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Investigation on different blends of Jojoba oil with coir pith generated producer gas in a diesel engine in dual fuel mode

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***Abstract:*-- The present paper elaborates about the experiment carried out on a single cylinder diesel engine utilizing jojoba oil methyl ester and coir pith generated producer gas in dual fuel mode. Various experiments conducted to measure the physiochemical properties of both biodiesel and producer gas. Simultaneously, emission analysis was calculated at different loading conditions with various diesel blends. The results were contrasted with data laid down by various researchers. Result depicted that carbon dioxide (CO2) and carbon monoxide (CO) shows marginal hike, while nitric oxide (NO) and hydrocarbon (HC) shows a reducing curve, for all prepared test fuels in dual operation that of single operating mode under different loading conditions. The fuel blends show better emissions than that of diesel in both the ways.**

***Index Terms:*— Dual fuel; biodiesel; emission; fossil diesel; single cylinder engine.**

I. INTRODUCTION

The world is confronted with the twin crisis of spiralling value of fossil fuels and the limited supply of fuels[1]. Diesel vehicles are extremely fuel efficient and highly reliable compared to their petroleum counterparts and are used mainly for transportation globally. This has led to the exaggerated exploration into alternative renewable energy for ensuring energy security and resolving global issues [1]. Diesel emissions consist of organic as well as inorganic species in different phase's namely gaseous and particulate phases. (DPM)Diesel particulates matter is carbonaceous particles with adsorbed heavier hydrocarbons. Composition and toxicity are powerfully influenced by engine operational conditions. The size and chemical composition of DPM could vary with engine style and operative conditions like engine speed, load, fuel properties, cetane range, spray characteristics and fuel injection system pressure additionally to the lubricating oil used. According to USEPA (United states Energy Protection Agency) prolonged exposure to diesel engine exhaust leads to the damage or respiratory organ (lung), possibly leading to carcinogenicity in lungs. Fine particles from exhaust penetrate deeper into the human tract and might probably cause serious metabolic process diseases. Therefore global interest is generated in order to control the effects of DPM. It can be achieved by reducing the proportion of diesel and increasing the proportion of Biofuel (Biodiesel).

Biodiesel is a monoalkyl ester (organic compound) derived from fats and vegetable oils [2]. The physical, as well as chemical properties of biodiesel are similar to that of Diesel. Biodiesel is renewable and degradable so it has attracted as an alternative fuel to the fossil fuels. Degumming, Esterification, and transesterification are the processes which have been widely used to reduce the high viscosity and FFA (free fatty acid) of the oil. Biodiesel has attracted interest in recent times due to its merits like renewability, higher combustion efficiency, higher cetane number, biodegradability, lower sulphur aromatic content, and high oxygen content, and the demerits of biodiesel are lower energy content, high viscosity, requires high temperature for ignition, purification cost is more and high NOx(nitrogen oxide)emissions [3-4].

Biodiesel can be produced from edible as well as non-edible oils, but India being a developing country the edible oils are used for cooking purpose so the biodiesel is preferred to be produced from non-edible oils. But a major disadvantage of using Non-edible oils is the percentage of FFA which causes the undesired soup formation and thereby reducing the final yield during the base catalyst transesterification process [5]. Thus, various techniques were successfully developed to reduce the acid value such as pre-treatment of crude oil using degumming and acid catalyst esterification. A pre-treatment process using degumming must be carried out to reduce the viscosity of the fuel and acid catalyzed esterification must be carried out for high FFA oil before the base catalyzed transesterification process [4]. This reaction is very useful for handling vegetable oil with high FFA and high viscosity.

Biodiesel could be a promising substitute fuel which provides fairly satisfactory performance, reduced emissions, except NOx, and not requiring any engine modifications[6]. The problem of greater NOx production may be overcome by retarding the injection timing, requiring engine modification, or by using exhaust gas recirculation (EGR) system in the engine, which reduces the volumetric efficiency due to the higher pressure of air and temperature. Hence attempts should be made to reduce the NOx emissions by using biodiesel blend fuels [6].

However, a further possible method of reducing NOx emissions from engines running on biodiesel could be the use of producer gas with diesel. Gasification process involves a conversion of biomass feedstock into combustible gasses using a downdraft fixed bed gasifier. Producer gas can be produced by partial combustion of biomass which can be used as an alternative fuel for internal combustion engines. The decrease in emissions can be achieved by designing the injection system of fuel and gas. The primary benefit of the use of dual fuel in diesel engines is a notable reduction in NOx emissions [7]. The addition of gas has improved the combustion process higher than those for diesel fuel at lower engine loads but lowers at higher engine loads. According to literature 76-63% diesel can be saved in dual-fuel mode using alternative fuel [8-9].The present paper elaborates about the emission analysis of a single cylinder vertically water cooled diesel engine utilizing jojoba oil methyl ester and coir pith producer gas both in natural aspirated and dual fuel mode.

II MATERIAL AND METHODS

A.SOURCE OF JOJOBA OIL

SimmondsiaChinesis, commonly known as jojoba, is a semi-arid perennial shrub native to simmondsiaceae family, which is in northwest associated with Mojave and Sonoran deserts of Mexico, California, Arizona, Middle East, and Latin American Countries [7]. Jojoba is an extraordinary plant, whose seed contains 40-55% oil wax and can grow up to 1-2 m tall, having a broad, dense crown. The flower is small,having five to six sepals which are greenish yellow in colour and no petals. This tree can easily grow in the soil having rimming fertility with fewer water supplies. Jojoba can grow in the places where the salinity percentage is more, and can withstand high temperatures. So they are generally cultivated in desert and semi-desert regions where the availability of water is less. The requirement of fertilizer is less for the cultivation of jojoba oil is minimum but during the initial year of cultivation it requires more amount of nitrogen, because it helps in increasing the growth of the plant.

III. PHYSICAL AND CHEMICAL PROPERTIES OF BIODIESEL

A. FREE FATTY ACID (FFA) COMPOSITION OF JOJOBA OIL

FFA is an important parameter for determining the percentage of acid present in any biodiesel feedstock. The percentage differs for different types of biodiesel feedstock and it depends upon the type of feed stock selection, feedstockquality, environmental conditions and so on. The FFA for jojoba oil depends on the type of soil and the climate in which it is grown, as well as the extraction method through which the jojoba oil is extracted. It primarily consists of cis 11-Eicosenoic acid,Erucic acid,Oleic acid Nervonic acid and minimum percentages of other acids. FFA composition is tabulated in Table I.

TABLE I. Free Fatty Acid composition of jojoba oil[9].

Free Fatty Acid	Structure	Percentage(Mole fraction)
Cis 11-Eicosenoic acid	C20:1	76.7
Erucic acid	C22:1	12.1
Oleic acid	C18:1	9.3
Nervonic acid	C24:1	1.0
Palmitic acid	C16:0	0.3
Palmitoleic acid	C16:1	0.3
Strearic acid	C18:0	0.2

TABLE II. Physico-chemical properties of jojoba biodiesel(JOME)[10-11]

Properties	Diesel	JOME	Reference[a]	Reference[b]	ASTM Methods
Density(Kg/m^3)	846.3	869.8	873.7	873.8	D1298
Kinematic viscosity at 40^{0}C	3.64	4.7	4.46	4.64	D445
Acid value (mg KOH/g)	0.35	0.4±0.03	N/d	N/d	D664
Cloud point ^{0}C	-14	7	N/d	N/d	D2500
Pour point ^{0}C	-15	10	12	12	D2500
Fire point ^{0}C	55	154	100(closed cup)	100(closed cup)	D93
Calorific value (mJ/Kg)	74	179	N/d	N/d	D93
Cetane Index	42.72	43.23	45.2	45.18	D240
Carbon (%, w/w)	81.33	77	78.95	78.85	-
Hydrogen (%, w/w)	12.78	8.07	7.95	7.65	-
Nitrogen (%, w/w)	1.97	Nil	N/d	N/d	-
Sulphur (%, w/w)	0.2	Nil	Nil	Nil	-
Moisture (%, w/w)	0.05	N/d	N/d	N/d	-
Ash content(%, w/w)	0.01	Nil	Nil	Nil	-

B.KINEMATIC VISCOSITY

Kinematic viscosity is a measurement of a fluids thickness over a period of time. The greater the fluidity, the lesser the viscosity. In case of engine, high viscosity leads to improper

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functioning of fuel injector, and poor atomization of fuel spray increases the Sauter mean diameter of the fuel droplets [12-13].The preferred method of measuring the viscosity is ASTM D445. The acceptable viscosity range of biodiesel according to ASTM D 6751 is between 1.9 and 6.0 mm2/s [8].Kinematic viscosity is the ratio of absolute (or dynamic) viscosity to density.

C.SPECIFIC GRAVITY

It is defined as the ratio of the density of a substance to the density of a reference substance (water) or, it is the ratio of the mass of a substance to the mass of a reference substance (water) for the same given volume. Biodiesel is classified under higher specific gravity than neat biodiesel which directly influences the air-fuel ratio and exhaust gas like NOx emission reduces [12].

D.FLASH POINT

As far as transportation and safety regulations, the flash point mostly characterises the combustible (or) ignitable properties of biodiesel. Flash point is the lowest (or) minimum temperature at which vapours of the fuel will ignite of flash when an ignition source is applied. Biodiesel comes under the category of non-combustible if its flash point is over the base worth level of 130oC as sketched out in ASTM D93.The results accompanied an acknowledgment with the results of the other researchers as shown in Table II[10,12,14].

E.OXIDATION STABILITY

One of the improvement parameter concerns that limit the utilization of biodiesel as an alternative fuels in a CI engine its poor oxidation stability. Oxidation stability is a chemical reaction that occurs with a combination of the lubricating oil and oxygen. Biodiesel acts as lubricating oil so there is no need of other lubricants to be used. The oxidation rate is accelerated by high temperatures, acids, water and catalysts such as copper. Oxidation will ultimately lead to increase in the oils viscosity and deposits of sludge and varnish. The rate of oxidation depends on the quality and type of oil as well as the additive used. The referee test method for oxidation stability is ASTM D675 and EN14112 in European norms, utilizing the Ramcimant method with a minimum IP of 3h at 110oC[8].The figured out result from the experimentation was analogous to that of Sanford et al[15].

F. CALORIFIC VALUE

Calorific value is an important property which represents the total energy released as heat when a substance(biodiesel) undergoes complete combustion with oxygen under standard conditions (or) it represents the amount of heat transferred to the chamber during combustion and indicates the available energy in the fuel[8].The preferred test for the detection of calorific value in biodiesel is AST, D240,utilizing a bomb calorimeter. The experimental data and other reference values are incorporated in Table II [10]

G. CETANE NUMBER

The cetane number gives an indication of the ability of fuel to self-ignite when it is exposed to high temperature and pressure in a diesel engine. The cetane number is an important factor in determining the quality of the fuel, energy content, density, lubricity, cold-flow properties and sulphur content. the referee test method for determining the cetane number is found in ASTM D613[8].ASTMD6751 requires a minimum cetane number of 47 to meet the above standards[8].The experimental data of jojoba oil and biodiesel are depicted in Table II in comparison to diesel and reference values collected from the literature [10-12].

H.SULFUR CONTENT

The sulfur content of biodiesel is limited to 0.05% max by mass according to ASTM [16].The test conducted examined low amount of sulphur content in the test fuels and approximately nil in biodiesel, as stated in table II, in compression with diesel,and reference values obtained from various pieces of literature[10,15].

IV. SOURCE OF COIR PITH

India is one of the leading countries of the world in the cultivation and production of coconuts along with other grains. Around 14,000 million coconuts are being produced annually in India, particularly in the states of Andhra Pradesh, Kerala, Tamil Nadu ,Goa, Orissa and the Union territories. The coconut tree (Cocos nucifera) is a member of the family Arecaceae (Palm family) and the only species of the genus Cocos. Coconut palms are grown in more than 90 countries of the world, with a total production of 61 million tonnes per year .Most of the production is in tropical Asia, with Indonesia, the Philippines, and India accounting collectively for 73% of the world total[18].

Table III. Physical and chemical properties of producer gas[18]

Average particle size(Micron)	Porosity(%)	Density(g/cc)	Absorptivity(%)
300	83.25±9.23	0.131±0.012	65.0±7.24
750	76.80±6.74	0.099±0.007	59.0±6.34
1500	71.36±8.12	0.085±0.004	53.0±5.44
2000	68.41±7.45	0.079±0.005	42.0±4.94

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V. EXPERIMENTAL SETUP AND EXPERIMENTATION

The setup consists of a single cylinder, 4 stroke, vertical water cooled diesel engine with 3.5 kW power at 1500 RPM connected to an eddy current dynamometer. "EnginesoftLV" software is applied for online combustion analysis. Piezosensor and crank angle sensor which measures the combustion pressure and the corresponding crank angle respectively, are mounted into the engine head[19-22]. Type K-Chromel (Nickel-Chromium Alloy) / Alumel (Nickel-Aluminium Alloy) thermocouples are used to measure gas temperature at the engine exhaust, calorimeter exhaust, water inlet of the calorimeter and water outlet of calorimeter, engine cooling water outlet and ambient temperature. The specification of the engine is given in Table IV. A computerized data acquisition system is used to collect, store and analyze the data during the experiment by using several detectors.

Fig 1. Schematic of test engine setup[21]

TABLE IV. Specification of test engine rig[21]

Test Engine Sl. No.	Specification Particulars	Description
1	Engine Type	4-stroke, single cylinder, Bi-fuel engine.
2	Stroke Length	110 mm
3	Bore Diameter	80 mm
4	Compression Ratio	16:1
5	Rated Speed	3.5 KW
6	Rated Power	1500 rpm
7	Dynamometer	Eddy Current Type

VI.RESULT AND DISCUSSION

A.CARBON MONOXIDE (CO)

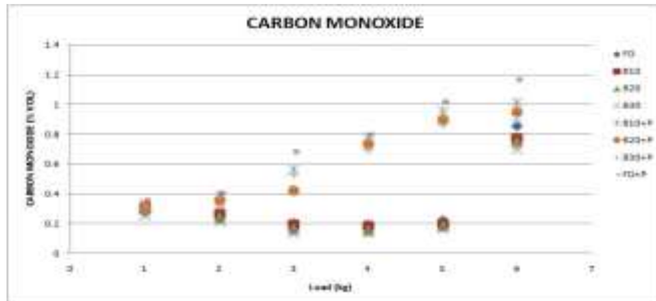

Fig 2. Variations of Carbon monoxide with respect to Load (kg)

Figure 2 depicts the variation of carbon monoxide with respect to load. From the given figure it might be inferred that emission of carbon monoxide is slightly higher for dual fuel mode than single condition for all test fuel under diverse loading conditions as a result of insufficient ignition and vicinity of CO in the producer gas[8,21]. The graph shows a step reduction in the CO emission due to complete combustion and, it increments at higher load on account of fuel abundance and incomplete combustion. CO emission is less for biodiesel than diesel due to the pressure of oxygen in biodiesel an hence it is called oxygenated fuel.

B. CARBON DIOXIDE (CO2)

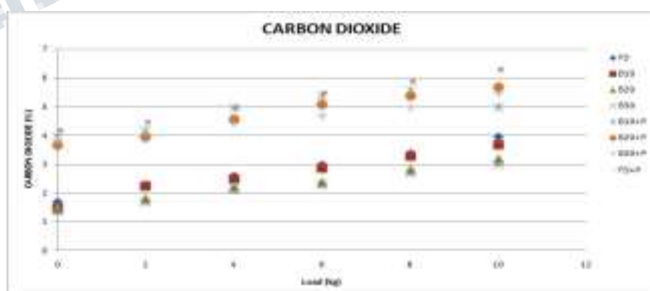

Fig 3. Variations of carbon dioxide with respect to Load (kg)

Figure 3 depicts the variation of carbon dioxide in variation with respect to load. From the given figure, it might be inferred that emission of carbon dioxide is less for single mode in comparison to that of double operating mode under different loading conditions. This is imputable to the fact that producer gas is a mixture of carbon monoxide and carbon dioxide. Hence, when there is complete combustion automatically, there is an increase in carbon dioxide emission [16].

C. HYDROCARBON (HC)

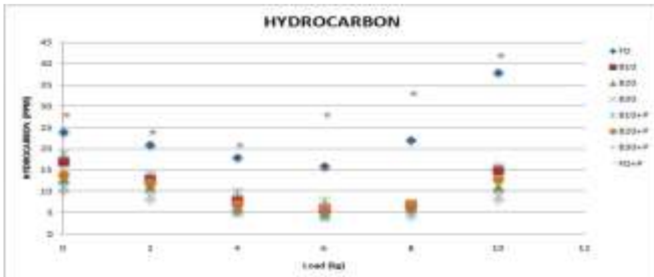

Fig 4. Variations of Hydrocarbon with respect to Load (kg)

Figure 4 depicts the variation of Hydrocarbon in variation with load. From the given figure it might be inferred that emission of Hydrocarbon shows very similar curves to that of carbon monoxide emissions. Emission is less for all test fuels prepared with diesel blends[8,21]. Likewise, it can also be stated that dual fuel mode emits less hydrocarbon in contrast to single operating mode because of complete combustion.

D. NITRIC OXIDE (NO)

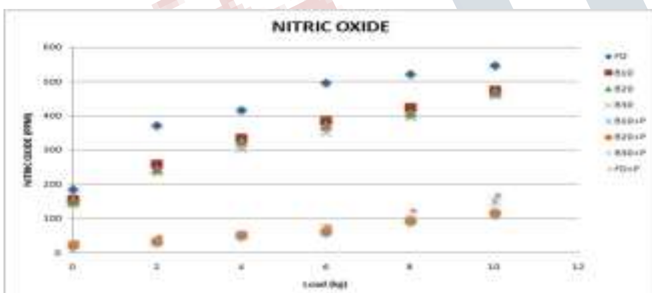

Fig 5. Variations of Nitrogen Oxide with respect to Load (kg)

Figure 5 depicts the variation of Nitric oxide with respect to load. From the given figure it might be inferred that emissions of Nitric oxide is less for dual fuel mode in comparison to that of single operating condition because of the absence of Nitrogen in producer gas and also due to low adiabatic temperature of the flame [8,21]. NO increases for both operating conditions due to increase in energy input.

VII.CONCLUSION

From the experimental results, it might be summarised the nitric oxide, hydrocarbon and smoke opacity are reduced in dual fuel mode as compared to single operating mode for all test fuel blends. The residue of the emission parameters like CO2 and CO increases slightly for dual mode than that of single mode. Under distinctive loading conditions waste oil methyl ester shows better performance than conventional diesel. Hence, it might be concluded that producer gas mixed with biodiesel blends would be beneficial for reducing NO and HC without making any modifications in the present engines.

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