THE USE OF PALM OIL IN DIESEL ENGINE

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Abstract. *A research about the use of palm oil in Diesel generators was carried on and is presented in this paper. The objective was to determinate the engine modifications required to improve its performance, emissions and durability when using palm oil as fuel. In previous research carried on, lubricant oil dilution and deterioration was presented after 100 hours of operation.*

With palm oil (heated to 80 °C), partial combustion and carbon deposits in the injectors was also present after 300 hours of operation. Then several operations variables where investigated as well as modifications on engines installations. A double filtering device was installed before the fuel pump admission. Also a Kit was installed in the diesel engine constituted by a heater using the diesel engine cooling water to re-heat the palm oil to 96 °C.

Those modifications results in ignition delay improvements and better combustion in ASTM CFR Engine, installed in the Thermal Engines Laboratory (LMT). This engine was used in order to investigate the variation of operation parameters using palm oil as fuel and the results were compared to those obtained with diesel oil operation.

The results using turbo generation (higher maximum indicated pressure in the operation) as well as a ignition delay modification, improved performance and emissions in the Diesel generator installed in a isolated village, a improvement in lub oil performance and a lower carbon deposit were also achieved.

***Keywords**: palm oil, diesel engine.*

1. Introduction

Experiment and tests were conducted, in a previous COPPE/CEPEL research, at the Engine Laboratory of CEPEL/ELETROBRAS. A naturally aspirated MWM229 direct injection four-stroke 70 kW diesel generator was selected for the test of performance and durability. It is a type of engine that represents a large population of engines used for electric generation in the Amazon Region.

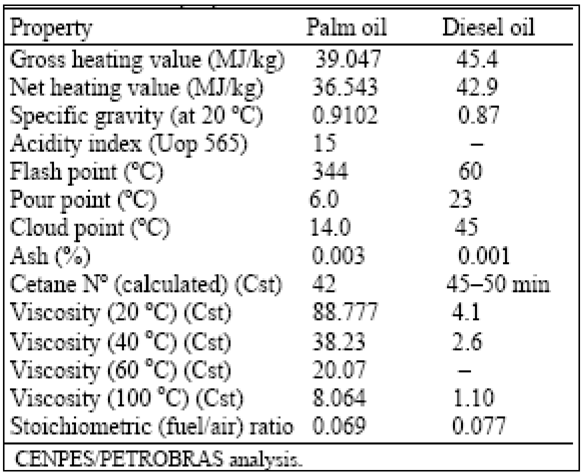
However, a naturally aspirated engine is more sensitive to fuel quality due to the longer ignition delays and lower performance of the injection equipment typical of this engine design. Sensors are installed in the system in order to measure the following parameters: pressure and temperature of lubricant oil; fuel consumption; fuel admission temperature; temperature of cooling water; pressure and temperature of intake air; exhaust gas temperature; ambient temperature (dry bulb); atmospheric pressure and humidity.

The palm oil used was provided in natura oil, but the examination of a sample showed it had a high percentage of oleine. The physical–chemical characteristics of the palm oil to be used on the test were analyzed by CENPES/PETROBRAS, the Brazilian Oil Research Center, and the results are compared to diesel oil characteristics and presented in Table I. ASTM standard procedures were adopted in the analyses. It is possible to note that palm oil presents, when compared to diesel oil:

- Higher density;
- Much higher viscosity;
- Lower heating value;
- Higher flash point

The distillation curves suggest that palm oil could show thermal cracking at temperatures that may be encountered by the fuel spray in naturally aspirated diesel engines. Goetllen *et al.* (1985) present the same conclusions.

Table 1. Palm oil properties



Property	Palm oil	Diesel oil
Gross heating value (MJ/kg)	39.047	45.4
Net heating value (MJ/kg)	36.543	42.9
Specific gravity (at 20 °C)	0.9102	0.87
Acidity index (Uop 565)	15	–
Flash point (°C)	344	60
Pour point (°C)	6.0	23
Cloud point (°C)	14.0	45
Ash (%)	0.003	0.001
Cetane N° (calculated) (Cst)	42	45–50 min
Viscosity (20 °C) (Cst)	88.777	4.1
Viscosity (40 °C) (Cst)	38.23	2.6
Viscosity (60 °C) (Cst)	20.07	–
Viscosity (100 °C) (Cst)	8.064	1.10
Stoichiometric (fuel/air) ratio	0.069	0.077

CENPES/PETROBRAS analysis.

In this previous research, lubrication oil analysis showed reduction in viscosity. The oil dilution was attributed to incomplete combustion caused by the poor atomization and nonvolatility of palm oil. The results indicated that required limits would be reached after 100 h of operation and lubricant oil was changed. For a diesel operation, this change would be done after 200 h. Specific fuel consumption of palm oil is slightly higher than diesel (almost 10% higher at low loads) as showed in Fig. 4. The lower mass based heating values of vegetable oils required higher fuel mass flows to maintain constant energy input to the engine. Also at given injection pump settings, higher densities of vegetable oils caused the observed mass fuel flow to increase (Srivastava, Prasad, 2000). The deposits increase substantially around the injector nozzle inside the cylinder when the oil was heated to 50 ^{o}C in the first 50 hours of operation, but this decreased to acceptable limits after 350 hours of operation with the palm oil heated to 85 ^{o}C.

The minimum CO emissions were obtained with diesel in all level of charge compared with the palm oil. Due to the high viscosity, the air- fuel mixing process is affected by the difficulty in atomization of the palm oil. The HC emissions showed to be lower with diesel, but these emissions of both fuels were lower in partial load, but tended to increase at higher loads. This is due to the lack of oxygen resulting from the operation at higher equivalence ratios. The diesel NOx emissions were higher than palm oil. This is due to the lower combustion temperature of palm oil because of the higher ignition delay of palm oil.

2. Experimental Apparatus

The present research presents the experiments performed at Thermal Engines Laboratory (LMT/UFRJ). An ASTM CFR engine (Waukesha manufactory), with one (1) cylinder, was selected for the study of operational cycle. The engine was tested with standard diesel fuel and also with palm oil as an alternative fuel, with the same characteristic described in Pimentel *et al.* (2000). When tested with palm oil, attending the properties of Tab. 1, the fuel is preheated by an electric heater to the admission temperature of 85 ^{o}C in engine admission (Pimentel, 2002) in order to decrease its viscosity to a value near to the diesel oil at ambient temperature. An electric motor is coupled to the CFR engine in order to start the engine and also provides load variation at constant speed (rpm).

The engine had the standard operation parameters as the following:

- Injection Timing –13 degree before TDC
- Fuel Flow –13 ±0.2 ml/minute
- Ignition delay – 13 degree. The compression ratio to give this delay was 12.36:1.
- RPM: 900 (constant)

For obtaining the performance and emissions data of the engine it was used the following parameters:

- Injection Timing – range –11, 13 and 15 crank angle;
- Fuel Flow – range – 13, 14 and 16 ml/minute;
- Compression ratio range – 11.91:1, 12.36:1 and 13.86:1;

In each operation condition, performance, fuel flow, injection timing, compression ratio and emissions were registered.

The following measurements instruments are provided:

1-Volumetric type flow meter, to measure fuel consumption by the Burette method (ASTM D613);
2- Lubricating oil temperature thermocouple;
3- Admission air temperature thermocouple linked to an electric resistance in order to maintain a constant value of the air temperature;
4- Engine water cooling temperature;

5- Exhaust gas thermocouple;
6- Palm oil admission temperature thermocouple that is also linked to an electric heater in order to maintain a constant value of the oil admission temperature;
7- Admission air pressure sensor;
8- Cylinder pressure transducer;
9- Crankshaft angle measurement device;
10- RPM measurement device;
11- Exhaust gases analyzer;
12- Data acquisition system;
13- Ignition delay meter.

For obtaining the curve of pressure (P) versus crankshaft angle (θ) experimentally, we used the AVL 364 angle encoder, described in Fig. 1.

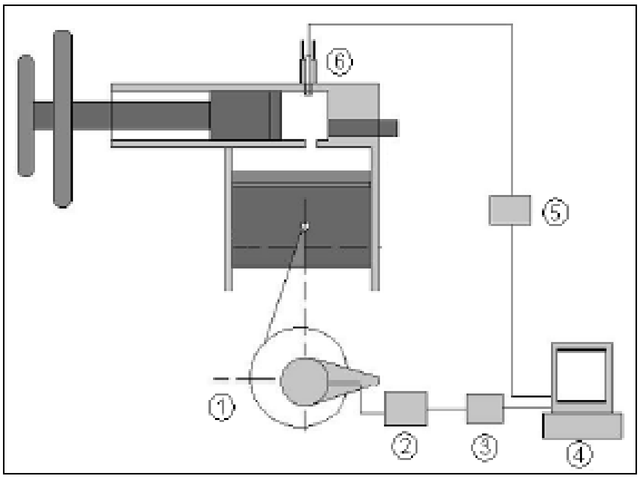


Figure 1. System measurer for the curve pressure vs. the crankshaft angle (P-θ)

In the Fig. 1, we have:
1- Crankshaft angle sensor;
2- Signal converter;
3- Amplifier;
4- Acquisition data;
5- Amplifier;
6- Pressure transducer.

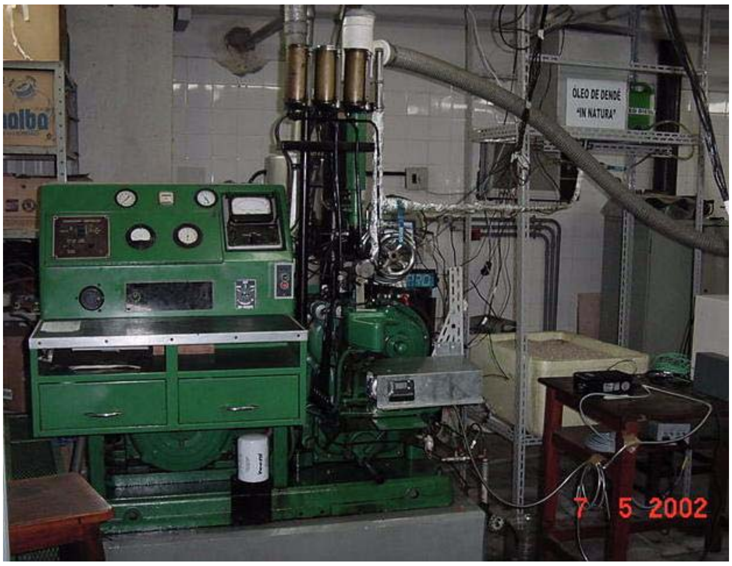


Figure 2. Test device –CFR Cetane Engine

Gaseous emission data included nondispersive infrared (NDIR) analysis of carbon monoxide (CO), carbon dioxide (CO2) and hydrocarbons (HC) and chemiluminescent measurements of NOx and oxygen (O_2). The emissions measurements were done according to specifications and procedures described on SAE Engine Test Code J816b. The device used in the test was a NAPRO model 2010 analyzer.

3- Experimental Test

Experimental test were planned using deviation analysis and reliability techniques in order to fulfill the requirements.

The objective of the test was to achieve the variation of the operational characteristics of the engine, measuring its performance and emissions, when varying one of the parameters defined already (fuel flow, compression rate and engine timing), maintaining the others with constant fixed values.

Then the best performance of the engine with palm oil as fuel is being achieved, especially as function of the compression rate and engine timing, compared to its values operating with diesel oil.

Figure 3 shows the increase in power with compression rate for both fuels, and we can notice that with a compression rate of 12,36 the engine using palm oil presents the same power that it presents using diesel oil, with a compression rate of 11,91.

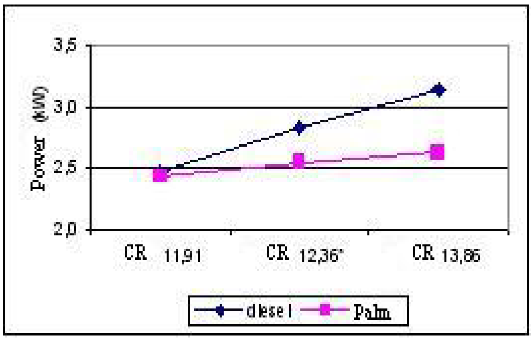


Figure 3.Power vs. Compression Rate (CR)

The specific consumption as function of compression rate for both fuels is presented in Fig. 4.

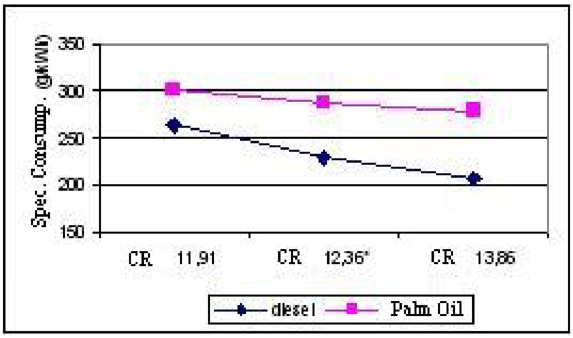


Figure 4. Specific consumption vs. Compression Rate (CR)

The emissions measured in the same load conditions of the test results described in figures 3 and 4, can be observed in the Figs. 5, 6, 7.

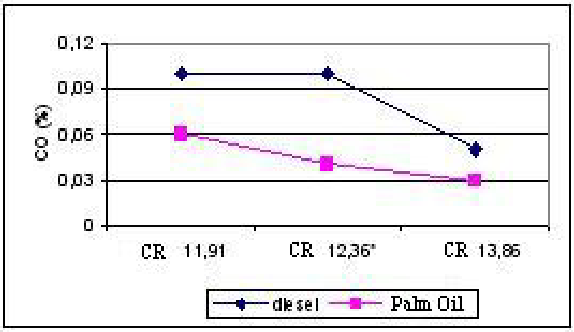


Figure 5.CO emissions vs. Compression Rate (CR)

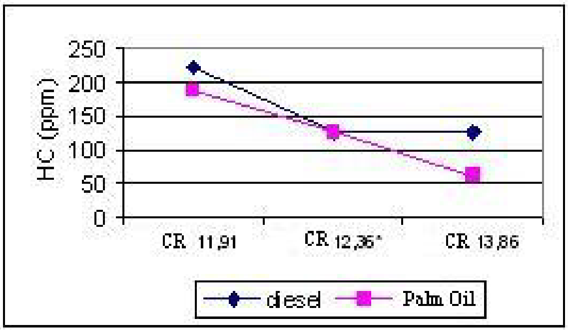


Figure 6.HC emissions vs. Compression Rate (CR)

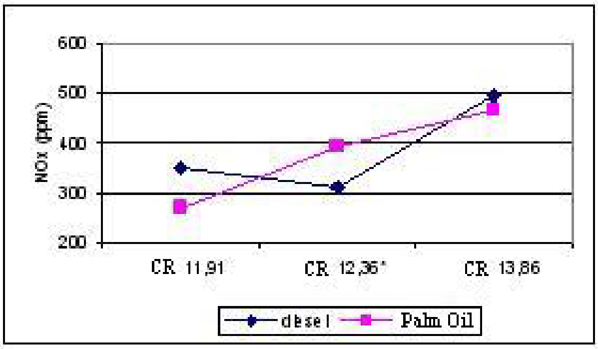


Figure 7.NO_X emissions vs. Compression Rate (CR)

Figure 8 shows the power of the engine as function of the ignition timing. It can, also, be observed that the engine performs a similar power value running with injection advance of 11^o for diesel oil or 13^o for palm oil.

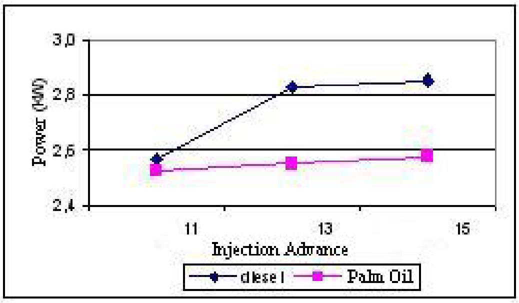


Figure 8.Power vs. Injection Advance (θ)

The specific consumption curves and emissions shows similar results as the observed with compression rate variable (Figs. 9 to 11). It should be noted that when the engine operates with palm oil the CO and HC emissions are lower and NO_X emissions are higher than those values obtained with diesel oil operation.

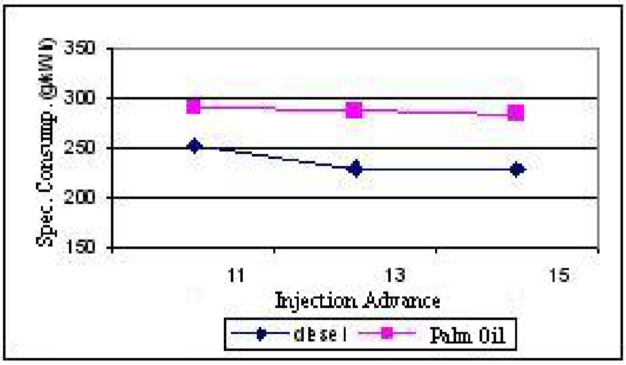


Figure 9. Specific consumption vs. Injection Advance (θ)

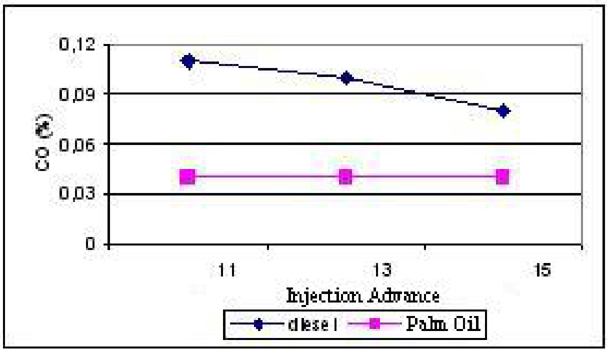


Figure 10. CO emissions vs. Injection Advance (θ)

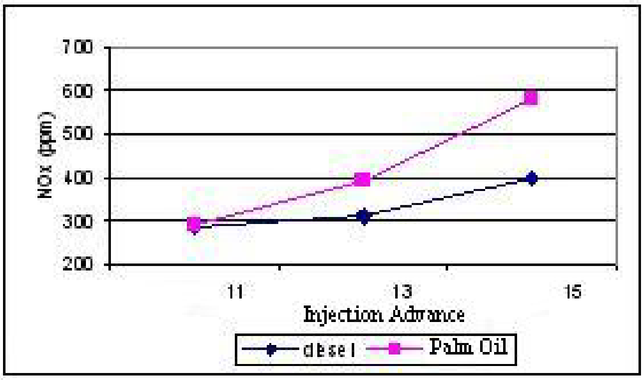


Figure 11. NO_X emissions vs. Injection Advance (θ)

A kit was designed and constructed in order to use the heat of the engine water cooling system to preheat the palm oil in a service tank to 60 °C and after-heater to heat it to 85±5 °C. Figure 12 shows the diagrammatic schedule of the kit.

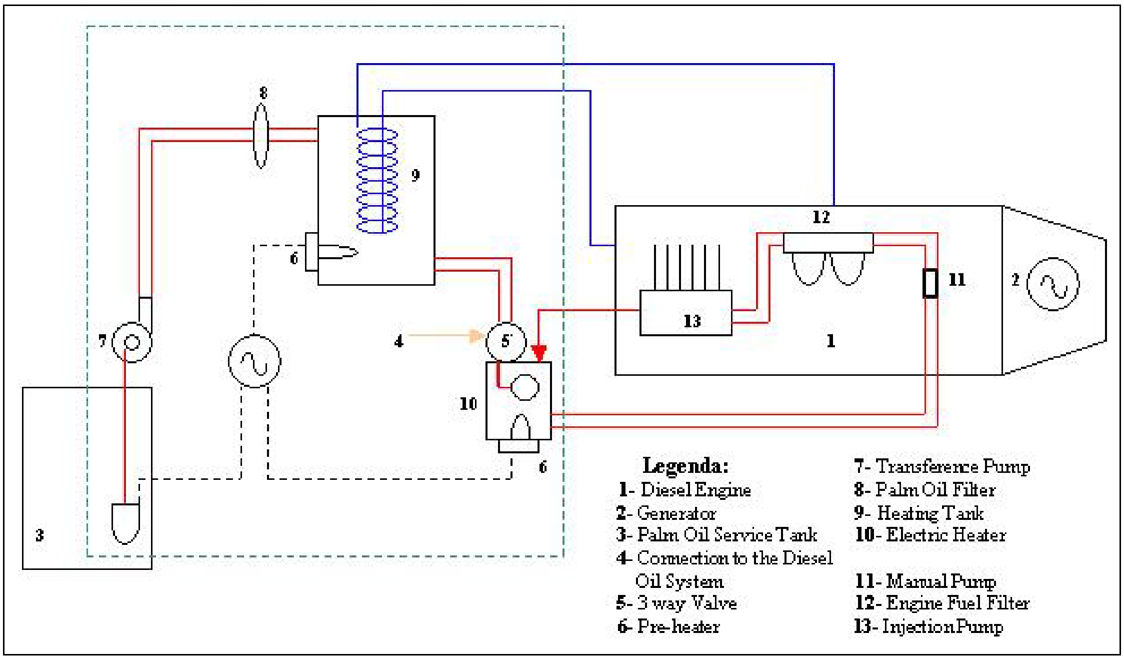


Figure 12. Conversion Device (kit) Diagram

In order to improve the use of palm oil in the diesel engine, several modifications were introduced:

- Addition of a turbo charger, which has a similar effect as increasing compression rate, because it increases the air inlet temperature and pressure, and also, the maximum combustion pressure and temperature;
- Increasing the injection advance of the diesel engine;
- Installing a fuel pre-heating device for the palm oil (Fig.12).

4. Conclusions and Recommendations

The most important contribution of the research is to define the improvements to be installed in order to modify the diesel engine for using palm oil with better performance, emissions and durability. They are defined above, at item 3 of the paper. The use of a CFR engine and a system described at Fig. 1, made possible to obtain the required results.

The installation of this kit in a diesel engine provided with turbo-charge, is presenting already several improvements as the following:

- Better emissions – lower levels of CO, HC and NO_X;
- Less contamination of the lubricating oil, which is being change every 200 hours;
- The injectors can stay in proper use for 800 hours.

5. References

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6. Responsibility notice