AIJST
Aceh International Journal of Science and Technology
pISSN : 2088-9860 eISSN : 2503-2348

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Aceh Int. J. Sci. Technol., 11(3)182-189
December 2022
doi: 10.13170/aijst.11.3.22711

Aceh International Journal of Science and Technology
ISSN: p-2088-9860; e-2503-2398
Journal homepage: http://jurnal.unsyiah.ac.id/aijst

The Simulation of Combustion Characteristics from Diesel Fuel and Biodiesel in Different Engine Rotation

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Received : September 16, 2022
Received in revised from December 04, 2022
Accepted : December 07, 2022
Online : December 31, 2022

Abstract – The combustion characteristics of fuel are important to understand. Diesel engines can ruin by using fuel from diesel and biodiesel. The characteristics between biodiesel and diesel fuel are different. Diesel fuel has low viscosity, high volatility, and low density, and the cetane number is around 48. However, biodiesel has high density, low volatility, high viscosity, and higher cetane number than diesel fuel. Using biodiesel can reduce the particulate matter from the engine. This happened because biodiesel has high oxygen content and can reduce emissions. These are some advantages of using biodiesel in diesel engines. In this research, the simulation of the combustion characteristics was investigated by diesel-rk simulation. The fuels are diesel and biodiesel made from soybean methyl ester (SME). In this simulation, pure diesel fuel (DF), SME100, SME20 (20%SME blends to 80%DF), and SME40 (40%SME blends to 60%DF) are investigated. The combustion was set up with 1500, 1800, and 2000 rpm. The results show that DF has higher Specific Fuel Consumption (SFC) in all engine rotations than SME. Moreover, the NO_2 emission from DF is lower than SME. However, the particulate matter in SME40 can reduce up to 16.1% compared to DF. Moreover, the higher the engine rotates, the fewer emissions from NO_2 and PM from SME20, SME40, and DF can be reduced. It can be confirmed that the higher rotation in the engine can decrease its emissions. In addition, biodiesel can be replaced with diesel fuel, which is environmentally friendly.

Keywords: Diesel fuel, soybean methyl ester, diesel-rk, simulation, combustion

Introduction

Currently, the availability of diesel fuel will decrease over time. Therefore, alternative fuels to replace diesel fuel is very important to investigate. Many researchers study biodiesels and expect to find the fuel properties corresponding to diesel fuel. Biodiesels have been investigated for over a century (Knothe *et al.*, 2010), and the results show that they can be used in the engine without any modifications.

Many researchers investigated diesel fuel blended with other fuels to improve the quality of fuel and fewer emissions (Yudistirani *et al.*, 2019; Bhikuning *et al.*, 2019). However, another way to reduce engine emissions is to use biodiesel. Biodiesel can be made from rapeseed (Hu *et al.*, 2017), jatropha (Bhikuning *et al.*, 2018), coconut oil (Bhikuning, 2013), used cooking oil (Bhikuning *et al.*, 2019), palm oil (Nongbe *et al.*, 2017), and so on. The advantages of using biodiesels are the high cetane number; the emissions can be reduced, such as SOx, HC, and some particulate matter (Kegl, 2006). This happened because biodiesel has oxygen content and can reduce the emissions from the exhaust gas. Therefore, biodiesel is friendly to the environment. However, biodiesel has many disadvantages, such as low volatility, high viscosity, and high density, which can make it difficult to spray atomize (Bhikuning *et al.*, 2020). Therefore, it is suggested to blend biodiesel and diesel fuel to improve the fuel properties and combustion.

Many researchers have investigated the study of combustion from soybean methyl ester. The soybean methyl ester is made from pure soybean oil processed by transesterification using methanol. Therefore, it is important to analyze the combustion effect in the diesel engine compared to diesel fuel.

Shroder *et al.* (2012) have investigated the emissions from biodiesel compared to diesel engines. They analyzed that NOx emissions from soybean methyl ester and other biodiesel were higher than diesel fuel. This can be

doi: 10.13170/aijst.11.3.22711

assumed that oxygen content in biodiesel can affect higher NOx and decrease CO_2 emissions (Bhikuning, 2019). However, the emission from CO, HC, and particulate matter decreased compared to diesel fuel.

Uttarakavatam *et al.* (2012) analyzed the characteristic curves, performance, fuel economy, and exhaust emission from soybean methyl ester using a four-stroke diesel engine and compared it to diesel fuel. The biodiesel was mixed, such as B25, B50, and B75. The results show that biodiesel's specific fuel consumption (SFC) has been higher than diesel fuel due to the lower caloric value of biodiesel. Furthermore, the mechanical efficiency, fuel consumption, and thermal brake efficiency were nearly identical.

Celik *et al.* (2017) analyzed the determination effects of hazelnut and soybean methyl ester on diesel fuel on the emission and performance in diesel engines. The experiments were conducted at 2200 rpm with 5 different loads. The results show that by blending 15% hazelnut methyl ester,15% soybean methyl ester, and 70% diesel fuel, there was an increase in the value of CO_2 emission by 46.55% and higher NOx compared to diesel fuel. Nevertheless, there was a reduction in the value of CO emissions by 46.03%.

Elkelawy *et al.* (2019) researched soybean mixture with sunflower oil and conducted diesel engines running for 1400 rpm. The biodiesel blended with a composition of diesel fuel D70B30 (70% diesel−30% biodiesel), D50B50 (50% diesel−50% biodiesel), and D30B70 (30% diesel−70% biodiesel). The results show that CO emission was reduced by 33.8% for D50B50. Brake-specific fuel consumption (BSFC) is rising to 11.43% for D30B70. Nevertheless, NOx from biodiesel blends was higher compared to diesel fuel.

Vellaiyan (2018) analyzed the diesel fuel emission with biodiesel soybean mixed with water blends. The results show that soybean biodiesel can promote hydrocarbon (HC), smoke and carbon monoxide (CO) at a lower level than diesel fuel. The increase of water percentage in soybean can decrease Nox and smoke opacity compared to diesel fuel.

In this study, diesel and biodiesel are simulated by diesel RK software. In this simulation, the fuels are diesel fuel (DF), pure SME (SME100), and biodiesel made from soybean methyl ester. The composition of blending is SME 20% blended to 80% DF (SME20) and SME 40% blended with 60% DF (SME40). The simulation was assumed in the engine condition of 1500, 1800, and 2000 rpm. The injection pressure is 1480 bar, and the compression ratio is 16,3. This study aims to investigate the combustion and the effect of the emission on its biodiesel blends compared to diesel fuel by using diesel rk software.

Materials and Methods

Fuel Properties

In this study, three fuels are being examined: diesel fuel and biodiesel. Biodiesel is made from Soybean Methyl Ester (SME). All fuel properties can be seen in Table 1. Blending between 20% and 40% soybean methyl ester with 80% and 60% diesel fuels were chosen to follow the Ministry of Indonesia regulation. Indonesia has used 20% of blended biodiesel; there will be new blending oil with 40% biodiesel in the future.

Table 1. The Fuel Properties (Al-Dawody et. Al, 2021.

Properties	Units	Diesel Fuel (DF)	Soybean Methyl Ester (SME)	Soybean Methyl Ester 20%+ Diesel Oil 80% (SME20)	Soybean Methyl Ester 40%+ Diesel Oil 60% (SME40)
LHV	MJ/kg	42.5	36.22	41,18	39.89
Density (323 K)	kg/cm³	830	885	841	852
Viscosity (323 K)	PaS	0.00692	0.00463	0,00334	0.003677
Cetane Number	-	48	51.3	48,68	49.37
Surface Tension (323 K)	N/m	0.028	0.0433	0,03122	0.03436
Carbon Content	%	0.87	0.7731	0,8496	0.8297
Oxygen Content	%	0	0.1081	0,02591	0.0473
Hydrogen Content	%	0.126	0.1188	0,1245	0.123

Engine Specification

In this study, all fuels assumed to be conducted in a single-cylinder direct injection diesel engine system (bore x stroke: φ 85 x 96.9 mm, exhaust 550 cc air volume, and compression ratio 16.3). The engine specification can be shown in Table 2.

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Table 2. Engine Specification (Bhikuning et al., 2019)

Description		Specification
Engine		Supercharged direct-injection single-cylinder 4 stroke
Bore x Stroke	[mm]	85 x 96.9
Displacement	[cm3]	550
Compression ratio		16.3
Number of holes		7
Fuel injection system		Common rail
Injection Pressure	[bar]	1480
Engine speed	[rpm]	1500, 1800, 2000

Software Model

The simulation is made from diesel-rk. Diesel-rk can compute the combustion characteristics from SI and DI engines. Diesel-rk was developed by Moscow Bauman Technical University. Diesel-rk software is the same as thermodynamic software (Pham, 2019). In this software, the simulation of combustions can calculate various things, such as the performance calculation of engines, the emissions, and the spray analysis.

Figure 1 describes how to run the diesel-rk software from the start to the end of the program. First of all, create a new project in the software. Then, fill in the engine specifications and save the project. The engine setting from the operating system is essential in calculating combustion in diesel-rk software. Afterward, check the correction of the nozzle configuration and the shape of the combustion chamber. Then, check the correctness of the injection chambers. After all the important data have been input, then calculate all by clicking the run. Lastly, analyze all the results from the output data.

Results

Specific Fuel Consumption (SFC)

Figure 2 shows the specific fuel consumption from all fuels. Specific fuel consumption (SFC) is important to measure to find the engine's efficiency in using the fuel to generate work (Heywood, 2011). It is shown that SFC from SME100 is higher than DF and SME40. This happened because the lower caloric value in biodiesel was made higher in SFC (Srithar *et al.*, 2014). In order to enhance SFC, it is suggested to blend biodiesels into diesel fuel. SFC in SME20 and SME40 can decrease by up to 15.75% and 18.4% compared to SME100, although diesel fuel is still more efficient than SME100, SME20, and SME40. These results of SFC have similar to other researchers (Srithar *et al.*, 2014; Islam *et al.*, 2013). Higher specific fuel consumption in SME100, SME40, and SME 20 as compared to diesel fuel is due to the high density and viscosity can be difficult for the engine to atomize the fuel, resulting in incomplete combustion of the engine. However, blending with diesel fuel 20% and 40% in pure soybean methyl ester (SME100) can reduce the specific fuel consumption because the viscosity and density are improved than SME100.

Break Mean Effective Pressure (BMEP)

As can be seen in Figure 3, BMEP from SME100 is the lowest than diesel fuel and SME40. However, by blending with 20% and 40% soybean methyl ester in diesel fuel, BMEP in SME20 and SME40 can increase up to 12.05% and 11.14% than SME100 at 1500 rpm. At 1800 rpm, BMEP in SME20 and SME40 is lower by 0.81% and 1.8% than diesel fuel. Moreover, at 2000 rpm, the BMEP of SME 40 is down to 18.85% from diesel fuel. In addition, the lower value of BMEP in SME100 is due to the lower torque compared to DF and SME40. However, higher engine rotation reduces the BMEP of diesel fuel and SME40; this happened due to lower caloric value and higher viscosity in biodiesel as compared to diesel fuel.

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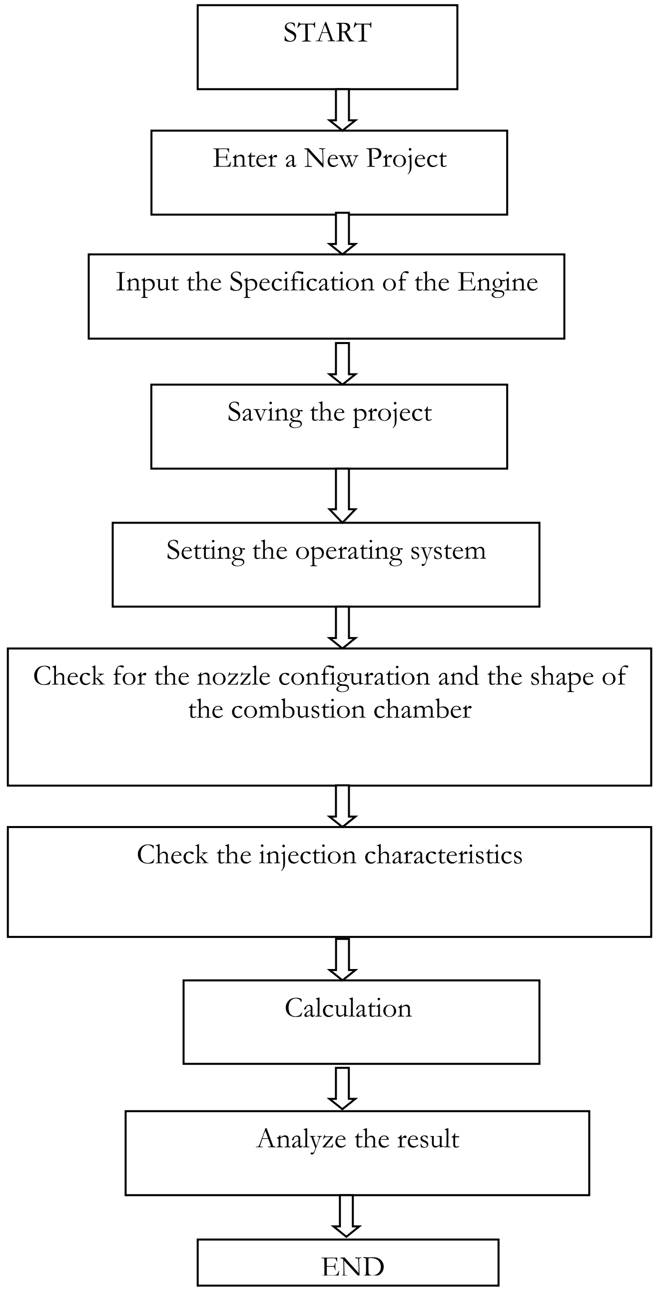

Figure 1. The use of diesel-RK Software (Bhikuning, 2021)

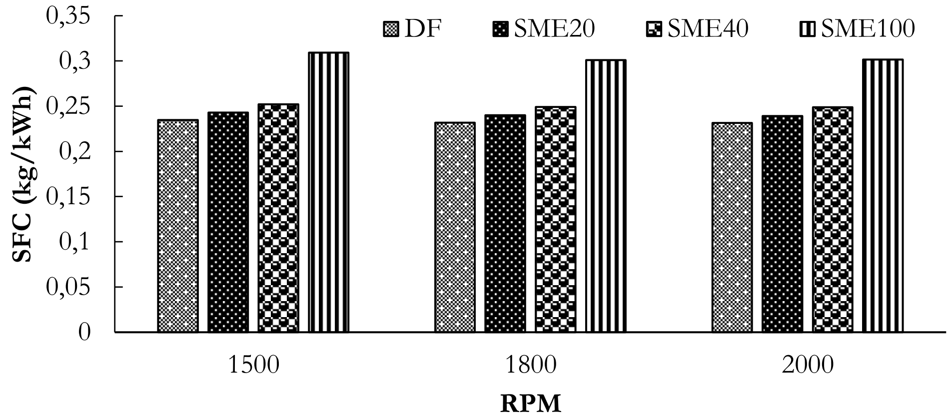

Figure 2. Specific fuel consumption from all fuels

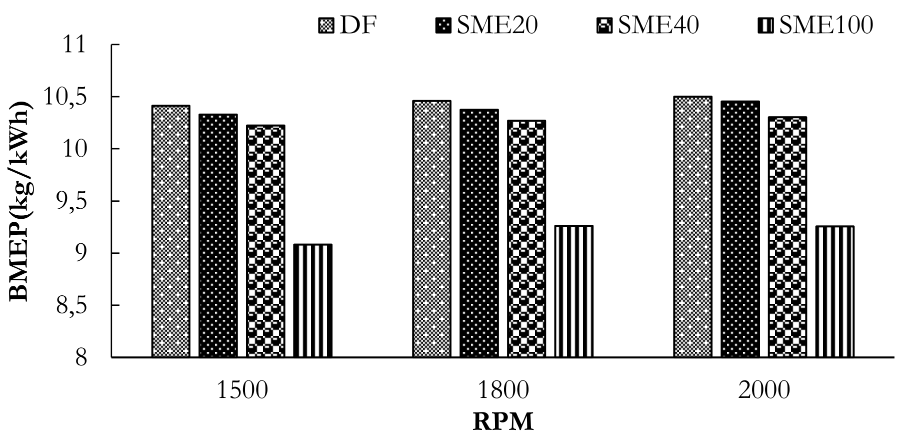

Figure 3. Break Mean Effective Pressure (BMEP) from all fuels

Mechanical efficiency (η_m)

Figure 4 shows the mechanical efficiency of all fuels. Mechanical efficiency is defined as the ratio of the brake power delivered by the engine to the indicated power (Heywood, 2011). Engine friction and indicated power are necessary to calculate mechanical efficiency (Shrithar, 2014). It shows that the higher engine rotates, the more mechanical efficiency decreases. In every engine that rotates, SME20, SME40, and SME100 have lower mechanical efficiency than DF. The mechanical efficiency of SME40 at 1800 rpm is reduced to 0.74% from 1500 rpm. Compared to DF, at 2000 rpm, SME 20 and SME40 are reduced by about 0.32% and 0.22%. DF has the highest mechanical efficiency of all fuels compared to SME20, SME40, and SME100.

Emissions

NO_2 and PM Emission

Figure 5 shows the NO_2 emission from all fuels. It can be seen that NO_2 emissions from SME20 and SME40 are higher than DF. At 1500 rpm, NO_2 of SME20 and SME40 are higher by 2,21% and 2.87% than DF. NO_2 emission decreases when the engine rotation increases. These results agree with other researchers (Altun *et al.*, 2008; Labeckas *et al.*, 2005). At 2000 rpm, NO_2 in SME40 is decreased to 12.46% than at 1500 rpm. Moreover, NO_2 in DF at 2000 rpm is lesser 19.35% at 1500 rpm. At higher rotation engines, higher blended SMEs have higher NO_2. Higher NO_2 in biodiesel is due to the oxygen content, residence time, and maximum temperature (Li *et al.*, 2015; Smith *et al.*, 2012).

For particulate matter (PM), blended SME in DF can decrease PM emissions. SME40 can diminish emissions by up to 16.10% compared to DF at 2000 rpm. Moreover, SME20 can reduce the PM emission by 13.07% compared to DF at 1800 rpm. PM emission decreases when the engine rotation increases. SME40 at 2000 rpm

doi: 10.13170/aijst.11.3.22711

can decrease the PM emission to 35.84% more than 1500 rpm. Blending biodiesel in diesel fuel can lower PM emissions due to high oxygen content, lack of hydrocarbons, and sulfur in biodiesel (Yusop *et al*., 2018; Traviss, 2012). Therefore, running the engine at around 2000 rpm is suggested because the emissions can be reduced with DF or biodiesel as the fuel.

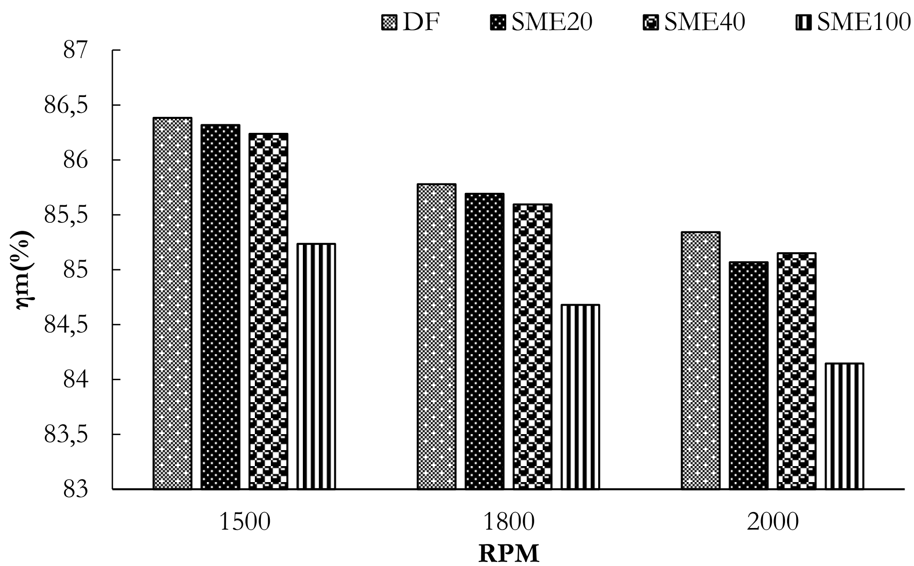

Figure 4. Mechanical efficiency from all fuels

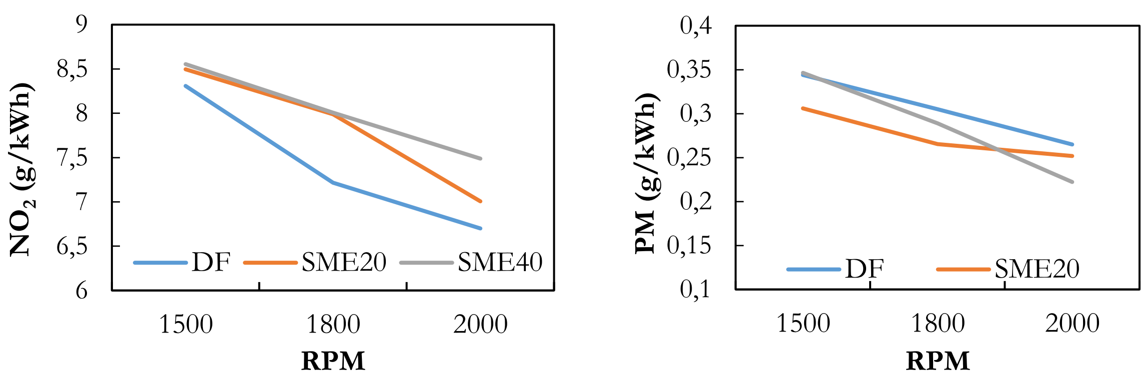

Figure 5. NO_2 and PM Emission from all fuels

Carbon Dioxides (CO_2)

Figure 6 shows CO_2 emissions from all fuels. It is shown that CO_2 emissions from blended biodiesel of SME40 are the highest of all fuels. It is pointed out at 1500 rpm that SME20 has 764.19 g/kWh and SME40 has 774.76 g/kWh of CO_2. Meanwhile, diesel fuel (755.79 g/kWh) has the lowest CO_2 emission of all fuels—higher CO_2 emission for SME100 and SME40 because of the higher oxygen content in biodiesel. However, running in higher engine rotation at 2000 rpm can reduce CO_2 emission more than lower rotation engines. These results agree with other researchers that higher engine rotation can decrease CO_2 emissions (Abed et al., 2018; Gad et al., 2018; Labeckas et al., 2005).

doi: 10.13170/aijst.11.3.22711

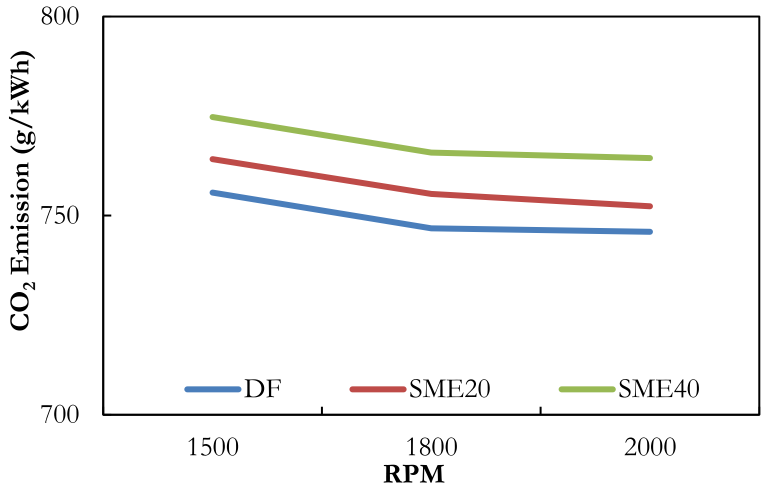

Figure 6. CO_2 Emissions from all fuels

Conclusion

Diesel-rk software can calculate the combustion process and compute diesel fuel and biodiesel emissions. In the calculation, specific fuel consumption in SME100 is the highest than SME20, SME40, and diesel fuel. BMEP and mechanical efficiency of SME20, SME40, and SME100 are lower than DF. Blending between biodiesel and diesel fuel can improve the PM emissions compare to DF. A higher rotation engine can decrease the emissions in the engine. Therefore, it is suggested to run the engine at around 2000 rpm to avoid the formation of emissions. Moreover, biodiesel can be one of the alternative fuels to replace diesel fuel due to its being friendly to the environment and can be used without any modifications to the diesel engine.

Acknowledgment

The author would like to thank The Faculty of Industrial Technology, Mechanical Engineering Department, Trisakti University, for their support.

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Submission date: 04-Dec-2022 02:20PM (UTC+0700)
Submission ID: 1970622311
File name: Aceh_4-Annisa.docx (65.76K)
Word count: 3455
Character count: 18374

The Simulation of Combustion Characteristics from Diesel Fuel and Biodiesel in Different Engine Rotation

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Abstract – The combustion characteristics of fuel are important to understand. Diesel engines can ruin by using fuel from diesel and biodiesel. The characteristics between biodiesel and diesel fuel are different. Diesel fuel has low viscosity, high volatility, low density, and cetane number is around 48. However, biodiesel has high density, low volatile, high viscosity and has higher cetane number than diesel fuel. Using biodiesel can reduce the particulate matter from the engine. This happened because biodiesel has high oxygen content and can reduce emissions. These are some advantages of using biodiesel in diesel engines. In this research, the simulation of the combustion characteristics were investigated by diesel-rk simulation. The fuels are diesel fuel and biodiesel made from soybean methyl ester (SME). In this simulation, pure diesel fuel (DF), SME100, SME20 (20%SME blends to 80%DF) and SME40 (40%SME blends to 60%DF) are investigated. The combustion was set up with 1500, 1800, and 2000 rpm. The results show that in all engine rotations, DF has higher Specific Fuel Consumption (SFC) than SME. Moreover, the NO_2 emission from DF is lower than SME. However, the particulate matter in SME40 can reduce up to 16.1% compared to DF. Moreover, the higher the engine rotates, the emissions from NO_2 and PM from SME20, SME40, and DF can be reduced. It can be confirmed that the higher rotation in the engine can decrease the emissions in the engine. In addition, biodiesel can be replaced with diesel fuel and it is environmentally friendly.

Keywords: Diesel fuel, soybean methyl ester, diesel-rk, simulation, combustion

Introduction

Currently, the availability of diesel fuel will decrease over time. Therefore, alternative fuels to replace diesel fuel is very important to investigate. Many researchers study biodiesels and expect to find the fuel properties which correspond to diesel fuel. Biodiesels have been investigated for more than one century (Knothe. G, at al. 2010) and the results show that they can be used in the engine without making any modifications.

Many researchers investigated diesel fuel blended with other fuels to improve the quality of fuel and fewer emissions (Yudistirani et al, 2019; Bhikuning et al, 2019). However, another way to make fewer emissions in the engine is to use biodiesel. Biodiesel can be made from rapeseed (Hu et al, 2017), jatropha (Bhikuning et al, 2018), coconut oil (Bhikuning, 2013), used cooking oil (Bhikuning et al, 2019), palm oil (Nongbe et al, 2017), etc. The advantages of using biodiesels are high cetane number, the emissions can be reduced such as SOx, HC, and some particulate matter (Kegl, 2006). This happened because biodiesel has oxygen content and can reduce the emissions from the exhaust gas. Therefore, biodiesel is friendly to the environment. However, there are many disadvantages to using biodiesel such as low volatility, high viscosity, and high density which can make it difficult to spray atomization (Bhikuning et al., 2020). Therefore, it is suggested to blend biodiesel and diesel fuel to improve the fuel properties and combustion.

The study of combustion from soybean methyl ester has been investigated by many researchers. The soybean methyl ester is made from pure soybean oil that has been processed by transesterification using methanol. Therefore, it is important to analyze the combustion effect in the diesel engine compared to diesel fuel.

Shroder, et al. (2012) have investigated the emissions from biodiesel compared to diesel engines. They analyzed that NOx emissions from soybean methyl ester and other biodiesel were higher than diesel fuel. This can be assumed that oxygen content in biodiesel can affect higher NOx and decrease of CO_2 emissions (Bhikuning, 2019). However, the emission from CO, HC, and particulate matter was decreased as compared to diesel fuel.

Uttarakavatam, et al. (2012) analyzed the characteristic curves, performance, fuel economy, and exhaust emission from soybean methyl ester by using a four-stroke diesel engine and compared it to diesel fuel. The biodiesel was mixed such as B25, B50, and B75. The results show that the specific fuel consumption (SFC) of biodiesel has shown to have higher than diesel fuel due to the lower caloric value of biodiesel. Furthermore, the mechanical efficiency, fuel consumption, and brake thermal efficiency were nearly the same from each other.

Celik, at al (2017) analyzed the determination effects of hazelnut and soybean methyl ester on diesel fuel on the emission and performance in diesel engines. The experiments were conducted on 2200 rpm with 5 different loads. The results show that by blending 15% hazelnut methyl ester,15% soybean methyl ester, and 70% diesel fuel, there was an increase in the value of CO_2 emission by 46.55% and higher NOx compared to diesel fuel. Nevertheless, there was a reduce in the value of CO emission by 46.03%.

Elkelawy, et al (2019) researched soybean mixture with sunflower oil and conducted diesel engines running for 1400 rpm. The biodiesel blended with a composition of diesel fuel D70B30 (70% diesel−30% biodiesel), D50B50 (50% diesel−50% biodiesel), and D30B70 (30% diesel−70% biodiesel). The results show that CO emission was reduced by 33.8% for D50B50. Brake-specific fuel consumption (BSFC) is rise to 11.43% for D30B70. Nevertheless, NOx from biodiesel blends was higher compare to diesel fuel.

Vellaiyan (2018) analyzed the emission of diesel fuel with biodiesel soybean mixed with water blends. The results show that soybean biodiesel can promote hydrocarbon (HC), smoke and carbon monoxide (CO) at a lower level compared to diesel fuel. The increase of water percentage in soybean can decrease Nox and smoke opacity compared to diesel fuel.

In this study, diesel fuel and biodiesel are simulated by diesel RK software. In this simulation, the fuels are diesel fuel (DF), pure SME (SME100), and biodiesel made from soybean methyl ester. The composition of blending are SME 20% blended to 80% DF (SME20) and SME 40% blended with 60% DF (SME40). The simulation was assumed in the engine condition of 1500, 1800, and 2000 rpm. The injection pressure is 1480 bar and the compression ratio is 16,3. The purpose of this study is to investigate the combustion and the effect of the emission on its biodiesel blends compared to diesel fuel by using diesel rk software.

Materials and Methods

Materials

Fuel Properties

In this study, there are three fuels being examined, the fuels are diesel fuel and biodiesel. Biodiesel is made from Soybean Methyl Ester (SME). All fuel properties can be seen in Table 1. Blending between 20%, 40% soybean methyl ester with 80%, 60% diesel fuels were chosen in order to follow the regulation from the Ministry of Indonesia. Indonesia has used 20% of blended biodiesel and in the future, there will be new blending oil with 40% biodiesel.

Table 1. The Fuel Properties (Al-Dawody et al., 2011)

Properties	Units	Diesel Fuel (DF)	Soybean Methyl Ester (SME)	Soybean Methyl Ester 20%+ Diesel	Soybean Methyl Ester 40%+ Diesel Oil 60% (SME40)

				Oil 80% (SME20)	
LHV	MJ/kg	42.5	36.22	41,18	39.89
Density (323 K)	kg/cm^3	830	885	841	852
Viscosity (323 K)	PaS	0.00692	0.00463	0,00334	0.003677
Cetane Number	-	48	51.3	48,68	49.37
Surface Tension (323 K)	N/m	0.028	0.0433	0,03122	0.03436
Carbon Content	%	0.87	0.7731	0,8496	0.8297
Oxygen Content	%	0	0.1081	0,02591	0.0473
Hydrogen Content	%	0.126	0.1188	0,1245	0.123

Engine Specification

In this study, all fuels assumed to be conducted in a single-cylinder direct injection diesel engine system (bore x stroke: φ 85 x 96.9 mm, exhaust 550 cc air volume, and compression ratio 16.3). The engine specification can be shown in Table 2.

Table 2. Engine Specification (Bhikuning et al., 2019)

Description		**Specification**
Engine		Supercharged direct-injection single-cylinder 4 stroke
Bore x Stroke	[mm]	85 x 96.9
Displacement	[cm^3]	550
Compression ratio		16.3
Number of holes		7
Fuel injection system		Common rail
Injection Pressure	[bar]	1480
Engine speed	[rpm]	1500, 1800, 2000

Method

Software Model

The simulation is made from diesel-rk. Diesel-rk can compute the combustion characteristics from SI and DI engines. Diesel-rk was developed by Moscow Bauman Technical University. Diesel-rk software is the same as thermodynamic software (Pham, 2019). In this software, the simulation of combustions can calculate various things such as the performance calculation of engines, the emissions, and the spray analysis.

The Method

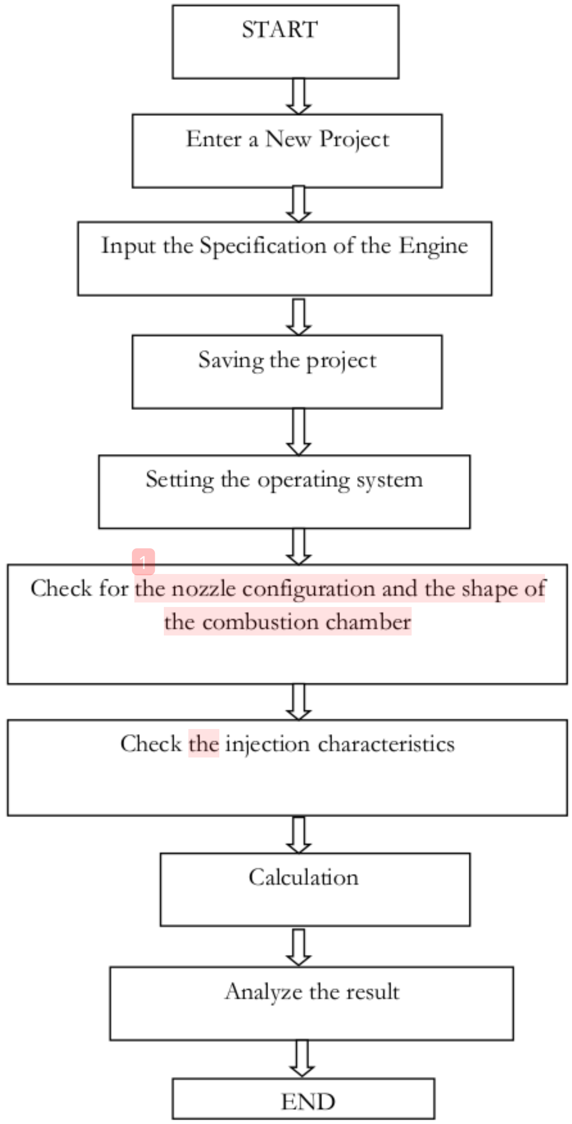

Figure 1. The use of diesel-RK Software (Bhikuning, 2021)

Figure 1 describes how to run the diesel-rk software from the start to the end of the program. First of all, create a new project in the software. Then, fill in the engine specifications and save the project. The engine setting from the operating system is important in calculating combustion in diesel-rk software. Afterward, check the correction of the nozzle configuration and the shape of the combustion chamber. Then, check the correctness of the injection chambers. After all the important data have been input, then calculate all by clicking the run. Lastly, analyze all the results from the output data.

Results

Specific Fuel Consumption (SFC)

Figure 2 shows the specific fuel consumption from all fuels. Specific fuel consumption (SFC) is important to measure in order to find the engine efficiency in using the fuel to generate work (Heywood, 2011). It is shown that SFC from SME100 is higher than DF and SME40. This happened because the lower caloric value in biodiesel made higher in SFC (Srithar et al., 2014). In order to enhance SFC, it is suggested to blend biodiesels into diesel fuel. SFC in SME20 and SME40 can decrease by up to 15.75% and 18.4% compared to SME100, although diesel fuel is still more efficient than SME100, SME20, and SME40. These results of SFC have similar to other researchers (Srithar et al., 2014; Islam et al., 2013). Higher specific fuel consumption in SME100, SME40, and SME 20 as compared to diesel fuel is due to the high density and viscosity can be able to difficult for the engine to atomize the fuel, resulting the incomplete combustion in engine. However, blending with diesel fuel 20% and 40% in pure soybean methyl ester (SME100) can reduce the specific fuel consumption because the viscosity and density are improved than SME100.

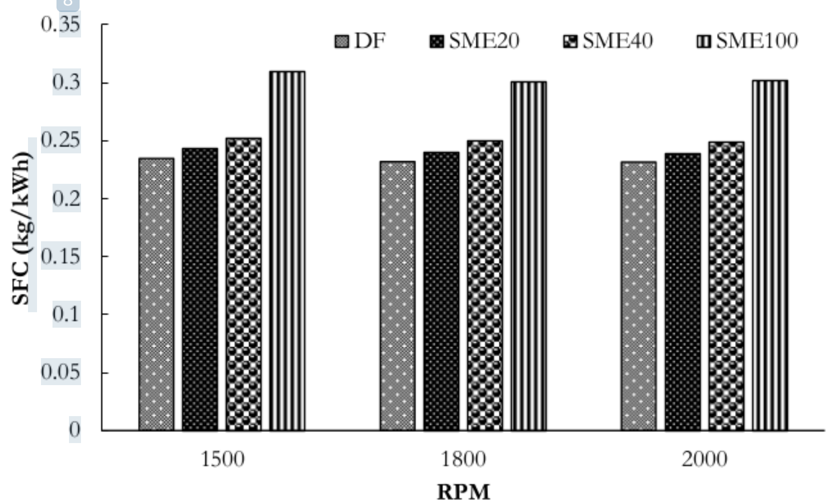

Figure 2. Specific fuel consumption from all fuels

Break Mean Effective Pressure (BMEP)

As can be seen in Figure 3 that BMEP from SME100 is the lowest than diesel fuel and SME40. However, by blending with 20% and 40% soybean methyl ester in diesel fuel, BMEP in SME20 and SME40 can increase up to 12.05% and 11.14% than SME100 at 1500 rpm. At 1800 rpm, BMEP in SME20 and SME40 are lower by 0.81% and 1.8% than diesel fuel. Moreover, at 2000 rpm BMEP of SME 40 is down up to 18.85% from diesel fuel. In addition, the lower value of BMEP in SME100 is due to the lower torque compared to DF and SME40. However, higher engine rotation reduces BMEP of diesel fuel and SME40, this happened due to lower caloric value and higher viscosity in biodiesel as compared to diesel fuel.

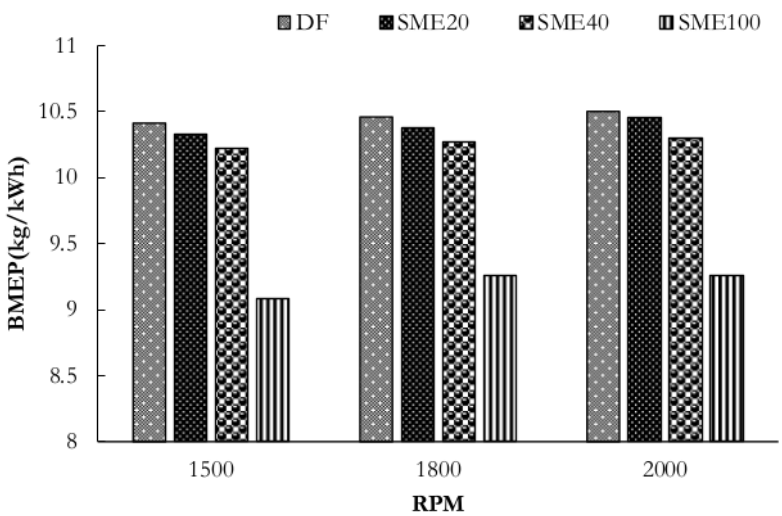

Figure 3. Break Mean Effective Pressure (BMEP) from all fuels

Mechanical Efficiency (η_m)

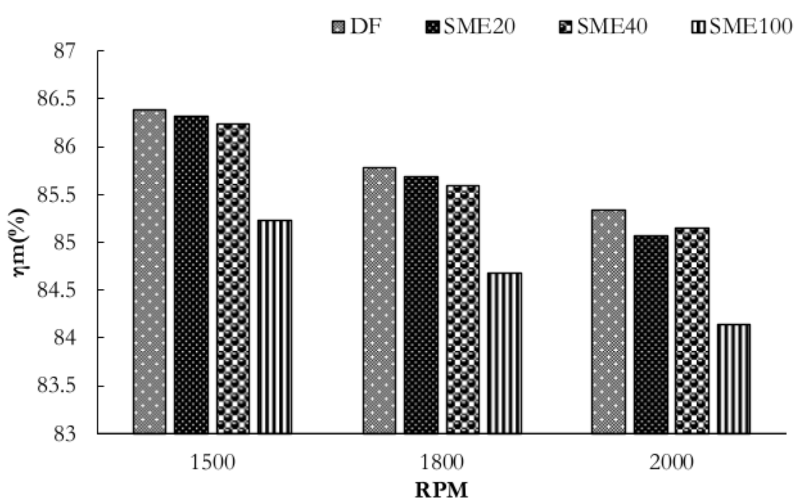

Figure 4. Mechanical efficiency from all fuels

Figure 4 shows the mechanical efficiency of all fuels. Mechanical efficiency is defined as the ratio of the brake power delivered by the engine to the indicated power (Heywood, 2011). Engine friction and indicated power are necessary to calculate mechanical efficiency (Shrithar, 2014). It shows that the higher engine rotates, the mechanical efficiency decreases. In every engine rotates, SME20, SME40, and SME100 have lower mechanical efficiency as compared to DF. The mechanical efficiency of SME40 at 1800 rpm is reduced to 0.74% from 1500 rpm. As compared to DF, at 2000 rpm, SME 20 and SME40 are reduced by about 0.32% and 0.22%. From all fuels, DF is the highest mechanical efficiency compared to SME20, SME40 and SME100.

Emissions

NO_2 and PM Emission

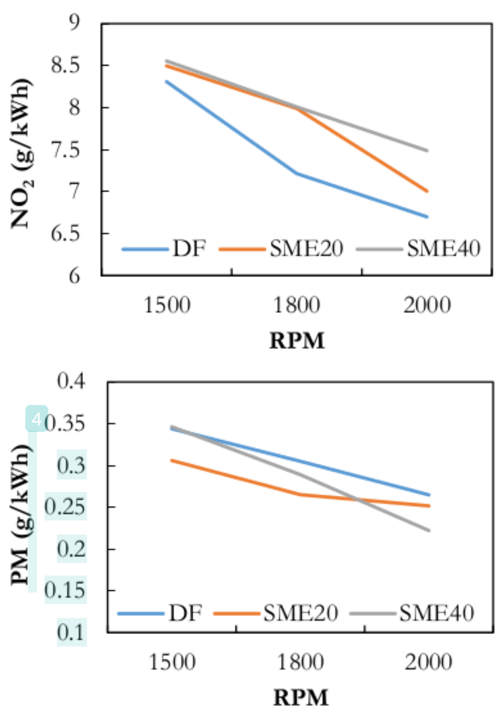

Figure 5. NO_2 and PM Emission from all fuels

Figure 5 shows the NO_2 emission from all fuels. It can be seen that NO_2 emissions from SME20 and SME40 are higher than DF. At 1500 rpm, NO_2 of SME20 and SME40 are higher by 2,21% and 2.87% than DF. NO_2 emission decreases when the engine rotation increases. These results are in agreement with other researchers (Altun et al., 2008; Labeckas et al., 2005). At 2000 rpm, NO_2 in SME40 is decreased to 12.46% than at 1500 rpm. Moreover, NO_2 in DF at 2000 rpm is lesser 19.35% at 1500rpm. At higher rotation engines, higher blended of SME have higher NO_2. Higher NO_2 in biodiesel is due to the oxygen content, residence time, and maximum temperature (Li et al., 2015; Smith et al., 2012).

For particulate matter (PM), blended SME in DF can decrease PM emissions. SME40 can diminish the emission by up to 16.10% compared to DF at 2000 rpm. Moreover, SME20 can reduce the PM emission by 13.07% compared to DF at 1800 rpm. PM emission decreases when the engine rotation increases. SME40 at 2000 rpm can make down the PM emission up to 35.84% than at 1500 rpm. Blending biodiesel in diesel fuel can make lower PM emissions due to high oxygen content and lack of hydrocarbons, and sulfur in biodiesel (Yusop et al., 2018; Traviss, 2012). Therefore, it is suggested to run the engine at around 2000 rpm due to the emissions can be reduced with DF or biodiesel as the fuel.

Carbon Dioxides (CO_2)

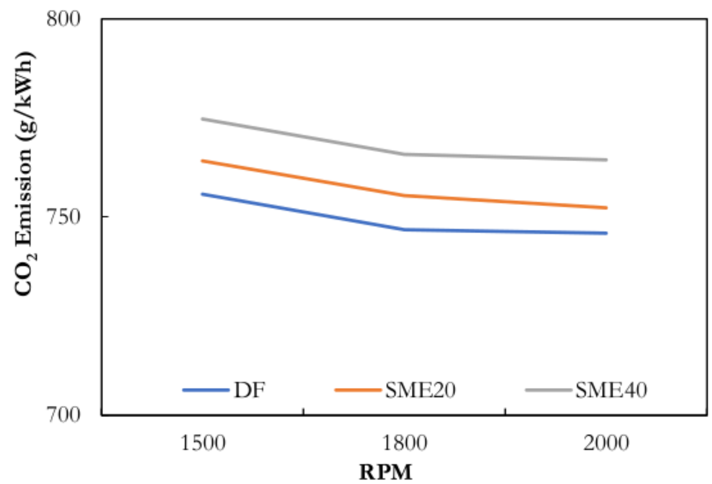

Figure 6. CO_2 Emissions from all fuels

Figure 6 shows CO_2 emissions from all fuels. It is shown that CO_2 emissions from blended biodiesel of SME40 is the highest from all fuels. It is pointed out at 1500 rpm that SME20 has 764.19 g/kWh and SME40 has 774.76 g/kWh of CO_2, meanwhile, diesel fuel (755.79 g/kWh) has the lowest CO_2 emission from all fuels. Higher CO_2 emission for SME100 and SME40 because of the higher oxygen content in biodiesel. However, running in higher engine rotation at 2000 rpm can reduce CO_2 emission than lower rotation engine. These results are the same agreement with other researchers that higher rotation in engines can decrease in CO_2 emission (Abed et al., 2018; Gad et al., 2018; Labeckas et al., 2005).

Conclusion

Diesel-rk software can calculate the combustion process and compute the emissions in diesel fuel and biodiesel. In the calculation, specific fuel consumption in SME100 is the highest than SME20, SME40 and diesel fuel. BMEP and mechanical efficiency of SME20, SME40, and SME100 are lower than DF. Blending between biodiesel and diesel fuel can improve the PM emissions compare to DF. A higher rotation engine can decrease the emissions in the engine. Therefore, it is suggested to run the engine at around 2000 rpm to avoid the formation of emissions. Moreover, biodiesel can be one of the alternative fuels to replace diesel fuel due to its being friendly to the environment and can be used without making any modifications to the diesel engine.

Acknowledgment

The author would like to thank The Faculty of Industrial Technology, Mechanical Engineering Department, Trisakti University for their support.

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