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Performance Analysis on 4 Stroke Diesel Engine with Eucalyptus oil & Diesel Bending Using Dual Fuel Mode

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Abstract: Nowadays, the increasing oil consumption throughout the world induces crucial economical, security, and environmental problems. As a result, intensive researches are undertaken to find appropriate substitution to fossil fuels. In view of the large amount of eucalyptus trees present in arid areas, we focus in this study on the investigation of using eucalyptus biodiesel as fuel in diesel engine. Eucalyptus oil is converted by transesterification into biodiesel. Eucalyptus biodiesel characterization shows that the physicochemical properties are comparable to those of diesel fuel. In the second phase, a single cylinder air-cooled, DI diesel engine was used to test neat eucalyptus biodiesel and its blends with diesel fuel in various ratios (75, 50, and 25 by v %) at several engine loads. The engine combustion parameters such as peak pressure, rate of pressure rise, and heat release rate are determined. Performances and exhaust emissions are also evaluated at all operating conditions. Results show that neat eucalyptus biodiesel and its blends present significant improvements of carbon monoxide, unburned hydrocarbon, and particulates emissions especially at high loads with equivalent performances to those of diesel fuel. However, the NOx emissions are slightly increased when the biodiesel content is increased in the blend.

INTRODUCTION:

In the wake of present energy-environment crises, it has become crucial to find renewable and alternative clean energy sources. One of the principal routes to undertake the problem of increasing prices and pollution problems of petroleum fuels is by using biomass sources, particularly vegetable oils. Several chemical properties of oils, among them are the high viscosity and high molecular weight, cause poor fuel atomization and low volatility, leading to incomplete combustion and severe engine deposits, injector coking, and piston ring sticking [1–4].

To overcome these problems caused by the high viscosity of vegetable oils, several techniques have been used such as preheating the oil, blending or diluting the oil with other conventional fuel, oil microemulsification, transesterification, or thermal cracking/pyrolysis [5–7]. Previous researches showed that the most suitable technique to improve the properties of vegetable oils is the transesterification. It consists of a catalyzed chemical reaction implying vegetable oil and an alcohol which produces esters (biodiesel) and glycerol [8–12]. Methyl or ethyl esters of vegetable oils referred to as biodiesel have several advantages and can be used in any existing design of diesel engine without any hardware modification. Numerous biodiesels derived from different sources have been tried as alternative to diesel fuel for several years. A lot of researchers have reported that biodiesels are of comparable performance to diesel fuel. Moreover, significant reduction in emissions of carbon monoxide, hydrocarbon, and smoke observed. However, a slight increase in NOx emissions and specific fuel consumption were depicted [13–16]. The eucalyptus tree is no edible specie capable of growing in nearly all climatic conditions. It grows up to nearly 200 meters. In Algeria, the eucalyptus trees occupy a surface of 430 km2 with potential production of 144800 m3 per annum. Eucalyptus oil can be extracted from eucalyptus leaves, abundantly available throughout the year. Currently, the eucalyptus oil uses are limited just for few traditional applications such as medicine or traditional pharmacopoeia. But there is not a comprehensive investigation on applying eucalyptus oil in diesel engines yet except an experimental investigation related to performance and emissions of diesel engine running with paradise biodiesel-eucalyptus oil blend [17]. Hence, a study was carried out to run a diesel engine with esterifies eucalyptus oil which is produced from Algerian eucalyptus and its blend with diesel fuel at Department des Systèmes Energétiques et Environment, Ecole des Mines de Nantes. The important physical and chemical properties of the obtained eucalyptus biodiesel are also determined. The engine tests are carried out on a Lister-Petter diesel engine fuelled with neat eucalyptus biodiesel, neat diesel fuel, and their blends (containing 75%, 50%, and 25% biodiesel by volume). Experiments are conducted at different power outputs (20%, 50%, 70%, and 90% load). The results of combustion parameters, engine performance, and exhaust emissions are determined and discussed.

EUCALYPTUS OIL:

Types and production:

Eucalyptus oils in the trade are categorized into three broad types according to their composition and main end-use: medicinal, perfumery and industrial.[1] The most prevalent is the standard cineole-based "oil of eucalyptus", a colourless mobile liquid (yellow with age) with a penetrating, camphoraceous, woody-sweet scent.[2] China produces about 75% of the world trade, but most of this is derived from the cineole fractions of camphor laurel rather than being true eucalyptus oil.[3] Significant producers of true eucalyptus oil include South Africa, Portugal, Spain, Brazil, Australia, Chile, and Swaziland.Eucalyptus polybractea or Blue-leaf Mallee, a species yielding high quality eucalyptus oil

Medicinal and antiseptic:

The cineole-based oil is used as component in pharmaceutical preparations to relieve the symptoms of influenza and colds, in products like cough sweets, lozenges, ointments and inhalants. Eucalyptus oil may have antibacterial effects on pathogenic bacteria in the respiratory tract.[5] Inhaled eucalyptus oil vapor is a decongestant and treatment for bronchitis.[6] Cineole may control airway mucus hypersecretion and asthma via anti-inflammatory cytokineinhibition although there is insufficient evidence.[7][8][citation needed] Pre-clinical results also show that eucalyptus oil stimulates innate cell-mediated immune response by effects on the phagocytic ability of human monocyte derived macrophages [9]fragrance component to impart a fresh and clean aroma in soaps, detergents, lotions, and perfumes. It is known for its pungent, intoxicating scent. Due to its cleansing properties, Eucalyptus oil is found in mouthrinses to freshen breath.

Industrial:

Research shows that cineole-based eucalyptus oil (5% of mixture) prevents the separation problem with ethanol and petrol fuel blends. Eucalyptus oil also has a respectable octane rating and can be used as a fuel in its own right. However, production costs are currently too high for the oil to be economically viable as a fuel.[18] Phellandrene- and piperitone-based eucalyptus oils have been used in mining to separate sulfide minerals via flotation.If consumed internally at low dosage as a flavouring component or in pharmaceutical products at the recommended rate, cineole-based 'oil of eucalyptus' is safe for adults. However, systemic toxicity can result from ingestion or topical application at higher than recommended doses.[19] The probable lethal dose of pure eucalyptus oil for an adult is in the range of 0.05 mL to 0.5 mL/per kg of body weight.[20] Because of their high body-surface-area-to-mass ratio, children are more vulnerable to poisons absorbed transdermally. Severe poisoning has occurred in children after ingestion of 4 mL to 5 mL of eucalyptus oil.[21]

LITERATURE REVIEW

The whole world is facing the crises of depletion of fossil fuels as well as the problem of environmental degradation. The rapid depletion of fossil fuel reserves with increasing demand and uncertainty in their supply, as well as the rapid rise in petroleum prices, has stimulated the search for other alternatives to fossil fuels. In view of this, there is an urgent need to explore new alternatives, which are likely to reduce our dependency on oil imports as well as can help in protecting the environment for sustainable development. Many alternative fuels are being recently explored as potential alternatives for the present high-pollutant diesel fuel derived from diminishing commercial resources. Biodiesel emerges as one of the most energy-efficient environmentally friendly options in recent times to full fill the future energy needs. Biodiesel is a renewable diesel substitute that can be obtained by combining chemically any natural oil or fat with alcohol. During the last 15 years, biodiesel has progressed from the research stage to a large scale production in many developing countries.

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In Indian context, non-edible oils are emerging as a preferred feedstock and several field trials have also been made for the production of biodiesel. Vegetable oils either from seasonal plant crops or from perennial forest tree's origin, after being formulated, have been found suitable for utilization in diesel engines. Many traditional oil seeds like pongamia glabra, jatropha, mallous philippines, garcinia indica, thumba, karanja and madhuca indica etc. are available in our country in abundance, which can be exploited for biodiesel production purpose. Many vegetable oils, animal fats and recycled cooking greases can also be transformed into biodiesel. Biodiesel can be used neat or as a diesel additive in compression ignition engines. Dr. Rudolf Diesel, who invented the first Diesel Engine in 1895, used only biofuel in his engine. His visionary statement was “The use of vegetable oils for engine fuel may seem insignificant today, but such oils may become in course of time, as important as petroleum and coal tar products of the present time”. The above prediction is becoming true today as more and more biodiesel is being used all over the world. In 1900 at the world fair in Paris, a small version of a diesel engine ran on plant oil. This was organized by the French society for the support of the Otto engine. At that time, crude oil was available in abundance; hence, vegetable oils could not attract as a source of fuel much. Despite the widespread use of fossil petroleum-derived diesel fuels, interest in vegetable oils as fuel for internal combustion engines was reported in several countries during the 1920s and 1930s. While engineers and scientists have been experimenting with vegetable oils as fuel for a diesel engine since 1900, it is only recently that the necessary fuel properties and engine parameters for reliable operation have become apparent. In recent times, due to realization that crude oil is limited and poses a threat to well being of mankind from emissions of exhaust gases, vegetable oil has been revisited for its scope as a fuel in compression ignition engines. Some operational problems were reported due to the high viscosity of vegetable oils compared to petroleumdiesel fuel, which results in poor atomization of the fuel in the fuel spray and often leads to deposits and coking of the injectors and valves. To lower the viscosity of vegetable oil, chemical and thermal processes were tried to make vegetable oil compatible to compression ignition engines. Attempts to overcome these problems included heating of the vegetable oil, blending it with petroleum-derived diesel fuel or ethanol, pyrolysis, cracking of the oils, micro-emulsification and transesterification, where triglycerides from vegetable oils react with a lower alcohol to produce fatty acid alkyl esters possessing properties similar to mineral diesel. Transesterification of a vegetable oil was conducted as early as 1853 by scientists E. Duffy and J. Patrick, many years before the first diesel engine became functional. On August 31, 1937, G. Chavanne of the University of Brussels (Belgium) was granted a patent for a procedure for the transformation of vegetable oils for their uses as fuels. The use of biodiesel was recognized much later and became technically relevant only after the energy crisis in the year 1973 and afterwards. More recently, in 1977, Brazilian scientist Expedito Parente invented and submitted first industrial process for the production of biodiesel for patent.

BIO DIESEL PREPARATION AND ITS CHARACTERIZATION

To remedy the problem of eucalyptus oil high viscosity (30 cSt at 40°C) [18], ethyl transesterification is tested in this study. Biodiesel was prepared using 97 mL (92 g) of eucalyptus oil and 42 mL (33 g) of ethanol with 1 g of sodium hydroxide (NaOH) as catalyst (1% of oil by weight). After dissolving NaOH catalyst in ethanol, the eucalyptus oil was added to the reaction tank to start the transesterification reaction. The mixture was agitated thoroughly for 1 hr at 45°C.The stirring process is characterized by the mixture color conversion from clear yellow to reddish yellow. Once the separation is operated, the glycerol is removed as a dark-brown-colored liquid from the bottom of the flask. Then, the eucalyptus biodiesel is washed to remove the remaining alcohol and catalyst in the biodiesel phase. The previous parameters affecting the transesterification yield such as the reaction time and the ratios oil: alcohol: catalyst has been fixed after adjustments, which give the optimal yield estimated at 95%. The important chemical and physical properties of the biodiesel and its blends were then determined by standard methods and compared with diesel (Table 1). It can be seen that the main eucalyptus biodiesel properties are comparable to those of diesel fuel. These results show that eucalyptus oil holds good potential as biodiesel no edible feedstock.

Table 1: Properties of tested fuels.

Property	Diesel	EB100	EB75	EB50	EB25
Average molecular weight	310	275	245	213	170
Carbon content (wt.%)	77.0	—	—	—	86
Hydrogen content (wt.%)	12.18	—	—	—	14
Oxygen content (wt.%)	10.32	——	—	0	
Nitrogen content (wt.%)	0	—	—	—0	
Gross heating value (MJ/kg)	40	40.76	42.53	43.8	45.7
Specific gravity at 15°C	896	891	884876	852	
Viscosity at 40°C (cSt)	2.99	2.62	2.36	1.91	1.57
Flash point (°C)	105	84	76	71	67
Cetane number	53	52.25	51.550.75	49	

ENGINE SPECIFICATION:

RESEARCH ENGINE TEST SETUP:

SYSTEM CONSTANTS:

- No. of Cylinders - 1
- No. of Strokes - 4

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• Cylinder Diameter	-	80mm
• Stroke Length	-	110mm
• Compression Ratio	-	16.5
• Constant Speed	-	1400rpm
• Connecting rod Length	-	232mm
• Cylinder Volume	-	552.9cc
• Clearance Volume	-	33.5cc
• Pressure Sensor Baseline	-	1.02300V
• Pressure Sensor Sensitivity	-	25 bar/Volt
• Injection Spark Angle	-	337°

WORKING PRINCIPLE:

A heat engine is a machine, which converts heat energy into mechanical energy. The combustion of fuel such as coal, petrol, Diesel generates heat. This heat is supplied to a working substance at high temperature. By the expansion of this substance in suitable machines, heat energy is converted into useful work.

Heat engines can be further divided intotwo types:

(i) External combustion and

(ii) Internal combustion.

In a steam engine the combustion of fuel takes place outside the engine and the steam thus formed is used to run the engine. Thus, it is known as *external combustion engine.*

In the case of *internal combustion engine,* the combustion of fuel takes place inside the engine cylinder itself.

The IC engine can be further classified as:

- (i) stationary or mobile,
- (ii)horizontal or vertical and
- (iii) Low, medium or high speed.

The two distinct types of IC engines used for either mobile or stationary operations are:

(i) Diesel and

(ii) Carburetor.

5.1 Compression Ignition (Diesel Type) IC Engine

In this only the liquid fuel is injected in the cylinder under high pressure.

5.2 CONSTRUCTIONAL FEATURES OF IC ENGINE:

A brief description of these parts is given below.

5.2.1 Cylinder:

The cylinder of an IC engine constitutes the basic and supporting portion of the engine power unit. Its major function is to provide space in which the piston can operate to draw in the fuel mixture or air (depending upon spark ignition or compression ignition), compress it, allow it to expand and thus generate power. The cylinder is usually made of high-grade cast iron. In some cases, to give greater strength and wear resistance with less weight, chromium, nickel and molybdenum are added to the cast iron.

5.2.2 Piston:

The piston of an engine is the first part to begin movement and to transmit power to the crankshaft as a result of the pressure and energy generated by the combustion of the fuel. The piston is closed at one end and open on the other end to permit direct attachment of the connecting rod and its free action. The materials used for pistons are grey cast iron, cast steel and aluminium alloy. However, the modern trend is to use only aluminium alloy pistons in the tractor engine.

5.2.3 Piston Rings:

These are made of cast iron on account of their ability to retain bearing qualities and elasticity indefinitely. The primary function of the piston rings is to retain compression and at the same time reduce the cylinder wall and piston wall contact area to a minimum, thus reducing friction losses and excessive wear. The other important functions of piston rings are the control of the lubricating oil, cylinder lubrication, and transmission of heat away from the piston and from the cylinder walls. Piston rings are classed as compression rings and oil rings depending on their function and location on the piston. Compression rings are usually plain one-piece rings and are always placed in the grooves nearest the piston head. Oil rings are grooved or slotted and are located either in the lowest groove above the piston pin or in a groove near the piston skirt. Their function is to control the distribution of the lubricating oil to the cylinder and piston surface in order to prevent unnecessary or excessive oil consumption ion.

5.2.4 Piston Pin:

The connecting rod is connected to the piston through the piston pin. It is made of case hardened alloy steel with precision finish. There are three different methods to connect the piston to the connecting rod.

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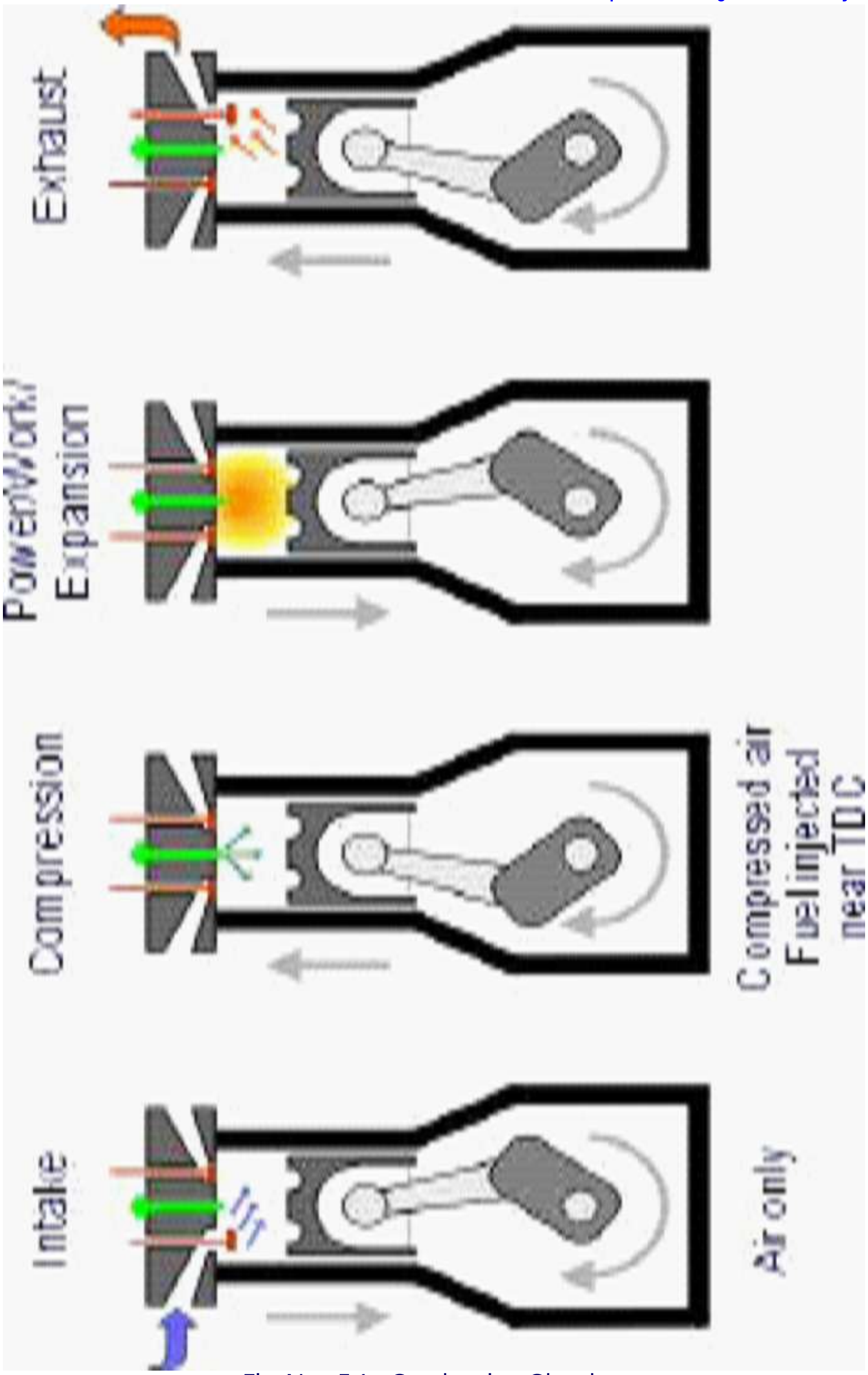

Fig. No.: 5.1. Combustion Chamber

5.2.5 Connecting Rod:

This is the connection between the piston and crankshaft. The end connecting the piston is known as *small end* and the other end is known as big *end.* The big end has two halves of a bearing bolted together. The connecting rod is made of drop forged steel and the section is of the I-beam type.

5.2.6 Crankshaft:

This is connected to the piston through the connecting rod and converts the linear motion of the piston into the rotational motion of the flywheel. The journals of the crankshaft are supported on main bearings, housed in the crankcase. Counter-weights and the flywheel bolted to the crankshaft help in the smooth running of the engine.

5.2.7 Engine Bearings:

The crankshaft and camshaft are supported on anti-friction bearings. These bearings must be capable of withstanding high speed, heavy load and high temperatures. Normally, cadmium, silver or copper lead is coated on a steel back to give the above characteristics. For single cylinder vertical/horizontal engines, the present trend is to use ball bearings in place of main bearings of the thin shell type.

5.2.8 Valves:

To allow the air to *enter into* the cylinder or the exhaust, gases to escape from the cylinder, valves are provided, known as *inlet* and *exhaust* valves respectively. The valves are mounted *either on* the cylinder head or on the cylinder block.

5.2.9 Camshaft:

The valves are operated by the action of the camshaft, which has separate cams for the inlet, and exhaust valves. The cam lifts the valve against the pressure of the spring and as soon as it changes position the spring closes the valve. The cam gets drive through *either the* gear or sprocket and chain system from the crankshaft. It rotates at half the speed of the camshaft.

5.2.10 Flywheel

This is usually made of cast iron and its primary function is to maintain uniform engine speed by carrying the crankshaft through the intervals when it is not receiving power from a piston. The size of the *flywheel varies* with the number of cylinders and the type and size of the engine. It also helps in balancing rotating masses.

5.3 Materials used for engine parts:

1. Cylinder head Cast iron, Cast Aluminium
2. Cylinder liner Cast steel, Cast iron
3. Engine block Cast iron, Cast aluminum, Welded steel
4. Piston Cast iron, Aluminium alloy
5. Piston pin Forged steel, Casehardened steel.
6. Connecting rod Forged steel. Aluminium alloy.
7. Piston rings Cast iron, Pressed steel alloy.
8. Connecting rod bearings Bronze, White metal.
9. Main bearings White metal, Steel backed Babbitt base.
10. Crankshaft Forged steel, Cast steel
11. Camshaft Forged steel, Cast iron, cast steel,
12. Timing gears Cast iron, Fiber, Steel forging.
13. Push rods Forged steel.
14. Engine valves Forged steel, Steel, alloy.
15. Valve springs Carbon spring steel.
16. Manifolds Cast iron, Cast aluminium.
17. Crankcase Cast iron, Welded steel
18. Flywheel Cast iron.
19. Studs and bolts Carbon steel.
20. Gaskets Cork, Copper, Asbestos.

5.4 PRINCIPLES OF OPERATION OF IC ENGINES:

5.4.1 ENGINE SPECIFICATION

The schematic diagram of the complete experimental setup of LPG-Diesel/Vegetable oil dual fuel engine. It is a single cylinder four-stroke, and water cooled diesel engine test rig which is modified to work in dual fuel mode (see Appendix A for Engine Specifications) and is directly connected to mechanical loading. It is provided with temperature sensors for the measurement of jacket temperature, calorimeter water and calorimeter exhaust gas inlet and outlet temperature. Pressure sensors are provided for combustion gas pressure and fuel injection pressure and an encoder is fixed for crank angle plots. Provision is also made for volumetric liquid fuel flow measurement. A differential pressure transducer detects the air pressure across the orifice. The LPG cylinder is connected to the inlet manifold through a rubber hose provided with a control valve. The volumetric LPG flow rate is measured by a rotometer

Fig. No.: 3.1. 4- Stroke Diesel Engine

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In four-stroke cycle engines there are four strokes completing two revolutions of the crankshaft. These are respectively, the suction, compression, power and exhaust strokes. The piston is shown descending on its suction stroke. Only pure air is drawn into the cylinder during this stroke through the inlet valve, whereas, the exhaust valve is closed. These valves can be operated by the cam, push rod and rocker arm. The next stroke is the compression stroke in which the piston moves up with both the valves remaining closed. The air, which has been drawn into the cylinder during the suction stroke, is progressively compressed as the piston ascends. The compression ratio usually varies from 14:1 to 22:1. The pressure at the end of the compression stroke ranges from 30 to 45 kg/cm^2. As the air is progressively compressed in the cylinder, its temperature increases, until when near the end of the compression stroke, it becomes sufficiently high (650-80O°C) to instantly ignite any fuel that is injected into the cylinder. When the piston is near the top of its compression stroke, a liquid hydrocarbon fuel, such as diesel oil, is sprayed into the combustion chamber under **high pressure (140-160 kg/cm^2)**, higher than that existing in the cylinder itself. This fuel then ignites, being burnt with the oxygen of the highly compressed air. During the fuel injection period, the piston reaches the end of its compression stroke and commences to return on its third consecutive stroke, viz., **power stroke**. During this stroke the hot products of combustion consisting chiefly of carbon dioxide, together with the nitrogen left from the compressed air expand, thus forcing the piston downward. This is only the working stroke of the cylinder. During the power stroke the pressure falls from its maximum combustion value **(47-55 kg/cm^2),** which is usually higher than the greater value of the compression pressure (45kg/cm^2), to about **3.5-5 kg/cm^2**near the end of the stroke. The exhaust valve then opens, usually a little earlier than when the piston reaches its lowest point of travel. The exhaust gases are swept out on the following upward stroke of the piston. The exhaust valve remains open throughout the whole stroke and closes at the top of the stroke. The reciprocating motion of the piston is converted into the rotary motion of the crankshaft by means of a connecting rod and crankshaft. The crankshaft rotates in the main bearings, which are set in the crankcase. The flywheel is fitted on the crankshaft in order to smoothen out the uneven torque that is generated in the reciprocating engine.

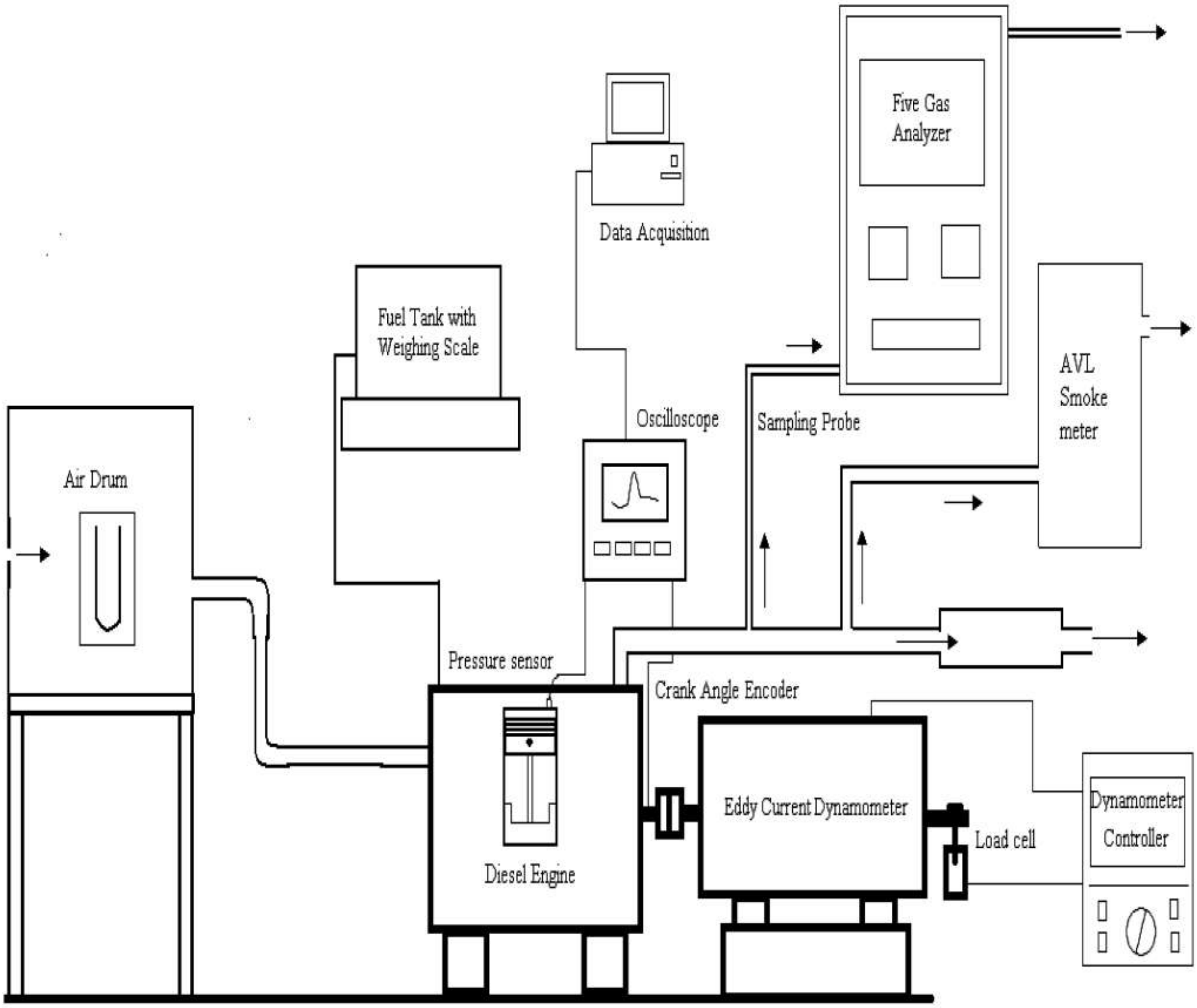

Fig. No.: 5.2. Layout of Experimental Setup

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TABULATION:

TABULATION 1

This Readings are taken with 100% Diesel using Engine Test Express V5-80 in single cylinder high speed diesel engine.

OBSERVATION TABLE										
Fuel : Diesel Date : 15/4/2022Injection Pressure: 185bar										
S.No	Load "VI"	Time Taken for 5cc of fuel consumption "Sec"			Exhaust gas Temperature "°C"	Emission "PPM"				
		t_1	t_2	T		Co	Co_2	HC	NO_X	
1.	0	62	61	61.5	160	150	500	260	680	
2.	0.9	39	41	40	169	192	1700	290	1250	
3.	1.8	34	33	33.5	185	383	3200	340	1370	
4.	2.7	28	27	27.5	198	457	3650	430	1425	
5.	3.6	16	14	15	207	525	4100	490	1550	

Where:

Co = Carbon Monoxide in PPM
Co_2 = Carbon di Oxide in PPM
HC = Hydro Carbons in PPM
No_x = Nitrous Oxide in PPM
V = Voltage in Volts
I = Current in Ampere

Formula:

Load = Voltage * Current= 220*4.09 = 899.8 Watts = 0.9 Kw

TABULATION 2

This Readings are taken with blending of 80% Diesel and 20% Eucalyptus oils using Engine Test Express V5-80 in single cylinder high speed diesel engine.

OBSERVATION TABLE									
Fuel : Diesel with Eucalyptus oils Date : 15/4/2022 Injection Pressure: 185bar 20% Blending of Eucalyptus oils.									
S.No	Load "VI"	Time Taken for 5cc of fuel consumption "Sec"			Exhaust gas Temperature "°C"	Emission "PPM"			
		t_1	t_2	T		Co	Co_2	HC	NO_X
1.	0	60	59.5	60	231	120	200	200	650
2.	0.9	43	42	43	308	130	1500	210	1250
3.	1.8	33.5	33	33.5	408	250	3000	260	1335
4.	2.7	26	27	26	538	383	3250	310	1390
5.	3.6	21	20.5	21	704	453	4250	360	1425

Where:

Co = Carbon Monoxide in PPM
Co_2 = Carbon di Oxide in PPM
HC = Hydro Carbons in PPM
No_x = Nitrous Oxide in PPM
V = Voltage in Volts
I = Current in Ampere

Formula Load = Voltage * Current

TABULATION 3

This Readings are taken with blending of 70% Diesel and 30% Eucalyptus oils using Engine Test Express V5-80 in single cylinder high speed diesel engine.

OBSERVATION TABLE									
Fuel : Diesel with Eucalyptus oil Date : 15/4/2022 Injection Pressure: 185bar 30% Blending of Eucalyptus oil.									
S.No	Load "VI"	Time Taken for 5cc of fuel consumption "Sec"			Exhaust gas Temperature "°C"	Emission "PPM"			
		t_1	t_2	T		Co	Co_2	HC	NO_X
1.	0	53	54	53	270	110	180	170	600
2.	0.9	39	40	39	305	115	1400	210	1175
3.	1.8	30	31	30	396	180	2800	230	1225
4.	2.7	24	23	24	540	220	2900	255	1275
5.	3.6	18.5	16	18	715	300	3200	290	1325

Where:

Co = Carbon Monoxide in PPM
Co_2 = Carbon di Oxide in PPM
HC = Hydro Carbons in PPM
No_x = Nitrous Oxide in PPM
V = Voltage in Volts
I = Current in Ampere

Formula:

Load = Voltage * Current

3. Engine Test Equipment and Procedure:

A constant speed engine tests are carried out on a single cylinder DI air-cooled LISTER PETTER (TS1) diesel engine developing a power output of 4.5 kW at 1500 rpm. It has a bore of 95.3 mm, a stroke of 88.9 mm, a displacement volume of 630 cm3, and a compression ratio of 18. The experimental setup is shown in Figure 1. An electrical dynamometer is used for loading the engine. An orifice meter connected to a large tank is attached to the engine manifold to measure the air flow. The fuel flow rate is measured with a Carioles mass flow meter. This meter uses the Coriolis Effect to measure the amount of fuel moving through the element. Chromel-alumel thermocouple in conjunction with a slow speed digital data acquisition system is used for measuring the exhaust gas temperature. An exhaust analyzer (COSMA) is used for measuring hydrocarbons (HC) by a flame ionization detector, while carbon monoxide (CO) emissions are measured using an infrared device. Nitrogen oxide (NO) in the exhaust is measured by using a BECKMAN chemiluminescence NO/NOx analyzer. The particulate matter emissions containing carbon smoking emissions are measured by a balance type TEOM1105. The accuracies of the measurements and the uncertainties in the calculated results are shown in Table 2.

Table 2: The accuracies of the measurements and the uncertainties in the calculated results.

Measurements	Accuracy
Load	±0.1 N.m
Speed	±3/min
Temperatures	±1.6°C
Cylinder pressure	±2 bars
Crank angle	±0.05°V
Fuel volumetric rate	±0.5%
Air flow rate	±1.0%
HC	±10 ppm
CO	±50 ppm
NO	±100 ppm
Particulates	±10 ng/s
Calculated results	Uncertainty range (%)
Power	0.4–1.9
BSFC	0.6–2.0
BTE	0.7–2.0

Figure 1: Photographic view of the experimental setup. (1) Diesel engine, (2) gas analyzer, (3) particulate analyzer, (4) diesel tank, (5) biodiesel tank, (6) orifice meter, (7) air tank, (8) wires of different sensors

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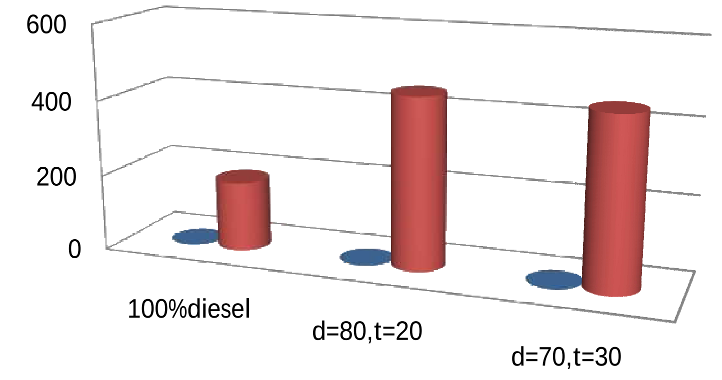
A high-speed digital data acquisition system in connection with two AVL piezoelectric transducers is used for measuring the cylinder pressure and fuel line pressure histories. An optical shaft position encoder is used to give signals at TDC. Engine in-cylinder pressure and crank angle signals are sampled for 100 consecutive cycles at the increments of 0.1 crank angle intervals. Before each experiment, the engine is regulated according to the manufacturer catalogue values. All data are collected after the engine has stabilised. During the entire investigations, the working parameters of the test engine are fixed as injection timing of 20°CA before TDC for, engine speed of 1500 rpm, and compression ratio of 18. Experiments are performed with neat eucalyptus biodiesel and its blends with diesel fuel (75% eucalyptus biodiesel, 50% and 25% proportions by volume) at various engine power outputs (0.9, 2.25, 3.15, and 4.05 kW). The legend EBX represents a blend including X% biodiesel, that is, EB100 represents neat eucalyptus biodiesel. Readings of engine speed, fuel flow, air flow, and so forth are recorded in order to determine engine performance parameters. Exhaust gas analyzers are calibrated carefully before making measurements, based on the manufacturer's recommended procedure. Standard span gases and zero gas are used for the calibration of HC, CO, and NO

RESULTS AND DISCUSSION:

ENGINE PERFORMANCE:

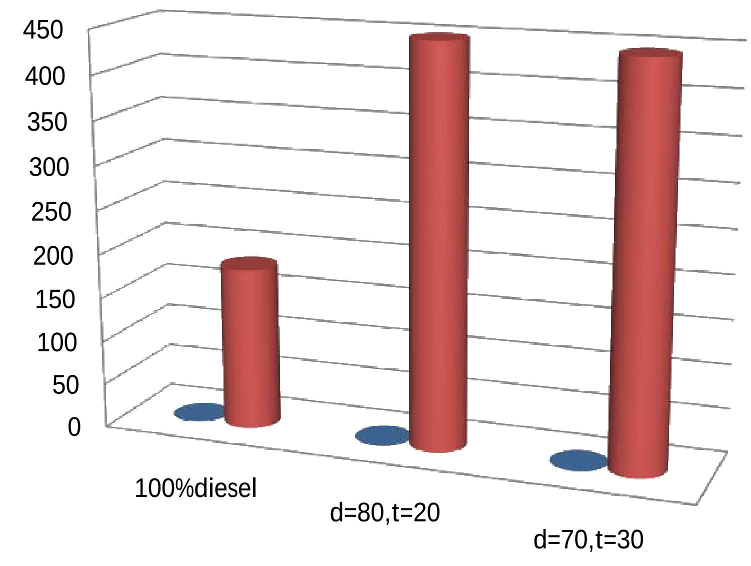
The variation of brake specific fuel consumption of diesel oil at different loads. It is found that the specific fuel consumption for the blend B20 is close to diesel. However if the concentration of eucalyptus oil in the blend is more than 30% the specific fuel consumption was found to be higher than diesel at all loads. This is because of the combined effects of lower heating value and the higher fuel flow rate due to high density of the blends. Higher proportions of eucalyptus oil in the blends increases the viscosity which in turn increased the specific fuel consumption due to poor atomization of the fuel.



	100%diesel	d=80,t=20	d=70,t=30
BP	0.0206	0.0211	0.0215
SFC	183.8	449.8	445.2

Fig. No.: 6.1. B.P. Vs SFC

The variation of brake thermal efficiency of the engine with various blends is shown and compared with the brake thermal efficiency obtained with diesel. It was observed that brake thermal efficiencies of all the blends were found to be lower at all load levels. Among the blends B20 is found to have the maximum thermal efficiency of 29.40% at a brake power of 3.9 kW while for diesel it was 30.9% and for B50 it decreased to 26.1%. It was observed that as the proportion ofeucalyptus oil in the blends increases the thermal efficiency decreases. The decrease in brake thermal efficiency with increase in eucalyptus oil concentration is due to the poor atomization of the blends due to their higher viscosity.

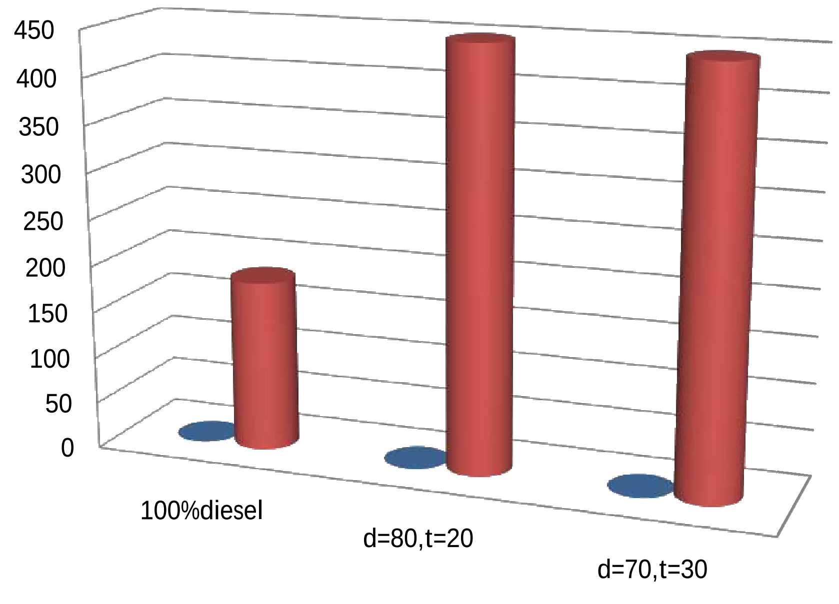


	100%diesel	d=80,t=20	d=70,t=30
BP	0.0206	0.0211	0.0215
TE	183.8	449.8	445.2

Fig. No.: 6.2. B.P. Vs T.E

The variation of exhaust gas temperature with load for various blends and diesel. The results show that the exhaust gas temperature increases with increase in brake power for all blends.

At all loads, diesel was found to have the lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of eucalyptus oil in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher. Moreover the engine being air cooled runs hotter which resulted in higher exhaust gas temperatures.



	100%diesel	d=80,t=20	d=70,t=30
BP	0.0206	0.0211	0.0215
ET	183.8	449.8	445.2

Fig. No.: 6.3. B.P. Vs Exhaust Temperature

4.1. Combustion Parameters and Heat Release:

The determination of combustion characteristics is based on the cylinder pressure variation with respect to crank angle. Figure 2 shows cylinder pressure profiles at different power outputs for diesel fuel, eucalyptus biodiesel, and their corresponding blends. It can be seen that EB100 results in higher peak pressure as compared to diesel fuel for all tested loads. For 0.9 kW engine power output representing 20% load, one can observe the shift of the different curves and the increasing of the maximum cylinder pressure. The peak pressures are found equal to 70.98 bar, 70.99 bar, 72.43 bar, 72.64 bar, and 72.74 bar, respectively, for neat diesel fuel, EB25, EB50, EB75, and EB100. Also, Figure 2 (power output of 0.9 kW) shows that peak pressure increases with the increase of the amount of biodiesel in the blend. This is due to the enhanced combustion rate as a result of rapid combustion of biodiesel at the premixed combustion period. For the other load, the same trend is observed. Diesel fuel represents the lowest peak pressure occurs so far after TDC.

TYPES OF EMISSIONS

7.1 EMISSION TYPES

The scope of the emissions impact analysis of this report covers five types of emissions: NOx (nitrogen oxides), PM (particulate matter), HC (hydrocarbons), CO (carbon monoxide), and CO2 (carbon dioxide). While CO2 is not a hazardous air toxin, it is considered a greenhouse gas emission causing global warming and, in some cases, may be capable of generating emissions credits.

7.1.1. NOx

Nitrogen oxides (NOx) is the generic term for a group of highly reactive gases containing nitrogen and oxygen in varying amounts, including nitric oxide (NO), nitrous oxide (N2O), nitrates (NO3), and nitrogen dioxide (NO2). NOx and volatile organic compounds, in the presence of hot, stagnant air and sunlight, convert to ozone. NOx are classified as hazardous airborne toxins because of their deleterious health and environmental effects. The U.S. Environmental Protection Agency (EPA) has noted that NOx is a major cause of ground- level ozone (a.k.a. smog), acid rain, respiratory disease (emphysema and bronchitis), water quality determination, and global warming.

7.1.2. HC

The Agency for Toxic Substances and Disease Registry reports that hydrocarbons (HC) “enter the air mostly as releases from volcanoes, forest fires, burning coal, and automobile exhaust”.

A 1999 EPA study estimates that on-road vehicle sources were responsible for 29 percent of the total emission of HC. Mobile sources release two types of regulated HC measured as speculated hydrocarbons (C1-C22) and a subset of known or suspected carcinogenic compounds titled polycyclic aromatic hydrocarbons (PAH). A presentation given to the National Biodiesel Board entitled “Biodiesel Tier I Health Effects” presented a correlation between the emission rate of C1 to C12 and the potential reduction of ozone and also stated that HC are a carcinogen. The Department of Health and Human Services reiterated this health concern, specifying that some PAHs are known to cause cancer.

7.1.3. CO

Carbon monoxide (CO) is produced from incomplete combustion whenever any carbon fuel, such as gas, oil, kerosene, wood, or charcoal is burned. Unlike many gases, CO has no odor, color, or taste, and it does not cause skin irritation. According to the Centers for Disease Control and Prevention¸ red blood cells can attach themselves to CO at a quicker rate than oxygen. If there is a large quantity of CO in the air, the red blood cell may replace oxygen with CO, leading to possible tissue dama ge, carbon monoxide poisoning or death. As CO levels increase and remain above 70 parts per million (ppm), symptoms may become more noticeable (headache, fatigue, nausea). As CO levels increase above 150 to 200 ppm, disorientation, unconsciousness, and death are possible.

7.1.4. CO2

Carbon dioxide is a naturally occurring gas that is linked to global warming. It is also released into the atmosphere by human activity, such as when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned (95). Carbon dioxide by itself is not considered to be a toxin. However, any impacts on global climate could cause health problems.

7.2 EFFECT ON EMISSIONS

Generally, compression ignition engine operates with lean mixtures and hence the CO emission would be low. CO emission is toxic and must be controlled (Mani et al., 2009a; Mani and Nagarajan, 2009b; Mani et al., 2011). It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air fuel ratio relative to the stoichiometric proportions.

Rich combustion invariably produces CO, and emissions increase nearly linearly with the deviation from the stoichiometry (Murugan et al., 2005). The Naima and Liazid 41 Concentration of CO emission varies from 14.14 g/kWh at 25% of rated power to 5.75 g/kWh at rated power for diesel, whereas it varies from 18.51 g/kWh at 25% of rated power to 6.19 g/kWh at rated power for waste plastic oil. The results show that CO emission of waste plastic oil is higher than diesel. The reason behind increased CO emission is incomplete combustion due to reduced in-cylinder temperatures. The drastic increase in CO emission at higher loads is due to higher fuel consumption (Mani et al., 2009a; Mani and Nagarajan, 2009b; Mani et al., 2011).CO2 varies from 1305.97 g/kWh at 25% of rated power to 789.36 g/kWh at rated power for diesel. It can be observed that in waste plastic oil it varies from 1163.25g/kWh at 25% of rated power to 888.715 g/kWh at rated power. From the results, it is observed that the amount of CO2 produced while using waste plastic oil is lower than diesel. This may be due to late burning of fuel leading to incomplete oxidation of CO (Mani et al., 2009a; Mani andNagarajan, 2009b; Mani et al., 2011).The formation of NOx is highly dependent on in-cylinder temperature, oxygen concentration and residence time for the reactions to take place. It can be noticed that the NOx emission increases in the waste plastic oil operation. NOx varies from 12.15 g/kWh at 25% of rated power to 7.91 g/kWh at rated power for diesel and from 14.68 g/kWh at 25% of rated power to 8.93 g/kWh at rated power for waste plastic oil. The reason for the increased NOx is due to the higher heat release rate and higher combustion temperature (Mani et al., 2009a; Mani and Nagarajan, 2009b; Mani et al., 2011).Unburned hydrocarbon is a useful measure of combustion inefficiency. Unburned hydrocarbon consists of fuel that is incompletely burned. The term hydrocarbonmeans organic compounds in the gaseous state and solid hydrocarbons are the particulate matter (Mani et al., 2009a).

At light load, large amounts of excess air and low exhaust temperature and lean fuel air mixture regions may survive to escape into the exhaust. Unburned hydrocarbon varies from 0.431 g/kWh at 25% of rated power to 0.1389 g/kWh at rated power for diesel. In the case of waste plastic oil it varies from 0.4393 g/kWh at 25% of rated power to 0.147 g/kWh at rated power.

7.3 PERFORMANCE CHARACTERISTICS OF EMISSIONS:

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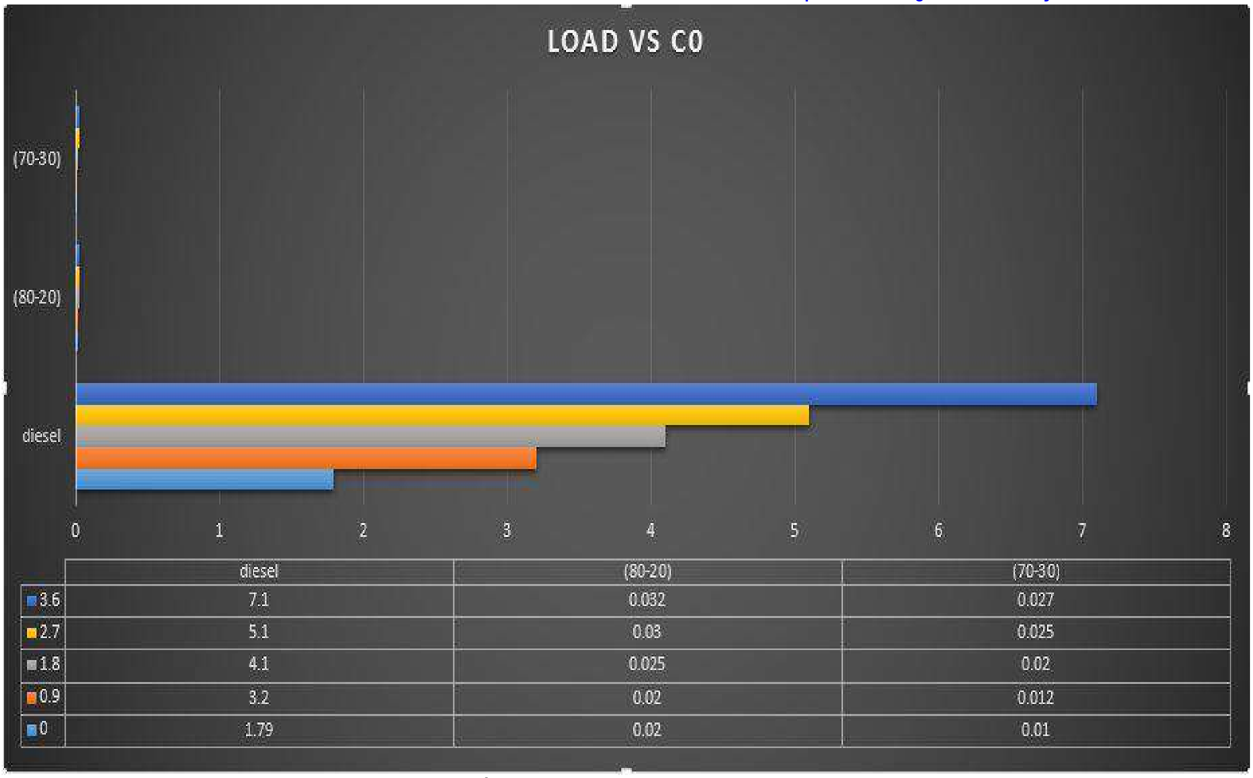

Fig. No.: 7.1. LOAD Vs CO

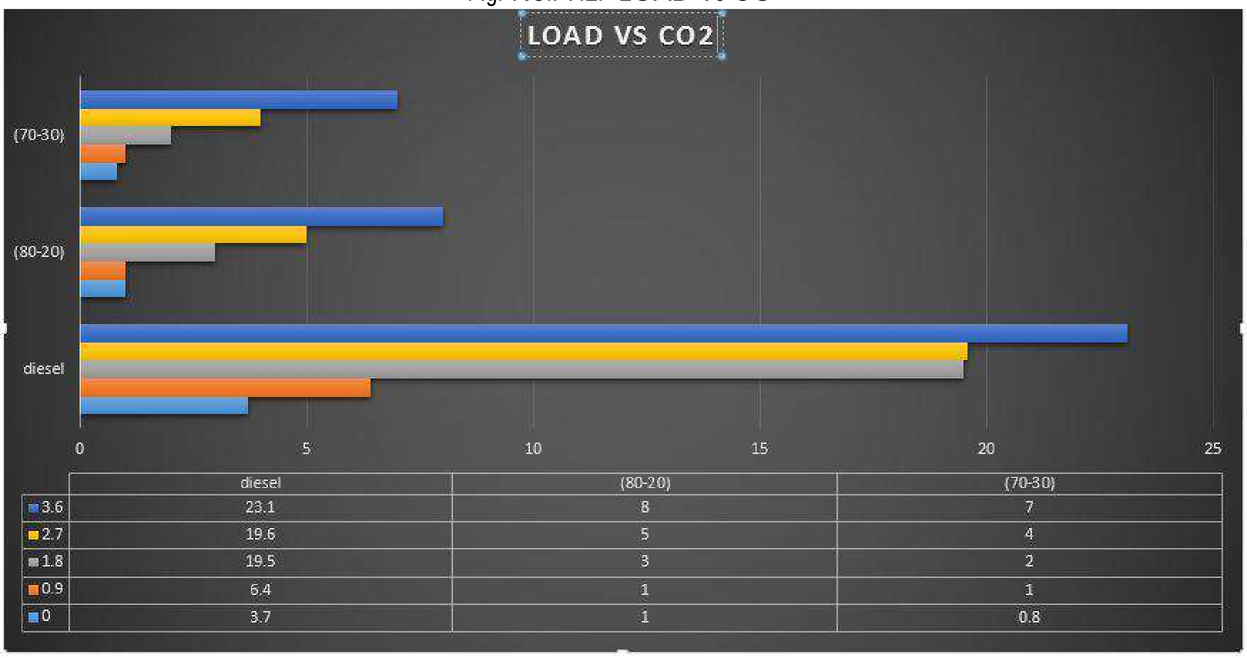

Fig. No.: 7.2. LOAD Vs CO_2

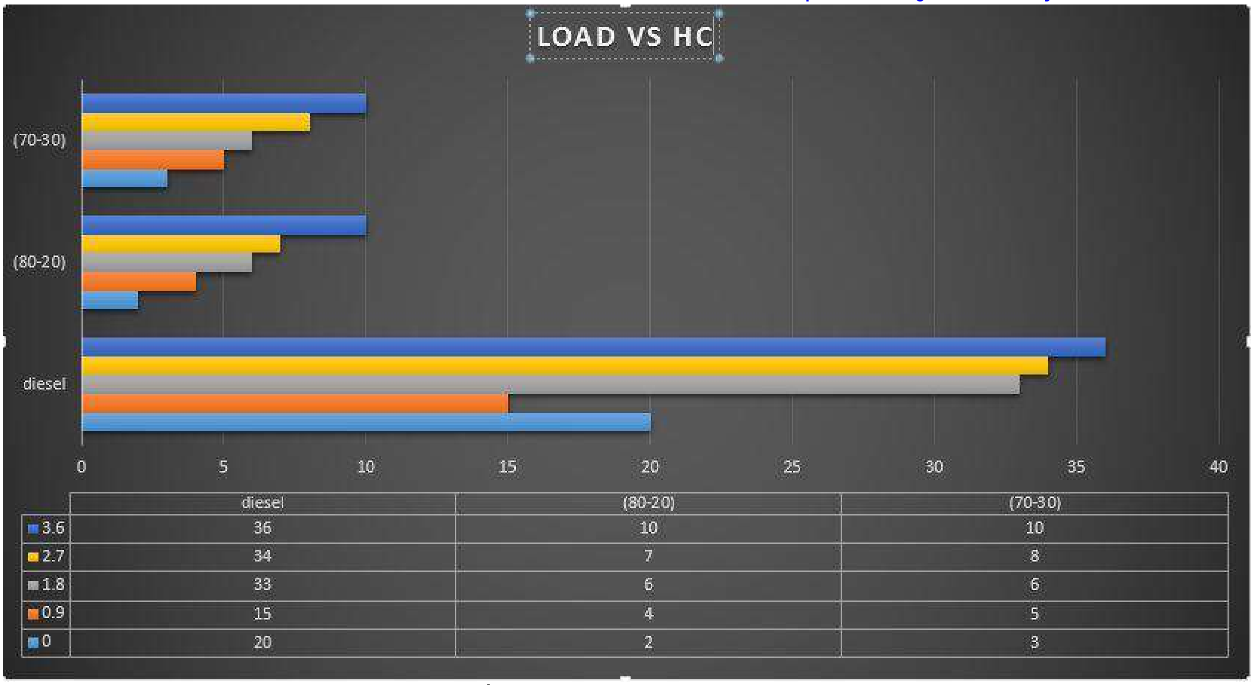

Fig. No.: 7.3. LOAD Vs HC

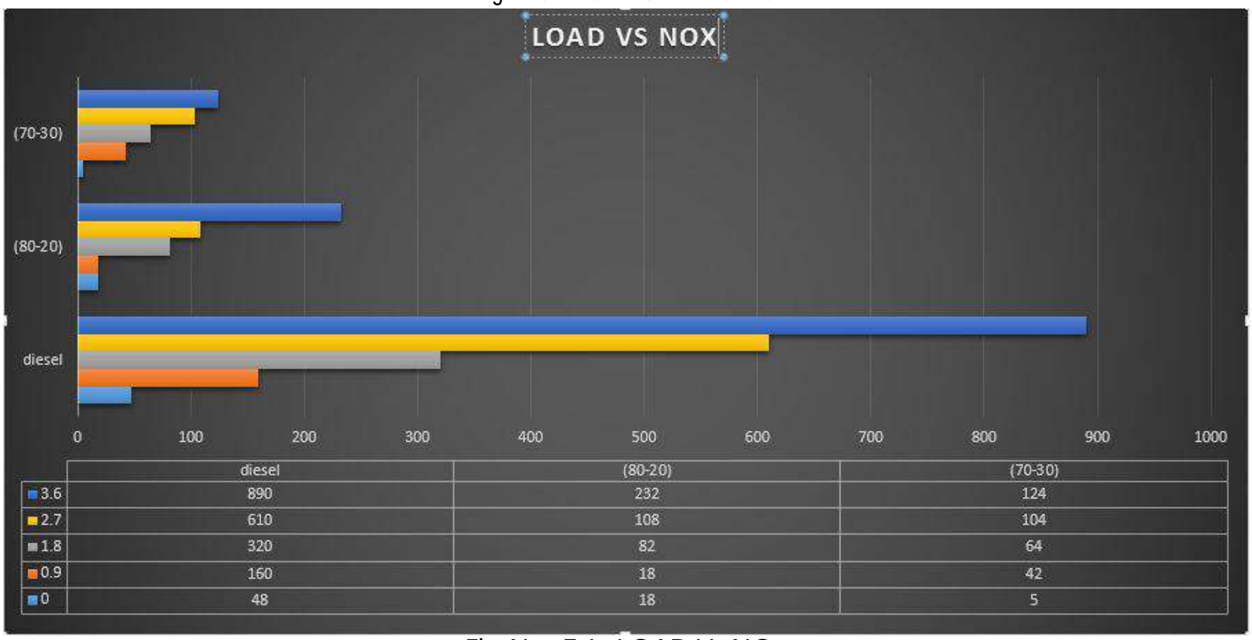

Fig. No.: 7.4. LOAD Vs NO_X

RESULTS

A series of engine tests were carried out using diesel and biodiesel to find out the effect of various blends on the performance and emission characteristics of the engine. Investigations are carried out on the engine mainly to study the effect of specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emissions such as NOx, CO, CO2, HC and smoke opacity. It was found that the specific fuel consumption decreases from 0.649 to 0.336 kg/kW-hr at varying loads in the range of 0 – 3.9 BkW while Pramanik reported a decrease in SFC from 0.693 to 0.332 kg/kW-hr. The brake thermal efficiency varies from 0-29.39% in the load range of 0-3.9 BkW while Pramanik reported a maximum brake thermal efficiency of 27.11% for a load range of 0 – 3.078 BkW in his studies on a single cylinder diesel engine coupled with a hydraulic dynamometer. Exhaust gas temperature and NOx emission increases with increase in BkW for all the cases. NOx emission reaches a maximum of 1656 ppm for a blend of 50% at full load while a maximum of 1800 ppm for biodiesel was reported in the literature by the researchers5. These trends and the variations in the fuel properties such as viscosity and density for various blends are in accordance with the findings of many such researchers. A detailed discussion on the NOx, CO, CO2, HC and smoke opacity were presented here under to understand the behaviour of the engine running on biodiesel.

PHOTOGRAPHY

Fig. No.: 9.1. 4- Stroke Diesel Engine

Fig. No.: 9.2. 4- Stroke Diesel Engine Test Rig

Fig. No.: 9.3. Electrical Circuits for Engine Test Rig

Fig. No.: 9.4. Software Control

Fig. No.: 9.5. Waste Cooking Oil

Fig. No.: 9.6. Pressure Gauge

CONCLUSION

The aim of this study is to investigate the suitability of eucalyptus biodiesel as an alternative to diesel fuel. Some properties of eucalyptus oil show that it is not possible to fuel diesel engines with this crude oil due to problems generated by its high viscosity and low volatility. In order to decrease the oil viscosity, transesterification technique is carried out under optimum reaction condition.

Analysis of basic properties of eucalyptus biodiesel shows that transesterification process is successfully employed to make the viscosity and other characteristics comparable to those of diesel fuel. On the basis of the exhaustive engine tests, the following conclusions can be drawn: (i)analysis of combustion shows that biodiesel and all its blends exhibit similar pressure-time history as diesel fuel. No undesirable combustion features such as unacceptable high cylinder pressure rises are observed. The combustion starts earlier as the concentration of biodiesel in the blend is increased due to decreasing of ignition delay. The combustion duration increases with increase in the proportion of biodiesel in the blend due to rise of the fuel quantity injected in the cylinder; (ii)the BSFC increases and BTE decreases with addition of biodiesel content in the blend. A reverse behaviour is observed with increase in engine load; (iii)CO, HC, and particulates in the exhaust emissions decrease, whereas NOx increase with increases in percentage of biodiesel in the blend. However, the level of emissions increases with increase in engine load for all fuels tested. A general conclusion is that the eucalyptus biodiesel can be used in the form of blends to compromise on the NO emissions and thermal

REFERENCE

1. E. Porpatham, A. Ramesh and B. Nagalingam-Investigation on the effect of concentration of methane in biogas when used as fuel for spark ignition engine, Fuel. International Journal, UK, 2007. *International Journal of Engineering Research & Technology* (IJERT) Vol. 1 Issue 7, September - 2012 ISSN: 2278-018.
2. Crookes R.J. Comparative biofuel performance in internal combustion engines, *International Journal of Biomass and Bioenergy*, vol. 30, pp. 461-468, 2006.
3. Rittmann BE. Opportunities for renewable bioenergy using microorganisms. *Biotechnology and Bioengineering*, vol. 100, pp. 203-212, 2008.
4. Zheng Y, Pan Z, Zhang R, El-Mashad HM, Pan J, Jenkins BM. Anaerobic digestion of saline creeping wild ryegrass for biogas production and pretreatment of particleboard material. *Bioresource Technology*, vol. 100, pp. 1582–1588, 2009.
5. Phan Minh Duc, Kanit Wattanavichien, Study on biogas premixed charge diesel dual fuelled engine. *Energy Conversion and Management*, vol. 48, pp. 2286–2308, 2007.
6. Jiang C, Liu T, Zhong J. A study on compressed biogas and its application to the compression ignition dual-fuel engine. *Biomass*, vol. 20, pp. 53–59, 1989.
7. Leif G, Pal B, Bengt J, Per S. Reducing CO2 emission by substituting biomass for fossil fuels. *Energy*, vol. 20, pp. 1097–1103, 1995.
8. Henham A, Makkar MK. Combustion of simulated biogas in a dual fuel diesel engine. *Energy Conversion and Management*, vol. 39, pp. 2001–2009, 1998.
9. Rao PV, Baral SS, Ranjan Dey, Srikanth Mutnuri. —Biogas generation potential by anaerobic digestion for sustainable energy development in India‖. *Renewable and Sustainable Energy Reviews*, vol. 14, pp. 2086-2094, 2010.
10. Ferrer I, Ponsa S, Vazquez F, Font X. —Increasing biogas production by thermal (700 C) sludge pre-treatment prior to thermophilic anaerobic digestion‖. *Biochemical Engineering Journal*, vol. 42, pp. 186–192, 2008.
11. Demirbas A. Bio-fuels from agricultural residues. *Energy Sources* A, vol. 30, pp. 101–109, 2008.
12. Rittmann, B.E.—Opportunities for renewable bioenergy using microorganisms *Biotechnology and Bioengineering*.vol. 100, pp. 203-212, 2008.
13. Barik, D. & Murugan, S. Dept. of ME, NIT, Rourkela, Odisha, India-Production and Application of Biogas as a Gaseous Fuel for Internal Combustion Engines. *International Journal of Engineering Research & Technology* (IJERT) Vol. 1 Issue 7, September - 2012 ISSN: 2278-018
14. Hartmann, A. 1989. *Anaerobic Digestion Technology*. Course on‖Energy in Agriculture: General Aspects and Minihydro‖, Bologna.
15. S. Ramadhas, S. Jayaraj, and C. Muraleedharan, "Characterization and effect of using rubber seed oil as fuel in the compression ignition engines," Renewable Energy, vol. 30, no. 5, pp. 795–803, 2005. View at Publisher · View at Google Scholar · View at Scopus
16. K. Pramanik, "Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine," Renewable Energy, vol. 28, no. 2, pp. 239–248, 2003. View at Publisher · View at Google Scholar · View at Scopus
17. A. Silvico, R. Carlos, V. G. Marious, S. R. Leonardodos, and F. Guilherme, "Performance of a diesel generator fuelled with palm oil," Fuel, vol. 81, pp. 2097–2102, 2002. View at Google Scholar
18. O. M. I. Nwafor, "Emission characteristics of diesel engine running on vegetable oil with elevated fuel inlet temperature," Biomass and Bioenergy, vol. 27, no. 5, pp. 507–511, 2004. View at Publisher · View at Google Scholar · View at Scopus
19. M. Senthil Kumar, A. Kerihuel, J. Bellettre, and M. Tazerout, "A comparative study of different methods of using animal fat as a fuel in a compression ignition engine," Journal of Engineering for Gas Turbines and Power, vol. 128, no. 4, pp. 907–914, 2006. View at Publisher · View at Google Scholar · View at Scopus
20. P. Ndayishimiye and M. Tazerout, "Use of palm oil-based biofuel in the internal combustion engines: performance and emissions characteristics," Energy, vol. 36, no. 3, pp. 1790–1796, 2011. View at Publisher · View at Google Scholar · View at Scopus
21. M. Gumus and S. Kasifoglu, "Performance and emission evaluation of a compression ignition engine using a biodiesel (apricot seed kernel oil methyl ester) and its blends with diesel fuel," Biomass and Bioenergy, vol. 34, no. 1, pp. 134–139, 2010. View at Publisher · View at Google Scholar · View at Scopus

22. L. C. Meher, D. Vidya Sagar, and S. N. Naik, "Technical aspects of biodiesel production by transesterification—a review," Renewable and Sustainable Energy Reviews, vol. 10, no. 3, pp. 248–268, 2006. View at Publisher · View at Google Scholar · View at Scopus
23. I. Gigür, F. Karaosmanoglu, and H. A. Aksoy, "Methyl ester from safflower seed oil of Turkish origin as a biofuel for diesel engines," Applied Biochemistry and Biotechnology, vol. 45-46, no. 1, pp. 103–112, 1994. View at Publisher · View at Google Scholar · View at Scopus
24. L. Peterson, D. L. Reece, D. L. Hammond, R. Cruz, and J. A. Thompson, "Comparison of ethyl and methyl esters of vegetable oils as diesel fuel substitute," in Proceedings of the Alternate Energy Conference (ASAE '92), pp. 99–110, 1992.
25. N. Ozsezen, M. Canakci, A. Turkcan, and C. Sayin, "Performance and combustion characteristics of a DI diesel engine fueled with waste palm oil and canola oil methyl esters," Fuel, vol. 88, no. 4, pp. 629–636, 2009. View at Publisher · View at Google Scholar · View at Scopus
26. Baiju, M. K. Naik, and L. M. Das, "A comparative evaluation of compression ignition engine characteristics using methyl and ethyl esters of Karanja oil," Renewable Energy, vol. 34, no. 6, pp. 1616–1621, 2009. View at Publisher · View at Google Scholar · View at Scopus
27. M. A. Hess, M. J. Haas, T. A. Foglia, and W. N. Marmer, "Effect of antioxidant addition on NOx emissions from biodiesel," Energy and Fuels, vol. 19, no. 4, pp. 1749–1754, 2005. View at Publisher · View at Google Scholar · View at Scopus
28. J. P. Szybist, S. R. Kirby, and A. L. Boehman, "NOx emissions of alternative diesel fuels: a comparative analysis of biodiesel and FT diesel," Energy and Fuels, vol. 19, no. 4, pp. 1484–1492, 2005. View at Publisher · View at Google Scholar · View at Scopus
29. Agarwal, S. Sinha, and A. K. Agarwal, "Experimental investigation of control of NOx emissions in biodiesel-fueled compression ignition engine," Renewable Energy, vol. 31, no. 14, pp. 2356–2369, 2006. View at Publisher · View at Google Scholar · View at Scopus
30. G. Labeckas and S. Slavinskas, "The effect of rapeseed oil methyl ester on direct injection Diesel engine performance and exhaust emissions," Energy Conversion and Management, vol. 47, no. 13-14, pp. 1954–1967, 2006. View at Publisher · View at Google Scholar · View at Scopus
31. P. K. Devan and N. V. Mahalakshmi, "A study of the performance, emission and combustion characteristics of a compression ignition engine using methyl ester of paradise oil-eucalyptus oil blends," Applied Energy, vol. 86, no. 5, pp. 675–680, 2009. View at Publisher · View at Google Scholar · View at Scopus
32. L. Tarabet, K. Loubar, M. S. Lounici, S. Hanchi, and M. Tazerout, "Experimental evaluation of performance and emissions of DI diesel engine fuelled with eucalyptus biodiesel," in Proceedings of the Internal Combustion Engines: Performance, Fuel Economy and Emissions, pp. 167–176, IMechE, London, UK, 2011.
33. L. Tarabet, M. S. Lounici, K. Loubar, S. Hanchi, and M. Tazerout, "Experimental investigation of eucalyptus biodiesel combustion in DI diesel engine," in Proceedings of the 5th European Combustion Meeting, Cardiff, UK, 2011.