ANALYSIS OF BIODIESEL TYPE AND CONTAMINATION LEVEL ON LUBRICANT PROPERTIES OF DIESEL STATIONARY ENGINEES.

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Abstract. *The lubricant analysis is a tool with many applications in industry, which allows detecting faults in machinery or equipment before they cause a system fault or breakdown. This work uses the oil analysis technique in diesel cycle engines that use blends of biodiesel as fuel. For that purpose it was used three stationary cycle diesel engines with power of 10 HP each one. One of the diesel engines was powered with commercial-type diesel, with a regulated mixture of 3% of biodiesel by volume; other with B100 pure biodiesel of animal origin and a third one with B100 biodiesel of vegetal origin added with animal origin. Oil samples were collected every 40 hours of test on each of the engines. Subsequently, these tests were repeated by contaminating the lubricant with 1%, 2% and 3% percents of fuel, simulating real cases in each of the engines. Laboratory analysis of samples were compared to each other to observe the influence of biodiesel type and contamination percentage on the lubricant properties (viscosity and magnetic particles quantities). In addition to these tests the analytical ferrography and fuel consumption were observed and discussed for each situation*

Keywords*: biodiesel, oil analysis, ferrography, predictive maintenance*

1. INTRODUCTION

Maintenance is defined according to ABNT (Brazilian Technical Standards Association) as being, actions for which an item is maintained in order to remain in accordance with a specified condition. Furthermore, it is divided into corrective and preventive maintenance.

The approach of corrective maintenance is based on the correction of a failure or breakdown of equipment, in other words, a technique that is designed to repair a damage. This is a technique that requires a high stock of spare parts, which makes its implementation difficult to be done

Preventive maintenance consists of a series of actions or guidelines that can stop or minimize the need for corrective maintenance.

Predictive maintenance is the monitoring or periodic monitoring of performance and / or deterioration of machines parts. The purpose is to do maintenance only when it is needed or if it is needed. (Viana,1991).

Mirshawka (1993) defines predictive maintenance as a "maintenance based on knowledge of state / condition of an item, through continuous or periodic measurements of one or more significant parameters. The intervention of predictive maintenance quest for early detection of symptoms that precede an malfunction.

Between the monitoring techniques used in predictive maintenance it can be mentionated:

– Analysis of vibration of rotating and alternative equipment;
– Analysis of current and magnetic flux in electric motors;
– Analysis of lubricating oil (tribology and ferrography);
– Thermography for electrical and mechanical systems;
– Ultrasound for detection of leaks and defects in valves and blowing out.

Among advantages of predictive maintenance it can emphasized:

– Identifying equipment with chronic problems and offer solution patches
– Avoid premature elimination of components exchange with remaining useful life still significant.
– Increase the useful life of machinery and components for the improvement of installation and operation.

The disadvantages are found in the predictive maintenance inspection, through specific monitoring tools, which also requires specialist to conduct the service.

With the wide deployment of biodiesel, it becomes necessary to study its effect on internal combustion engines. An improperly lubricated engine may suffer from excessive heat, wear and noise, and will often fail if the issue is not resolved. Upon adding a lubricating fluid to an engine, the very operation of that engine begins to impact the functionality of the oil. An example of this is the degradation of lubricating oil by the presence of fuel contaminants such as biodiesel.

This work addresses the technical analysis of lubricating oil in internal combustion engines, operating with biodiesel, and seeks to evaluate the biodiesel influences on the lubricating properties of these engines through predictive maintenance technique.

2. BIODIESEL

Biodiesel is chemically known as ethyl or methyl ester of fatty acids, depending on the alcohol used.

The definition adopted for Biodiesel in Law N^o. 11097 of 13 September 2005, introduced in the Brazilian energy matrix is:

"Biofuels is a fluid derived from renewable biomass for use in internal combustion engines with compression ignition, or regulated as to generate other types of energy, which can partially or fully replace fossil fuels."

In Brazil, the National Petroleum Agency (ANP), through Order N^o 255/2003 defines biodiesel as a fuel composed of monoalquilésteres of long chain fatty acids, derived from vegetable oils or animal fats.

The new fuel can be mixed with diesel, in any proportion, or can be used in its pure form. Its use can be applicable in a large scale with some adaptation. One can mention small thermoelectric power plants, in very distant locations from the commercial circuits, which consume large volumes of fuel where the pure biodiesel can be applied.

Since this type of fuel is clean, it brings great benefit to the environment. The emission of CO_2, one of the main reasons of the greenhouse effect, is reduced by 7% in using B5 (5% biodiesel and 95% of Diesel), 9% in using B20 and 46% in the case of using pure Biodiesel

Emissions of soot and particulate materials are reduced by up to 68% with the use of biodiesel, and there is a decline of 36% of unburnt hydrocarbons. Also there is an extremely significant reduction in sulfur gases that cause of acid rain, that is, 17% for B5, 25% for B20 and 100% for pure biodiesel, since, unlike the diesel oil, biodiesel does not contains sulfur. (MB OF BRAZIL, 2008).

In relation to the economic advantages one can cite the reduction of oil refined diesel imports. According to Brazilian Ministry of Mines and Energy, Brazil spent US $ 4,9 billion with diesel import in 2008 and the use of biodiesel in Brazil prevented the importation of 1.1 billion liters of diesel, creating a domestic economy of $ 976 million in 2008.

3. LUBRICATING ANALYSIS

The first lubricating oil analysis were made around 1940 by the railway company Western United States during the aquisition of a new fleet diesel trains. Following the success of the lubricant analysis ,the American Navy used the technique of spectrography in the jet engines of their aircraft in 1950, which was also used experimentally by the turbine manufacturer Rolls-Royce at the same time. The technique was widespread and refined by the U.S. army and air force at the end 50s and the early 60th.

The oils analysis identify the symptoms of wear in a component, by amount of particles, size, shape and composition, providing precise information on the conditions of surfaces in motion (Barraclough *et al,* 1999) (Anderson *et al* 1999).

3.1. **Ferrography**

There are two types of ferrography, the direct reading ferrography and the analytical ferrography

The direct reading ferrography consists of a quantitative measurement of the particle concentration in a fluid through the precipitation of this particle in a glass tube under a strong magnetic field. Two rays of transported light by optical fiber shock inside the tube in two positions that correspond to the big and small particles position that were deposited by the magnetic field. The light is reduced in relation to the deposited particle inside the glass tube and that reduction is electronically monitored and measured (Malpica, 2007)

Two reading set are obtained (particle bigger than 5 microns and particle smaller than 7 microns). Generally more than 20.000 particle bigger than 7 microns indicate an alert and particle beyond 40.000 indicate problems in machine ferrous components (Rueda, 2005). Figure 1 illustrates a directing reading ferroscopy.

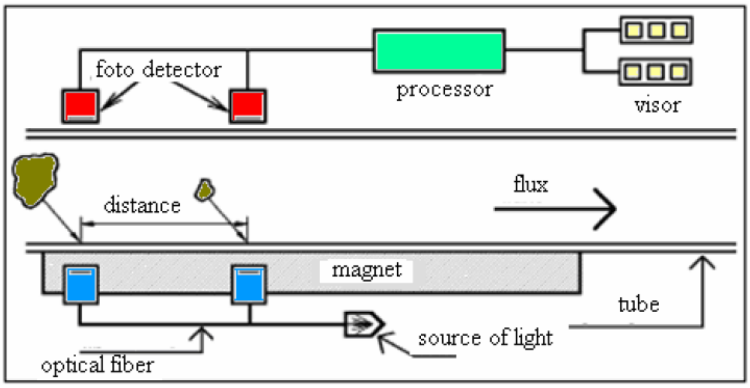

Figure 1 - Direct reading ferrography schematic apparatus

The particle number has a code corresponding to a norm ISO 4406, or others norms, for lubricant analysis. The code is a number that goes from 1 to 24. The lubricant maker recommends the amount of wear particle according to these numbers.

Table 1- Recommended values by norm ISO 4406

Code	Particle	
	from	to
24	80.000	160.000
23	40.000	80.000
.	.	.
.	.	.
2	0,02	0,04
1	0,01	0,02

The analytical ferrography is the magnetic particle separation that is found in the lubricant. A slid rests in a magnet that attracts the ferrous particles and allows the adhesion of this particle to the slid.

The prepared slid at this away it is named ferrogram. The ferrogram is than ready to optical inspection through a bichromatic microscope.

3.2. **Viscosity**

Viscosity is a fluid property corresponding to microscope transportation of movement by molecular diffusion. That is to say, as larger the viscosity, smaller the speed of the fluid movement. It is defined by viscosity Newton's law:

$$\tau = \mu \frac{\partial u}{\partial y} \tag{1}$$

Where μ is the viscosity coefficient, viscosity or dynamic viscosity and du/dy is the derived of speed in function to the fluid height.

Many fluids, as water or most of gases, satisfy the Newton's law and so they are known as Newton's fluids. The non Newton's fluid has a more complex and non linear behavior.

Viscosity can be understood as the measurement of the resistance of a fluid to the deformation caused by a torque. It is commonly noticed as the "oil Thickness", or the leakage resistance. So, water is "thin" having a low viscosity, while vegetable oil is "thicker", having high viscosity.

4. MATERIALS AND METHODS

For this work it was used 3 Diesel engines of the Toyama brand with 10 HP each one. The characteristics of the engines are in Tab.2. The engines were nominated M1, M2 and M3, where M1 was supplied with pure Biodiesel B100 of animal origin, M2 was supplied with commercial Diesel B3 and M3 with Biodiesel B100 of vegetable origin mixed with animal (90% vegetable and 10% animal).

Table 2 - Engine specification

Max potency	10 HP
Nominal potency	9 HP
Cylinder capacity	406 cc
Max RPM	3600 rpm
Compression ratio	23:1

Figure 2 - Motor used in tests

In agreement with the manufacturer's recommendations the engines worked for 20 hours in a rotation measured of 2500 rpm with the lubricant specified in Tab 3. That was the run in period. The rotation was monitored with a tachometer of Oppama brand, PET-2000 DX model.

In the effective period of the tests the engines were used in a controlled rotation of 3000 rpm and operating in that first phase without any equipment coupled in the engines. Every 40 hours of operation the lubricant was collected and changed. To simulate a contamination for fuel, the lubricant in each engine was contaminated, to each test, with percentages of 1, 2 and 3% of the fuel used by each one.

Table 3 shows the lubricant specification used in tests

Table 3 – Lubricant specifications

Brand	Petrobrás
Model	Lubrax Md 400
SAE	40
API	CF
Flash point [°C]	262
Pour test [°C]	-6
Viscosity (40 °C)[cSt]	163,5
Viscosity (100 °C)[cSt]	15,46
Viscosity index	95

In oil analysis several equipment were used, as rotary particle separator, automatic particle quantifier, rheometer and optical microscope.

The oil samples were put in the rotary particle depositor – RPD and than analyzed in a Neophot 21.

The RPD separates the particles into three concentric rings, depending on the wear particle size.

Utilizing the automatic particle quantifier the PQ index (an index that represents the magnetic particles inside the oil) in 2 ml of oil was obtained.

The viscosity was obtained with a small lubricant sample that was deposited in the cylindrical spindle of the Brookfield reomether, equipment coupled with thermal bath and control software.

The Figure 3 shows the equipments used to perform the analysis.

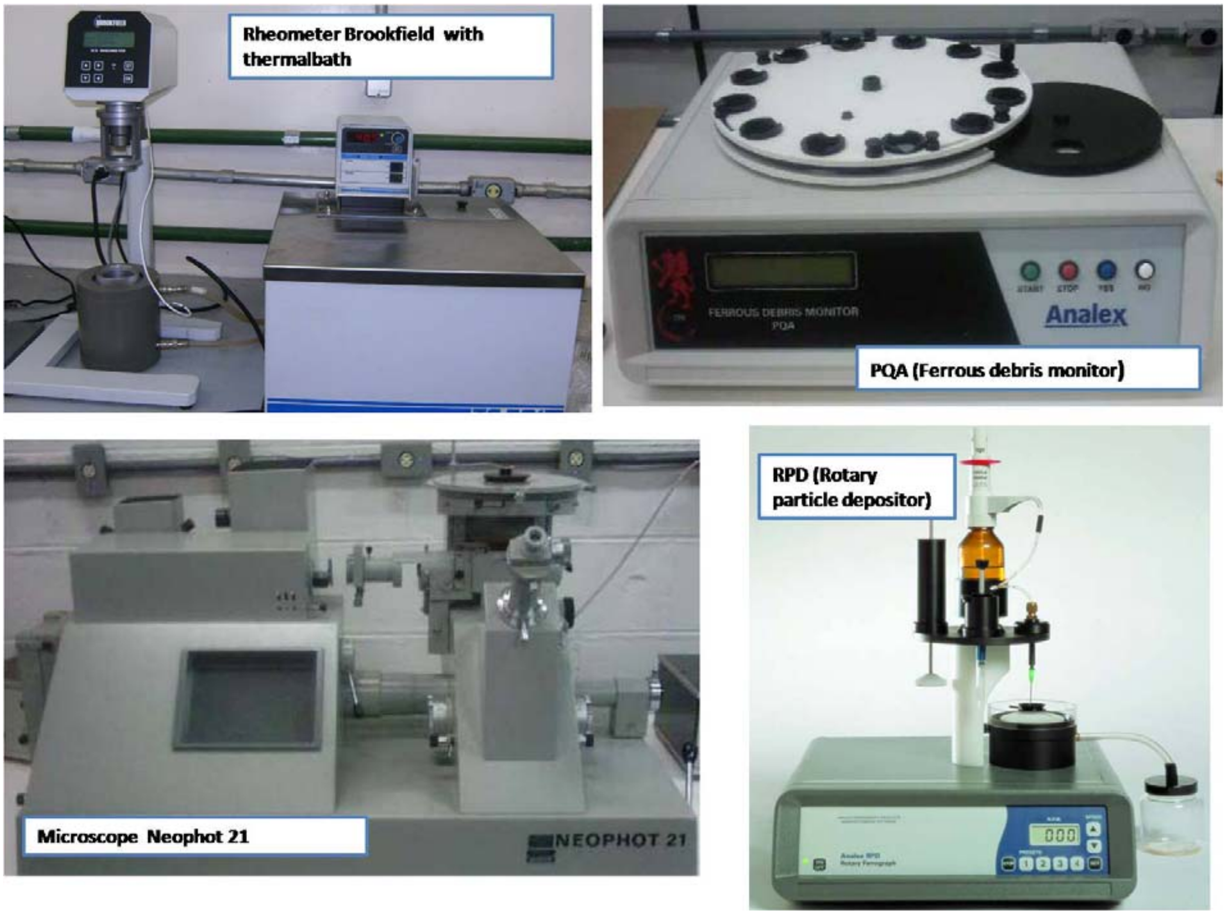

Figure 3 - measuring equipment used in tests

5. RESULTS AND DISCUSSION

5.1. Motor M1

The Figure 4 was obtained in the RPD tests and photographed in reflected light microscope. Table 4 shows others results for this engine.

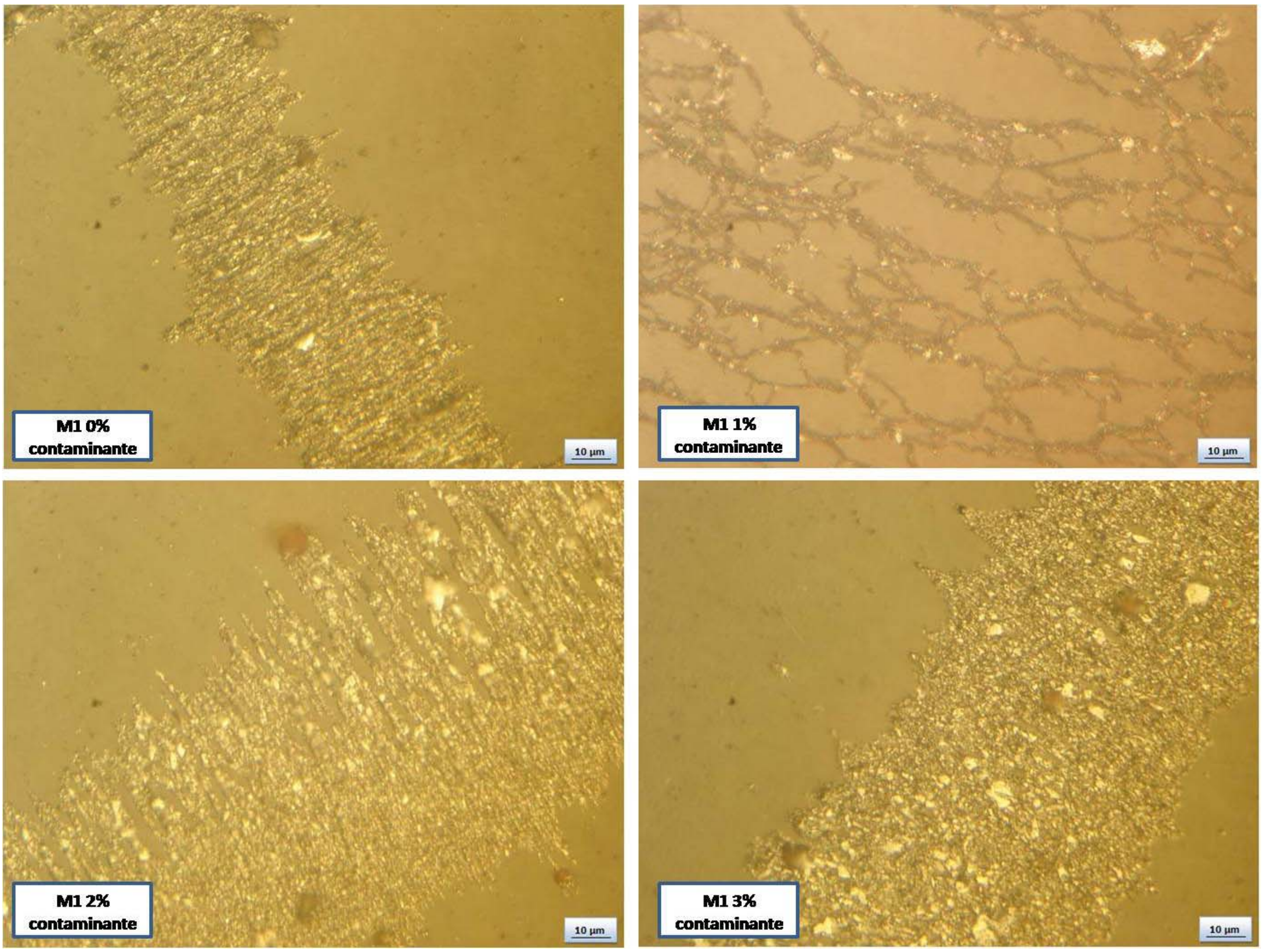

Figure 4 – Wear insides motor M1, contaminated with 1, 2 e 3% (animal biodiesel), pictures of the internal ring with increase of 500x

Comparing the four pictures it can be noticed that size of the found wear particles does not indicate abnormal wear and tear in the engine.

Table 4 - Values of tests in SAE 40 API CF used oil from motor M1

Sample	Viscosity 40 ^{0}C (cSt)	PQ index (new/used)
M1 0%	180,80	12/15
M1 1%	167,41	12/16
M1 2%	151,78	12/18
M1 3%	140,62	12/21

The behavior of the viscosities obtained in the engine is demonstrated according Figure 5.

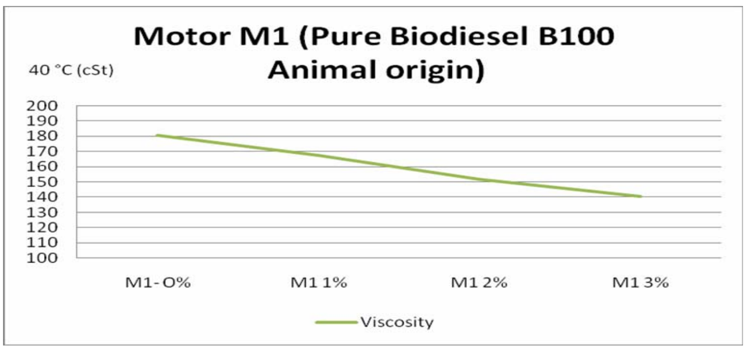

Figure 5 - Behavior of the lubricant viscosity of motor M1, with contaminant levels of 1, 2 and 3%, measured to 40°C

5.2. Motor M2

The Figure 6 was obtained in the RPD tests and photographed in reflected light microscope. Table 5 shows others results for this engine

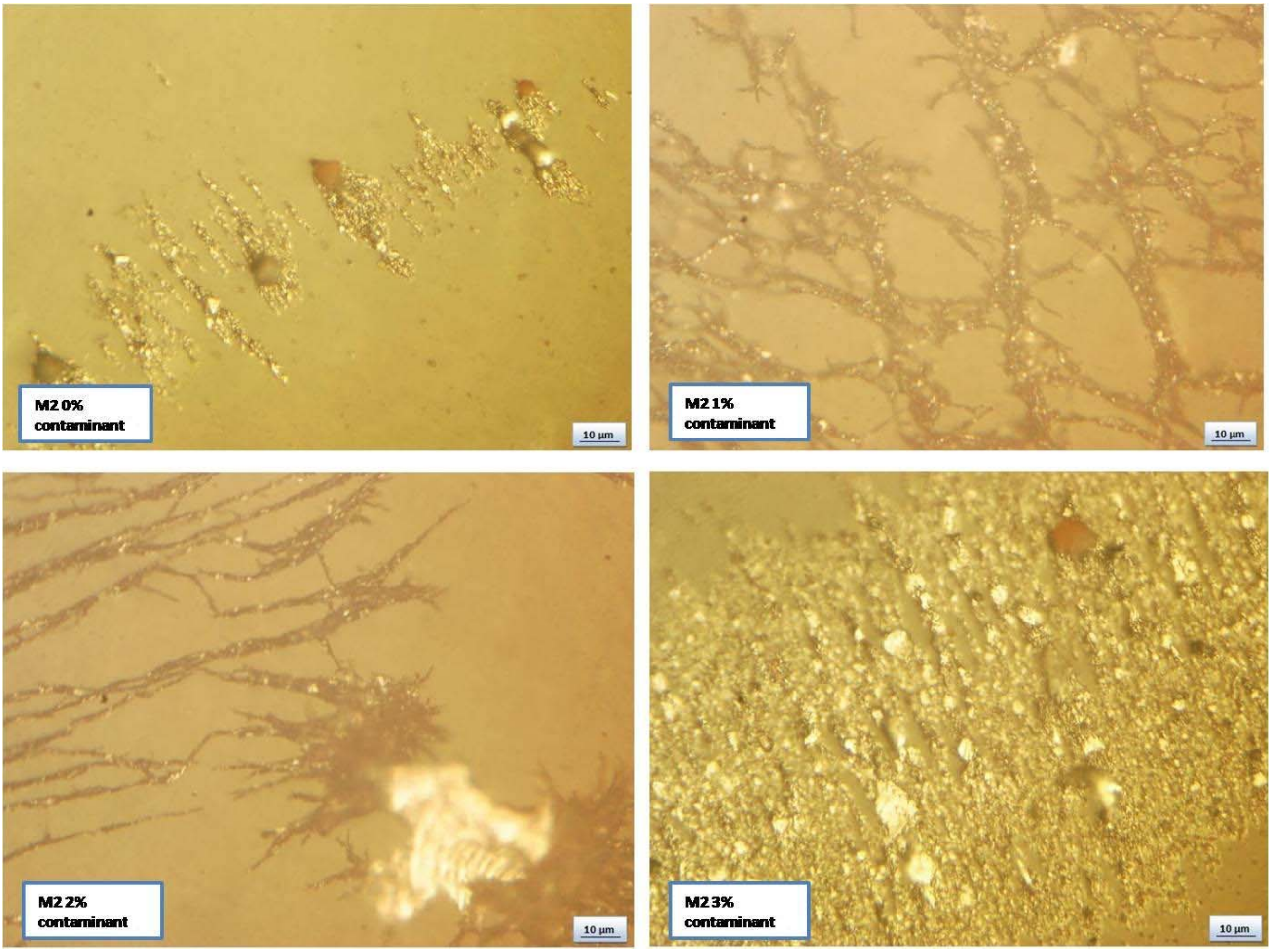

Figure 6 - Wear insides motor M2, contaminated with 1, 2 e 3% (diesel B3), pictures of the internal ring with increase of 500x

Comparing the four pictures it can be noticed that size of the found wear particles also does not indicate abnormal wear and tear in the engine

Table 5 - Values of tests in SAE 40 API CF used oil from motor M2

Sample	Viscosity 40 ^{0}C (cSt)	PQ index (new/used)
M2 0%	185,27	12/26
M2 1%	175,22	12/30
M2 2%	165,18	12/27
M2 3%	150,67	12/24

The behavior of the viscosities obtained in the motor is demonstrated according Figure 7.

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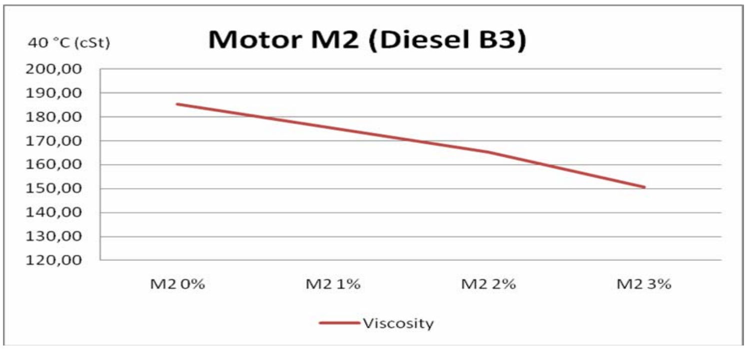

Figure 7 - Behavior of the lubricant viscosity of motor M2, with contaminant levels of 1, 2 and 3%, measured to 40°C

5.3 Motor M3

The Figure 8 was obtained in the RPD tests and photographed in reflected light microscope. Table 6 shows others results for this engine

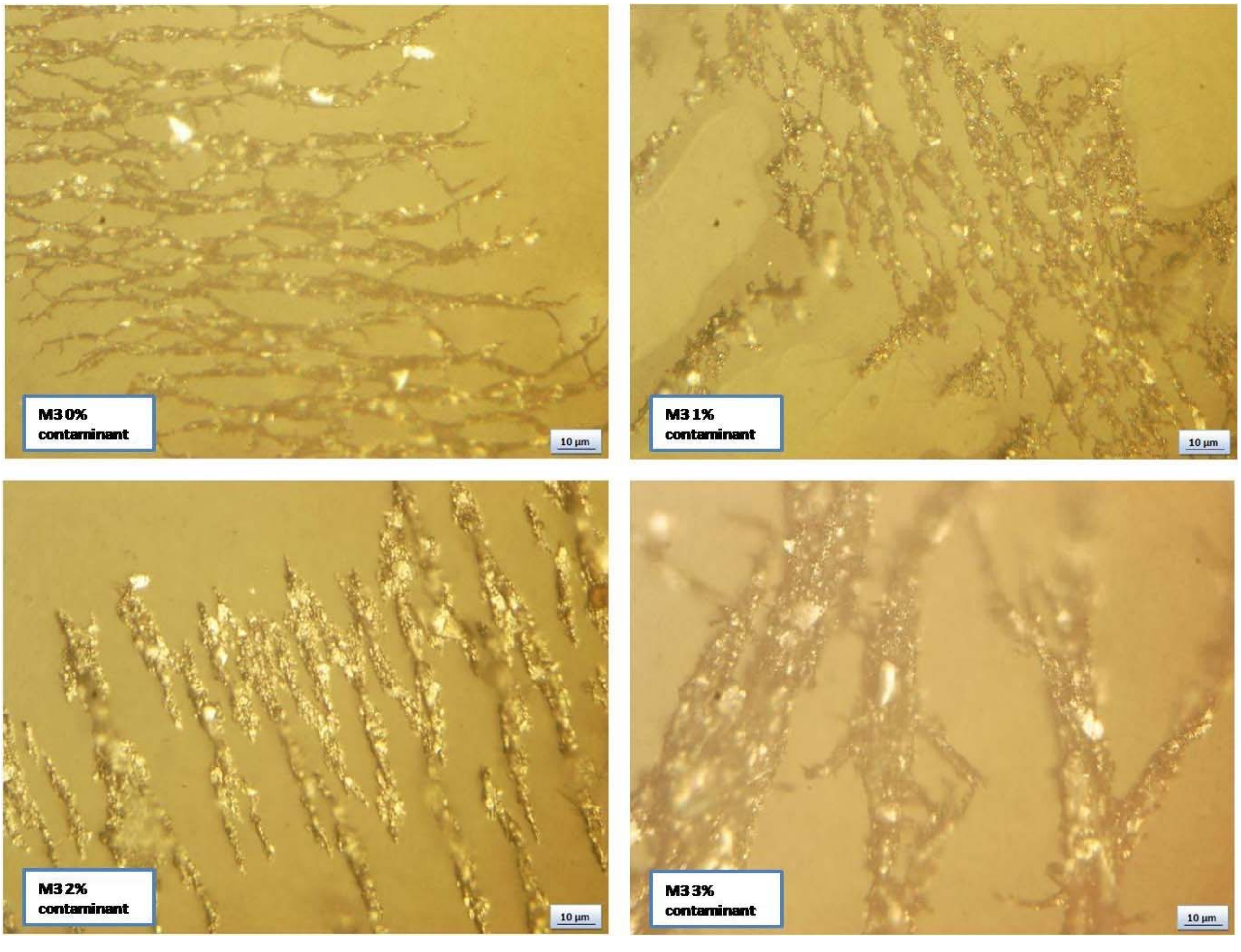

Figure 7 - Wear insides motor M3, contaminated with 1, 2 e 3% (diesel B3), pictures of the internal ring with increase of 500x

Comparing the four pictures it can be noticed that size of the found wear particles also does not indicate abnormal wear and tear in the engine

Table 6 - Values of tests in SAE 40 API CF used oil from motor M3

Sample	Viscosity 40 ^{0}C (cSt)	PQ index (new/used)
M3 0%	169,64	12/19
M3 1%	145,09	12/17
M3 2%	130,58	12/19
M3 3%	122,77	12/25

The behavior of the viscosities obtained in the motor is demonstrated according Figure 9.

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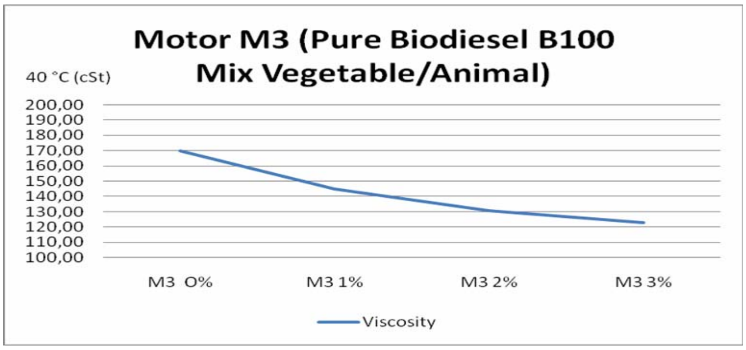

Figure 9 - Behavior of the lubricant viscosity of motor M3, with contaminant levels of 1, 2 and 3%, measured to 40°C

Table 7 presents results regarding the medium fuel consumption.

Table 7 – Medium fuel consumption of three engines

Engine	Medium consumption (liter/h)
M1	0.52
M2	0.48
M3	0.52

According to Table 7 it can be seen that the medium consuption was almost the same for both B100 and B3.

6. CONCLUSION

Wear particle analysis for automotive engines provides important information regarding engine condition.

The generated particles inside the engines were small due to low solicitation that the engines were submitted.

The medium consumption of fuel among the engines was not very affected by using pure biodiesel of animal and vegetal origin.

During operation a possible lubricant contamination, by diesel or by biodiesel, obviously decreasce de viscosity of the lubricant and modify the lubricity power. With the contamination grade used in this experiment the wear was not of mensurable warning since the ferrograpy and PQ index showed benign particle and normal values, respectively.

Even though presenting a normal wear the test should be continued in order to determine the consequence of a longer period and of a load imposed to the enginees working with the same lubricant and biodiesel.

7. ACKNOWLEDGEMENT

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