Evaluation of Crude Palm Oil Pre-treatment Process as Fuel on Diesel Engine Power Plant

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Abstract. Experimental studies of the CPO (Crude Palm Oil) fuel pre-treatment system for diesel power plants with a capacity of 2 544 kW were carried out to determine the fuel heating temperature requirements and to evaluate the reliability of the pre-treatment system. The fuel pre-treatment consists of the heating process, mechanical separation process and filtering process. The CPO at the booster module was heated from 64 ºC to 81 ºC by set the thermal oil temperature. The result shows that a minimum CPO heating of 78 ºC is required in the booster module to produced kinematic viscosity CPO less than 13 cSt at the engine inlet. When there is a disturbance in the thermal boiler system, CPO deposits are found in the booster module strainer, which clogs the fuel supply to the engine, causing hunting loads. Redundancy equipment is needed to increase the reliability of the pre-treatment system. In addition, it is also necessary to add a heating process through the CPO fuel line starting from the storage tank to the engine inlet so that the thermal loss that occurs can be minimized and the work of the thermal boiler is reduced.

Keywords: Bioenergy, *Elaeis guineensis* Jacq., fuel pre-treatment, kinematic viscosity, renewable energy.

1 Introduction

Indonesia was one of the largest palm oil producers globally, which produced 5 600 $\times 10^6$ L of biodiesel in 2018, while the consumption of petrodiesel was 32 196 $\times 10^6$ L. Indonesia's government has converted petrodiesel to biodiesel in the transportation, industry, and electrical generation sectors. In 2020, Indonesia increased fuel blend from diesel and crude

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palm oil (CPO) to 30 % [1, 2]. In the power generation sector, several studies on the use of CPO as fuel for diesel power plant are being carried out by both the government of Indonesia and other research institutions.

CPO is obtained from the extraction or the pressing process of the oil palm pulp and has not been refined [3]. Palm oil is naturally reddish due to its high carotene content, including alpha-carotene, beta-carotene, and lycopene. Crude palm oil contains at least ten types of carotenes, along with tocopherols, tocotrienols, phytosterols, and gicolipids [4, 5].

The main challenge in using CPO as a fuel is the different viscosity, density and flashpoint with diesel oil. Temperature affects the density and kinematic viscosity of palm oil, where the higher temperature decreases the density and kinematic viscosity value [6–8]. The density of CPO at 25 ºC ranges from 0.909 g mL^{-1} to 0.917 g mL^{-1}, while at 55 ºC the density values decrease to be in the range of 0.888 g mL^{-1} to 0.892 g mL^{-1} [6]. Tests on 205 samples of Crude Palm Oil (CPO) in Indonesia, the density of CPO at 40 ºC ranged from 0.85 g mL^{-1} to 0.94 g mL^{-1} [9]. The decreasing kinematic viscosity concerning heating temperature tends to be exponential, while density tends to be linear [7].

At the same temperature conditions, the kinematic viscosity of CPO is much greater than diesel. At room temperature, CPO has a viscosity of about 10 to 15 times higher than diesel [10, 11]. The oil's viscosity decreases by about 30 % for every increase in temperature of 10 ºC [12]. The viscosity that is too high makes the atomized fuel into a larger droplet, resulting in deposits on the engine. However, if the viscosity is too low, it produces too fine spray so that a rich zone is formed, which causes the formation of soot. High viscosity also causes droplet formation in the fuel spray to get bigger, so that the ignition delay is getting longer.

CPO pre-treatment technologies commonly used include the heating process, both mechanical and chemical separation, and filtration. Previous studies conducted heating of CPO by range from 50 ºC to 70 ºC for diesel engine single-cylinder, 4-stoke, air-cooled, direct injection, compression ignition [13]. Meanwhile, various vegetable oils are preheated to 60 ºC before entering the diesel engine [14]. Preheating is also carried out on several variations of the CPO-diesel mixed fuel for four-cylinder high-speed diesel engines [15].

Generally, previous studies related to pre-treatment systems were carried out using high speed and low-capacity diesel engines. This study aims to evaluate the pre-treatment system in low-speed diesel engines power plant with a capacity greater than 2 500 kW. Evaluation is carried out to determine the need for fuel heating temperature, which results in kinematic viscosity according to engine requirements.

2 Experimental method

Before CPO fuel enters the diesel engine power plant, CPO fuel is pre-treated through a heating process using thermal oil heating media, separation using a separator and filtering using a booster module. Typical fuel pre-treatment in this study used for the diesel engine type 8M-453-B, a rated capacity of 2 554 kW, 600 RPM rated speed, compression-ignition and eight-cylinder arrangement.

The layout of fuel pre-treatment shown in Figure 1. The CPO fuel received through the tank car is put into the storage tank and then pumped to the settling tank. The separation process using a separator is carried out on the line between the settling tank and the service tank. From the service tank, an advanced filtering process is carried out through the booster module to maintain the quality of CPO to meet the criteria required by the diesel engine. A closed-cycle heating process is carried out where the hot fluid thermal oil from the supply header is flowed to the storage tank, settling tank, service tank and booster module. After heating the CPO, the thermal oil accommodated in the return header then reheated using a thermal boiler that uses biodiesel fuel. The fuel and thermal oil pipes from the storage tank to the booster module are isolated to minimize heat losses. However, there is no insulation on the pipe after the booster module arrives at the engine inlet, so that heat loss occurs in the fuel. Furthermore, there is no heating process through the CPO line, so that even though it has been isolated, there are still thermal losses in the area.

The heating temperature and outlet temperature of CPO fuel were monitoring in each tank. In addition, a stirrer is also installed in each tank. CPO sampling was carried out on the taping line before and after the fuel pre-treatment then analyzed the characteristic in the laboratory. Analyze the relationship between kinematic viscosity and heating temperature in two scenarios, namely the amount of heat loss along the line between the booster module and diesel engine inlet of 10 ºC and 15 ºC was carried out to obtain the heating temperature required.

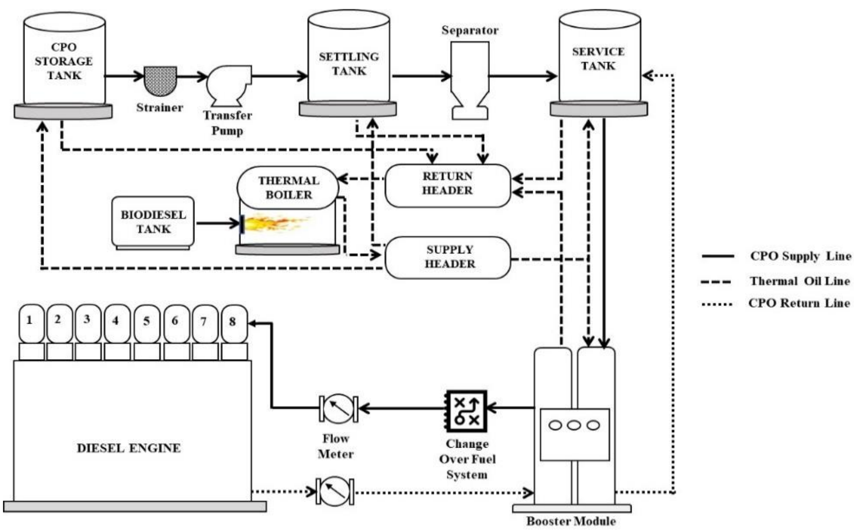

Fig. 1. Crude palm oil pre-treatment by heating, separating, and filtering process.

3 Results and discussion

In maintaining and monitoring the quality of CPO before going through the pre-treatment process, laboratory testing is carried out on three samples when fuel is received. The content of kinematic viscosity and flash point in CPO is higher than diesel oil or Marine Fuel Oil (MFO) (Table 1). The CPO parameter value still meets the SNI 8483:2018 standard limits.

Table 1. Crude palm oil properties before pretreatment process.

Parameter	Unit	CPO_1	CPO_2	CPO_3
Acid number	mg KOH g^{-1}	11.48	10.85	12.63
Iodium	g-I_2 100 g^{-1}	29.16	29.31	26.46
Kinematic viscosity @50 ºC	$mm^2 s^{-1}$ (cSt)	39.77	39.98	40.11
Saponification number	mg KOH g^{-1}	199.13	198.81	197.41
Flash point	ºC	232	232	236
Carbon residu	%-wt	0.19	0.17	0.15
Moisture	%-wt	0.14	0.11	0.14
Sedimen	%-wt	0.004	0.016	0.012

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Table 1. Continue.

Parameter	Unit	CPO_1	CPO_2	CPO_3
Ash	%-wt	-	-	-
Phosphor	mg kg^{-1}	0.7	1.4	0.9
Sodium (Na)	%	0.000 28	0.000 11	0.000 58
Sulphur	%-mass	0.001	0.001	0.003

Analysis of the kinematic viscosity characteristics of CPO after going through the fuel treatment system was carried out to determine the optimal CPO operating temperature range. The method used is to graph the kinematic viscosity correlation to CPO temperature. The two parameters are taken from the recording on the display booster module, which measures temperature and kinematic viscosity in real time. The exponential correlation of the kinematic viscosity to CPO temperature is $y = 0.0038\,x^2 - 0.8189\,x + 50.953$ (Figure 2) with $R^2 = 0.9935$ where y is the kinematic viscosity (in cSt) and x is the temperature of CPO (in ºC).

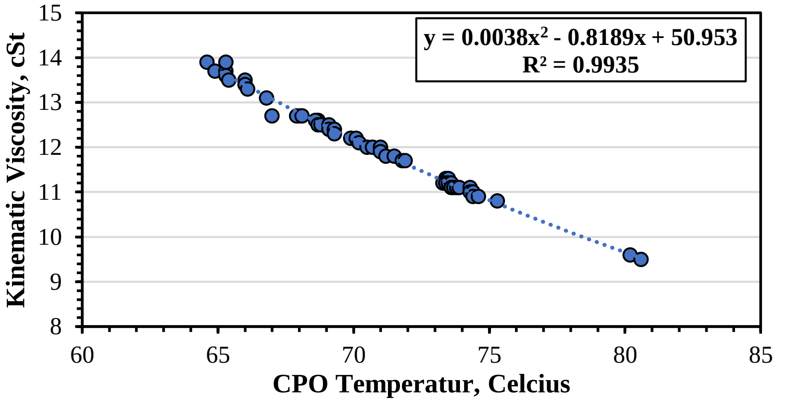

Fig. 2. Kinematic viscosity of CPO at booster module.

Based on the decreasing CPO temperature conditions, the kinematic viscosity (KV) value is simulated on the booster module display and the engine inlet in two conditions, namely at a temperature difference of 10 ºC and 15 ºC. This simulation aims to get a safe engine operation when using CPO fuel.

Table 2. Simulation of CPO heating temperature to obtain a kinematic viscosity that matches the requirements of diesel engines.

Display booster module		Engine inlet, ΔT = 10 ºC		Engine inlet, ΔT = 15 ºC	
Temp ºC	KV cSt	Temp ºC	KV cSt	Temp ºC	KV cSt
60	15.50	50	19.51	45	21.80
61	15.14	51	19.07	46	21.32
62	14.79	52	18.65	47	20.86
63	14.44	53	18.23	48	20.40
64	14.11	54	17.81	49	19.95
65	13.78	55	17.41	50	19.51
66	13.46	56	17.01	51	19.07

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Table 2. Continue.

Display booster module		Engine inlet, ΔT = 10 ºC		Engine inlet, ΔT = 15 ºC	
Temp	**KV**	**Temp**	**KV**	**Temp**	**KV**
ºC	**cSt**	**ºC**	**cSt**	**ºC**	**cSt**
67	13.14	57	16.62	52	18.65
68	12.84	58	16.24	53	18.23
69	12.54	59	15.87	54	17.81
70	12.25	60	15.50	55	17.41
71	11.97	61	15.14	56	17.01
72	11.69	62	14.79	57	16.62
73	11.42	63	14.44	58	16.24
74	11.16	64	14.11	59	15.87
75	10.91	65	13.78	60	15.50
76	10.67	66	13.46	61	15.14
77	10.43	67	13.14	62	14.79
78	10.20	68	12.84	63	14.44
79	9.98	69	12.54	64	14.11
80	9.76	70	12.25	65	13.78
81	9.55	71	11.97	66	13.46
82	9.35	72	11.69	67	13.14
83	9.16	73	11.42	68	12.84
84	8.98	74	11.16	69	12.54
85	8.80	75	10.91	70	12.25
86	8.63	76	10.67	71	11.97
87	8.47	77	10.43	72	11.69
88	8.32	78	1.20	73	11.42
89	8.17	79	9.98	74	11.16
90	8.03	80	9.76	75	10.91
91	7.90	81	9.55	76	10.67
92	7.78	82	9.35	77	10.43
93	7.66	83	9.16	78	10.20
94	7.55	84	8.98	79	9.98
95	7.45	85	8.80	80	9.76
96	7.36	86	8.63	81	9.55
97	7.27	87	8.47	82	9.35
98	7.20	88	8.32	83	9.16
99	7.13	89	8.17	84	8.98
100	7.06	90	8.03	85	8.80

areas where CPO is not allowed to enter diesel engines
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Based on the operational data at the initial running test period, the thermal losses between the booster module and the engine inlet is 10 ºC. So that to get the appropriate kinematic viscosity (< 13 cSt), the heating temperature in the booster module needed to be maintained at a minimum of 78 ºC (Table 2). The higher fuel heating temperature produces lower kinematic viscosity but requires a greater consumption of biodiesel fuel in the thermal boiler. So, it is necessary to optimize the operation where the diesel engine remains safe to operate, and the energy requirements of the thermal boiler are not significant. Meanwhile, the reliability of the thermal boiler must be maintained to keep the stability of the heating process.

The problem found in this pre-treatment system is that the number of thermal boilers is only one. When there is a disturbance in the form of a thermal boiler burner off, the heating process of the CPO fuel is not optimal and causes the kinematic viscosity of CPO to increase. Besides that, there is a blockage in the booster module strainer (Figure 3). The CPO pipeline from the service tank to the booster module is only isolated, there is no heating process. So that when the initial fuel flows to the engine, the remaining CPO fuel that settles when there is a thermal boiler disturbance is carried away and clogs the strainer. As a result, the supply of CPO fuel to the engine is reduced and causes the engine load to become hunting. This condition shows that the optimal CPO heating system in the initial phase of operation is critical. A circulation line of CPO fuel should be added from the service tank to the booster module back to the service tank. Considering the massive clogging condition, it is necessary to mitigate the risk related to the shorter filter replacement time interval.

Fig. 3. Blockage in the strainer booster module.

4 Conclusion

Experimental studies of the CPO fuel pre-treatment system for diesel power plants were carried out to determine the fuel heating temperature requirements and the reliability of the pre-treatment system. To get a kinematic viscosity that meets the limitations of a diesel engine, a minimum CPO heating of 78 ⁰C is required in the booster module. In terms of kinematic viscosity, this pre-treatment system can produce CPO output according to machine requirements. When there is a disturbance in the pre-treatment system, the thermal boiler burner is off, CPO deposits are found in the booster module strainer, which clogs the fuel supply to the engine, causing hunting loads. Redundancy equipment is needed to increase the reliability of the pre-treatment system. In addition, it is also necessary to add a heating process through the CPO fuel line starting from the storage tank to the engine inlet so that the thermal loss that occurs can be minimized and the work of the thermal boiler is reduced.

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