Effect of engine oil dilution by waste ayurvedic oil biodiesel on tribological behavior of liner-ring tribo pair material

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Abstract. The fastest exhaustion of petroleum-based fossil fuels and its ever-ending environmental issues which scares the researchers to search for the alternate source for commercial diesel fuel. In this way, the biodiesel as an alternate fuel plays an important role in a diesel engine. There are many vegetables were used as a biodiesel feedstock, the utilization of waste feedstock as a biodiesel resource will be the prime importance in the reduction of waste management followed by its dumping processes in the earth surface. The present experimental investigation is used to examine the utilization of waste ayurvedic oil (WAO) biodiesel blends diluted in the synthetic oil and its tribological study using pin on disc tribometer under standard test conditions. The ultrasound irradiation assisted transesterification process method is employed in the conversion of waste ayurvedic oil in to WAO methyl ester (WAOME). Then the WAOME was added with diesel fuel to form the biodiesel blends and named as B10, B15 and B20. In addition to this, the blends were contaminated with synthetic lubrication oil (SAE20W40) to study the dilution effects of the biodiesel. The real-time cylinder liner-ring tribopair materials were used for the investigation. The experimental results reveal that, the tribological behavior i.e., lower coefficient of friction and wear was observed with WAO20 biodiesel blend than other biodiesel blends and diesel fuel.

Keywords: waste ayurvedic oil biodiesel; ultrasonication; fuel from waste; pin on disc.

1. Introduction

At present, the cost of biodiesel is high as compared to diesel fuel as biodiesel is produced from refined vegetable oils. The best method to cut down the cost of biodiesel is the use waste feedstock such as waste cooking oil, waste fish oil, waste transformer oil, waste plastic oil, waste mango seed oil and wastes from animal fat. Many researchers reported the use of biodiesel as a diesel engine fuel from such waste feed stocks [1-10]. Oil feed stock is the prime cost involved in the synthesis of biodiesel that accounts for more than 60% of the overall biodiesel processing cost. If any waste source is used as biodiesel feedstock, the economics of biodiesel could be greatly promoted. Additionally, the use of biodiesel from waste feedstocks also cut down the cost of waste treatment which is a prime importance of waste management system.

Knothe & Razon [11] found that, the biodiesels were derived from many sources which comprise of fatty acid methyl ester or fatty acid ethyl ester. The biodiesels have high flash point, biodegradability, low sulfur content, good burning efficiency, minimized emission characteristics and it has 10 wt % oxygen content. This concluded that, the biodiesel was partial substitute for fossil fuels. Pelitli et al. [12] investigated the waste oils from the various vehicle engine crankcases and waste gearboxes removed while the vehicles maintenance and analyze the oil managements. This study leads the fitness for recycling the oil, amount of quantity can be recovered or disposal of the oils used. The investigations based on the various analysis of cadmium, lead, total halogens, flash points, chlorine, arsenic, chromium etc. From the various metals analyzed from the various engine crankcase oils the lead plays the higher quantity and arsenic, cadmium and chromium play lesser than lead. The more amount of removed metals
was noticed with the vehicles around 15 to 35 years old. From the investigation findings the engine crankcase oils and gearbox oils can be used for recycling [13].

Out of various feedstocks used by many of the researchers, none of the investigators walked through in the studies of utilizing the Waste Ayurvedic Oil. The various authors investigated the various biodiesel production methods on different food stock and found that influencing parameter as time and temperature are 120min and 50°-60°C. As well as the molar ratio between the alcohol and oil is 6-12:1 with the suitable catalyst as 1% by weight [14,15]. In the transesterification and pyrolysis-based biodiesel process, more amount of power is needed and larger amount of reaction time is wasted. To overcome the difficulties the ultrasonic based transesterification process method is used for the conversion of biodiesel.

In IC engines, the various engine components produce friction between the metal-metal contact, which in-turn reduces the engine life and hence lubricity behavior of fuel is one of the most predominant factors in extending engine reliability [16]. Masarof et al. [17] investigated the friction and wear characteristics of palm and calophyllum inophyllum biodiesel blends in addition to performance and emission behavior. They confirmed that 20% of palm oil biodiesel blend displayed the favorable engine performance, lower emissions together with better lubricating performance. Shanta et al. [18] studied the tribological effects of various biodiesels from peanut oil, soybean oil, canola oil and chicken fat in a pin on disk tribometry test setup. The test was conducted on steel disk with stainless steel ball material. The investigation result analysis clears that, the frictional force and specific wear rate were minimum with the mixture of animal fat with lubricating oil as a feed stock than the other mixtures of lubricating oil with biodiesel blends. The main influencing parameter of low distillation temperature of biodiesel improves the lubricating oil dilution. Arumugam and Sriram [19] analyzed the engine cylinder liner and piston ring tribo pair material in a pin on disc tribometer. The various lubricating oils were rapeseed oil-based lubricant, rapeseed oil biodiesel based lubricating oil, commercially available lubricating oil and diesel-based lubricant. From the various studies like coefficient of friction, frictional force and wear depth it is concluded that, the rapeseed oil-based biodiesel contaminated with the commercially available synthetic lubricant shown a better performance and better impact in the life of the engine than all other lubricants used.

From the above literatures, it is proven that rare attempts were made to efficiently exploit waste ayurvedic oil as diesel engine fuel, in spite of it being as waste and sparingly feasible resource. Many literatures reported the usefulness of waste cooking oil, waste fish oil, waste transformer oil, waste plastic oil and wastes from animal fat as biodiesel. Apart from the various waste feed stocks to be used as alternative engine fuels which are listed above, one such important waste feedstock for the synthesis of biodiesel is waste ayurvedic oil.

2. Materials and Methods

2.1 Synthesis of waste ayurvedic oil biodiesel using ultrasonic irradiation-based transesterification method

In this study, biodiesel is formulated from WAO via ultrasonic irradiation assisted transesterification process [20, 21]. For this, WAO was collected from in and around ayurvedic hospitals located in southern region of Tamilnadu, India and it was filtered using filtering cloth in order to remove sediments and other foreign bodies present in it. The other chemical substances such as methanol, sodium hydroxide pellets, hydrochloric acid and anhydrous sodium sulphate was purchased from M/S Maruthi traders, Chennai.

The ultrasonic irradiation-based transesterification process setup was used to convert the WAO in to WAO methyl ester. The 1000ml triple neck glass flask was used for this process among three neck the centre neck is used for ultrasonic probe and remaining two is used for thermocouple and addition of reaction mixtures. 400g filtered WAO, 80g methanol and 4g of NaOH pellets were added in the flask. The ultrasonic irradiation was applied for this process. After the process, the mixture was left to 12 h to settle down then, the top layer was separated using separating funnel and allowed to bubble wash to attain
purified WAO methyl ester (WAOME). At final, the WAOME was blended with diesel fuel in the volume basis to prepare the blends such as,

- WAO10: 10% of WAOME+90% of diesel.
- WAO15: 15% of WAOME+85% of diesel.
- WAO20: 20% of WAOME+80% of diesel.

To prepare the homogeneous mixing the blends were mixed thoroughly using mechanical stirrer at 60°C with 500rpm for 15min. Table 1 shows the properties of WAO biodiesel blends and diesel fuel. Finally, the WAO biodiesel blends and the diesel fuel were contaminated by 10% with synthetic lubrication oil (SAE 20W40) and the mixture was mixed thoroughly with mechanical stirrer in the glass flask.

Table 1: Properties of WAO biodiesel blends and diesel fuel

| Properties                  | WAO10  | WAO15  | WAO20  | Diesel  |
|-----------------------------|--------|--------|--------|---------|
| Density, kg/m³              | 837.7  | 842.1  | 854.1  | 830.2   |
| Kinematic Viscosity @40°C, cSt | 2.69   | 3.02   | 3.41   | 2.71    |
| Flash point, °C             | 61     | 65     | 71     | 56      |
| Fire point, °C              | 56     | 60.5   | 64     | 48.5    |

2.2 Tribological test configuration

To study the tribological characteristics of WAO biodiesel such as coefficient of friction and wear, Wear and friction monitor (Make: Ducom, India: Model: TR20LE-400PHM) was used in accordance with ASTM G99. The tribometer was connected to a personal computer with data accusation system. The pins used for the tribotest were made out of engine’s piston ring material i.e., AISI-304 and the disc were made out of engine’s cylinder liner material AISI-316 steel with a hardness of 60 HRC. The specifications of the pin and disc are as follows:

- Length of the pin : 30mm
- Diameter of the pin : 10mm
- Thickness of the disc : 8mm
- Diameter of the disc : 165mm

The details of the test matrix are as follows:

- Load : 80N
- Temperature : ambient
- Disc speed : 300rpm
- Sliding velocity : 0.7835m/s
- Duration : 1 hour
- Sliding distance : 2850m
- Fuels used : WAO10, WAO15, WAO20 and diesel.

In general, the lubricity behavior of any fuel is evaluated using fuel dilution method [22-24] for which commercial engine oil i.e. SAE20W40 was diluted with 10% of WAO biodiesel such as WAO10, WAO15, WAO20 and also with commercial diesel and accordingly four different lubricant samples were prepared. The wear and coefficient of friction (COF) was measured using linear variable differential transformer and electronic sensors respectively.

3. Results and discussion

When biodiesel is used as fuel for diesel engine, it may lead to some degree of fuel dilution problem with engine oil [19]. The measurement of tribological behavior of WAO biodiesel is much more
important in order to study the fuel lubricity and anti-wear properties. The variation of co-efficient of friction (COF) and wear between pin-disc tribo pair under the influence of various ayurvedic oil biodiesel fuels and diesel fuel are shown in Fig. 1. (a) & (b).

From Fig. 1(a) it is depicted that all the three blends of WAO biodiesel showed the reduced COF as compared to diesel fuel. Under similar operating conditions, WAO20 had the lowest COF followed by WAO15 and WAO10. Out of the four-test fuel, diesel fuel is showed highest COF. The lowest COF is mainly attributed by the presence of polar groups and long-chain fatty acids in WAO biodiesel. Further, the existence of oxygen moieties and double bonds present in WAO20 biodiesel is responsible for the overall improvement of lubricity behavior of WAO biodiesel. The Fig. 1(b) shows the wear of pin material under the influence of various WAO biodiesel and as well as diesel. The wear of pin was increased with increase in experimental time. The variation in pin wear was only considered in this tribological study due to the hardness of the pin material was much lower than disc material.

![Fig. 1. Tribological behavior as a function of time (a) co-efficient of friction (b) wear](image-url)
The wear of pin was increased with increase in experimental time. The variation in pin wear was only considered in this tribological study due to the hardness of the pin material was much lower than disc material. It is depicted that the wear was dramatically reduced for WAO20 it was nearly about 56% lower than diesel fuel. Similarly, the reduction in wear was about 9% and 58% respectively for WAO15 and WAO10 as compared to diesel fuel. This wear reduction trend confirms the anti-wear behavior of WAO20 biodiesel. The adsorption of polar groups that is present in the WAO20 biodiesel on the pin-disc tribo pair surfaces during the rubbing, providing them good anti-wear properties. Typically, the interactions between ZDDP (Zinc dialkyl dithiophosphate) additive molecules present in the SAE20W40 and WAO20 biodiesel which are responsible for the formation of wear protective layer are much stronger than that of WAO10 and WAO15. The similar studies by Maleque et al. [25], reported the better anti-wear behavior of palm oil-based biodiesel is due to the formation of hydrocarbon protective layer by the presence of long-chain fatty acid in biodiesel.

4. Conclusions

In the current tribological investigation, the lubricity behavior of WAO biodiesel was instrumented using pin on disc tribometer. The outcome of the experimental study is summarized as follows:

- It is achievable to originate the biodiesel from one such waste source is waste ayurvedic oil (WAO).
- The use of WAO biodiesel improved the anti-friction and anti-wear behavior compared to diesel fuel and in particular WAO20 was outperformed which suggested that higher fraction of WAO in biodiesel may play a vital role on reducing the friction and wear.
- As compared to diesel, the wear was reduced significantly of about 56% for WAO20 due to the adsorption of polar groups present in WAO20 biodiesel.
- Under similar tribological conditions, WAO20 had the lowest COF of about 0.04 while the COF for the diesel is 0.13.
- The reduced COF with WAO based biodiesel might be due to the existence of oxygen moieties and double bonds which is not a part of diesel fuel.
- From the above investigation results it is observed that, WAO20 performs better wear scuffing protection to the engine liner-ring tribo pair material and best alternate for diesel fuel.

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