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PERFORMANCE AND EMISSION CHARACTERISTICS OF BIODIESEL PRODUCED FROM WASTE VEGETABLE OIL

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ABSTRACT
In the view of limited fossil fuel reserves which is continuously depleting and other environmental issues, the efforts are made to find a potential alternate self -sustainable, biodegradable and environment friendly fuels. This has promoted bio diesel significantly in past decade due to its similar characteristics. Although there are various problems like carbon deposition, wearing of engine, severe corrosion associated with bio-diesel usage in engine compatibility. The present study was intended to produce bio-diesel optimally from mixture of waste vegetable oil via Transesterification reaction. Further we have prepared and analyzed the performance characteristic of various bio-diesel blends in the 4 stroke diesel engine. The optimum conditions to achieve maximum performance of biodiesel blends were investigated with different load conditions. The fuel properties of blends including density, kinematic viscosity and calorific value lie within the standards. We have found satisfactory results without engine modifications for B60. Bio-diesel will play a significant role in advancement of internal combustion engines which are facing various problems due to increase in pollution and rapid depletion of fossil fuels. Also, it will make major contribution in the coming years and will lower the pollution because of its eco-friendly nature.

Keywords: Biodiesel; Transesterification; Blends; Waste Vegeatble oil (WVO); Emission; Biofuel..

I. INTRODUCTION
Energy is an essential resource for the mankind and its sustainable development .Energy crisis is the biggest problem due to increase in population, depletion of fossil fuels and various other natural resources. As a result there is hike in the prices of fossil fuels and also the rapid increase of toxic substances in the atmosphere. Diesel and other petroleum products demand has significantly increased but, these resources are non-renewable and resulting as a huge impact on the greenhouse gases. These concerns have significantly increased the demand for alternate resources that are renewable, self- sustained and economically feasible [1].

In order to resolve the issues the biofuel demand has increased in the various fields and applications. The Bio-diesel is the renewable, non-toxic and bio-degradable substitute for the fuel which can reduce the level of toxic gases in atmosphere by approximately 80% more than fossil fuels [2]. Bio-diesel obtained from cooking oil and other resources had resulted in deforestation, biodiversity and had created conflict between food and fuel. But, in this paper we are utilizing waste cooking oil obtained from kitchen waste in order to avoid the impact on the food and other agricultural sector [3].

Research has shown that the biodiesel has energy density which is almost similar to regular diesel [4]. The fuel is prepared by using waste vegetable oil and methanol as starting material for transesterification reaction. To fasten this reaction sodium methoxide is used as catalyst. In transesterification process triglycerides reacts with methanol in presence of sodium to breakdown the triglycerides into glycerol and Fatty acid methyl esters [5]. Fatty acid methyl esters are subjected to series of purification and removal of by-products which yields pure bio-diesel. Glycerol is by-product which can further be purified and commercially used in pharmaceutical industry.

There are various limitations like high viscosity, low volatility and PUFA (Poly-unsaturated Fatty acids) of Absolute bio-diesel (B100) which affects automotive compatibility of the engine. Thus, to analyze and estimate the performance and efficiency, it is required to blend the biofuel with diesel in different ratios. The blends were mixed using in-line mixing method and the preliminary tests like flash-fire point, viscosity, calorific value etc. were performed. Further, It was tested in the engine to obtain performance characteristic curves of various blends and were compared with absolute biodiesel and commercially available diesel [6].

II. EXPERIMENTAL SECTION

1. Biodiesel Production Process

Transesterification is a process of conversion of triglycerides to fatty acid ester in presence of alcohol. In these process the R' group from three esters are exchanged with –OH group from alcohol [7]. It is slow exchanging reaction, It is preferable to use acid/base as a catalyst to fasten the reaction. Biodiesel can be produced via, chemical reactions, transesterification and esterification. WVO has triglycerides which upon reaction with low molecular weight- alcohol will yield biodiesel and glycerol as by-product. These alcoholic esters resemble in various properties of diesel. For larger conversion of WVO, Methanol is preferred. For better yield alkali catalysts are considered more efficient [8].

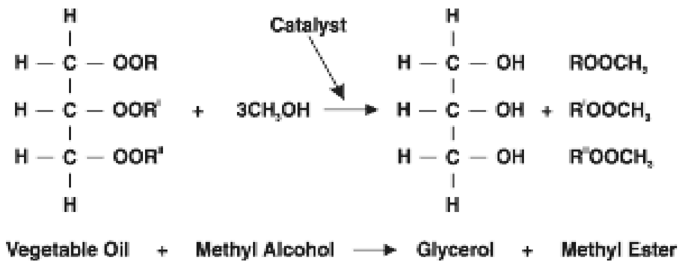

Fig 1: Schematic representation of Trans-esterification reaction

Materials Required

WVO, Methanol, Sodium hydroxide pellet, Distilled water and Muslin cloth.

Apparatus Required

Beaker (500ml, 2Litres), Filtering sieve, Funnel, pilot plant Reactor and Magnetic stirrer.

Pilot plant Reactor

Feed Inlet, Outlet, Water inlet, Pressure gauge, Reaction vessel, Motor, Temperature controller, Coolant vessel, Stirrer speed controller, Water outlet.

Fig: Image of the bioreactor developed for the Biodiesel production

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Procedure

Waste vegetable oil (WVO) was collected from various restaurants and college cafeteria. It is the feed stock for transesterification process. WVO has high viscosity. In order to reduce the viscosity, it was heated to 45C and subjected to filtration to remove all food particles and sediments in it. WVO was filtered thrice using muslin cloth for better and clean input. It is important to remove any moisture content present in WVO before treating with alcohol and catalyst as the efficiency of production reduces. Hence, it was heated to 105^0C for 15 minutes for complete removal of water from WVO. High temperature is achieved under pressure of reaction vessel which is regulated by pressure gauge. Further WVO was allowed to cool down until 60^0C with the help of coolant vessel.

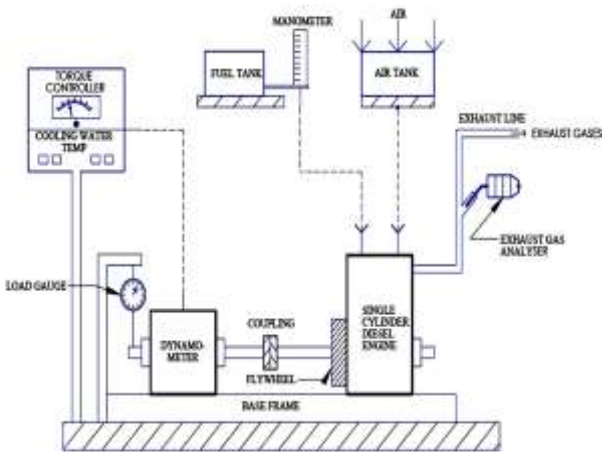
WVO is now free of sediments and moisture. In the reaction vessel Sodium methoxide (Methanol and sodium hydroxide) was gradually supplied in 1:5 mole excess to WVO in reaction vessel from feed inlet. The agitator speed was set to 300rpm using stirrer speed controller for efficient mixing of the reactants. The reaction was carried out for one hour continuously with constant temperature of 60^0C. Later, the temperature was allowed to cool down. Through the feed outlet a complete mixture of products were collected and poured in separating tank. It was allowed to settle over-night for better efficient separation of biodiesel and glycerol. After over-night separation based upon densities two distinct phases of glycerol and biodiesel are formed [9].

Both biodiesel and glycerol are collected separately. At this stage Biodiesel contains some amount of soap formed during the reaction [10]. It is important to have soap free, methanol, and moisture free biodiesel. It was subjected to washing with warm water in presence of phosphoric acid to remove the soap formed. It is preferred to use distilled water for good yield after washing. One fourth volume of water was added and agitated for 30 minutes. After the wash, water and biodiesel were allowed to separate over time of 3-4 hours. This process was repeated twice until pH of water is 7 [11]. Further for removal of methanol from Biodiesel it was heated on magnetic stirrer for 1 hour at 65C to vaporize it completely.

2. Performance testing of biodiesel blends

Experimental Setup

Engine performance test was performed on a 5.22 BHP Diesel Engine RAJKOT, single cylinder, four-stroke, naturally aspirated, water cooled direct injection compression ignition engine of a 3.69 kW rated power at 1200 rpm engine speed The other equipment includes drum brake rope dynamometer which is used to measure the acting force on the shaft, speedometer to measure the revolutions on the output shaft, and a stopwatch note the time required for fuel consumption



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Type	Vertical engine
Make	Rajkot
No of cylinder	1
Number of strokes	4
Fuel used	Diesel

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Rated power	3.9kW
Rated speed	1500
Bore	80mm
Stroke	110mm
Compression ratio	16:1
Air box orifice diameter	20mm

Procedure

Mixing the diesel and bio-diesel using in-line mixing method for various blends like B40, B50 and B60 with the respective ratios. The density ,kinematic viscosity and calorific value of the mixture was obtained.(Verified by Bangalore Test House).Engine was flushed with the respective blend and cranked to ensure that all the foreign fuel is burnt away[12]. Once smooth running of the engine was attained, the load was applied on the engine using the rope brake dynamometer. Various parameters such as spring balance reading, engine speed, exhaust gas temp etc. were noted down. On each different load, the values of current, voltage, speed, and time taken to consume 10cc of fuel consumption were noted respectively. All the results such as BP, IP, Specific fuel consumption, brake thermal efficiency, indicated thermal efficiency , mechanical efficiency and Specific fuel consumption was calculated and respective graphs were plotted.

3. Emission Testing

An emission testing consist of the test cycle which undergoes repeatable and comparable measurements of exhaust emission for different fuels and engine conditions. The results are calibrated with the MOT (Ministry of transport) Standards.

Experimental setup

INDUS model PEA205 is a 5-gas analyzer meant for monitoring CO, CO2, HC, O2 and NO in automotive exhaust. CO, CO2 and HC (Hydrocarbon residue) are measured by NDIR technology and O2 and NO by electrochemical sensors. It has many control features to prevent faulty measurements. A built-in dot matrix printer is provided to print out a hard copy of the results.

Gas Analyzer Specifications

Manufacturer	Indus Scientific Private Limited
Gases Measured	Carbon monoxide (0-15%), Hydrocarbon (0-30000ppm as hexane), Oxygen (0-25%), Oxides of Nitrogen (0-5000ppm) and Carbon dioxide (0-20%)
Operating temperature	0 to 45°C
Power supply	90-270 V AC/ 11-12 V DC
Features	Color LED display for each gas for distinct view,

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Procedure

The exhaust gases are measured using CO sensors and NDIR (Non-Destructive Infrared) sensors which are built in the exhaust gas analyzer. The light source helps the sensors to detect the different emissions like CO, CO_2, NO and O_2 emissions. The results were displayed and the hard copy of results was printed to get the respective values.

III. RESULTS & DISCUSSION

Performance Characteristics

A. Input Power v/s Brake Power

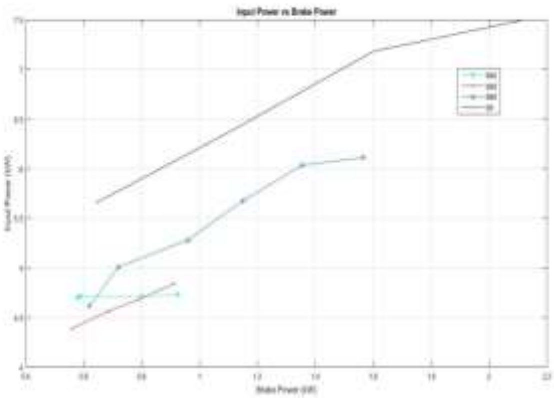

Fig 2

From the graph in Fig 2 we can observe that B50 and B60 blends have similar characteristics like Diesel as the slopes are similar to Diesel (B0).As the brake power increases the input power increases whereas, in case of B40 the input power remains constant for a certain operating range i.e around 0.6 to 1KW.The input power is lesser than the Diesel, hence less power is converted to mechanical energy resulting in less power output.

B. Mass Flow Rate v/s Brake Power

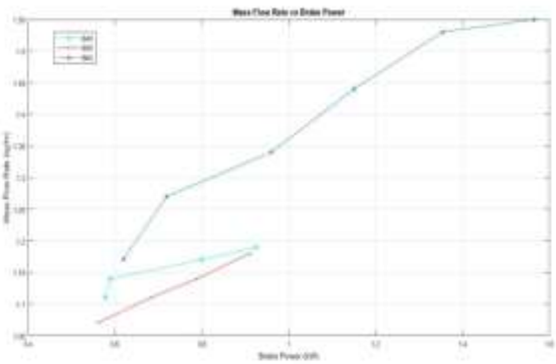

Fig 3

In the Fig 3 The Mass flow rate is higher in B60 than other blends like B40 and B50 .At certain operating range the mass flow rate of B60 decreases whereas the B40 blend mass flow rate increases at the same operating range along with B50.Diesel has higher mass flow rate than all the blends around 1.3 to 1.7 kg/s as shown in table

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C. Brake Thermal Efficiency v/s Brake Power

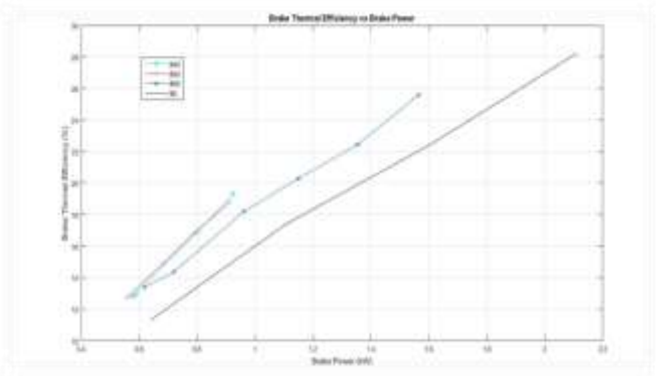

Fig 4

In Fig 4 The Brake thermal efficiency of B40 ,B50 and B60 is higher than Diesel as obtained from the graph therefore, we can conclude that B40,B50 and B60 can covert the most of the heat energy into mechanical energy than diesel .

D. Specific Fuel Consumption v/s Brake Power

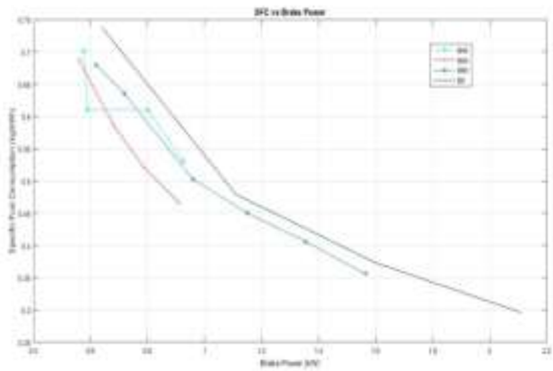

Fig 5

In the Fig 5 the specific fuel consumption (SFC) of B40 is lesser at an instant around 0.8 KW.But, B50 is comparatively lesser in overall operating range. Diesel SFC is higher than all the other bio-diesel blends. Therefore the prepared blends of bio-diesel are better to use in order to save more fuel and give more mileage.

Emission Characteristics

A. ***Nitrogen Oxide (NOx) v/s Load***

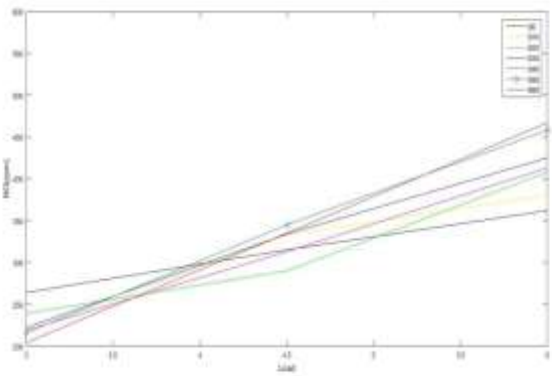

Fig 6

In Fig 6,the NOx emissions are more in case of (CI) Compression Ignition engines compared to Spark Ignition Engines (SI). As we can observe the graph and conclude that the NOx emissions are very less than diesel at the initial operating range i.e. around 4.2KW BP.But, at the higher operating range and higher loads the NOx emission increases more than the diesel. This can be controlled by the use of catalytic converters at the exhaust and hence, it can be used at higher loads without causing any harm to the atmosphere.

B. ***Carbon Dioxide (CO_2) v/s Load***

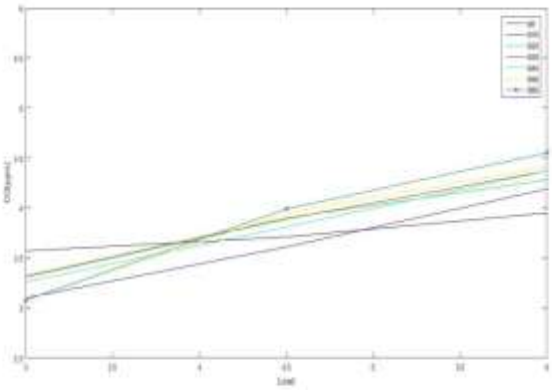

Fig 7

In Fig 7,the CO2 emissions are lesser than diesel during the lower loads and it increases after it reaches the critical point the CO2 emissions increases and are more than diesel. The CO2 emissions are less harmful than CO emissions. Therefore, the CO is converted into CO2 to reduce the effect of harmful CO.

C. ***Carbon Monoxide (CO) v/s Load***

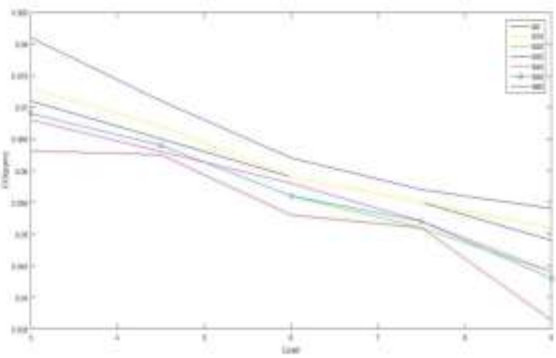

Fig 8

In Fig 8, the CO is very less compared to the diesel in the B40, B50 and B60 blends. Therefore, the use of these blends will reduce CO emissions drastically and also less CO2 is formed as catalytic converters convert CO to CO2 to minimize the harmful effects of the poisonous gases.

CI engines will have very low CO when operated lean and will increase if operated at rich mixtures. Therefore, we can use B40, B50and B60 as fuel which will have very less CO (carbon monoxide-the colorless, odorless and poisonous gas)

D. ***Hydrocarbons (HC) v/s Load***

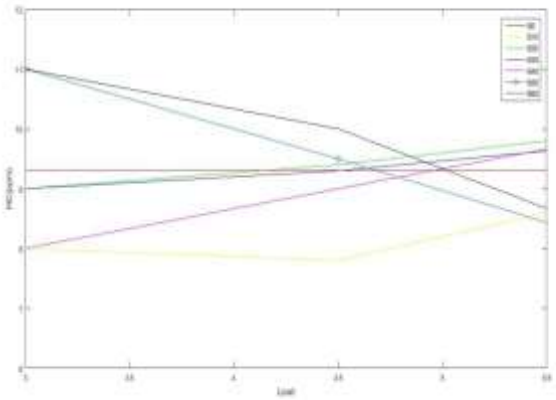

Fig 9

HC emissions are of 2 types: Un-Burnt Hydro-carbons (UBHC) and partially reacted hydrocarbons. UBHC's are due to mixing of fuel with lubricating oil and due to crevice flow, incomplete combustion, valve overlap etc. HC emissions can react with atmosphere to form photochemical smog.

As observed in the above graph the HC emissions are very less than the diesel in case of all bio-diesel blends like B40, B50 and B60 in wide operating range and up to the critical point. After the critical point all blends will have high HC emissions except B50 blend .Therefore, B50 will be preferred in case of less HC emissions

E. ***Oxygen (O_2) v/s Load***

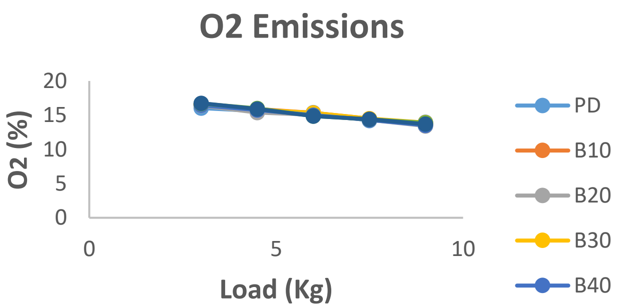

Fig 10

O2 emissions are similar to Diesel and therefore, it is independent of any blend or Diesel as it is not affecting the emission much with respect to each other.O2 is required for combustion process in the cylinder and also these emissions decreases with increasing loads or BP.

IV. CONCLUSION

The biodiesel production from the waste vegetable oil has yielded the production based on optimized data obtained from Design expert software. Diesel engine can perform satisfactorily with WVO methyl esters and their respective blends without affecting engine compatibility. It can be inferred from the performance characteristics curves that, the B60 curves have similar slopes to that of commercially available diesel. Hence, It is the close performer. It is also observed that there is significant reduction in CO and un-burnt Hydrocarbons for all biodiesel blends when compared to the diesel fuel. However, NOx emissions of biodiesel is marginally higher than that of petroleum diesel. SOx emissions were found to be minimal when compared to the diesel.

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V. SCOPE FOR FUTURE WORK

Implementation of Exhaust Gas Re-circulation (EGR) to reduce the temperature in combustion chamber as NOx emissions in the exhaust gas is mainly dependent on the combustion chamber temperature. Provision of EGR can be utilized to reduce NOx, Mixing of Additives like Di-Tertiary Butyl Peroxide (DTBP) and Di Methyl Carbonate (DMC) etc. with biodiesel blends to improve the performance parameters .To employ the Exhaust Gas Treatment (EGT) techniques like DeNOx AdBlue dosing systems to reduce NOx emissions, Particulate filter Regeneration by burning off the HC deposits using a Glow Plug at the exhaust manifold. Future research on HCCI(Homogeneous charge compression ignition) technology in order to reduce NOx emissions and have the engine to perform better.

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