Based On Oil Analysis Applicable To Transportation Fleets Using A Viscosimeter

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Abstract

At the present paper we try to explain the analysis techniques use in engine oil for the lubricating in a maintenance period of a city bus (Mercedes Benz Boxer 40), in a transportation company. This experiment is done to estimate the optimal time for the oil change. using devices such as the rotational viscometer and the atomic absorption spectrometer as they can detect the incipient form when the oil loses its lubricating properties, and therefore cannot protect the mechanical components of diesel engines such these trucks. Timely detection of lost property in the oil, allows us taking preventive plan maintenance for the truck and subsequently these methodologies could be use in a fleet.

Keywords: *Atomic absorption spectrometry, rotational viscometer, lubricating oils, maintenance, predictive velocity rate.*

I. Introduction

1. Introduction

As result of global economic development and technological advances in the automotive market, we can encounter the domestic market vehicles designed to transport freight and public passengers, some of the assigned maintenance techniques found on this vehicles are not adequate because the operation of the unit varies depending on factors that are involved such as: the road conditions, the conditions of operation by the driver to unit, resistance to the movement and the time allowed to provide engine maintenance. Considering these factors engine maintenance in truck fleets should be taken into account. The experimentation that we did, was focused primarily forward or delayed oil change in the engine according to information obtained by the laboratory tests applied to the lubricating oil containing elements of wear in engines. A modern oil analysis plan should be considered as a string where the integrity and strength of each link (selection of the optimal location of the sample port, suitable frequency range of the tests performed, appropriate analysis and interpreted by trained personnel) is identical, and is the effective tool to increase engine reliability. This plan uses technology, knowledge of equipment operation and results of oil analysis to establish specific maintenance actions and enable optimum lubrication.

One of the keys to keep the engines running at peak performance, is the monitoring and analysis of the properties of lubricating oils, such as pollution, chemical composition and viscosity. Knowing how to interpret the changing properties of the lubricant may increase both lifetime, and the proper equipment operation. The existence or amount of debris particle, wear parts, erosion and pollution can provide details about the causes that affect the reliability and performance of the engine. Analysis of lubricating oils, fuels and other fluids can provide critical early warning information that can lead to a mechanical failure. Analyzing and determine trends in the data means given the opportunity to schedule maintenance before a critical failure occurs. Having a good diagnosis in viscosity and properties in the oil can increased equipment availability and higher productivity, lower maintenance costs, less disruption and optimum equipment performance.

II. Factors to consider for maintenance:

Here are the most important factors affecting the performance of the truck Mercedes Benz Boxer 40, which were studied by monitoring the truck in several conditions. 1) conditions of the route, 2) operating conditions, 3) maintenance conditions, and 4) resistance to movement. Some of these factors are variable and cannot be controlled, they are simply referred to understand that maintenance must also be modified from the possibility that these factors occur and can lead to the loss of oil properties and unnecessary wear in the engine components.

2.1 Conditions of the route:
These conditions refer to those that cannot be controlled, such as imperfections in the road, passenger numbers, hours when a lot of passenger demand exists, traffic in the area, climate, etc. The surveyed route was done on a transportation bus which was characterized by a distance of 25.02 km. Consisting with 1km dirt, the route produced per day on average eight laps. The lap last about 1 hour and 32 minutes, in which the frequent stops to pick up passengers is among the first 5km of the route. The stops on average range from 25 to 20.

2.2 Operating conditions:
When auditing the driver of the bus Mercedes Benz Boxer 40 (see Figure 1), it was observed that sometimes he kept the engine revolutionized unnecessarily, making changes in the gear box at inappropriate times, and usually going at high speed. These factors were taking in consideration when making oil analysis.

Figure 1: Mercedes Benz Boxer 30

2.3 Maintenance conditions:
The transportation line has a maintenance plan already established for all its units, and this is done every 3 months of operation of the bus and it should go to the maintenance shop for tuning. This period of maintenance was established by the transportation line, the maintenance shop does a check up every 350 hours of operation (approximately 1 month of operation, considering the rate of use that is given in this route)

2.4 Resistance to movement:
Vehicles can maintain a speed, acceleration and hill climbing, because the drive wheels exert a pushing force on the shaft and against the ground, transmitted by the tire-asphalt friction. This is called in-wheel traction that can be obtained by dividing the wheel torque between the radius of the wheel [7]. The wheel drive force, due to a number of forces which are counteracting in the advance and vehicle acceleration, known as "drag forces or movement" and are described below:

a) Rolling resistance (Rr):
The rolling resistance is caused by vehicle motion. It opposes the thrust force and its value depends on the mass of the vehicle, the steering geometry, type, profile and inflation pressure of the tires of the driving speed, road conditions and surface thereof. [10]

b) Aerodynamic resistance (Ra):
The air opposes the vehicle as it passes through based on its external form. The force of air resistance depends on the size and shape of the vehicle, driving speed, air density and wind speed and direction.

c) Slope resistance (Rp):
The resistance of a slope depends on the profile of the road and the vehicle mass. The vehicle needs to have a greater driving force to overcome the resistance offered by the slope (See Figure 2). Therefore, with greater power output to prevent a decrease in speed and power compensation slope.

d) Inertia resistance (Ri):

Inertia is the property that has the bodies to remain in its state of rest or motion, while some force on them, or the resistance of matter to change its state of rest or motion is applied. As a result, the body retains its state of rest or uniform motion unless there is a force acting on it.

f) Mechanical friction resistance (Rrm):

The friction of the parts of a motor and transmission creates resistance and thus reducing power and useful movement, this results in a loss of 5 to 20% depending on the vehicle.

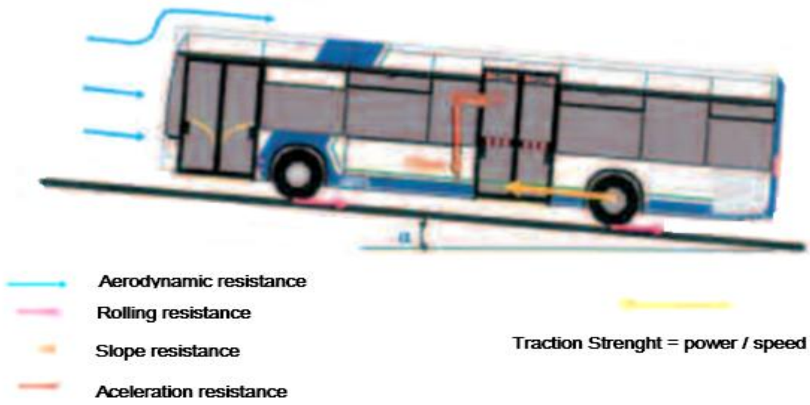

Figure 2: Resistance to movement

III. Specifications and engine lubricating oil

a) Bus: Mercedes Benz Boxer 40 (engine MERCEDES-BENZ MBE 900) see table 1.

Table 1. Technical characteristics of the engine

Motor specs	
Configuration	6 cylinder straight engine
Displacement	7.2 L
Compression Ratio	18:1
Diameter	4.17 in (106 mm)
Stroke	5.35 in (136 mm)
Weight	1310 lbs. (954 kg)
Electronics	DDEC VI
Power	350HP @ 2200RPM

b) Oil Type: 15W-40 see table 2.

Table 2. Mobil Delvac MX 15W - 40

Sae Grade	15W – 40
Viscosity, ASTM 445	-
Low cSt@ 100°C	12.5
High cSt@ 100°C	16.3
Viscosity Index, ASTM 2270	140
Sulfated Ash, % weight, ASTM 874	1.1
TBN, mg KOH/g, ASTM 874	10
Freezing Point, °C, ASTM D97	-33
Flash Point, °C, ASTM D92	240
Density @ 15°C, Kg/L, ASTM 4052	0.88

IV. Methodology

For the study of the lifetime lubricating oil, in the bus Mercedes Benz Boxer 40, we proceeded to compare 3 samples with different usage times and analyze the properties on each of them. When analyzing the viscosity, color and presence of contaminants in each sample we could get an idea of progressive wear suffered over time, just to get the right moment in which the lubricating oil, lost its protective properties for the engine and thus should be changed.

Therefore, the following methodologies were made three times in the oil following a time period that is describe below:
• Oil 15W40 new.
• Oil 15W40 with 2 months of use in the unit.
• Oil 15W40 with 3 months of use in the unit.

4.1 Methodology used

The characterization was to measure the most representative properties the Mobil Delvac MX 15W-40 oil, which is use by the transportation line in the bus. For the lubricating oil to work optimally protecting the engine against wear it is necessary to consider the following indicators:
1) Analysis of viscosity
2) Color
3) Outdoor and indoor pollution

4.2 Experimental procedure for the extraction of samples

In the experimental procedure we had to do several steps to get the samples that we wanted. The first Step is connecting the vacuum pump with two hoses where the lubricating oil could circulate, then remove the dipstick measurement of engine oil to get one end of a hose to suck the crankcase and oil that is deposited in the oil pan. The next step is connecting the other hose to the container where the oil sample will be collected, after that, run the vacuum pump to extract the fluid (100 mL) of the engine case into the collection vessel, finally remove the hose compartment seal the bottle and label the sample to get a good control analysis of the samples.

4.3 Experimental procedure for measuring viscosity.

For the analysis of the viscosity of the oil extracted a rotational Brookfield viscometer (fig.5) was used, capturing viscosity measured trough torque that is necessary to rotate at a constant speed immersed in the fluid sample to study its spindle [3].

Figure 3. Brookfield

The torque is proportional to the viscous drag on the spindle submerged, and thus the viscosity of the fluid. Selecting the needle to rotate in the fluid and the speed at which can be rotated to calculate the shear and cutting relationship, later the relationship between these two gave the viscosity. To calculate the shear stress at the wall of the rotating shaft, the equation (1) is used.

$$\tau_w = \frac{T}{2\pi Rb^2 L} \qquad (1)$$

T = time measured torque (Nm).
Rb = radius of the shaft (m).
L = effective length of the tree (m).

To calculate the ratio of the surface cut on the tree, equation (2).

$$\gamma = 2N\pi \cdot \left(\frac{2}{1-(K)^2}\right) \qquad (2)$$

- N = revolutions per second (rps).
- K = Rb / Rc.
- Rc = radius of the vessel.

Finally, to calculate the viscosity in mPa · s Equation (3) is used

$$V = \frac{\tau_w}{\gamma} * 1000 \quad (3)$$

4.4 Experimental Procedure for the analysis of color.

In any oil is very common that after performing an oil change, this changes its color due to detergents containing but must have a blackish-brown-soot color, if it is not that color, it is an indicator that the oil it is not performing its function, or presence of contamination exists.

4.5 Experimental Procedure for the measurement of particles in the spectrometer.

When samples of diesel engine oil were processed for subsequent measurement in the atomic absorption spectrometer (Fig. 4) we prepared, cathode lamps use to hollow and measure the level of metal particles that are in the remaining acid such as:

Iron [Fe]
Aluminum [Al]
Chromium [Cr]

for each element readings were made with metal standards for ppm of the element in mg / l.

Figure 4. Atomic absorption spectrometer

V. Results

5.1) Results of the analysis of viscosity:

There can be observed in (table 3) the viscosity in comparison to the three samples of lube oil operating temperature of the motor (80 ° to 100 °) is given, you can see that as the temperature increases the viscosity decreases, being this normal while you are in the range allowed by the SAE which is 12.5cTS to 16.3cTS. Normal oil and two months of use are in this range which means that the lubricant oil is in excellent condition, but the oil with 3 months of use, is out of this period, indicating that as is not appropriate for protection against wear (fig. 5).

Table 3. Oil Viscosity 15W40

Temperature °C	Viscosity of the oil (Brand New)	Viscosity of the oil (2 month used)	Viscosity of the oil (3 month used)
80	26	22	16
85	23	19	14
90	20	17	12
95	18	15	11
100	16	13	10

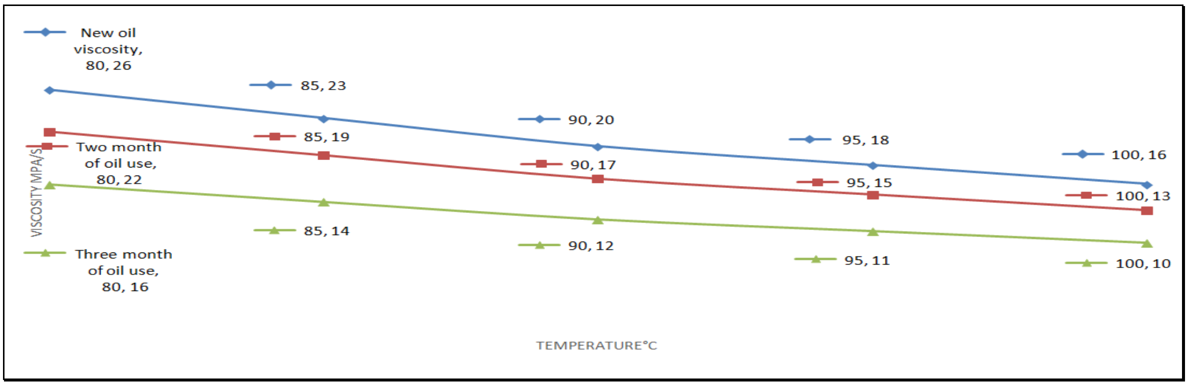

Figure 5. Viscosity of lubricating oil samples

5.2) Color analysis results:

This analysis was simply a visual inspection and found that the detergents present in the lubricating oil were doing its function of cleaning the inner walls of the engine which took a dark brown color as expected, but nothing out of the ordinary.

5.3) Presence of metals in the oil

In (Figures 6 and 7) a graph of particle detachment Fe and Cu respectively shown, note that with increasing time of lubricating oil used particle detachment also increased (tables 4 and 5), this indicated that because it's missing the mattress of hydrodynamic oil featuring, these mechanical components have more friction between them, so they tend to shed particles.

Table 4. Release of Fe

Time of use (months)	Absorbance	ppm(mg/L)	mg Fe	gr Fe/gr Oil
0	0	0	0	0
2	0.012	3.290456432	0.32904564	6.5809E-05
3	0.146	8.850622407	0.88506224	0.00017701

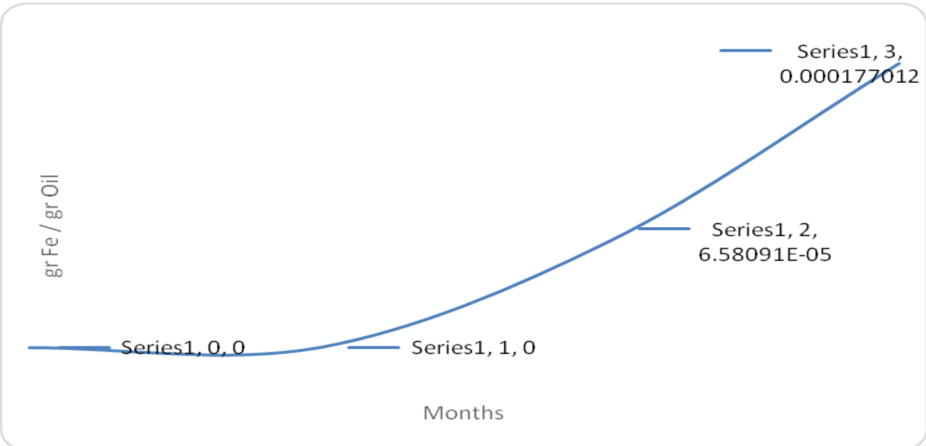

Figure 6. Release of Fe

Table 5. Release of Cu

Time of use (months)	Absorbance	ppm(mg/L)	mg Cu	gr Cu/gr Oil
0	0	0	0	0
2	0.007	0.782352941	0.078235294	1.56471E-05
3	0.028	1.4	0.14	0.000028

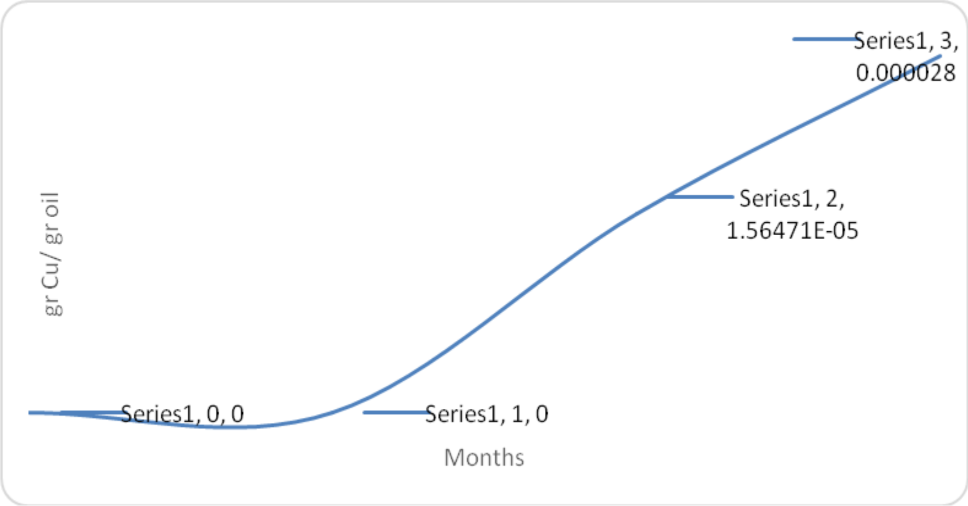

Figure 7. Release of Cu

VI. Discussion

Based on the above indicators viscosity loss and chalking is the relationship between lower viscosity and the lubricant with detachment of metal from the engine components and they will be store in the oil, this is because the hydrodynamic cushion provided oil on optimal state decreases as time of use passes by.

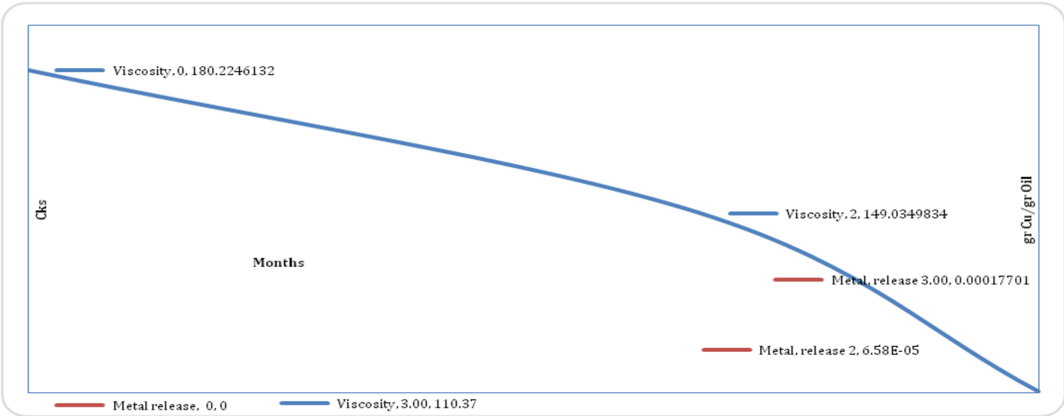

Figure 8: Relationship between viscosity and detachment of metal particles.

Therefore, based on the graphic we have from the extracted lube oil bus Mercedes Benz Boxer 40 lost its optimum viscosity before 3 months of use, so the holding period must have stopped to avoid more wear between their mechanical elements, which was not done due to the maintenance plan already established. This method of analysis on the life of the lubricating oil in the engine of this bus, seeks to amend the maintenance plan based on the results obtained with the viscometer and spectrometer, as instruments that can estimate the optimal date to change the oil. To determine the time of change accurately, we should have removed samples with shorter intervals, such as extractions every week, but following a new methodology, which is proposed by H. Espinoza [6], which lets you take samples of oil and add the exact amount of extracted oil with new one for the engine to always have the same level of oil and therefore no damage any other component from the lack of oil.

VII. Conclusions

The new proposed maintenance plan using a viscometer aims to extend the engine life by analyzing the lubricant containing in the engines of the vehicles, it is suggested to use at least a cheap viscometer to determine when the oil lost its optimal properties; spectrometer is not as necessary because only confirms chalking, but if you want to know exactly what are the mechanical elements that tend to wear out during operation and at what speed, then it will be convenient to use the atomic absorption spectrometer for these cases.

References

[1] A.H. Mehrkesh, S. Hajimirzaee, M.S. Hatamipour, A Generalized Correlation for Characterization of Lubricating Base-oils from Their Viscosities, Chinese Journal of Chemical Engineering, Volume 18, Issue 4, August 2010, Pages 642-647, ISSN 1004-9541.

[2] Arnobio Roberto Caneca, M. Fernanda Pimentel, Roberto Kawakami Harrop Galvão, Cláudia Eliane da Matta, Florival Rodrigues de Carvalho, Ivo M. Raimundo Jr., Celio Pasquini, Jarbas J.R. Rohwedder, Assessment of infrared spectroscopy and multivariate techniques for monitoring the service condition of diesel-engine lubricating oils, Talanta, Volume 70, Issue 2, 15 September 2006, Pages 344-352, ISSN 0039-9140.

[3] Brookfield viscometer dial reading, (2007) Manual No. M00-151-H0612.

[4] Detroit Diesel, (2007) Mercedes-Benz MBE 900 for recreational vehicles..

[5] DG Mobility (2012) Phase II integrated transport system, Route R-24, Guanajuato, Mexico.

[6] Espinoza, H. Diagnóstico de fallos en motores de encendido por compresión de automoción. Tesis doctoral, Universidad Politécnica de Valencia, España. 1990.

[7] Institute for Diversification and Saving of Energy (November 2005) Manual of efficient driving for drivers of commercial vehicles, Madrid.

[8] J.M. Al-Besharah, C.J. Mumford, S.A. Akashah, O. Salman, Prediction of the viscosity of lubricating oil blends, Fuel, Volume 68, Issue 6, June 1989, Pages 809-811, ISSN 0016-2361.

[9] Lihui Dong, Gequn Shu, Xingyu Liang, Effect of lubricating oil on the particle size distribution and total number concentration in a diesel engine, Fuel Processing Technology, Volume 109, May 2013, Pages 78-83, ISSN 0378-3820

[10] Luque, Pablo (2004). Ingenieria del Automovil Sistemas y Comportamiento Dinamico. Thomson, Madrid.

[11] Mobil Delvac MX 15W-40 High Performance Diesel Engine Oil, 2007.

[12] Ramona M. Díaz, M.Isabel Bernardo, Ana M. Fernández, M.Belen Folgueras, Prediction of the viscosity of lubricating oil blends at any temperature, Fuel, Volume 75, Issue 5, April 1996, Pages 574-578, ISSN 0016-2361

[13] Trujillo, G. (2007). "Oil analysis, proactive and predictive strategy." Machinery Lubrication Magazine in Spanish. Noria Corporation. |

[14] Young Gun Ko, Choong Hyun Kim, Confirmation of heavy metal ions in used lubricating oil from a passenger car using chelating self-assembled monolayer, Journal of Colloid and Interface Science, Volume 301, Issue 1, 1 September 2006, Pages 27-31, ISSN 0021-9797