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Corrosion Effects of Chicken Fat Biodiesel on Compression Ignition Engine Cylinder

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ABSTRACT

Objective of this presentation is to investigate the corrosion behavior of biodiesel, prepared by chicken fat, on the cylinder of the compression ignition engine. The weight loss method and surface morphology test were used to calculate the amount of cylinder surface corrosion. Material used to test was selected from the cylinder liner of a compression ignition engine. These material coupons were dipped in chicken fat biodiesel of different concentrations for duration of 150 days under standard conditions. W D, Callister method was used to ascertain the corrosive rates of chicken fat biodiesel blends of B100, B80, B60, B40, B20 and B0. The calculation has shown corrosive values of 0.55 mpy, 0.46 mpy, 0.364 mpy, 0.176 mpy, 0.018 mpy and 0.004 mpy respectively. The morphological micrographs taken from Scanning Electron Microscope showed some changes on surface of sampling coupons of cylinder due to corrosive effects by the biodiesel and weight loss within the immersion duration. By this experiment, Chicken Fat biodiesel of different concentration with less or up to 20% biodiesel content can be used as alternative fuel without any major modification to the engine fuel system, has been found. The outcome of current research can act as a path in identifying the blends of Chicken Fat biodiesel and fossil fuel that could suitably be used on a long-term basis on a compression ignition engine without much alteration. To protect the environment this study surely enhances the use of chicken fat biodiesel as CI engine fuel.

Keywords— Chicken fat biodiesel, Compression ignition engine, Cylinder liner, Electron microscope, Weight loss.

I. INTRODUCTION

Rapid price rise and high emission rates of the petro diesel and because of low emission and environmental benefits, it has made biodiesel as accepted alternative fuel. The process of producing biodiesel from other low cost feedstock may considerably reduce the cost of biodiesel [1]. Due to the rapid increase in population and urbanization, demand for energy and its resources are increasing every day. Due to this, major conventional energy like coal, petroleum and natural gas are getting extinct. Production of Biodiesel has opened a new era of modern technological area for researchers as it is giving huge advantage in overcoming rise in petroleum price and for its environmental advantages [2]. Due to non-presence of sulfur, it does not contribute to greenhouse gases. Biodiesel used as an alternative compression ignition engine fuel, is extracted from renewable biological resources commonly animal fat and vegetable oils. The biodiesels are nontoxic, biodegradable and has low emission so it is environmental friendly [3].

Due to high fuel efficiency and commercial transport network, compression ignition engines are used as versatile engines resulting in increase in usage of fossil fuels like petrodiesel which has resulted into a raising demand for fossil diesel. The unsustainable nature immanent in the continuous usage and demand of petrodiesel fuel is made clear by growing environmental concerns and other conflicting aspects. Biodiesel used as an alternative fuel to diesel fuel degrades the metallic components and also decreases the lifespan of compression ignition engine parts. Investigation of biodiesel impact on corrosion and degradation of fuel system materials has been rarely done by researchers, but still biodiesel has become a major domain in research area as reported by [4]. Biodiesel and its corrosion effects have drawn a lot of attention by researchers in India as potential renewable sources of energy. The main intention of this paper is to investigate the corrosive effects of Chicken Fat biodiesel, caused by presence of high linoleic acid in oil (17.9-22.8%) and density 0.9g/cm^3 which are processed in India, on compression ignition engine cylinder.

In automobile components, friction and wear commonly occur due to sliding contact surfaces and the common components that go through these are piston and cylinder liners, but biodiesel provides good lubrication due to its high viscosity than fossil diesel. Friction and wear however increase because of the hygroscopic nature of biodiesel. Biodiesel normally absorbs moisture and corrosive wear will increase and auto oxidation likely influences the characteristics of wear.

Corrosion can be defined as the unintentional attack on metal and destruction of metal surfaces; it is electrochemical and normally begins to attack on surfaces. In economic term, it is estimated that nearly 4 to 5 % of industrialised nation's income is spent on maintenance, prevention of corrosion and replacement of products lost or contaminated because of corrosion behaviour of metal surfaces. Problem of corrosion is a major issue in automobile components including rusting.

II. LITERATURE REVIEW

A. **Biodiesel as compression ignition fuel.**

Any natural oil or animal fat can be used to be converted as renewable Biodiesel. "Biodiesel" normally refers to "fatty acid methyl ester" (FAME) processed by transesterification, which is a chemical process that reacts on a feedstock oil or fat with alcohol (usually methanol) and a base potassium hydroxide catalyst. When it is referred in technical terms, biodiesel is a diesel engine fuel comprised of monoalkyl esters of long chain fatty acids developed from vegetable oil or animal fat represented as B100. Till now many vegetable oils have been used to produce biodiesel non-edible oils like karanja, mahua, neem and Jatropha and edible oils like linseed, palm coconut, sunflower, soya bean, peanut, cotton seed as in [5] and [6]. H.J Kim [7] investigated many animal fats, vegetable oils and recycled cooking oils can also be converted into biodiesel and also many different methods to develop it. Biodiesel can be used in its purest form or as diesel additive and is commonly used as a fuel additive in 20% blends B20 with petrodiesel in compression ignition engines. Depending upon the cost of fuel and derived benefits, other blend concentrations can also be used.

At Paris exposition in 1900s, Rudolf Diesel used peanut oil as biodiesel to test his engine. It was a strong belief of Rudolf Diesel that the utilization of biofuel will be the real future of his engine. A speech given by Rudolf Diesel 1912 quoted 'The use of vegetable oils as engine fuels may seem insignificant today but such oils may become in the course of time as important as petroleum, as the coal tar products of the present time'.

Some alterations were done on engine in the year 1920s by diesel engine manufacturers to utilize the low viscosity fossil diesel. Due to recurrent acute shortage of petroleum, research works started efforts into vegetable oil as diesel substitute during the 1930's and 1940's. The main focus scientifically was on straight vegetable oil in the 1970's and 1980's.

Comparison of fossil diesel and biodiesel are shown in (Table 1) specially its ignition properties and viscosity. Biodiesel has more benefits in avoiding wear of the engine by its lubricating properties. The alcohol components of biodiesel contain more oxygen which gives good and complete combustion of the fuel. Precautions should be taken in temperate countries, since Biodiesel is sensitive to cold weather and may require some antifreezing solutions as additives, similar to those used with fossil diesel. United States Environmental Protection Agency (EPA) has analyzed B20 blends, 20% biodiesel blended with 80% fossil diesel, and has ascertained that the different blends can reduce emissions by 15%, CO and 20% PM emissions respectively. Emissions NOx were increased by 3% in the EPA study.

Table 1: Comparison of Biodiesel and Fossil Diesel fuel Properties.

Properties	Fuel	
	Diesel	Biodiesel
Density (kg/m^3)	850	890
Viscosity (mm^2/s)	5	7
Flash Point (°C)	85	125
Calorific Value (KJ/kg)	50x10^3	58-59x10^3
Cetane Number	44-48	58
Fuel Equivalence value	1	0.91

B. **Problems with Biodiesel as Engine Fuel**

Depending upon the consideration of pressure, viscosity and air fuel mixture ratio, compression ignition engine fuel system is used to store the fuel and deliver it to the combustion chamber with proportionate fuel rate and at required velocity [8]. Emission of pollutants such as HC, CO_2, and CO is less in the compression ignition engine.

The engine parts are composed of metals such as aluminum, stainless steel and copper and its alloys, corrosion becomes a very important thing in the usage of biodiesel fuel [9] as these parts are more susceptible to corrosion. In engine components, percentage of aluminum consists of engine blocks 19%, cylinder heads 70%, and piston 100%. Injectors and pumps mostly consist of copper and its alloys. Fuel filter, valve bodies, nozzle and pump ring parts are composed of stainless steel [10-11]. Degradation of fuel varies with the specific metal used. Observation shows that biodiesel degrades through absorption of moisture, microbial attack during storage and auto-oxidation. Corrosion of stainless steel, aluminum and copper in petrodiesel and palm biodiesel were tested by Masjuki HH. [12]. Immersion test conducted at standard conditions by Fazal MA on B100 and petrodiesel was done at 80ºC for 600 and 1200 h with mixing rate of 250 rpm. Corrosion rate in copper, aluminum and carbon steel has been calculated to be 0.586 mpy, 0.202mpy, and 0.015mpy (mils per year) respectively. Main disadvantage of corrosion is dual in nature as the fuel composition changes due to corrosion leading to biodiesel fuel properties degradation.

Car manufacturers are now producing flexible-fuel vehicles, which can run on any combination of fossil diesel and biodiesel. Manufacturers of fuel injection equipment such as Bosch, Densu and Delphy have shown their concern on some biodiesel properties such as corrosion of cylinder liner by free methanol, corrosion of nonferrous metals, reversion of biodiesel to fatty acid resulting in filter plugging due to free water and dissolution, sedimentation on moving components causing filter plugging and injector coking, corrosion of zinc, salt of organic acid, organic compounds formation, and while in operation with biodiesel and its blends fuel injection pump may suffer badly. Some of the problems of FIP are low pressure fuel systems blockage, corrosion of fuel injection equipment components, elastomeric seal failures, fuel injector holes blockages, pump seizures due to high fuel viscosity when in low temperature, increased dilution of engine oil in the sump, injection pressure increase as reported in [13].

Many researchers tested the corrosion topics of biodiesel as fuel for CI engines. Reference [14] reported that as there is no sulfur the oxidation in the biodiesel fuel container is lower. As reviewed by [15] preparation of biodiesel is normally done using acid or alkali catalysts which are either heterogeneous or homogenous. Sulfuric acid which is homogeneous acid catalyst is generally used for acid esterification and gives corrosive nature to biodiesel fuel [16]. Purity of biodiesel should also be high in order to have CI engines compatibility. So incomplete and inadequate conversion or purification by water washing or other means will result in impurities such as catalyst, free fatty acids, glycerol and alcohol which causes deposits on the engine, corrosion and eventually failure of the fuel.[17].

Y.C. Sharma [18] reviewed the effects of corrosion on the engine parts that come in contact with a newly developed biodiesel fuel and its blends show aluminum, copper, copper alloys like bronze and elastomers caused significant levels of corrosion as compared to low corrosion with conventional diesel fuel, and stainless steel samples show more resistance to corrosion in biodiesel samples as compared to copper alloys, copper and aluminum. Measurement of corrosion was done using common methods such as weight loss through static immersion tests and electrochemical techniques by electrochemical impedance spectroscopy. Specific metal surfaces of the strips were tested by optical, atomic force microscopy, scanning electron microscope revealing the type and extent of corrosiveness.0

The automobile components used by current markets are gray cast iron with lamellar graphite (ASTM Grade 40) with pearlitic type microstructure as material for cylinder liner. Aluminum alloy is also used in certain applications. Liner materials are usually from different alloys of cast iron such as aluminum, manganese, copper, nickel, silicon, etc. Copper exhibits severe corrosion with biodiesel and its blends.

Table 2: Chemical compositions for cylinder liners (wt. %)

Materials	C	Al	Si	Mg	Ni	Cu	Fe
Gray cast iron	3.5	…	…	0.04	0.12	0.51	Balance
Al-Si-1	…	Balance	23.19	1.00	0.96	2.70	0.19
Al-Si-2	…	Balance	16.13	0.64	0.04	5.00	0.49
Al-Si	…	Balance	23.0-28.0	0.8-2.0	1.0-5.0	3.0-4.5	1.0-1.4

III. CHICKEN FAT BIODIESEL

A. Oil Extraction Process

- The 5 kg of waste chicken fat was collected from the poultry & it was cleaned by washing in water
- It was later heated till it reached 120°C to lose all its moisture content and was strained which in turn filtered it.
- After the filtration process 2 Liters of purified chicken oil was obtained.
- 750 ml of purified oil was used for experimentation

Figure 2: Stages of oil extraction

The free fatty acid level (FFA) of oil was less than 1% therefore the esterification process was done with base catalyst.

B. Base Catalyst Esterification

Steps involved:

- The 750ml of chicken fat oil obtained after filtration was heated for 75^{o}C.
- In a beaker 225ml of methanol (30% in oil) and 3.75 grams of KOH (potassium hydroxide) pellets were added and allowed it to dissolve.
- The heated oil was transferred to the round bottom flask of the esterification setup (figure 3).

Figure 3: Experimental Trans-esterification setup

- The methanol and KOH mixture was poured to the other beaker in the set up.
- The methanol and KOH mixture was slowly allowed by opening the valve into the flask containing chicken fat oil.
- The magnetic stirrer speed was maintained at 900 rpm, it stirred the mixture of oil, methanol and KOH so that the mixture does not solidify.
- The stirring was carried on for 90 minutes.
- In a test tube a sample of mixture was taken and kept aside for few minutes to check if the glycerin was forming a separate layer in the bottom.
- The process was completed as a separate glycerin layer was formed.
- The mixture was poured into the settling flask and allowed to settle for 60 minutes for the glycerin to form a separate layer.

- The glycerin layer was separated from the remaining biodiesel.

C. **Water Wash**

The biodiesel obtained was washed 3 times with water to remove the catalyst. If clear wash water is got back it indicates that the catalyst is not present in the biodiesel. This was later heated to 100 degree centigrade to get dry biodiesel which was free from moisture .Thus neat bio diesel was obtained.

D. **Blending of Fuel**

The produced biodiesel was blended with the fossil diesel in different percentages B100, B80, B60, B40, B20, and B0 (100% fossil diesel).

- Measuring jar and beaker were used to carry out the process of blending. The exact concentrations of fossil diesel and chicken fat biodiesel were added to the beaker and then transferred to the bottle. Bottles were shaken well and were allowed to stay upside down to ensure proper mixing of fuels.
- The bottles were stored in dry place and kept still for the next 24 hour. Blends were checked for every 6 hour-time intervals for any layer formation.
- All the blends were stable and passed the 24 hours stability test and were ready to be used.

Figure 4: Chicken fat biodiesel blends

IV. METHODS AND MATERIAL PREPARATION

A. **Selection of Materials**

The test sources for the experiment are: (i) Chicken Fat biodiesel (B100); (ii) Blends of Chicken Fat with fossil diesel (B80, B60, B40, and B20) and (iii) Fossil diesel (B0). Cylinder liner material of compression ignition engine was selected to prepare as test coupons. The sample material was surface grinded to 800 grit finish. The test coupons were polished with 10 µm diamond paste, cleaned in distilled water and rinsed with methyl/isopropyl alcohol to remove scratches and oxide layer on the specimen. These coupons were then dried, weighed in analytical balance and preserved for the experimentation.

B. Investigation and Experimentation.

Chicken fat biodiesel blends B100, B80, B60, B40, B20, and B0 were taken as immersing source in which weighed test coupons were individually and fully immersed and allowed to stay for 150 days duration.The initial weight of the coupons were recorded and the final weight of the specimen coupons after immersion test duration were recorded to get the material weight loss value. Later respective corrosive rates in mils per year (mpy) were calculated according to [19]

$$\text{The corrosion rate in mpy} = \frac{W \times 534}{D \times T \times A}$$

W=Weight loss in mg
D=Density g/cm^3
A=Area of exposure in square inch
T=Time in hours

V. RESULTS AND DISCUSSION

A. **Results**

Figure 5, shows the graph plotted between corrosive rates verses chicken fat biodiesel blends on six test coupons of cylinder liner material. The concentrations of blends were, chicken fat biodiesel B100, Blends of chicken fat with fossil diesel B80, B60, B40, B20 and pure Fossil diesel B0.

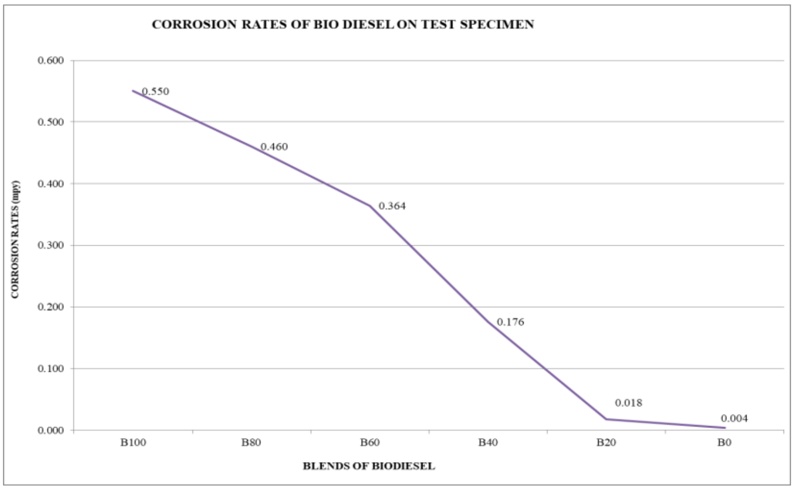

Figure 5: Corrosion rates of biodiesel on a test specimen

B. **Results and analysis.**

Chicken fat blends of B80 and B100 showed maximum corrosion effect. Whereas blends B20 and B0 (fossil diesel) showed not much effect within the immersion duration as shown in figure 5. Coupons when exposed to the fuel blends with just up to 20% Chicken Fat biodiesel content showed less weight loss, which is negligible. Without any modification of an engine, chicken fat biodiesel blends with 20% biodiesel content and below can directly be used as a fuel.

Figure 8 and 9 shows that the morphology of the coupon obtained by scanning electron microscope displays more corrosion more as compared to Figure 6 and 7. The higher chicken fat biodiesel concentration corrosive rates are higher than the blends having lesser biodiesel concentration. Corrosion effect on cylinder liner material by fossil diesel and 20% biodiesel blend is comparatively low as only negligible changes are seen on the coupons exposed.

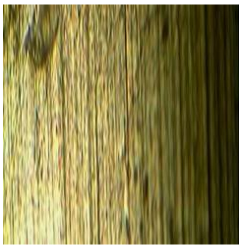

Figure 6: Micrograph sample of 0% biodiesel exposure

Figure 7: Micrograph sample of 20% biodiesel exposure

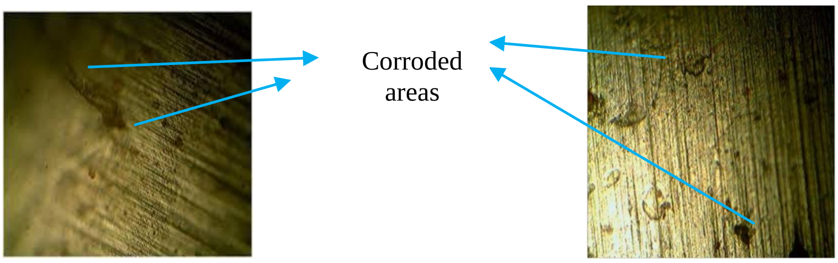

Figure 8: Micrograph sample of 80% biodiesel exposure

Figure 9: Micrograph sample of 100% biodiesel exposure

VI. CONCLUSION

Thorough investigation of effect of corrosive behavior by chicken fat biodiesel with different concentrations on cylinder liners of compression ignition engine has been done. Weight loss method described by W D Callister and analysis of micrographs taken from SEM was used to ascertain corrosion rate. Following conclusions were made

- Exposure of cylinder liner material in biodiesel can increase oxidation instability
- Pure chicken fat biodiesel B100 and chicken fat biodiesel blend B80 were found to exhibit more corrosive than fossil fuel as corrosive rates were 0.55mpy and 0.46mpy respectively.
- Formation of oxide compounds and their dissolution seems to degrade the metal surfaces.
- Blends with biodiesel concentration of up to 20% B20 exhibited not much effect as the loss in weight was negligible within the testing duration.
- Based on the test results it is clear that blend of 20% biodiesel extracted from chicken fat with fossil fuel is suitable to use as an alternate fuel for compression ignition engine without modification

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