with near-zero emissions of NO_x and PM have been developed and introduced in regions with the most stringent emission standards: North America, Europe and Japan. While new clean diesel engines are gradually replacing the population of older diesel engines in these regions, older engines already in service are being retrofitted with clean diesel technologies to decrease emissions. As this trend spreads to other parts of the world, the environmental focus has shifted to climate changing emissions and energy efficiency. The environmental benefit of low greenhouse gas emissions, traditionally associated with the diesel engine, is no longer sufficient. To meet future greenhouse gas and fuel economy regulations, new technologies are being developed; low temperature combustion, waste heat recovery, powertrain electrification, to name a few that further increase the efficiency not only of the diesel engine powertrain but the entire vehicle as well. Under low-carbon regulatory policies, the scope for potential improvements is no longer limited to engines and vehicles, but also includes life cycle effects of fuel production and engine manufacture [27].

Currently, biofuels are being investigated in detail for application in CI engine with exciting potential opportunities to increase energy security and reduce gas emissions. This could have significant effects on economic development and poverty reduction programmes throughout the world.

1.2 Motivation and Need for Alternate fuels

Probably in this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. Although fuel economy of engines is greatly improved from the past and will probably continue to be improved, increases in number of automobiles alone dictate that there will be a great demand for fuel in the near future. Another reason motivating the development of alternate fuels for the internal combustion engine is concern over the emission problems of gasoline engines. Combined with other air-polluting systems, the large number of automobiles is a major contributor to the air quality problem of the world. Quite a lot of improvements have been made in reducing emissions given off by an automobile engine. If a 35% improvement made over a period of years, it is to be noted that during the same time the number of automobiles in the world increases by 40% thereby nullifying the improvement. Lot of efforts has gone into achieving the net improvement. In cleaning up automobile exhaust. However, more improvements are needed to bring down the ever increasing air pollution due to automobile population. A third reason for alternative fuel development is the fact that a large percentage of crude oil must be imported from other countries which control the larger oil fields [4].

1.3 Biodiesel

Biodiesel is a generic name for fuels obtained by vegetable oils and their derivatives (especially Methyl esters). Esterification can be done either by methanol or by ethanol. Biodiesel can be used in a Diesel engine without modification. Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils or recycled restaurant greases [6].

Biodiesel is safe, biodegradable, and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxins. Blends of 20% Biodiesel with 80% Petroleum Diesel (B20) can be used in unmodified Diesel engines. Biodiesel can also be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. Biodiesel is a clean burning Diesel fuel additive produced from vegetable oils instead of Petroleum. Biodiesel blends operate in Diesel engines, from light to heavy-duty, just like Petroleum Diesel fuel. No engine conversions are required at all, unless an engine has old fuel lines. As a result, Biodiesel can now compete with other alternative fuels and clean-air options for urban transit fleets and government vehicles across the country [6].

1.4 Characteristics of WCME

There is a growing interest in the use of vegetable oils for making renewable diesel, which is less polluting than conventional petroleum diesel fuel. Renewable fuels such as biodiesel and ethanol are important because they can replace petroleum fuels. They also offer many priorities like regional development, sustainability and finally the security for supply [27].
Some of the properties of WCME are as follows:

Table 1: Comparative Fuel Properties

Properties	*Diesel*	*WCME Biodiesel*
Cetane number	40-55	50-65
Energy density(MJ/kg)	43	37
Density (kg/m^3)	838	870
Viscosity@40°C (mm^2/s)	3.5	4.4
Lubricity	Baseline	Good
Oxygen content wt%	0	10

2. Experimental Setup

Experimental study on a VCR diesel engine (computerized), fuelled with diesel and different percentages of WCME blended with diesel were investigated with respect to the performance and emission characteristics.

The setup consists of single cylinder, four stroke, Diesel engine connected to eddy current type dynamometer for loading. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

The setup enables study of engine performance for BP, IP, FP, BMEP, IMEP, BTE, ITE, mechanical efficiency, volumetric efficiency, SFC, AFR and heat balance. Labview based Engine Performance Analysis software package "EnginesoftLV" is provided for on line performance evaluation.

A brief specification of the test engine, used for the study is given in the Table 2 and schematic arrangement of the experimental setup is shown in Figure 1.

Table 2: Test Engine Specifications

Make	Kirloskar
Engine Model	TV 1
Engine Type	Vertical, 4-stroke, water cooled, VCR diesel engine
No. of Cylinder	One
Maximum power	5.2 kW@1500RPM
Bore	87.5 mm
Stroke	110.0 mm
Compression Ratio	18:1
Capacity	661.45cc

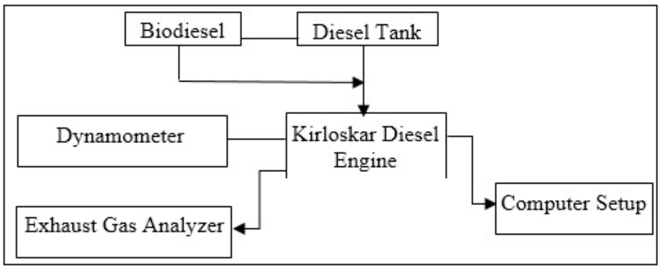

Figure 1: Schematic Diagram of Experimental Setup

Exhaust gas composition was measured using NDIR based exhaust gas analyzer [Make: AVL; Model: Digas 444]. The analyzer measures CO, CO_2, HC, O_2 and NOx in the exhaust.

3. Testing Procedure

1. Ensure cooling water circulation for eddy current dynamometer and piezo sensor, engine and calorimeter.
2. Start the set up and run the engine at no load for 4-5 minutes.

3. Switch on the computer and run "EnginesoftLV". Confirm the EnginesoftLV configuration data.
4. Gradually increase load on the engine.
5. Wait for steady state (for @ 3 minutes) and log the data in the "EnginesoftLV" software.
6. Gradually decrease the load.
7. View the results and performance plots in "EnginesoftLV".
8. Corresponding emission readings for exhaust gases CO, CO_2, HC, NOx are also noted from exhaust gas analyzer.

Experiments were conducted with WCME and diesel blends having 15%, 20%, 25% WCME on volume basis at different load levels. Engine performance tests on pure diesel were also conducted as a basis for comparison. The experiments were repeated thrice and the average values were taken for performance and emission measurements.

4. Results and Discussions

4.1 Engine Performance

Performance curves show similar trends as shown by diesel engines. Brake power increases with load as it is directly proportional load for all fuels.

Figure 2 shows variation of SFC with load. The result shows that SFC is higher for all WCME blends than diesel under various loading conditions. This is due to high viscosity, density and lower heating value of biodiesel.

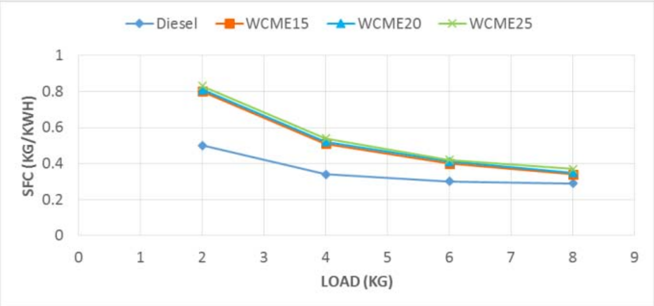

Figure 2: Variation of specific fuel consumption with load

Figure 3 shows variation of BTE with load. The result shows that BTE of WCME blends is slightly lower than that of diesel fuel. This is due to WCME's lower heating value, higher density and increased viscosity which leads to poor atomization and fuel vapourization.

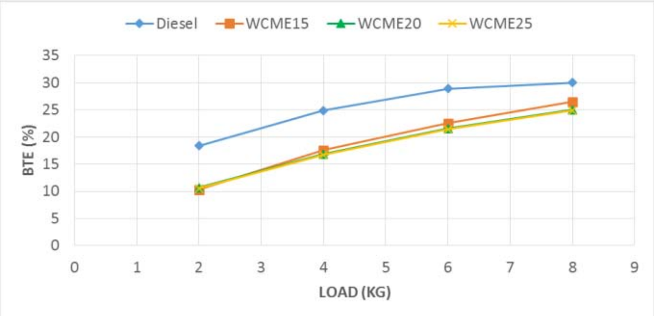

Figure 3: Variation of Brake Thermal Efficiency with load

4.2 Engine Emission

Figure 4 shows variation of CO with load. The result shows that CO emission increases with increase in load for all fuels. Diesel has higher CO emission than all blends. Among the blends, CO decreases with increasing percentage of biodiesel in diesel. This is due to the oxygen content in biodiesel which allows more carbon molecules to oxidize when compared with diesel fuel.

Figure 4: Variation of Carbon monoxide with load

Figure 5 shows variation of CO_2 with load. The result shows that CO_2 emission increases with increase in load for all fuels. Diesel has the lowest CO_2 emissions. Among the blends, CO_2 decreases with increasing percentage of biodiesel due to increase in oxygen content.

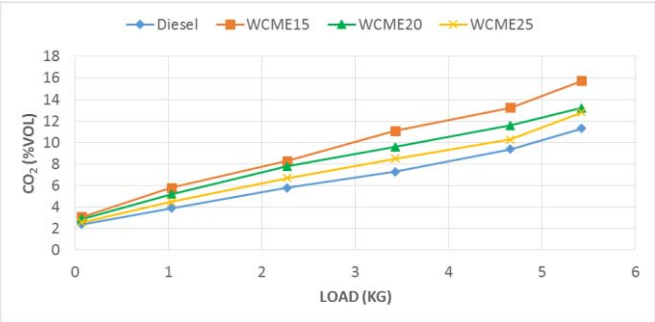

Figure 5: Variation of Carbon dioxide with load

Figure 6 shows variation of HC with load. The result shows that HC emission decreases with increase in percentage of WCME in the blend. HC emission increases as load increases with diesel and blends of WCME as the result of increase in fuel consumption at high engine loads.

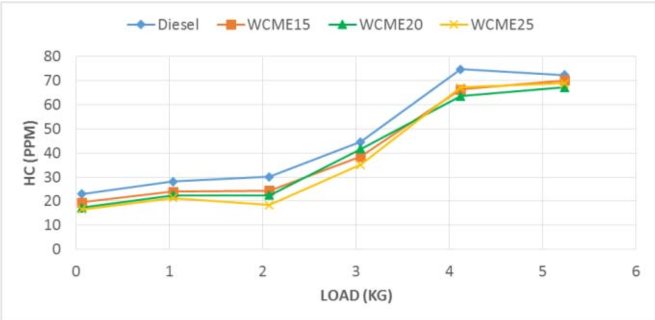

Figure 6: Variation of Hydrocarbon with load

Figure 7 shows variation of NOx with load. The result shows that NOx formation in the cylinder is affected by oxygen content, combustion flame temperature and reaction time. NOx formation of all biodiesel and blends is slightly higher than that of diesel fuel. As load increases, the NOx formation increases and attains maximum value at maximum load. This is due to higher temperature of combustion and the presence of oxygen with biodiesel cause higher NOx emission.

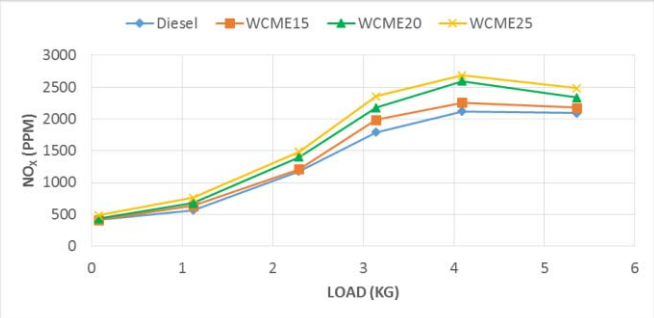

Figure 7: Variation of Nitrogen oxides with load

5. Conclusions

WCME biodiesel, produced from renewable and often domestic sources, represents a more sustainable source of energy and will therefore play an increasingly significant role in providing the energy requirements for stationary and transportation purposes. Therefore, more studies need to done on WCME engine performances and emissions. Although there are data available on WCME performance and emissions, there have been inconsistent trends for WCME engine performances and its emissions due to the different tested engines, the different operating conditions, the different measurement techniques or instruments, etc. Therefore, in the present study, efforts have been made to perform the engine performance and emissions tests under controlled conditions.

The following conclusions have been made from this study:

1 BP increases with the load for diesel and its blends with biodiesel.
2 SFC is higher for biodiesel blends than diesel.
3 BTE of diesel is higher than biodiesel blends.
4 CO and HC emissions decreases with increasing percentage of biodiesel in blends with diesel.
5 Diesel has lowest CO_2 emission and among all fuel blends CO_2 emission decreases with increasing percentage of biodiesel.
6 NOx emission increases with increasing percentage of biodiesel in blends.

Nomenclatures

WCME	Waste cooking oil methyl ester
VCR	Variable compression ratio
rpm	Revolutions per minute
SFC	Specific fuel consumption
BTE	Brake thermal efficiency
CO	Carbon monoxide
CO_2	Carbon dioxide
HC	Hydro carbon
NOx	Nitrogen oxides
CI	Compression Ignition
PM	Particulate matter
N_2	Nitrogen dioxide
H_2O	Water
H_2	Hydrogen
O_2	Oxygen
IC	Internal Combustion
BP	Brake Power
IP	Indicated Power
FP	Frictional Power
BMEP	Brake mean effective pressure
IMEP	Indicated mean effective pressure
ITE	Indicated thermal efficiency
AFR	Air-Fuel ratio
NDIR	Non-dispersive Infra-red

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