STUDY ON THE CHARACTERISTIC AND EFFECTS OF DIESEL-PROPANOL-BIODIESEL AND BIODIESEL BLEND IN A COMPRESSION IGNITION ENGINE

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Abstract

This research aimed to study biodiesel production from refined palm oil stearin and propanol as an alternative fuel. The experimental results found that biodiesel production from refined palm oil stearin using sodium hydroxide as the base catalyst was 74%. Using biodiesel from refined palm oil stearin as an emulsifier in diesel: propanol: biodiesel D90P5B5(RPO), D85P5B10(RPO), and D80P5B15(RPO) at 99.9% propanol purity, the experiments examined the homogeneity and stability of the fuel produced. It was found that D90P5B5(RPO), D85P5B10(RPO), and D80P5B15(RPO) (virtue of propanol 99.9%) were homogeneous. From the results, the physical properties of D90P5B5(RPO) and D90B10(RPO) from the experiment met the high-speed diesel standards except for the flashpoint of diesohol, which was lower than standard high-speed diesel fuel. Furthermore, the results of the lubricating properties test evaluated by High-Frequency Reciprocating Rig (HFRR) according to CEC-F-06-A-96, D90P5B5(RPO) had a wear scar test 236 and D90B10(RPO) had a wear scar test 234, which were related to the better viscosity and lubricity properties than standard high-speed diesel fuel.

Keywords: Biodiesel, Transesterifications, Methyl ester, Propanol, Diesohol

1. Introduction

Biodiesel production can help meet the country's renewable energy needs. Palm oil produces the highest yield and is one of its economic crops, so it could be used as an alternative energy source for petroleum fuels. Thus, refined palm oil stearin was used in this research because the advantage of refined palm oil stearin is its low iodine content and, therefore, less polymerization than high iodine type oils. Also, biodiesel production from refined palm oil stearin is suitable because it uses the unused portion of palm oil to its full potential. Many researchers [1,2,3] researched several types of alcohol as an additive in fuels. DYC. Leung et al. [4] studied biodiesel production using methanol with the reaction temperature set below the boiling point. F Ma et al. [5] examined the interaction between methanol and sodium hydroxide and mixing to elevate the reaction, and JM. Encinar et al. [6] studied the mixing rate. Many studies [7,8,9] found using different catalysts in the transesterification process, biodiesel was produced at a low-cost, production can reduce CO_2 emissions, and compete with diesel fuel. DYC. Leung and Y. Guo [10] have reported the best temperature range was 50 to 60 °C. In this study produced biodiesel from Refined Palm Oil Stearin by using the transesterifications method. Propanol was an ingredient in diesohol production and used biodiesel as an emulsifier for the production of diesohol and biodiesel blend at low mixing ratios. Then the physical properties were studied, homogeneity and lubricating properties tests were evaluated by High-Frequency Reciprocating Rig (HFRR) according to CEC-F-06-A-96 of D90P5B5(RPO), D85P5B10(RPO), D80P5B15(RPO), D90B10(RPO), D85B15(RPO), and D80B20(RPO).

2. Objective

1. To study the biodiesel production process from Refined Palm Oil Stearin using the transesterification method and biodiesel as an emulsifier for producing diesohol and biodiesel blends at low mixing ratios.
2. To Analyze the physical properties of D90P5B5(RPO) and D90B10(RPO).
3. To study the homogeneity and observe the mixture stratification of D90P5B5(RPO), D85P5B10(RPO), D80P5B15(RPO), D90B10(RPO), D85B15(RPO), and D80B20(RPO), plus, examination the lubricating properties test evaluated by High-Frequency Reciprocating Rig (HFRR) according to CEC-F-06-A-96 of D90P5B5(RPO) and D90B10(RPO).

3. Methodology

1. Sodium hydroxide catalyst for biodiesel production from refined palm oil stearin.
2. Test for homogenization and emulsification stability by mixing diesel fuel at a low mixing ratio. To do this, the diesel: propanol: biodiesel ratio must be determined at 90:5 : 5 (by volume). However, it must be mixed using pure propanol 99.9%. The biodiesel mixture was added by continuously increasing the mixing ratio by volume 5% of the mixing balance from 5% -15% by volume of mixed diesel and biodiesel blends D90B10(RPO), D85B15(RPO), and D80B20(RPO) shall be stored for six months to observe the stratification characteristics of the mixture.
3. Testing the physical properties of standard diesel fuel, diesohol D90P5B5(RPO) and biodiesel blend D90B10(RPO).
4. Testing the lubricating properties of fuel using the method HFRR according to diesohol fuel D90P5B5 (RPO) characteristics and according to the biodiesel blend D90B10(RPO).

4. Equipment

4.1 Methods and Materials

Equipment for used in the transesterification process:

1. Magnetic stirrer temperature range: Room temperature to 340 $^{\circ}$C, at 50-1,700 rpm.
2. Bar stirring cylindrical, separating funnel, flat bottom flask, condenser, and thermometer.

4.2 Oil used in the experiment

1. Refined palm oil stearin.

4.3 Chemicals used in the experiment

1. Industrial grade methanol.
2. Propan-1-ol (n-Propanol) AR grade with a purity of 99.9%.
3. Industrial grade sodium hydroxide.
4. Sodium sulfate.

Test Description	Test Method	Testing Instrument
Intensity	ASTM D1500	Colorimeter
Density at 15 °C , g/cm^3	ASTM D4052	Digital Density Analyzer
Cetane Index	ASTM D976	Calculation
Distillation , °C	ASTM D86	Automatic Distillation Analyzer
Flash Point	ASTM D93	Pensky-Martens Closed Cup Apparatus
Fatty Acid Methyl Ester, %vol	EN 14078	Fourier Transform Infrared Spectrometer
Pour Point , °C	ASTM D97	Automatic Pour Point Tester
Viscosity at 40 °C , cSt	ASTM D445	Viscometer
Total Contamination , mg/kg	EN 12662	Fibre glass Filter
Micro Carbon Residue (MCR) , %wt	ASTM D4530	Coking Tester
Ash , %wt	ASTM D482	Ash Content Tester
Total Sulfur Content , mg/kg	ASTM D5453	UV Fluorescence Analyzer
Water Content , mg/kg	ASTM D6304	Coulometric Karl Fischer Apparatus
Water and Sediment , %Vol.	ASTM D2709	Oil Test Centrifuge
High-Frequency Reciprocating Rig (HFRR)	CEC-F-06-A-96	HFRR Instrument

Figure 1 Testing Instrument

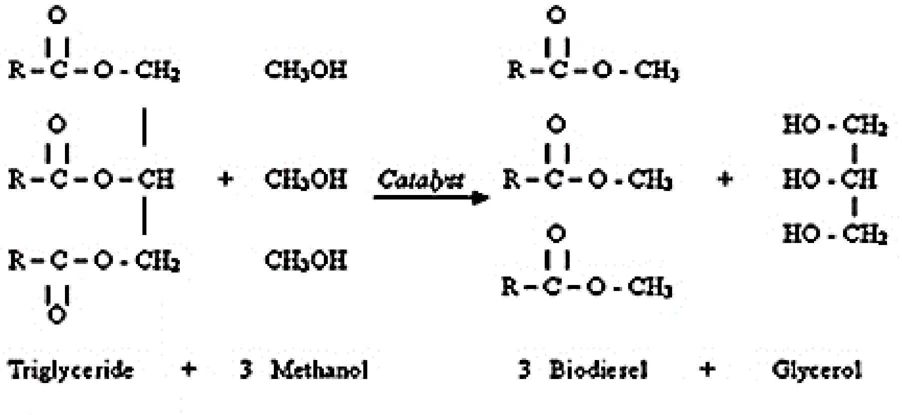

Figure 2 Transesterification of methanol and triglyceride

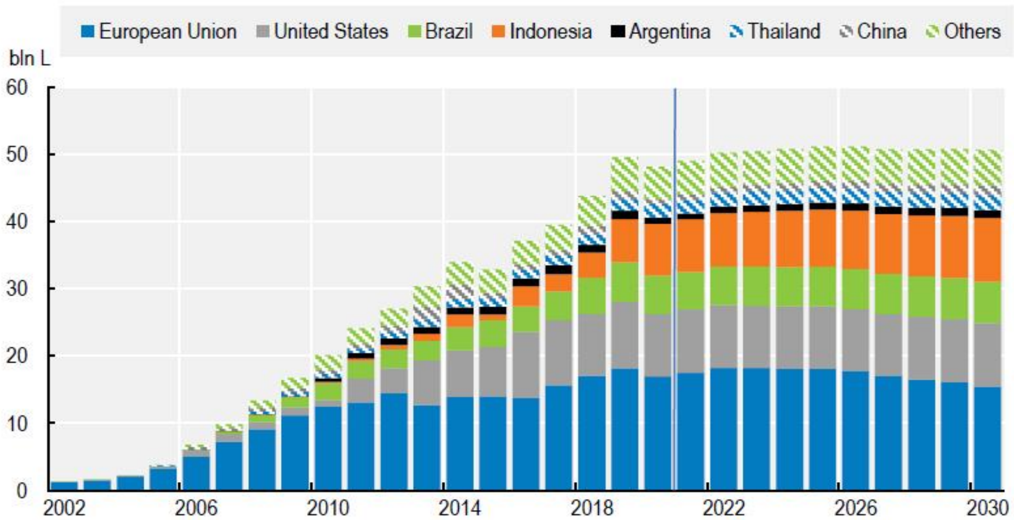

Figure 3 Progression of the world biodiesel consumption [11]

From Figure 3 Progression of the world biodiesel consumption, the share of production in the US global is down to 17%. Vegetable oil production is expected to increase globally by 1.3%. Thailand is expected to produce 3.8 million tons of palm oil in 2000.

5. Results

Table 1 The volumetric ratio of methanol to refined palm oil stearin, 0.3%NaOH(wt/vol), at 60 $^{\circ}$C, 60 min

(Methanol : RPO) (by volume)	Yield (%)
1 : 1	-
1 : 2	74
1 : 3	73
1 : 4	71.5

From Table 1 The volumetric ratio of methanol to refined palm oil stearin, 0.3%NaOH(wt/vol), at 60°C, 60 min, the maximum percentage of biodiesel production from refined palm oil stearin was 74% at 1:2; increasing the volume ratio decreases the production rate.

Table 2 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:3, at 60°C, for 60 min

%NaOH(wt/vol)	Oil (cc)	Biodiesel (cc)	Yield (%)
0.2	250	162.5	65
0.3	250	157.5	63
0.4	250	182.5	73

From Table 2 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:3, at 60°C, for 60 min, the results showed that the percentage by mass of catalyst with a volumetric methanol to refined palm oil stearin at 1:3, 60°C, and 0.4%NaOH(wt/vol) had the rate of 73%, compared to 0.2% NaOH(wt/vol) and 0.3%NaOH(wt/vol).

Table 3 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:2, at 60°C, for 60 min

%NaOH(wt/vol)	Oil (cc)	Biodiesel (cc)	Yield (%)
0.2	250	169	67.6
0.3	250	185	74
0.4	250	180	72

From Table 3 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:2, at 60°C, for 60 min, the results showed that the percentage by mass of catalyst with a volumetric methanol to refined palm oil stearin at 1:2, 60°C, and 0.3%NaOH(wt/vol) had the highest rate at 74%, compared to 0.2% NaOH(wt/vol) and 0.4%NaOH(wt/vol).

Table 4 Change in proportional time at a volumetric ratio of methanol to refined palm oil stearin, 0.3%(wt/vol)NaOH at 60°C

Time (min)	Oil (cc)	Biodiesel (cc)	Yield (%)
30	250	177.5	71
60	250	185	74

From Table 4 Change in proportional time at a volumetric ratio of methanol to refined palm oil stearin, 0.3% (wt/vol) NaOH at 60°C, the reaction of the volumetric ratio of methanol to refined palm oil stearin, 0.3% NaOH(wt/vol), at 60°C, and a reaction time of 60 min was more complete than at 30 min, with a difference in production percentage of 3%. Therefore, biodiesel production from refined palm oil stearin was 60 minutes due to the significant percentage difference.

Table 5 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:2, at 60°C, for 60 min

%NaOH(wt/vol)	Oil (cc)	Biodiesel (cc)	Yield (%)
0.2	250	169	67.6
0.3	250	185	74
0.4	250	180	72

From Table 5 Percentage change by NaOH catalyst mass proportional to methanol to refined palm oil stearin 1:2, at 60°C, for 60 min, biodiesel production from refined palm oil stearin using sodium hydroxide base catalyst with a reaction time of 60 minutes was conducted. The optimum catalyst content was 74% at the volume ratio of methanol: refined palm oil stearin at 1:2, at a reaction time of 60 min. Moreover, the percentage of catalyst mass per oil volume 0.3%NaOH(wt/vol) was the percentage by volume of the product obtained with the highest oil consumption of 74% compared to the percentage by catalyst mass of 0.2%NaOH(wt/vol) and 0.4%NaOH(wt/vol).

Table 6 The number of biodiesel rinsing times with distilled water, by volume methanol to refined palm oil stearin 1: 2, reaction temperature of 60 ^{O}C, and time 60 min. Then, the biodiesel was washed with distilled water at a ratio of 1: 3, a reaction temperature of 40 ^{O}C, and Na_2SO_4 at 45% by weight of biodiesel. The time required for rinsing was 30 minutes.

%NaOH (wt/vol)	Time	Yield (%)
0.3	2	74

From Table 6 The number of biodiesel rinsing times with distilled water, by volume methanol to refined palm oil stearin 1:2, reaction temperature of 60 ^{O}C, and time 60 min. Then, the biodiesel was washed with distilled water at a ratio of 1: 3, a reaction temperature of 40 ^{O}C, and Na_2SO_4 at 45% by weight of biodiesel. The time required for rinsing was 30 minutes, the washing of the soap and methanol catalyst from the biodiesel refined from palm oil stearin was with distilled water at 40 ^{O}C, and it was found that the percentage ratio of the catalyst mass to the oil volume was 0.3%NaOH(wt/vol) can remove the soap and methanol catalyst from the oil.

Therefore, the biodiesel was rinsed with water twice to neutralize the biodiesel. Then Na_2SO_4 at 45% by weight of biodiesel was added to remove the water from the biodiesel, ensuring that the water content percent by weight was not higher than 0.050 following the characteristics and quality standards of fatty acid methyl ester biodiesel according to the Department of Energy Business's announcement ASTM D 2709.

Table 7 Stability observation of fuel at 35 ° C used in the production of diesel

Diesel : Propanol : Biodiesel(RPO) (AR Grade)	Stability Observation
D90P5B5(RPO)	Homogeneous
D85P5B10(RPO)	Homogeneous
D80P5B15(RPO)	Homogeneous

From Table 7 Stability observation of fuel at 35 ° C used in the production of diesel, a small amount of propanol was soluble in large quantities of diesel fuel without stratification. Consequently, when biodiesel from refined palm oil stearin was used as an emulsifier in diesel mixtures, the diesel and propanol could blend without stratification. Therefore, the emulsion of diesohol was stable. The different mixing ratios of diesel were then assessed for stratification characteristics when kept under controlled conditions for six months. The refined palm oil stearin from the experimental results remained clear and had no stratification. Furthermore, the results showed that the experimental condition, by using 99.9% purity propanol, at 35 ^{O}C, the temperature used in the production of diesohol could produce diesohol with no characteristics of separation of diesel production.

Table 8 Stability observation of fuel at 35 ° C used in the production of diesel

Diesel : Biodiesel	Stability Observation
D90B10	Homogeneous
D85B15	Homogeneous
D80B20	Homogeneous

Table 9 Appearance of Fuel

Description	Method	High Speed Diesel	Diesel	D90P5B5 (RPO)	D90B10 (RPO)
Appearance					
Color	Visual Inspection	Bright and Clear	Bright and Clear	Bright and Clear	Bright and Clear
Intensity	ASTM D1500	Max 4.5	1	1	1

Table 10 Physical Properties of Fuel

Description	Method	High Speed Diesel	Diesel	D90P5B5 (RPO)	D90B10 (RPO)
Density at 15°C (g/cm^3)	ASTM D4052	0.81 - 0.87	0.8295	0.8300	0.8337
Cetane Index	ASTM D976	Min 50	57.4	58.0	57.6
Viscosity at 40°C (cSt)	ASTM D445	1.8 - 4.1	2.9	2.7	3.0
Flash Point (°C)	ASTM D93	Min 52	65	< 30	68
Pour Point (°C)	ASTM D97	Max 10	-6	-6	-6
Total Sulfur Content, mg/kg	ASTM D5453	Max 50	40	36	32
Cleanliness					
Micro Carbon Residue (MCR) , (%mass)	ASTM D4530	Max 0.3	< 0.01	0.01	< 0.01
Ash (%wt)	ASTM D482	Max 0.010	< 0.001	< 0.001	< 0.001
Water and Sediment, %Vol.	ASTM D2709	Max 0.05	< 0.01	< 0.01	< 0.01
Total Contamination (mg/kg)	**EN 12662**	**Max 24.0**	**2.4**	**2.0**	**17.1**

Table 11 Distillation of Fuel

Description	Method	High Speed Diesel	Diesel	D90P5B5 (RPO)	D90B10 (RPO)
Distillation	ASTM D86				
Initial Boiling Point (° C)		-	169.9	97.5	175.4
90%vol. Recovered (° C)		Max 357	349.8	348.3	346.0

Table 12 Result of Wear Scar Test

Type of Fuel	Wear Scar Test µm
D90P5B5 (RPO)	236
D90B10 (RPO)	234

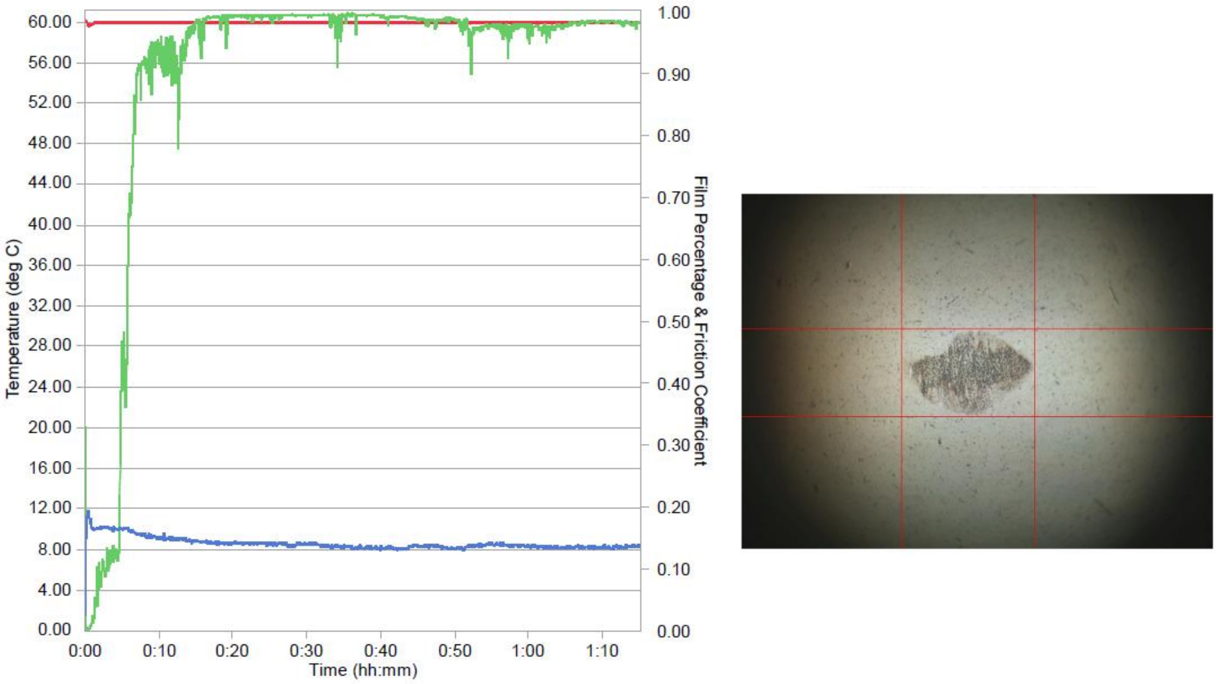

Figure 4 The wear scar test of D90P5B5(RPO)

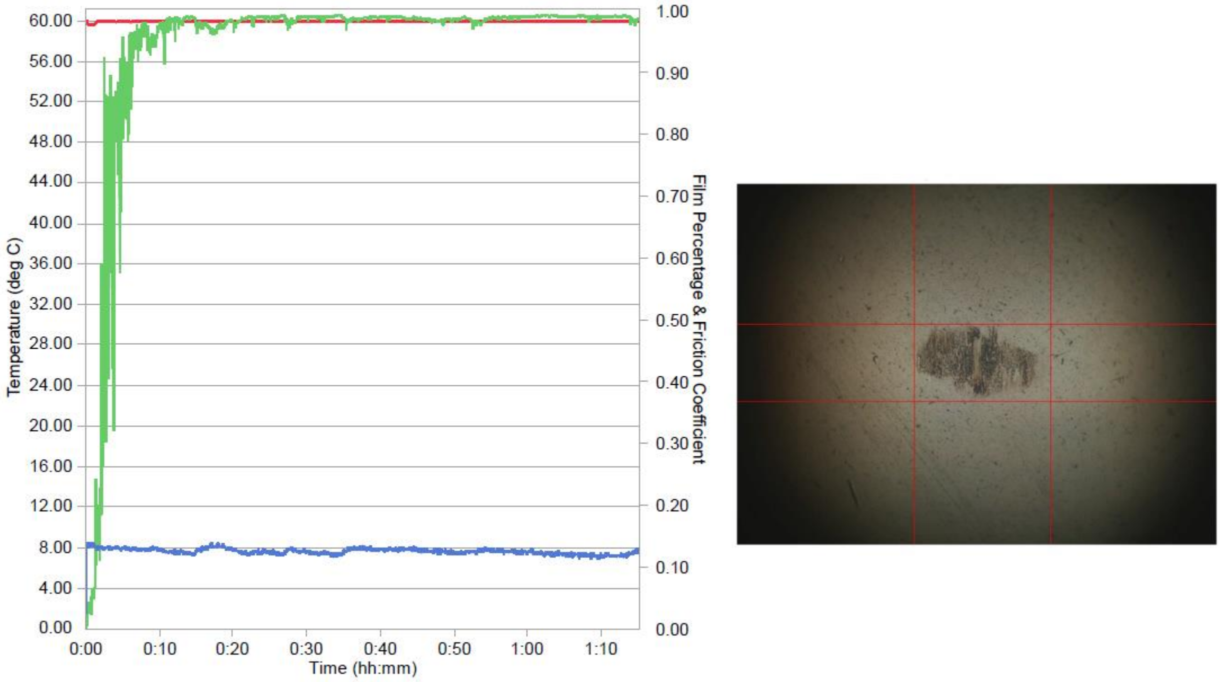

Figure 5 The wear scar test of D90B10(RPO)

6. Conclusion

Using sodium hydroxide as a catalyst at low temperature and pressure results in large product volumes and reduces production time to convert to methyl ester, with no additional processes. There are no side effects and requirements for using other substances compared to acid as a catalyst.

Diesel engine performance is influenced by the fuel properties's density, which directly affects the engine's performance characteristics. The main benefit of biodiesel in diesohol is that biodiesel has a high viscosity, compensating for the low viscosity of propanol-diesel blends. When biodiesel is mixed as a substantial proportion of the mixture, the propanol production is limited. The tendency is for the density and viscosity of the fuel to be increased because biodiesel has a higher density and viscosity than diesel fuel.

From Tables 10, although biodiesel is denser than diesel fuel, it has a lower thermal energy value. For example, the experimental at a low mixing ratio diesohol D90P5B5(RPO) was 0.8300 g/cm^3 and the low mixing ratio biodiesel blend D90B10(RPO) was 0.8337 g/cm^3 within the high-speed diesel fuel benchmark. The density value represents the amount of fuel energy at higher densities. Therefore, the cost of heating energy will be higher than the same fuel.

The viscosity of D90P5B5(RPO) was 2.7 cSt and the low mixing ratio biodiesel blend D90B10(RPO) was 3.0 cSt within the standard for high-speed diesel fuel. Therefore, the quality standards are set at 4.1 cSt at 40^{O}C of the viscosity value following the characteristics and quality of high-speed diesel oil announced by the Department of Energy Business; it must be at least 1.8. and not higher than 4.1 cSt, while the viscosity requirement of the low-speed diesel oil is not higher than 8.0 cSt.

The results of the low mixing ratio of the diesel D90P5B5(RPO) showed it had a lower flash point than the diesel fuel standard specified set by the Department of Energy Business ASTM D93, which assigns the flash point not lower than 52 °C. Therefore, since propanol has a low flashpoint, people must be fully aware of this during transportation, movement, and storage. In addition, when propanol is added to the fuel, the fuel's flashpoint is reduced.

Biodiesel, produced from oil plants, had a low sulfur content when used as a fuel ingredient. As a result, Diesohol D90P5B5(RPO) and biodiesel blend D90B10(RPO) had lower sulfur content than standard diesel fuel. The composition of sulfur, when burning, was converted to sulfur dioxide. Therefore, D90P5B5(RPO) and D90B10(RPO) can reduce sulfur dioxide emissions.

From table 12, the results of the lubricating properties test assessed by using the High-Frequency Reciprocating Rig (HFRR) Tested to the Standards CEC-F-06-A-96, D90P5B5(RPO) had a scar value of 236 and D90B10(RPO) had a scar value of 234, which is not over 460. From the experiment, the fuel produced has lubricating properties. Therefore, when used in compression ignition engines, it can reduce the wear of metal parts inside the engine.

7. References

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