Proceedings of the 16th Tri-University International Joint Seminar and Symposium 2009
Mie University, Japan, October 19–22, 2009

TRIU09EY-06

Performance Evaluation of Diesel Generator Set Using Transformer Reused Oil

Parachawee Krisadawat[1], Nirun Suwannasit[2], Wassanai Wattanutchariya[3]

[1, 3] Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, THAILAND.
E-mail: wattanwa@gmail.com, r_raiwa@hotmail.com

[2] Provincial Electricity Authority, 208 Chiangmai-Lumphun Rd. Muang Chiangmai 50000, THAILAND
E-mail: nirun6796@hotmail.com

Abstract. Nowadays, the diesel fuel is more necessary for many human activities, for example, transportation, manufacturing industries, and also the production of electricity. Rising fuel price is creating flown-on effects in almost every economy and society. For Thailand, this tends to be a big problem that can be solved ifficultly. Therefore, this research aims to increases the way of renewable energy usage by using the transformer reused oil, which has no value, to substitute the diesel fuel for the generator and evaluate the environmental impacts from the combustion test. The scope of this study focused on the performance evaluation and the deterioration of 25 kilowatt diesel generator when using the transformer reuse oil as the fuel, and running the test at 15 kilowatt or 60% of load heater for 200 hours discontinuously. The results of this experiment suggested that the performance of transformer reused oil is better than the diesel fuel at normal wear rate on the engine part due to higher temperature operating condition. The fuel consumption for transformer reused oil was 0.34 liter /kilowatt-hour, while the fuel consumption for diesel fuel was 0.38 liter/kilowatt-hour. Furthermore, the good combustion and no black smoke combustion help preserve the welfare of environment.

Key words: transformer reused oil, diesel generator set, diesel fuel

1. Introduction

Rising price of diesel fuel leads to the increase of living cost and impacts country's economics. One necessary requirement for living is the electricity. The production cost of electricity also depends on the fuel price. At present, the Provincial Electricity Authority (PEA) produces the electricity by using diesel generator, which uses diesel oil as the fuel. Therefore, electricity manufacturing cost is up following the fuel cost at 8-10 baht per kilowatt hour. Unfortunately, PEA still needs to sell the electricity as the normal price which causes some loss to the organization.

For solving this problem, this research aims to study how to reuse the used transformer oil, which needs to throw way after its working period, to substitute for the diesel fuel to run the generator. Currently, PEA has sold the used transformer oil to the private organization at 5 baht per liter for making the house colors. But, if this research is success, it could replace the diesel fuel which cost 30 baht per liter. Furthermore, with 600,000 liters of used transformer oil in PEA's materials store, this could save about 18,000,000 baht per year on the electricity generation cost.

2. Research Methodology

The methodology of this research divides into 3 parts. First of all, a 25 kilowatts diesel generator set (show in figure 1) was selected and run the performance test with transformer reused generator oil as the fuel. The result of the test shows in table 1. The diesel engine was set to run at 60% of load heater at the speed of 1500 rpm. After that, the data acquisition was turned on to record the test result every 30 minutes for 8 hours for 25 days or 200 hours discontinuously in order to evaluate the values of fuel consumption in liter per kilowatt-hour. These results were also compared with the general diesel generator set. Second, the balances of plant of the system were recorded consisting of the exhaust gas temperature, the cooling water temperature and the inlet fuel temperature, as well as the diesel generator's pressure. Atomic Absorption Spectroscopy (AAS) (as show in figure 2) and Dielectric Strength machine (show in figure 3) were used to evaluate the wear rate of the engine based on the change in electric currents at the inlet valve, outlet valve, compression ring, connecting rod bearing after 200 hours running period. Finally, air pollution such as carbon monoxide (CO), hydrocarbon (HC) and black smoke were measured to evaluate the quality of the combustion and confirm that this replacement method is still follow the standard of air pollution for the heavy duty diesel engines level 3 (TIS. 1295-2541) (show in table 2).

Fig.1 25 kilowatts diesel generator set

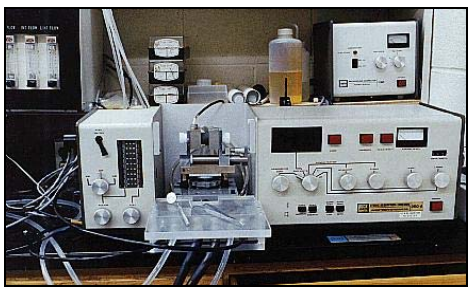

Fig.2 Atomic Absorption Spectroscopy (AAS)

Fig.3 Dielectric Strength Machine

Table 1. Characteristics of diesel generator set [1]

Diesel Generator Set	Details
BRAND	FORD 2711E RANGE
ENGINE	4 CYL.
MODEL NUMBER	2711E
TYPE – OVERHEAD VALVE	DIRECT INJECTION DIESEL
BORE	107mm. (4.22in)
STROKE	115mm. (4.52in)
CAPACITY	4150cc. (254in^3)
MAX. B.H.P. OVERLOAD CONTINUOUS	 71 at 2500 rpm 64 at 2500 rpm
MAX. TORQUE (LBS. FT) OVERLOAD CONTINUOUS	 178 at 1600 rpm 160 at 1600 rpm
COMPRESSION RATIO	1:16
FIRING ORDER	1-3-4-2
VALVE CLEARANCE AT NORMAL WORKING TEMPERATURE	INLET 0.381 mm. (.015 in) EXHAUST 0.305 mm. (.012 in)
LUBRICATION SYSTEM TYPE	PRESSURE FEED BY BI – ROTOR TUPE PUMP
OIL PRESSURE (MIN.)	2.11 kg./sq.cm. (30 lbs./sq.in.) at 1600 rpm.
OIL TEMPERATURE	74°C - 116 °C (165 - 240 °F)

Table 2. EU Emission Standards for HD Diesel Engines, g/kWh (smoke in m^{-1}) [2]

Tier	Date	Test	CO	HC	NOx	PM	Smoke
Euro I	1992, < 85 kW	ECE R-49	4.5	1.1	8.0	0.612	
	1992, > 85 kW		4.5	1.1	8.0	0.36	
Euro II	1996.10		4.0	1.1	7.0	0.25	
	1998.10		4.0	1.1	7.0	0.15	
Euro III	*1999.10, EEVs only*	*ESC & ELR*	*1.5*	*0.25*	*2.0*	*0.02*	*0.15*
	2000.10	ESC & ELR	2.1	0.66	5.0	0.10 0.13[a]	0.8
Euro IV	2005.10		1.5	0.46	3.5	0.02	0.5
Euro V	2008.10		1.5	0.46	2.0	0.02	0.5
Euro VI†	2013.01		1.5	0.13	0.4	0.01	

† Proposal (2008.12.16)
a - for engines of less than 0.75 dm^3 swept volume per cylinder and a rated power speed of more than 3000 min^{-1}

3. Result and Discussion

Prior to the test, the transformer used oil preparation need to be performed. This oil was run through the oil filter machine to screen out any contaminant or large particle. Then, the oil was filled into the tank and prepared for the test, as shown in figure 4. Figure 5 illustrates the bottle of diesel oil, transformer oil, and used transformer oil, consecutively.

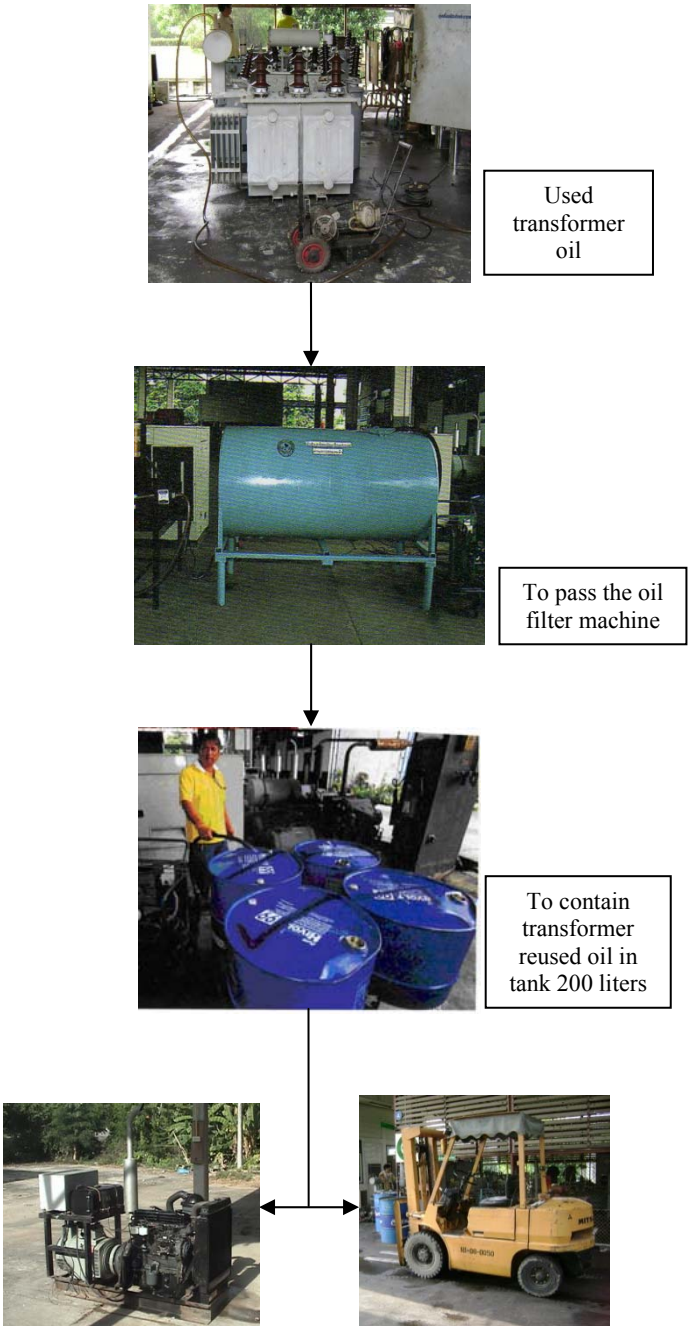

Fig. 4 Preparation process for transformer used oil

Fig. 5 Diesel oil, transformer oil and transformer used oil

After 200 hours test period, the results show that when using the transformer reused oil as fuel, the diesel generator consumes 1,080 liters in order to generate 3,160 kilowatt-hours electricity or about 0.34 liter/kilowatt-hour for fuel consumption. During the period of the test, the diesel engine works normally without overheated. On the other hand, the general diesel generator set consumes about 0.38 liter/kilowatt-hour at the same running condition. According to, if palm oil is used as the fuel for the generator, it will consume about 0.42 liter/kilowatt-hour[3]. Thus, using the transformer reused oil gives capability better than others.

The relationship between the percent of load heater and the rate of fuel consumption of diesel oil and transformer reused oil is show in figure 6. As can be seen from this graph, the rate of fuel consumption of diesel generator is higher than that of transformer reused oil at all the percent of load heater.

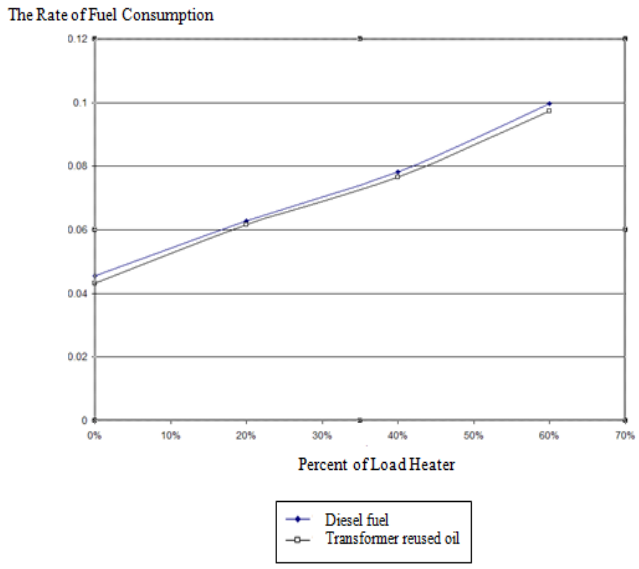

Fig.6 Relationship of fuel consumption and the percent of load heater

Next, the engine parts' deteriorate during test run was observed by photographs, and measurement, which show that the wear rate of the equipments. For example, the measuring of the inlet and exhaust valve is shown in figure 7 and figure 8. Table 3 and 4 illustrate the result of the inlet valve measurement before and after the test run. As can be seen from these tables, the wear rate of the component are insignificant and considered to be normal for the diesel engine operation.

Fig. 7 Inlet valve measurement

Fig. 8 Exhaust valve measurement

Table 3. The results of inlet valve measurement before test run

	Piston no. 1	**Piston no. 2**	**Piston no. 3**	**Piston no. 4**
List of measuring items	IN	IN	IN	IN
1. Valve stem (mm)	9.47	9.47	9.47	9.47
2. Valve guide (mm)	9.52	9.51	9.53	9.53
3. Clearance (mm)	0.05	0.04	0.06	0.06
4. Valve face (mm)	2.00	2.00	2.00	2.00
5. Valve edge (mm)	-	-	-	-
6. Valve seat (mm)	2.10	1.70	2.00	1.90
7. Valve size (mm)	34.70	34.66	34.70	34.66
8. Valve Height (mm)	57.55	58.00	57.55	58.00
9. X-axis of valve size (mm)	45.15	45.08	45.10	45.11
10. Y-axis of valve size (mm)	45.10	45.14	45.09	45.10

Table 4. The results of inlet valve measurement after test run

	Piston no. 1	**Piston no. 2**	**Piston no. 3**	**Piston no. 4**
List of measuring items	IN	IN	IN	IN
1. Valve stem (mm)	9.43	9.43	9.43	9.43
2. Valve guide (mm)	9.46	9.46	9.5	9.5
3. Clearance (mm)	0.03	0.03	0.07	0.07
4. Valve face (mm)	2.00	2.00	2.00	2.00

5. Valve edge (mm)	-	-	-	-
6. Valve seat (mm)	1.75	1.75	1.75	1.75
7. Valve size (mm)	34.70	34.66	34.70	34.66
8. Valve Height (mm)	57.55	58.00	57.55	58.00
9. X-axis of valve size (mm)	45.15	45.08	45.10	45.11
10. Y-axis of valve size (mm)	45.10	45.14	45.09	45.10

The exhaust gas of diesel generator set with transformer reused oil as the fuel were evaluated when the system was run at 0%, 10% , 20%, 30% and 40% of its load. Figure 9 illustrates the result of this test. From this graph, it shows that carbon monoxide (CO) is increasing proportional to the percent of load heater, while nitrogen oxide (NO_x) is disproportional. However, both CO and NO_x generation of the reused oil are still lower than those of general diesel engine combustion. Furthermore, the level of sulfur dioxide (SO_2) has not been detected from the exhaust gas of this reused oil. Therefore, this result encourages the use of this substitute fuel due to the environmental friendly of its running conditions.

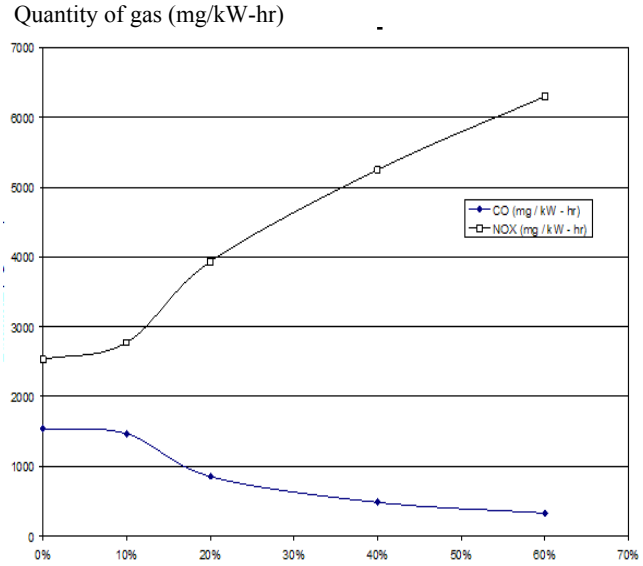

Fig.9 Comparison the quantity of gas with percent of load heater diagram

4. Conclusion

The result of the test run of the transformer reused oil guarantee the same or even better performance of the generator set. The reused oil generator consumes less fuel during the electricity generation without overheated. The wear rate of the mechanical parts inside the generator was normal. Moreover, the exhaust gases of this system contain fewer amounts of carbon monoxide (CO) and nitrogen oxide (NO_x) than diesel fuel usage and have no sulfur dioxide (SO_2) detected. It has no black smoke , which means that the fuel consumption for transformer reused oil has more benefits for the environment following the aims of project.

Even if the transformer reused oil does not affect the performance of the generator set and the wear rate of engine parts is normal, the good preparation of the used oil must be concerned. All contaminant such as poly chlorinated biphenyl (PCB_s) or particle larger than 5 micron must be screen out of the used oil prior to the operation of the generator. The used oil quality should be comparable to the diesel fuel standard that follow American Society for Testing and Materials (ASTM) standard[4].

Acknowledgements

The authors gratefully acknowledge the support from Provincial Electricity Authority (PEA), Petroleum Authority of Thailand (PTT), and the Energy Research Center of Maejo University for their material donation and performance test facilities.

References

[1] Amporn Pakdeechart, (1997). "Diesel Technology". Bangkok: Amerin Printing and Publishing Co. Ltd. (In Thai).

[2] DIESELNET, 2006. Heavy-Duty Diesel Truck and Bus Engines [online]. Available from: http://www.dieselnet.com/standards/eu/hd.php [Accessed 21 July 2009].

[3] Silvio C.A. de Almeida, Carlos Rodrigues Belchior, Marcos V.G. Nascimento, Leonardo dos S.R. Vieira, Guiherme Fleury, (2002). "Performance of a diesel generator fuelled with palm oil" Fuel, pp: 2097 – 2102

[4] Vittaya Yangkon, (2007). "Transformer Reused Oil Quality Exploration". Provincial Electricity Authority Book No. PL.6/2550 LV.25 Apr. 2007, PTT Public Company Limited.