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EFFECT OF MAGNESIUM OXIDE NANOPARTICLE AS ADDITIVE WITH DIESEL KARANJA BIODIESEL BLEND ON PERFORMANCE OF DIESEL ENGINE

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Abstract
The research study was conducted to produce biodiesel from Karanja oil (Pongamia pinnata) to evaluate the performance and compare the efficiency of samples involving conventional diesel, B10(10% biodiesel and 90% conventional diesel), B10MgO5(10% biodiesel, 85% conventional diesel and 5% Magnesium Oxide), and B10MgO10(10% biodiesel, 80% conventional diesel and 10% Magnesium Oxide), tested with the diesel engine. The production process undergoes a two-step transesterification process since the free fatty acid (FFA) percentage is more than 4%. The titration process reduces the FFA by using Ethanol and Potassium Hydroxide (KOH). Apart from that, the pre-treatment of oil for acid and base transesterification uses methanol as a reactant with the presence of Sulfuric Acid (H_2SO_4) and Sodium Hydroxide (NaOH) as a catalyst. Moreover, Karanja Biodiesel undergoes three characterization tests: Bomb Calorimeter Test, Fourier Transform Infrared Spectroscopy (FT-IR), and Diesel Engine Performance Testing. From the Bomb Calorimeter test, the highest calorific value was recorded by conventional diesel with 45.5815 MJ/kg, followed by B10MgO10 and B10MgO5. While the smallest value was obtained by B10 with 38.7741 MJ/kg. The inclusion of MgO as an additive increases the calorific value for biodiesel. Throughout FT-IR analysis, four fuel samples were evaluated from the wavelength range from 600 cm^{-1} to 4000 cm^{-1}. The oxidation process that happens due to the presence of magnesium oxide introduces a new bond at the B10MgO5 and B10MgO10 which is the O-H bond. Meanwhile, the performance of the diesel engine is analyzed at the speed of 1400 rpm until 2200 rpm with an interval of 200 rpm. Conventional diesel has a higher brake horsepower (BHP) value at the speed of 2200 rpm. While Karanja biodiesel with 10% Magnesium Oxide as additives has a greater BHP value among other samples from the speed of 1400 to 1600 rpm. Next, the addition of MgO reduces fuel consumption in the blended Karanja biodiesel samples.

Keywords: Karanja, biodiesel, transesterification, engine performance.

1. INTRODUCTION

Diesel engine usage in recent times has been increasing rapidly due to the industrial revolution that requires vehicles with big capacity as a medium of transportation. Therefore, the usage of diesel as fuel tremendously increased day by day, and it created awareness among society regarding the availability of sources and their sustainability for an extended period. Diesel stands as a conventional fuel that comes under non-renewable energy. Once the source has been fully utilized, the global will face the situation of finding an alternative to substitute diesel (Zulkefli, 2019). Scientific people should develop biodiesel as a replacement or alternative source through research and implementation in current vehicles. Fatty Acid Methyl Esther (FAME) comes from a long chain of fatty acids that belong to the biodiesel character. Triglycerides conversion that produces biodiesel can be found in natural materials in the vegetable oils like sunflowers, palm, and soya beans (Karthikeyan et al., 2017). Research on available resources is being studied to produce biodiesel. The hike and instability of fuel prices worldwide due to war and globalization creates the opportunity for biodiesel to be introduced in the market as a replacement for fossil fuels. Many types of non-edible oil are available worldwide, such as Karanja, jatropha, mahua, neem, and tobacco seed oil. It is a local product, a fuel that can be renewed for diesel engine extract from natural oil especially crude Karanja oil. (Singh & Moses, 2015) stated that a non-edible plant that can be renewable such as Pongamia pinnata stands as unusual among tree seeds. Seeds from the Karanja tree can produce oil through extraction, which has the same characteristics as diesel, but some character such as solidifying point, kinematic viscosity, ignition point, and flash point is higher in Karanja oil. Therefore, the effect of additives is very important in improvising the biodiesel character. Additive in the groups of nanoparticles like Magnesium Oxide gives better impact on the performance and emission of the engine (Sachuthananthan et al., 2018).

In a recent study conducted by (Ganesan et al., 2017), Palm Stearin Methyl-Ester (PSME) oil has been carried out in this study by using magnesium oxide as an additive in a Compression Ignition (CI) diesel engine. Its focus is on the study of engine power, torque, brake specific fuel consumption, brake thermal efficiency, and exhaust gas temperature. The sample of studies consists of a diesel blend together with magnesium oxide by adding a sufficient amount of biodiesel (PSME) based on a ratio. Certain mixing ratios were prepared to study the efficiency test by using a diesel blend with magnesium oxide. Based on the experiment conducted, the medium load capacity for the B40 blend value increased especially in brake thermal efficiency (BTHE) once tested at the engine. While B10 ratio shows that there is not much difference in terms of exhaust gas temperature compared to diesel fuel. Diesel fuel has the highest exhaust temperature compared to any mixing ratio of blended fuel.

This research was mainly conducted to find a solution or alternative to diesel usage. The availability of Karanja Oil was studied to produce biodiesel by using it as feedstock. Furthermore, the biodiesel produced should be suited to use in CI diesel engines. Apart from that, the most common issue end-users face is operability problems, stability problems, and process controls, which often correlate with biodiesel production. Biodiesel typically has high fuel consumption, low efficiency, and low calorific value, which is inappropriate for direct engine application. Thus, for biodiesel to meet the requirement of international fuel standards, biodiesel blend with diesel and additives has now become a strategy to enhance its properties (Shrivastava et al., 2019). Regarding this, the effect of Karanja biodiesel blended with additives and tested in a diesel engine to study efficiency and emissions. As far as we know, no previous research has studied the influence on diesel engine performance and emission of Magnesium Oxide with Karanja biodiesel blend.

2. MATERIALS AND METHOD

2.1 Karanja Biodiesel Production

The crude karanja oil (CKO) undergoes one-step or two-step transesterification depending on the Free Fatty Acid (FFA) content, whether it is less or more than 4%, respectively (Thiruvengadaravi et al., 2012). The percentage of FFA in CKO was calculated to be equal to more than 4%. Based on that, the two-step transesterification process was decided for this research. The two-step process will be acid and base-catalyzed transesterification. Firstly, acid-catalyzed transesterification starts with the preparation of methoxide solution. Methoxide solution is the solution with a mixture of methanol and sulphuric acid (H_2SO_4) that react acts as an acid catalyst. Methoxide was formed by mixing methanol and catalyst together until they were fully dissolved. The methanol boiling point stands at 60°C, yet it was set as reaction temperature to reactive methanol during the solution preparation. Methanol was mixed with sulfuric acid using a magnetic stirrer at 300 rpm for around 10-15 minutes under the temperature of 60°C. On the other hand, CKO was heated at 60°C with a magnetic stirrer rotating at 240 rpm for about 15 – 20 minutes (Sachuthananthan et al., 2018). Then, the methoxide solution was poured into the CKO solution, and the mixture was allowed to mix for around 1 hour. Later, the mixture was left to settle down for 2 hours in a separatory funnel to form two different layers where the glycerol located at the upper and bottom layers was the pre-treated oil. The best samples with the lowest FFA percentage from each alcohol to oil ratio molarity (7:1, 8:1, and 9:1) will proceed with base catalyzation. 1% NaOH (wt/wt of oil) was mixed with methanol (methoxide solution) by using a magnetic stirrer with a hot cum plate for 30 – 45 minutes with the speed of 250 rpm at 60°C. The upper layer will be collected and proceed for purification by the washing process. This washing process is mainly done to purify the Karanja biodiesel by removing excessive alcohol, glycerine, and soap. Finally, the solution obtained was heated until 100°C to remove excess water and moisture content before placing it in a beaker covered with aluminium foil.

2.2 Blending Karanja Biodiesel

The blending process of Karanja biodiesel (B10) was conducted with Magnesium Oxide (MgO) as an additive by using the ultrasonication process. The ultrasonication process creates sufficient mixing between the B10 and MgO by forming cavitation and microbubbles. Firstly, 30 ppm and 60ppm of MgO were prepared for the added percentage (5% and 10%), respectively. Then, it was added and stirred together with B10 in the beaker. The ultrasonication process started with the addition of distilled water into the ultrasonicator. Next, the mixture of B10 and MgO in the beaker will be placed in the equipment. The process was done twice, with every cycle taking 15 minutes. Once the mixture is dispersed completely, it means the samples are ready, as shown in Fig. 1.

Fig. 1: Sample of conventional diesel, B10, B10MgO5 and B10MgO10.

2.3 Karanja Biodiesel Characterization

The Karanja biodiesel analysis took place at Chemical Laboratory, Faculty of Engineering, University Malaysia Sarawak. The flow chart for testing is shown in Fig. 2. Three machines were utilized to characterize and test the fuels that are bomb calorimeter, Fourier transforms infrared spectroscopy (FT-IR), and Diesel Engine test.

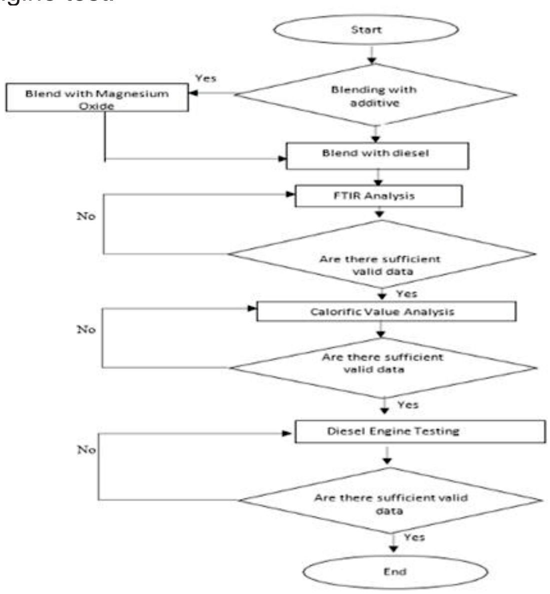

Fig. 2: Flowchart of characterization and testing.

3. RESULTS AND DISCUSSION

3.1 Effect of Acid Catalysed Transesterification towards FFA based on the ratio

The pre-treatment process involves mixing of three oil samples with different methanol to oil molar ratios (7:1, 8:1, and 9:1) with 1% of H_2SO_4 (wt/wt of oil). After the crude oil had been pre-treated and heated to remove excess moisture content, 2g of oil samples were weighed, and then a titration process was used to check the FFA content. The result of titration for the pre-treated Karanja oil from acid-catalyzed transesterification is shown in Fig. 3.

3.2 Effect of Base Catalysed in Biodiesel Yield

The concentration of sodium hydroxide used is 0.5%,0.6%, and 0.7%. Various amounts of catalyst percentage were used to detect the best one that can produce the highest biodiesel yield. All three samples of Karanja biodiesel with molarity 9:1 were set with the same reaction temperature at 60ºC and a duration of 1 hour (Sharma & Singh, 2008). The settling was for one day at room temperature, and the results are shown in Fig. 4.

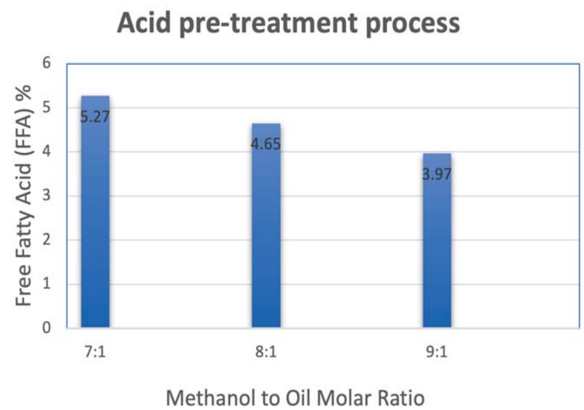

Fig. 3: FFA content against methanol to oil molar ratio.

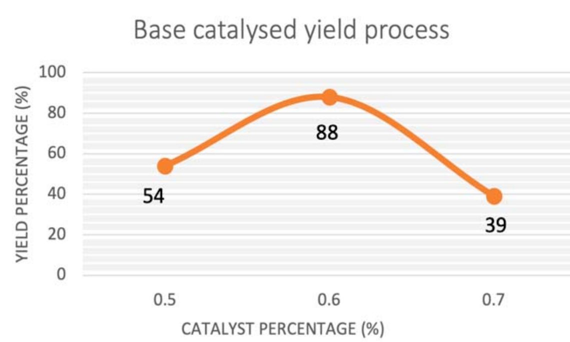

Fig. 4: Biodiesel yield against amount of catalyst.

3.3 Bomb Calorimeter Analysis Test

The highest calorific value was recorded by conventional diesel with 45.5815 MJ/kg, followed by B10MgO10 and B10MgO5. Both blended fuels with Magnesium Oxide (5 % and 10%) recorded 44.1474 and 42.9404 MJ/kg, respectively. While the smallest value was obtained by B10 with 38.7741 MJ/kg. The bar graph of calorific value against sample fuels is plotted and displayed in Fig. 5.

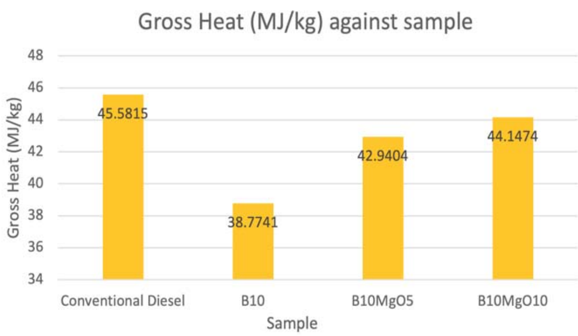

Fig. 5: Calorific value (MJ/kg) against sample.

3.4 Fourier Transform Infrared Spectrometer (FT-IR) Analysis

Based on the FT-IR spectrum results, the high absorbance and intensity are indicated by peaks with low transmittance percentages. Fig. 6 shows the infrared spectrum of diesel. The C-H stretches at 2918.30 to 2852.72 cm^{-1} is indicating peaks with high absorbance and intensity. The follow-up peaks occur from 1456.26 to 1373.32 cm^{-1} represents C-H bending. The existence of alkane is confirmed throughout this range. C-H types of functional groups show the presence of hydrocarbon in the diesel. At the end of the figure, another peak occurs at 721.38 cm^{-1}. This falls under the family of the alkene. Over here, it is seen that alkane has more peaks than alkenes. Moreover, The C-H bond that comes from stretching has higher energy than bending. The other samples of biodiesel are B5, B10MgO5, and B10MgO10 were compared to conventional diesel. The existence of a C-H bond in all three biodiesel samples indicates that it can act as fuel like diesel. There are no arguments about this. Fig. 7 shows the infrared spectrum for B10. The stretching of the C-H bond occurs at the peak at the range from 2922.16 to 2852.72 cm^{-1}. Additionally, the peak with C=O stretch at 1745.48 cm^{-1} updating that the functional group of esters is being formed in this fuel sample. Fig. 8 and 9 also show the presence of ester with the inclusion of C=O stretch. B10MgO5 and B10MgO10 recorded the value of 1743.65 for this type of stretch. The oxidation process that happens due to the presence of magnesium oxide introduces a new bond at the last two samples (Karthikeyan et al., 2017).

It is an O-H stretch at the peak value of 3965.61 and 3734.19cm^{-1} respectively for both B10 samples with the addition of MgO (5% and 10 %) as additive. The O-H bond shows the presence of oxygen. Oxygen promotes complete combustion in the CI engine, reducing black smoke through the exhaust. It also happens due to the reduction of hydrocarbon percentage in exhaust gases. Combustion efficiency will improve when biodiesel has to burn at a high rate due to the existence of the O-H bond. This proves that the Karanja biodiesel blended with MgO can improve performance and emission for the diesel engine.

3.5 Engine Performance Analysis

The performance of the diesel engine was investigated with three key parameters, which are brake horsepower (BHP), brake specific fuel consumption (BSFC), and mechanical efficiency. The BHP value obtained by B10 was the lowest in the graph shown in Fig. 10. There is close data between B10MgO10 and conventional diesel that can be seen in this figure due to each line that intersects each other. Conventional diesel has a

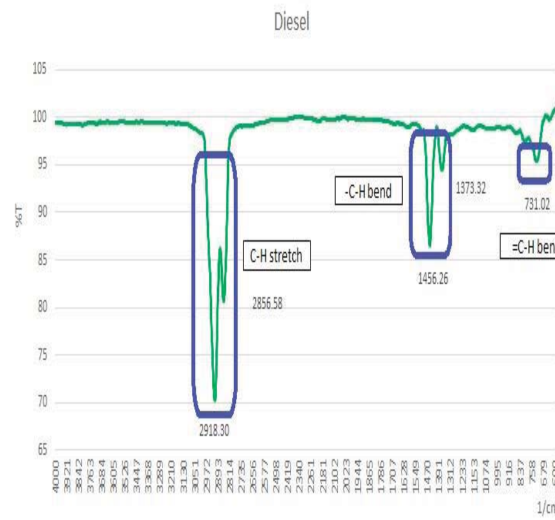

Fig. 6: Infrared spectrum of diesel.

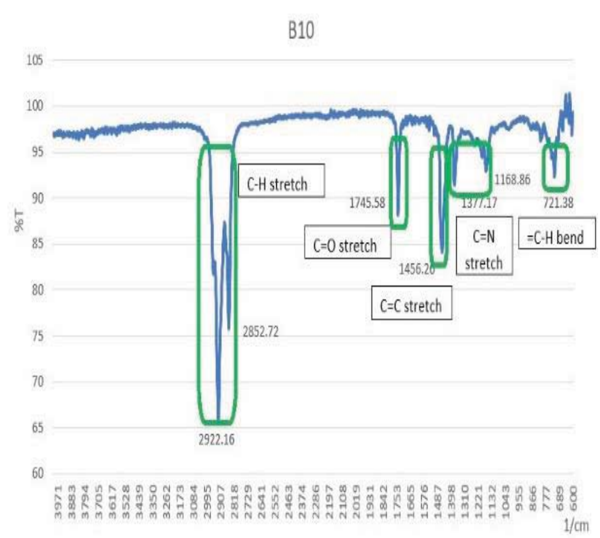

Fig. 7: Infrared spectrum of B10.

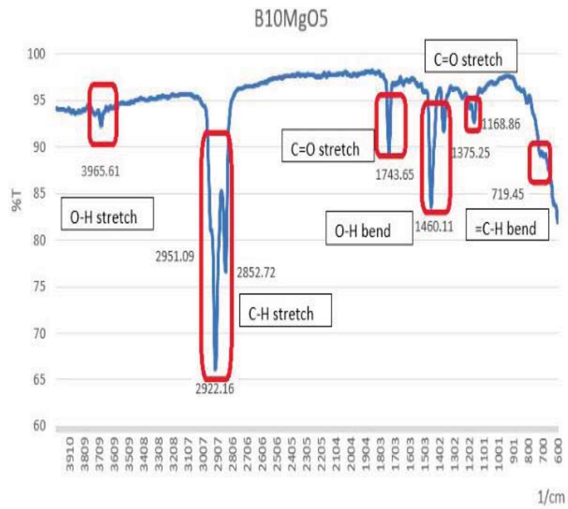

Fig. 8: Infrared spectrum of B10MgO5.

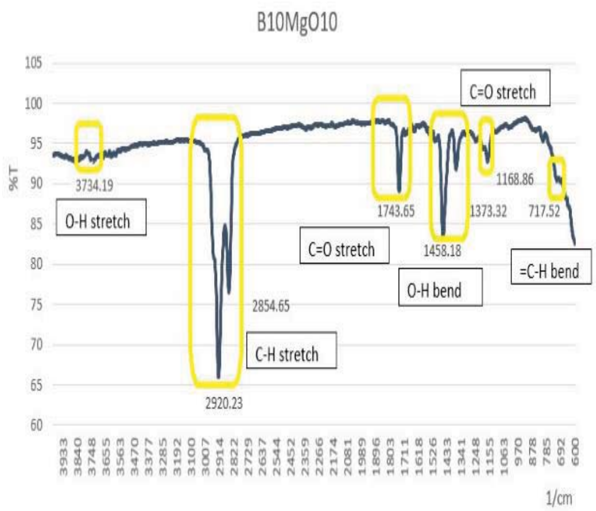

Fig. 9: Infrared spectrum of B10MgO10.

higher BHP value at a speed of 2200 rpm. While Karanja biodiesel with 10% Magnesium Oxide as additives has a greater BHP value among other samples from the speed of 1400 to 1600 rpm. It seems that the addition of MgO improves the characteristics of BHP effectively. From B10 to B10MgO10, the Karanja biodiesel is able to compete with conventional diesel in terms of diesel creating high engine power. (Dhar & Agarwal, 2014) mentioned that BHP is strongly linked to calorific value. The engine power increase when the calorific value gets higher. Moreover, the addition of magnesium oxide also provides complete combustion in the diesel engine since the value of torque and brake horsepower increases.

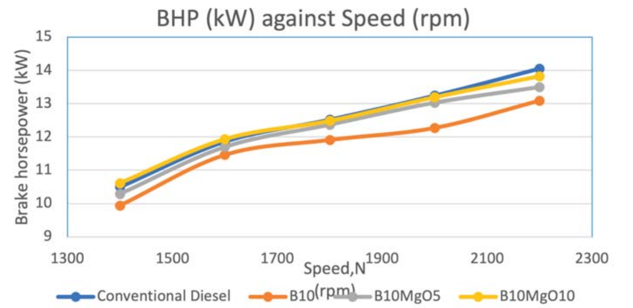

Fig. 10: Brake horsepower (kW) against speed (rpm).

Significantly, the addition of MgO reduces fuel consumption in the blended Karanja biodiesel samples. The results showed that increasing the amount of additive will increase the BSFC. (Ganesan et al., 2020) stated that low BSFC proves that fuel has a high percentage of fuel efficiency. The fact is supported due to the engine capability of consuming little fuel yet producing high power. Indeed, B5MgO10 has the highest calorific value compared to the other samples except for conventional diesel, as shown in Fig. 11. (Lee et al., 2017) updated that the highest energy content in the sample improves the combustion process in the diesel engine yet reduces brake-specific fuel consumption.

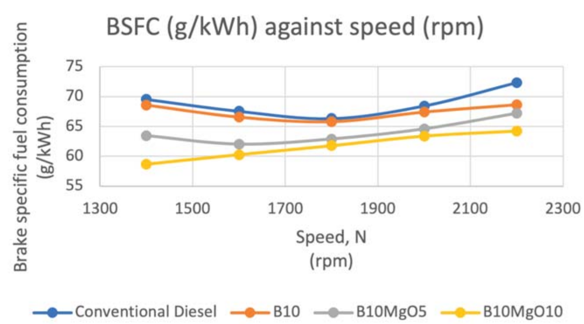

Fig. 11: Brake specific fuel consumption (g/kWh) against speed (rpm).

Based on the data obtained, a graph of mechanical efficiency against speed was plotted. Figure 12 showcases that the highest mechanical efficiency at 2200 rpm (maximum speed) is achieved by conventional diesel at 24.31%, followed by B10MgO10, B10MgO5, and B10 at 23.91%, 23.36%, and 22.65%, respectively. Although conventional diesel has better mechanical efficiency at the maximum speed, it was B10MgO10 initially that performed the highest efficiency at the starting of the diesel engine cycle. During the speed of 1400 and 1600 rpm, the mechanical efficiency for B10MgO10 was the highest among all by obtaining 18.36 % and 20.64% respectively. It can be concluded here that the presence of Magnesium Oxide as an additive will enhance mechanical efficiency at a lower speed (Prasad & Gupta, 2016). However, as the speed increases, conventional diesel becomes optimum in mechanical efficiency, especially starting at 1800 rpm.

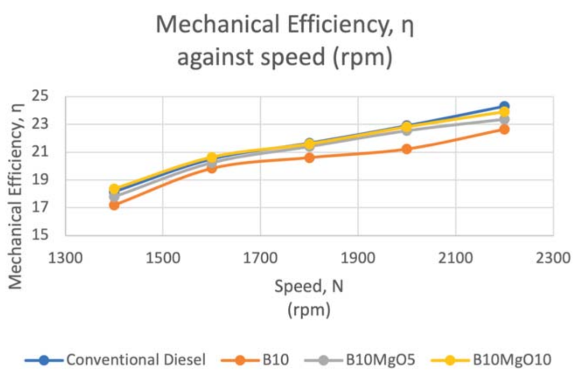

Fig. 12: Mechanical Efficiency, η against Speed (rpm).

4. CONCLUSIONS

Karanja Biodiesel was produced from non-edible oil through the transesterification process. Indeed, Bomb Calorimeter analysis found that the highest calorific value was recorded by conventional diesel with 45.5815 MJ/kg followed by B10MgO10 and B10MgO5. While the smallest value was obtained by B10 with 38.7741 MJ/kg. Besides that, the FT-IR analysis also proves that the Karanja Biodiesel, together with blended samples has the same functional group as conventional diesel. It is the C-H (hydrocarbons) group that updates the capability of blended Karanja Biodiesel with additives specifically has the potential to be used as fuels. Besides, B10MgO5 and B10MgO10 samples also consist of an O-H bond. This functional group indicates the presence of oxygen in the mentioned fuel samples. Since they contain oxygen, the burning process of biodiesel is more effective and eventually increases the efficiency of combustion. Finally, the performance of the diesel engine was investigated with three key parameters, which are brake horsepower, brake specific fuel consumption, and mechanical efficiency. The performance of the diesel engine is analyzed at the speed of 1400 rpm until 2200 rpm with an interval of 200 rpm.

Karanja biodiesel with 10% Magnesium Oxide as additives has a greater BHP value among other samples from the speed of 1400 to 1600 rpm. It seems that the addition of MgO improves the characteristics of BHP effectively. Moreover, the results showed that the increasing amount of additives will increase the BSFC value. Low BSFC proves that fuel has a high percentage of fuel efficiency. B5MgO10 has the lowest BSFC value compared to the other samples. Furthermore, conventional diesel has better mechanical efficiency at the maximum speed, it was B10MgO10 initially that performed the highest efficiency at the starting of the diesel engine cycle. It can be concluded here that the presence of Magnesium Oxide as an additive will enhance the mechanical efficiency at a lower speed.

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