A Suitable Blending Ratio for Using Jatropha Oil as Fuel in High Speed Diesel Engine

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Abstract

This paper presents a suitable blending ratio for using Jatropha oil in high speed diesel engine. Two types of blended fuel, namely diesel blended with crude Jatropha oil (J) and diesel blended with bio-diesel froma Jatropha oil (BJ), were tested in a high speed, 4-cylinder, direct injection, water-cooled, EFL 250 truck type, 2,369 cc, 74 bhp diesel engine. The crude Jatropha oil and bio-diesel from Jatropha oil were blended with diesel in 5 different portions, 2%, 5%, 10%, 20% and 30% by volume, respectively. Experimental results revealed that torque and power output from the engine which used J and BJ were respectively 2-6% and 0.3-9% less than those from the engine which used diesel. The specific fuel consumption of both fuel blends was 5-11% and 4-25% higher than that of diesel fuel. Moreover, it was found that the engine which used blended fuel produced less carbon monoxide, carbon dioxide and smoke. Comparison of both blended fuels revealed comparable engine performance and emission. Also, the suitable blending ratio between the crude Jatropha oil and bio-diesel from Jatropha oil with diesel fuel were formed to be 10% and 30%, respectively.

Keywords: Diesel Engine, Jatropha Oil, Engine Performance

Introduction

Due to the current increasing fuel cost, Thailand needs to produce more alternative energy for domestic consumption. Currently, Thailand is gradually replacing gasoline and diesel with gasohol and bio-diesel. Diesel, especially, has high fuel consumption rate. Presently, bio-diesel is produced from various materials. For example, palm oil, coconut, rice bran, Jatropha, and used vegetable oil or animal fat, etc. Jatropha is one of the oil-bearing genuses, which can replace diesel oil. Also, Jatropha is used for making bio-diesel fuel without impact on food consumption. Many researches reveal that Jatropha is an oil-bearing plant, which can be used directly with diesel engine without modifying

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the engine, but has to reduce the viscosity (Pramanic, 2003). This can be done by blending the diesel oil. Therefore, the oil from Jatropha is one of the alternatives to produce fuel and replace the oil imported from aboard. This is because Jatropha can be planted in almost any regions and give quick yield, which is very beneficial to the farmers for home-usage or village-usage. Especially, agriculturists with low income can grow Jatropha and make diesel oil from Jatropha oil for small engine. This helps agriculturists to reduce fuel cost and become independent. Jatropha oil can be used by blending the diesel oil with the crude Jatropha oil and bio-diesel directly. Most of previous researches involved testing Jatropha oil with low speed diesel engine. It is conclusive that Jatropha oil can be used with low speed diesel engine without any impact to the engine (Chumsanti et al., 2005). But the study about the engine capacity when using Jatropha oil with high speed diesel engine is rare because the viscosity of Jatropha oil is a lot greater than that of diesel oil. (Reddy and Ramesh, 2006) Additionally, there is no obvious conclusion on the most efficient way to use Jatropha oil in the high speed diesel engine. Therefore, this research aimed to experiment in blending crude Jatropha oil and bio-diesel from Jatropha oil with diesel oil using different ratios. Then, test it with high speed diesel engine in order to analyze the engine performance and the impact from gas emission. Ultimately, the goal is to find the suitable blending ratio for using Jatropha oil with high speed diesel engine with consideration on the engine performance and emission.

Jatropha oil and bio-diesel from Jatropha oil

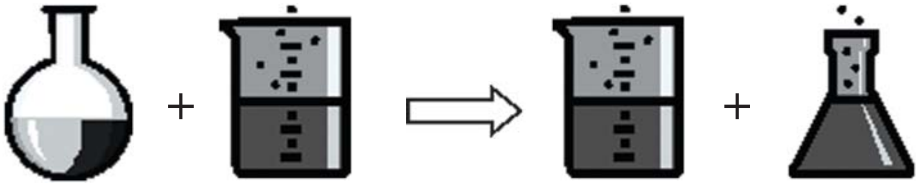
Jatropha

Jatropha is native to Central America. It belongs to the same family as rubber tree, Jatropha gossypifolia Linn., Croton stellatopilosus Ohba, etc. Jatropha is a medium hedge about 2- 7 meters in height, age greater than 20 years. It has black seeds with white meat, which can be crushed and processed to produce fuel (Natural Agriculture, 2005). With increasing fuel usage in present day, renewable energy sources are to be provided, making Jatropoha one of the alternatives (Augustus, Jayabalan and Seiler, 2002). Generally, Jatropha seeds contain approximately 55 % oil. The efficiency in extracting oil from Jatropha seeds depends on the tools capacity and the extracting method. Jatropha oil extraction used in this research is to crush the seeds using hydraulic press. The hydraulic press machines are small, cheap, easy to use, with high efficiency. First, the shells from the mature Jatropha seeds were removed. The seeds were insolated for 2-3 days, then chipped to be put into solar oven for 1-2 hours at 40- 50 ^{o}C. Afterwards, the Jatropha seeds were processed by the hydraulic press by continuously crushing them and let the oil flow out of the cylinder into the bucket and let it subside. After that, filter the oil using 0.3 micron filter machine in order to get the purest oil. As a result, we will get about 20% of Jatropha oil from Jatropha seeds including shells. The pressing machine is shown in Figure 1.

Figure 1. Jatropha oil Hydraulic pressing machine (Rak, 2006)

Bio-diesel from Jatropha Oil

After getting Jatropha oil from pressing, the humidity in Jatropha oil molecule needs to be removed by boiling it at about 100 - 105 ^oC and let it subside. After that, heat the isolated crude Jatropha oil again at about 55 ^oC in order to prepare the oil for transesterification process as shown in Figure 2.



Jatropha oil Methanol Methyl Ester or Bio - Diesel Glyceral

Figure 2. Transesterification

To produce bio-diesel oil from Jatropha oil, we used 5 crude Jatropha oil to one Methanol by volume. Use 12 grams of potassium hydroxide as catalyst per one liter of crude Jatropha oil (Chumsanti et al., 2005). Measure 200 cc. of Methanol per one liter of crude Jatropha oil and blend it with 12 grams of industrial grade potassium hydroxide. Then, blend them together. Pour the liquid into the crude Jatropha oil prepared earlier. Mix or shake them for reaction to take place around 5 - 10 minutes. Let it subside for precipitation. As a result, the liquid will be isolated into 2 parts: the upper part is bio-diesel and the bottom one is glycerin. The bio-diesel is 90% of the total volume. Release the glycerin in the bottom part out and wash with water by mixing 10% of water with bio-diesel. Let it subside. The liquid will be isolated into 2 parts, which are bio-diesel on top and the water at the bottom. Let the water out and leave the bio-diesel. Get rid of the water and residue methanol by boiling bio-diesel at 100 - 105 ^oC, resulting in purer and clearer bio-diesel. Finally, filter the bio-diesel by using 0.3 micron oil filter. The finished bio-diesel can now be used.

Chemical and Physical Properties

This research tested 2 types of oil, which are diesel oil blending with crude Jatropha oil (represented by J) and diesel oil blending with bio-diesel from Jatropha oil (represented by BJ) with 2, 5, 10, 20, and 30 blending ratio by volume, respectively. Table 1 and 2 show the chemical and physical properties of these 2 types of oil (Tested by the Department of Chemical Technology, Faculty of Science, Chulalongkorn University). The difference in viscosity for both blended oil were insignificant. But with the ratio greater than 20 %, the difference will increase. The crude Jatropha oil (J100) was 4 and 10 times higher in viscosity than bio-diesel from Jatropha oil (BJ100) and diesel oil, respectively. Moreover, heat value in both oils were also insignificant. Heat value for crude Jatropha oil is lower than the blended bio-diesel from Jatropha oil, with an average of approximately 0.4%. The heat value from both blended fuels decreased as the blending ratio of the crude Jatropha oil or bio-diesel increased.

Table 1. Physical and chemical properties of crude Jatropha oil & diesel oil blend (J)

Property	Diesel	J2	J5	J10	J20	J30	J100	Standard
1. Specific gravity at 15.6 ^{o}C (kg/l)	0.84	0.84	0.842	0.846	0.852	0.870	0.917	ASTMD1298
2.Kinematic Viscosity at 40 ^{o}C (mm^2/s)	3.5	3.51	3.68	4.10	5.14	9.95	35.46	ASTM D227
3. Flash point (^{o}C)	65	72	77	77	84	87	207	ASTM D92
4.Heating Value (kJ/kg)	45,000	44,764	44,537	44,000	43,750	43,220	39,000	ASTM D611

Table 2. Physical and chemical properties of bio-diesel oil from Jatropha & diesel oil blend (BJ)

Property	Diesel	BJ2	BJ5	BJ10	BJ20	BJ30	BJ100	Standard
1. Specific gravity at 15.6 °C (kg/l)	0.84	0.836	0.838	0.841	0.847	0.853	0.89	ASTMD1298
2. Kinematic Viscosity at 40 °C (mm^2/s)	3.5	3.53	3.65	3.79	4.09	4.92	9.34	ASTM D227
3. Flash point (°C)	65	71	76	79	83	86	189	ASTM D92
4. Heating Value (kJ/kg)	45,000	44,860	44,567	44,111	43,680	43,690	39,204	ASTM D611

Jatropha Oil Usage in Engines

Based on the fact that Jatropha oil properties are suitable to be used as fuel (Pramanik, 2003), Jatropha oil has been tested for engines in the form of crude Jatropha oil and bio-diesel from Jatropha. Jatropha oil can be used directly 100% or blended with diesel oil in different ratio. From the experiment by using Jatropha oil in the engine, it has been found that most of the experiments were using one cylinder diesel engine, which has low cycle of around 1,500 per minute. Pramanik, for example, had studied the property and the suitable ratio in blending the crude Jatropha oil for diesel engine, which revealed that around 40 - 50 % blending ratio for Jatropha oil and diesel oil can be used with the engine without heating the oil or modifying the engine (Forson et al., 2004). Furthermore, blending 2.64% Jatropha oil by volume with diesel oil will give higher Cetane Number (CN) than using diesel oil, which can replace oxidizing agent in diesel oil. Based on the research on the engine capacity when using Jatropha oil as fuel, it has been found that the engine using Jatropha oil as fuel or blending with diesel oil will have lower thermal efficiency and power because Jatropha oil has lower heating value. According to the research on the blending ratio, Jatropha oil at 20% by volume will yield engine performance close to that of the engine using just diesel oil (Agarwal, 2007).

In addition, when using bio-diesel from Jatropha oil in diesel engine at various diesel oil blending ratios, the test results revealed that blended fuel has reducing thermal efficiency and power. Oil consumption increased, whereas the gas emission, CO and HC from the engine that is using Jatropha decreased, comparing with the one using diesel. (Roa et al., 2008 and Gera and Jha, 2008)

Engine Performance and Emission Testing

After blending crude Jatropha oil and bio-diesel from Jatropha with diesel oil in 5 different ratios as shown in Table 1 and 2, we tested the oil blended with each blending ratios with high speed, direct injection, EFL 250 ISUZU Truck, 2,369 cc, 4-cylinder, water-cooled diesel engine as shown in Table 3. MT 504 Engine Dynamometer was setup on the testing platform with Eddy Current dynamometer as displayed in Figure 3. Then, we test the engine at 1,000, 1,700, 2,000, 2,500, 3,000 and 3,500 revolutions per minute (rpm) by turning on the throttle valve at 50% and maintaining the engine at constant speed of approximately 4,000 rpm. Then, increase the engine load by using the dynamometer to reduce rpm until achieving the desired speed. The measure was done from high rpm to the lower ones. (Panudach et al., 2003; Apichit and Jinda, 2003; Forson et al., 2004)

Table 3. Technical details of the test engine

Engine	ISUZU
Model	EFL 250 Truck
No. of cylinder	4
Cylinder size x Stroke	86 x 102 mm.
Cylinder Volume	2369 cc.
Highest horse power	74/3800 BHP/rpm
Highest torque	156/2000 N-m/rpm
Pressing ratio	20:1
Combustion Chamber	Swirl chamber
Speed	700 rpm
Cooling system	By water

Fuel consumption rate was measured by comparing the time used for each speed mentioned earlier with 40 cc of fuel. Also, the temperature of exhaust gas was measured by Type K thermocouple setup at exhaust pipe.

The equipment setup at the end of exhaust pipe was used to measure the amount of black smoke from the engine. Exhaust gas analyser, Testo 325-1, was used at 1,000 - 3,500 rpm. CO and CO_2 can be measured in ppm and in percentage, respectively. To measure the black smoke, the car exhaust pipe was attached to the opacity type exhaust gas analyser, Techno-Test 490. Accelerate the engine to the highest cycle speed, and then decelerate to reduce the cycle speed. After 2 -3 minutes, measure the result. The standard value was 50%, which was the standard for exhaust gas from the diesel car engine.

Figure 3. Test Engine Platform

Engine Performance Test Result

Table 4 and 5 show the test result from 2 types of blended fuel. The experiment result revealed the similarity in torque and power output value in both fuel types. This is because the heating values from both types of blended fuel were almost equal. The blended bio-diesel (BJ) had a slightly higher heating value than that of the blended crude Jatropha oil (J). As a result, torque and power output from the blended bio-diesel was higher than the blended crude Jatropha oil around 2.3% and 2%, respectively. The torque and the power output from the engine using blended bio-diesel and crude Jatropha oil was less than those from the engine using diesel oil, 2- 6 % and 0.3- 9 %, respectively.

Table 4. Torque from the engine compared to the cycle speed in both types of fuel

Rpm	Torque (N-m)										
	Diesel	J					BJ				
		J2	J5	J10	J20	J30	BJ2	BJ5	BJ10	BJ20	BJ30
1000	83.33	82.03	81.33	78.00	76.50	75.33	82.03	81.33	77.67	76.63	75.67
1700	116.00	114.67	109.67	110.67	106.77	108.20	116.00	112.00	115.23	113.37	110.00
2000	109.67	107.07	106.07	104.80	107.13	106.73	109.07	108.27	109.67	109.13	107.33
2500	92.87	92.43	92.33	90.43	90.43	92.77	93.07	93.20	93.51	93.73	94.50
3000	57.33	55.43	54.43	52.40	54.77	55.50	57.37	53.60	58.10	55.43	54.93
3500	44.07	43.93	39.67	39.33	38.97	39.07	44.03	43.50	41.37	42.10	40.40
Ave.	83.88	82.59	80.58	79.27	79.09	79.60	83.59	81.98	82.59	81.73	80.47

Table 5. Power output from the engine compared to the cycle speed in both types of fuel

rpm	Power (kW)										
	Diesel	J					BJ				
		J2	J5	J10	J20	J30	BJ2	BJ5	BJ10	BJ20	BJ30
1000	8.73	8.59	8.52	8.17	8.01	7.89	8.59	8.52	8.14	8.03	7.93
1700	20.66	20.42	19.53	19.71	19.01	19.27	20.66	19.95	20.52	20.19	19.59
2000	22.98	22.43	22.22	21.96	22.45	22.36	22.85	22.68	22.98	22.87	22.49
2500	24.32	24.21	24.18	23.68	23.68	24.30	24.37	24.41	24.49	24.55	24.75
3000	18.02	17.42	17.11	16.47	17.21	17.44	18.03	16.85	18.26	17.42	17.26
3500	15.70	15.65	14.13	14.01	13.88	13.91	15.68	15.49	14.73	15.00	14.39
Ave.	18.40	18.12	17.62	17.33	17.38	17.53	18.37	17.98	18.19	18.01	17.73

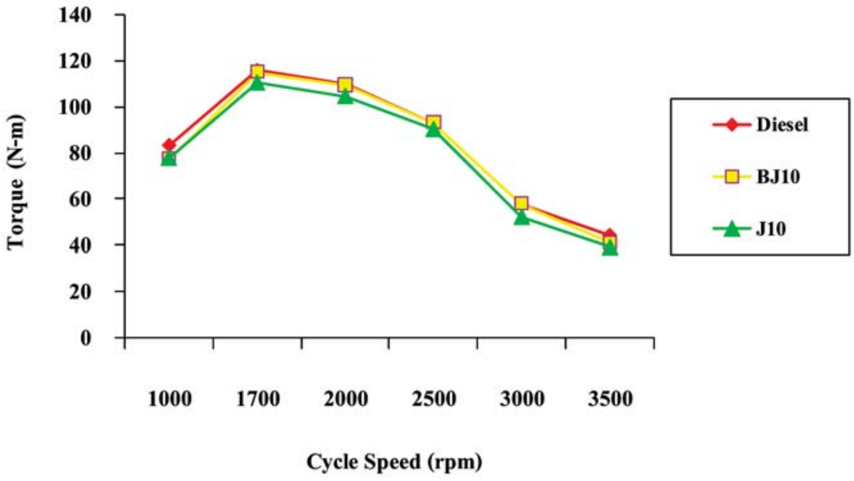


Figure 4. Torque value from engine using blended fuel with 10% ratio

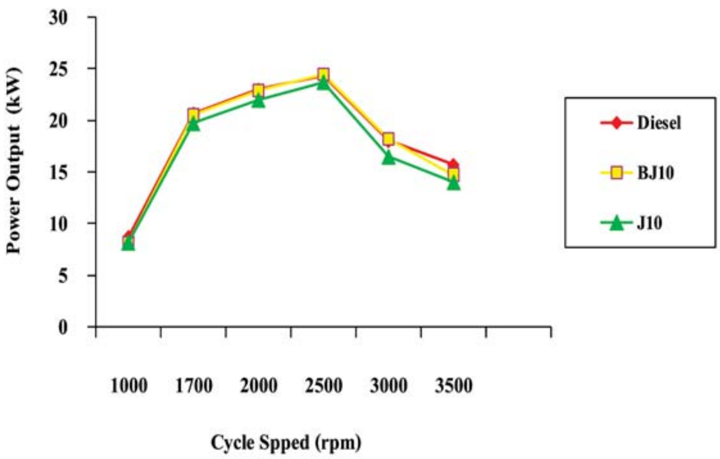


Figure 5. Power output from the engine using blended fuel with 10% ratio

Figure. 4 and 5 show torques and power output from the engine with different cycle speeds and with 3 different types of fuel, which are diesel oil, blended fuel with bio-diesel (BJ10), and blended fuel with crude Jatropha oil (J10). Torque and power output from the engine using BJ10 and J10 was slightly less than the one using diesel. While torque and power output from BJ10 was greater than from J10 around 2% and 2.2 %, respectively. This is because the heating value from BJ10 was greater than that of J10. When comparing the temperature of exhaust gas releasing from the engine, we found only insignificant difference. Reason is because the heating values of both types of fuel were very close. Consequently, the temperatures inside the combustion chamber were almost equal. The average temperature of exhaust gas was 378 - 402 ^{o}C.

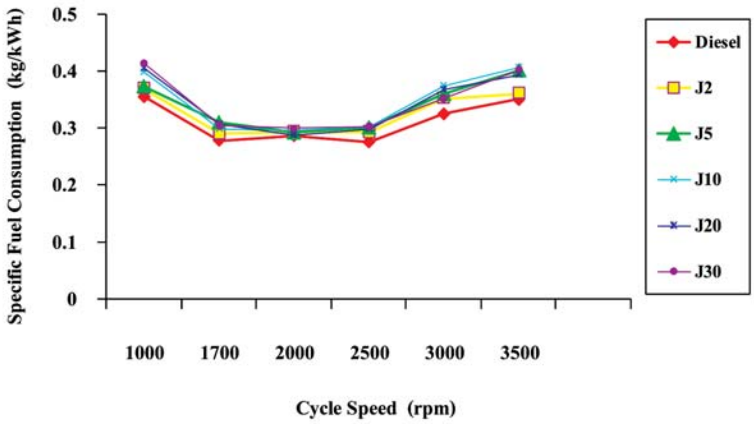


Figure 6. Specific fuel consumption rate of blended bio-diesel oil comparing with diesel oil

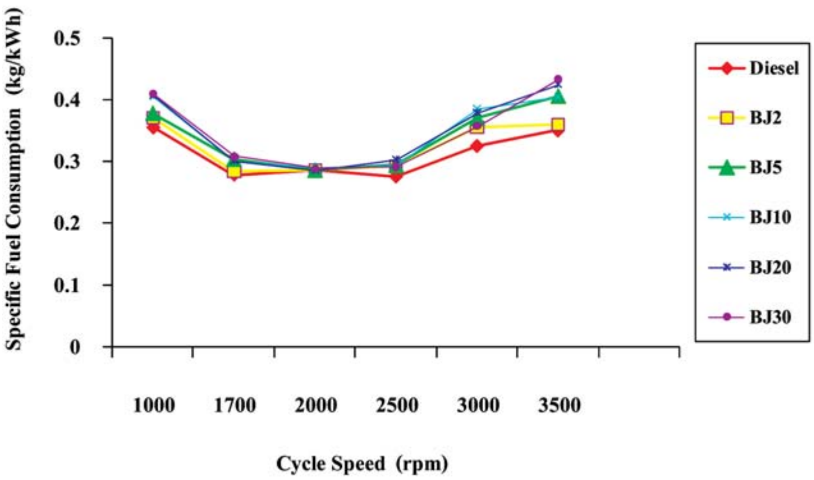


Figure 7. Specific fuel consumption rate of blended crude Jatropha oil comparing with diesel oil

According to the specific fuel consumption rate displayed in Figure 6 and 7, the fuel consumption rate of BJ and J was 5 - 11 % and 4 - 25 % greater than that of diesel oil, respectively. The fuel consumption rate increased in proportion with the increasing Jatropha oil ratio. This is because the heating value from the blended fuel decreased with respect to the increasing ratio. When comparing the fuel consumption rate of BJ and J, the fuel consumption rate of BJ was approximately 2.2 % less than that of the blended crude Jatropha oil, due to the similar reason when comparing the torque and power output. When comparing the thermal efficiency at the same speed, it is found that the thermal efficiency of BJ is about 2% greater than that of J (Watcharaphon, 2007).

Gas Emission Test Result

According to the experiment analyzing the amount of carbon monoxide (CO), carbon dioxide (CO_2), and exhaust gas released from the engine using two types of blended fuel, we have found that the results were very similar. The amount of carbon monoxide and exhaust gas decreased with the increasing blending ratio of crude Jatropha oil or bio-diesel from Jatropha. This is because the blended fuel had the component of increasing oxygen from the increasing Jatropha oil. Hence, allowing more complete combustion, as displayed in Figure. 8 and 10. For both types of fuel, the amounts of released carbon dioxide were very close, and also similar to the value from diesel oil. Generally, carbon dioxide value should have increased. However, the amount of gas inside the combustion chamber was controlled during the experiment. Consequently, the amounts of carbon dioxide from the experiment in different types of fuel were not much different, as shown in Figure. 9.

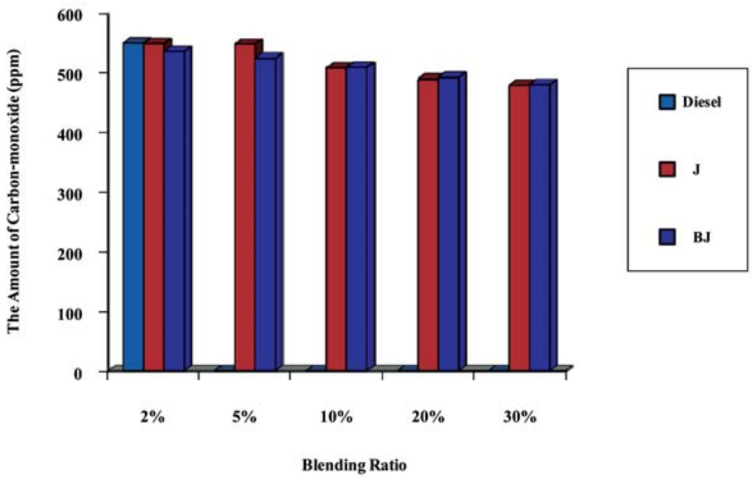


Figure 8. The amount of carbon monoxide (CO) at 2,000 rpm for both blended fuel

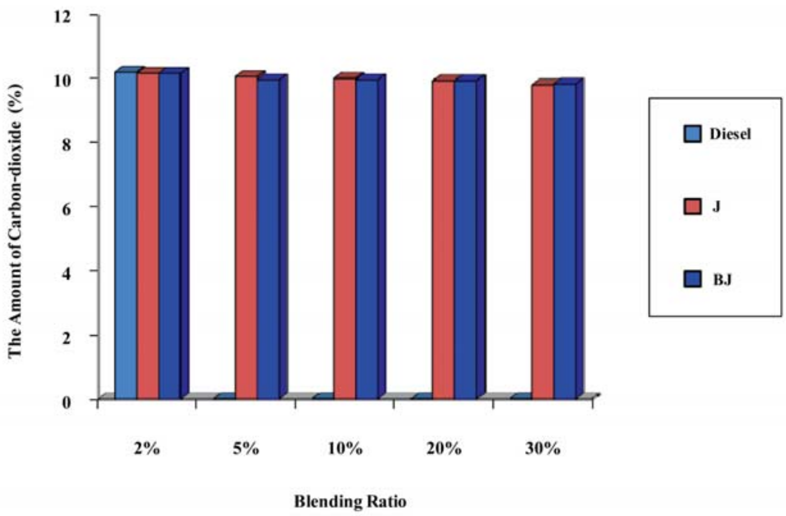


Figure 9. The amount of carbon dioxide (CO_2) at 2,000 rpm for both blended fuel

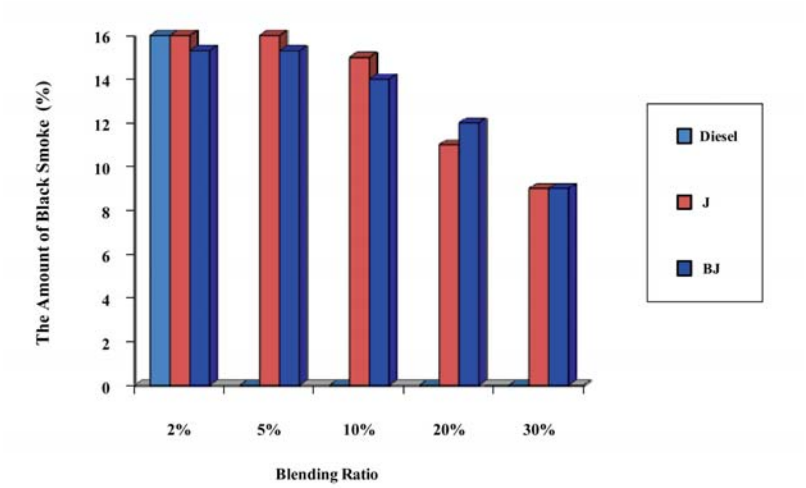


Figure 10. The amount of exhaust gas from both blended fuel

Conclusion

The experiment involved using crude Jatropha oil and bio-diesel blended with diesel oil at different ratios in high speed diesel engine. Eventually, the engine performance and exhaustion were compared and analyzed. The torque and average power output from the engine using the blended bio-diesel and the blended crude Jatropha oil was 2 - 6% and 0.3 - 9% less than that of the diesel oil, respectively. Meanwhile, those from engine using the blended bio-diesel were, respectively, around 2.3% and 2% greater than those of the blended crude Jatropha oil. Considering the rate of specific fuel consumption from the high speed engine (2,000 rpm), the experiment results revealed that the blended bio-diesel and the blended Jatropha oil was 5 - 11% and 4 - 25% less than that of the diesel oil, respectively. The blended bio-diesel has around 2% lower fuel consumption rate than the blended crude Jatropha oil. The heating value of the high speed engine using both blended fuel was lower than the one using diesel oil. The amount of carbon monoxide, carbon dioxide, and exhaust gas from high speed engine, using both types of blended fuel were less than those from the engine using diesel oil. It can be concluded that the suitable blending ratio for diesel and the crude Jatropha oil to be used with high speed diesel engine is 10%. The suitable blending ratio for diesel and bio-diesel from Jatropha oil to be used with high speed diesel engine is 30%. This is because the quality of the blended fuel gives the right viscosity within the controlled range; less than 5 centistokes (Notification of Department of Energy Business : To determine the aspects and quality of bio-diesel - methyl ester of fatty acid, 2005) Furthermore, the value of torque, power output, heating value, fuel consumption rate from the engine using both blended fuel are very closed to those from the engine using diesel oil. But the exhaust gas from the engine using the blended fuel was less than that of diesel oil.

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