STRAIGHT VEGETABLE OIL AS ADDITIVE IN DIESEL ENGINE TO REDUCE NO_XEMISSION

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ABSTRACT: There is significant research going on to use various Straight Vegetable Oil (SVO) as alternative fuels in diesel engine however the physical property of SVO limits direct use of SVO in diesel engine. The addition of SVO in diesel reduces the combustion temperature in cylinder which leads to higher ubHC and CO emissions, higher carbon deposits and improper combustion. In another side Addition of SVO also reduces NOx emissions significantly. Reduction in cylinder combustion temperature leads to decrease in thermal efficiency of engine and drop in power output. The present project focuses on reduction of NOx emissions from diesel engine by using various SVO in small proportion as additive in diesel to reduce NOx emission. In present assessment SVO such as palm, cotton seed castor and karanja are selected to use as additive in diesel. CI engines are most widely used in transportation, agriculture, building and construction equipment and it is most versatile engine to use alternate fuels. Considering above single-cylinder, 4-stroke, 18 CR,water cooled diesel engine of 3.5 kW at 1500 rpm was selected for the present investigation.The experiments are going to carry out to test the selected fuel to measure the engine performance and emissions. The various blends of SVO and diesel is prepared to carry out the engine performance tests along with the corresponding emission measurements at various load.The performance and NOx emission characteristics of engine will be studied by using diesel, palm, cotton seed castor and Karanja and their blends with diesel and by analyzing the performance characteristics and emission characteristics at the rated load and compared with pure diesel finding out most suitable SVO along with optimum blend ratio.
Keywords: SVO, NOx, Alternate fuels, CI Engine, emissions.

I. INTRODUCTION

Increasing energy demand and environment concerns have encouraged an evolution of alternative fuel sources. As an alternative fuel source, SVO is attractive because it reduces harmful engine emissions. In the face of escalating oil prices and depleting oil reserves, the search for alternative sources of fuels has been intensified more than ever before in the history of mankind. Aside energy security concerns, issues of climate change as a result of the emission of carbon dioxide (CO2), carbon monoxide (CO), unHC and NOx emissions.

It is very commonly believed that Rudolph Diesel fuelled one of his early engines with peanut oil at the Paris Exhibition in 1900. He estimated in his report "...the inclusion of vegetable oils in engine fuels may seem unimportatnt for use today, but such oils may become, in the course of time, as significant as petroleum and the coal-tar products of the present time…"The references to research on vegetable oil fuels had expanded vast in recent. However biodiesel fuelled engine emit very high NOx in the environment. In convention diesel engine NOx emission is major concern which need to be reduced. In present work focuses on reduction of harmful emission of diesel such as NOx, unHC, CO and particulate matter. In present assessment various Straight vegetable oil SVO such as palm, cotton seed castor Karanja use as additive in diesel to reduce NOx emissions.

1.1 Energy Crisis

The world has realized that the petroleum products are non-renewable in the near future it will be finished as they are used as alarming rate. Due to the growing economy and vast demand of energy lead the world to a energy crisis. These energy demands are mainly based on oil and coal. The automobile sector and combustion engines mainly based on the petroleum fuels which are a non-renewable energy source. Which is finishing in a very rapid pace and other renewable energies are growing very slow pace. This energy crisis came to focus during the oil crisis in 1973.The global expected around 147 trillion kWh of energy which is expected to rise in the coming future .

(Fig. 1.1) shows how the world energy consumption is increasing day by day.

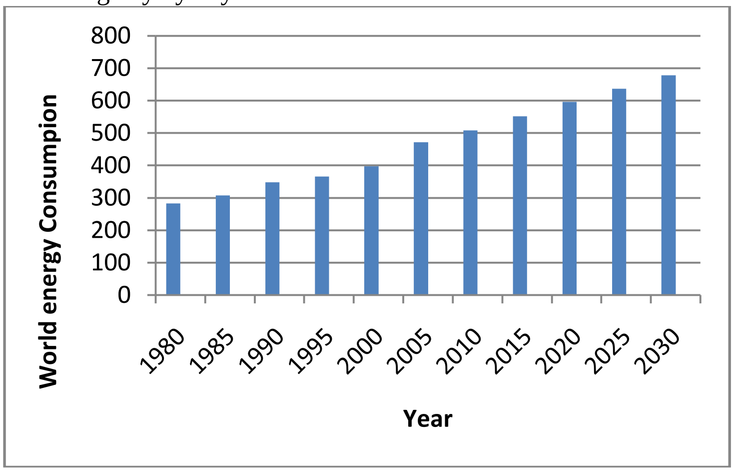

Fig. 1.1 World Energy Consumption Trend [2]

Hence the growing economy the India and China are becoming the giant and take over very quickly the world economy. So in these countries are now required huge amount of energy. Hence India needs a huge amount of energy sources.

II. METHODS AND MATERIAL

In order to achieve the objective of the present work, the following methodology has been planned:

- To select at 4 liquid biofuel sample, i.e., SVO Palm, Karanja, Cotton seed Castor and Diesel for comparative assessment.
- Fuel characterization experiments to evaluate the biofuel properties for the considered biofuels.
- To design and incorporate the necessary instrumentation for engine performance evaluation.
- Experimental evaluation of the engine performance parameters and engine emissions using the considered biofuels and petro-diesel.
- Comparative assessment to find out suitable SVO and suitable blend percentage considering engine performance with respect to NOx emission.

Experimental Setup

- The different equipment's and setup which is required for experiment is shown in the figure 1
- F1 fuel injector pressure sensor
- F2 Air flow measuring
- PT peizo sensor N rpm pick up and TDC encoder
- T1 Cooling water inlet temp to engine
- T2 Cooling water outlet temp from engine
- T3 Cooling water inlet temp to calorimeter
- T4 Cooling water outlet temp from calorimeter
- T5 Exhaust gas inlet temp to calorimeter.
- T6 Exhaust gas outlet temp from calorimeter.

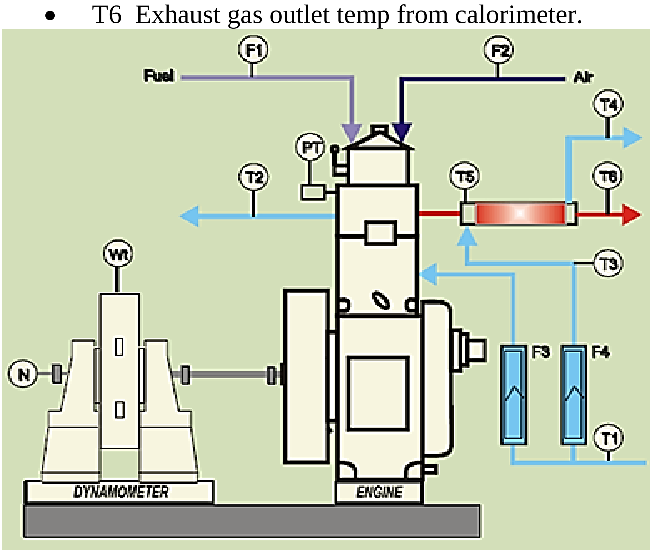

Figure 1.Experimental Setup

III. THEORY OF EXPERIMENTATION

Experimentation

The experimentation is going to conduct in following steps

Fuel characterization:SVOs blended with diesel in varying percentages from 10% to 30% and various physical and chemical properties would be tested.

Engine performance tests: The engine performance tests would be carried out to evaluate IHP, BHP, FHP, ITE, BTE, MECH EFF., BSFC, etc for each of the blends under various load condition.

Emission analysisThe major engine exhaust gases namely CO, CO_2, O_2, NO_x, and unHC at the variousloading condition for various blends would be measured using AVL five gas analyser

IV. ENERGY ANALYSIS

The various engine performance parameters used for testing the performance of CI engine are brake power, indicated power, frictional power, break mean effective pressure, indicated mean effective pressure, BTE, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance etc. To evaluate these performance parameters, engine shaft speed, load on the engine, fuel consumption rate, airflow rate, temperature of engine cooling water, and engine exhaust gases are required to be measured.

The performance parameters were calculated from the fundamental relations between these measurements while varying the load on the engine from 0% to 100% in approximate steps of 25%.

Some of the above performance parameters used for the energy analysis modelling are described below:

Indicated Power (IP): The indicated power IP is the total power developed by the combustion of fuel of an IC engine and is given by,

$$IP = \frac{n.p_{mep}.L.A.N.K}{60000}$$

where, k = 1⁄2 for 4-stroke engine and k = 1 for 2-stroke engine

Brake Power (BP): The brake power (BP) is the power developed by the engine at the output shaft and is given by,

$$BP = \frac{2\pi NT}{60000}$$

Friction Power (FP): The friction power is the power lost due to friction and is given by,

$$FP = IP - BP$$

Indicated Thermal Efficiency :Indicated thermal efficiency is the ratio of indicated power to the energy supplied by the fuel which is given by,

$$ITE = \frac{IP}{Energy\ supplied\ by\ the\ fuel}$$

Where,

$$Energy\ supplied\ by\ the\ fuel\ is = m_f * CV\ of\ the\ fuel$$

Brake Thermal Efficiency (BTE): A measure of overall efficiency of the engine is given by the brake thermal efficiency. Brake thermal efficiency is the ratio of indicated power to the energy supplied by the fuel which is given by,

$$BTE = \frac{BP}{Energy\ supplied\ by\ the\ fuel}$$

Mechanical Efficiency (η_{mech}) :Mechanical efficiency is the ratio of brake power to the indicated power, and is given by,

$$n_{mech} = \frac{BP}{IP}$$

Brake Specific Fuel Consumption (BSFC):Brake specific fuel consumption is the amount of fuel consumed per kW of brake power developed and is given by,

$$BSFC = \frac{m_f}{BP}$$

Brake Specific Energy Consumption (BSEC):Brake specific fuel consumption is the amount of fuel consumed per kW of brake power developed and is given by,

$$BSEC = \frac{Energy\ supplied\ by\ the\ fuel}{BP}$$

V. RESULT AND DISCUSSION

The various experiments are carried out for all the three groups. The results are categorized into three main sections, viz., fuel characterization tests results, engine test results which include the performance of the engine and emission analyses and thermodynamic analyses consisting based on first and second laws.the results pertaining to use of SVO blends are presented and discussed. In th fuel characterization tests various physical and chemical properties of selected SVO blends, are evaluated and the results are presented in. These results are compared with corresponding results of diesel. The evaluated results of engine parameters like BTE ,BSEC, etc along with their emissions., for various blends of considered SVOs along with petro diesel counterpart are presented in the following subsections.

5.1Fuel Characterization

The results of tests of various physio chemical properties of different blends of Cotton seed oil, palm oil and karanja oil are tabulated in Tables 5.1, 5.2, and 5.3 respectively .The following significant observations are made regarding the physio chemical properties of the SVOs and their blends. All tested SVO and their blends have higher density and viscosity when compared with diesel. The density and viscosity increase with increase in SVO percentage in the blend. All the tested blends have higher flash point than diesel which make them safer in handling and transportation. However, the cloud point and pour point of SVOs and their blends are higher than petro diesel. These properties are very significant in cold climates but in tropical countries like India SVOs and their blends may not pose a serious problem except in few areas.

Table 5.1 Physio chemical properties of Karanja oil and its blends with petrodiesel

Property	KO 10	KO20	KO30	diesel
Density, kg/m^3	866	877	886	835
Calorific value, MJ/kg	43.21	42.96	41.59	44.62
Kinematic Viscosity @40 ^{0}C	4.92	6.15	7.52	2.83
Flash point	89	109	125	72
Cloud point, ^{0}C	97	120	131	6.4
Pour point, ^{0}C	8.4	10.3	11.2	3.0
Cetane index				48

Table 5.2 Physio chemical properties of palm oil and its blends with petrodiesel

Property	PO10	PO 20	PO 30	diesel
Density, kg/m^3	848	859	867	835
Calorific value, MJ/kg	43.62	43.96	42.94	44.62
Kinematic Viscosity @ 40^{0}C	4.32	5.35	6.52	2.83
Flash point, ^{0}C	102	123	136	72
Cloud point, ^{0}C	8.1	10.3	11.2	6.4
Pour point, ^{0}C	4.2	4.5	5.1	3.0
Cetane index				48

Table 5.3 Physio chemical properties of cottonseed oil and its blends with petrodiesel

Property	CO 10	CO 20	CO 30	diesel
Density, kg/m^3	834	847	856	835
Calorific value, MJ/kg	42.70	42.40	41.96	44.62
Kinematic Viscosity @ 40^{0}C	3.42	4.50	5.20	2.83
Flash point, ^{0}C	65	70	75	72
Cloud point, ^{0}C	-9	-4	-2	6.4
Pour point, ^{0}C	-14	-9	-6	3.0
Cetane index				48

Critical observations of the above tabulated results clearly depict that the physiochemical properties of all oils are within comparable domain. Further, based on these properties cotton seed oil seems to be superior as biofuel source, closely followed by palm oil and then karanja oil. In Indian context, palm oil and cotton seed oil being edible its use as a biofuel source may not be recommended. Neither karanja seed nor its oil has any established usage as per available literature. Hence karanja oil has an edge over palm oil and cotton seed oil as biofuel source.

5.2 Engine Performance

The experiments carried out using the various blends of the SVOs considered in the present work on the experimental setup the results obtained in terms of engine performance parameters like like BTE BSEC,ETGetc are described in the following subsections.

5.2.1Brake Thermal Efficiency

BTE is a very significant engine performance parameter as it measures the actual power output available from the engine shaft. It is calculated for various blends of karanjaoil , palm oil cotton seed oil and diesel at constant load of 85% on the engine. These results are analyzed and represented graphically in graph

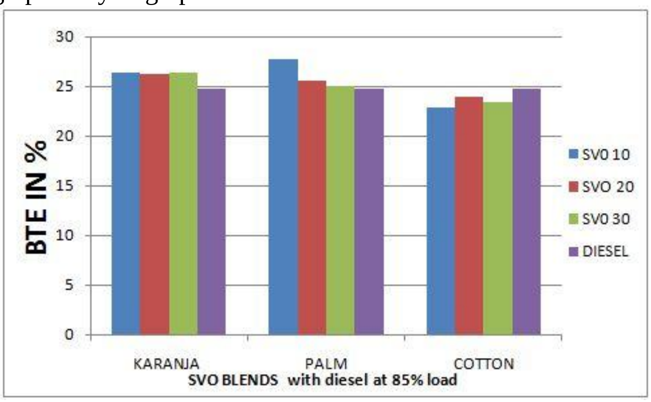

Chart 1. Variation of BTE at 85% load against various svo blends and diesel

Brake thermal efficiency is the ratio of energy in the brake power to the input fuel energy. The brake Thermal Efficiency characteristics of Karanja oil , Plam oil , Cotton seed oil Biodiesel, diesel blends has been plotted. The graph indicate the increase of Brake thermal efficiency in case of cotton seed oil and Karanja oil because of lower viscosity.Where as in case of palm oil it goes on decreasing.

5.2.2 Brake Specific Energy Consumption

BSEC is a reliable parameter for comparison as it takes into account calorific value and the density of the fuel blends

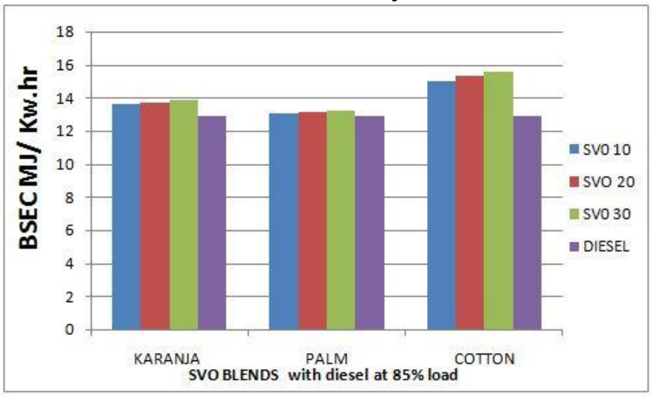

Chart2.. Variation of BSECat 85% load against various svo blends and diesel

It is observed that BSEC increases with increase in blend ratio for all the considered SVOs and all the blends show higher BSEC than that of petrodiesel. Cotton seed oil has highest bsec compared to all other oils and diesels.. PO10 and KO10 are found to have the lowest BSEC among their corresponding blends.

5.3 Emission Analysis:

The environmental pollution is mainly due to automobile exhaust. To minimize the formation of pollutants, biodiesel are used as a fuel for the diesel engines. The effects of reduction in pollutants from the diesel engine are measured. The major emission parameters are discussed here are Carbon Monoxide, Hydrocarbon, Carbon dioxide, Oxygen, and Oxides of nitrogen.

5.3.1. CO_2 EMISSIONS

The CO_2 emission from a compression ignition engine is the result of better combustion, while HC and CO are of poorer combustion

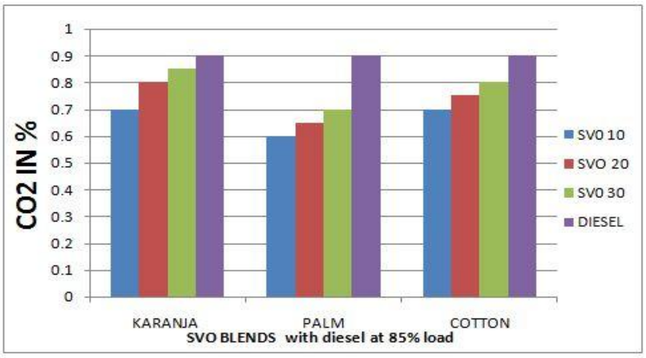

Chart3. Variation of CO_2at 85% load against various svo blends and diesel.

In the above chart it can be clearly seen that the Co2 emissions are higher in volume % for pure diesel compared to the SVO OIL blends.

5.3.2 CO EMISSIONS

The effect of fuel viscosity on fuel spray quality would be expected to produce higher CO emissions with increasing SVO %-age in the blend. It is reported that physical properties like density and viscosity can have a greater influence on hydrocarbon emissions than its chemical properties

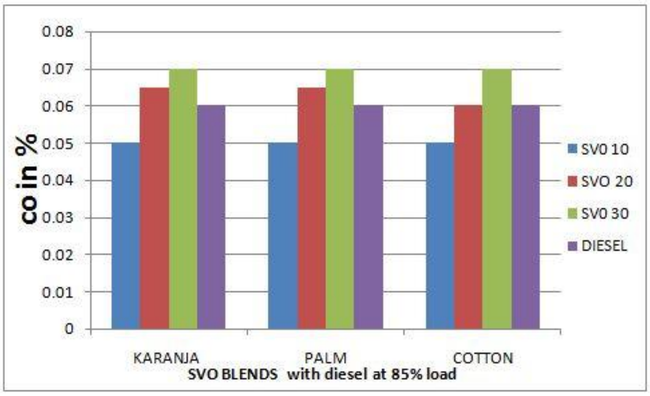

Chart4. Variation of COat 85% load against various svo blends and diesel

CO emissions are found to be less for SVO10 compared to petrodiesel and all higher order blends show higher CO emissions.With the increasing blend ratios of SVOs, the CO emissions show an increasing trend.

5.3.3. Hydrocarbon Emission

These emissions for SVO blends are found to be higher than petrodiesel and have an increasing trend with increase in blend percentage of all the considered SVOs. The viscosity and density increase with the increase in blend percentage of SVOs resulting in higher droplet size. This is the possible reason for the obtained trend.

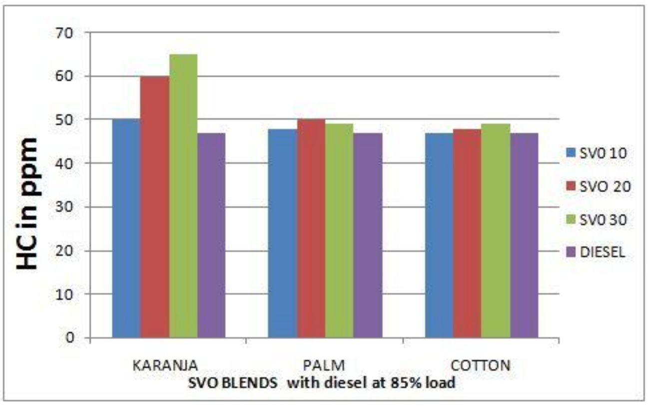

Chart5. Variation of HC at 85% load against various svo blends and diesel

Karanja oil has highest viscosity compared to cotton palm and diesel this is the reason we can see the unburned hydrocarbon percentage is maximum in the graph.

5.3.4 NO_x EMISSIONS

Among the considered SVO blends tested, it is observed that the PO blends show slightly higher NO_x emission. It may be due to its higher CV resulting in higher peak in-cylinder temperature. Secondly, the higher CN number of PO blends results in longer duration of higher temperature in the engine cylinder.

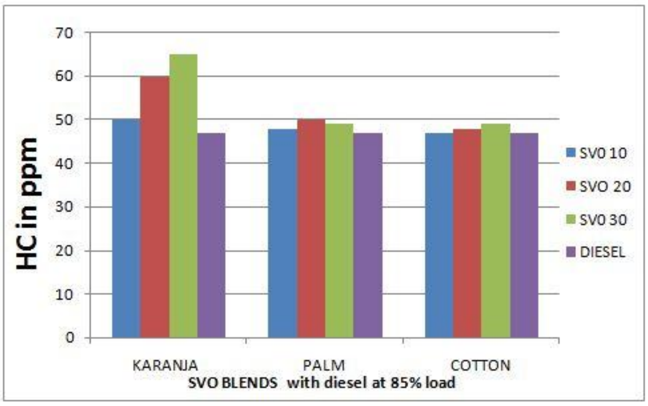

Chart6. Variation of NO_x at 85% load against various svo blends and diesel

Karanja oil has less NO_x emission as compared to other oils and diesel as the blend goes on increasing emissiongs goes decreasing gradually

5.4 Exhaust Gas Temperature

The reason for the blends showing increasing EGT for increasing percentage of SVOs in the blend may be due to the presence of higher boiling point constituents in SVOs than in petrodiesel. These constituents do not adequately evaporate during the main combustion phase and continue to burn in the diffusion combustion phase. This resulted in a slightly higher exhaust gas temperature

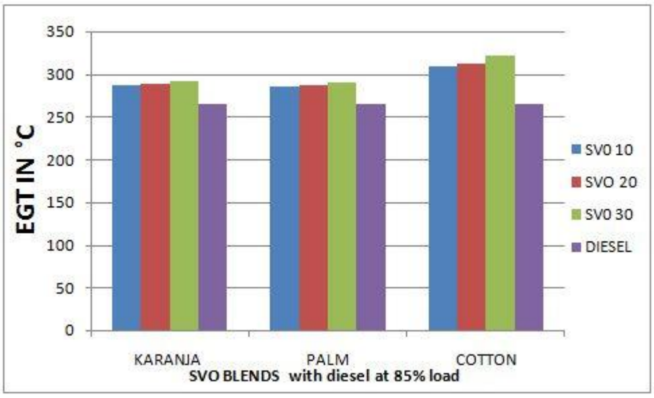

Chart7. Variation of EGT at 85% load against various svo blends and diesel

VI. CONCLUSION

The objective of the presented dissertation is to establish the use of straight vegetable oil in a smaller capacity, portable compression ignition engine used for rural and agricultural application without any engine modification and to evaluate the suitable blend which is most useful for the compression ignition engine. The engine selection is done based on the usages in the rural and agricultural application. Thus a single cylinder, 4- Stroke engine of 7 BHP at 1500 rpm has been selected for experimentation. The required instruments have been incorporated in the experimental set up for this purpose. For measuring fuel properties the required instruments as per ASTM standards are used. Based on the availability and suitability on the selected engine, The Palm oil as straight vegetable oil has been selected for the present work.

The engine performance tests along with the corresponding emission measurements at 85% load have been done on the experimental set up for the various blends of Palm straight vegetable oil. The blends are considered 10%, 20% 30% with Diesel and normal diesel..

- The Engine performed best at the 85% loading condition for straight vegetable oil. The results are comparatively similar for diesel fuel and this is also comparatively similar with the available literature. So the engine may be operated at 85% loading condition for straight vegetable oil.
- With the increasing of the percentage of straight vegetable oil in the blends the NOx emissions are showing decreasing trend. This decreasing trends resembles the improper combustion and reduction in cylinder temperature due to the increase of the viscosity of the fuel. From the comparison for all blends karanja straight vegetable blend is considered as best and which is matching with the available literature.
- So the engine performed best for the 10% karanja oil blend at 85% load condition.

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