DIESEL GENERATOR ADAPTATION FOR THE USE OF PALM OIL FUEL

Valéria Said de Barros Pimentel

Antônio Carlos Rodrigues Belchior

Silvio Carlos Anibal de Almeida

Department of Mechanical Engineering, Federal University of Rio de Janeiro

Ilha do Fundão, CT – sala G-204.Rio de Janeiro, RJ, Brazil. Postal Code 21.945-970.

Telefax 55-21- 2906626; Telephone: 55-21-2808832, E-mail silvio@serv.com.ufrj.br.

Marcos V. G. Nascimento

Leonardo dos S. R. Vieira

Guilherme Fleury

CEPEL/ELETROBRÁS

S17P01

Abstract. *This paper presents several aspects about the use of palm oil as alternate fuel for diesel-generator. Preliminary studies of the state of the art of previous test results analysis are described. It follows the description of palm oil properties and characteristics used in investigation. The apparatus specification and test procedures are also presented. Performance and emissions data acquisition, general results and observation relevant to the diesel fuel are discussed. Lubricant oil contamination and combustion chamber, nozzle deposits formed and fuel pump wear are reported. Finally, conclusions and recommended future engine modifications are also included in the paper.*

Key words: Palm Oil, Combustion, Diesel Engines.

1. INTRODUCTION

Investigation on the use of palm oil as alternative diesel engine fuel dates back several decades. Most of the investigations were done on diesel propulsion engine and very few on stationary diesel engine generator. This paper deals with the use of palm oil as a fuel produced regionally and confined to areas where it could be readily available as in small villages on the several rivers of amazon area and use for electric power generation. It could substitute the diesel oil in those regions where the conventional fuel arrives with high transportation cost. For this reason, CEPEL/ELETROBRAS as the research leader jointed efforts with COPPE/UFRJ and decided to develop the project. The feasibility of these vegetable oils on diesel generators increased in recent days with the higher petroleum fuel prices.

The investigation effort was designed to address the performance, emissions characteristics, components parts wear, combustion chamber deposits and lubricating oil contamination.

The engine design and configuration were selected to represent engines currently in wide use in electrical generation, which are also quite sensitive to fuel quality.

2. OBJECTIVES OF THE PROJECT

Specific objectives are the following:

- The effects of palm oil fuel on diesel performance characteristics as specific consumption, maximum power developed.
- The similar oil effects on gaseous and particle exhaust emissions.
- The increase of maintenance cost due to most severe wear of several engine components.
- The feasibility of palm oil use as diesel alternative fuel on the event of its price increase or severe shortages and availability on isolated villages and regions.

3. STATE OF THE ART

The following conclusions are taken from some previous investigations in Malaysia, German and USA (Pratt, 1981).

- Indirect injection diesel engines with pre-combustion chamber are more suitable for low quality fuels as vegetable oil in general.
- Vegetable oil presents higher values of viscosity than diesel oil at the same temperature with consequent poor atomization in the injections.
- The filtering (3 microns filter) of the oil is necessary.
- It is necessary to use lubricant oil with higher detercency due to the alteration of its required physical specifications and contamination after about 100 hours of engine operation.
- Injectors should be cleaned and tested after 150 hours of operation.
- The constituents of the palm oil react with copper piping existing in the engines when their temperature is over 50^o C.
- The palm oil service tank connected to the fuel piping of the engine must have thermal insulation.
- Using diesel oil to start the engine

Those previous recommendations were take into account in the specifications of the diesel-generator test installation.

4. TEST FUEL PROPERTIES AND CHARACTERISTICS

The palm oil to be tested was produced by a Brazilian palm oil plant and sold as oil *in natura*, but the examination of a sample showed that it had a high percentage of oleine. The physical-chemical characteristics of the palm oil to be used on the test were analysed by

CENPES/PETROBRAS, and the results are compared to diesel oil characteristics and presented on table 1. ASTM standard procedures were adopted in the analyses.

Table 1 – Diesel Palm Oil Test Fuel Properties

	Palm oil	Diesel oil
Gross calorific value (MJ/kg)	39,047	45,4
Net calorific value (MJ/kg)	36,543	42,9
Specific gravity (at 20^o)	0,9102	0,87
Water and sediments (%)	0	trace
Acidity index (Uop 565)	15	—
Flash point (^{o} C)	>344	60
Pour point (^{o} C)	6,0	-3
Cloud point (^{o} C)	14,0	45
Ash (%)	0,003	0,001
Cetane N^o (calculated) (Cst)	42	45 (min) - 50
Viscosity (20^o C) (Cst)	88,777	4,1
Viscosity (40^o C) (Cst)	38,23	2,6
Viscosity (60^o C) (Cst)	20,07	—
Viscosity (100^o C) (Cst)	8,064	1,10
Stoichiometric (Fuel/air) Ratio*	0,069	0,077

CENPES/BR Analysis
*Estimate by (N.J. Barsic and Humke A.L., 1981)

We can note that palm oil presents, when compared to diesel oil:

- Higher density;
- Much higher viscosity;
- Lower calorific value (heating value);
- 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. Guetler presents the same conclusions (Guetler, H.J., 1985).

5. APPARATUS AND PROCEDURE

A naturally aspirated MWM 229 direct injection diesel-generator, maximum continuous power 68 kW was selected for the test. It is a type of engine that represents a large population of engines used for electric generation in the amazon. 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.

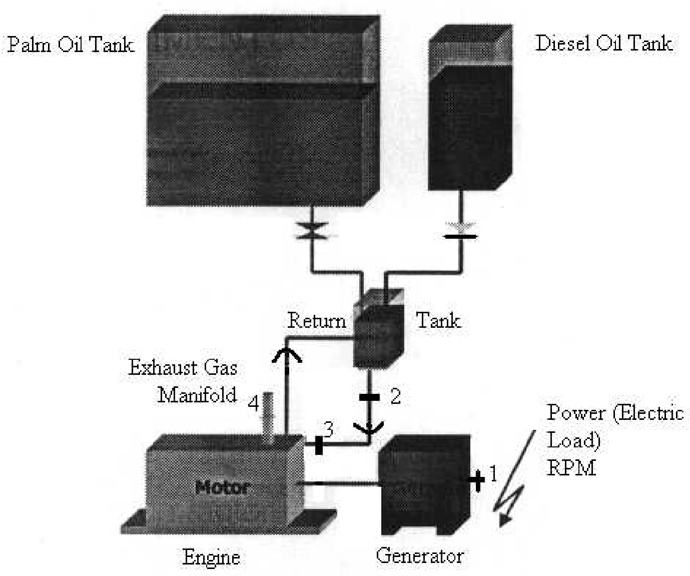

Fig1: Engine Test Apparatus

Legends of figure 1:

1⇒ Power (electric load) measurements

2⇒ Fuel consumption

3⇒ Fuel admission temperatures

4⇒ Exhaust gas emission temperature and sample

Other measurements:

- Pressure and temperature of lubricant oil;
- Temperature of cooling water;
- Pressure and temperature of intake air;
- Ambient temperature (dry bulb), atmospheric pressure and humidity;

A new diesel generator was use in the test in order to present reliable results in the performance and endurance test.

The high viscosity value presented by palm oil and its characteristics to react with certain metals are considered in order to specify the fuel system. The study presented by (Feitosa, V.M., 1998) and the conclusions of the state of the art presented in the item 3 of this paper establishes the requirement to start the engine with diesel oil.

The fuel system was designed and installed in Engine Laboratory of CEPEL. Consisting of two different tanks, one conventional for the diesel oil (used for starting and stopping the engine) and connected to the palm oil tank made of inox steel and supplying the engine by a piping of the same material. Palm oil is heated in an insulated tank up to a temperature of 100^{o} C, in order to decrease its viscosity to a adequate value for a proper atomization on the injection nozzle. Two filters are installed: one at the exit of the tank and other at the fuel pump.

The electric charge generated is absorbed by (4) four water tanks provided with electric resistances, corresponding to the generator electric rated power at 100%, 75%,, 50% and 25%, respectively. The engine test was performed maintaining constant RPM and variation of the electric load applied to the diesel generator, according to its real operation profile.

The engine was tested for performance and endurance on a cycle recommended by the alternate fuels committee of the Engine Manufactures Association (EMA).

The test cycle was repeated twice every day to a total of 350 hours of operation. An acquisition data system was installed consistent of an windows software and a IBM PC-Pentium computer 200 MHz. Gaseous emissions data including measures of CO, CO2, NOx, HC and opacity were measured according to specifications and procedures SAE J816B. Statistical analyses were also adopted and measures of performance were corrected to standard atmospheric conditions (SAE J816B).

Table 2 presents the temperature admission of palm oil during the tests.

Table 2- Palm oil admission temperature

Operation (hours)	Palm Oil Admission Temperature
First 50 hours	50 ^oC
50 to 350 hours	100 ^oC

Gaseous emission data included nondispersive infrared (NDIR) analysis of carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC) and chemiluminescent measurements of NO_X and oxygen (O_2). The emissions measurements was done according to specifications and procedures described in SAE Engine Test Code, J816b. The equipment used was a NAPRO model 2010 analyzer. Opacity was measured with partial flow type meter.

6. ENGINE PERFORMANCE RESULTS

Engine performance and emissions were influenced by basic differences between diesel fuel and palm oils such as mass based heating values, viscosity, density and molecular oxygen content.

Fuel flow rate. The lower mass based heating value of palm oil requires larger mass fuel flow to maintain constant energy input to the engine.

Palm oil viscosity, even after heating the oil, is high and contributes to increased fuel flows by reducing internal pump leakage.

At the constant injection pump calibration for diesel fuel, fuel flow rate to the injection nozzle on a mass basis increased with palm oil when compared to using diesel oil. Also the specific fuel consumption are higher using palm oil.

Figure 2 presents the specific fuel consumption as a function of rated power and thermal efficiency for two different temperatures of the palm oil (50 ^oC and 100 ^oC).

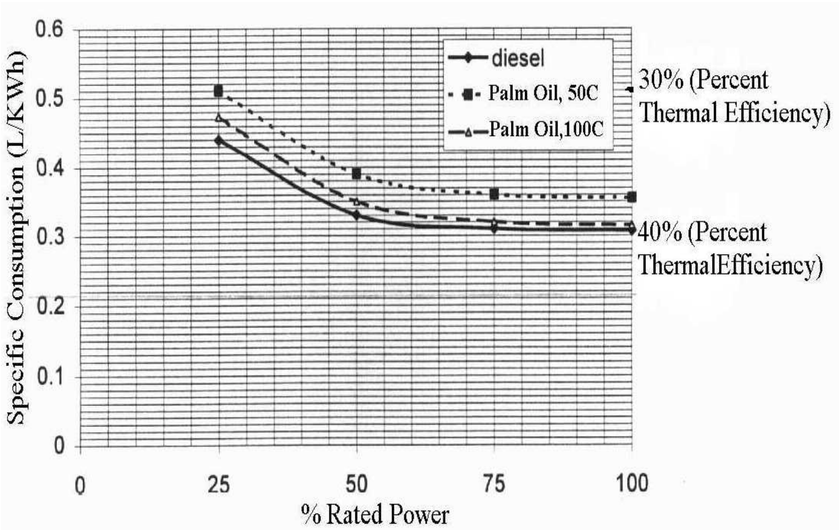

Figure 2 – Specific Fuel Consumption As Function Of Rated Power

Exhaust temperature. Increases in exhaust temperature are also indicative of lower engine performance, because of the lower release rate and retarded heat release associated with lower thermal efficiency contribute to higher exhaust temperatures. Figure 3 shows the exhaust temperature versus rated power.

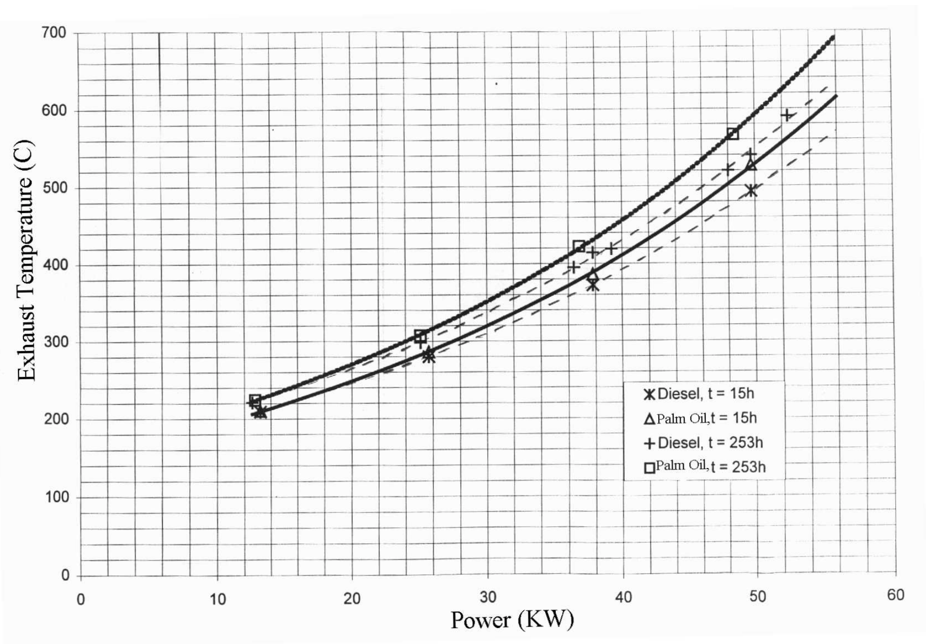

Figure 3 – Exhaust Temperature As Function Of Rated Power

7. ENDURANCE TEST

The specific fuel consumption and the exhaust temperature increased along the operation hours of the diesel engine, but decreased always just after the injectors were cleaned for carbon deposits accumulations and had its opening pressure checked and regulated. This was done at 50, 120, 160, 220 and 350 hours of operation, when the specific fuel consumption increased 5%.

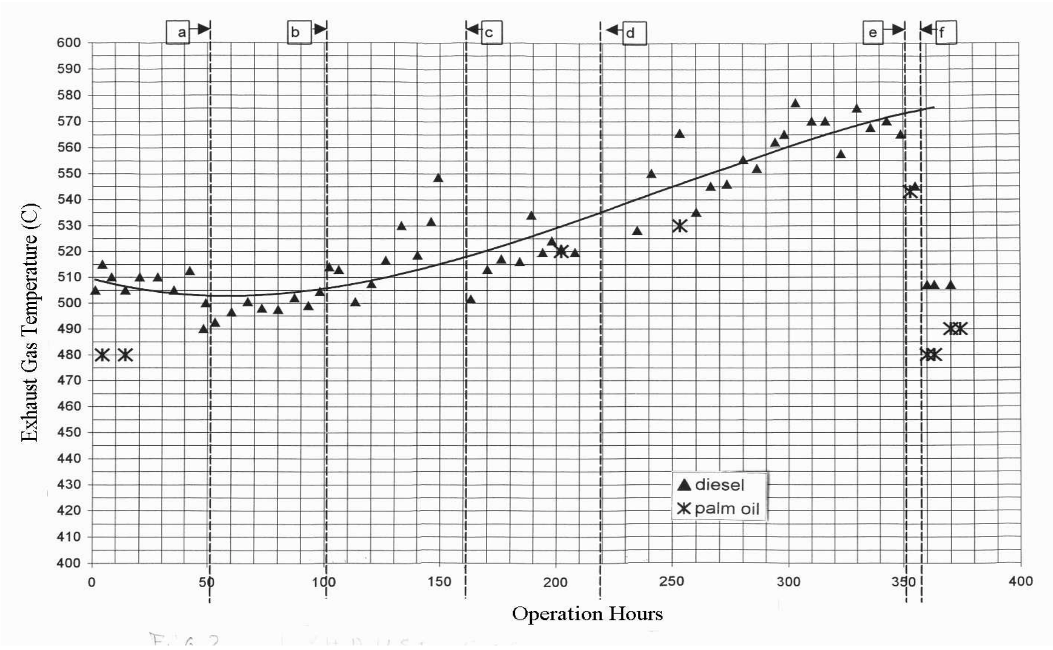

Figure 4 - Exhaust Temperature versus Engine Operation Hours

Figure 4 presents the exhaust temperature as a function of engine operating hours

The Bosh fuel injection pump was also visually inspected at the same time. In the case of any abnormality the pumps were sent to FA-Diesel S.A. for expert analysis and overall.

The exhaust gas temperature also presented variations when the injection system was inspected due to improper performance of diesel engine.

It was performed a periodic sampling of the engine lubricant oil followed by a laboratory analysis of its condition (degradation and contamination). Table 3 shows the results of oil analysis.

Table 3 – Oil Analysis

Property	New oil	After 50 h	After 100 h	Required Limit
Viscosity (40 ^{o}C – cst)	110,6	80,83	74,10	70
Viscosity (100 ^{o}C – cst)	15,22	12,25	11,87	11
Viscosity Index (cst)	144	148	156	—
Flash Point (^{o}C)	228	228	230	200
Total Base Number (mgHOH/g)	13,5	12,9	9,7	9,0
Pentane Insolubles (%P)	—	0,19	0,20	—

The results indicated that required limits would be reached in a few hours of operation and lubricant oil was changed. When operated with diesel oil this change would be done at 200 hours of operation.

Fuel filter. Palm oil filter had to be changed every 100 hours of operation, because they was clogged. When allowing palm oil to separate in the storage tank and conducting to the engine only to the portion, the filter life could be extended to acceptable limits.

Cylinders Deposits. Figures 5 shows the aspect of the cylinder head of the diesel engine operating with palm oil compared to operation with diesel oil. The deposits increased substantially around the injector nozzle inside the cylinder when the engine operated with palm oil heated to 50 ^{o}C in the first 50 hours, compared to operation with diesel oil.

This occurrence is due to the incomplete combustion, inadequate atomization and higher ignition delay presented by the palm oil (heated at 50 ^{o}C). When heated at 100 ^{o}C the oil presented better combustion, deposits and acceptable limits after 350 hours of operation.

The deposits measured in other regions of the cylinder head presented as well, high levels when the engine operated with palm oil heated at 50 ^{o}C and acceptable levels when heated at 100 ^{o}C (almost similar to operation to operation with diesel oil). This is due to the lower viscosity presented by the palm oil heated to 100 ^{o}C and better atomization and combustion.

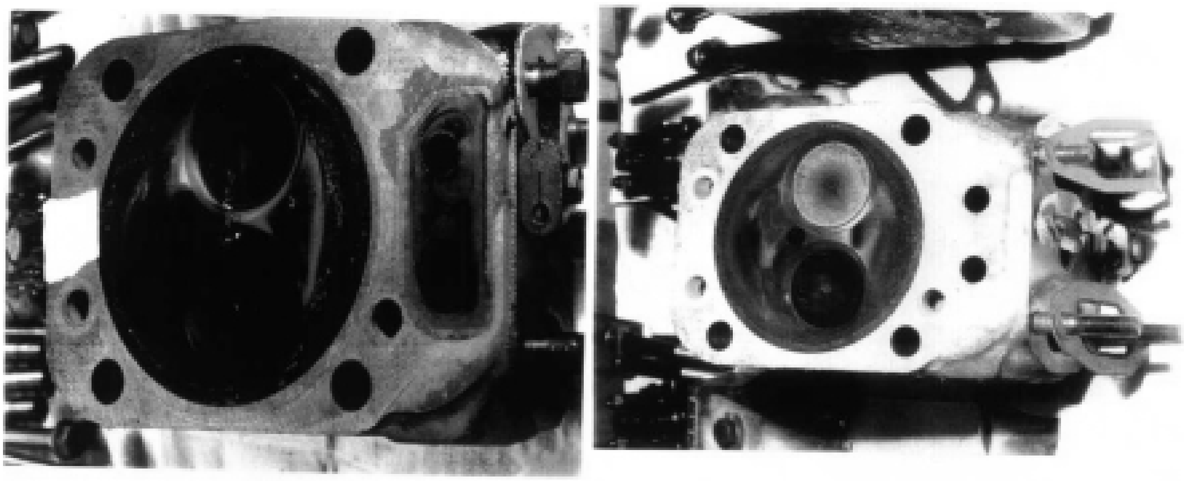

Figure 5 - Cylinder Head And Deposits In Valves In A Diesel Engine Operating With Palm Oil

Exhaust gas emissions. Figure 6 shows the exhaust gas emissions analysis at the beginning of the test and after 350 hours of operation (before and after cleaning the injector) with the engine operating with palm oil and diesel oil. In the last condition we can state the following:

- -oxides of nitrogen are only slightly lower;
- -unburned hydrocarbon (HC) and carbon monoxide (CO) are much lower in partial power and almost the same in rated power. This is due to the poor fuel spray produced in the injector with higher viscous palm oil.
- -O2 and CO2 emissions are almost the same when operating with diesel fuel
- -opacity emissions are higher with palm oil, as expected due to incomplete combustion.
- NO_X emissions are lower with engine operation with palm oil due to incomplete combustion and lower maximum combustion temperatures.

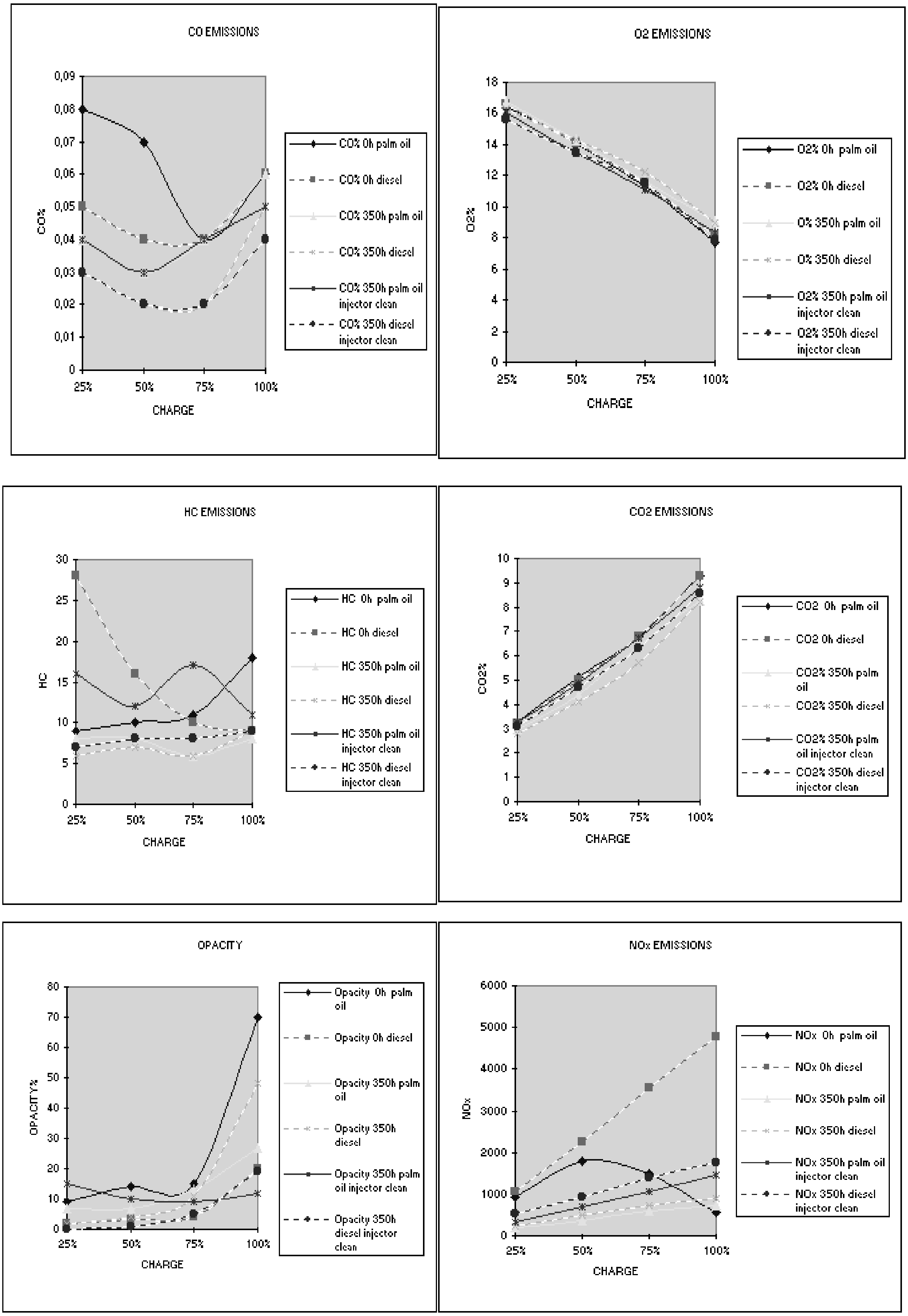

Figure 6- Emissions In A Diesel Engine Operating With Palm Oil

8. CONCLUSIONS AND RECOMMENDATIONS

Increasing the palm oil temperature the performance and endurance of the diesel generator increases compared to operation in ambient conditions and also the emissions and endurance. However, other engine modifications are required to improve lubricating oil degradation, performance, emissions and reach a more efficient combustion. We present the following recommendations:

–Increasing injection fuel pressure;

– Installing a turbo-charger in diesel engine in order to increase the temperature and pressure inside the cylinders;

–Using special lubricants with convenient additives;

– Adapt the injecting system to the particular use.

REFERENCES

Baisic, N.J. & Humble, A.L.,1981, "Performance and Emissions Characteristics of a Naturaly Aspirated Diesel Engine whith Vegetable Oil Fuels" SAE - Technical Paper Series nº 810262. Society of Automotive Engineers.

Engine Test Code, 1978, "Spark Ignition and Diesel " SAE J816b – SAE Handbook.

Feitosa, E.T., ENCIT 98, "Determinação da Fração de Combustível em Motores de Combustão Interna".

Goetllen, H.Z., Ziejewski, M., Kaufman, K.R., and Pratt, G.L.,1985, "Fuel Injection Anomalies Observed During Long-Burn Engine Performance Test on Alternate Fuels", SAE Technical Paper Series nº 852089. Society os Automotive Engineers, Iulsa, Oklahoma.

Pratt, G., 1981, "Sunflower oil for Fuel"- North Dakota University "Seminar On Vegetable Oil as Diesel Fuel", Northern Agricultural Energy Center, Peoria, IL, USA