Emission Characteristics of VCR Diesel Engine using WCME Biodiesel

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Abstract - *The objective of this study is to investigate the emission characteristics of a Kirloskar diesel engine fuelled with diesel and its different blends with WCME biodiesel (10, 20, 30% by vol). The experiment was performed on a single cylinder, four stroke VCR diesel engine at different loads and a constant speed of 1500 rpm. The compression ratio was kept 18:1. Exhaust gas emissions were measured by AVL 4-gas analyzer. The parameters used to measure engine emissions were CO, CO_2, HC and NOx. The results were compared with pure diesel and also among different biodiesel blends. The experimental results showed that CO and HC emissions decreases with addition of biodiesel in the blends with diesel. Diesel has lowest CO_2 emissions. NOx and CO_2 emissions increases with addition of biodiesel percentage in blends.*

Key Words: **Emission, Performance, Diesel Engine, Biodiesel, Alternate Fuels.**

1. INTRODUCTION

1.1 Background

Petroleum is the largest contributing energy source to mankind, surpassing all other resources like; coal, nuclear, hydro, natural gas and wind [3].

In the world of today, energy is a lifeline of all human activities. It has now become a necessity for day to day routine life. It is essential in the fields of industrial, food and agricultural production, the fuel for transportation as well as for the generation of electricity.

The number of diesel engines is increasing continuously every year because of having high efficiency, enhanced fuel economy. Diesel engines are preferred over spark ignition engines in almost all heavy-duty applications due to their reliability and durability. Therefore, the world's demand for diesel fuel increases every year. Since the fossil fuel resources are limited and non-renewable and will gradually diminish. Also fossil fuels causes air pollution and global warming hence it is required to find renewable energy sources and fuels [4].

In India, the total consumption of petroleum products increased considerably to 184.674 million tonnes in 2015-16 over the previous year which was 165.52 million tonnes. Imports of crude petroleum increased to 202.851 million tonnes in 2015-16, over the preceding year level of 189.435 million tonnes with an increase of 7.08% [5].

Presently the major portion of the energy supply depend upon petroleum-based fossil fuel supplies. This supply is heavily stressed due to the increasing number of vehicles on roads every year. In addition, diesel engines have been considered one of the major air pollution sources with emissions of particulate matter (PM), NOx, HC, CO [6].

Currently, biofuel derived from waste cooking oil is being investigated in detail for application in diesel engine with an intent to explore potential opportunities in energy security improvement and exhaust gas emissions reduction.

1.2 Motivation for Alternate Fuels

The future oil supplies are not stable and concentration of pollutants emitted to the atmosphere is increasing day by day. This has motivated the development of alternative energy sources and engine technology [2].

1.3 Emission Legislation

The stringent emission regulations that has established in most countries shows the concern for the environment. Newly produced engines have to pass certain emission limits in order to get approved for sale. The test differs for different regions and also for different types of vehicles [2].

Table -1: Regulated Pollutants in Diesel Exhaust & their Health and Environmental Effects [7]

Pollutant	Source	Description	Environmental and health effect
NOx	Reaction between oxygen and nitrogen in the engine combustion chamber	It consists of 90% NO and 10% NO_2.	Damages lung tissue and plants. Formation of ground level ozone & smog and contributes to global warming.
PM	Product of fuel or lubricating oil consumption	Tiny carbon particles (soot or smoke) with toxic organic compounds	PM affect respiratory system and carry toxic substances into lungs and blood stream.
CO	Incomplete combustion of	Higher toxic	CO is hazardous in high

	carbon-containing fuels	gas	concentration because it binds with hemoglobin in the blood, impairing its ability to transport oxygen to the brain and other vital organs.
HC and NMHC	Unburned or partially burned fuel, fuel spills	HC contains both reactive species, called VOCs and nonreactive species, such as methane	HCs are ozone precursors.

1.4 Responsive Solutions to reduce Exhaust Emissions

One of the main reasons to use alternate fuels is to replace petroleum oil, this study focuses on the engine emissions aspects of alternate fuels. Several techniques can be employed to reduce emissions. To achieve this goal, the following can be done:

1. Improve engine technology
2. Use of improved fuels
3. Using after-treatment devices [2].

1.5 Biodiesel

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. Most biodiesel produced at present is produced from waste vegetable oil sourced from restaurants, industrial food producers. Though oil straight from the agricultural industry represents the greatest potential source it is not being produced commercially simply because the raw oil is too expensive. After the cost of converting it to biodiesel has been added on it is simply too expensive to compete with fossil diesel. Waste vegetable oil can often be sourced for free or sourced already treated for a small price. (The waste oil must be treated before conversion to biodiesel to remove impurities). The result is Biodiesel produced from waste vegetable oil can compete with fossil diesel. Biodiesel is safe, biodegradable, and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxins. [11].

1.6 Properties of WCME Biodiesel

There is a lot of research going on in the use of vegetable oils for making renewable diesel, due to its less polluting nature than conventional diesel fuel. Renewable fuels such as biodiesel, hydrogen fuels and ethanol are important because they have a tendency to replace petroleum fuels. They also offer many advantages like rural development, sustainability and the security in fuel supply [2].

Some of the properties of WCME are as follows:

Table -2: Comparative Fuel Properties

Properties	Diesel	WCME Biodiesel
Cetane number	40-55	55-65
Energy density(MJ/kg)	43	38
Density (kg/m3)	838	872
Viscosity@40°C (mm2/s)	3.5	4.5
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 emission characteristics.

The setup consists of single cylinder, four stroke, Diesel engine connected to eddy current type dynamometer for loading purpose. 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 and emission characteristics but the study is focused on engine emissions.

A brief specification of the test engine, used for the study is given in the Table 3 and schematic arrangement of the experimental setup is shown in Figure 1.

Table -3: 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

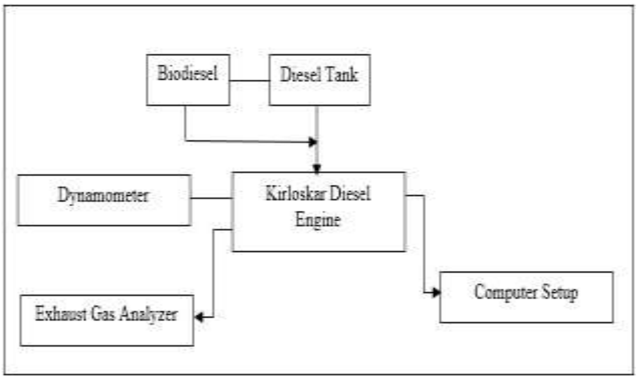

Fig -1: Schematic Diagram of Experimental Setup

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

3. TESTING PROCEDURE

1. Start the cooling water supply to ensure proper circulation for eddy current dynamometer, engine and calorimeter.

2. Start the experimental set up and run the engine at no load about 5 minutes.

3. Switch the computer on and run "EnginesoftLV" software. Confirm the configuration data of EnginesoftLV.

4. Gradually increase load on the engine.

5. Wait for steady state to be achieved (for about 5 minutes) and log the data in the "EnginesoftLV" software.

6. Gradually decrease the load on the engine.

7. Emission readings for exhaust gases CO, CO_2, HC, NOx are also noted from exhaust gas analyzer.

8. View the results and corresponding plots in "EnginesoftLV".

Experiments were conducted with diesel and WCME blends having 10%, 20%, 30% WCME on volume basis at different load levels. Engine emission tests were also conducted on pure diesel as a basis for comparison. The experiments were repeated thrice and the average values were taken for emission measurements.

4. RESULTS AND DISCUSSIONS

4.1 Engine Emissions

Chart 1 shows variation of Carbon monoxide (CO) with load. The result shows that CO emission increases with increase in load for all the fuels tested. Diesel has higher CO emission than all biodiesel 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.

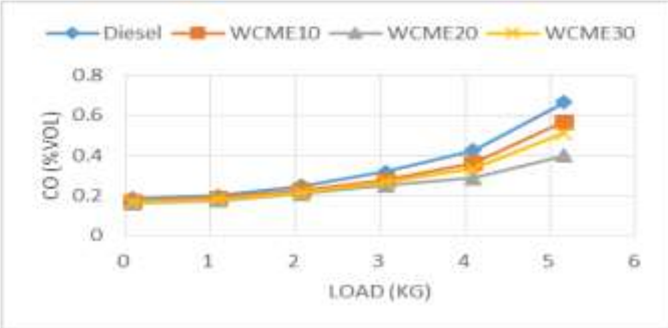

Chart -1: Variation of Carbon monoxide with Load

Chart 2 shows variation of Carbon dioxide (CO_2) with load. The result shows that CO_2 emission increases with increase in load for all fuels tested. Diesel has the lowest CO_2 emissions. Among the blends, CO_2 increases with increasing percentage of biodiesel due to increase in oxygen content.

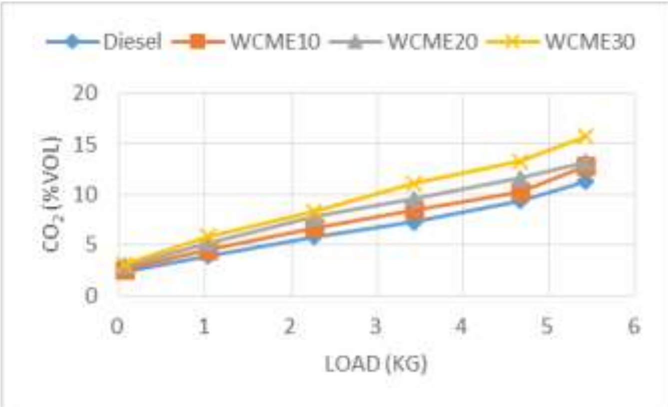

Chart -2: Variation of Carbon dioxide with Load

Chart 3 shows variation of Hydrocarbon (HC) with load. The result shows that HC emission decreases with increase in percentage of WCME in the blends. HC emission increases as load increases with diesel and blends of WCME as the result of increase in fuel consumption at high engine loads.

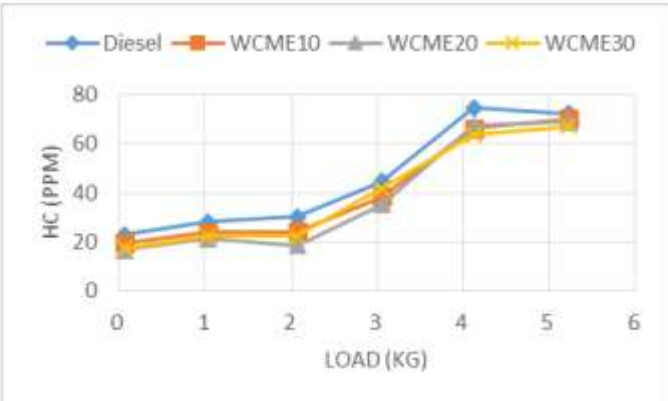

Chart -3: Variation of Hydrocarbon with Load

Chart 4 shows variation of Nitrogen oxides (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.

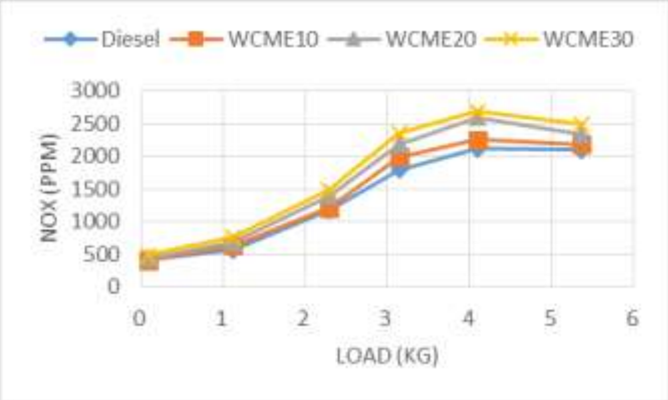

Chart -4: Variation of Nitrogen oxides with Load

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 [1].

The following conclusions have been made from this study:

1 CO and HC emissions decreases with increasing percentage of biodiesel in blends with diesel.
2 Diesel has lowest CO_2 emission and among all fuel blends CO_2 emission decreases with increasing percentage of biodiesel.
3 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
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
AFR	Air-Fuel ratio
NDIR	Non-dispersive Infra-red

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