EXPERIMENTAL INVESTIGATION ON DIESEL ENGINE USING LINSEED OIL

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***Abstract*:** **In a modern day world alternative source of energy are given importance due to gradual depletion of fossil fuels reserves vegetable oils can be used as an alternative to diesel in CI engines. Crude linseed oil is converted to linseed oil ethyl esters by trans esterification process. The obtained bio-diesel fuel properties are measured. In the initial stage the tests are conducted on the four stroke single cylinder water cooled direct injection diesel engine with constant speed by using diesel and base line data is generated by varying loads with constant loads. In second stage, experimental investigation has been carried out on the same engine with same operating parameters by using the linseed oil ethyl esters in different proportions as L10, L20and L30 to find out the performance and emission. The performance and emission parameters obtained by the above are compared with the base line data obtained earlier by using diesel and optimum linseed oil blend is obtained. After finding optimum blend, in the third stage tests are conducted on the same engine with addition of 1-hexanol (Ignition improver) 0.5%, 1%volume ratios to optimum blend find out performance and emissions parameters. The main purpose of ignition improver is to improve combustion process and reduction in emissions. The performance and emissions parameters obtained by the above tests are to be compared with diesel base line data and optimum blend L30.The blend L30 with added ignition improver 10ml showed best performances increase in brake thermal efficiency, decrease in BSFC and reductions in emissions CO, HC and smoke density. However, its diesel blends showed maximum brake thermal efficiencies.**

Finally results show engine performance and emissions have been to justify the potentiality of the linseed oil ethyl esters of as alternative fuel for compression ignition engine fuel.

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I) INTRODUCTION

Diesel fuel has an essential function in the industrial economy of a developing country and used for transport of industrial and agricultural goods and operation of diesel tractors and pump sets in agricultural sector. The requirement of petro diesel in India is expected to grow from 39.815 MM Tin 2001-02 to 52.324 MMT in 2006-07 and just over 66 MMT in 2011-12. The domestic supply of crude oil will satisfy only about 22% of the demand and the rest will have to be met from imported crude. This has stimulated recent interest in alternative sources to replace petroleum-based fuels. Of the alternative fuels, bio-diesel obtained from vegetable oils holds good promises as an eco-friendly alternative to diesel fuel Vegetable oil is a promising alternative fuel for CI engine because it is renewable, environment friendly and can be produced in rural areas. The use of non-edible vegetable oils compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and they are too expensive to be used as fuel at present. The term, bio-diesel, was first introduced in the United States during 1992 by the National Soy Development Board (presently National Biodiesel Board), which has pioneered the commercialization of biodiesel in the USA.

Bio-diesel is essentially sulphur free and engines fuelled with biodiesel emit significantly fewer particulates, hydrocarbons, and less carbon monoxide than those operating on conventional diesel fuel. Emissions of NOx, however are slightly higher than those of diesel engines operating on conventional diesel fuels. One of the problems associated with non-edible seeds is that the mechanical presses are not efficient for extraction of oils. Same mechanical press cannot be used for different type of seeds. Therefore, several methods have been proposed in recent years like solvent extraction technique, ultra sonication, etc. A great variety of new approaches, based on different principles such as supercritical fluid extraction, microwave irradiation, closed system at high temperature and pressure have been developed in the last few years. Another problem with non-edible vegetable oil seeds is that they contain high free fatty acid sand are not suitable as a feed stock for production of biodiesel by conventional alkaline transesterification method. Therefore, to use high free fatty acid and high moisture contain oil as a feed stock for production of biodiesel, several techniques have been proposed in recent years like acid catalysed, lipase catalysed and super critical trans esterification .The trans esterification reaction proceeds with catalyst or without catalyst by using primary or secondary monohydric aliphatic alcohols having1-8 carbon atoms as follows:

Linseed oil, also known as flax seed oil or simply flax oil is a clear to yellowish drying oil derived from the dried ripe seeds of the flax plant (Linumusitatissimum, Linaceae). It is obtained by pressing, followed by an optional stage of solvent extraction. Cold pressed oil obtained without solvent extraction is marketed as flaxseed oil Flax seeds come in two basic varieties, brown and yellow or golden, with most types having similar nutritional values and equal amounts of short-chainomega-3 fatty acids. The exception is a type of yellow flax called Linola or solin, which has a completely different oil profile and is very low in omega-3. Although brown flax can be consumed as readily as yellow, and has been for thousands of years, it is better known as an ingredient in paints, fibre and cattle feed. Flax seeds produce a vegetable oil known as flaxseed or linseed oil; it is one of the oldest commercial oils and solvent-processed flax seed oil has been used for centuries as a drying oil in painting and varnishing.[1]

One hundred grams of ground flax seed supplies about 450 kilo-calories, 41 grams of fat, 28 grams of fiber, and 20 grams of protein. Flax seeds are chemically stable while whole and milled flaxseed can be stored at least 4 months at room temperature with minimal or no changes in taste, smell, or chemical markers of rancidity. Ground flaxseed can go rancid at room temperature in as little as one week. Refrigeration and storage in sealed containers will keep ground flax from becoming rancid for even longer.

The linseed producing countries are Canada (~34%), China (~25.5%) and India (~9%), though there is also significant production in USA (~8%), Ethiopia (~3.5%) and throughout Europe.

Table1: Scientific Classification of Linseed Oil

1) *Scientific Classification*	
2) *Kingdom*	3) *Plantae*
4) *Division*	5) *Magnoliophyta*
6) *Class*	7) *Magnoliopsida*
8) *Order*	9) *Malpighiales*
10) *Family*	11) *Linaceae*
12) *Genus*	13) *Linum*
14) *Species*	15) *L. usitatissimum*
16) *Binomial name*	17) *Linumusitatissimum*

Linseed oil is a "drying oil", as it can polymerize into a solid form. Due to its polymer-forming properties, linseed oil is used on its own or blended with other oils, resins, and solvents as an impregnator and varnish in wood finishing, as a pigment binder in oil paints, as a plasticizer and hardener in putty and in the manufacture of linoleum. The use of linseed oil has declined over the past several decades with the increased use of synthetic alkyd resins, which are functionally similar but resist yellowing. It is edible oil but, because of its strong flavor and odor, is only a minor constituent of human nutrition. Linseed oil, extracted from flax seed, is one of the most useful natural oils**.** It is used as a preservative for wood, concrete, and an ingredient in paints, varnishes, and stains. As if that wasn't enough, it is also used in soaps, inks, and in the production of linoleum! Note that the first three letters of linoleum are *Lin*... For linseed. Linseed oil is a slow-drying liquid with good preservative properties and water resistance.

Before the advent of modern preservatives and synthetics, it was commonly used as a stand-alone preservative for wood, natural (hemp) rope, and masonry, as a conditioner for natural boar's hair paint brushes, and as an additive for oil paints. It was also valuable inside as a furniture finish and for wood floors.

II) Chemical aspects:

Linseed oil is a triglyceride, like other fats. Linseed oil is distinctive in terms of fatty acid constituents of the triglyceride, which contain an unusually large amount of α-linoleic acid, which has a distinctive reaction toward oxygen in air.

Specifically, the constituent fatty acids in a typical linseed oil are of the following types [5].

- The triply unsaturated α-linolenic acid (51.9-55.2%),
- The saturated acids palmitic acid (about 7%) and stearic acid (3.4-4.6%),
- The monounsaturated oleic acid (18.5-22.6%),
- The doubly unsaturated linoleic acid (14.2-17%).

Having a high content of di- and triunsaturated esters; linseed oil is particularly susceptible to polymerization reactions upon exposure to oxygen in air. This polymerization, which is called "drying," results in the rigidification of the material. The drying process can be so exothermic as to pose a fire hazard under certain circumstances. To prevent premature drying, linseed oil-based products (oil paints, putty) should be stored in air-tight containers.

Representative triglyceride found in a linseed oil, a triester derived (from the top) of linoleic acid, alpha-linolenic acid, and oleic acid.[2]

Linseed oil uses:

Most applications of linseed oil exploit its drying properties, i.e. the initial material is liquid or at least pliable and the aged material is rigid but not brittle. The water-repelling (hydrophobic) nature of the resulting hydrocarbon-based material is advantageous.

Paint binder:

Linseed oil is a common carrier used in oil paint. It can also be used as a painting medium, making oil paints more fluid, transparent and glossy. It is available in varieties such as cold pressed, alkali refined, sun bleached, sun thickened, and polymerized (stand oil). The introduction of linseed oil was a significant advance in the technology of oil painting.

Wood finish:

When used as a wood finish, linseed oil dries slowly and shrinks little upon hardening. Linseed oil does not cover the surface as varnish does, but soaks into the (visible and microscopic) pores, leaving a shiny but not glossy surface that shows off the grain of the wood. A linseed oil finish is easily repaired, but it provides no significant barrier against scratching. Only wax finishes are less protective. Liquid water will penetrate a linseed oil finish in mere minutes and water vapour bypasses it almost completely. Garden furniture treated with linseed oil may develop mildew. Oiled wood may be yellowish and is likely to darken with age. Because it fills the pores, linseed oil protects wood from denting by compression. Additionally, a lather may use linseed oil when reconditioning a guitar, mandolin, or other stringed instruments fret board; lemon-scented mineral oil is commonly used for cleaning, then a light amount of linseed oil (or other drying oil) is applied to protect it from grime that might otherwise result in accelerated deterioration of the wood **[4].**

Additional uses:

- Animal feeds
- Earthen floors
- Textiles
- Bicycle maintenance as a thread fixative, rust inhibitor and lubricant
- Leather treatment
- Composition ornament for moulded decoration
- Animal care products

III) Trans esterification process:

There are so many investigations on bio-diesel production of non-conventional feed stocks of oils have done in last few years. Overview of trans esterification process to produce biodiesel was given for introductory purpose. It is reported that enzymes, alkalis, or acids can catalyse process. Alkalis result in fast process. It is mentioned that catalysed process is easy but supercritical method gives better result. Adaptation of the vegetable oil as a CI engine fuel can be done by four methods Pyrolysis, Micro emulsification, Dilution, and Trans esterification. Out of these in this study Trans esterification process is used [2].

III A) Equipment for Constant Heating:

In trans esterification process we need constant heating to separate the esters, for this we used a steam bath it is shown in fig.2

Fig.2 Steam Bath

Separation of ethyl esters:

After trans esterification the mixture at the end is settle for at least 10 hours. The lower layer will be of glycerine and the upper layers ethyl ester (bio-fuel). After settling we have to separate the ethyl ester from the glycerine shown in fig 3and 4 the mixture is separated by using a separating flask [3].

Fig.3 Process of Separation **Fig.4 Formation of Glycerin**

Glycerin is the useful by–product produced in process of making bio-diesel, which is used in the makinng of soap's and many other beauty products.

Washing of bio-fuel:

Washing the ester is necessary to improve fuerl properties largely by removing the residual , free glycerol and small amount of KOH remaining from the catylist. The primary purpose of the ester washing step is the removal of any soaps formed during the transesterification reaction. In addition water provides a medium for addition of acid to nutralize the remaining catylist and a means to remove the product salts. The phase separation between the ester and water is typically very clean and complete . there can be various methodologies for washing like agitation , mechanical stirring, aeration mixing. Combination of both aeration and mechanical stirring.

Usually three or four washes are used, each of six to eight hours, often less for the first wash; with a settling period of at least 1 hour between washes (some people settle it for much longer). After it's settled the water is removed via a bottom-drain and replaced with fresh water. Washing is completed when the water is clear after settling, with a pH of 7 (or the same as your tap-water).After washing , water and soap formation have to be removed from the esters.

Heating:

Heating of esters is necessary after water washing to remove the water particles and exes methanol present in the bio-fuel. The standereds say it always absorbs some water from the atmosphere, 1,200 ppm or more, but this is dissolved water, which is harmless, unlike suspended water, which must be removed. The bio-fuel is heated to a temperature of above the bioling point of water i.e., above 100ºC. At that temperature the water particles in the bio-fuel gets evoperated. After the heating process the pure bio-diesel can be obtained [3].

Preparation of Blends with Diesel:

The obtained Bio- Diesel is blended for conducting the performance test, the Lin seed Bio-Diesel is mixed in proper proportions.

Procedure:

1. The Bio- Diesel is first filtered form impurities.
2. Required amount of fuel and Bio- Diesel is taken into the measuring jar and mixed thoroughly the amount of proportions shown in table 3.1.

Obtained LSOEE fuel properties are find out and these values are tabulated in tables

Blending Percentage of Fuel:

Table 2:

Notation	Fuel Quantity	Bio-Diesel Quantity	Diesel Quantity
L10	1 LITRE FUEL	100 ml	900ml
L20	1 LITRE FUEL	200 ml	800ml
L30	1 LITRE FUEL	300 ml	700 ml
D100	1 LITRE FUEL	0 ml	1000 ml
L100	1 LITRE FUEL	0ml	1000ml

Fig.5 (a) Raw Linseed Oil (b) L100 (c) L10

Fig.6 (a) L20 (b) L30 (c) D100

Table 3: Specific gravity- Result:

S.No	Oil	Blend	Specific Gravity
1.	Diesel	D100	0.835
2.	Linseed Oil Crude		0.925
3	Linseed Oil Ethyl Ester Blends With Bio- Diesel (LSOEE)	L10	0.815
		L20	0.822
		L30	0.832
		L100	0.917

Table 4: Viscosity – Results:

S.NO	OIL		Kinematic Viscosity (stokes)	Dynamic Viscosity (Poise)
1	Diesel	D100	0.364	0.652
2	Linseed Oil Crude		3.85	3.53
3.	Linseed oil Ethyl Ester Blends With Bio-Diesel (LSOEE)	L10	0.80	0.65
		L20	0.85	0.657
		L30	1.00	0.832

Table 5: Flash and Fire points – Results

S.No	*Oil*		*Flash Point ^{o}C*	*Fire Point ^{o}C*
1.	*Diesel*	*D100*	*58*	*62*
2.	*Linseed Oil*	*L100*	*185*	*192*
3.	*Linseed OIL Ethyl Ester Blends with Bio- Diesel (LSOEE)*	*L10*	*64*	*69*
		L20	*73*	*82*
		L30	*89*	*96*

Table 6: Carbon Percentages –Results

Oil		% of Carbon
Diesel	D100	0.12
Linseed Oil Ethyl Ester Blends with Bio- Diesel (LSOEE)	L10	3.2
	L20	4.1
	L30	5.6
	L100	15.1

Table 7: Calorific value - Results

	Crude	L10	L20	L30	L100
Lin seed oil	32306	42187	41861	41542	39307
Diesel	42500	42500	42500	42500	42500

After find all properties of LOEE then next stage performance and emissions parameters are find with the help of 4-stroke single cylinder compression ignition diesel engine, gas analyser and smoke meter.

Experimental setup and procedure:

Using LSOEE oil tests are to be conducting on different equipment's, to be found some of the fuel properties. Later performance and emission tests were conducted on 4- stroke single cylinder water cooled diesel engine coupled with a rope brake dynamometer, with the help of Smoke meter and multi gas analyser

The improvement in the performance of the CI engines, over the past century, has resulted from the complimentary refinement of the engine design and fuel properties. Calculate the fuel properties like flash point, fire point, specific gravity, calorific value for different oils for different blends using the suitable equipment.

Specific Gravity:

Specific gravity is the relative measure of the density of a substance. It is defined as the ratio of the density of the substance, ρ, to a reference density. With the help of digital balance to find out specific gravity. The specific gravity of conventional diesel fuel is about 0.835.

Fig: 7 Digital balances

Viscosity:

The resistance to flow, exhibited by fuel blends, is expressed in various units of viscosity. It is a major factor of consequence in exhibiting their suitability for mass transfer and metering requirements of engine operation. High value of viscosity reduces volatility and gives poor atomization of oil during injection of the CI engine. This results in incomplete combustion and ultimately carbon deposits on the injector nozzle as well as in the combustion chamber.

The SI physical unit of dynamic viscosity is the Pascal-second (pa.s), which is identical to 1 kg.m^{-1}.s^{-1}. The CGS physical unit for dynamic viscosity is the poise.

The relation between poise and Pascal-second is:

10p = 1 kg.m -1.s-s = 1 pa.s

1 cp = 0.001 mpa.s

Kinematic viscosity is the absolute viscosity over density.

Kinematic viscosity has S.I units ($m^2.s^{-1}$).

The CGS physical unit for kinematic viscosity is the stokes.

1 stokes = 100 centistokes = 1 $cm^2.s^{-1}$ = 0.0001 $m^2.s^{-1}$.

1 centistokes= 1 mm^2/s.

Flash and fire point test:

A key property for determining the flammability of fuel is the flash point. The flash point is the lowest temperature at which an applied ignition source causes the vapours of sample to ignite. The fire point is sometimes used to designate the fuel temperature producing sufficient vapour to maintain a continuous flame. The fire point is the minimum temperature to which it must be heated so that vapours burn at least 5 seconds.

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The two parameters have a great importance while determining the fire hazards.

Calorific value:

The calorific value of a fuel is the thermal energy released per unit quantity of fuel when the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustible mixture. It measures the energy content in a fuel. This is an important property of biodiesel that determines the suitability of the material as alternative to diesel fuels. A bomb calorimeter will measure the amount of heat generated when matter is burnt in a sealed chamber (Bomb) in an atmosphere of pure oxygen gas. A known amount of the sample of fuel is burnt in the sealed bomb, the air in the bomb being replaced by pure oxygen under pressure. The sample is ignited electrically. As the sample burns heat is produced and rises in the temperature. Since the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly, and rise in temperature enables the determination of heat of the combustion of the sample. Bomb calorimeter experimental setup shown in fig.7

If W = Water equivalent of the calorimeter in calories per degree centigrade

T = Rise in temperature (registered by a sensitive thermometer) in degrees centigrade.

H = Heat of combustion of material in calories per gram.

M = Mass of sample burnt in grams.

$$W \times T = H \times M$$

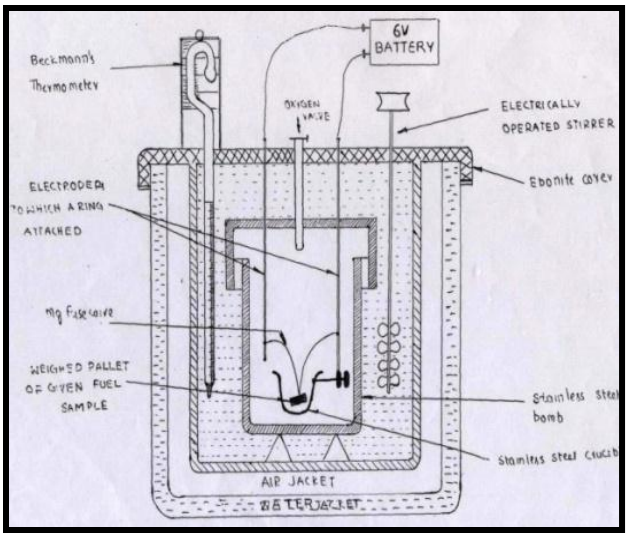

Fig: 8 Bomb Calorimeter

IV CONCLUSION:

In this experimental study, the effect of linseed oil ethyl ester blends and diesel fuel on engine performance and exhaust emissions were investigated on single cylinder ,water cooled and direct injection at constant speed of 1500 rpm .Out of all blends of linseed oil ethyl esters L30 shows best results in performance and emissions parameters.

The conclusions of this investigation are compared with diesel base line data at full load as follows:

1. The maximum brake thermal efficiency for L30 (34.4%) was higher than that of diesel.
2. The brake thermal efficiency increased in 7.21% compared with diesel.
3. Brake specific fuel consumption is decreases in blended fuels. In L30 fuel the BSFC is lower than the diesel in 4.56%.
4. Significant reductions were obtained in smoke level, CO emissions with L30 blend. Smoke level was decreased by19.6% with L30 compared to diesel at maximum load of the engine.
5. The highest decrease in CO emissions was obtained with L30 as 40%compared to diesel fuel.
6. Significant reductions were obtained in unused oxygen emissions with L30 was decreased by 8.5% compared to diesel at maximum load of the engine.
7. On the other hand, NOx emissions were increased with L30 compared to diesel

fuel. NOx emissions were increased by 11.8% with L30 compared diesel.

8. The marginal increases in carbon dioxide emissions were 6.66% compared to diesel.
9. Reductions in unburned hydrocarbon emissions were 8.6% compared to diesel

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