Experimental investigation on performance, emission and combustion characteristics of a diesel engine powered by using biodiesel from waste cooking oil

S.Srinivasan[1],G.Sai Krishnan[2],K.Kanagaraja[3],M.R.Saroj Nitin[4]

[1,2,3,4]Department of Mechanical Engineering, Rajalakshmi Institute of Technology,

Chennai, Tamil Nadu, India

*Corresponding Author Email: g.saikrishnan@gmail.com

ABSTRACT

The present article investigates about the Extraction of biodiesel from waste cooking oil by using acidic ionic liquid as a catalyst. In this various properties have been investigated with the extracted waste cooking oil. One of the most important properties of waste cooking oil is that it generally contains more alkaline based catalysts which will be acting as a catalyst while carrying out Trans-Esterification Process. In the current Research work, a two-step process is carried out i.e. Esterification and trans Esterification .The ionic liquid butyl-methyl imidazolium hydrogensulfate (BMIMHSO4) was found to be effective due to its longer side chain. In this study, the performance and emission characteristics of biodiesel blends of 10,20 and 30 percentage were investigated and it is compared to diesel fuel, and found to be acceptable according to the ASTM D 6751 standards. The tests have been performed using an Kirslokar vertical six-cylinder diesel engine at different engine speeds, ranging from 1000 to 2000 rpm under full throttle load.. It was apparent that the fuel properties of biodiesel including density, kinematic viscosity and calorific value lie within the standards biodiesel properties. Biodiesel can make a major contribution in the future if it meets the few percent of petroleum and it can provide improved fuel properties lower emission of unburned hydrocarbons, carbon monoxide but higher level of oxides of nitrogen. In order to enhance the effectiveness of using waste cooking oil the tribological properties have been analysed in the engine .The waste cooking oil-based biodiesel can also be effectively used as an alternative without any engine modifications.

Keywords: Waste Cooking Oil, Bio Diesel, butyl-methyl imidazolium hydrogen sulfate Emission.

I. INTRODUCTION

There is a great deal of information and enthusiasm about the development and increased production of our global energy needs from alternative energy sources. Solar energy, wind power and moving water are all traditional sources of alternative energy that are making progress. The main reason for this is due to depletion of fossil fuels, and the another parameter is increasing demands for diesels and uncertainty in their availability is considered to be the important trigger for many initiatives to search for the alternative source of energy, which can supplement or replace fossil fuels. The Research was initiated by Rudolph et al in the year 1893 where he used pea nut oil as a source of bio diesel[1].Later in the upcoming years the researchers started focusing on the vegetable oils as a n altenative for the diesel fuel[2].

Oil production, oil seed processing and extraction also were considered in this meeting [2]. Vegetable oils hold promise as alternative fuels for diesel engines [3,4]. But their high viscosities, low volatilities and poor cold flow properties have led to the investigation of various derivatives. Fatty acid methyl esters, known as Biodiesel, derived from triglycerides by transesterification with methanol have received the most attention [5,6]. The automobile is a very important requirement for the current scenario. Diesel engines are predominately used because of its high persistence and thermal efficiency that uses conventional diesel as its fuel.

The problem is fossil fuels are non-renewable. They are limited in supply and will one day be depleted. There is no escaping this conclusion. Fossil fuels formed from plants and animals that lived hundreds of millions of years ago and became buried way underneath the Earth's surface where their remains collectively transformed into the combustible materials we use for fuel . There are many materials or substances that can be used as fuels other than conventional fuels like fossil fuels like petroleum, coal and natural gas as well as nuclear materials such as uranium, thorium and artificial radioisotope fuels that are made in nuclear reactors .Thus biodiesel will be a possible solution for such problems. Biodiesel has the vital advantages of abundant source, eco friendly, cheap, good engine tribological characteristics. Bio diesels are mainly obtained from ethanol, but there needs more catalyst and possesses some environmental issues that led to the usage edible oils, waste oils, vegetable oils. Vegetable oils are abundant sources due to the many sources available; it has long chain carbon structure resulting in good ignition[1,2]. There many researchers worked in vegetable oils, namely mahuma oil, rapeseed oil, fish oil, etc., these oils can be used directly through blending and other processes. However, due to usage of these vegetable oils many glitches occurred leading to long term issues resulting in the malfunction of engine lubricating oil due to polymerization [3]. The viscosity level of these oils is the main reasons for all foresaid issues, which is 30 to 60 cSt at 40°C while it is 3 to 4 cSt for diesel at the same temperature. In order to decrease the viscosity of vegetable oils, four main techniques, namely gasification dilution (blending), micro-emulsion, and transesterification are employed [4-7]. Seyed et al.[8] investigated about performance and emission charactericts of disel engine fueled by synthesized non-edible rapeseed oil. Ramadhas et al. [9] identified the problems of using vegetable oils in compression ignition engine and concluded that owing to high viscosity and volatility vegetable oils possess some serious problems in compression ignition engine that leads to decrease the efficiency that could be reduced due to transesterification. Thiyagarajan et al. [10] investigated about the various emissions that are coming out of the usage of biodiesel in the engine. It was concluded that the percentage of emissions from exhaust gas could be easily reduced by incorporating biodiesel oil to the conventional diesel. Deepak agarwal et al. [11] reviewed about the production, combustion, emission and performance characteristics of biodiesel. It was cleared stated that vegetable oils blended with diesel prevents the engine failure reduces wear of the piston and the combustion characteristics. Owing to this many new plants have been opened in many European countries from the last decade, for example: Czech Republic, Germany and Sweden. Experiments with 50% biodiesel fuel are underway. Countries in other parts of the world also witnessed the local production of biodiesel starting up.

2.MATERIALS AND METHODS

Food waste was taken from restaurants, household waste and roadside shop waste. The food waste is first crushed and the oil obtained is heated at high-temperature boiling, waste oil was used as raw material for biodiesel production. The component analysis showed that waste cooking oil was mainly consists of protein, fat and cellulos, thus it could be selected as a suitable material for biodiesel production due to the high carbon content and abundant nutrient. The waste oil is first screened to eliminate suspended solid impurities, then added dilute sulphuric acid for to remove phospholipids which remained in the waste oil (Degumming). By using dilute sodium hydroxide solution to remove free fatty acids, the waste oil was water-washed to bring it to neutral condition. Activated clay with 5% dosage (mass/mass of oil) was added at 100 °C to bleach it, dehydration or vacuum distillation the waste oil. The oil colour was dark brown, containing a small amount of impurities, bad odour. The oil is allowed to cool.

Fatty acid Waste cooking oil (%)

Saturated fatty acid	Percentage present in waste cooking oil (%)	Formula
Heneicosanoic acid	0.074	$C_{21}H_{42}O_2$
Cis-11-Eicosenoic acid	0.166	$C_{20}H_{38}O_2$
Linolenic acid	0.24	$C_{18}H_{30}O_2$
c-Linolenic acid	0.33	$C_{18}H_{30}O_2$
Linoleic acid	11.45	$C_{18}H_{32}O_2$
Oleic acid	43.65	$C_{18}H_{34}O_2$
Stearic acid	4.35	$C_{18}H_{36}O_2$
Palmitic acid	38.32	$C_{16}H_{32}O_2$
Lauric acid	0.37	$C_{12}H_{24}O_2$
Myristic acid	1.05	$C_{14}H_{28}O_2$
TOTAL	100	

Three blends of fuel were tested

1. Conventional diesel blend (100% conventional diesel, 0% biodiesel),

2. B 10 (90% conventional diesel, 10% biodiesel),

3. B 20 (80% conventional diesel, 20% biodiesel)

Collection of waste cooking oil

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Pre processing the oil

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Synthesis of oil

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Post processing of oil

↓

Performance and emission testing

3. SYNTHESIS OF WASTE COOKING OIL

The Transesterification is the process of interchanging the organic group R″ of an ester with the organic group R′ of an alcohol. The reactions are often carried out in the presence of acid/base catalyst. The reaction can also be conducted with the help of enzymes (biocatalysts) particularly when we analyze chemically, the transesterified biodiesel is a mixture of mono-alkyl esters (long chain fatty acids). The fatty acid ethyl Esters are used in this process, The Ethyl Esters are often called as fatty acid ethyl esters. This process removes the glycerin from the waste cooking oil or fat and the byproducts left behind include ethyl esters and glycerin. Biodiesel fuel is free from such substances as sulphur and aromatics, which are found in traditional fuels. At this stage of biodiesel fuel production, biodiesel attains combustion properties which are very similar to those of petroleum diesel**.** The waste oil is taken in a three-necked flask. The condenser tub,thermometer, stirrer respectively. Ethanol was used as the raw material and ionic liquid butyl-methyl imidazolium hydrogensulfate (BMIMHSO4) as the catalyst for transesterification. The oil is mixed with the mixture ethanol and BMIMHSO4, in order to carry out transesterification process .The amount of ethanol and potassium hydroxide to be mixed is found by titrating lime water against 10ml 91%isopropyl alcohol and 1ml of waste cooking oil, phenolphthalein is used as the indicator. It was found that the normality was 2, and we added 9 grams of ionic liquid butyl-methyl imidazolium hydrogensulfate (BMIMHSO4). Before Transesterification reaction, suspended food particles and residual carbon in waste cooking oil is filtered using fine filters. The filtered waste cooking oil was poured into the chemical reactor and then heated to 60^0C. From titration the value of BMIMHSO4 to be dissolved in ethanol is found and the solution poured into the reactor containing waste cooking oil at 60^0C. The mixture was stirred continuously for about 1 hour and 30 minutes while maintaining the temperature with the help of temperature monitors. After transesterification, the mixture was allowed to settle for about 8 hours. The esterification product was taken into a glass vessel, the upper liquid is biodiesel and the bottom liquid is glycerol. Then the biodiesel was separated from glycerol by separating funnel and finally washed with 5% water followed by drying under the sun to remove the residual water content. Then the raw biodiesel was washed in hot water remove soap and catalyst before drying. The liquid was light yellow transparent oily liquid with ester flavor.

4. ENGINE SPECIFICATION

KILOSKAR ENGINE	
Type	Four stroke, single cylinder vertical air cooled diesel engine
Rated power	4.4 KW
Rated speed	1500 rpm
Bore diameter (D)	87.5 mm
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Stroke (L)	110 mm
Compression ratio	17.5:1
Orifice diameter	29.6mm
Coefficient of discharge (C_d)	0.6
Calorific value of fuel	42,500 KJ/Kg
Density of diesel	860 kg/m^3

AVL PRESSURE TRANSDUCER GH14D/AH01	
Sensitivity	18.99 pC/bar
Linearity	<± 0.3 %
Mean range	250 bar
Temperature range	400ºC
Natural frequency	115 KHZ

5. RESULTS AND DISCUSSION:

5.1. Properties of the prepared biodiesel

The properties of waste cooking oil Bio diesel Viscosity, Density, Flash point, Fire Point and calorific value is given below.

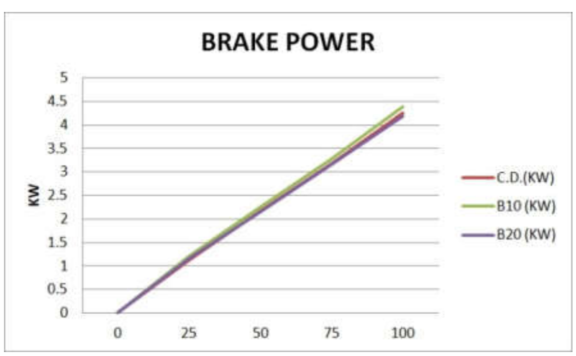
Parameter	Value
Calorific value	36,640.63 KJ/Kg
Density	920 Kg/m^3
Viscosity	4.4 cstokes
Flash point	175 º c
Fire point	178 º c

5.2 Performance properties of the diesel engine

The various performance properties such as brake power, indicated power, total fuel consumption, specific fuel consumption, mechanical efficiency and brake thermal efficiency are discussed below.

5.2.1 Brake power (KW)

Brake power of the engine without considering loss in power caused by the gearbox, generator, differential, water pump and other auxiliaries.

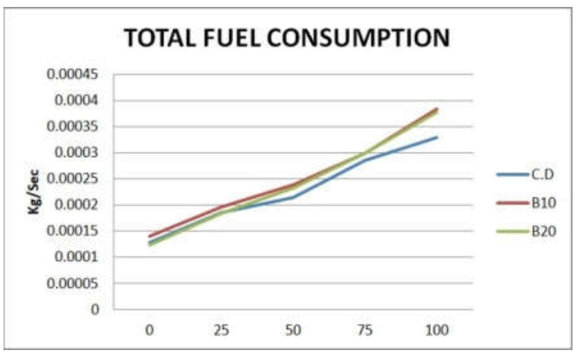


5.2.2 Indicator power (KW)

Indicator power is the power obtained at the output shaft, considering the losses in the engine by driving the rotating masses of the engine.

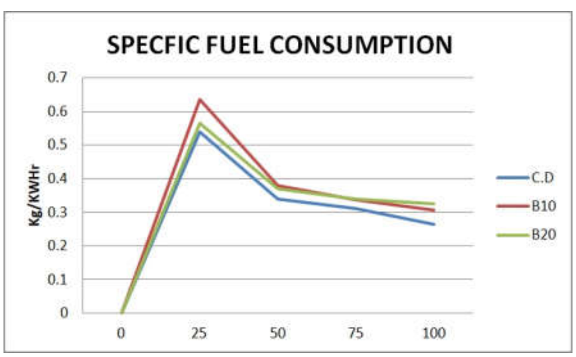
5.2.3 Total fuel consumption

Total fuel consumption is the amount of fuel consumed for travelling certain distance



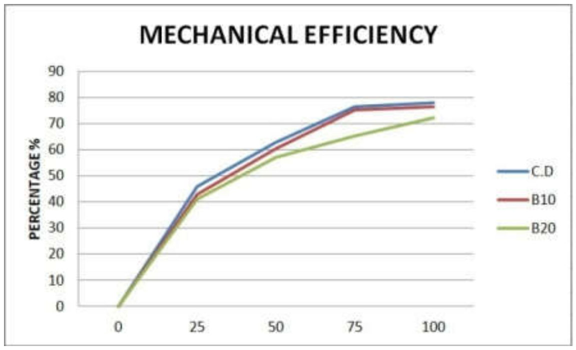
5.2.4 Specific fuel consumption

Specific fuel consumption is the fuel efficiency of the engine with respect to thrust output



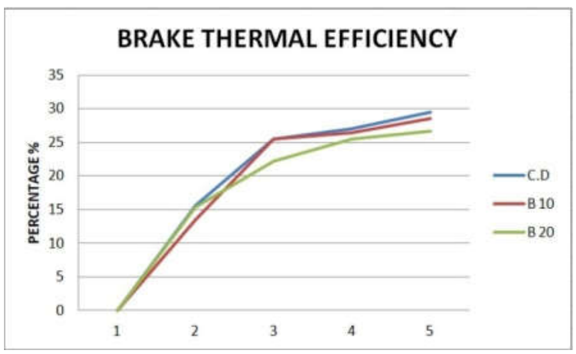
5.2.5 Mechanical efficiency

Mechanical efficiency measures the efficiency of a machine in transforming the input energy to output power.



5.2.6 Brake thermal efficiency

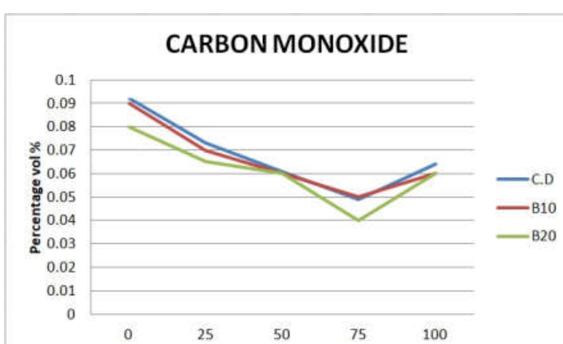
Brake Thermal Efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. It is commonly used to evaluate effectiveness of an engine which converts the heat from a fuel to mechanical energy.



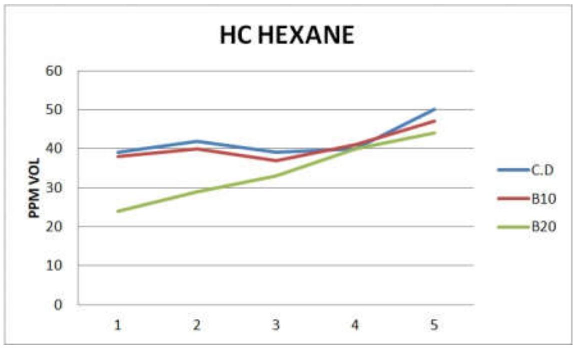
5.3 Emission result of diesel engine

The various gases which are emitted from a diesel engine are carbon monoxide (CO), hydro carbon (HC), carbon dioxide (CO_2), oxygen (O_2) and oxides of nitrogen (NO_x). The amount of these gases emitted by the engine is analyzed

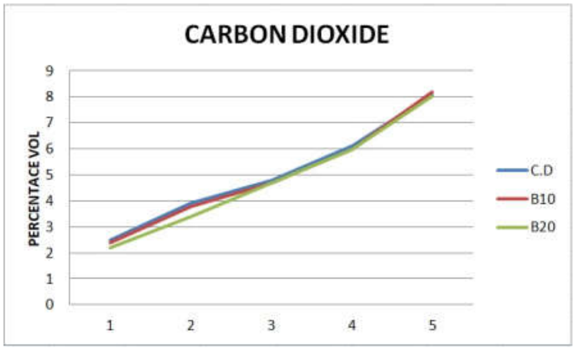
5.3.1 Carbon monoxide (CO)



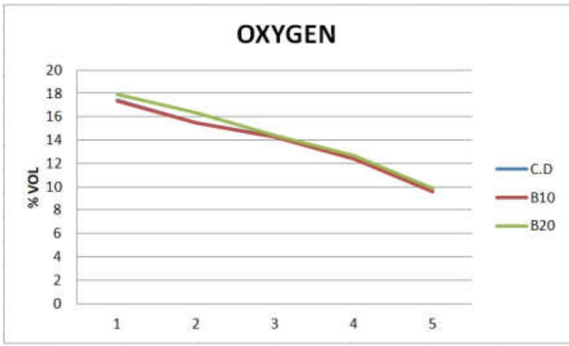
5.3.2 Hydro carbon (HC)



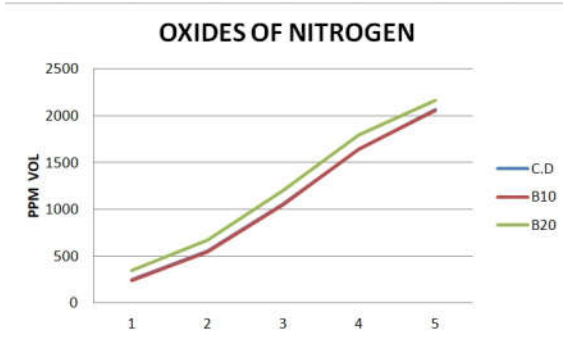
5.3.3 Carbon dioxide (CO_2)



5.3.4 Oxygen (O_2)



oxides of nitrogen (NO_x)



The amount of these gases emitted by the engine is analyzed

4. CONCLUSIONS

The performance and emission characteristics of diesel engine powered by biodiesel from waste cooking oil is carried out. The preparation process and result obtained were discussed in a detailed manner. Diesel engine was selected to carry out the experiment. The comparative studies of conventional diesel, B10, B20 were made. Based on the results obtained the followings conclusions are derived.

The limits specified by the ASTM D 6751-02 is found to be ideal for the Neem oil fuel and performed well within the limit.

On comparison with conventional diesel, all the properties except heating value were found to be higher for Neem oil.

Above findings, make sense that the biodiesel obtained from Neem oil can be effectively used as an alternative for conventional diesel.

The Damages in the Piston Wear can be reduced considerably by using the Neem oil Bio Diesel.

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