



Investigation of Blended Palm Biodiesel-Diesel Fuel Properties with Water Emulsification

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ABSTRACT

Under the crisis of global warming and drastic climate changing, carbon-neutral renewable energy is considerably proposed as a feasible clean alternative energy to fractionally replace fossilized fuel. To cop up with ever stringent emission regulations, researchers have investigated different types of renewable fuels like biodiesel and water emulsion. The fuel physical characteristics are among the most important parameter to determine the quality of each fuel before it being tested in the engine. This study aims to evaluate the stability period and mean droplet size of the particles and to characterize the physicochemical properties of emulsified biodiesel blend B20 in terms of kinematic viscosity, density and calorific value with different percentage of water; 5%, 10%, 20%, and 30%. The tested fuel samples were compared with diesel fuel and blended palm biodiesel (B20). The experimental results show that when the proportion of water was increased in diesel-biodiesel blends, the dispersed water droplets become larger. The stability period in terms of days for emulsion fuels becomes lower when the amount of water was increased to the blends. The least stability period for emulsion obtained by emulsion with 20% and 30% water content which is 2 days. The kinematic viscosity and density of biodiesel emulsions were larger than those of the neat biodiesel. The calorific value for emulsion with 5% water content is comparable to blended fuel and conventional diesel even though there was a slight reduction.



1) Introduction

Under the crisis of global warming and drastic climate changing, carbon-neutral renewable energy is considerably proposed as a feasible clean alternative energy to fractionally replace fossilized fuel [1].

Moreover, the depleting reserves of this source and the emerging threats over high levels of pollutants coming from vehicular exhaust have enthused the scientists and researchers towards exploring for inexhaustible alternative energy sources to steer clear of this problem [2].

Among the various kinds of renewable energy, biofuels energy, ranked fourth in the world's total energy consumption is fast becoming the major part in lessening the dependency on fossilized fuel, due to its advantages such as lower handling and storage cost, lower technical threshold, outstanding lubricity, biodegradable, less carbon footprint and rich sources [3-5].

Despite their superior advantages, biodiesel portrayed as one of the major pollutant contributors in terms of nitrogen oxides (NO_x). In general, biodiesel can be considered a kind of oxygenated fuel because it comprises about 10 wt. % of oxygen. With the high oxygen content in biodiesel, the engine testing could result in the reduction of particulate matter (PM), hydrocarbon (HC), carbon monoxides (CO), soot and other exhaust emissions, but concurrently emitted a large amount of NO_x, especially under elevated temperature burning environment [6]. Tüccar *et al.* [7] studied *Citrus sinensis* biodiesel in a multi-cylinder direct injection diesel engine blended with conventional diesel with volumetric ratios of 5-20%. They reported the reduction in CO emissions whereas NO_x values increased.

Similarly, Öztürk [8] reported that by using the mixture of hazelnut soapstock and canola oil biodiesel, the HC, CO and smoke emissions decreased, but at the same time NO_x emission increased. It is expected that the burning of pure biodiesel would produce about 10% more NO_x than that of conventional diesel, primarily due to the high oxygen content of the pure biodiesel [9]. The two elements of nitric oxide (NO) and nitrogen dioxide (NO₂) are combined to form NO_x [10].

Nitrogen oxides produced during the combustion process at elevated temperature are believed to aggravate asthmatic conditions. NO_x is called ozone precursor because it reacts with the oxygen in the air to produce ozone, which is

a relatively low amount can cause coughing, chest pain, throat irritation and shortness of breath. In a large quantity, the ozone can increase the risk of harmful respiratory effects and finally, damage the lungs when inhaled [11]. Researchers and scientists have investigated different types of alternative fuels and techniques such as biodiesel and water emulsion to cope up with ever-stringent emission regulations. The purpose of the emulsification technique being applied to the blended fuel is to reduce NO_x formation and to enhance the combustion efficiency for petroleum-based fuels. From the emulsification technique, water is mixed homogeneously with the conventional diesel fuel on a volume basis, typically in presence of an appropriate surfactant that reduces the surface tension between oil and water, maximizing their superficial contact area, hence, activating their surfaces [12].

Water emulsification with biodiesel is a convenient and feasible method as the existing engine due to unnecessary prior or post-modification. Furthermore, the presence of tiny water particles may lead to a micro explosion, which also enhances further fuel atomization [13].

The emulsion fuel produced from the emulsification technique is yet to be tested on engine experimental investigations must undergo physical properties test beforehand. This study aims to evaluate the stability period and mean droplet size of the particles and to characterize the physicochemical properties of emulsified biodiesel blend B20 in terms of kinematic viscosity, density and calorific value with different percentage of water; 5%, 10%, 20%, and 30%.

2) Materials and methods

Palm oil methyl ester (POME) was provided by a local supplier from a processing plant located in Shah Alam, Malaysia. Diesel fuel was supplied by a commercial company. Table 1 shows the properties of conventional diesel and POME.

Table 1: The specifications of POME and conventional diesel

Property	Diesel	POME
Density (kg/m ³)	826	867
Viscosity (mm ² /s) (cSt)	5.14	7.50
Calorific value (MJ/kg)	44.8	38.6
Cetane number	47.8	55.5

Sulfur (ppm)	1-10	-
Flashpoint (°C)	93	165
Pour point (°C)	12	7.0
Oxygen content, %	0	-
Lubricity	Good	Excellent

The samples were prepared through blending and external force which is through mechanical stirring. The palm oil methyl ester (POME) biodiesel-diesel blend B20 is prepared first before it was emulsified with water.

By using IKA RW 20 digital overhead stirrer, POME was added into conventional diesel and mixed at a low stirring rate. Then, the mixture was stirred uninterruptedly at 800 rpm for about 20 minutes.

Then, the mixture was left for half an hour to reach equilibrium at certain room temperature before they were undergone any test as suggested by Lim, Ooi and Hong [14]. Similarly, the emulsified fuel was blended using the same stirrer at a speed of 800 rpm for 20 minutes.

Maawa [15] concluded that when the rotational speed increases until 1400 rpm, the stabilization of the emulsion increases as well. On the other hand, when the rotational speed was further increased (>1000 rpm), only a slight effect on stabilization was noticed [16].

According to Aziz *et al.* [17] technique, both surfactants Tween 80 and Span 80 were added into the mixture of biodiesel B20 and water. The test fuels were biodiesel blend (B20), B20 emulsified with 5% water (B20E5), B20 emulsified with 10% water (B20E10), B20 emulsified with 20% water (B20E20) and B20 emulsified with 30% water (B20E30). The amount of each surfactant was set at 1 % of the total volume. The stability of the emulsions was recorded in terms of days.

2-1) Droplet Size Observation and Fuel Property Testing

Photos comparing the droplet size of emulsion were taken using Meiji IM 7100 inverted binocular metallurgical microscope. The viscosities of the tested fuels were measured using the Cannon-Fenske routine viscometer and the method used is according to ASTM D445-06 for transparent and opaque liquids. The kinematic viscosity range for this test 1.6–8.0 mm²/s for size 75. The determination of viscosity is performed using KV1000 digital constant temperature kinematic viscosity bath at a

temperature of 40 + 0.1°C. The kinematic viscosity is calculated by multiplying the efflux time by the viscometer constant, as shown in Eq. 1

$$v = k_v t \quad (1)$$

where k_v , expressed in mm²/s², act as a constant of the viscometer. t is the efflux time of the liquid to be examined, in seconds. The density of the fuel is measured conforming to ASTM D1298 using model DA-130N Portable Density/Specific Gravity Meter at 15°C. from Kyoto Electronics Manufacturing. The apparatus has a range of 0 to 2.0000 g/cm³ with an accuracy of +/- 0.001 g/cm³ with a graphic LCD.

The calorific value of the samples was determined using an Oxygen Bomb Calorimeter model 6772 from Parr Instrument Company, according to ASTM D4809. Figure 1 depicted different analytical apparatus to observe mean droplet size and fuel properties. All the test methods conform to the ASTM standard procedures for each equipment. The tests were conducted under controlled room temperature, pressure and relative humidity to ensure that the result is not influenced by environmental conditions.

2-2) Statistical Analysis of Fuel Properties

A statistical analysis technique called "Tukey Grouping" is implemented on the data. The purpose of the technique is to provide specific information on the relations between the variables.

Tukey Grouping stated that if the variables have the same letter, the difference between those variables is not statistically significant [18].

Further investigation by using a one-way analysis of variance (ANOVA) is also conducted to determine the level of significance of the different percentages of water on the fuel properties. In this analysis, the F value represents the probability distribution in repeated sampling, 'df' represents the degree of freedom, and P-value represents the weight of significance.

The difference between the fuels for certain properties is considered significant when the value of F is larger than F_{crit}. A 5% significance level which is equivalent to a 95% confidence level was used for all the statistical analyses in the present study.

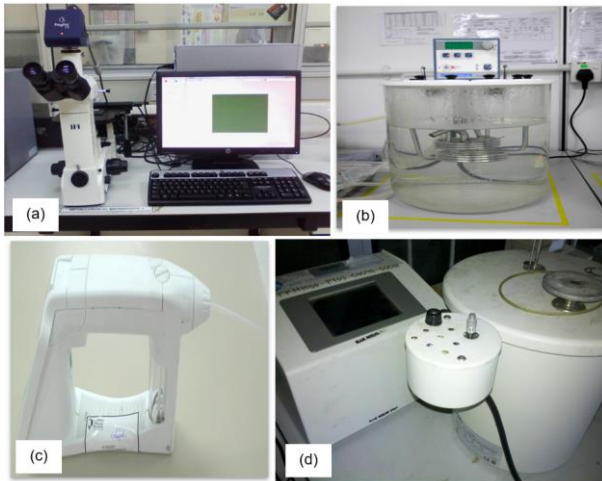


Figure 1: Analytical instrument
 (a) The Meiji IM7100 Inverted Metallurgical Microscope connected to the computer,
 (b) Koehler Digital Constant Temperature Kinematic Viscosity Bath,
 (c) Portable Density/Specific Gravity Meter,
 (d) Oxygen Bomb Calorimeter

3) Results and Discussion

3-1) Stability Period and Droplet Observation

Figure 2 shows photographs of the microstructure of emulsified fuel with different percentages of water content (5%-30%). The round dots are the droplet of water while the rest is dispersed mixed diesel-biodiesel [19].

The introduction of water in biodiesel could form micro-emulsions in the water-in-oil (W/O) structure. Figure 2(a) is emulsified blended fuel with 5% of water, In Figure 2(a), the water droplets are dispersed more tightly and even, followed by Figure 2(b), Figure 2(c) and Figure 2(d). It can be concluded that the more volume of water in W/O, the heavier the molecules, and the larger the dispersed droplets.

Figure 3 illustrates the stability period and the mean particle size of the emulsions. The stability period was observed in days and mean particle size was observed using Meiji IM7100 Binocular Inverted metallurgical microscope. The days of stability of the emulsion is decreased when the water proportion is increased. On the contrary, the mean particle size of the droplet increased when the water content is increased.

B20E5, B20E10, B20E20 and B20E30 had mean particle size distributions of 15 μm , 25 μm , 65 μm , and 78 μm , respectively. The stability period in terms of days for B20E5, B20E10, B20E20 and B20E30 are 32, 15, 2 and 2 separately.

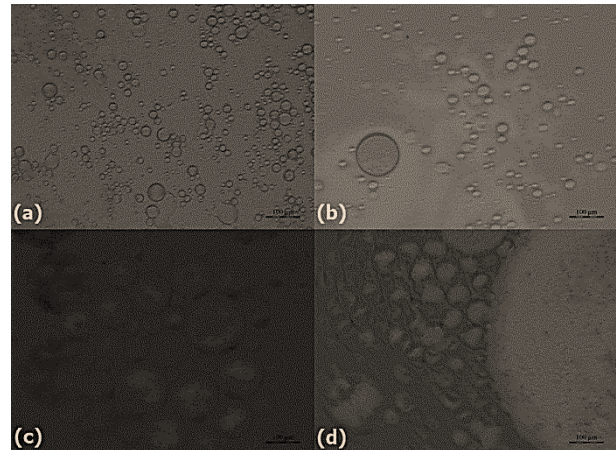


Figure 2: Comparison of microscopic photos for emulsion with different water contents.
 (a) 5% water content. (b) 10% water content.
 (c) 20% water content. (d) 30% water content.

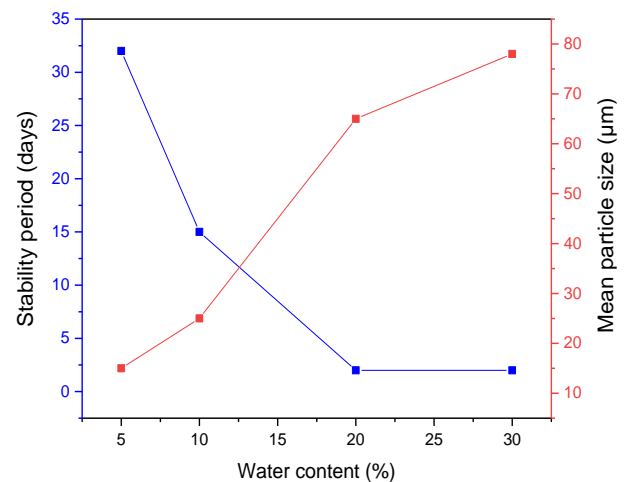


Figure 3: Effect of water content to the emulsion stability period and mean particle size

3-2) Kinematic Viscosity Analysis

The kinematic viscosity of the fuels at 40 $^{\circ}\text{C}$ varies in the range of 3.8–5.24 mm^2/s for diesel, POME biodiesel-diesel blend (B20) and emulsions as shown in Figure 4. The figure shows the effect of blending 20% biodiesel with 80% of diesel and different percentages of water in the blend to the kinematic viscosity.

According to ASTM standard D7467, the minimum limit for kinematic viscosity covered by ASTM D445 is 1.9 mm^2/s while the maximum limit is 4.1 mm^2/s . The kinematic viscosity for the diesel, B20, B20E5, B20E10, B20E20 and B20E30 were 3.91 mm^2/s , 4.02 mm^2/s , 4.38 mm^2/s , 4.72 mm^2/s and 5.24 mm^2/s respectively. The kinematic viscosity for B20 and B20E5 is still in range, but for the B20E10, B20E20 and B20E30, it exceeded the maximum limit for the standard specifications of biodiesel blend.

When diesel is blended with POME biodiesel at 20% volume, the kinematic viscosity increased by about 2.89%. The increase is expected as the biodiesel is more viscous than pure diesel. When it is blended, the blended fuel would adopt the property of biodiesel.

Generally, the viscosity of biodiesel highly depends on the number of percent conversion of triglyceride into the alkyl ester compounds. Notably, when water was introduced to the biodiesel-diesel blend, the kinematic viscosity increased.

Similar results obtained by Alahmer [20] by using up to 15% of water content and Badran *et al.* [21] by using up to 30% of water content. The increased of emulsion viscosity can be explained by the flow pattern distortion of liquid layers due to the presence of another immiscible liquid droplet having a size exceeding the liquid molecular size, hence the hydrodynamic interaction between water droplets in the fuel will increase the coefficient of internal friction of emulsion [22].

The highest increment of kinematic viscosity experienced by B20E30 was 37.89%. The percentage increase of kinematic viscosity concerning diesel for B20E5, B20E10 and B20E20 were 5.79%, 15.26%, and 24.21%, respectively.

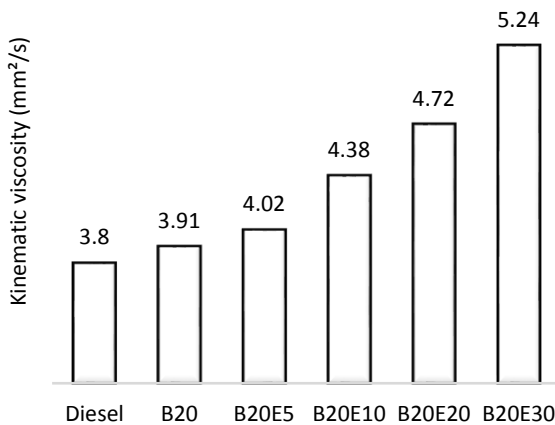


Figure 4: Effect of biodiesel blend and water content on kinematic viscosity

Viscosity is an indication of the material’s ability to flow. The lower viscosity indicates that the fuel easily flows while the higher viscosity indicates that the fuel tends to form larger droplets of injection.

The high kinematic viscosity may influence the atomization process ultimately resulting in incomplete combustion and increasing the

deposition of solid unburned particles, hence reducing the engine efficiency.

For the long-term consequence, the very high viscosity of the fuel is likely a given effect to the durability of the engine, especially to the fuel injector. Table 2 illustrates the Tukey Grouping test for variable kinematic viscosity for all tested fuels. The 20% of POME and different percentage of the water content has a statistically significant effect on the fuel kinematic viscosity since all types of fuel have different letters.

Table 3 represents the outcomes of the one-way ANOVA for the kinematic viscosity of the fuels. From the ANOVA table, the value of F is much larger than Fcrit, therefore it is safe to state that the adding of POME and water emulsification have a significant effect on the blended fuel kinematic viscosity.

Table 2: Tukey Grouping test for variable kinematic viscosity

Fuel	N	Mean	Tukey Grouping
Diesel	3	3.80	A
B20	3	3.91	AB
B20E5	3	4.02	B
B20E10	3	4.38	C
B20E20	3	4.72	D
B20E30	3	5.24	E

Table 3: Analysis of variance (ANOVA) for kinematic viscosity

Source of Variation	Between Groups	Within Groups	Total
Sum of Squares	4.6043	0.0404	4.6447
df	5	12	17
Mean square	0.9209	0.0034	
F	273.52		
P-value	6.28E-12		
F _{crit}	3.1059		

3-3) Density Analysis

The density of the tested fuels varies in the range of 820–890 kg/mm³ for diesel, POME biodiesel-diesel blend (B20) and emulsified fuels respectively as shown in Figure 5. The figure shows the effects of blending 20% biodiesel with 80% of diesel and different percentages of water in the blend on the density.

The test method ASTM D1298 is used to test the density of the biodiesel-diesel blend according

to the ASTM D7467 standard. The method stated that the minimum is 820 kg/m³ and the maximum limit for the blend is 858 kg/m³. The density of the diesel fuel, B20, B20E5, B20E10, B20E20 and B20E30 were 820 kg/m³, 854 kg/m³, 860 kg/m³, 871 kg/m³, 877 kg/m³ and 890 kg/m³.

It was clearly shown that the density of all emulsified fuels is out of range for ASTM D7467 standard. The density increase by about 4.15% when 20% of POME biodiesel was blended with 80% of pure diesel in volume. The density of biodiesel is higher than pure diesel. It is important to characterize the density of the blended fuel as it will affect the engine performance directly due to the different mass of fuel injected [23]. As the water was introduced to the blend, the fuel becomes denser which agrees with several works of literature [21, 24, 25].

Vellaiyan and Amirthagadeswaran [26] reported that the increase in density is due to the high density of water over biodiesel, therefore the emulsion fuels adopted the water high-density properties.

The increase in water proportion increased fuel density which is the maximum value of 8.54% of density acquired by B20E30 for pure diesel. The increase of density for pure diesel for B20E5, B20E10 and B20E20 were 4.88%, 6.22%, and 6.96% respectively.

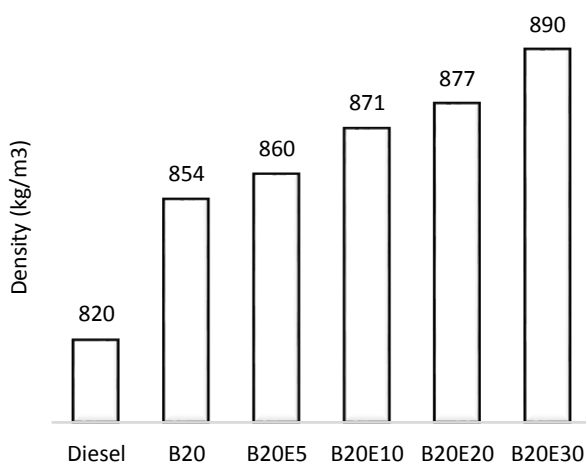


Figure 5: Effect of biodiesel blend and water content on density

Table 4 depicts the Tukey Grouping analysis for the blended fuel and emulsion fuels on the fuel density. From this table, it is determined that there is a statistically significant effect of the biodiesel and water content on the fuel density. However, emulsion fuel with 5% water content

and 10% water content shared the same letters (two letters in Tukey Grouping), hence there is no statistically significant effect between these two types of fuel. Table 5 shows the result of one-way ANOVA for all tested fuels.

The value of F is larger than F_{crit}, therefore it is safe to conclude that the blended diesel fuel with 20% of POME and emulsification with different percentages of water have a significant effect on the fuel density.

Table 4: Tukey Grouping test for variable density

Fuel	N	Mean	Tukey Grouping
Diesel	3	820	A
B20	3	854	B
B20E5	3	860	BC
B20E10	3	871	BC
B20E20	3	877	CD
B20E30	3	890	D

Table 5: Analysis of variance (ANOVA) for density

Source of Variation	Between Groups	Within Groups	Total
Sum of Squares	8766	528	9294
df	5	12	17
Mean square	1753.2	44	
F	39.845		
P-value	4.57E-07		
F _{crit}	3.1059		

3-4) Calorific Value Analysis

Calorific value refers to the quantity of heat produced by the complete combustion by a given mass. Figure 6 illustrates the variation of calorific value of the diesel, POME biodiesel-diesel blend and emulsified fuels.

The values vary between 31.03 MJ/kg to 42.50 MJ/kg. The calorific value is not specified in ASTM D7467 standard. The highest calorific value 42.50 MJ/kg was achieved by pure diesel, followed by POME biodiesel blend B20 with 42.05 MJ/kg. The reduction of 1.06% when pure diesel blends with biodiesel is caused by the higher oxygen content in biodiesel [27].

When 5% of water was introduced to the blend, the calorific value decreased by 1.98% compared to mineral diesel. When the water concentration further increased, the calorific value became lower. This behavior is in agreement with Nadeem *et al.* [28].

The calorific value decreases with the

percentage of water in the emulsion as the water has no calorific value [24]. The calorific value for B20E10, B20E20 and B20E30 were 38.67 MJ/kg, 35.94 MJ/kg and 31.03 MJ/kg respectively. The maximum reduction of 26.99% for pure diesel was obtained by B20E30, followed by B20E20 (15.44%), and B20E10 (9.01%).

Table 6 illustrates the Tukey Grouping analysis for the tested fuel calorific values. From the table, the addition of 20% POME to the conventional diesel and when 5% of water proportion is emulsified to the blended fuel, there was no statistically significant difference to the fuel calorific value since they have the same letter. However, when further water proportion was added to the blended fuel, it shows a significant variation in fuel calorific value.

Table 7 presents the results of one-way ANOVA performed on all the tested fuels. From the ANOVA table, since the value of F is much larger than Fcrit, this means the calorific value for all tested fuels is not equal. The addition of POME and water content to the fuel has a significant effect on the calorific value.

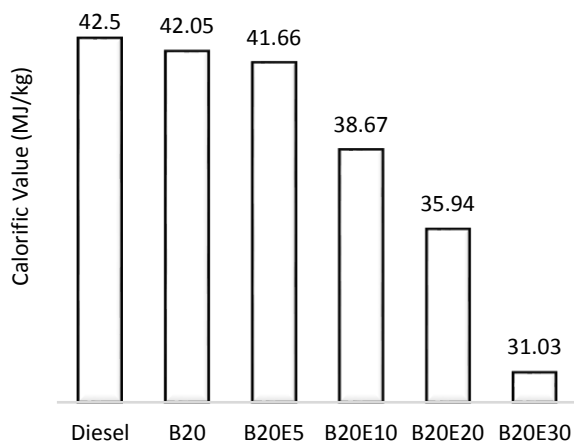


Figure 6: Effect of biodiesel el blend and water content on calorific value

Table 6: Tukey Grouping test for variable calorific value

Fuel	N	Mean	Tukey Grouping
Diesel	3	42.50	A
B20	3	42.05	A
B20E5	3	41.66	A
B20E10	3	38.67	B
B20E20	3	35.94	C
B20E30	3	31.03	D

Table 7: Analysis of variance (ANOVA) for density

Source of Variation	Between Groups	Within Groups	Total
Sum of Squares	302.55	11.644	314.2
df	5	12	17
Mean square	60.511	0.9703	
F	62.361		
P-value	3.62E-08		
F _{crit}	3.1059		

4) Conclusions

The stability period for the biodiesel-diesel emulsion fuel was observed manually and the mean droplet sizes of the emulsion were calculated through the calculation software. The results from fuel properties measurements were obtained to characterize the measured properties of blended fuel B20 and emulsion fuels.

All the properties are compared with blended fuel standard specifications ASTM D7467. A statistical analysis using Tukey Grouping was conducted on the experimental data to indicate the interaction between the test fuels, and the analysis of variance (ANOVA) was used to evaluate the level of significance of the different percentages of water. It can be concluded that;

- [1] When the proportion of water was increased in diesel-biodiesel blends, the dispersed water droplets become larger.
- [2] On the contrary, the stability period in terms of days for emulsion fuels becomes lower when the amount of water was increased to the blends. The least stability period for emulsion obtained by B20E20 and B20E30 which is 2 days.
- [3] All emulsion fuels displayed higher kinematic viscosity than the diesel and diesel-biodiesel blend. An increment of 37.89%, which is the highest increment concerning conventional diesel, was obtained by B20E30. Therefore, it can be concluded that the more water percentages in the fuel, the higher the kinematic viscosity. All emulsion fuels have exceeded the kinematic viscosity maximum ASTM D7467 limit except for B20E5.
- [4] The results show that the density of all emulsion fuel was higher than blended fuel and conventional fuel. Furthermore, it has exceeded the density maximum ASTM D7467 limit.

- [5] The calorific value for B20E5 is comparable to blended fuel and conventional diesel even though there was a slight reduction. It can be concluded that B20E5 is the best alternative for emulsion fuel.
- [6] From the Tukey Grouping test analysis, it can be concluded that there is a statistically significant effect of the biodiesel and water content on the fuel kinematic viscosity, density, and calorific value.

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مطالعه تجربی بررسی خصوصیات سوخت ترکیبی دیزل زیستی - دیزل همگن شده با آب

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کلیدواژه‌ها:

امولسیون آب

سوخت جایگزین

بیودیزل

روغن پالم

خواص سوخت

چکیده

گرمایش کره زمین و تغییرات آب و هوایی، محرکی قوی برای جایگزینی سوخت‌های متداول فسیلی با سوخت‌های جایگزین بی‌کربن است. به منظور تطابق با الزامات قوانین آلاینده‌ها، محققین ترکیب سوخت‌های جایگزین تجدید پذیر نظیر دیزل زیستی با آب را بررسی کرده‌اند. مشخصه‌های فیزیکی سوخت از مهمترین مشخصه‌ها برای تعیین کیفیت هر سوخت قبل از آزمایش در موتور است. نوشتار حاضر به بررسی ویژگی‌های مخلوط دیزل زیستی (B20) با درصد‌های مختلف آب، می‌پردازد. در این تحقیق درصد آب از ۵٪ تا ۳۰٪ تغییر کرده و گرانروی سینماتیک، چگالی و ارزش حرارتی سوخت مورد بررسی قرار می‌گیرد. نتایج نمونه‌های آزمون با نتایج سوخت دیزل و ترکیب ۲۰٪ روغن پالم با دیزل مقایسه شده است. نتایج تجربی نشان می‌دهد که با افزایش نسبت آب در محلول دیزل - دیزل زیستی، قطرات پخش شده آب در محلول بزرگتر می‌شوند. با افزایش مقدار آب در محلول، دوره پایداری سوخت کمتر می‌شود. کمترین زمان پایداری برای محلول سوخت حاصل از ترکیب با ۲۰٪ و ۳۰٪ آب، ۲ روز است. گرانروی سینماتیکی و چگالی محلول دیزل زیستی بیشتر از دیزل زیستی خالص بود. ارزش حرارتی محلول با ۵٪ آب قابل مقایسه با سوخت دیزل و دیزل زیستی بود و میزان کاهش ارزش حرارتی بسیار جزئی بود.



تمامی حقوق برای انجمن علمی موتور ایران محفوظ است.



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اطلاعات مقاله

چکیده

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پذیرش: ۲۹ بهمن ۱۳۹۸

کلیدواژه‌ها:

موتور احتراق داخلی

احتراق

عیب‌یابی با روش نوری

تزریق مستقیم بنزین

سوخت مایع / بخار

گرمایش کره زمین و تغییرات آب و هوایی، محرکی قوی برای جایگزینی سوخت‌های متداول فسیلی با سوخت‌های جایگزین بی‌کربن است. به منظور تطابق با الزامات قوانین آلاینده‌ها، محققین ترکیب سوخت‌های جایگزین تجدید پذیر نظیر دیزل زیستی با آب را بررسی کرده‌اند. مشخصه‌های فیزیکی سوخت از مهمترین مشخصه‌ها برای تعیین کیفیت هر سوخت قبل از آزمایش در موتور است. نوشتار حاضر به بررسی ویژگی‌های مخلوط دیزل زیستی (B20) با درصدهای مختلف آب، می‌پردازد. در این تحقیق درصد آب از ۵٪ تا ۳۰٪ تغییر کرده و گرانروی سینماتیک، چگالی و ارزش حرارتی سوخت مورد بررسی قرار می‌گیرد. نتایج نمونه‌های آزمون با نتایج سوخت دیزل و ترکیب ۲۰٪ روغن پالم با دیزل مقایسه شده است. نتایج تجربی نشان می‌دهد که با افزایش نسبت آب در محلول دیزل - دیزل زیستی، قطرات پخش شده آب در محلول بزرگتر می‌شوند. با افزایش مقدار آب در محلول، دوره پایداری سوخت کمتر می‌شود. کمترین زمان پایداری برای محلول سوخت حاصل از ترکیب با ۲۰٪ و ۳۰٪ آب، ۲ روز است. گرانروی سینماتیکی و چگالی محلول دیزل زیستی بیشتر از دیزل زیستی خالص بود. ارزش حرارتی محلول با ۵٪ آب قابل مقایسه با سوخت دیزل و دیزل زیستی بود و میزان کاهش ارزش حرارتی بسیار جزئی بود.



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