Preparation of Palm Oil Esters-diesel Fuel Mix and Its Performance Test on Stationary Engine

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ABSTRACT

As the consumption and import of diesel fuel increase in Indonesia, palm oil esters are now being considered to gradually replace the petroleum based fuel. A study on the laboratory preparation of methyl esters from crude palm oil has been successfully carried out in LEMIGAS R & D Centre for Oil and Gas Technology, Jakarta. Preliminary evaluation of palm oil methyl esters as diesel fuel and as diesel fuel substitute was initiated based on performance test on stationary engine. The test showed that the torque and power are lower and specific fuel consumption is larger when using the ester.

INTRODUCTION

At present Indonesia consumes about 17 million kilo litres of petroleum diesel fuel. The growth rate of diesel fuel consumption in the country is about 6% per year. As the current fuel consumption pattern in Indonesia is not compatible with the existing refinery configuration, import of petroleum based fuel is still needed and tends to increase from year to year.

Indonesia is presently the second largest palm oil producer in the world and has a considerable potential of expansion. In 1993 the oil palm planting area has reached 1.62 million hectares and produced 3.42 million tonnes of crude palm oil (CPO). It is estimated that in the year 2000 the CPO production will reach 7.5 million tonnes and in 2005 will increase to 9.9 millions tonnes. It should be therefore worthwhile to examine the use of palm oil as fuel subtitute as well as fuel extender.

Research on vegetable oils as diesel fuel either in 'pure' form or in blend with conventional diesel fuels has been reported from time to time in some references. The research showed that the use of vegetable oil apparently have good potential as alternative fuel.

However, some inconveniences are still observed as evident from its inferior physical and chemical properties compared to conventional diesel fuel. The viscosity of this oil is much higher (20 times that of diesel which may lead to coking of the injectors and rings.

The esters of palm oil have better properties than crude palm oil such as higher cetane number, lower coking deposit and lower emissions. The chemistry of esterification is in many ways much simpler than that of petroleum processing. Palm oils, which are triglycerides can be converted to methyl or ethyl esters by a process known as 'transesterification'.

PREPARATION OF PALM OIL METHYL ESTER

The esterification conducted in this study followed a process flow as presented in *Figure 1.* Crude palm oil, methanol and a catalyst were mixed at 60°C. The reaction products were decanted to separate the glycerol and methyl esters. The esters were washed with water to remove the rest of methanol. The reaction was conducted with different reaction time, catalyst quantity and methanol:CPO ratio. The results are as presented in *Table 1.* The optimal conditions gave 98.88% yield of esters. The properties of these esters are comparable with those of petroleum diesel. These esters have very low sulphur content, therefore will produce less pollution on combustion. Its cetane index is in the acceptable range for conventional engine usage. The calorific value of these esters is lower than that of petroleum diesel, but the esters have higher specific gravity. However these differences can be somewhat compensated.

PREPARATION OF ESTERS-DIESEL FUEL MIX

Some ester-diesel fuel mixtures have been examined in order to formulate appropriate mix compositions matching diesel fuel specification . The properties of compositions are represented in *Table 2.* Among four compositions (80/20, 75/25, 70/30, 65/35v/v) evaluated, the 70/30 v/v diesel fuel /ester mix was found to be the best.

STATIONARY ENGINE PERFORMANCE TEST

Performance test on stationary engine was carried out using 70:30 diesel fuel: palm oil methyl esters mix. As a comparison the engine was also tested with 100% of esters and diesel fuel.

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Elaeis Special Issue, November 1995, pp. 52-57

TABLE 1. CHARACTERISTICS OF ESTERS OBTAINED UNDER DIFFERENT REACTION CONDITIONS

No	CHARACTERISTICS	RESULT			
1	Yield, %wt	98.41	98.48	98.88	98.89
2	Spec.Gravity 60/60°F	0.8754	0.8754	0.8756	0.8749
3	Kin. Viscosity, 40°C cSt	4.886	4.954	4.967	4.724
4	Calc. Cetane Index	54.2	54.5	53.5	53.8
5	Pour Point, °C	12	12	12	12
6	Conr. Carb. Resid., %-wt	0.036	0.034	0.032	0.039
7	Distillation °C				
	IBP	246	293	305	280
	Rec. 5% vol	311	320	319	321
	10% vol	313	322	320	322
	20% vol	321	323	321	322.5
	30% vol	323.5	324	323	324
	40% vol	325	325	325	326
	50% vol	327.5	326	327	328
8	Stability	no	yes	yes	yes
9	Molar Ratio MeOH/CPO	8	9.5	10.65	10.65
10	Relative Reaction Time	1	2	2	4
11	Catalyst (relative weight)	1.25	1.25	1	1
12	Reaction Temperature °C	60	60	60	60

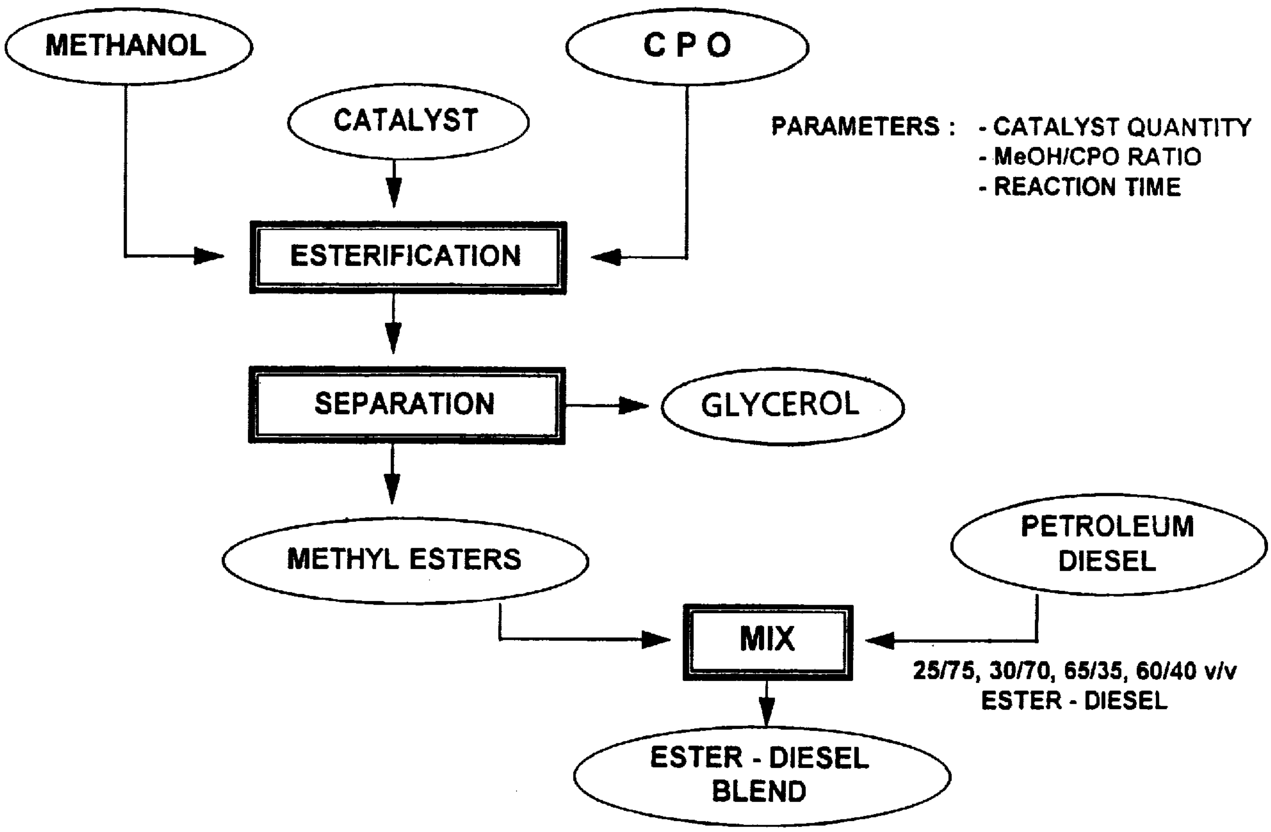

Figure 1. Ester preparation

TABLE 2. CHARACTERISTICS OF ESTER, PETROLEUM DIESEL AND THEIR MIXTURE

No	CHARACTERISTICS	PRODUCTS			DIESEL SPECIFICATION (INDONESIA)		
		Ester	Diesel-Ester 70 : 30	Diesel	Min	Max	Methode ASTM
1	Spec. Gravity 60/60°F	0.88	0.85	0.83	0.82	0.87	D 1298
2	Calc. Cetane Index	53.5	60.2	63	48	-	D 976
3	Kin. Viscosity, 40°C cSt	4.97	4.07	3.78	1.6	5.8	D 445
4	Pour Point, °C	12	6	3	-	18	D 97
5	Conr.Carb. Resid., %-wt	0.03	0.02	0	-	0.1	D 189
6	Sulfur Content, %-wt	0.03	0.1	0.14	-	0.5	D 1551
7	Copper Strip Corr. 100°C 2 hrs	1A	1 A	1A	-	No. 1	D 130
8	Colour ASTM	5	4	3.5	-	3	D 1500
9	Neutralization Value						D 664
	- SAN mgKOH/gr	nil	nil	nil	-	nil	
	- TAN mgKOH/gr	10.6	2.98	0.15	-	0.5	
	- TBN mgKOH/gr	nil	nil	0.27	-	-	
10	Flash Point COC. °C	186	-	72	66	-	D 92
11	Distillation °C						D 86
	IBP	305	192	187	-	-	
	Rec. 5% vol	319	225	201			
	10% vol	320	243	227	-	-	
	20% vol	321	272	250	-	-	
	30% vol	323	291.5	268.5	-	-	
	40% vol	325	299.5	283	-	-	
	50% vol	327	312	296	-	-	
	60% vol	332	321	308	-	-	
	70% vol	340	328.5	324	-	-	
	80% vol	346	338.5	342	-	-	
	90% vol	-	356	368	-	-	
	FBP °C	346	371	371	-	-	
	Rec. 300°C %-vol	-	40.5	53.5	40	-	
12	Ash Content %-wt	0.01	0	nil	-	0.01	D 482
13	Water Content %-vol	Trace	Trace	Trace	-	-	D 95
14	Calorific Value, Btu/lb	16,830	20,764	22,450	-	-	D 240
15	Sediment By Extract., %-wt	0.01	nil	nil	nil	nil	D 473
16	BS&W %-vol	Trace	Trace	nil	-	-	D 1796

TABLE 3. EMISSION LEVEL

Gas Composition	FUEL								
	DIESEL			DIESEL - ESTER 70/30			ESTER		
	Load 1/2 Max	Load 3/4 Max	Load Max	Load 1/2 Max	Load 3/4 Max	Load Max	Load 1/2 Max	Load 3/4 Max	Load Max
HC, ppm	10	15	18	10	13	16	9	11	14
CO, ppm	300	1150	1650	260	1120	1390	210	610	710
CO_2, %vol	8.9	11.2	11.4	9	11	11	8.8	11	11

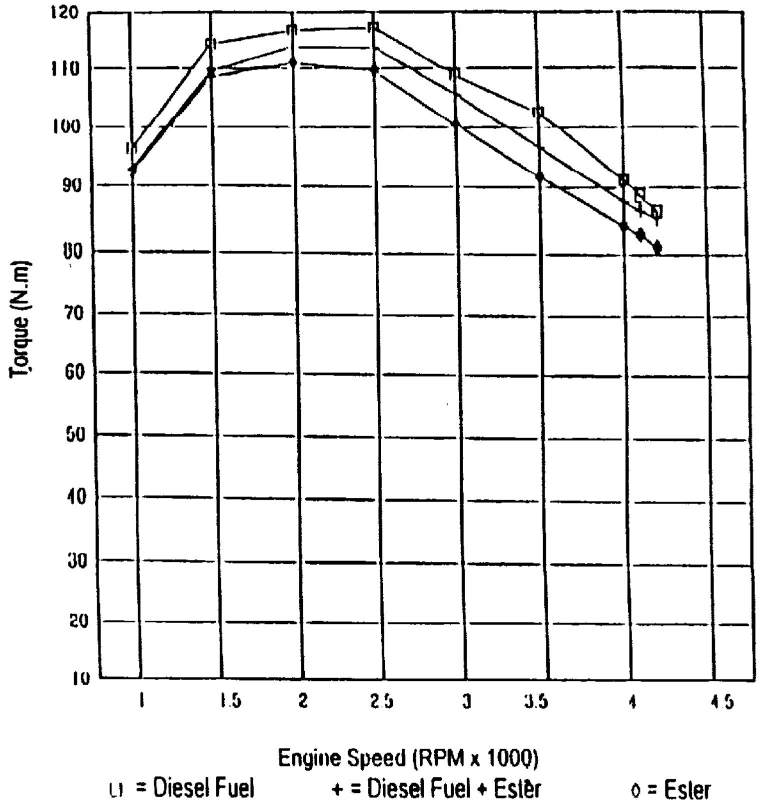

Figure 2. Engine Torque (Nm) vs Engine speed (rpm)

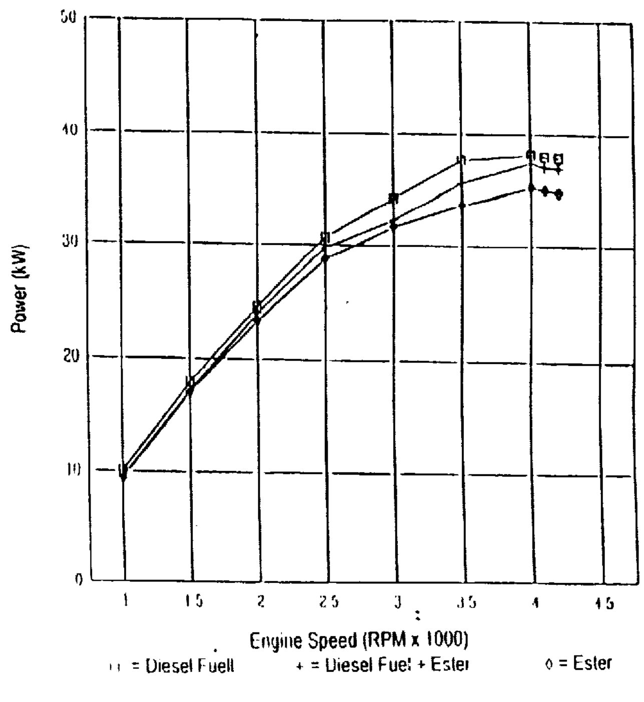

Figure 3. Engine power (kW) Engine speed (rpm) on maximum load

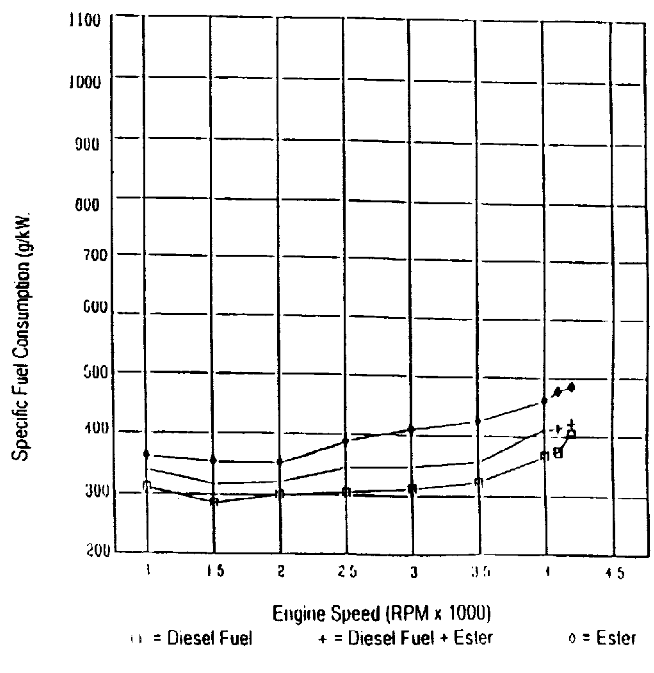

Figure 4. Specific fuel consumption (gram/kWh) vs Engine speed (rpm) on maximum load

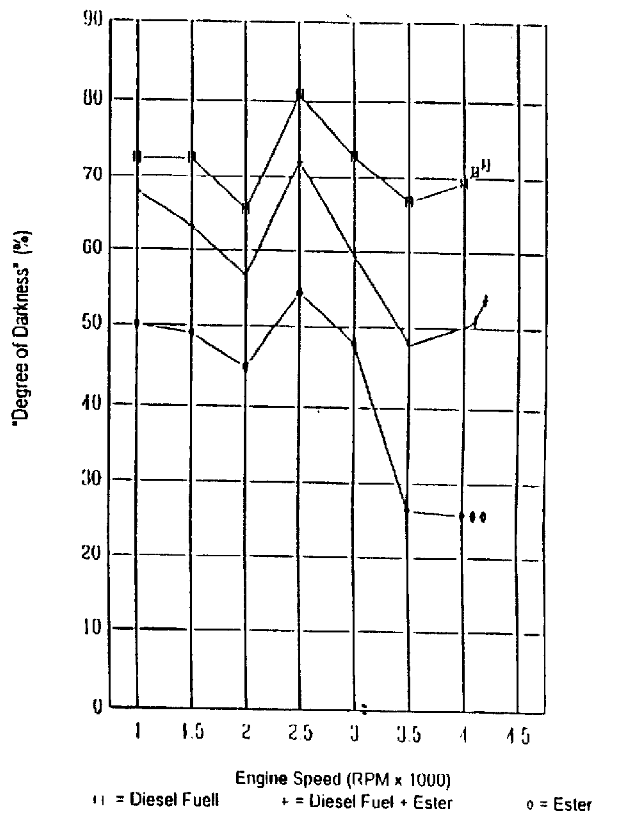

Figure 5. "Degree of Darkness" (%) vs Engine speed (rpm) on maximum load

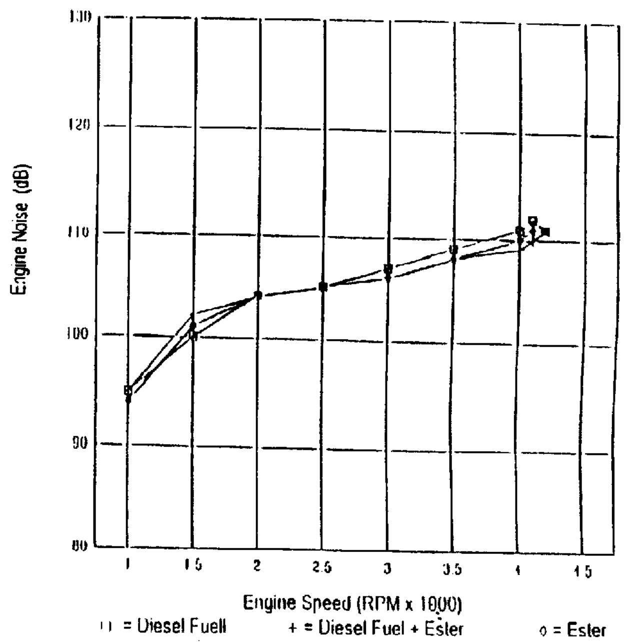

Figure 6. Noise (dB) vs Engine speed (rpm) on maximum load

The parameters measured were: engine torque, power, specific fuel consumption, noise, smoke and emission level.

The engine has the following specifications:

Type	:	4 - stroke Diesel Engine In line Water Cooled Overhead valve Direct injection
No. Of Cylinder	:	4
Displacement	:	2,238 cm^3
Compression ratio	:	21 to 1
Bore x Stroke	:	88 x 92 mm

RESULTS

Engine Torque

Figure 2 shows the engine torque at different engine speeds. It can be seen that the torque decreases when the ester content of the fuel increases. The maximum engine torque of 117 Nm is obtained at 2500 rpm for diesel oil, 144 Nm and 110 Nm at 2000 rpm for the 70/30 mixture and ester, respectively.

Engine Power

Figure 3 shows the engine power. The engine maximum charge were 383, 37.5 and 35.2 kW at 4000 rpm for diesel, mixture and ester, respectively. The power of the engine decreases 8% when using 100% ester and 2% when using 30% ester in the blend.

Specific Consumption

The specific consumptions of the engine are presented in *Figure 4*. The specific consumption increases when the ester content is increased. Compared to diesel fuel, the increase when using ester is about 24%. Note that the calorific value of the ester is 25% lower. When using 70/30 v/v diesel:ester mix, the specific fuel consumption increase is 11%.

Noise, Smoke and Emission Level

The results are presented in *Figures 5 to 6* and *Table 3*, the smoke is represented by "degree of darkness" Relatively, there is no difference in engine noise using three types of fuel. It can be seen that ester fuel produces lower degree of darkness and lower emission-level of polluting gas.

CONCLUSION

Methyl esters of palm oil is shown to be a promising substitute as alternative diesel fuel. The laboratory preparation of methyl esters of palm oil at selected operating conditions has been successfully conducted with high yield of esters. The study showed that the esters can be used as a blending component of diesel fuel without making the physico-chemical properties of the resultant blend to deviate from diesel fuel specifications significantly. The preliminary test on stationary engine indicated that palm oil ester or its diesel-ester blend reduces the power output and the specific fuel consumption is higher due to the lower calorific value of the esters. The use of the esters, on the other hand, lowers the pollution emission level. The 70/30 v/v mix of petroleum diesel-palm oil methyl esters seems appropriate as diesel fuel which should be furthermore confirmed in field trial in the future.

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