Engineering Universe for Scientific Research and Management
ISSN (Online): 2319-3069
Vol. XV Issue IX
Sep 2023

Experimental Investigation & CFD analysis of I.C. Engine using various Diesel Blends

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Abstract

The diesel fuel used in engines for power generation in various industrial applications produce high exhaust pollutants because of poor engine performance. It has become a need to reduce these pollutants by using suitable additives along with diesel and improve the engine performance. The present research work focuses at improving the engine performance by using selected blending agents of linseed oil and watermelon seed oil, having low contaminants in the emission. The performance study of a diesel engine with these diesel blends were carried out at different compression ratios and loads using five chosen samples. The combustion performance parameters like Mechanical, Volumetric, Brake thermal efficiencies and Specific Fuel Consumption are studied. The fuel sample blends containing 90% Diesel has shown better combustion performance compared with diesel at high compression ratio. The Specific fuel consumption for the blend containing watermelon seed oil and ethanol (5% each by volume) is lesser than diesel at all compression ratios. The Brake thermal efficiency for the blend containing linseed oil and leishman's solution (5% each by volume) is higher at compression ratios 17 and 17.5 compared with diesel at high compression ratio.

Keywords: Diesel blends, Linseed oil, Watermelon seed oil, Performance analysis, Emission control.

1. Introduction

The general morphology of oil plants and seeds and availability of oils are explained. Combustion parameters such as density, viscosity, flash point, fire point, cetane number and calorific value of all types of chosen oils and their blends with diesel oil are presented in this chapter. Effect of blending vegetable oil with diesel on viscosity is discussed. Effect of heating on viscosity of oils and their blends with diesel is studied.

1.1 Diesel

Diesel fuel in general is any liquid fuel used in diesel engines, whose fuel ignition takes place, without spark, as a result of compression of the inlet air mixture and then injection of fuel. Diesel engines have found broad use as a result of higher thermodynamic and thus fuel efficiencies. This is particularly noted where diesel engines are run at part-load; as their air supply is not throttled as in a petrol engine, their efficiency still remains high. The most common type of diesel fuel is a specific fractional distillate of petroleum fuel oil, but alternatives that are not derived from petroleum, such as biodiesel, biomass to liquid (BTL) or gas to liquid (GTL) diesel, are increasingly being developed and adopted. To distinguish these types, petroleum-derived diesel is increasingly called petro diesel. Ultra-low-sulfur diesel (ULSD) is a standard for defining diesel fuel with substantially lowered Sulphur contents. In the UK, diesel fuel for on-road use is commonly abbreviated DERV, standing for diesel-engine road vehicle, which carries a tax premium over equivalent fuel for non-road use (see Taxation). In Australia diesel fuel is also known as 'distillate'.

1.2 Linseed Oil

It is golden-yellow or amber of brown drying oil with peculiar odor and bland taste. The oil polymerizes on exposure to air. Soluble in ether, turpentine etc. and slightly soluble in alcohol. The drying property is due to the linoleic ad linolemic groups. Linseed oil is principally used, being a drying oil, in the paint and varnish industry and also in the manufacture of linoleum, oilcloth, printing and lithographic inks and soft soaps. Locally it is also used for cooking. It is also employed in the preparation of lubricants, greases and polishes. Raw linseed oil is used in pharmaceuticals as emollient, demulcent, expectorant and diuretic. The expeller cake is harmless and is a palatable of protein rich (30%) livestock feed it is hot pressed. The poisonous effect of linseed is due to the presence of a cyanogenetic glycoside, phaselounation (linamarin). Cattle poisoning is caused by the hydrocyanic acid or prussic acid which is released by the activity of the enzyme linase on finamarin. Hot pressed linseed cake is harmless as the linamarin traction is not hydrolyzed to HCN owing to the denaturizing of the enzyme linase during cooking.

1.3 Leishman's Solution

Leishman's solution is applied in conventional staining techniques to uniformly stain chromosomes. These techniques leave centromers constricted, thus enabling the measurement of chromosome length, centromeric position, and arm ratio. Slides can be easily de-stained and banded by most banding procedures. Orcein-stained chromosomes cannot be destained! Leishman's stain belongs, as Giemsa and Wright's stain, to the group of Romanovsky stains. It is considered as an easy to do technique which gives a fairly acceptable contrast. For the detection of malaria parasite Leishman staining seems more sensitive.

1.4 Watermelon Seed Oil

Water melon seed oil is also known as Ootanga oil and Kalahari oil. The growth in the production of biodiesel, which is principally fatty acid methyl esters (FAME). In the past decade, the general desire to cut down the release of greenhouse gases into the atmosphere has resulted in phenomenal development of the biodiesel production. The straight watermelon seed oil required certain modification on the engine whereas blends of it can be used in conventional engines. The NNFCC estimates that the total net greenhouse gas savings wen using watermelon seed oil instead of fossil fuels range from 18 to 100%.

1.5 Ethanol

It is also called grain alcohol that is volatile, flammable, colorless liquid. It burns with a smokeless blue flame invisible in normal light. It is a widely used industrial solvent with other applications as thermometer liquid and as a fuel additive. It is produced from many feedstock such as sugarcane, miscanthus, sorghum, barley, hemp, corn, corn cobs, etc. Ethanol's hydroxyl group is able to participate in hydrogen bonding, rendering it more viscous and less volatile than less polar organic compounds of similar molecular weight, such as propane.

2. Literature Review

Balaji mohan et al [1] (2014) experimented with a stationary diesel engines used for power generation in household and commercial applications. The NOx emissions were corrected based on the recommendation correction factor by Fritz and Dodge to avoid any discrepancies arising due to different ambient conditions while testing. On varying NOP and static injection timing, it was found that obtained emissions were lesser than limits by maximum of 5.7% and 11.8% for NOx, 91.5% and 90% for HC, 15.7% and 11.1% for CO and 21.4% and 5.7% for smoke respectively. Jerekias Gandure et al [2] (2014) investigated the fuel characteristics of biodiesel derived from kernel oils of Sclerocarya birrea, Tylosema esculent, Schiziophyton rautanenii and Jatropha curcas plants with petroleum diesel. The various fuel properties include flash point, cloud point, kinematic viscosity, density, calorific value, acid value and free fatty acids are compared. The values were determined and discussed in light of major biodiesel standards such as ASTM D 6751 (American Society of Testing and Materials. Masjuki et al [3] (2013) stated that complete substitution for petroleum derived fuels by biofuel is impossible form the production capacity and engine compatibility point of view. Only marginal replacement of diesel by biofuel can prolong the depletion of petroleum resources and abate the radical climate change caused by automotive pollutants. Stanislaw et al [4] (2012) described the results of the tests of CI Perkins 1104C-44 engine fuelled with camelina saliva oil. The engine was not especially calibrated for felling with the vegetable fuel. During the test the engine performance and emissions were analyzed. For comparison the same speed characteristics was examined for standard fuelling of the engine with diesel oil.

Hassana et al [5] (2012) investigated the phase stability of DE and DBE blends at different component concentrations, as well as the effects of using DBE blends including ethanol of various proportions on a CI engine performance. The experimental results of the phase stability revealed that the DE blends was not stable and separated after 2, 5, 24 and 80 hours for 20%, 15%, 10% and 5% ethanol concentration respectively. Whereas for DBE blends the separation time is longer. The experimental results of the engine performance indicated that the equivalence air-fuel ratio and the brake specific fuel consumption for the fuel blends are higher than that of diesel fuel and increases with the increase of the ethanol concentration in the blends. G.R. Kannan et al [6] (2011) studied the use of ferric chloride ($FeCl_3$) as a fuel borne catalyst (FBC) for waste cooking palm oil based biodiesel. The metal based additive was added to biodiesel at a dosage of 20lmol/L. Experiments were conducted to study the effect of ferric chloride added to biodiesel on performance, emission and combustion characteristics of a diesel at different operating conditions. The results revealed that the FBC added biodiesel resulted in a decreased brake specific fuel consumption (BSFC) of 8.6% while the brake thermal efficiency increased by 6.3%. FBC added biodiesel showed lower nitric oxide (NO) emission and slightly higher carbon dioxide (CO_2) emission. Slight improvement in BSFC, BSEC and brake thermal efficiency was observed with FBC added biodiesel at optimized operating condition. Although slight increase in NO and CO2 emission was observed as well. S.Naga Prasad et al [7] (2010) studied the wide scope of production of vegetable oils from different oil seeds. It is observed that 25% of neat oil mixed with 75% of diesel is the best suited blend, without heating and without any modification of the engine. Methyl ester of Linseed oil is a better performing fuel due to better performance and lower emissions compared to other esters. The calorific value is lower and viscosity is higher for all esters except linseed oil ester. Brake Specific Fuel Consumption for linseed oil is increased compared to diesel at rated load and is result of delay in ignition process. Suryanarayana Murthy et al [8] (2009) identified the best way to use fish oil as fuel in compression ignition (CI) engines is to convert into biodiesel. Brake specific energy consumption decreases and thermal efficiency of engine slightly increases when operating on 20% biodiesel than that operating on diesel. It can be used in CI engines with very little or no engine modifications. Brake specific fuel consumption for B100 is higher than the diesel fuel and it is decreased in blended fuels. In B20, fuel the BSFC is lower than the diesel fuel and all other fuel.

N.R. Kumar et al [9] (2009) produced and blended non-edible jatropha (Jatropha curcas), karanja (Pongamia pinnata) and polanga (Calophyllum inophyllum) oil based methyl esters with conventional diesel in proportion less than 10 mg/kg. The fuel blends (Diesel, B20, B50 and B100) were tested in a water-cooled three cylinder tractor engine under full/part throttle position for different engine speeds (1200, 1800 and 2200 rev/min). There is a reduction in smoke for all the biodiesel and their blends when compared with diesel during full throttle performance test. L.M. Das et al [10] (2009) experimented to access the practical applications of biodiesel in a single cylinder diesel using Diesel, neat biodiesel from Jatropha, Karanja and Polanga; and their blends (20 and 50 by V %). The engine combustion parameters such as peak pressure, time of occurrence of peak pressure, heat release rate and ignition delay were computed. The ignition delays were shorter for neat Karanja and Polanga biodiesel when compared with diesel.

3. Experimental Set Up

3.1 Blending of Fuel

The blends of varying proportion of linseed oil & lieshman solution with diesel and watermelon seed oil & ethanol with diesel were prepared, analyzed and compared. From properties and engine test result it can be established that oil can be substituted for diesel without any engine modification and without preheating of the blends. The various blend proportions chosen for the present work are listed in the table 1. The blending process followed is the ―stirring method‖.

Table 1 – Various Samples taken for the Test

Symbol	Description
S1	Diesel 100%
S2	Diesel 95 %+ Watermelon seed oil 3% + Ethanol2%
S3	Diesel 95% + Linseed oil 3% + Leishman’s solution 2%
S4	Diesel 90 %+ Watermelon seed oil 5% + Ethanol5%
S5	Diesel 90% + Linseed oil 5% + Leishman’s solution 5%

Table 2 – Properties of the Sample at Ambient Conditions

	Density	Flash point	Fire point
	kg/m^3	^0C	^0C
Sample 1	862	47	52
Sample 2	811	39	42
Sample 3	829	47	55
Sample 4	809	37	40
Sample 5	817	35	43

3.2. Engine Setup

The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The detailed specification of the engine set up with all its dimensional details is listed in the table 3.

Table 3 – Engine Specification

Engine type	Single cylinder, 4 stroke, water cooled, Stroke 110 m Capacity 661 cc, Bore 87.5mm.
Diesel mode	Power 3.5 KW, Speed 1500 rpm, CR range 12:1-18:1. Injection variation:0-25 Deg BTDC
Dynamometer	Type eddy current, water cooled, wit
Calorimeter	Type Pipe in pipe
Load indicator	Digital, Range 0-50 Kg, Supply 230V
Load sensor	Load cell, type strain gauge, range 0-
Temperature sensor	Type RTD, PT100 and Thermocoupl
Air flow transmitter	Pressure transmitter, Range (-) 250 m
Software	―Engine soft‖ Engine performance a
Overall dimensions	W2000 x D2500 x H1500 mm

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ISSN (Online): 2319-3069 Vol. XV Issue IX
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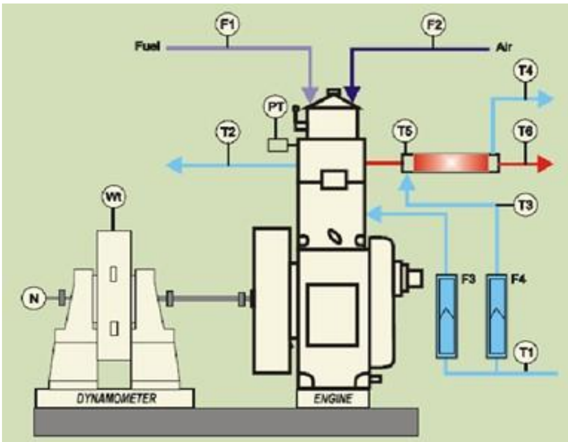

Figure 2 – Layout of the Engine Set Up

4. Results & Discussion

The experiment was conducted with the various fuel samples at different load conditions with varying compression ratios. There are five samples taken in the present work including diesel for the base of comparison. Three levels of compression ratio are taken within the range of 17 to 18, as it is identified as the optimum range for attaining good performance based on the literature. The output values of Specific Fuel Consumption, Brake Thermal Efficiency, Mechanical Efficiency and Volumetric Efficiency are noted during the operation of diesel engine at varying load conditions.

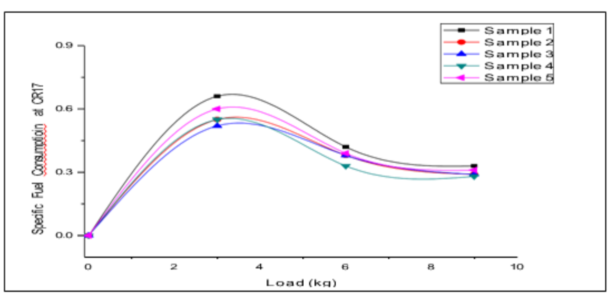

Figure 3 – Load vs SFC at CR 17:1

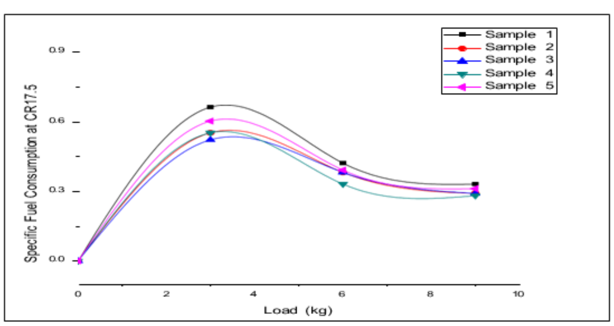

Figure 4 – Load vs SFC at CR 17.5:1

The figures 3 – 4 shows the Specific Fuel Consumption at three different compression ratios of 17, 17.5 and 18. From figures, it is seen that the value of SFC is lower than diesel for sample 4 (containing Diesel 90 %+ Watermelon seed oil 5% + Ethanol 5%). The same sample holds the better results at higher compression ratios as well. The samples 2, 3 and 5 almost have a similar value for SFC at the compression ratio of 17 and 17.5. However, there is a difference in their SFC values at the compression ratio of 18. The sample 4 is followed closely by the samples 3 and 2. It is clear that the SFC of diesel in its pure state is higher than the blended form, on all three compression stages. The lowest value of SFC is attained by the sample 4 at the compression ratio of 17.

5. Conclusion

The experiments were conducted with all the five fuel samples and their results were plotted for various compression ratio and different load conditions. The samples with 90% of diesel (Sample 4 & 5) show good combustion performance than diesel fuel in high compression ratio. The Specific fuel consumption is less for the sample 4 (Diesel 90 %+ Watermelon seed oil 5% + Ethanol 5%) in all compression state. The Brake thermal efficiency is higher for the sample 5 (Diesel 90% + Linseed oil 5% + Leishman's solution 5%) at compression ratios of 17 & 17.5. However, sample 3 gives better result for Brake thermal efficiency at compression ratio 18. The value of η_{mech} is high for the sample 4 (Diesel 90 % + Watermelon seed oil 5% + Ethanol 5%) in all the compression state. The η_{vol} is higher for the diesel fuel. But the sample 5 (Diesel 90% + Linseed oil 5% + Leishman's solution 5%) shows result closer to that of diesel during high compression ratio 18. It can be concluded that the fuel samples 4 and 5 has better combustion performance compared to diesel with reduced emission levels as identified by the previous literatures.

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