A Review on Performance Analysis of VCR Engine Working With Fumigated Bio-Diesel

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Abstract - *Biodiesel has become one of the most versatile alternative fuel options for diesel engine applications. The world faces the energy demand, increased petroleum rates and decrease of fossil fuel resources. Biodiesel has been extracted from vegetable oils that have been considered as alternative fuel. This paper reviews the fumigated biodiesel, different methodologies used for testing the emission characteristics and performance of engine by using fumigated biodiesel. The application of biodiesel in automobile industry, the challenges of biodiesel industry development and the biodiesel policy are discussed as well. The properties of biodiesel such as density, flash point, Kinematic viscosity, calorific value are found out for different biodiesel and the properties are compared with diesel. The emission of carbon dioxide, carbon monoxide, hydrocarbon and oxides of nitrogen gases, smoke, in exhaust were recorded.*

Keywords: Biodiesel, Emission, Fumigation, Performance, Alternative fuel.

1. INTRODUCTION

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of biology, it has provided an effective way to fight against the problem of petroleum scarce and the influences on environment. Biodiesel is a renewable, clean-burning diesel replacement that is reducing U.S. dependence on foreign petroleum, creating jobs and improving the environment. Made from a diverse mix of feed stocks including recycled cooking oil, soybean oil, and animal fats, it is the first and only EPA-designated Advanced Biofuel in commercial-scale production across the country and the first to reach 1 billion gallons of annual production. Meeting strict technical fuel quality and engine performance specifications, it can be used in existing diesel engines without modification and is covered by all major engine manufacturers' warranties, most often in blends of up to 5 percent or 20 percent biodiesel. It is produced at plants in nearly every state in the country. Bio-diesel is the most valuable form of renewable energy that can be used directly in any existing, unmodified diesel engine .Biofuel are diversified as alcohols, ethers, esters, carbonates and acetate compounds, containing inbuilt oxygen, and are emerging as potential substitute for diesel. Significantly, these less viscous biofuel, which are deemed to be synthesized from plants parts, unlike the triglycerides (vegetable oils), have one phenomenon in unison, which relates to their lower cetane number and viscosity. Despite their lower ignition quality, these fuels could be used in diesel engine by blending it with diesel, which is regarded as the simplest way to use alcohol or other less viscous fuels, the above discussion on fuels with lower viscosity and cetane number identifies three new research scopes: (1) though a variety of vegetable oil based fuels have been conceived, lesser attention or interest has been paid to conceive less viscous biofuel in the likes of ethanol and methanol (2) there seems to be a lack in sufficient data on fumigation studies for fuels with lower viscosity and cetane number, whereas a lot of data have been made available for the operation of these fuels in blend fuel mode. (3) Absence of contributions to examine the fundamental study on vaporization of the fuels being fumigated and couple it with engine fumigation study. With the above stated shortcoming, we decided to embark on a research work that would address the limitations of previous research works. In this work, we have chosen pine oil, a new renewable fuel derived from pine trees, as a potential candidate for diesel engine. Rather than using it in blends with diesel, it was inducted into the engine cylinder through inlet manifold, while diesel was supplied through main injection system. Further, the inlet air was also preheated to evaporate the injected fuel, whereby, hot vaporized biodiesel/air mixture was inducted into the cylinder. The preheat temperature was decided based on the outcome of suspended droplet evaporation study, conducted prior to engine study. Biodiesels have calorific values close to diesel fuel which makes it a potent candidate for replacement of diesel. However, it has very high viscosity but that can be reduced by transesterification. There are different methods available to reduce viscosity of the vegetable oils such as Preheating, Trans-esterification, pyrolysis etc. A lot of researchers and scientists are already working on developing new and efficient methods of synthesizing biodiesel from biofuel.

This biodiesel can be used as an alternate fuel. It can be directly fuelled in CI engine without much engine modifications.

2. Production

Biodiesel is typically produced by the reaction of a vegetable oil or animal fats with an alcohol such as methanol or ethanol in the presence of catalyst to yield mono-alkyl esters (biodiesel) and glycerin. This reaction is called transesterification. Raw or refined vegetable oil or recycled greases that have not been processed into biodiesel are not biodiesel. Care must be taken to then separate the finished biodiesel from the glycerin, catalyst, soaps and any excess alcohol that may remain.
Different methodologies used for production of biodiesel are:

- Direct Use and Blending
- Transesterification Process
- Thermal Cracking (Pyrolysis)
- Micro-emulsion

2.1 Direct Use and Blending

The animal fat or vegetable oil can be used as a fuel in direct injection engine; it has a good heating value and could give a sufficient power. But it has some problems due to its unacceptable properties, so it cannot be used in DI engine without any modification. To avoid such problems the alternative fuel sources are directly blended with conventional fossil fuels. This kind of blending will improve the fuel quality, reduces the fossil fuel consumption, etc., so it is also preferable as a most convenient way to use an alternative fuels such as biofuel. The bio oil and diesel blends will be in different ratio like 10:1, 10:2, 10:3.

2.2 Transesterification

The transesterification process is a reaction between triglycerides in the vegetable and alcohol which produces the biodiesel (mono alkali ester) and glycerol. In this process some catalyst also used to increase the speed of the reaction and quality of the outcome product. The amount and types of catalyst are decided by the amount of free fatty acid present in the feed stock oil. The higher amount of free fatty acid is unfavorable for biodiesel production which leads to formation of soap and biodiesel yield efficiency.

2.3 Thermal Cracking (Pyrolysis)

Thermal cracking is a process of convert the complex structure of hydrocarbons into its simplest structure with or without catalyst. Due to this process the density and viscosity of oil will reduce. In vegetable oil as an alternative fuel this two properties are affecting the atomization of engine. So the fuel treated by this process which could be use directly in diesel engine without any modification. Generally alumina, zeolite and redmud are used as a catalyst in thermal cracking process for biodiesel production. The thermal cracking process will happens by the temperature between 250O°C and 350O°C. the thermal cracking biodiesel plant has a reactor with safety valve, drain pipe, temperature indicator, etc., the oil or animal fat need to be convert into the biodiesel is placed inside the reactor, then heat is applied to the reactor. Now the oil or animal fat get vaporized and reach the condenser through pipe. The condenser cools the vapor in the liquid

2.4 Micro emulsion

The micro emulsion is defined as thermodynamically stable, isotropic liquid mixtures of oil, water and surfactant (compounds that lower the surface tension of a liquid, the interfacial tension between two liquids).; this process will solve the problem in viscosity and some other atomization properties of oil. Generally the alcohol used to increase the volatile property of oil, it reduces the smoke. Alkyl nitrate will be the cetane number improver. The microemulsion process also used to get a good spry property when injected into the engine by nozzle. If microemulsified. The diesel used in diesel engine, some problems will arise such as incomplete combustion, carbon deposit and nozzle failure collected in the beaker which is called as biodiesel.

3. EXPERIMENTAL STEUP

A single cylinder four stroke diesel engine is used to perform the experiment. The engine specifications are mentioned in table 2. Furthermore, this experiment requires biodiesel as an additional fuel, so a separate fuel tank is provided for it. Along with that, the biodiesel fuel requires to be fumigated into vapors before entering the engine. So, we have placed a fumigator in between the fuel tank and the engine. The fumigator has a temperature regulator by means of which we can adjust the temperature values according to the fuel properties. The fumigator consists to two parts namely the fumigation box and the temperature controller. The fumigator is connected to the biodiesel fuel tank. The fumigation box consists of an inlet nozzle of 1 inch diameter through which fuel can be supplied from the biodiesel tank and an outlet nozzle of the same diameter as inlet nozzle through which fumigated vapors will leave. There is one more nozzle at the middle through which a thermocouple is placed. The thermocouple is connected to the temperature controller box which controls the temperature of the heating coil. The controlling unit is digital micro-processor based unit with dual display PV & SV type. The maximum temperature till which this fumigator will work effectively. The incoming air from the air box gets mixed with the vaporized fuel and enters the engine. Since the ignition point of the biodiesel fuel is very high, it doesn't undergo auto ignition. Air flow rate is measured and diesel flow rate is calculated. The gas emission is being recorded by HEXA Gas analyzer The incoming air from the air box gets mixed with the vaporized fuel and enters the engine. Since the ignition point of the biodiesel fuel is very high, it doesn't undergo autoignition. Air flow rate is measured and diesel flow rate is calculated. The gas emission is being recorded by HEXA Gas analyzer [1] [2].

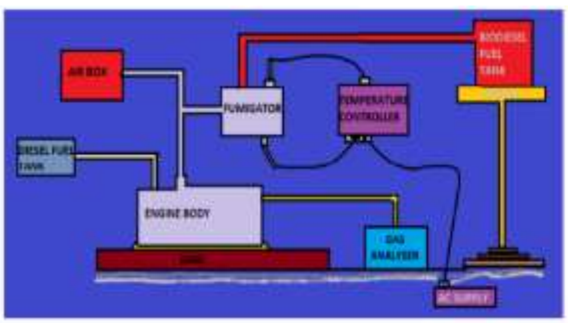

Fig.1 - schematic representing the complete experimental setup

4. ENGINE SPECIFICATIONS

In order to study the performance, combustion and emission characteristics of fumigated biodiesel engine, experiments were conducted on a single cylinder, four stroke, direct injection, water cooled, VCR engine. The engine load was applied using an eddy current dynamometer. An orifice meter connected to a large surge tank was attached to the engine to make air flow measurements. The fuel consumption rate was measured using the glass burette and stop watch. A digital tachometer was employed for measuring the engine speed.

Table -1: specifications of the diesel engine used for the experiment

ENGINE	SPECIFICATION
NAME	KIRLOSKAR(VCR)
MODEL	AV2
CYCLE	4STROKE
BHP	5
RATED POWER	3.7KW
RATED SPEED	1500rpm
BORE DIAMETER	80mm
STROKE LENGTH	110mm
COMPRESSION RATIO	17.5:1

The performance, combustion and emission characteristics presently investigated brake specific fuel consumption (BSPC), brake thermal efficiency (BTE), exhaust gas temperature (EGT), smoke, oxides of nitrogen (NO_X), carbon monoxide (CO), and unburned hydro carbon (HC).

5. PROPERTIES OF BIODIESEL

5.1 Calorific value of fuel

When fuels are burnt, heat is produced. The amount of heat produced by different types of fuels on burning is expressed in terms of calorific value. Calorific value of a fuel may be defined as the amount of heat produced on complete burning of 1 gm. of fuel. S.I. unit of calorific value of fuels is kilojoule per gram (KJ/g).

There are two types of calorific values

Higher Calorific Value (HCV) or **Higher Heating Value (HHV)** or **Gross Calorific Value**:

When 1 kg of a fuel is burnt, the heat obtained by the complete combustion after the products of the combustion are cooled down to room temperature (usually 15 degree Celsius) is called higher calorific value of that fuel.

Lower Heating Value (LLV) or **Lower Calorific Value (LCV)** or Net **Calorific Value**:

When 1 kg of a fuel is completely burned and the products of combustions are not cooled down or the heat carried away the products of combustion is not recovered and the steam produced in this process is not condensed then the heat obtained is known as the Lower Calorific Value.

5.2 Cetane Number and Cetane Index

Cetane Number is a measure of the ignition quality of diesel fuel. In its simplest terms, Cetane Number measures the delay between the start of fuel injection into the combustion chamber and the beginning of compression ignition (auto-ignition). – Cetane index is a calculated number used as a substitute for cetane number. Cetane index calculations cannot account for cetane improver additives, and therefore do not measure total cetane number for additized diesel fuels.

5.3 Viscosity

Viscosity is a measure of a liquid's resistance to flow. High viscosity means the fuel is thick and does not flow easily
.

5.4 Flash Point and fire point

The **flash point** of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a flash point requires an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed.

The **fire point** is the temperature at which the vapor continues to burn after being ignited. Diesel fuel flash points vary between 52 and 96 °C (126 and 205 °F). The fire point of a fuel is the lowest temperature at which the vapour of that fuel will continue to burn for at least 5 seconds after ignition by an open flame. At the flash point, a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire.

5.5 pour point and cloud point

The pour point of a liquid is the temperature below which the liquid loses its flow characteristics. In crude oil a high pour point is generally associated with a high paraffin content, typically found in crude deriving from a larger proportion of plant material. In the petroleum industry, cloud point refers to the temperature below which wax in diesel or biowax in biodiesels forms a cloudy appearance. The presence of solidified waxes thickens the oil and clogs fuel filters and injectors in engines.

6. PERFORMANCE CHARACTERISTICS

6.1 Brake Mean Effective Pressure (BMEP)

Defined as the average pressure the engine can exert on the piston through one complete operating cycle.
If N is the number of revolutions per second, and η_c the number of revolutions per cycle, the number of cycles per second is just their ratio (W) which can be expressed by

$$W=\frac{P\eta_c}{N}$$

6.2 Brake Horsepower (BHP)

It is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, water pump, and other auxiliary components like power steering pump, muffled exhaust system, etc

$$BHP = IHP-FP$$

Where

BHP is brake horses power
IHP is indicated horse *power*
FP is frictional power

6.3 Mechanical Efficiency

The work output is also defined as brake horse power and input is indicated horse power and the ratio of BHP to IHP is defined as mechanical efficiency.

6.4 Brake Specific Fuel Consumption (BSFC)

The BSFC defined as the fuel flow rate per unit of power output is a measure of the efficiency of the engine in using the fuel supplied to produce work. It can be calculated by

$$BSFC\ (g/kWh) = W_f / P_b$$

Where,

W_f = fuel consumed (g/h)
P_b = brake power (kW) which can be calculated by:
$P_b = Pg/g$ Where, Pg = load (kW) at generator end
η_g = efficiency of the generator

6.5 Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft

$$BTE\ (\eta_b) = P_b/(mf \times NCV)$$

Where,

P_b = brake power (kW)
mf = fuel consumption (kg/sec)
NCV = net calorific value (kJ/kg) .

7. EMISSION CHARACTERISTICS

7.1 CO emission

Carbon monoxide is emitted with the exhaust gas due to the incomplete combustion of carbon. This incomplete combustion occurs due to the dissociate process. If we reduce CO emission, we have to run the engine with lean mixture and this in turn reduces the power output. Thermal reactor is the device which injects the exhaust stream and flame to produce combustion of CO and CO_2. Thus the method used to reduce the CO emission by using fumigated biodiesel.

7.2 Hydrocarbon emission

Hydrocarbon level in the exhaust gas is the range of 1000-3000 ppm. HC emission rises rapidly as the mixture becomes substially richer than the stoichiometric. In lean mixture, HC emission can rise rapidly due to incomplete combustion of misfire in a fraction of the engine's operating cycles. Crevice volume plays a vital role in HC emission. Poor ignition system is due to improper spark timing. Poor swirl and turbulence in the combustion. During scavenging 15-40% of the entering fresh mixture flows through the cylinder directly into the exhaust and escapes the combustion process completely. HC emission depends on the fuel filling in the fuel filling in the fuel tank, area of which the vehicle runs, fuel volatility, temperature of the fuel.

7.3 oxides of nitrogen (NO_X)

Oxygen and nitrogen molecules are formed due to the peak combustion temperature and persists during expansion and exhaust in non-equilibrium amounts within the combustion chamber. Formation of NO_X depends upon pressure and air fuel ratios, combustion duration, avoiding knocking combustion, Reducing the spark timing, Decreasing the compression ratio, charge temperature, speed and mixture.

7.4 Particulate emission

Small, solid particles and liquid droplets are collectively termed as particulates. These are present in the atmosphere in fairly large numbers and sometimes pose a serious air-pollution. Particulate range in diameter of 0.0002 μm with life time varies for a few seconds to several months. Its life time depends on the settling rate, size, density, and turbulence of air. SOF (Soluble Organic Fraction) these higher molecular organic substance are soluble when extracted with the solvent and are referred to as the SOF of diesel particulate matter.

8. RESULT AND CONCLUSION

The transesterification of vegetable oil decreases its viscosity and the properties of biodiesel depends on feed stock i.e. vegetable oil and process technologies employed. However, there is a correlation among the properties of biodiesel. Correlations have been established between flash point, density, and viscosity and heating value. Viscosity is one the most important parameters required in the design of combustion process. The tested fumigation of biodiesel are directly injected to mixed with air to the suction stroke at the end of combustion diesel fuel is injected the power has produced and exhaust has released. The testing of performance and emission characteristics can be checked by using various compression ratios and various fumigation density injected and compared with diesel fuel with various load condition the emission rates HC, CO, NO_X, Particulate matter, smoke of emission characteristics can be compared by using various compression ratio (VCR).

9. Nomenclature

CO	Carbon monoxide
HC	Hydrocarbon
NO_X	oxides of nitrogen
BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
BHP	Brake Horsepower
W_f	fuel consumed
P_b	brake power
η_g	efficiency of the generator
mf	fuel consumption
NCV	Net Calorific Value
HCV	Higher Calorific Value
IHP	Indicated Horse Power
FP	Frictional Power
SOF	Soluble Organic Fraction

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