International Journal of Advance Research In Science And Engineering http://www.ijarse.com
IJARSE, Vol. No.3, Special Issue (01), September 2014 ISSN-2319-8354(E)

A COMPARITIVE STUDY ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF LOW SULPHUR DIESEL LIKE FUEL WITH BIODIESEL FROM COTTON SEED OIL IN CI ENGINES

[1]Libin P Oommen, [2]Carol Abraham

[1,2]Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala (India)

ABSTRACT

After industrialization the energy consumption of the world increased rapidly. The amount of petroleum fuel sources are decreasing day by day. So it is necessary to find alternative fuel sources, which are economical, easily available, reliable and efficient. Through this paper, we make a comparative study of performance and emission characteristics of two fuels, Biodiesel from Cotton Seed Oil (CSO) and a Low Sulphur Diesel-like Fuel (LSDLF) produced from Waste Lubricating Oil (WLO). The performance and emission tests were carried out in a standard test engine and the respective graphs are plotted and compared. From the analysis it was evident that the fuel consumption of engine running on Biodiesel from CSO is higher than that of LSDLF. The NOx emission of the Biodiesel is also higher than that of LSDLF. Thus it was concluded that LSDLF is better than biodiesel from CSO and can be used in a commercial diesel engine as a suitable alternative to commercial diesel.

Keywords: Alternative Fuel, Cotton Seed Oil, LSDLF, Performance Test, Waste Lubricating Oil

I INTRODUCTION

The energy demand in the world is increasing day by day. The major part of the energy consumed worldwide comes from fossil fuel sources. But the amounts of them are decreasing very rapidly [1-3]. Studies say that within 40 years, the present reservation of the petroleum fuel including diesel will deplete at an increased consumption rate estimated to be order of 3% per annum. The depletion of conventional fossil fuels, increasing air pollution caused by them, and their increasing cost etc. make alternative fuel sources more attractive.

But the alternative fuel source for petroleum should be competitive, technically feasible, environment friendly and cheap. Many number of research works are carried out on renewable energy sources have focused on different waste energy sources. These wastes are commonly known as waste lubricating oils, vegetable oils, plastics, etc. The main problem of alternative fuel source is that they cannot be directly used as a fuel without purification, because it will have many adverse effect on living beings and environment.[4-6]. Through this paper, we are intended to compare the effectiveness of two alternative fuels, Biodiesel from cotton seed oil (CSO) and Low Sulphurized Diesel Like Fuel (LSDLF) obtained from Waste Lubricating Oils (WLO).

Biodiesel from vegetable oils can be used as an effective alternative for commercial diesel. Dr.Rudlof Diesel developed the first diesel engine running on bio diesel. Later the abundant availability of petroleum fuel replaced the biodiesel. He used peanut oil as a fuel for the engine. The use of biodiesel in United States has a rapid increase now a day. Europe uses biodiesel, meeting current specifications for more than twenty years ago. Raw vegetable oils cannot be used as a direct fuel, because it leads to severe engine problems including engine deposits, injector chocking and piston ring sticking [7].The higher viscosity of vegetable oil is the main reason for this. This can be solved by through transesterification of vegetable oil to form methyl ester [8-11]. With the help of this process, we get a fuel viscosity that is close to that of diesel fuel. It is defined as the process of reacting a triglyceride with an alcohol in the presence of a catalyst to produce glycerol and fatty acid esters. The molecular weight of the ester molecule is roughly one-third that of a neat vegetable oil molecule and the ester has a viscosity approximately twice that of diesel fuel. In contrast, raw vegetable oil has a viscosity of 10 to 20 times that of diesel fuel.

Methyl esters is obtained [12] from used frying oil. Their fuel properties are compared with Austrian standards valid for rapeseed oil methyl ester. The content of the free fatty acids of the oil was between 0.26% and 2.12%. The removal of solid particles from the fuel is carried out through filtration at 40 ˚C. Then the oil was trans esterified using alkaline catalyst. But cloud points and pour points of vegetable oil esters are known to be much higher than diesel fuel and they will cause problems in cloudy weather.

The waste lubricating oils can be used as an efficient alternative fuel source. The WLOs are potentially inexhaustible energy sources since they are continuously used in mechanical parts of machines. Waste lubricant engine oil is one of the most important types of the WLOs since it will last as long as there are engines in use whether it is originated from crude oil or from other sources [13]. There is a large amount of WLO is discharged into the environment per year. The annual lubrication oil demand is about 40 million metric tons out of which 60% is generated as WLO. Around 7.6 million metric tons per year in United States, 2.2 million in the European Union and about 500,000 tons of WLO in Turkey are used.

It has been emphasized in many studies that waste engine oil harms people and environment. As there are inorganic matters such as lead, copper and halogens (C1, F, Br, and so on) in the structure of these oils. Without proper purification, the can be only used in cement industries [14, 15, 16]. One litre of WLO can contaminate 800,000 litres of water not usable, 5,000,000 tons of clean water undrinkable. Therefore, waste oils are one of the most abundant pollutant residues that are generated nowadays, reaching the value of 24 million metric tons per year. The WLO contains a high amount of sulphur. The primary product of combustion is sulphur dioxide (SO_2), which is a major environmental pollutant. The SO_2 reacts with atmospheric water vapour to produce sulphurous and sulphuric acids, both of which contribute to acid rains. As a result of the widespread distribution of the acid rain, the whole atmosphere may be threatened. So if we can use these WLO as an alternative fuel source, then we can reduce its amount and also can have an effective alternative fuel.

By using pyrolitic distillation method, we can produce a diesel like fuel (DLF) from WLO. But the sulphur value in DLF is far more than the standard values, so sulphur amount should be decreased with chemical methods. Hydro desulphurization (HDS) processes are used to reduce the sulphur levels in commercial fuels in today's refineries.[17]. However, the HDS processes consume huge amount of energy because these processes take place at high temperatures and high pressures, while the oxidative desulphurization (ODS) technology is proposed due to the less energy need. Thus ODS technology can be used to produce LSDLF from DLF [18]. Thus by applying oxidative desulphurization (ODS) method to DLF produced from WLO we can produce a desulphurized fuel named as low sulphur diesel-like fuel (LSDLF).

There have been many studies performed to produce alternative fuels from different fuel sources for gasoline and diesel engines and to investigate the effects of the fuels on the engine performance and emissions. Waste lubricating oils originated from crude oil [19] and biodiesel from non-edible plant oils [20, 21] were used as a fuel sources for the diesel engine.

Nye et al. [22] have investigated the effects of several important reaction parameters on the methnolysis of rapeseed, and found that one present NaOH or KOH was an effective reaction rate enhancer at room temperature, a 60-min reaction time was allowed. They concluded that a 6:1 molar ratio of methanol to oil gave the best conversion. The performance and emission characteristics of ethyl esters from waste hydrogenated soybean oil have been compared [24] with diesel and they found that biodiesel had a higher specific gravity and 1.9 times the viscosity than No. 2 diesel fuel at 40 ˚C.

Arpa et al. [23] produced gasoline-like fuel (GLF) and diesel-like fuel (DLF) by using WLO. These fuels were used in gasoline and diesel engines to examine the effects of the fuels on performance and emission of the both engines. However, the amount of sulphur in the DLF was very high. M.J. Fuentes and R. Font studied about the combustion nature of the waste lubricating oil form car.

II OBJECTIVES OF THE WORK

The various objectives of this work includes

- To obtain an alternative fuel, that can be effectively used in Diesel engine.
- To Study the performance and emission characteristics of Biodiesel from Cotton Seed Oil (CSO) and a Low Sulphurized Diesel Lie Fuel (LSDLF) from Waste Lubricating Oil (WLO).
- To compare the performance of a diesel engine using these two fuels.

III PRODUCTION OF THE FUELS UNDER TEST

3.1 Preparation of biodiesel from Cotton Seed Oil (CSO)

A mixture of Methanol (99.9%) and sodium hydroxide are taken in a glass bottle. The bottle is provided with a narrow neck in order to prevent the splashing of the mixture. It is shacked for 15 minutes and while mixing it become heated and we get sodium methoxide. The cotton seed oil (one litre) is heated in an electric oven for 45-50˚C.This hot oil is mixed with the sodium methoxide and stirred well about one hour and is heated in an oven about 55-60 ˚C. After 24 h, we get a clear reddish liquid on the top with heavy black glycerine setting out at the bottom.
Then the biodiesel was separated from glycerin. The production of biodiesel from cotton seed oil depends on many factors like, amount of catalyst present, reaction time etc.

3.2 Preparation of LSDLF from WLO

The production process mainly consists of two processes, pyrolitic distillation followed by oxidative desulphurization on waste lubrication oils.

3.2.1. Pyrolitic distillation system.

An efficient pyrolitic distillation system is used to obtain a fuel having properties similar to commercial diesel from waste lubrication fuel. The diagrammatic representation of the system is given in Fig 1. The system consists of a waste oil tank, oil pump, oil filer, reactor, condenser, fuel storage tank and a control panel. The waste oil storage tank was used to collect WLO having several poisonous materials it. The WLO was pumped from the tank to the reactor, and then it was made to flow through the filters with 20 µm. The most important part of the system is the reactor as thermal treatment during heating of the WLO was performed there. The reactor, designed for this type of studies and experiments, was a fully insulated cylindrical chamber of inner diameter 30 cm and height 40 cm. In order to be able to complete all characteristic and performance tests, the reactor with the large volume for purpose of loss.

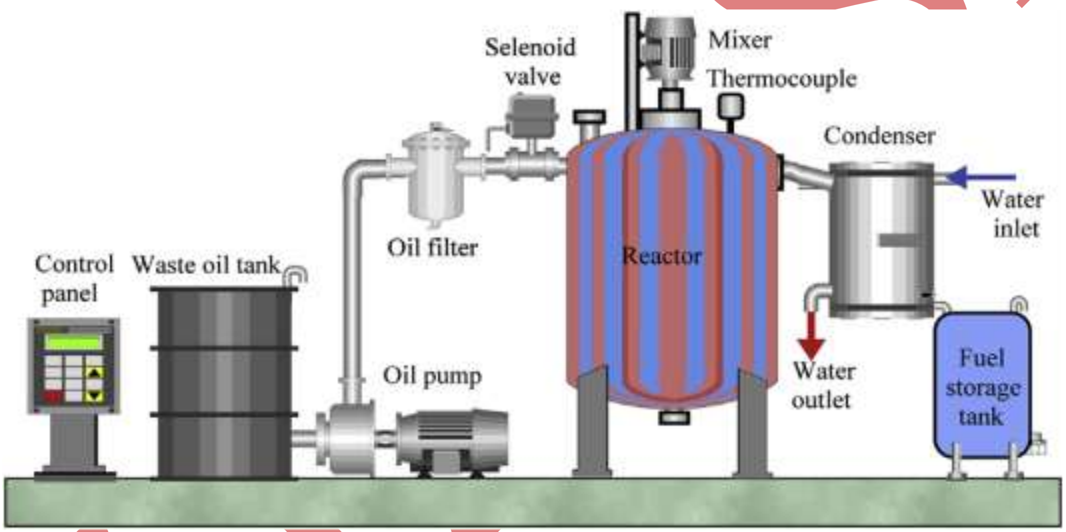


Fig 1. Schematic diagram of the pyrolitic distillation system.

An another important part of the reactor is an electric heater having a heating a capacity of 5kW can be used to heat the oil up to 600° C. The control unit is used to control the temperature inside the reactor by adjusting the voltage input. Desired temperatures were measured by means of thermocouple. Another part of the system is a mixer that is used in the reactor. The mixer is employed for blending the waste oil sample taken into the reactor to obtain uniform temperature. Otherwise, there would be a temperature layer within the reactor. Also a water cooled condenser unit that is used to distillate the oil vaporized in the reactor.

The pyrolitic conditions have very much importance in the process. Heating rate, time and temperature of WLO etc. are very much important. If the heating rate is very high, then heavy hydrocarbons will be produced during the pyrolysis process. The following curve gives the relationship between the temperature and the time required for pyrolysis.

3.2.2 Oxidative desulphurization (ODS)

The HDS method requires huge amount of energy and that is why we prefer ODS. It uses Hydrogen peroxide with an organic acid to reduce the sulphur level. The fuel is mixed with H2O2 and formic acid and the oxidative reaction takes place below 100°C. [27].The mixture of 10 g of 98% hydrogen peroxide and 20 g of 30% formic acid was prepared, and 2, 4, 6, 8, and 10 g from the mixture was added into the five samples of 100 ml DLF, respectively. The samples were heated up to 40, 50, 60 and 70 °C under atmospheric pressure for 120 min. Then all samples were washed with 15 ml of distilled water to remove unused oxidant in the fuel sample. Fuel samples staying at the upper layer of the container were used in sulphur determination.

IV EXPERIMENTAL SET UP

In order to predict the behaviour of the fuel inside the engine, we must have a clear cut idea about the performance and emission characteristics of the fuel. This will help us to now about the effect of the fuel on the performance of the engine and its emission parameters and thus we can predict the commercial utility of the fuel.

For the comparative study of the two fuels, Biodiesel from cotton seed oil and LSDLF we use a single cylinder, water-cooled, 4-stroke, diesel engine. The experimental set up is given in Fig 2.The engine was a commercial diesel engine and it was coupled with a dynamometer (the specifications are given in the Table 4.1). All experiments were conducting at standard temperature and pressure. A tachometer is used to measure the engine speed. A water brake dynamometer was used for engine torque measurement. The outlet temperature of both exhaust gas and cooling water is obtained from respective thermocouples on their passages.During testing, the engine was made run for ten minutes in order to obtain the steady state and then the recording process began. The measurement began at when the engine started operating faultless and it was loaded partially for an interval of 500 rpm.

Table 4.1 Test Engine Specifications

Engine type	Four stroke
Fuel type	Diesel
Bore	80 mm
Stroke	70 mm
Cooling type	Air cooled
Maximum Torque	40 Nm at 2000 rpm

4.1 Exhaust Gas Analyzer

To measure the exhaust emissions from the test engine, we use Greenline 8000 model exhaust gas analyzer. The exhaust emissions were measured at 30 cm from the exhaust valve. A filter paper is used to measure the some emissions from the engine. The specifications of the exhaust gas analyzer are given in Table 4.2. A probe is placed inside the exhaust pipe and the emission results are printed out with the help of a printer.

Table 4.2
Specifications of a Greenline 8000 Exhaust gas analyser

Parameter	Sensor type	Range	Accuracy
O_2	Electrochemical	0-25%	+-0.1%
CO	Electrochemical	0-8000ppm	<300= +-10ppm
NO	Electrochemical	0-4000ppm	<100 ppm=+-5 ppm
NO_x	Calculated	0-4000ppm	-
SO_2	Electrochemical	0-4000ppm	<100 ppm= +-5ppm
T_{gas}	Thermocouple	0-1000	-

V RESULTS AND DISCUSSION

The performance and emission characters of a fuel are very much important in order to predict whether the fuel can be used commercially in an engine or not. In our work we compare the performance and emission characteristics of Biodiesel from CSO and LSFLD from WLO.

5.1 Performance Results.

The performance of the fuels inside the engine is evaluated by considering the break specific fuel consumption (BSFC) and the break thermal efficiency of the two fuels, Cotton Seed Methyl Ester (CSMO) and Low Sulphur Diesel Like Fuel (LSDLF)) with the engine speed. The performance tests were carried out in the specified test engine and the readings were taken at equal intervals. The Brake Specific Fuel Consumption (BFC) and The Break Thermal Efficiency compared by plotting them against the engine speed.

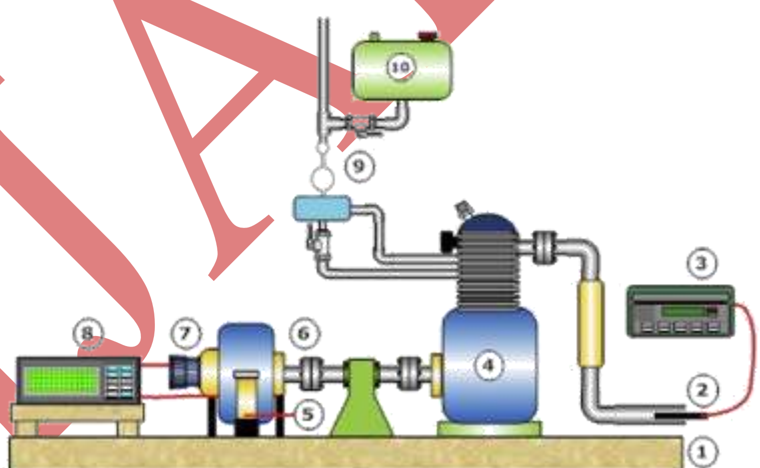


Fig 2. Schematic representation of the experimental set up. 1. Engine Chassis 2. Exhaust gas analyzing probe 3. Exhaust gas Analyser 4. Single cylinder diesel engine 5. Load cell 6. Dynamometer 7. Tachometer 8. Control unit 9. Fuel burette 10. Fuel container

5.1.1 Break Thermal Efficiency Vs Engine Speed

The break thermal efficiency of the biodiesel from cotton seed oil (CSO) and the LSDLF from WLO are plotted against the engine speed and is given in figure 3.. The brake thermal efficiency is defined as the actual brake work per cycle divided by the amount of fuel chemical energy. It is clear from the figure that as the engine speed increases, the output power increases, which leads to the increase in the break thermal efficiency of the biodiesel from CSO. After a particular value of the test engine speed, 850 rpm, the engine efficiency decrease

The break thermal efficiency gives an idea about the output generated by the engine with respect the heat supplied in the form of fuel. From Fig 3, it is clear that break thermal efficiency of LSDLF is slightly higher than that of Biodiesel from CSO

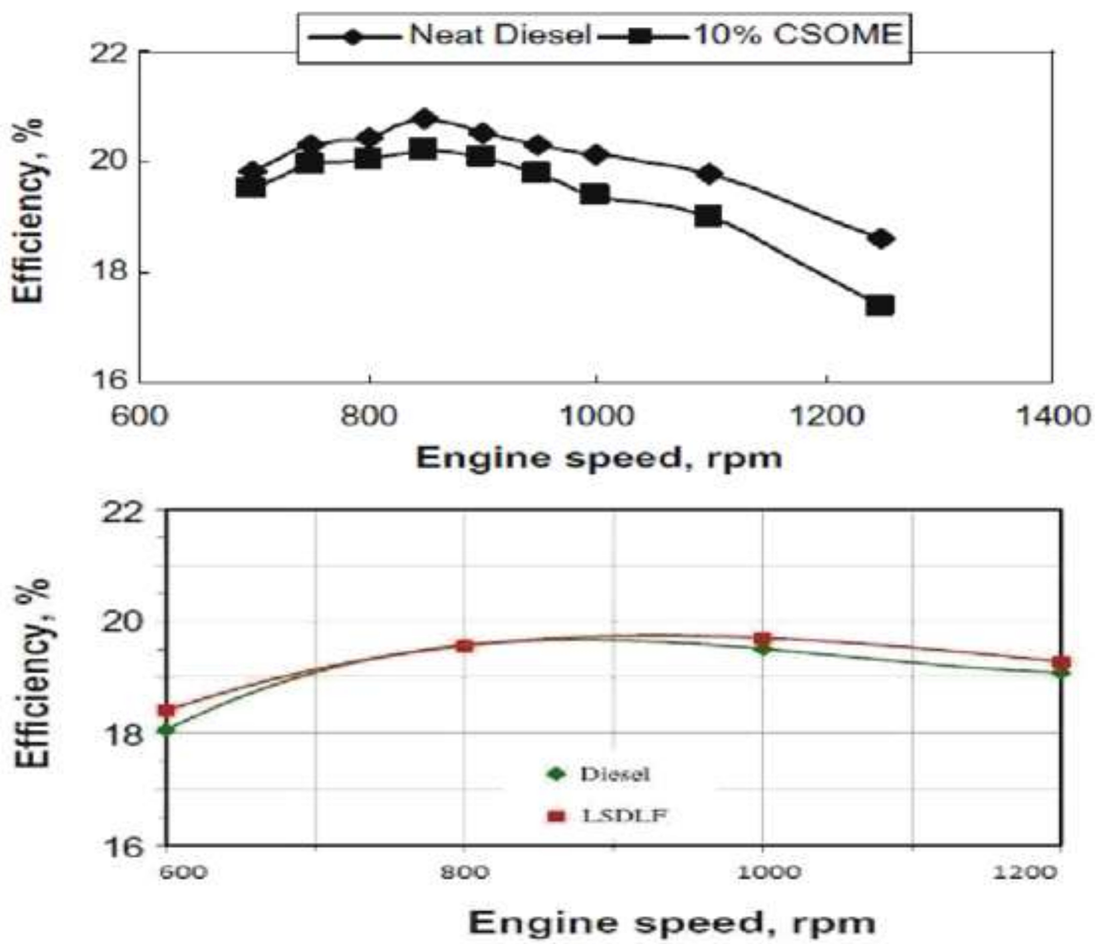


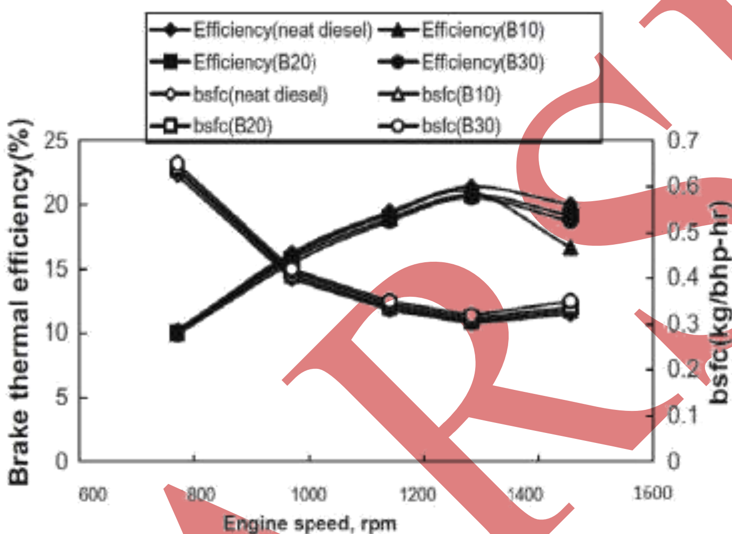
Fig 3. Comparison of break thermal efficiencies of biodiesel from CSO and LSDLF

5.1.2 Break Specific Fuel Consumption (BSFC) Vs Engine Speed

The amount of consumption is one of the major performance characteristic of the fuel. The BSFC is the ratio of the fuel consumption to the power of the engine, which shows the amount of fuel supplied to the engine per unit power production**.** The following figure, Fig 4 shows the comparison between BSFC of Biodiesel and LSDLF.

The BSFC curve has a higher value at low speeds, slightly levels of at higher speed and then again increases at higher speeds. At low speeds the heat loss to the combustion chamber walls is proportionately higher and combustion efficiencies higher resulting in larger fuel consumption. At the high speed the frictional power increases with a rapid rate, resulting in a slower decrease in break power with a consequent increase in BSFC.

It is very clear from the figure that the fuel consumption of the biodiesel is much higher compared with the commercial diesel. This is due to the fact that the biodiesel have a poor heating value when comparing with commercial diesel. SO we need more amount of biodiesel than the commercial diesel. It is one of the main drawback of the biodiesel form cotton seed oil (CSO).



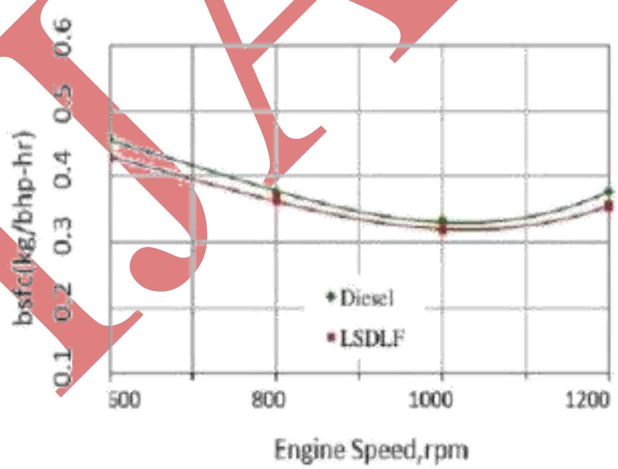


Fig 4. Comparison in BSFC of Biodiesel and LSDLF with engine speed

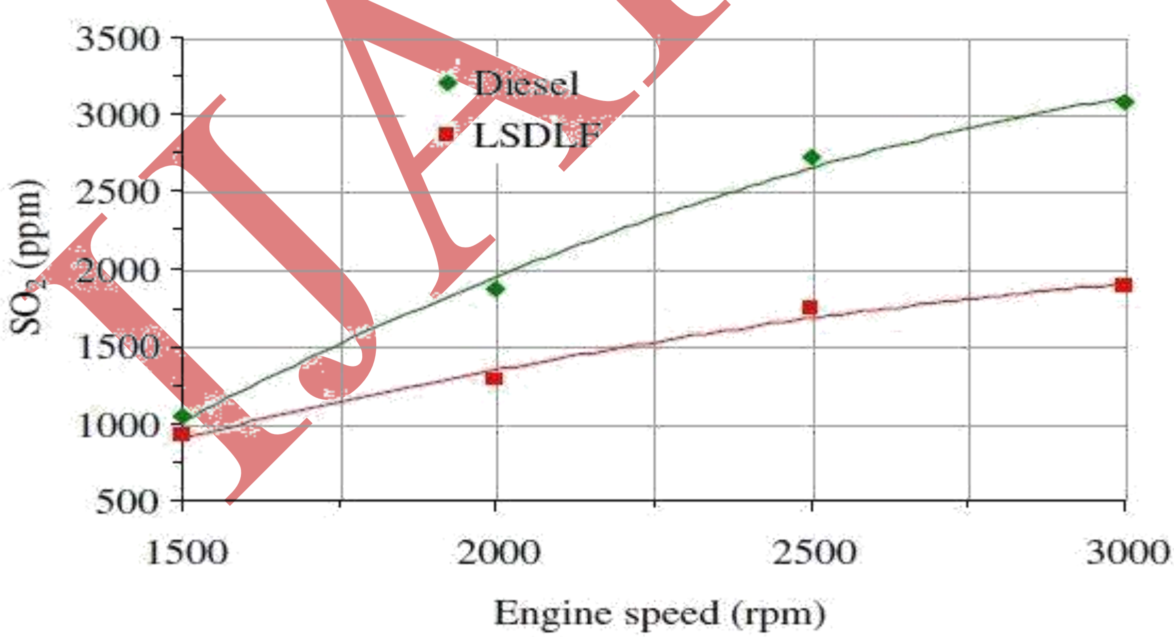
5.2 Emission Results

When a fuel is burnt in engine cylinders, some main compounds or substances can be exhausted from the engine. These substances like SO_2, NOx, hydrocarbons etc. will have adverse effect in the environment and combustion efficiency. In this study, the emission characteristics of the two fuels are compared by considering the SO_2 emissions and NOx emissions.

5.2.1 Comparison of SO2, emissions

SO2, values are of great importance in terms of energy and the environment. Therefore, it is necessary to decrease the sulphur amount of fuels to standard values. The comparison of SO2, emission from biodiesel blends and LSDLF is given in Fig 5.Different biodiesel blends are tested in the test engine and the SO2, produced from each of the blend is given in the data. As the Speed increases the amount of SO2, increased, which is followed by a decrease in its amount. When the engine runs at higher speed, the concentration of SO2, again increases. Thus it is clear that as the speed increases, the emission of SO2, increases.

At the rated speed of 2000 rpm, the Biodiesel blends have noticeable amount of SO2 emission Initially the SO2 emission is lower, but it increase as the speed increases . As the speed reaches above 2500 rpm, the amount of SO2 emission again falls. But after a short period it again increases. Thus we can conclude that the amount of SO2 emission from biodiesel from CSO is much higher.



When we consider the SO2 emission from LSDLF, as a result of the oxidative desulphurization method, sulphur amount of DLF is decreased to a value of 420 ppm, and it is named as LSDLF. It is seen from the figure that the SO2, values for the LSDLF are lower compared to those of biodiesel blends at rated speed of 2000 rpm.The result is normally expected results, because the amount of sulphur in LSDLF is lower than that of the diesel fuel.. This is positive effect on environment, because the lower SO2, gases release to the atmosphere decrease sulphuric acid (H2SO4) formation by reacting with water vapour in the atmosphere, and they harm all living things. The formation of H2SO4 will leads to acid rain, which will harm all the human life.

Thus we can conclude that the SO2, emission from LSDLF is quite lower than the biodiesel blends from cotton seed oils. The Oxidative desulphurization method (ODS), which is used in the production process of Low Sulphur Diesel like Fuel (LSDLF) results in the lower SO2 emission from LSDLF.

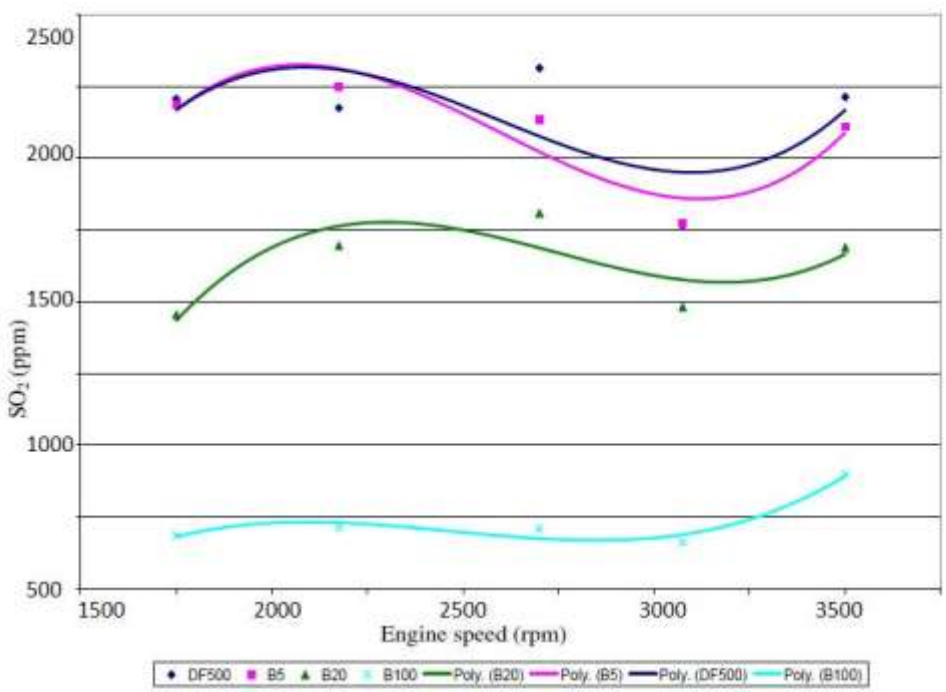


Fig 5. Comparison of emission of SO2 from Biodiesel and LSDLF with engine speed

5.2.2 NOx Emissions

The formation of the NOx highly depends on combustion temperatures, the oxygen concentration and residence time for the reaction to take place. It is considered that nitrogen (N2) and oxygen (O2) in the combustion chamber dissociate into their atomic states, and participate in a series of reactions at high combustion temperature.

A comparative study on the NOx emissions from the both fuels has been conducted and the results are given in figure 6. At rated speed, the NOx emission from the biodiesel blends are higher compared with LSDLF. This is due to the presence of extra oxygen present in the biodiesel molecules. This extra oxygen will leads to the formation of extra NOx emissions. Thus it is clear that the NOx emissions from biodiesel from cotton seed oil are higher than

LSDLF from WLO.

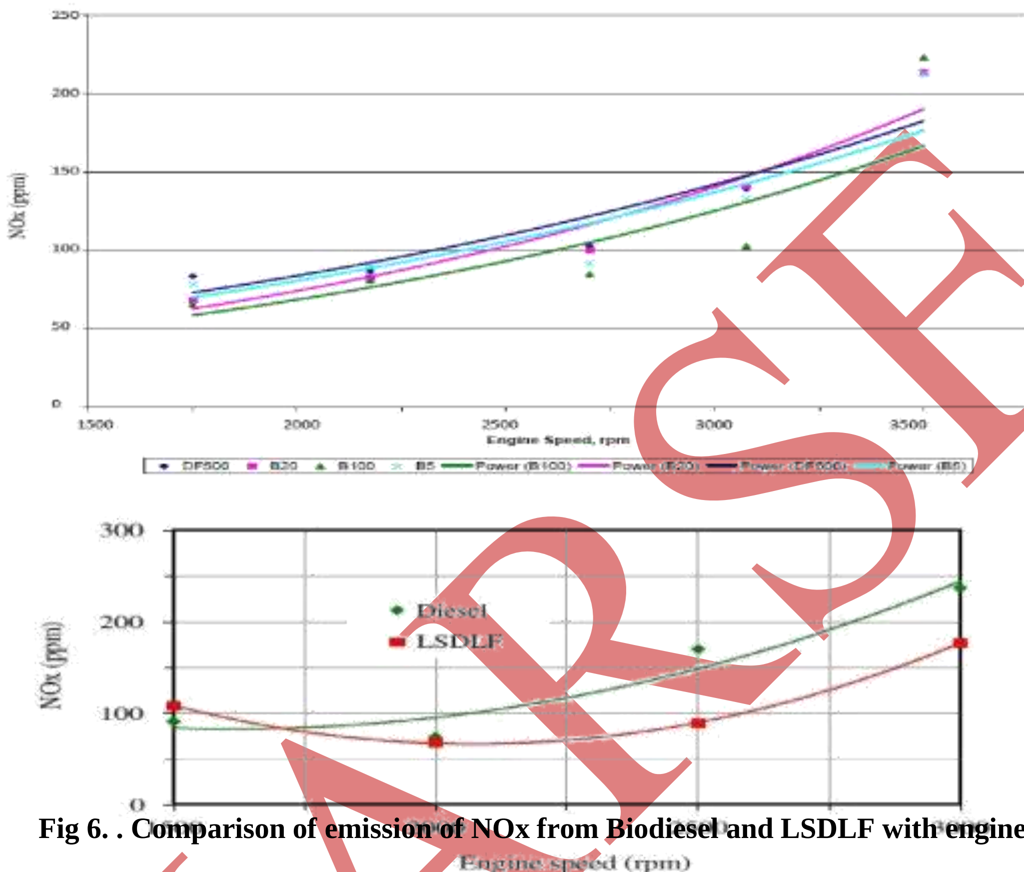


Fig 6. . Comparison of emission of NOx from Biodiesel and LSDLF with engine speed

VI CONCLUSIONS

The world is in dire need of cheap, efficient, alternative fuel source. We need a cheap, effective, reliable, efficient alternative fuel. Through this study we compare two alternative fuels, Biodiesel from Cotton Seed Oil (CSO) and Low Sulpher Diesel Like Fuel (LSDLF) from Waste Lubricating Oil (WLO) and we got the following conclusions.

- Biodiesel from cotton seed oil and LSDLF from WLO are two better alternatives for commercial diesel.
- Although the performance characteristics of both fuels are slightly similar, the Break Specific Fuel Consumption (BSFC) of engine is high, when it is running on biodiesel than running on LSDLF.
- On comparison it's clear that the emissions of SO2 and NOx from the biodiesel are larger when we compare with LSDLF.
- Thus from both performance and emission results of the two fuels, LSDLF have lesser fuel consumption, higher break thermal efficiency, lesser NOx emission problems than Biodiesel from Cotton Seed Oil (CSO).

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