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Review Article

A Complete Assessment of Tribo-corrosive Behaviour of CI Engine Using Emulsified Dual Fuel Bio-Diesel Blend

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Abstract

Biodiesel is relatively higher corrosive compare to Diesel. Biodiesel is self-oxidation in nature. The current investigations are to determine the tribological and corrosive behavior of biodiesel and their dual biodiesel emulsified fuel blend on CI engine vital parts (i.e., Piston, Valves, Cylinder liner, Cylinder head, Fuel pump, Bearings). The emulsified fuel was made from dual biodiesel (i.e., Neem and Palm) with Diesel and water. The tribological and corrosive effects were performed on metal surfaces of Copper, Aluminum, and Iron. These metals were selected based on the base composition of engine vita parts. A static immersion test was conducted for corrosion for 150 days at room temperature and for tribology, a pin-on-disc apparatus test was performed. These test also includes scanning electron microscopic, weight, dimension and physical visualization analysis of corroded and worn-out metal surfaces. To identify the cause of the corrosion, wear on the metal surface, the Gas chromatography-mass spectrometry test has been conducted. This test will also help to determine the chemical composition of the test fuels. It has been observed that biodiesels have good anti-wear properties in comparison to Diesel and emulsified fuel. On the other hand, Diesel and emulsified fuel show good corrosive properties compare to biodiesels.

Keywords: CI Engine; Dual Bio diesel; Emulsification; GC-MS, SEM Analysis; Wear Analysis; Friction Analysis; Corrosion Analysis

Introduction

Since the early 18th century, fossil fuel plays a vital role in the energy sector for providing a prime source of energy to automobiles. Due to the presence of sulphur in the fuel, it provides lubricity to the fuel pump, but combustion of the fuel inside the engine also produces toxic gases like SO, SO_2 as a by-product in the exhaust. As IC engines are air-breathing engines and due to the presence of 78% Nitrogen in the atmosphere and high-temperature generation inside the combustion chamber of IC engine because of the high CV of Diesel, it produces NOx a highly toxic gas for human and the environment [5, 14]. Due to a huge population in India, to fulfil the demand of local people, the government has to import a huge amount of crude from other countries, which ultimately reduces the value of the Indian rupee.

To overcome these problems, the government has decided to consume biodiesel in the engines. These biodiesels are made from plant seed oil. Due to India's high population, it has been selected to use non-edible plants seed to produce biodiesel. Currently, a majority part of Indian people are still dependent on agriculture, by using biodiesel leads to an increase in the growth of Indian farmers, it will also increase their income [12, 17]. Currently, India cultivates a huge amount of Neem and Palm trees. It has been studied from the literature that these two biodiesels are neither consumed by humans nor animals that's why they are categorized as non-edible plants [9]. The biodiesels made from Neem and Palm seed have to go through a process known as transesterification. In this process, the oil extracted after crushing these seed are collected and stored inside a large container. A mixture of alcohol with biodiesel is prepared, later on, to boots up the process, KOH is mixed in the mix [10]. The mixture is allowed to settle for few hours and then washed with hot water to remove soap; after that, the biodiesel and glycerine are separated and collected for further use. This biodiesel cant is used directly in modern engines because of its sticky and higher density. It has to be mixed with standard Diesel in the blended form [2, 6, 18, 21].

Various researchers have observed that biodiesel shows almost similar properties as Diesel and can be a perfect replacement in the future. Still, the massive problem of this biodiesel is a fatty acid in them. These fatty acids have two types saturated and unsaturated. This biodiesel degrades itself and converts into oxides when directly in contact with the atmosphere and direct sunlight. Due to this problem, metal parts in the engine get corroded. Apart from this from the literature, it has also been observed that biodiesel has good lubricating properties due to its high fatty acid [7]. It has been observed that the physical and chemical properties of different plant seeds are different from each other so which means that one plant biodiesel can have high corrosive properties. One can have lesser, similarly lubrication properties. So to overcome this problem, a dual blend of such biodiesel, where one has lower corrosion and one has higher lubricating properties, can be mixed to form an optimum fuel.

Various researchers have work on the engine emission part with biodiesel to fulfil the government emission norms, but it has been observed that only a few crops of biodiesel can reduce the emission up to BS 4. But due to the new policy of emission, the emission level should be lower. To fulfil this demand, a new method was implemented by researchers that are known as emulsification of fuel. In this method, the blended fuel is mixed with water in various proportions to generate water in oil type of emulsification during fuel combustion inside the CI engine combustion chamber. Due to huge pressure and temperature, the water droplets get superheated and explode [19]. Due to this, the fuel droplets get splits further into tiny droplets resulting in better emission properties or emission reduction. Due to micro explosion of in fuel, the steam generated by water reduces the in-cylinder pressure and temperature. Also, it reduces NOx formation, which gets caused due to the presence of huge temperatures [16, 20, 22].

Currently, various researchers are working on emulsified fuel, but corrosion and wear properties of emulsified fuel on CI engine parts are still rare. This paper aims to investigate the corrosion and lubrication properties of B20 duel biodiesel Diesel emulsified fuel.

Norouzi et al. perform an experiment using rapeseed biodiesel and their blends with Diesel on Aluminium and Copper metal coins for 600 hours at 80°C. They found that Copper metal gets more affected due to corrosion in comparison to Aluminium metal and as the percentage of biodiesel increases in the fuel, it becomes more corrosive [8]. Kornfeld et al. conducted work on the stability of the fuel. For the stability test, they have taken poultry fat-based biofuel and their blends with Diesel at various temperatures and the storage time was kept as one year. They suggest that the blended fuel shows more unstable fuel compare to pure biodiesel. Apart from this, they also stated that the blend should be prepared only when it is required and not for long-run storage [1]. Haseeb et al. compared more than eighty articles related to automotive material in relation to corrosion/oxidation/stability with biodiesel. After reviewing them, they found common claims by several authors that engine parts made from ferrous metal have lower corrosion in comparison to Copper metal. They also found that copper alloys are more prone to corrosion than ferrous metals [3]. In the first study, Deyab uses non-ionic surfactant for reducing the corrosion rate in a Zinc battery and found that PNE surfactant shows very promising results. Similarly, in the second study, Deyab conducted another experiment on carbon steel using BHT as an inhibitor and found that the blend with BHT shows 95% better results can be seen in comparison to the blend without BHT [13, 15]. Shanta et al. conducted a tribological study on balls made from AISI 316 grade stainless steel with a disc made from AISI 1018 grade steel using various animal fat-based biodiesel. After investigation, they found that pure animal fat-based biodiesel shows better lubricating properties than mineral lubricant mixed with biodiesel [4]. Jain and Suhane studied the tribological behaviour of the Castor and Mahua biodiesel blend; they found that with the blend of these two biodiesels, the coefficient of friction is found to be 90% lower and the wear is found to be 45 to 63% [11].

Experiment and methodology

To perform the test for corrosion and lubricating properties of dual biodiesel emulsified fuel, first of all, a selection of biodiesel is needed. Based on local production and their properties, it has been decided to select Neem and Palm biodiesel as our base fuel. India comes in is 1st and 5th rank for the production of Neem and Palm biodiesel. Both of these biodiesel has lower corrosive properties.

In the second stage of the experiment, the metals are selected for corrosion and wear tests. It is well known to everyone that in a typical engine Iron, Aluminium and Copper are used to make various components. So for that, these metals were chosen for the corrosion and wear test. A static immersion test was performed for the corrosion test based on ASTM G31 for 150 days [16, 19]. The wear test was performed as per ASTM G99 on pin-on-disc apparatus using a wet lubrication system. In the wear test, the metal pins were rubbed against the standard disc with a load to see the friction generation and metal wear. To observe the surfaces closely, the surface of both corroded and worn-out surfaces was observed under SEM. The weight of these test samples was recorded before and after the experiment to find out the metal loss during the experiment. For the preparation of emulsified fuel SPAN 80 and TWEEN 80surfactants were chosen due to their excellent properties during the combustion of fuel. The percentage of water was varied from 1 to 5% v/v%. The stability of fuels was checked for 48 hours of interval.

Result and discussion

The test fuel for the corrosion and wear test was prepared with a B20 blend which was made from 10% v/v Neem and Palm biodiesel; each after that, these test fuels were mixed with the rest of the Diesel. To prepare emulsified fuel, the above-mentioned B20 dual biodiesel blend was added with 1 to 5% water gradually with a surfactant as SPAN 80 and TWEEN 80. As the fuel stability of emulsified fuel is an essential parameter for engine performance, that's why a stability test was performed for a duration of 48 hours, as shown in Fig 1. It has been observed that with 5% water, 2% surfactant, the stability of fuel is found to be highest among all blends. This test fuel was chosen for a further test of corrosion and wear.

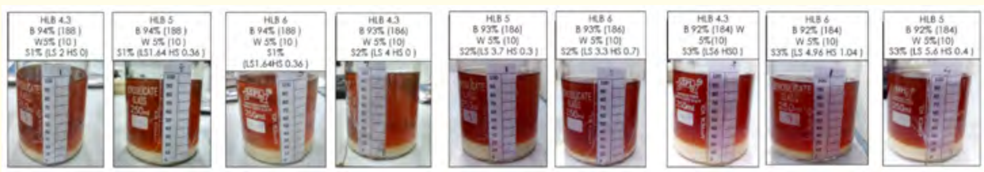

Figure 1: Stability testing of dual biodiesel emulsified fuel for a duration of 48 hours.

Fig.2 shows the test specimen's physical appearance before the test in which the from the left, the disc is made from EN31 grade hard steel prescribed to use as per ASTM G99. The metal pins were made from Copper, Aluminium and iron, and they are 12 mm in diameter and 30 mm in length with a dome shape at the tip. The metal coins were also made from the same metals and these coins were used for corrosion tests. These coins are having a diameter of 20mm and 4 mm in thickness.

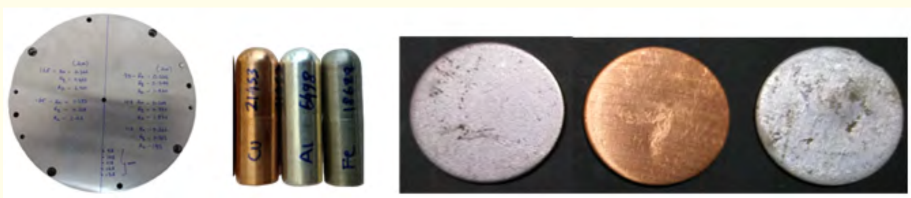

Figure 2: Test specimens before the test (Metal disc, Metal pin for wear test – Copper, Aluminium and Iron, Metal coin for corrosion test – Iron, Copper and Aluminium).

Fig.3 shows the physical visualization condition of metal coins or specimens at initial, after and cleaned (represented as 0, 150 days and cleaned in Fig. 3). A corrosion test was performed for a duration of 150 days on these metal coins to observe the deposits generated on the metal surface. It can be observed based on XRD results that on Aluminium coins Al_2O_3, AlOOH, on Copper coins $CuCO_3$ and on iron coins FeO, Fe_2O_3 can be clearly visible in Fig. 3 similar kind of deposition was also observed by Singh et al. and Chourasia et al [5, 21].

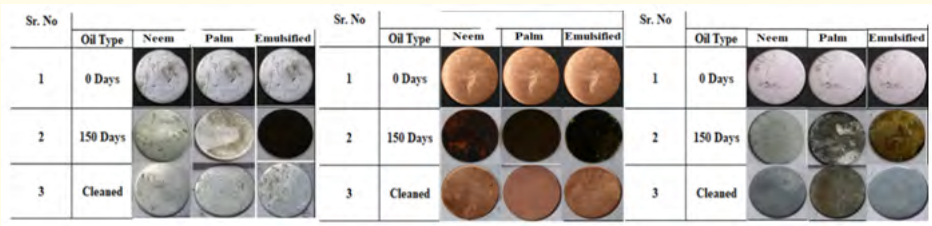

Figure 3: Metal coin condition initially, after test and after cleaning corrosion deposits – Aluminium, Copper and Iron.

Fig.4 shows the weight loss and corrosion rate of 1- Neem, 2- Palm and 3- Emulsified fuel. It can be observed from the figure that the Copper coin has shown the highest weight loss in almost all the fuels. Highest in Neem followed by emulsified fuel. In the case of Iron and Aluminium coins, the weight loss is marginal and shows an almost similar trend in almost all the test fuel. In the corrosion rate, the Iron coin shows the lowest corrosion rate compared to Copper and Aluminium; similar kind of claims are also stated by Jakeria et al. and Fazal et al. [9, 10]. Like weight loss, the corrosion rate of Copper is the highest, followed by Aluminium in almost all test fuels.

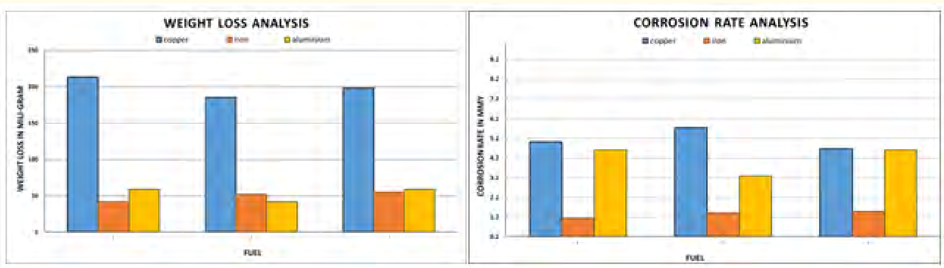

Figure 4: Weight and corrosion rate of metal coins (Copper, Iron and Aluminium).

Fig.5. Represents the SEM image of metal coin surface taken after the removal of all the slurry and deposit is as per ASTM G31 guidelines. It can be clearly seen from the results that pitting corrosion is found in almost all the surfaces of metals. In the case of the Copper coin with Palm and emulsified biodiesel, it can be observed that there are few intergranular types of corrosion were also found, these type of corrosion were also seen in the results of Fazal et al., Kaul et al., Chourasia et al. and Norouzi et al [2, 8, 10, 21]. In almost all the cases of the Copper coin with biodiesel, there is a huge amount of corroded surface present. In the case of neem biodiesel, the surface of Copper gets totally removed and again, the new surface gets corroded, which can also be reflected in the weight loss and corrosion graphs, as shown in Fig 4.

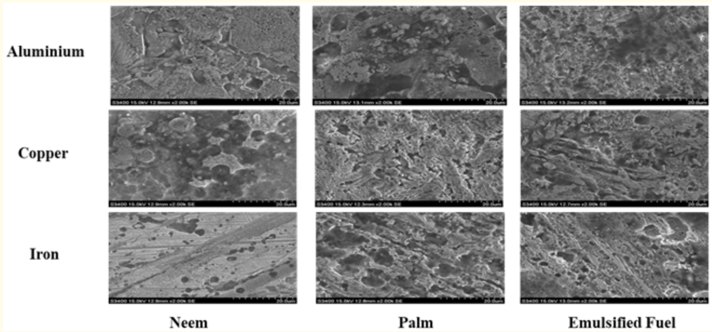

Figure 5: SEM analysis of the corroded surface of metal coin surface (Aluminium, Copper and Iron).

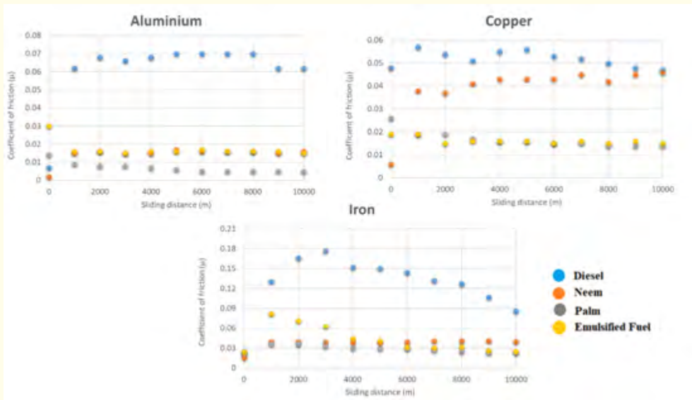

Figure 6: Coefficient of friction vs sliding distance (Aluminium, Copper and Iron).

To identify lubricating properties of test fuels, a pin on disc apparatus was used to perform this experiment. Fig. 6 represents the friction (CoF) coefficient of Aluminium, Copper and iron metal pins rubbed against EN31 grade metal disc; these samples are shown in Fig 2. In these graphs, it can be seen that Diesel shows the highest CoF compared to all the fuel blends. The Palm-based biodiesel shows the lowest CoF, followed by Neem biodiesel. The lowest CoF represents the best lubricating properties. In the Copper and iron pin with emulsified fuel, it can be observed that after covering a certain duration of sliding distance, the CoF reduces and reaches a steady state.

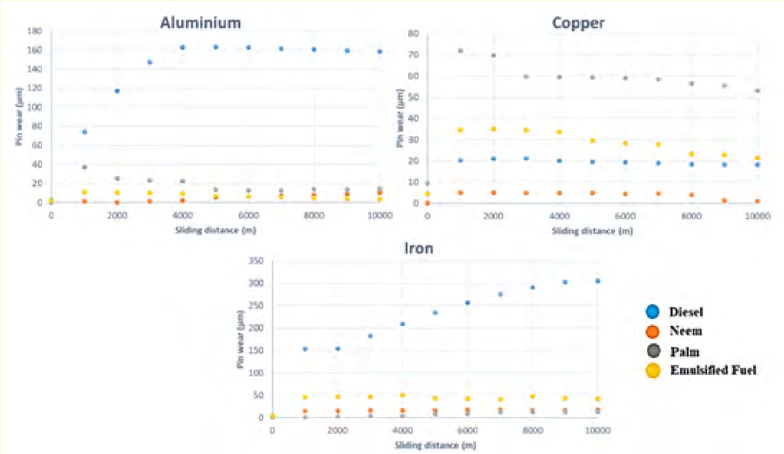

Figure 7: Wear vs sliding distance (Aluminium, Copper and Iron).

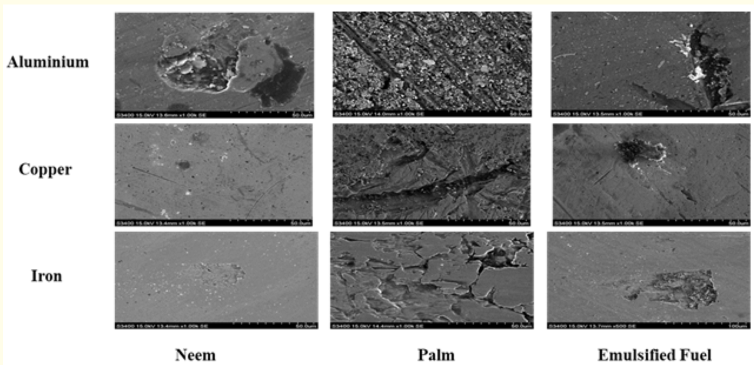

Figure 8: SEM analysis of the worn-out surface of metal pin surface (Aluminium, Copper and Iron).

Fig.7 shows the wear found on metal pins with respect to the sliding distance. The figure shows that with Diesel in almost all the metals, the wear is highest except in the Copper pin. Neem biodiesel shows the lowest or least wear of Aluminium and Copper in comparison to others. The wear with emulsified fuel with Copper and iron shows intermediate results.

Fig.8 represents the SEM images of the worn-out surface of metal pin tips after the experiments. It can be observed from the figure that in the case of Palm biodiesel with the Iron pin, fractures of surface layers are found. Adhesive wear and deep groves can be found on the Aluminium pin surface with Palm biodiesel. Delamination type of wear can be observed in Aluminium pin with Neem and emulsified biodiesel. Deep grooves type of wear can be seen in Aluminium and Copper surface of Palm biodiesel. In the case of Copper and iron pin with neem biodiesel, a complete layer is removed due to wear can be seen, almost similar kind of results were also observed in the works of Fazal et al [10].

Conclusion

Results show that dual biodiesel emulsified fuel blend can be a promising fuel in corrosion and anti-wear properties. 5% of water in dual biodiesel blend shows the highest stability of fuel. Although the wear and CoF values of emulsified fuel are higher than pure biodiesel, they are better lubricating properties. But pure biodiesel cant is used in the existing engine due to its corrosive nature and physical properties. That's why the emulsified fuel can be suggested as the best-compromised fuel for the CI engine due to its moderate to low corrosion and wear properties. Apart from this, an emulsified fuel can help in emission reduction, which is anadd-on advantage of it with the existing CI engine.

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