PERFORMANCE OF CI ENGINE USING WCSFO BIODIESEL BLEND – A REVIEW

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ABSTRACT

In recent year, energy is the basic need of everyone in the world and also the energy consumption is increasing with time. Basic source of energy are fossil fuel such as coal, natural gas and petroleum products such as gasoline and diesel. But these sources of energy are limited in quantity and they are non-renewable. They will not be available in nearby future for use hence growing concern regarding energy resources and environment has increased interest in the study of alternative sources of energy. To meet increasing energy requirement, these have been growing interest in alternative fuel like biodiesel to provide a suitable diesel oil substitute for internal combustion engine. Biodiesels are offers a very promising alternative to diesel oil since they are renewable and have been similar properties.

One of the economical sources for biodiesel production which doubles in the reduction of liquid waste and the subsequent burden of sewage treatment is waste cooking oil. This research work aims to carry energy and exergy analysis of Compression Ignition (CI) Engine to study performance and its characteristics. The thermal efficiency and the energy losses in the system are calculated from the 1st law of thermodynamics, while the maximum work output or exergy is calculated from the 2nd law of thermodynamics. Energy analysis is carried out for biodiesel blends (B10 to B50 with increment of 10). From this analysis best performed blend was chosen and exergy Analysis is carried out to check the effect of change in Compression Ratio (CR) and Injection Pressure (IP) on the exergy efficiency. Exergy analysis also allows us to find out some feature like availability which cannot be possible with the use of energy analysis.

Keyword: - *WCSFO Biodiesel, C.I. Engine, Exergy*

1. INTRODUCTION

In the world of today, energy is a life line of all human activities. It has now become a necessity for day to day routine life. Petroleum is the largest contributing energy source to mankind, surpassing all other resources like: coal, nuclear, hydro, natural gas and wind. It is essential in the field of industrial, food and agricultural production, as the fuel for transportation as well as for the generation of electricity. The number of diesel engine increasing continuously every year because of having high efficiency, enhanced fuel economy. Diesel engines are preferred over spark ignition engines in almost all heavy duty application due to their reliability and durability. Therefore, the world demand for diesel fuel increases every year. Since the fossil fuel resources are limited and non-renewable and will gradually diminish. Also fossil fuels causes air pollution and global warming hence it is required to find renewable energy sources and fuels.

1.1 Background of Study

Biodiesel is a fuel made from natural, renewable sources, such as new and used vegetable oils and animal fats, for use in a diesel engine. Biodiesel has physical properties very similar to petroleum-derived diesel fuel, but its emission properties are superior. Using biodiesel in a conventional diesel engine substantially reduces emissions of unburned hydrocarbons, carbon monoxide, sulphates, polycyclic aromatic hydrocarbons, nitrated polycyclic aromatic hydrocarbons, and particulate matter. Diesel blends containing up to 20% biodiesel called B20 can be used in nearly all diesel-powered equipment, and higher-level blends and pure biodiesel, B100 can be used in many engines with little or no modification. Lower-level blends are compatible with most storage and distribution equipment, but special handling is required for higher-level blends.

Biodiesel can be used in any diesel engine when mixed with mineral diesel. In some countries manufacturers cover their diesel engines under warranty for 100% biodiesel use. Many people have run their vehicles on biodiesel without problems. However, the majority of vehicle manufacturers limit their recommendations to 15% biodiesel blended with mineral diesel. In many European countries, a 5% biodiesel blend, B5 is widely used and is available at thousands of gas stations. Biodiesel can be made from waste and virgin vegetable and animal oil and fats (liquids). Virgin vegetable oils can be used in modified diesel engines. In fact the diesel engine was originally designed to run on vegetable oil rather than fossil fuel. There are also studies and efforts to commercialize biodiesel from algae.

1.2 Problem Statement

- Suitable alternative fuels are required to find out for IC engine among various fuels such as alcohol and biodiesel.
- Energy analysis just quantified the values of energy which lacks to assign quality index to energy.
- Exergy analysis of CI engine using biodiesel fuel and effect of operating parameters are not studied widely.
- Each human being in this world can feel the effect of economic crisis that is mainly caused by unstable price of petrol. Thus by using as alternative fuel, the problem could be tackle.

1.3 Objective of Study

The objective of this research is to analyse engine performance using Waste Cooking Sunflower Oil biodiesel fuel by energy analysis (1st law) and exergy analysis (2nd law).

1.4 Scope of Study

The scope of this research is:

- Performance measurement of biodiesel blends (B10 to B50 with increment of 10).
- Exergy analysis of more suitable blend.
- For that suitable blend, to check the effects of operating parameter(Compression Ratio and Injection Pressure) on the exergy efficiency of the engine.

2. LITERATURE REVIEW

2.1 Introduction of IC Engines

A heat engine is essentially a device which converts heat into mechanical work. Usually heat is generated in the engine by combustion of fuel. The internal combustion engine, the force on the piston is developed by the combustion of a mixture of air and fuel inside the cylinder.

2.1.1 Alternative Fuels for IC Engines

The utilization of non-petroleum based renewable alternative fuels like bio fuels such as biodiesel, methanol, ethanol, dimethyl ether, diethyl ether, butanol, bioethanol, synthetic natural gas, Fischer Tropsch diesels; hydrogen etc in the IC engines can be helpful to tame the CO_2 emissions and also one of the options to fulfil the need as transport fuel. The second generation fuels are suitable alternative and viable fuels for the internal combustion engines.

Classification of biofuel shown in fig. 1 and few fuels introduced briefly:

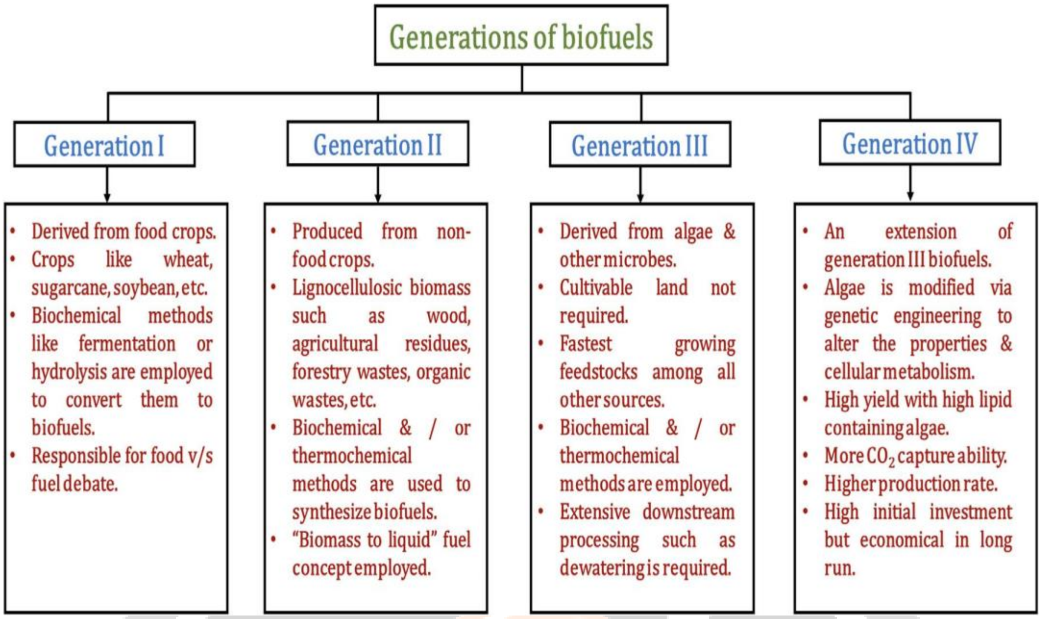


Figure 1: Classification of bio fuels

Vegetable oil and Biodiesel:

The idea of using vegetable oil for fuel has been around as long the diesel engine. Rudolph Diesel, the inventor of the engine that bears his name, experimental with fuels ranging from powered coal to peanut oil. Vegetable oils have become more attractive recently because of their environmental benefits and it is made from renewable resources.

The main plants whose oil have been considered as feed stocks for bio fuel are soya bean oil, rapeseed oil, palm oil, safflower oil, sunflower oil, jatropha oil, karanj oil, mustard oil, neem oil, olive oil, penault oil and waste vegetable oil. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blends. It can be used in compression ignition engines with little or no modification. Biodiesel is the simple to use, bio degradable, non toxic and essentially free of sulphur and aromatics.

2.1 Biodiesel Basics

Biodiesel is increased attention as an alternative, non-toxic, biodegradable, and renewable diesel fuel. Biodiesel is usually produced by the transtrification of vegetable oil or animal fat with short chain alcohol such as methanol or ethanol. It has higher oxygen content than petroleum diesel and its use in diesel engines have shown great reductions in emission of particulate matter, carbon monoxide, sulphur, polyaromatics, hydrocarbons, smoke and noise. In addition, burning of vegetable oil based fuel does not contribute to net atmospheric CO_2 levels because such fuel is made from agricultural materials which are produced via photosynthetic carbon fixation.

2.3.1 Process of Synthesizing Biodiesel

There are different processes which can be applied to synthesize biodiesel such as direct use and blending, micro emulsion process, thermal cracking process and the most conventional way is transesterification process.

2.3.1.1 Direct Use and Blending

The direct use of vegetable oils in diesel engine is not favourable and problematic because it has many inherent failings. Even though the vegetable oils have familiar properties as biodiesel fuel, it required some chemical modification before can be used into the engine.. Energy consumption with the use of pure vegetable oils was found to be similar to that of diesel fuel. For short term use, ratio of 1:10 to 2:10 oil to diesel has been found to be successful.

2.3.1.2 Micro-Emulsion Process

The problem of the high viscosity of vegetable oils was solved by micro-emulsions with solvents such as methanol, ethanol, and 1-butanol. Micro-emulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1-150 nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles.

The components of a biodiesel micro-emulsion include diesel fuel, vegetable oil, alcohol, and surfactant and cetane improver in suitable proportions. Alcohols such as methanol and ethanol are used as viscosity lowering additives, higher alcohols are used as surfactants and alkyl nitrates are used as cetane improvers. Micro emulsions can improve spray properties by explosive vaporisation of the low boiling constituents in the micelles. Micro-emulsion results in reduction in viscosity increase in cetane number and good spray characters in the biodiesel. However, continuous use of micro-emulsified diesel in engines causes problems like injector needle sticking, carbon deposit formation and incomplete combustion.

2.3.1.3 Thermal Cracking (Pyrolysis)

Pyrolysis can be defined as the conversion of one substance into another by means of heat in the absence of air (or oxygen) or by heat in the presence of a catalyst which result in cleavage of bonds and formation of a variety of small molecules. The pyrolysis of vegetable oil to produce biofuels has been studied and found to produce alkanes, alkenes, alkadienes, aromatics and carboxylic acids in various proportions. The equipment for thermal cracking and pyrolysis is expensive for modest biodiesel production particularly in developing countries. Furthermore, the removal of oxygen during the thermal processing also removes any environmental benefits of using an oxygenated fuel. Another disadvantage of pyrolysis is the need for separate distillation equipment for separation of the various fractions. Also the product obtained is similar to gasoline containing sulphur which makes it less ecofriendly (Parawira, 2010). Pyrolytic chemistry is difficult to characterize because of the variety of reaction path and the variety of reaction products that may be obtained from the reaction occur.

2.3.1.4 Transesterification

The most common way to produce biodiesel is the transesterification method, which refers to a catalyzed chemical reaction involving vegetable oil and alcohol to yield fatty acid alkyl esters (i.e., biodiesel) and glycerol. The reaction requires a catalyst, usually a strong base, such as sodium and potassium hydroxide or sodium methylate. A catalyst is usually used to improve the reaction rate and the yield. Since the reaction is reversible, excess alcohol is used to shift the equilibrium to the product side. Especially methanol is used as alcohol because of its low cost and its physical and chemical advantages. Methanol can quickly react with vegetable oil and NaOH can easily dissolve in it. To complete a transesterification reaction stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is necessary. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield.

The triglycerides are reacted with a suitable alcohol (Methyl, Ethyl, or others) in the presence of a catalyst under a controlled temperature for a given length of time. The final products are Alkyl esters and Glycerin. The Alkyl esters, having favorable properties as fuels for use in CI engines, are the main product and the Glycerin, is a by-product. The chemical reaction of the tri-glyceride with methyl alcohol is shown below. With higher alcohols the chemical equation would change correspondingly.

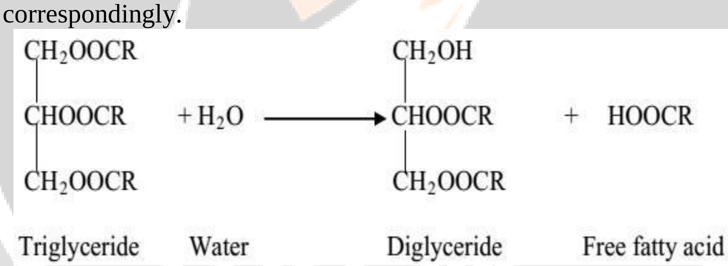


Figure 2: Transesterification of bio fuels

Biodiesel Production Process

Biodiesel derived from biological resources is a renewable fuel, which has drawn more and more attention recently. A fatty acid methyl ester is the chemical composition of biodiesel. Transesterification is widely used for the transformation of triglyceride into fatty acid methyl ester. The manufacturing process is based on the transesterification of triglycerides by alcohols to fatty acid methyl esters, with glycerol as a by product. The base catalyzed production of biodiesel generally has the following processes.

2.1.2.1 Mixing of Alcohol and Catalyst

This typical process is mainly done by mixing alkali hydroxide (commonly potassium hydroxide and sodium hydroxide) with common alcohols (methanol and ethanol) in the mixer with standard agitator to facilitate the mixing. Alkali hydroxide is dissolved in the alcohol to produce alkoxide solution.

2.1.2.2 Chemical Reaction

The alcohol and catalyst mixture is then charged into a closed reaction vessel and the oil is added. The reaction system is totally closed to the atmosphere to prevent the loss of alcohol, since it easily vaporizable. The reaction mixture is kept just near the boiling point of the alcohol to speed up the reaction. Excess alcohol is normally used to ensure total conversion of the oil to its esters as there is no problem of recovering of the alcohol for later use after recycling.

2.1.2.3 Separation

After the reaction is completed, there exists glycerol and biodiesel formation. Both have a significant amount of the excess alcohol that was used in the reaction which is in need of being recovered. The reacted mixture is sometimes neutralized at this step if the basic media that is caused by alkali hydroxide is occurred. The glycerol phase is much denser than biodiesel phase, making biodiesel to be floated. The two products can be separated by gravity using settling vessel. The glycerol is drawn off at the bottom of the settling vessel and biodiesel is drawn off at the top. In some cases, a centrifuge is used to separate the two materials faster by screening both phases.

2.1.2.4 Alcohol Removal

After the glycerol and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation commonly. But currently extractive distillation can instead be used to fasten the process and to be more economical. On the other hand, the alcohol is removed and the mixture neutralized before the glycerol and esters have been separated to prevent the effect of basic media inside the reactor. After the alcohol is being recovered it is used as main raw material.

2.1.2.5 Biodiesel Washing

After transesterification the upper ester layer may contain traces of NaOH, methanol and glycerol. Since the remaining unreacted methanol in the biodiesel has safety risks and can corrode engine components, the residual catalyst (NaOH) can damage engine components, and glycerol in the biodiesel can reduce fuel lubricity and cause injector coking and other deposits. These being water soluble is removed by washing (4 -6 times) the biodiesel with water maintained at 40-50ºC. Washing is carried out by spraying hot water over the biodiesel; precautions were taken to avoid soap formation. The washed biodiesel needs drying in order to remove trace impurities. In some processes washing step is not necessary depending on the quality of biodiesel produced.

After the completion of washing process the biodiesel may contain some traces of water. Biodiesel is heated to 110 ^{0}C to remove the trapped traces of water.

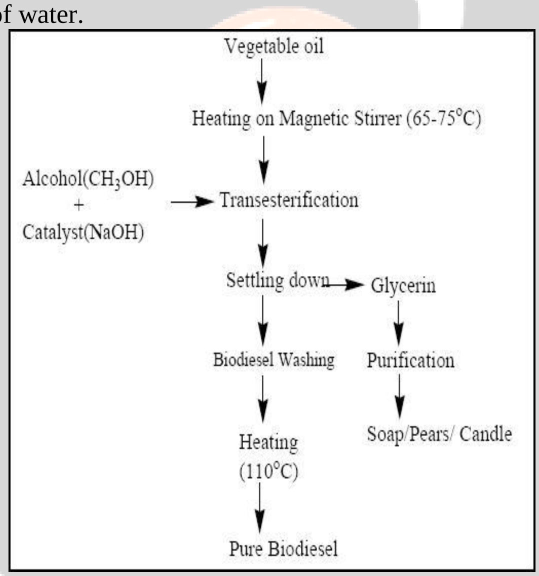


Figure 3: Flow chart of biodiesel production process

2.1.3 Advantages of Biodiesel

- It can be used for pure or blended with petro diesel in engine as well as in the diesel engine without any modifications.
- It does not contain sulphur therefore, no sulphur emission are emitted during the combustion.
- It can increase engine life due to the higher lubrication capacity.
- During the combustion biodiesel emits less harmful gases into the environment compared with petro diesel.
- Biodiesel reduces the health risk associated with petroleum diesel.
- The biodiesel transport and its storage are less dangerous than the petroleum diesel, because biodiesel has a flash point temperature of about 170°c in comparison of 60°c to 80°c for petroleum diesel.

2.1.4 Disadvantages of Biodiesel

- The biodiesel needs more additives, mainly in cold countries, due to its high cloud point.
- The biodiesel fuels lowered the premixed combustion of heat release because of the lower volatility.
- The biodiesel produces more NOx emissions than petro diesel.
- The viscosity of vegetable oil is much higher than that of diesel. It can cause problem in fuel handling, pumping, atomization and fuel jet penetration.

2.2 Literature Review

Canaski et al. (2006) have carried out energy and exergy analysis of 4-cylinder turbocharged diesel engine using two biodiesels soybean methyl ester and yellow grease methyl ester. It was seen that for B20 blends thermal efficiency were found almost similar to petroleum diesel and for B100 (pure biodiesel) thermal efficiency were found negligibly higher than petroleum diesel. So overall energetic and exergetic performance of engine with biodiesel fuel found almost similar. It is noticed that use of oxygen rich biodiesel fuel promote better combustion thus improve thermal efficiency. [1]

Sekmen et al. (2011) have carried out experimental work on 4 cylinder , direct injection diesel engine. Soybean methyl ester was used as fuel. as energy and exergy analysis gives better description of any thermal systems, both analysis were carried out. It was found that brake thermal efficiency is higher than diesel marginally and exergetic performance was also shown similar performance for pure diesel and biodiesel fuel. It was noticed that use of oxygen rich fuel promote better mixture formation and combustion thus improving thermal efficiency. Heat transfer irreversibility will be more if temperature difference of transferring surface is more. [2]

Debnath et al. (2013) have carried out the research work to explore the effect of compression ratio and injection timing on the energy and exergy potential of an engine. Single cylinder, direct injection, water cooled diesel engine fuelled with palm oil methyl ester (POME) was used for this purpose. In general, result indicated that increase in compression ratio gives higher shaft availability, cooling water availability and less exhaust availability. Exergy efficiency increases with increase in compression ratio and advancement of injection timing. Entropy generation is less with higher CR (here 17.5) and lower IT (20 degree before TDC) among other values. Kannan et al demonstrated that the injection of jatropha methyl ester which has a higher cetane number than diesel results lower ignition delay. [3]

Fu et al. (2013) carried out exergy and energy analysis of 4-stoke, 4-cylinder, naturally aspirated gasoline engine fuelled with gasoline. Purpose of the analysis was to check the exergetic performance of gasoline engine and to know about waste heat recovery potentiality of that engine. It was found that at low speed and low load condition waste heat availability mainly focuses on cooling water whereas at high speed high load waste heat was found more with exhaust gases. It was also given that maximum fuel efficiency can come up to 60% through waste heat recovery. [4]

Panigrahi et al. (2014) carried out experiment on single cylinder 4-stroke diesel engine running using mahua biodiesel blends. BSFC of biodiesel blend B20 was found marginal higher and thermal efficiency of the B20 blends was found higher than other blends and compatible with diesel results. Exergetic performance was also found nearer to diesel. Emission of NOx found little higher in case of biodiesel. [5]

K. Srithar et al (2014) carried out experiment on single cylinder, 4-stroke, a direct injection, diesel engine running using dual biodiesel fuels. The energetic and exergy analysis of DPN 1, DPN 2, DPN 3, DPN 4, DPN 5 and DPN 6 have been performed. In this study, test engine was operated at constant speed and varying load conditions, without modifications to engine or injection system. The energy and exergy values are computed using experimental data and compared for all the six DPN blends. The thermal efficiency of engine fuelled by DPN 1 was slightly higher than other DPN blends due to the higher combustion efficiency and the lower heat losses. However, the exergy efficiency of engine fuelled by DPN 6 was slightly higher than the value of DPN 1. DPN 1 blend gives lower BSFC, exhaust temperature, HC, CO, CO_2, NOx and smoke opacity than other blends. DPN 1 blend gives higher thermal efficiency than other blends. From the experimental test of this study, it can be confirmed that DPN 1 can be used for diesel engine for agricultural. [6]

G. Antolın et al.(2002) studied the Optimization of biodiesel production by sunflower oil transesterification. The tests showed that the Methanol and catalyst quantity were gave the major influences. Due to large quantity of methanol conversion of the TG and ME was maximum but slowed down separation of two phases during production of biodiesel. The calorific value of biodiesel was lower (12%) than that of diesel fuel, but lesser (6%) loss of energy. As compare to diesel sunflower biodiesel showed similar CO, HC, NOx and CO_2 emissions. [7]

Cumali Ilkılıç et al.(2011) studied the production of biodiesel from sunflower and its application to diesel engine. Performance and emission tests were conducted on a single cylinder diesel engine to fuel with biodiesel blends and diesel fuel. The test results showed that the reduction in performance for B5, B20 and B50 fuels were 2.2%, 6.3% and 11.2% respectively than that of diesel fuel. This low reduction can be neutralized by increase in BSFC. For biodiesel blends B5, B20 and B50 increased in BSFC by 2.8%, 3.9% and 7.8% respectively. Biodiesel showed that the slight reductions of PM and smoke emissions. NOx and HC emissions increased and CO emissions decreased for biodiesel blends. But increases in HC emissions can be ignored because it has very low amounts of all types of fuel test. It can be concluded that the use of biodiesel fuel safflower has beneficial effects in terms of reducing emissions and alternative diesel oil. [8]

Jinlin Xue (2013) studies the Combustion characteristics, engine performances and emissions of waste edible oil biodiesel in diesel engine. With no or minor modification on diesel engine reduction in PM, HC and CO emissions accompanying with minor loss of power, increase in consumption of fuel and NOx emissions than that of diesel. And also the combustion characteristics such as heat release rate, peak pressure, rate of pressure rise, and ignition delay for the WEO biodiesels showed slight differences as compare to diesel. Despite what was taken from the conflicting conclusions on the CO_2 emission of WEO biological, it reduces to a large extent from the point of view of the trading life cycle CO_2. Also motivating the storage and reusing of waste edible oil for production of biodiesel and relieve pressure on scarce resources, largely without greatly sacrificing emissions, economy and the engine power. [9]

G.R. Kannan et al.(2011) studied the performance emission and combustion characteristics of single cylinder water cooled direct injection diesel engine operated at a constant speed of 1500 rpm at different operating conditions fuelled with biodiesel. For production of waste cooking palm oil biodiesel ferric chloride ($FeCl_3$) used as a fuel borne catalyst. 20 kmol/L dosage of metal based additive was added to biodiesel. Due to mixing of fuel borne catalyst with biodiesel it was observed that the slight increment of brake thermal efficiency, BSFC and BSEC at optimized operating condition. Also with addition of fuel borne catalyst slight increment in emission of NO and CO_2 at optimized operating conditions .It can also seen that the significant reduction in emission of CO, UHC and smoke emission. Due to addition of fuel borne catalyst with biodiesel showed the higher cylinder gas pressure, heat release rate and shorter ignition at optimized operating conditions. [10]

K. V. Narayanan et al. (2015) studied the emission and performance analysis of 4-stroke, stationary DI engine at 1500rpm costant speed. Hydrotreated refine sunflower oil used as a alternate fuel. The results show that the emissions can be reduced by using hydro treated refined sunflower oil. A number of tests were conducted for different blends, different loadings and at a constant speed of 1500 rpm. The findings are based on full load condition when compared with petro diesel. The CO emission decreases for HTSF B25 and HTSF B100 by 9% and 37%. The emissions of HC decrease for HTSF B25 and HTSF B100 by 42% and 55% respectively. The NO_x emission decreases for HTSF B25 and HTSF B100 by 10% and 18.18%. The BSFC decreases in HTSF B25 and HTSF B100 by 25% and 12.5% respectively. There is an increase in brake thermal efficiency for HTSF B25 and HTSF B100 by 10% and 38%. [11]

Rizwana Naureen et al (2014) derived the different properties of Sunflower oil biodiesel was synthesized by base catalyzed transesterification with methanol. The dynamic viscosity (5.321 cp) and kinematic viscosity (4.719 mm^2s^1), density (0.86 g/cm^3), pour point (5.0 LC), cloud point (4.0 LC), flash point (183 LC) and acid number (0.07 mg KOH/g) of sunflower oil biodiesel met the ASTM. Density is the limits for petro-diesel and biodiesel. High viscosity indicates the poorer atomization of the fuel spray. The high percentage conversion of oil into biodiesel indicates that sunflower oil has great potential for commercial production of biodiesel. [12]

M. Vijay Kumar et al (2016) studied about additives in biodiesel are used for the improve combustion, fuel economy and to decrease the emission. A metal based additive will minimize the viscosity, pour point and increase the flash point properties of biodiesel fuel. The BSFC decreases significantly due to their catalyst effect by adding the metal based additives. the oxygenated additives will affect directly the properties such as cetane number, density, viscosity, volatility, flash point and calorific value. The oxygenated additive helps in reducing the viscosity and density as well as raising the quantity of oxygen in biodiesel fuel. Normally all exhaust emissions of carbon dioxide, carbon monoxide, hydrocarbon and smoke emissions are decreased very much with the addition of oxygenated additives to diesel and biodiesel fuels. Cetane number additives are very important in decreasing ignition delay period. Antioxidant is quite successful in controlling NO_x emission. [13]

Najeeb Ullah Khan et al (2017) have carried out research work on 4-stroke, single cylinder, diesel engine. WCME used as a biodiesel produced from renewable and often domestic sources. It was found that the CO and HC emissions decreases with increasing percentage of biodiesel in blends with diesel. Diesel has lowest CO2 emission and among all fuel blends CO2 emission decreases with increasing percentage of biodiesel. NOx emission increases with increasing percentage of biodiesel in blends. [14]

Sumit Sharma et al (2014) have carried out research work on 4-stroke, single cylinder, air cooled DI diesel engine. Waste cooking oil used as a biodiesel fuel. It was found that the specific energy consumption increase with change in % of biodiesel in the blends due to lower heating value of biodiesel. Brake thermal efficiency of WCME and its blends is slightly lower than that of diesel fuel. The maximum BTE of diesel fuel is 30% and WCME100 is 26%. Also reduction in CO, HC and smoke emission while increased in NOx emission. [15]

Goswami J et al (2014) have studied the emission and performance on single cylinder diesel engine using waste cooking oil as a biodiesel. It was derived that the CO and UBHC emissions were found to significantly decrease with biodiesel and its blends due to a more complete combustion caused by higher oxygen content. A sharp reduction in particulate matter and smoke intensity in WCO biodiesel and its blends. BSFC increases with increase in percentage of UCO biodiesel in the blend and is due to the lower heating value of UCO biodiesel and its blends. Slightly increase the NOx emission in case of WCO biodiesel as compared to the biodiesel. [16]

Likita Bwonsi et al (2017) have carried out the energy and exergy analysis on 4-stroke, single cylinder, air cooled, diesel engine fuelled with biodiesel fuel from palm kernel oil and its blends with petroleum diesel. It have concluded that the both thermal and exergy efficiencies reduce with increasing load and increase with increasing speed. Exergy efficiency maximum values range from 28.18% to 38.12% ; diesel100 is the most efficient and fuel sample B60 is the least efficient. It have also concluded that the diesel100 is more efficient than the biodiesel derived from palm kernel oil. [17]

Perihan Sekmen et al (2011) have carried out energy and exergy analysis of four cylinder, direct injection diesel engine using petroleum diesel fuel and biodiesel fuel. It have concluded that exergy of the petroleum diesel fuel is a greater the biodiesel. Because of the net calorific value of petroleum diesel is greater than biodiesel. In addition of use of biodiesel fuels shows the similar energetic and exergetic performance values with diesel fuel. It has also derived the destruction of exergy by irreversible process. It occurs due to combustion. This exergy losses are due to the exhaust gas and heat transfer. [18]

C. Sayin et al have carried out energy and exergy analysis of 4-stroke, four cylinder, gasolon engine using gasoline fuel. It has concluded that the engine operates less energy efficiency when a fuel with an octane rating higher the design rating is used. Operation with high octane rating lead to lower exergetic efficiency usually a higher exaust exergy loss and a higher exergy loss due to heat loss. It have also derived the destruction of exergy by irreversible process. It occurs due to combustion. In this exergy losses due to the exhaust gas and heat transfer. [19]

Ali Kharam et al (2017) have carried out performance and emission analysis on 4-stroke, single cylinder, direct injection, water cooled CI engine. Biodiesel and bio ethanol to diesel fuel used. It have derived that the BSFC is increased 30.6% respectively with the addition of bio ethanol to binary blend fuels. Volumetric efficiency is increased 3.7%. Emission of CO increased by an 80% and emission of NO increased 31.3% for a fuel containing a high level of bioethanol when compared to the diesel fuel. [20]

Akram Attari et al (2016) have derived performance on single Cylinder, stationary DI engines, water cooled, and running at 1500 rpm. Castor seed oil blended with diesel is used. The castor seed oil can be directly used in engine without any modification by proper blending with diesel. The blending percentage range from 80 to 95% diesel in order to have optimum result for performance as well as emission. Castor oil on its own cannot fatty used in the engine but certainly some amount of fuel is getting saved by the use of castor oil by its addition with diesel. [21]

Anushu Peyyala et al (2016) have derived performance analysis of single Cylinder, 4-stroke, direct injection, water cooled , diesel engine. Sunflower oil used as a biodiesel. It have concluded that BSFC of B10 is more than B20 with increase in load condition. The total heat generated maximum for B10 under increasing in loading condition. The B20 blend was preferable when harmfull emission like CO and Nox were necessary to reduced. Mechanical and thermal efficiency of B10 blends are more than the B20 blends with the maximum load condition. [22]

S. Ganesan et al (2017) have derived performance and emission analysis on CI engine using soapnut oil as biodiesel. It have derived the result diesel has a lower specific fuel oil consumption because of high calorific value, with blended fuel B10 the equivalent SFC was very closer but higher than that of the diesel. The CO, HC and CO2 emission are reduced as compared to the pure diesel. [23]

K. Sivaramakrishnan et al (2017) have investigation on performance and emission characteristics of a single cylinder, 4-stroke, variable compression, multi fuel engine fuelled with karanja biodiesel with diesel blend. BTE is maximum 30.46%. For B25 at full load at CR 18 which is 5% higher than diesel. HC emission reduced compare to the diesel. Minimum 16 ppm at B20 where it is 96 ppm for diesel at CR 16. CO emission of the blend B25 is lesser than the standard diesel. The SFC decreased with increased in CR B25 at CR 18 give 0.29 Kg/kwh of diesel. [24]

K. Nantha Gopal et al (2014) have derived the effect of pongamia biodiesel on emission and combustion characteristics of direct injection CI engine. It has concluded that SFBC increased with increased in % of biodiesel in the biodiesel blend because of the heating value of biodiesel. Reduction in CO, UBHC and smoke emissions for all biodiesel blends when compared to diesel fuel. The combustion analysis showed that the biodiesel added to the convection diesel fuel decreased the delay period and lowered the heat release rate of the premixed combustion. [25]

3 WCSFO BIODIESEL

3.1 Fuel Selections

There are more than 350 oil bearing plants available from which few have potentiality to be used as IC engine fuel. Details of oil species for biodiesel production are given below:

- **Edible vegetable oil**: Sunflower oil, Rapeseed oil, Rice bran oil, Soybean oil, Coconut oil, Corn oil, Palm oil, Olive oil, Pistachia Palestine oil, Sesame seed oil, Peanut oil, Opium Poppy oil, Safflower oil etc.
- **Non-edible vegetable oil**: Jatropha oil, Karanja or Pongamia, Neem oil, Jojoba oil, Cottonseed oil, Linseed oil, Mahua oil, Kusum oil, Orange oil, Rubber seed oil, Sea Mango, Algae and Halophytes etc.
- Waste or recycled oil
- Animal fats: Tallow, yellow grease, chicken fat and by- products from fish oil etc.

Currently more than 90% of the biodiesel oil is produced from edible oil because of its abundant agricultural production. For instance see the following major production of biodiesel respective to the continents:

- Palm oil - South Africa
- Soyabean oil - US
- Coconut oil - Philippines
- Rapeseed oil - Europe

The use of edible vegetable oil and animal fats for biodiesel production has recently been of great concern because they compete with food materials. As the demand for vegetable oils for food has increased tremendously in recent year, it is impossible to justify the use of these oils for fuel use purpose such as biodiesel production. It also has disadvantages such as inferior storage and oxidant stability, high feed stock cost, low heating value and higher NOx emission compared with diesel fuel. Moreover, these oils could be more expensive to use a fuel. Hence the contribution of no-edible oil and waste vegetable oil will be significant source for biodiesel production.

3.2 Limitation of Vegetable oil as Diesel Engine Fuel

The kinematics viscosity of different vegetable oils varies in the range of 32–42 cSt at 38ºC, which is about 10 times greater than that of petroleum diesel fuel. The flash point of the vegetable oils is very high (above 200 ºC). The CV of oils is in the range of 36–40 MJ/kg. The presence of chemically bounded of oxygen in vegetable oils lowers their heating values by about 10% then diesel. The CN of oils are in the range of 32–40. It has been found that the neat vegetable oils can be used as diesel fuels in conventional diesel engines, but this leads to a number of problems.

Waste cooking oil

The feedstock coming from waste vegetable oils or commonly known as waste cooking oils is one of the alternative sources among other higher grade or refine oils. Waste cooking oil is easy to collect from other industries such as domestic usage and restaurant and also cheaper than other oils (refine oils). Hence, by using these oils as the raw material, we can reduce the cost in biodiesel production. The advantages of using waste cooking oils to produce biodiesel are the low cost and prevention of environment pollution. These oils need to be treating before dispose to the environment to prevent pollution. Due to the high cost of disposal, many individuals dispose waste cooking oils directly to the environment especially in rural area. So that, the use of waste cooking oils is an effective way to reduce the cost of biodiesel production. Used cooking oil has sufficient potential to fuel the compression ignition engines. The kinematic viscosity of used cooking oil (UCO) is about 10 times greater, and its density is about 10% higher than that of mineral diesel. These properties play vital role in the combustion; therefore these must be modified prior to the use of UCO in the engine.

In both the cases that is Vegetable Oil and Waste cooking oil many techniques have been developed to reduce the kinematic viscosity and specific gravity of vegetable oils, which include pyrolysis, emulsification, leaning and transesterification. Among these techniques, transesterification is the hot favorite. This is because of the fact that this method is relatively easy, carried out at normal conditions, and gives the best conversion efficiency and quality of the converted fuel.

Table 1: Comparisons of fuel property of diesel, sunflower oil and WCSFO

Testing Properties	Diesel	Sunflower Oil Biodiesel	WCSFO Biodiesel
Density at 15°c, (gm/cm^3)	0.83	0.91	0.90
Specific Gravity, (gm/cm^3)	0.83	0.92	0.92
Flash Point, (°c)	53	260	318.4
Kinematic Viscosity at 40°c (cSt)	3.51	28	37

4. EXPERIMENTAL SETUP AND METHOD

4.1 Engine Setup

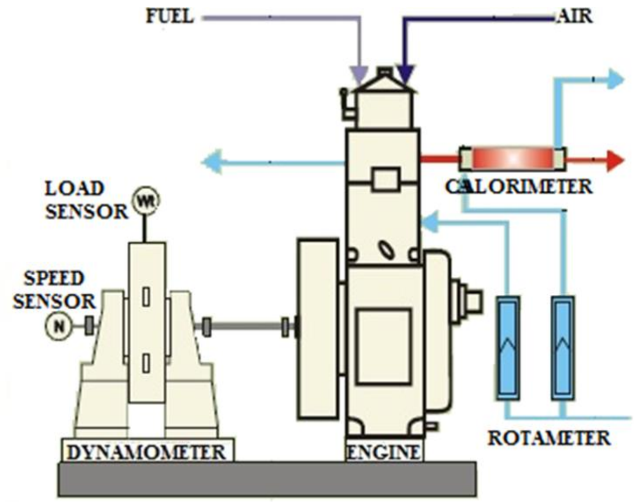


Figure 4: Schematic of test engine setup

Test engine setup is shown in the Figure 4. It is single cylinder, four stroke, water cooled VCR (variable compression ratio) engine manufactured by kirlosker. This engine set up consists of many sensors like temperature sensor, load sensor, speed sensor etc for respective measurements. Fuel is supplied from the fuel tank and air is supplied through air box setup having manometer. Engine output shaft is connected with the eddy current dynamometer. Speed sensor and load sensor is attached with dynamometer. Engine is cooled by water and flow rate of water is control by valve. This engine has arrangements to change compression ratio, injection timing, spark timing (in case of petrol engine head is attached) and injection pressure. It is designed especially for research purpose which allows the use of different fuel and changes in operating parameters.

4.2 Engine Specification

Specification of the engine provided by the manufacturer is shown in Table 2

Table 2: Test engine specification from engine manual

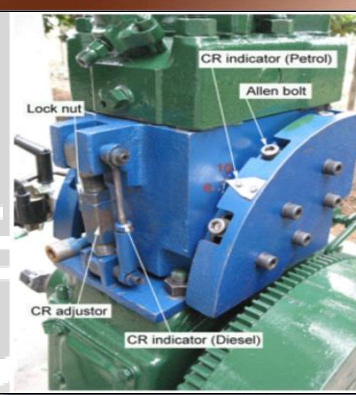
Particular	Specification
Engine	1 cylinder, 4 stroke, water cooled engine
Bore and stroke	87.5mm by 110 mm
Rated power	3.5 kW at 1500 rpm
CR range	12:1 to 18:1
Injection Variation	0-25 degree BTDC
Dynamometer	Eddy current type, water cooled with load unit
Propeller shaft	With universal joints
Air box	M S Fabricated with orifice meter and manometer
Calorimeter	Pipe in pipe type
Temperature sensor	RTD type PT100 and Thermocouple , type K
Load sensor	Load cell, type strain gauge, range 0-50 kg
Load indicator	Digital , range 0-50 kg, supply 230V AC
Digital voltmeter	Range 0-20V, panel mounted
Rotameter	Engine cooling 40-400 LPH, Calorimeter 25-250 LPH
Fuel tank	15 liter capacity with fuel metering pipe of glass

4.3 Experiment Method

First engine was made to run at manufacturers set value of compression ratio 17.5 and readings for energy analysis were taken for different blends (B10 to B50 with increment of 10). Engine was made to run for three different loading conditions such as low, medium and high for same blends. The measurements were taken after the steady state condition was reached. Though this engine setup has facility to automatic reading measurements at some fixed interval of time with data acquisition system, due to some technical problems readings were measured and noted manually. Load was varied with the help of voltage knob and reading directly indicates values in terms of load in kilogram. Fuel consumption was measured manually by measuring time for fixed amount of fuel consumption (10cc in this case) for different fuels at different loading conditions. Temperature readings were taken from the digital indicator which shows various temperature readings such as engine cooling water inlet and outlet, calorimeter water inlet and outlet and exhaust gas inlet and outlet temperature in calorimeter. Gas analyser was used for the measurement of exhaust gases volume fractions. During this initial experiment all readings were taken at compression ratio of 17.5 and injection pressure of 180 bar. These readings were used for energy analysis of all the blends. Then after energy analysis of these blends, best suitable blend was chosen whose performance was found similar to diesel fuel. Now during second experiment best suitable blend was used in which experiment was done at various combination of different compression ratio 16, 17 and 18 and injection pressure of 180 and 200 bar. This second experiment was done to check the effect of change in operating parameter on exergy efficiency of the engine as we already mentioned in the introduction that combustion process is major reason for the destruction of the exergy and somehow by setting the suitable operating parameters we can minimize that destruction of exergy and optimize the performance of the engine. Readings for this second experiment were taken similar way as taken during first experiment, only difference is that operating parameters are changed and fuel blend remains same throughout this second experiment.

4.4 Various Measurements and Adjustments

The various parts of experimental setup include:

<table>
<tr><th>Sr. No.</th><th>Name and Specification</th><th>Figure</th></tr>
<tr><td>1.</td><td>Dynamometer:
AG series eddy current dynamometers designed for testing of engines up to 400 kW.
It is bi-directional.
The shaft mounted finger type rotor runs in a dry gap.
A closed circuit system permits for a sump. Dynamometer load measurement is from a strain gauge load cell and speed measurement is from a shaft mounted three hundred sixty PPR rotary encoder.</td><td></td></tr>
<tr><td>2.</td><td>Compression Ratio Adjustment:
Lightly loosen 6 allen bolts providing for clamping the tilting block.
Loosen the lock nut on the adjuster and rotate the adjuster so that the compression ratio is set to maximum. Refer the marking on the CR indicator
Lock the adjuster by the lock nut
Tighten all the 6 allen bolts gently.
You may measure and note the centre distance between two pivot pins of the CR indicator. After changing the compression ratio the difference can be used to know the new CR.</td><td>
</td></tr>
<tr><td>3.</td><td>The load indicator shows reading of loads to the engine which are measure by load cell mounted at appropriate place on dynamometer. Load indicator directly indicates the value in terms of load in kilogram.
Digital voltmeter gives the reading of voltage generated in the temperature sensor fitted appropriate places for temperature measurements. From the voltage readings we can obtained temperature reading by multiplying it by some factor (constant numeric value) given by manufacturer.
Also in the image manometer can be seen adjacent to glass tube. This manometer shows the reading of suction pressure which is helpful for finding mass of air consumed from the air box.</td><td>
</td></tr>
</table>

5. CONCLUSION

This is a review paper showing background of Biodiesel, its technical properties and its enviro-economic aspects. The authors have even tried visualize the various types of biodiesel and is focusing on identifying the best suited bio-diesel for IC Engines. It is also reported that there is a sharp reduction in particulate matter and smoke intensity in WCO biodiesel and its blends. The reduction is mainly caused by reduced soot formation and enhanced soot oxidation due to increased oxygen content. There was no difference in PM emissions between WCO and fresh vegetable oil biodiesel. There was a noticeable difference between UCOME and UCOEE in smoke opacity but not in PM. The effective power depends on the load conditions showing a decrease at full-load conditions and no differences at partial load conditions. An increase in BSC has been found when using UCO biodiesel in most of the papers reviewed. BSFC increases with increase in percentage of UCO biodiesel in the blend and is due to the lower heating value of them. The findings from this review indicate that biodiesel derived from used cooking oil is a cheap green liquid fuel available because of the primary ingredient being a post-consumer waste product.

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