THE INFLUENCE OF INJECTION TIMING ON PERFORMANCE CHARACTERISTICS OF DIESEL ENGINE USING JATROPHA BIODIESEL WITH AND WITHOUT PARTIAL HYDROGENATION

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The Influence of Injection Timing on Performance Characteristics of Diesel Engine using Jatropha Biodiesel with and without Partial Hydrogenation

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Abstract

Experimental research has been conducted to investigate the effects of blend of hydrogenated and unhydrogenated Jatropha biodiesel with diesel fuel in volume ratio of 30:70 (B30) on combustion characteristics (BSFC, thermal efficiency and smoke emission) of single cylinder diesel engine. In this experiment, engine speed was kept constant at 1,500, 2,500, and 3,500 rpm with maximum engine load at BMEP 5 bar and injection timings were varied. Experimental result showed that at engine speed 1,500 rpm, BSFC of B30 hydrogenated and unhydrogenated Jatropha biodiesel were higher than it of diesel fuel at all injection timings (10° to 18° BTDC). At the same condition, partial hydrogenated Jatropha biodiesel showed higher BSFC than unhydrogenated Jatropha biodiesel. However, the difference in BSFC became smaller for all fuels at engine speed 2,500 rpm and 3,500 rpm at all injection timing. Jatropha biodiesel with and without partial hydrogenation tend to have higher thermal efficiency compared with diesel fuel at all engine speed and injection timing. The best injection timings to operate B30 Jatropha biodiesel with and without hydrogenation were 14°, 18° and 24° BTDC at engine speed 1,500, 2,500, and 3,500 rpm respectively. This conclusion was deduced based on the minimum value of BSFC and the maximum value of thermal efficiency. Smoke emissions for all fuels were in the same level for all conditions.

Keywords: jatropha, hydrogenation, BSFC, thermal efficiency, smoke emission.

I. Introduction

Several alternative fuels which can contribute as solution for fossil fuel crisis and environment cleaner have been investigated extensively. Biodiesel is one of such fuel due to its renewable and low exhaust gas emissions properties. For utilizing biodiesel in diesel engine, many researchers reported that non edible feedstock such as Jatropha might be the best raw material since it would not influence on edible oil market. The mainly disadvantage of biodiesel made from non-edible oils is its low oxidation stability because the large content of poly unsaturated fatty acids, especially linoleic (C18:2) and linolenic acid (C18:3). Various studies have shown that the oxidation stability of Jatropha biodiesel does not meet the requirements defined by EN 14214, in which the induction period should be a minimum of 6 h. Most Jatropha biodiesels were found had an induction period of about 3.23 to 4.21 h [1, 2, 3].

Partial hydrogenation is a method to improve the oxidation stability with the minimum detriment to the cold-temperature properties. The partial hydrogenation is designed to convert the poly-unsaturated FAME (fatty acid methyl esters) into mono-unsaturated and saturated FAME. Partial hydrogenation will alter the profile of FAME compositions and hence the physical properties other than oxidation stability such as cetane number, pour point, and cold flow plugging point. Fajar *et al.* [4] studied partial hydrogenation of Jatropha biodiesel and showed that the oxidation stability improved from 4.16 to 5.99 h. The cetane number also increased slightly from 55.87 to 56.65 after the hydrogenation. Wadumesthrige *et al.* [5] and Papadopoulos *et al.* [6] also found the similar phenomenon after studying partial hydrogenation of biodiesel from poultry fat and cotton oil. After hydrogenation, the physical characteristic of Jatropha biodiesel

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especially the cetane number will change, that further more give a great effect on combustion characteristic. Study on combustion of Jatropha biodiesel and its blends have been studied by many researchers. In general, combustions of blend of Jatropha biodiesel and diesel fuel have lower power than pure diesel fuel. Moreover, fuel consumption using Jatropha biodiesel blending is little higher than using pure diesel fuel. Combustion of Jatropha biodiesel blending tends to have lower emission of carbon monoxide and hydrocarbon compared with diesel fuel [7, 8, 9].

Combustion characteristics of biodiesel can be predicted by FAME composition or fuel properties related to combustion process such as cetane number, heating value and viscosity. Partial hydrogenation of biodiesel will decrease total content of unsaturated FAME and increase the content of saturated FAME adversely. Therefore, the changes on physical properties of biodiesel Jatropha depend on partial oxidation conversion level. Study conducted by Puhan *et al.* [10] showed that biodiesel with high total content of unsaturated FAME would have high cetane number, high calorie content and lower viscosity. Therefore, hydrogenated Jatropha biodiesel was expected to have higher cetane number, higher calorie content and lower viscosity compared with unhydrogenated Jatropha biodiesel. Besides that, the combustion of high content unsaturated FAME produces higher carbon monoxide (CO), hydrocarbon and smoke emissions. NOx emission also tends to be higher due to its longer ignition delay.

Cetane number of hydrogenated Jatropha biodiesel will be higher than original biodiesel as shown in Table 4. The combustion characteristics will be different due to its shorter ignition delay. To optimize an increasing in cetane number, optimum setting of injection timing can be used as one method to get lower emissions while engine performance can be kept at optimum condition. Therefore, mapping of engine performance related to setting of injection timing is necessary to investigate the effect of hydrogenation of biodiesel which then can result in the increasing in cetane number. Various studies also show that setting of injection timing can be expected to achieve higher engine performance with lower emissions.

Beside from injection timing, combustion from diesel engine can also be evaluated from smoke emission. Smoke is one of important parameter of exhaust gas emission consisting of solid and liquid phase. Solid phase consist of carbon particle, sulphate, nitrate and liquid phase resulted from condensation of hydrocarbon. Both of solid and liquid phase are the product of incomplete combustion. Smoke number is also used as standard to determine the quality of combustion related to negative impact on human health. Other parameters which can influence the combustion are injection pressure and compression ratio but it will not be discussed in this study.

The objectives of this study were to investigate the effect of mapping injection timing on the performance of single cylinder diesel engine such as brake specific fuel consumption (BSFC), thermal efficiency (TE) and Smoke Number, using blending fuel of Jatropha biodiesel with and without hydrogenation with diesel fuel on volume ratio of 30:70 (B30). The best injection timing for Jatropha biodiesel with and without hydrogenation will result minimum BSFC and smoke emissions with maximum thermal efficiency.

II. Investigation Procedure

A. Engine Testing Installation

An experimental research was conducted on Hydra single cylinder diesel engine with direct injection. The specification of the engine is shown in Table 1. In this experiment, all engine characteristics and others related parameters for analyzing purposes such as air flow rate, fuel flow rate, exhaust gas pressure, and temperature were monitored and recorded.

Eddy current dynamometer was used to measure power and torque. Here, engine load was kept constant at maximum level for all experimental condition. The engine test bench for this experiment is shown in Figure 1. Smoke emission was measured with AVL 415S smoke meter with an accuracy of ±0.16 FSN. Another parameters accuracy and uncertainty of power, BSFC and Brake Thermal Efficiency (BTE) are shown in Table 2.

Figure 1. The installation of Hydra single cylinder diesel engine

Table 1.
Engine specification

Engine Parameters	Basic Data
Bore x Stroke	80.26 mm x 88.9 mm
Max. power	9 kW/3600 rpm
Compression	203 : 1
Max. speed	4.500 rev/min
Injector	Bosch KBEL 88PV 1 870 005 546
Nozzle	Bosch 4 x 4 x 0.25 x 160°
Inj. Pressure	250 bar

B. Engine Testing Procedure

The engine testing procedures for performance mapping were as follows:

1. Testing was conducted at engine speed 1,500, 2,500 and 3,500 rpm respectively.
2. Diesel fuel at full load was used as a reference. Here, full load defined as engine load when smoke emission was at maximum of 5 Bosch Smoke Number (BSN) which was equal to BMEP 5 bar.
3. Injection timings were varied during testing.
4. After testing the diesel fuel, fuel blending of diesel fuel and Jatropha biodiesel (with and without hydrogenation) with volume ratio of 70:30 were tested at full load, the same conditions as diesel fuel. Therefore, the performance parameter of all fuels could be seen from the value of Brake Specific Fuel Consumption and exhaust gas emission (smoke number).

In this experiment, the engine was operated at optimum conditions in which the specific fuel consumption was low and the thermal efficiency was at the best value. These conditions could be achieved when the engine were set at full load. The engine speed was kept constant at 1,500, 2,500, and 3,500 rpm for the whole of experiment. The injection pressure was set constant at 250 bar.

Table 2.
The measurement accuracy and uncertainty of calculation result

Parameter	Accuracy	Calculation Result	Uncertainty
Load	±0.08 Nm	Power	±2.6%
Speed	±1.6 rpm	BSFC	±2.5 g/kWh
Time	±0.6 s	BTE	±2.6%

Table 3.
Tested fuel properties

Tested Fuel	Density (g/cm^3)	Calorie Cont. (MJ/kg)
Diesel fuel (B0)	0.8522	44.87
B30 unhydrogenated Jatropha	0.8613	43.37
B30 hydrogenated Jatropha.	0.8604	43.51

Three type fuels tested in this experiment were hydrogenated Jatropha biodiesel blended with diesel fuel with ratio 30:70 by volume (B30 with hydrogenation), unhydrogenated Jatropha biodiesel blended with diesel fuel with ratio 30:70 by volume (B30), and a pure diesel fuel (B0) as a reference fuel. B30 was utilized with the reason that from study conducted by Fajar *et al.* [11] B30 showed an acceptable condition for engine performance, emissions and fuel consumption without any engine modification.

III. Results and Discussion

A. Properties of Tested Fuels

Table 3 shows main properties of 3 types of fuels used in this experiment. The density of hydrogenated and unhydrogenated Jatropha biodiesel was higher than it of diesel fuel and the heating value of both Jatropha biodiesel was around 11% lower than diesel fuel (B0). Table 4 shows main properties of diesel fuel, B100 hydrogenated biodiesel and B100 biodiesel without hydrogenation. Cetane number and viscosity of hydrogenated and unhydrogenated Jatropha biodiesel were higher than diesel fuel.

B. Effects of Injection Timing on BSFC

Performances of diesel engines fuelled with diesel fuel, B30 unhydrogenated Jatropha biodiesel and B30 hydrogenated Jatropha biodiesel at full load were evaluated based on parameters BSFC and Brake Thermal Efficiency in various injection timing and engine speed.

Figure 2, 3, and 4 show the effect of various injection timing on BSFC for diesel fuel and B30 Jatropha biodiesel with and without hydrogenation. Diesel fuel had lowest BSFC compared with both of B30 unhydrogenated and hydrogenated Jatropha biodiesel at engine speed

Table 4.
Properties of diesel fuel, B100 hydrogenated Jatropha biodiesel and B100 unhydrogenated Jatropha biodiesel

Properties	Diesel Fuel	Jatropha Biodiesel	
		Unhydrogenated[a]	Hydrogenated[b]
Oxidation stability, hour	N/A	3.90	8.88
Cetane number	51	55.65	58.97
Kinematic viscosity 40 °C, cSt	3.61	3.87	3.97
Cloud point, °C	N/A	3.35	5.31
Pour point, °C	N/A	-3.20	-1.08
CFPP, °C	N/A	-2.02	1.08

[a, b] The properties were calculated based on the model proposed by Chen *et al.* [3]

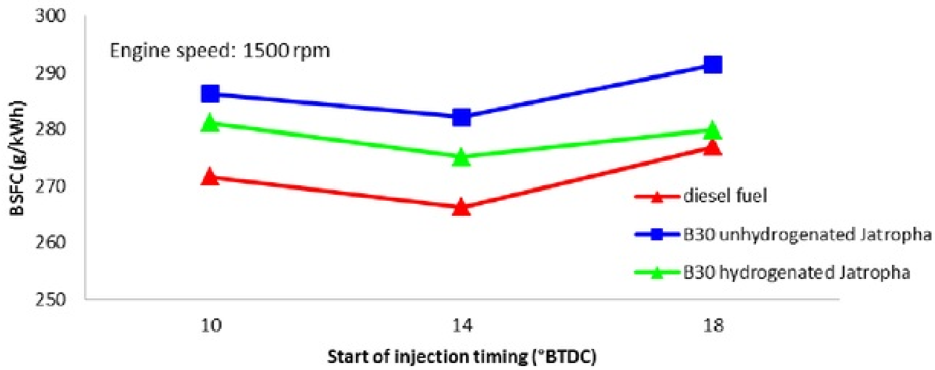

Figure 2. BSFC at engine speed 1,500 rpm

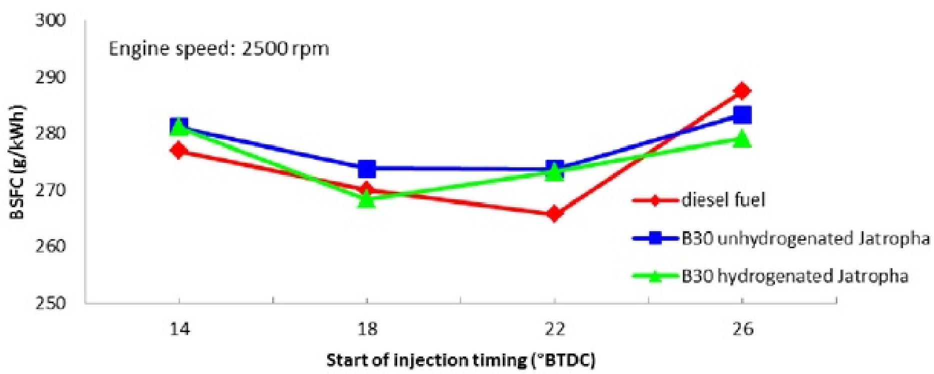

Figure 3. BSFC at engine speed 2,500 rpm

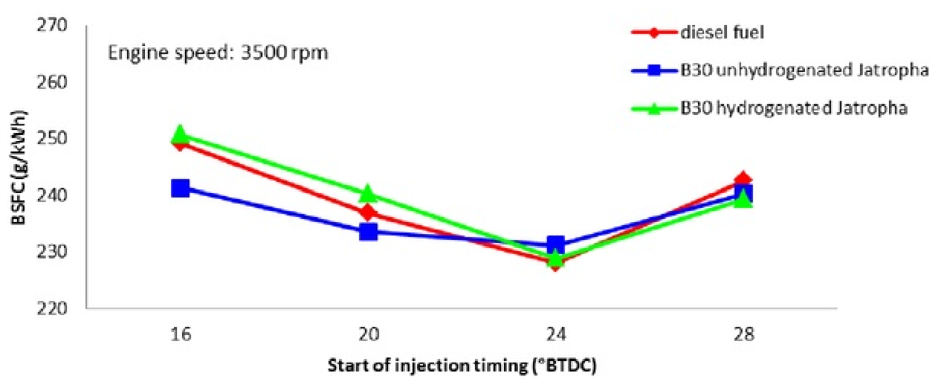

Figure 4. BSFC at engine speed 3,500 rpm

1,500 rpm. Here the higher calorie content of diesel fuel could be a reason for lower BSFC of diesel fuel. However the difference of BSFC became smaller when the engine speed increased and it was comparable with optimization of injection timing for all fuels. The results also showed that optimum injection timing for all fuels were in the same timing and the difference of BSFC became smaller varied with engine speed.

C. Effects of Injection Timing on Thermal Efficiency

Figure 5, 6, and 7 show the effect of various injection timing on thermal efficiency for diesel fuel, B30 Jatropha biodiesel with and without

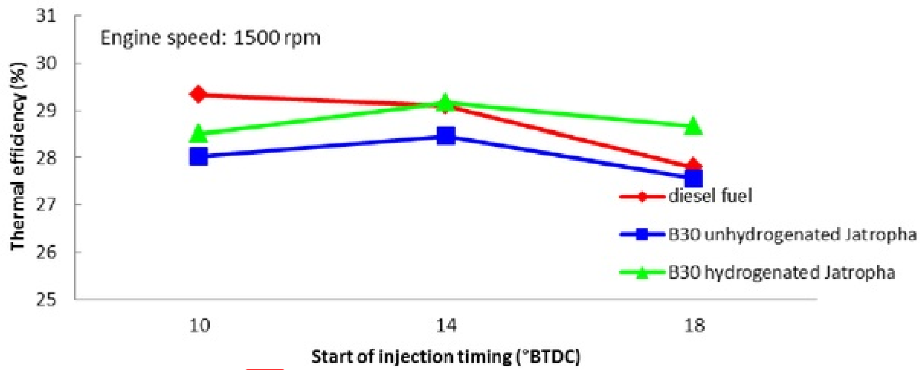

Figure 5. Thermal efficiency of tested fuels at engine speed 1,500 rpm

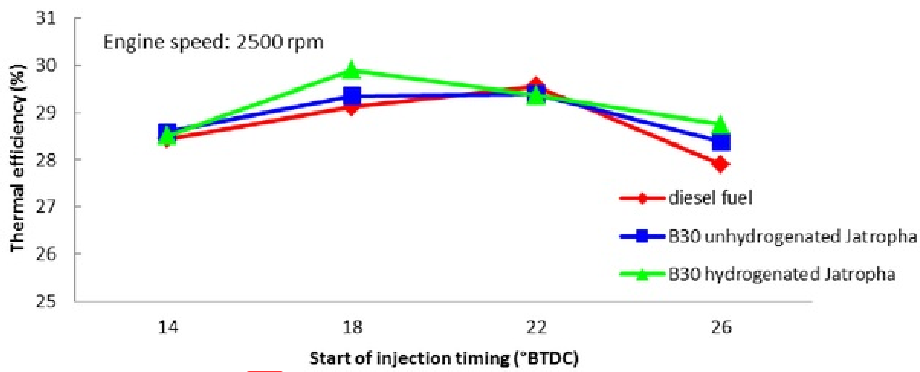

Figure 6. Thermal efficiency of tested fuels at engine speed 2,500 rpm

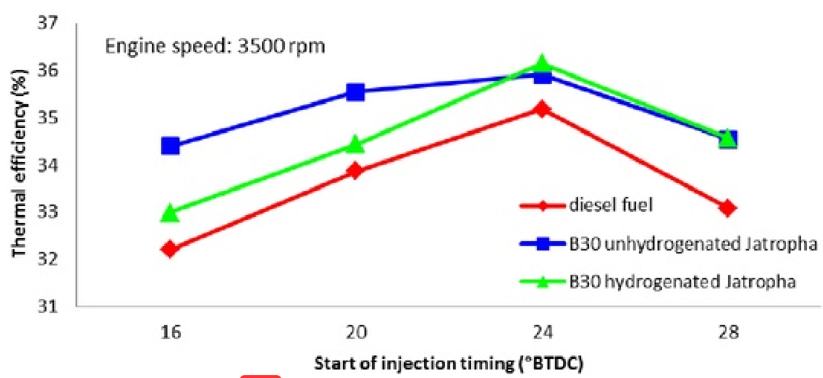

Figure 7. Thermal efficiency of tested fuels at engine speed 3,500 rpm

hydrogenation at engine speed 1,500, 2,500, and 3,500 rpm. The figure showed that B30 biodiesel with hydrogenation had higher thermal efficiency than diesel fuel and B30 biodiesel without hydrogenation for all engine speed.

The maximum thermal efficiency for B30 Jatropha with and without hydrogenation happened at injection timing of 14°, 18°, and 24° BTDC at engine speed 1,500, 2,500, and 3,500 rpm respectively. Meanwhile for diesel fuel, the maximum thermal efficiency was achieved at injection timing of 14°, 22°, and 24° BTDC.

From Figure 2, 3, and 4, the minimum BSFC and the maximum thermal efficiency for all fuels were achieved at the same injection timing. The high thermal efficiency of B30 Jatropha biodiesel

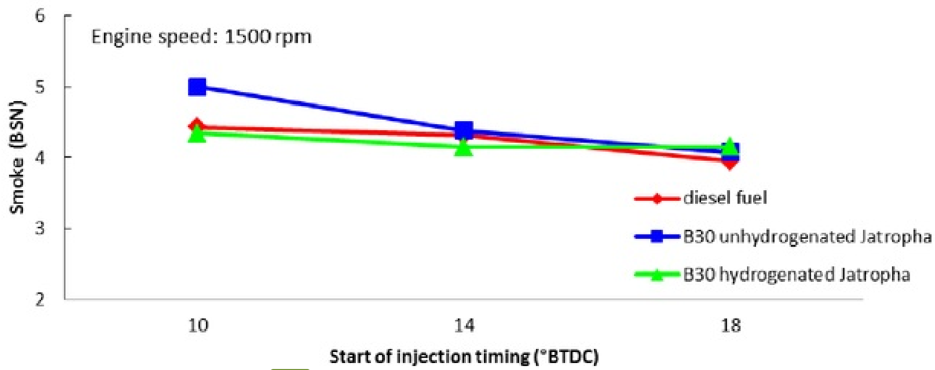

Figure 8. Smoke emission of tested fuels at engine speed 1,500 rpm

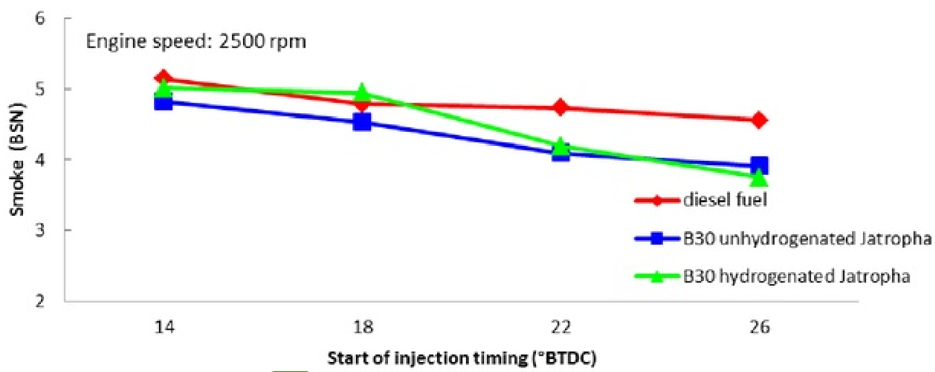

Figure 9. Smoke emission of tested fuels at engine speed 2,500 rpm

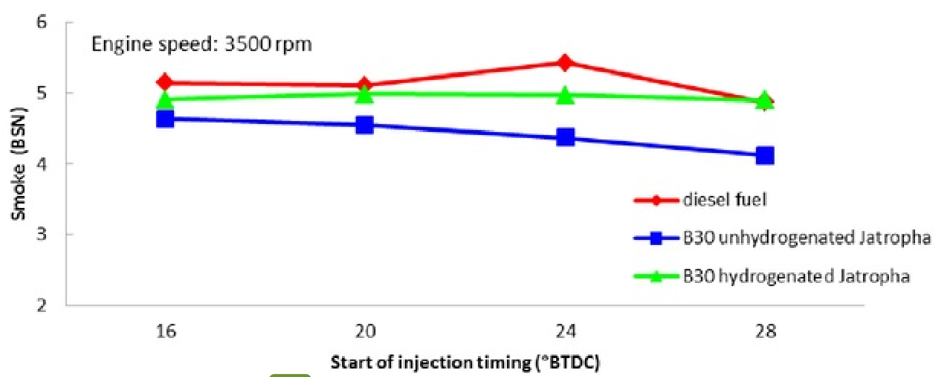

Figure 10. Smoke emission of tested fuels at engine speed 3,500 rpm

with hydrogenation might be caused by the increasing in cetane number and calorie content. The increasing in cetane number and calorie content for Jatropha biodiesel after hydrogenation could improve the combustion and also the thermal efficiency.

D. Effects of Injection Timing on Smoke Emission

Smoke emission is one of important exhaust gas parameter since it shows an efficiency of combustion. Smoke also becomes parameter for judgment of diesel engine condition related to performance of fuel injection systems and fuel properties. Figure 8, 9, and 10 show smoke emission at various injection timing for diesel fuel and B30 Jatropha biodiesel with and without hydrogenation. Smoke emissions of B30 Jatropha biodiesel with and without hydrogenation were lower than it of diesel fuel for all injection timings and engine speeds.

In general, although it was not significant, smoke became lower if the injection time was advanced. This phenomenon could be explained as follows: advancing the injection timing would shift part of diffusion combustion into premixed combustion. Here, fuel would be more accumulated during ignition delay period and caused an increasing in cylinder temperature during expansion stroke and gave enough time for oxidation of soot particle. Figure 8 to 10 also show that smoke numbers vary in a range of 4 to 5 at tested engine speed.

IV. Conclusion

In this experiment biodiesel made from Jatropha with and without hydrogenation were blended with diesel fuel with ratio of 30:70 by volume. Combustion characteristics (BSFC, thermal efficiency and smoke number) were analyzed and compared with ordinary diesel fuel available in Indonesia at various injection timing and at engine speed of 1,500, 2,500, and 3,500 rpm. The results might be summarized as follows: The BSFC of B30 Jatropha biodiesel with and without hydrogenation were higher than it of diesel fuel at 1,500 rpm on all of the variations of injection timing (10° to 18° BTDC). The difference in BSFC between the fuels would be smaller if the engine speed increased up to 3,500 rpm. Thermal efficiencies of the combustion of B30 biodiesel with and without hydrogenation tend to be higher than that of diesel fuel at all injection timing, especially at high engine speed 3,500 rpm. The highest thermal efficiency for B30 with and without hydrogenation was 36% and for diesel fuel was 35%. These values were achieved at engine speed 3,500 rpm and injection time 24° BTDC. The smoke level of B30 Jatropha biodiesel with and without hydrogenation were quite similar compared with diesel fuel at all injection timing, smoke emission tended to increase when engine speed increased from 1,500 to 3,500 rpm. The best injection timings to operate B30 Jatropha biodiesel with and without hydrogenation were 14°, 18°, and 24° BTDC at engine speed 1,500, 2,500, and 3,500 rpm respectively. This conclusion was deduced based on the minimum value of BSFC and the maximum value of thermal efficiency.

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References

[1] A. Sarin *et al.*, "Effect of Blends of Palm-Jatropha-Pongamia Biodiesels on Cloud Point and Pour Point," *Energy*, vol. 34, pp. 2016-2021, 2009.

[2] D. Chaithongdee *et al.*, "Effect of Antioxidant and Additives on the Oxidation Stability of Jatropha Biodiesel," *Kasetsart Journal Natural Science*, vol 44, pp. 243-250, 2010.

[3] Y.H. Chen *et al.*, "Property Modification of Jatropha Oil Biodiesel by Blending with Other Biodiesels or Adding Antioxidants," *Energy*, vol. 36, pp. 4415-4421, 2011.

[4] R. Fajar *et al.*, "Predicting Fuel Properties of Partially Hydrogenated Jatropha Methyl Ester: Used for Biodiesel Formulation to Meet the Fuel Specification for Automobile and Engine Manufacturer," *Kasetsart Journal Natural Science*, vol. 46, pp. 629-637, 2012.

[5] K. Wadumesthrige *et al.*, "Effects of Partial Hydrogenation, Epoxidation, and Hydroxylation on the Fuel," *Fuel Processing Technology*, vol. 90, pp. 1292-1296, 2009.

[6] C. E. Papadopoulos *et al.*, "Optimization of Cotton Seed Biodiesel Quality (critical properties) through Modification of its FAME Composition by Highly Selective Homogeneous Hydrogenation," *Bioresource Technology*, vol. 10, pp. 1812–1819, 2010.

[7] T. Ganapathy *et al.*, "Influence of Injection Timing on Performance, Combustion and Emission Characteristics of Jatropha Biodiesel Engine," *Applied Energy*, vol. 88(12), pp. 4376-4386, 2011.

[8] B. S. Chauhan *et al.*, "A Study on the Performance and Emission of a Diesel Engine Fueled with Jatropha Biodiesel Oil and its Blends," *Energy*, vol. 37, pp. 616-622, 2012.

[9] C. Y. Chen *et al.*, "Fuel Properties and Combustion Characteristics of Jatropha Oil Biodiesel–Diesel Blends," *Journal of the Taiwan Institute of Chemical Engineers*, vol. 44, pp. 214-220, 2013.

[10] S. Puhan *et al.*, "Effect of Biodiesel Unsaturated Fatty Acid on Combustion Characteristics of a DI Compression Ignition

Engine," *Biomass and Bioenergy*, vol. 34, pp. 1079-1088, 2010.

[11] R. Fajar *et al.*, "Efek Penggunaan Biodiesel Kualitas Standar pada Kendaraan Komersial," *Laporan Teknis BTMP-BPP Teknologi*, 2004.

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22 Ramlan, Nur Atiqah, Abdul Adam Abdullah, Mohd Herzwan Hamzah, Nur Fauziah Jaharudin, and Rizalman Mamat. "Evaluation of Diesel Engine Performance and Exhaust Emission Characteristics Using Waste Cooking Oil", Applied Mechanics and Materials, 2015. — 11 words — < 1%
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Biodiesel Engine Based on Mechanical Mechanics", Advanced Materials Research, 2014.
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26 Datta, Ambarish, and Bijan Kumar Mandal. "Effect of injection timing on the performance and emission characteristics of a CI engine using diesel and methyl soyate", Biofuels, 2015.
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27 Panneerselvam, N., A. Murugesan, C. Vijayakumar, and D. Subramaniam. "Performance, emissions and combustion characteristics of CI engine fuel with watermelon (Citrullus vulgaris) methyl esters", International Journal of Ambient Energy, 2015.
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emission characteristics of a diesel engine", Fuel, 2011.
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