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To Study of Vegetable Oils and Their Effects on Diesel Engine Performance

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Abstract- The rapid increasing the industrialization, motorization, in the world has remarkably raised the demand of the petroleum products. The reservations of such a petroleum based fuels are limited in the world. Furthermore, they are exhaustible and cost is rapidly increasing day to day. For those countries having not ability of petroleum recourses, are importing the petroleum fuels. So, it is quit necessary to focus on an alternative fuels which can be derived from the material available in the country. This paper reviews the combustion parameter and exhaust emission characterizes of different bio-fuels such as plastic oil, cocking oil, rubber seed oil, palm bio-diesel, ethanol etc. the paper also reviews the experimental works carried out in various countries in this field and scope, challenges being faced in this area of research are clearly described.

Index Terms- Alternative fuel; Vegetable oil; Bio-diesel; Renewable energy.

I. Introduction

In recent time, the world is facing problems with energy crises due to depletion of conventional energy sources and increase environmental problems. This situation has led to the search for an alternative energy resources, which should be not only in exhaustible but also less harmful to environment. For developing countries, fuels of bio origin such alcohol, vegetable oils, bio-mass, bio-gas, synthetic fuels etc. are becoming most popular. Such fuels can be used directly, while others need some modification before they are used as fuel. And also by the application of the bio-fuels the harmful emission from engine such as CO, SO2, soot, hydro carbon, etc. can be controlled.Increasing air pollution is the most important problems of developed countries today.Exhaust emission from motor vehicle have a main role in this pollution. It is not enough to change the design of engine of vehicle to cope with the legal regulation, so it is quit necessary to focus on alternative fuels. These alternative fuels can be produced from renewable energy sources such as sugar-cane, cassava, jetropha, karanja, soybean oil, sunflower oil, cotton seed oil, ground nut oil, sesame oil, palm kernels oil, castor oil.Furthermore bio-fuels have some advantages' over petroleum fuels, such as the reduction CO and hydro carbon emissions and well antiknock performance, which allow the use of higher compression ratio of engines. And also self -ignition temperature and fleshing point of bio-fuel are higher than those of petroleum fuels.
Due to low evaporation losses it safer for transportation and storage. Many researchers have been conclude that with the use of bio-fuels as a fuel in engines a reduction in harmful emissions as well as a comparable engine
Performance with petroleum fuels can be possible.Performance parameter such as specific fuel consumption, thermal efficiency, break power, ignition qualities, viscosity, torque, etc. can be comparable.

II. Production and Usage of Bio-Diesel

Many standardized procedures are available for the production of bio-diesel fuel oil. The commonly used methods for bio-fuel production are elaborated onbelow.

A. Blending

Vegetable oil can be directly mixed with diesel fuel and may be used for runningan engine. The blending ofvegetable oil with diesel fuel were experimented success-fully by various researchers. A diesel fleet was powered with a blend of 95% filteredused cooking oil and 5% diesel in 1982. In 1980, Caterpillar Brazil Company usedpre-combustion chamber engines with a mixture of10% vegetable oil to maintaintotal power without any modification to the engine. A blend of20% oil and 80%diesel was found to be successful[2]. It has been proved that the use of100% vegetable oil was also possible with some minor modifications in the fuelsystem. Thehigh fuel caused the major problems associated with the use of pure vegetable oilsas fuel viscosity in compression ignition engines. Micro-emulsification, pyrolysisand trans esterification are the remedies used to solve the problems encountered dueto high fuel viscosity.

B. Micro emulsification

To solve the problem ofhigh viscosity ofvegetable oil, micro emulsions withsolvents such as methanol, ethanol and butanol have been used. A micro emulsionis defined as the colloidal equilibrium dispersion of optically isotropic fluidmicrostructures with dimensions generally in the range of1–150 mm formedspontaneously from two normally immiscible liquids and one or more ionic ornon-ionic amphiphiles. These can improve spray characteristics by explosive vaporization ofthe low boiling constituents in the micelles. All micro emulsions withbutanol, hexanol and octanol will meet the maximum viscosity limitation for dieselengines. Czerwinski[3] prepared emulsion of53% sun flower oil, 13.3% ethanoland 33.4% butanol. This emulsion had a viscosity of6.3 centistokes at 40℃, acetane number of25. Lower viscosities and better spray patterns were observedwith an increase in the percentage ofbutanol.

C. *Cracking*

Cracking is the process ofconversion ofone substance into another by means ofheat or with the aid ofcatalyst. It involves heating in the absence ofair or oxygenand cleavage ofchemical bonds to yield small molecules. The pyrolyzed materialcan be vegetable oils, animal fats, natural fatty acids and methyl esters of fattyacids. The pyrolysis of fats has been investigated for more than 100 years, especially in those areas ofthe world that lack deposits ofpetroleum [4].SinceWorld War I, many investigators have studied the pyrolysis ofvegetable oil toobtain products suitable for engine fuel application. Tung oil was saponified withlime and then thermally cracked to yield crude oil, which was refined to producediesel fuel and small amounts of gasoline and kerosene.

D. Transesterification

Transesterification is otherwise known as alcoholysis. It is the reaction of fatoroil with an alcohol to form esters and glycerin. A catalyst is used to improve the reaction rate and yield[5].

Among the alcohols, methanol and ethanol are used commercially because of their low cost and their physical and chemical advantages. They quickly react with tri-glycosides and NaOH and are easily dissolved in them. To complete a transesterification process, 3:1 molar ratio ofalcohol is needed. Enzymes, alkalis or acids can catalyze the reaction, i.e. lipases, NaOH and sulphuric acid, respectively. Among these, alkali transesterification is faster and hence it is used commercially.
A mixture ofvegetable oil and sodium hydroxide (used as catalyst) are heatedand maintained at 65℃ for 1 h, while the solution is continuously stirred. Twodistinctlayers are formed, the lower layer is glycerin and the upper layer is ester.The upper layer (ester) is separated and moisture is removed from the esterby using calcium chloride. It is observed that 90% ester can be obtained fromTable 1[26].
Yield ofmethyl esters of vegetable oils by transest--erification processvegetable oils.

Table 1: The percentage yield (by weight) of some common vegetable oil methyl esters.

Temp-erature (K)	**Sunflower oil(%)**	**Corn oil (%)**	**Cotton oil (%)**	**Soyabean oil (%)**
620	79.6	80.5	82.3	84.2
630	93.6	95.8	96.5	96.8
640	96.8	97.2	97.6	97.9

III. PROPERTIES OF DIFFERENT VEGETABLE OILS [7]

Fuel type	**Calorific value (kj/kg)**	**Density (kg/m^3)**	**Viscosity at 27℃ (mm^2/s)**	**Cetane No.**
Diesel	43,350	815	4.3	47.0
Sun-flower oil	39,525	918	58.5	37.1
Sun flower methyl ester	40,579	878	10.3	45.5
Cotton seed oil	39,648	912	50.1	48.1
Cotton seed methyl ester	40,580	874	11.1	45.5
Soybean oil	39,623	914	65.4	38.0
Soybean methyl ester	39,760	872	11.1	37.0
Corn oil	37,825	915	46.3	37.6

IV. EXPERIMENT

A large number of experiments were carried out with vegetable oils as a replacement of I.C. engine fuel by researchers from various parts of the world. Most of these experiments were reported from US, Europe, India, Malaysia and Germany. A summary of these experimental results is given below.
Christopher et al.[8]conducted two tests in Chicago using bio-diesel as an alternative fuel for in-service motor coaches. This was an exploratory investigation to determine the effect of fuel on the engine performance characteristics and infra- structure needed to use this fuel. The testing proved that the bio-diesel could be used as a feasible alternative fuel. Montagu [9]conducted experiments by using rapeseed oil in diesel engines. The introduction of 5% of RME led to a reduction in the volumetric efficiency around 0.4%. It has been reported that, even after a 71,50,000 km run by vehicles no abnormal aging was observed. The increase in NOx and decrease in HC were detected. The increase of noise and smoke level occurrence during cold start was also noted.
The Ministry of Research and Technology in the Federal Republic of Germany, is promoting the use of agricultural raw material. In Germany, rapeseed oil was analyzed and found to be one of the major agricultural renewable materials. Hammerstein et al. [10]conducted experiments on naturally aspirated exhaust gas turbo- charged air cooled and water cooled engines using rapeseed oil. Experiments were conducted using filtered rapeseed oil. It has been reported that the brake power and torque using rapeseed oil as fuel are 2% lower than that of diesel. The heat release rate is very similar for both fuels. With all the engines tested, maximum brake power was obtained with rapeseed oil. Also, lower mechanical stresses and lower combustion noise were observed. The emission of CO and HC are higher, whereas NOx and particulate emission were lower in comparison with diesel fuel.
Tadashi et al [11], evaluated the feasibility of rapeseed oil and palm oil for diesel fuel in a naturally aspirated direct injection diesel engine. It was found that vegetable oil fuels gave an

acceptable engine performance and exhaust emission levels for short-term operation. However, they caused carbon deposit buildups and sticking of piston rings with extended operation.

Chio[12]conducted tests on bio-diesel blended with diesel fuel in the concentration of 20 and 40% by volume on a single cylinder caterpillar engine, using both single and multiple injection strategies. At high loads using single injection, particulate and CO emissions were decreased. A slight increase in NOx was noticed as the bio-diesel concentration increased. But in the case of multiple-injection, a decrease in particulate emission was observed with little or no effect on NOx. At low loads, addition of bio-diesel and multiple injection schemes were found to be detrimental to particulate matter and CO emission. Rapeseed oil esters are mixed with diesel and performance and emission characteristics studied by Peter[13]. This study has shown that there was a reduction in emissions when rapeseed oil was used as fuel.

A turbocharged diesel engine has been tested under steady state conditions to investigate the combustion characteristics of the blends of methyl isopropyl and methyl esters of soyabean oil with diesel. All the fuel blends revealed a significant emission reduction of CO, HC, particulate matter and solid carbon with similar engine performance. All ester blends experienced shorted ignition delay under both 100 and 20% load engine conditions.

Ghormade et al.[14] Used Soyabean oil as fuel to run a compression ignition engine. He found that there was only a slight variation in part loads efficiency. And there was no improvement in brake specific fuel consumption by blending.

Pangavhane et al.[15] conducted experiments by using soyabean oil in diesel engines. From the experiments it was reported that CO emissions and HC emissions reduced by 21 and 47%, respectively. However, NOx was found to increase with load.

Jacobus et al.[16]conducted trials on four vegetable oils, namely sunflower, cottonseed, soyabean oil and peanut oil blend with diesel. They compared the engine performance and emission characteristics and reported that all the oils provided almost similar characteristics.

Mariusz et al.[17]conducted experiments on sunflower oil and recommended incorporating dual fuel pre-heater for durability improvements of diesel engines. The durability of the engine increased through the prevention of engine operation at low load and low speed conditions, reduced exposure time of fuel injection sys- tem at very high temperature conditions during transition process from high to light loads and elimination of fuel injection of oil during shut down period.Samagaoperated a single cylinder water-cooled dual fuel engine using sunflower oil and groundnut oil. The performance characteristics obtained are comparable to that of diesel. He suggested some remedies to the practical problems encountered in the dual fuel operation of I.C. engines. Periodic cleaning of the nozzle tip is necessary to ensure adequate spray characteristics. Starting and stopping with diesel oil while running with vegetable oil eliminates filter clogging. Bio-diesel produced from vegetable oil is of higher unsaturated fatty acids and bio-diesel from animal fats is of higher content in saturated fatty acids. Kelvin et al.[18]attempted to identify the mechanism for bio-diesel emission reduction and engine performance by blending. He concluded that bio-diesel's particulate reducing effect could be attributed to its displacement of aromatic and short chain paraffin hydrocarbon and its oxygen content.

Barsic et al.[19]conducted experiments using 100% sunflower oil, 100% peanut oil, 50% of sunflower oil with diesel and 50% of peanut oil with diesel. A comparison of the engine performance was presented. The results showed that there was an increase in power and emissions. In another study, Rosa et al.[20]used sunflower oil to run the engine and it was reported that it performed well. Blends of sunflower oil with diesel and sunflower oil with diesel were used by Zeiejerdki et al.[21]for his experimentation. He demonstrated the least square regression procedure to analyze the long-term effect of alternative fuel and I.C. engine performance.

Dynamometer tests have been carried out by Masjuki et al.[22] to evaluate the performance, emission and wear characteristics of an indirect diesel engine fueled by blends of coconut oil and diesel fuel. The performance and emission characteristics results showed that 10-30% coconut oil blends produced a slightly higher performance in terms of brake power than that of diesel. All the coconut oil blends produced lower exhaust emissions including polycyclic aromatic hydrocarbons and particulate matter. The wear and lubricating oil characteristics results showed that coconut oil blends up to 30% produced similar results to that of diesel.

In India, karanja oil was experimented for analyzing its performance characteristics by SrinivasanRao[23],Karanja oil was found to give a better performance compared to that of diesel. Senthil Kumar etal.conducted experiments by blending jatropha oil with diesel. It has been reported that exhaust gas temperature, smoke, HC and CO are higher compared to diesel. Deshpande[24]used blends of linseed oil and diesel to run the CI engine. Minimum smoke and maximum brake thermal efficiency were reported in this study.

Masjuki et al.[25]used preheated palm oil to run a compression ignition engine.Preheating reduced the viscosity of fuel and hence better spray and atomization characteristics were obtained. Torque, brake power, specific fuel consumption, exhaust emission and brake thermal efficiency were found to be comparable to that of diesel.

Recently experimental investigations are carried out in a single cylinder DI diesel engine to examine the suitability of different vegetable oils such as Neem, Mahua, Linseed and Castor as alternate fuels.

Smoke emission of Castor and Mahua followed byNeem is lower compared with other oils. For Linseedoil smoke emission is on higher side for entire rangeof operation[27].

V. ENGINE PERFORMANCE COMPARISON

Recap et al.[7]ran a single cylinder engine with various types of vegetable oils. Some of the results obtained by them are presented here in the form of bar charts (Figs. 1-6)[26].

The engine was operated at 1300 rpm. Diesel fuel performance was used as reference. The observed maximum torque differences between the reference value and peak values of the vegetable oil fuels were about 10% obtained with that of raw sunflower oil, raw soyabean oil and opium poppy oil fuels Fig.1 [26].The maximum power differences between the reference value and peak values of the vegetable oil fuels were about 18% obtained with raw cottonseed oil and raw soyabean oil fuels

Fig.2 [26]. The minimum torque and power difference was about 3% between reference value and oils. These results may be due to the higher viscosity and lower heating values of vegetable oils.

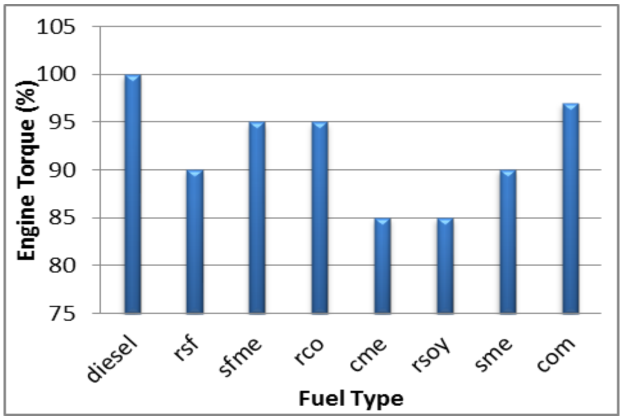

Fig.1 Maximum engine torque obtained at 1300 rpm.

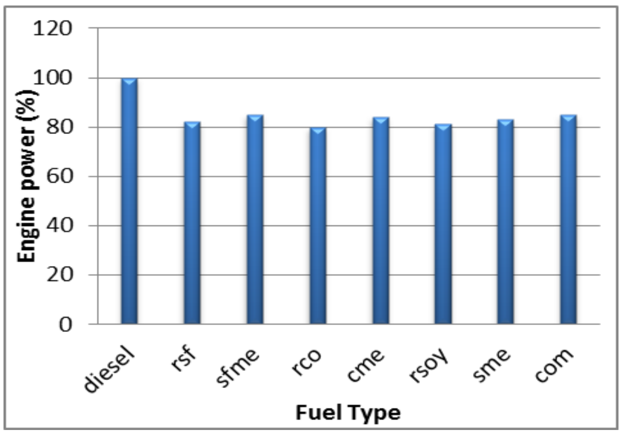

Fig.2. Maximum engine power obtained at 1300 rpm.

The specific fuel consumption of diesel was very low in comparison with all vegetable oils and their esters. Specific fuel consumption values of methyl esters were generally less than those of the raw oil fuels.

The higher specific fuel consumption values of vegetable oils are due to their lower energy content Fig.3 [26].

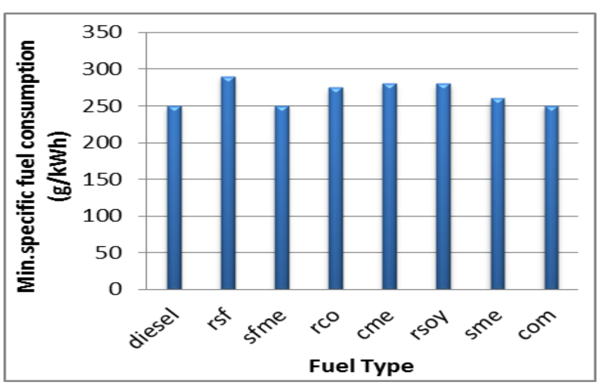

Fig.3Minimum specific fuel consumption at 1300 rpm.

Relatively low CO emissions were obtained with the esters in comparison with raw vegetable oils Fig.4 [26]. Maximum CO2 emissions were about 10.5% with diesel fuel and slightly lower with vegetable oil. It was due to better spraying qualities and more uniform mixture preparation of these esters Fig.5 [26]. NOx emissions withvegetable oil fuels were lower than those with diesel fuel and NOx values of methyl esters were higher than those of raw fuels. NOx formation was due to maximum combustion temperatures. Since the injected particle size of the vegetable oils were greater than those of diesel fuel, the combustion efficiency and maximum combustion temperatures with each of the vegetable oils were lower and NOx emissions were less Fig.6 [26].

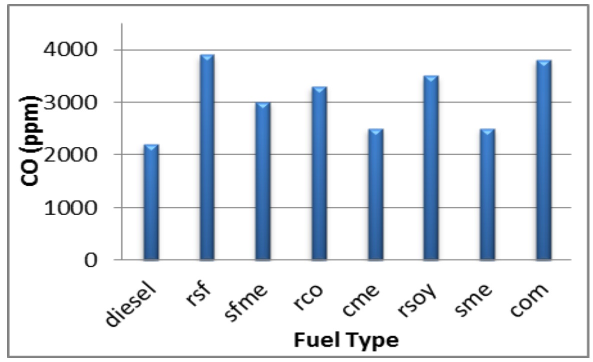

Fig. 4.CO emission at 1300 rpm (engine torque ¼ 35N-m).

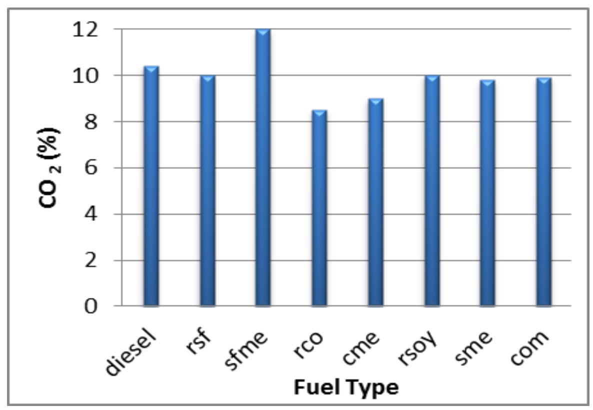

Fig.5 CO_2 emissions at 1300 rpm (engine torque ¼ 35 N-m).

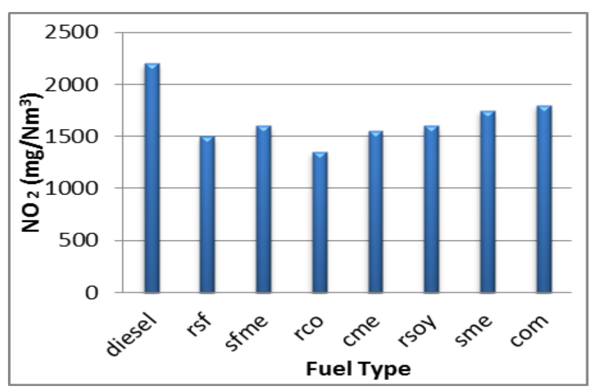

Fig.6. NO2 emissions at 1300 rpm (engine torque ¼ 35 N-m).

VI. ADVANTAGES

The following are some of the advantages of using vegetable oil as I.C. engine in India:

1. Vegetable oil is produced domestically which helps to reduce costly petroleum imports;
2. Development of the bio-diesel industry would strengthen the domestic, and particularly the rural, agricultural economy of agricultural based countries like India;
3. It is biodegradable and non-toxic;
4. It is a renewable fuel that can be made from agricultural crops and or other feed stocks that are considered as waste;
5. It has 80% heating value compared to that of diesel;
6. It contains low aromatics;
7. It has a reasonable cetane number and hence possesses less knocking tendency;
8. Low sulpher content and hence environment friendly;
9. Enhanced lubricity, thereby no major modification is required in the engine;
10. Personal safety is improved (flash point is 100°C higher than that of diesel);
11. It is usable within the existing petroleum diesel infrastructure (with minor or no modification in the engine).

VII. CHALLENGES

The major challenges that face the use of vegetable oil as I.C. engine fuels are listed below:

1. The price of vegetable oil is dependent on the feed stock price;
2. Feed stock homogeneity, consistency and reliability are questionable;
3. Homogeneity of the product depends on the supplier, feed stocks and production methods;
4. Storage and handling is difficult (particularly stability in long term storage);
5. Flash point in blends is unreliable;
6. Compatibility with I.C. engine material needs to be studied further;
7. Cold weather operation of the engine is not easy with vegetable oils;
8. Acceptances by engine manufacturers are another major difficulty;
9. Continuous availability of the vegetable oils needs to be assured before embarking on the major use of it in I.C. engines.

VIII. TECHNICAL DIFFICULTIES

The major technical areas (with respect to the use of vegetable oils as fuels in I.C. engines), which need further attention are the following:

1. Development of less expensive quality tests;
2. Study of the effects of oxidized fuel on engine performance and its durability;
3. Co-product development like the recovery of glycerol at reduced cost;
4. Continued engine performance, emissions and durability testing in a variety of engine types and sizes need to be developed to increase consumer and manufacturer confidence;
5. Studies are needed to reduce the production cost, develop low cost feed stocks and identify potential markets in order to balance cost and avail ability;
6. Research on the effect of glycerol on engine durability, emission and material compatibility;
7. Development of additives for improving cold flow properties, material compatibility and prevention of oxidation in storage, etc.

IX. CONCLUSION

Researchers in various countries carried out many experimental works using vegetable oils as I.C. engine fuel substitutes. These results showed that thermal efficiency was comparable to that of diesel with small amounts of power loss while using vegetable oils. The particulate emissions of vegetable oils are higher than that of diesel fuel with a reduction in NOx. Vegetable oil methyl esters gave performance and emission characteristics comparable to that of diesel. Hence, they may be considered as diesel fuel substitutes. Raw vegetable oil can be used as fuel in diesel engines with some minor modifications. The use of vegetable oils as I.C. engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuels.

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