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Experimental investigation on the performance and emission characteristics of WVOME fueled CI engine

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Abstract

Need of an appropriate supportable fuel for existing internal burning motors is by and large frantically felt nowadays, when oil holds are soon going to vanish from the surface of earth Biodiesel proposes one such choice The purpose of this article is to provide the physicochemical properties and characteristics of exhaust emissions from a WVOME (waste vegetable methyl ester oil) fueled diesel engine.in this experiment we found WVOME have good emission characteristics than neat diesel, in the experiment we found most important emission like CO and HC is lower than that of diesel fuel and it will increases engine performance also. This experiment includes some engine parameter like brake power, fuel consumption, and energy consumption included to this experiment, here we taken different blending of WVOME like B20, B40, B60, B80, B100.

Keywords:

HC;
CO;
NO_X;
BSFC;
WVOME.

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1. Introduction

Internal combustion engine continues to dominate many fields like transportation, agriculture and power generation. Conventional hydrocarbon fuels used by these engines lead to pollutants like hydrocarbons (HC), Carbon Monoxide (CO), Nitric Oxides (NO), Soot and Particulates which are harmful to human health, animal and plant life. Hence automobiles in the recent years are being subjected to increasingly stringent regulations. The product of complete combustion CO_2 is a green house gas that contributes to global warning. Thus there has been a need to find suitable alternatives to conventional hydrocarbon fuels, which can reduce pollution levels, especially from C.I. engines.

Promising alternative fuels for internal combustion engines are natural gas, liquefied petroleum gas (LPG), hydrogen, biogas, alcohols and vegetable oils (Nagarajan et al 2002). Gaseous fuels have been found to be attractive because of their wider ignition limits and capability to form homogeneous mixture. Even very lean mixture of these

Fuels can be burned in air and in addition they have lower hydrogen to carbon ratio. Thus very low emissions are possible when they are used in I.C. engines. One of the major challenges of diesel engine development is the simultaneous reduction of nitric oxide and particulate emissions. This is especially true for smaller engines, where the possibilities of using beneficial measures such as turbo charging, electronic engine control, particulate traps, etc., are expensive in relation to the fundamental cost of the engine.

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1.1 Energy crisis and need for alternate fuel for IC Engines

Fossil fuels are one time energy gift to the human race; once they are gone they are gone forever, alternate non-petroleum fuels yield energy security and environment benefits. They have been with us in one form or another for more than one hundred years. Before the introduction of gasoline as a motor fuel in late 1800s, vehicles were often powered by what are now considered alternate fuels [a]. The first Internal Combustion Engine designed, built and demonstrated by Rudolf Diesel at the 1900 Paris World fair ran on peanut oil. This was his dream to power an efficient Internal Combustion Engine with crude oil or vegetable oil .The early 1900s witnessed another similar event when Henry Ford built one of his first automobile fuelled by ethanol, which was often called “Farm alcohol” because it was made from corn.

1.2 Conventional Diesel Fuel and Diesel Engines:

Emissions from HCCI engines can be very low. HCCI engine also produces low levels of smoke and particulate emissions. This is attributed to the absence of diffusion-limited combustion and localized fuel-air regions, which discourages the formation of soot. The two general types of diesel are the direct injection (DI) engine and the indirect injection (IDI) engine. In DI engines, the fuel is directly, the fuel is injected into a pre-chamber, which is connected with the cylinder through a narrow passage. Rapid air transfer from the main cylinder into the pre chamber promotes a very high degree of air motion in the pre chamber, which is particularly conducive to rapid fuel air mixing. Combustion beginning in the pre chamber produces high pressure and the fuels are subjected to high shear forces. The IDI engine is no longer used for heavy bus and truck engines due to somewhat lower efficiency and higher fuel consumption than the DI system is used because of its ability to cover the wider speed range may lead to a continued use of IDI engines in urban areas, where the demand for low emissions can be more important than somewhat higher fuel consumption combined with low annual mileage. The IDI engine is also less sensitive to fuel quality. Tests of biodiesel as a fuel have been performed on both DI and IDI engines.

2. Waste vegetable oil (WVO)

Waste cooking oil refers to the used vegetable oil obtained from cooking food. Repeated frying for preparation of food makes the edible vegetable oil no longer suitable for consumption due to high free fatty acid (FFA) content [10]. Waste oil has many disposal problems like water and soil pollution, human health concern and disturbance to the aquatic ecosystem [8,10], so rather than disposing it and harming the environment, it can be used as an effective and cost efficient feedstock for Biodiesel production as it is readily available[1,3, 5,8 ,10, 13,14, 18,20]. Furthermore, Animal fats with high acid value and fat-containing floating sludge discharged in water systems are subject to environmental concern due to their high pollutant potential and it is a challenge for wastewater treatment plants to purify it. Therefore, conversion of low quality lipid-rich sources from slaughterhouses into commercial grade biodiesel is an opportune strategy for minimizing environmental damages while it can help meeting the energetic challenge [19]. WCO collected can also be used to prepare soaps and additive for lubricating oil [8].Many researchers have successfully converted used vegetable oil into biodiesel [2].

Vegetable oil contains saturated hydrocarbons (triglycerides) which consist of glycerol and esters of fatty acids [8]. Used vegetable oil(UVO) is a by-product from hotels, fast food restaurants and shops selling fritter and by-product of an operating vegetable oil refinery[11].For serving better quality food, they usually throw this waste cooking without any treatment [2,4]. In some places, UCO from restaurants were re-used by street sellers to fry their food ,this waste oil is termed as second –used cooking oil can also be utilized by converting to biodiesel[3].Distillate that is produced by deodorization of palm oil (DDPO) is also a promising and cost effective feedstock [23]. UCOs have different properties from those of refined and crude vegetable oils [3].The chemical and physical properties of WCO are different from those of fresh oil since some changes due to chemical reactions - such as hydrolysis, oxidation, polymerization, and material transfer between food and vegetable oil occur during the frying g process .The typical chemical and physical characteristics of WCO are shown in Table 1 .The usual values for Properties like density, kinematic viscosity, saponification value, acid value and Iodine value are shown in the table.[8].

3. Transesterification of non-edible and edible oil

Transesterification is the general term used to describe the important class of organic reactions, where an ester is transformed into another ester through interchange of al kyl groups and is also called as alcoholysis. Transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. However, the presence of a catalyst accelerates considerably the adjustment of the equilibrium. The general equation for transesterification reaction is given below.

$$RCOOR' + R''OH \leftrightarrow RCOOR'' + R'OH \text{ ---------------- Eq. (1)}$$

The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise of 90-98 percent triglycerides and small amounts of mono-glyceride, diglyceride and free fatty acids. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. The overall process is a sequence of three consecutive and reversible reactions in which diglyceride and mono-glycerides are formed as intermediates. The stoichiometric reaction requires one mole of triglyceride and three moles of alcohol. However, an excess of alcohol is used to increase the yield of alkyl esters and to allow phase separation from the glycerol formed. Several aspects including the type of catalyst (base or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content in alcohol) and free fatty acid content have influence on the course of transesterification. So in this work, the reactants of high purity have been used (methyl alcohol with 99.95% purity). In the base-catalyzed process, the transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. Also the alkaline catalysts are less corrosive than acidic compounds.

The mechanism of the base-catalyzed transesterification reaction of vegetable oil is shown in the Figure 2.1. The first step (Eq. 1.) is the reaction of the base with the alcohol, producing an alkoxide and the protonated catalyst. The nucleophilic attack of the alkoxide at the carbonyl group of the triglyceride generates a tetrahedral intermediate, from which an alkyl ester and the diglyceride are formed. The latter deprotonates the catalyst, regenerates the active species, and enables it to react with a second molecule of the alcohol thus starting another catalytic cycle. Diglycerides and monoglycerides are converted by the same mechanism to a mixture of alkyl esters and glycerol.

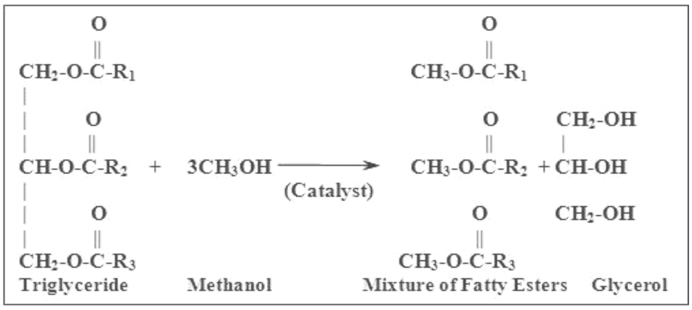

Fig. 1 Mechanism of the base-Catalyzed Transesterification Process

Alkaline metal alkoxides (such as CH_3ONa for the methanolysis) are the most active catalysts since they give high yields in short reaction times even if they are applied at lower molar concentrations. However, they require the absence of water which makes them inappropriate for typical industrial process. Alkali metal hydroxides (KOH and NaOH) are cheaper than metal alkoxide, but less active. Nevertheless, they are good alternatives since they can give the same high conversions of vegetable oils just by increasing the catalyst concentration by 1 or 2 folds.

4. Experimental set-up

The experiment is conducted on Kirlosker engine. Technical specifications of the kirlosker engine are tabulated in Tab. 2. The engine ran at constant speed at 1500 rpm for different load conditions. The rope brake dynamometer was used for applying loads to the engine. The smoke density was measured using an AVL smoke meter. Combustion parameters like pressure in cylinder, net heat release rate and maximum pressure were measured by AVL combustion analyzer. The AVL combustion analyzer placed with experimental setup was capable to measure the pressure up to 250 bar and capable to capture the heat release rate and cylinder pressure for each crank angle. The arrangement of experimental setup was placed in Fig. 1.2

Table 1 Specifications of test engine

Engine type	Single cylinder,4stroke,DI
Bore Diameter	87.5 mm
Stroke length	110 mm
Comp. ratio	16.5:1
power output	5.2 KW
Speed	1500 rpm
Fuel type	Diesel
Cooling System	Water
Injection pressure	220 kgf/cm2
Ignition Timing	23^0C Before TDC (rated)

Figure 2 Photographic view of the engine set-up

5. Test Engine and experimental setup details

The engine employed for the experimental work was a single cylinder, four stroke, and water-cooled, vertical, naturally aspirated DI diesel engine developing power of 3.73 kW at 1500 rpm with compression ratio of 16.5:1.

5.1 Data Acquisition System

It is an analog signal, which is converted to digital signal using fast 12bit ADC. For crank angle measurement encoder is used, which is connected to the engine axis. Axis angular Position corresponds to pistons linear motion. It is measured in terms of number of pulses. Encoder with 1000 pulses per revolution is used. Means when axis moves in 360 degrees, we get 1000 pulses. So resolution of crank angle movement is 1000/360 pulses/degree.

5.2 Dynamometer

The engine was coupled with range make Eddy current dynamometer as shown in figure and electronically operated control panel was used to vary the loads. The dynamometer can be operated in three different modes they are the constant current mode, the constant torque mode and the constant speed mode. in the constant torque mode the torque is kept constant and hence the overall power output will be proportional to the speed of the engine.

5.3 The AVL Digas analyzer

Diesel engine exhaust is a complex mixture of gases and particulates. The principal gases components are carbon dioxide carbon monoxide and nitrogen oxide while the particulate fraction comprises fine carbon particles formed by incomplete combustion. The carbon monoxide and unburned hydrocarbon emission are low in diesel engine due to the available excess air for combustion.

5.4 Computer Software

Software is based on ‘C’ & ‘Visual Basic’ languages. Software is Window based. The master controller in this system is the PC itself. Software is user friendly and allows the user to use Pointing device for selection of menues and parameters. To control the machine operations, software makes the use of I/O channels supplied with computer using I/O card. Input and output commands from computer are routed through the I/O card to the controller and then to machine.

6. Results

6.1 Brake Thermal Efficiency

The comparison carried out between brake thermal efficiency with brake power on different blends of WVOME in figure for all the blends the efficiency is directly proportional to brake power. Among B20, B40, B60, B80 and B100 blend ratios, biodiesel blend of B20 has higher brake thermal efficiency of 28.04% at full load. It is almost same as diesel. It is likewise noticed that the efficiency of B20 has increased by 4.56% compared to that of 100% biodiesel operation. The possible reason is due to fine spray particles of WVOME B20 blend fuel in the cylinder the better the spray characteristics are more effective is the utilization of air, which concludes in complete burning of fuel

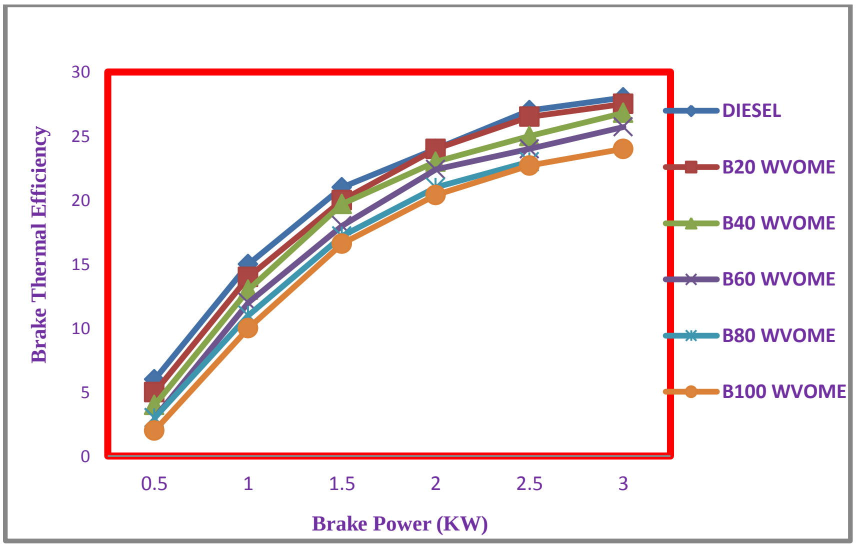

Figure 3 Variation of Brake thermal efficiency with Brake powe

6.2 Specific Fuel Consumption (BSFC)

The comparison between precise fuel consumption with various loads is shown in figure 4 The variation is observed in figure 1.4 that concludes diesel fuel has low specific fuel consumption than all biodiesel blends. it is observed that the methyl esters shows higher SFC compare to diesel as calorific value is less. However SFC is higher for all the other blends. The SFC decreases with the increasing loads. This variation is noted over the entire output range though lower than other blends. At maximum load, the **BSFC** for diesel is 0.3 kg/kW-hr. The **BSFC** for various blends B20, B40, B60, B80, and B100 of WVOME are 0.35, 0.37, 0.38, 0.40 and 0.41 Kg/kW-hr respectively. Here B20 and B40 are slightly closer with each other and B60 closer than B80.

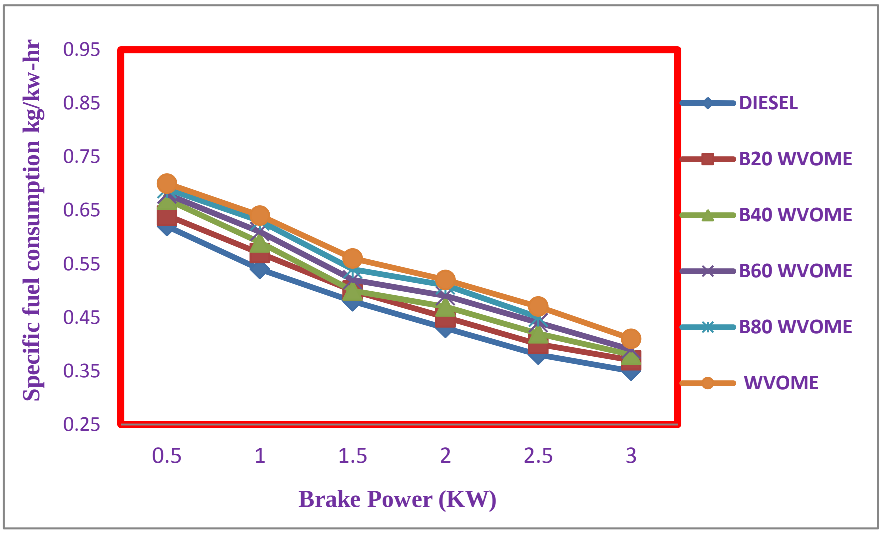

Figure 4 Variation of Specific fuel consumption with brake power

6.3 Carbon monoxide Emissions

From figure 5 it was observed that CO emissions are increased with increase in engine load for all the blends of WVOME. The lower CO emission of biodiesel compared to diesel is likely due to oxygen content inherently present in the biodiesel which helps in the more complete oxidation of fuel. CO emission is a toxic gas that has colorless and odorless. High quantity of oxygen present and higher cetane number will reduce the CO emission if percentage of blends of WVOME increases, CO reduces. The concentration of CO decreases with the increase in percentage of WVOME in the fuel. This may be attributed to the presence of O2 in WVOME, which provides sufficient oxygen for the conversion of carbon monoxide (CO) to carbon dioxide (CO_2). It can be observed that blending 20% WVOME with diesel results in a slight reduction in CO emissions when compared to that of diesel.

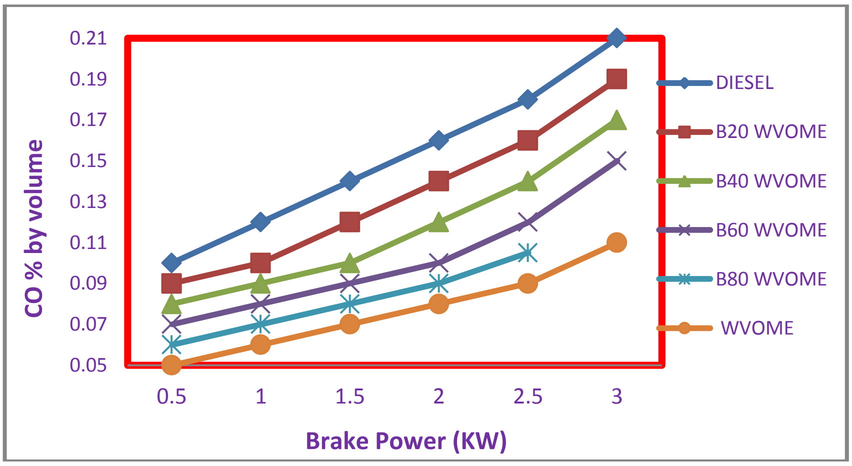

Figure 5 Variation of Carbon monoxide with Brake power (WVOME)

6.4 Carbon dioxide Emissions (CO_2)

From figure 6, it is observed that CO_2 increases with increasing load for all the blends of WVOME. If percentage of blends of WVOME increases, CO_2 increases. The CO_2 emissions are directly proportional to the percentage of WVOME in the fuel blend. Since WVOME is an oxygenated fuel, it improves the combustion efficiency and hence increases the concentration of CO_2 in the exhaust. Here shows how percentage of WVOME increase with $CO_{2,}$ diesel has less CO2 emission than WVOME.

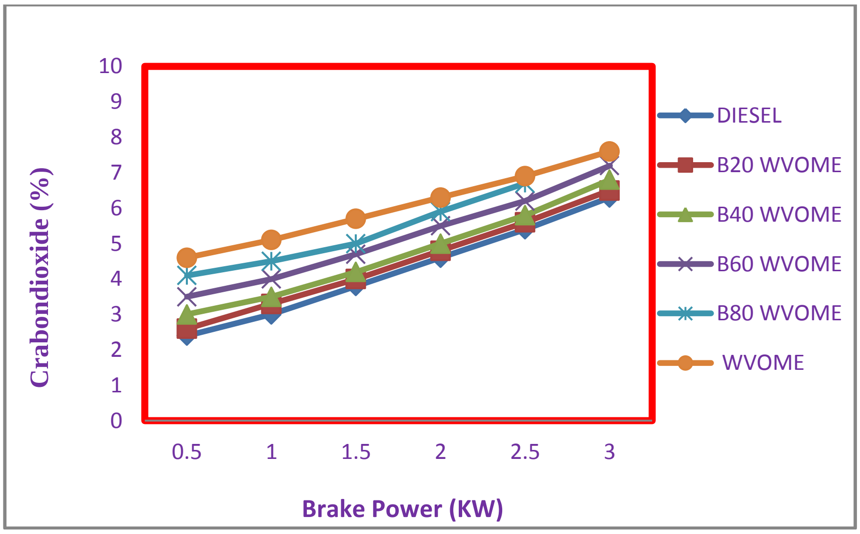

Figure 6 Variation of Carbon dioxide with Brake power (WVOME)

6.5 Exhaust Gas Temperature

In the graph of 7 show variation of exhaust gas temperature with BP, here as biodiesel blend increases as exhaust gas temperature increases with brake power because the EGT of biodiesel is higher than that of diesel. The heavier molecules of biodiesel lead to continuous burning even during exhaust which causes higher exhaust gas temperature.B80 blend has highest EGT than other blend of WVOME but diesel has lowest EGT than neat WVOME.

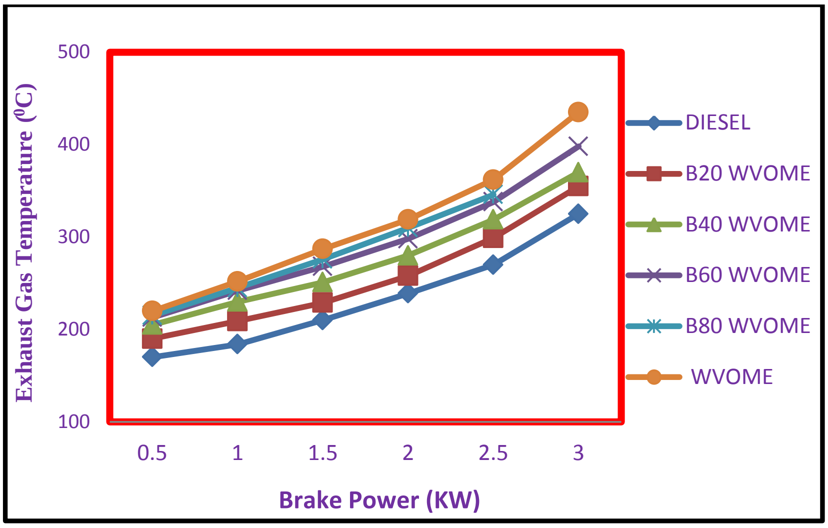

Figure 7 Variation of exhaust gas temperature with brake power

7. Conclusion:

The experimental investigations and performance carried out indicate that it is possible to operate a compression ignition engine with neat WVOME with certain modifications depending on the technique.

- **Brake thermal efficiency: -** The highest thermal energy obtained for diesel and B20 WVOME blends are closer to diesel, as percentage of WVOME increases as the BTE decreases. For neat WVOME the BTE is lower.

- **Specific Fuel Consumption (SFC):**- The SFC for WVOME is highest than diesel due to calorific value of diesel is higher than biodiesel, the SFC decreases with load.

- **Carbon monoxide Emissions: -**The lower CO emission of biodiesel compared to diesel is likely due to oxygen content inherently present in the biodiesel which helps in the more complete oxidation of fuel. CO emission is a toxic gas that has colorless and odorless. High quantity of oxygen present and higher cetane number will reduce the CO emission if percentage of blends of WVOME increases, CO reduces.

- **Carbon dioxide Emissions (CO_2): -** The CO_2 emissions are directly proportional to the percentage of WVOME in the fuel blend. Since WVOME is an oxygenated fuel, it improves the combustion efficiency and hence increases the concentration of CO_2 in the exhaust. So the diesel has minimum CO_2 emission than other WVOME blends, B20 has more closely to diesel and neat WVOME has highest CO_2 emission than B20 B40, B60, and B80.

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