Outlook

RV: CI3 2023 notification for paper 9560

De: ci32023@easychair.org <ci32023@easychair.org> on behalf of CI3 2023 <ci32023@easychair.org>
Enviado: domingo, 6 de agosto de 2023 13:40
Para: Leonel Caiza <lcaiza@tecnologicoismac.edu.ec>
Asunto: CI3 2023 notification for paper 9560

Dear Leonel Caiza-Caiza:

We are pleased to inform you that your work "DEGRADACIÓN DE ACEITES SINTÉTICOS: ENSAYOS FÍSICO_QUÍMICO DE VISCOSIDAD" has been accepted for oral presentation and publication at the IV International Conference on Research and Innovation - CI3 2023, to be held from August 30 to September 1 of this year.
All papers accepted at the conference will be published in the CI3 2023 Proceedings and indexed in the SCOPUS bibliographic database." To prepare the FINAL VERSION of your paper (version to be published), read carefully and follow the instructions below:

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Do not hesitate to contact us if you need more information (info@ci3.tech).

We look forward to hearing your presentation at CI3 2023!

Regards,

Ph.D. Marcelo Zambrano V.
GENERAL CHAIR
CI3 2023

SUBMISSION: 9560
TITLE: DEGRADACIÓN DE ACEITES SINTÉTICOS: ENSAYOS FÍSICO_QUÍMICO DE VISCOSIDAD

REVIEW 1
SUBMISSION: 9560
TITLE: DEGRADACIÓN DE ACEITES SINTÉTICOS: ENSAYOS FÍSICO_QUÍMICO DE VISCOSIDAD
AUTHORS: Jose Manopanta-Aigaje, Fausto Oyasa-Sepa, Leonel Caiza-Caiza and Marcela Herrera-Mueses

Overall evaluation SCORE: 2 (accept)
TEXT:
AFFAIR
Relevance: Demonstrates local experimental studies seeking a solution to lubricant performance and usage.
Supporting references: Bibliographic citations are limited to out-of-date documents, a review in recent years is recommended.
Importance of the results: Presents a descriptive graphic of the results, with analysis of correlations and significance. PRESENTATION
Quality of the figures:
Table 2: missing table footer with the abbreviations IC,ID,DP and their meaning Fig 2. Text of images is of low resolution, it is not read clearly
Fig 3. Theme of figure must be accompanied by the figure, not on another sheet Ec 3. Overlay text
Quality of the English language:
Typographical errors: "Mineral oils are", "fundamental you determine all the advantages", "And It was established",
Organization:
Mention of irrelevant text in Method. Describe the methodology directly and clearly.
Integrity: It is recommended that there be a more relevant bibliographic search directed to the scientific field for its discussion.

The article is favorable in the 6 article review criteria. With the exception of high copy density in the text of the Introduction and Theoretical Framework, the same ones that have been reviewed from the bibliographical citations, it is recommended to paraphrase these texts.

Degradation of synthetic oils: Physicochemical viscosity tests

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Abstract. The oils used in compression-ignition engines involving the running time of the automobiles under certain mileages within the preventive and corrective maintenance, were established as the object of this study, being analyzed the 15w 40 CI synthetic base oil to validate the degradation level of a lubricant in compression-ignition engines. The sample was taken in containers with capacity of 120 ml. International standards were considered the procedures: kinematic viscosity testing, ASTM D 445 Standard; total alkalinity and acidity value, ASTM D 4739 / ASTM D 664 Standards; infrared spectrum in used oils, NVE 751 Standard: oxidation, water, sulfation, nitration, fuel, soot; metal content by spectrometry, wear metals, contamination metals and additive metals, ASTM D 6595 Standard; oil spot test. For this study, literary analysis was used based on a comprehensive review of scientific papers, academic impact projects and reports that will make the readers have a clear view of the physical and mechanical characteristics of the lubricant. In the tribology analysis in engine oils, establishing the wear due to the movement of internal motor components, the degradation of a lubricant should be lower to maintain a better performance in a combustion engine, thus establishing a physicochemical test to determine at different mileages its durability with respect to friction and wear in a given sample of the lubricant.

Keywords: Lubrication, Degradation, Viscosity, Tests, Oxidation, Standard.

1 Introduction

The lubricant used for engines contains various chemical compounds such as heavy metals (e.g., chromium, cadmium, arsenic, lead, among others), polycyclic aromatic hydrocarbons, benzene and sometimes chlorinated solvents, PCBs, etc. [1]. Some researchers have analyzed the combustion and emission of recycled engine oil-diesel blends. The recycled oil was prepared in two stages. First, waste engine lubricant was treated and blend with diesel in different proportions. Properties such as flash point, kinematic viscosity, calorific value, cetane number, cloud point, pour point and density were measured according to (ASTM) Standards. The blends were fed into a diesel engine and the tests indicate an increase in brake thermal efficiency, gas temperature compared to that of diesel. A decrease in brake specific fuel consumption and NOx emissions in the exhaust gas combustion phase is determined [2]. In the local market, the oil used for category N3 engines belongs to the class called semi-synthetic, which depending on the parameters and quality can extend its change period, depending on the package of additives added, which can be antioxidant, detergent, diluent or anti-corrosive [3]. The analysis and monitoring of engine oil provide greater reliability about the real condition of the engine and prevents unexpected corrective maintenance. In diesel and gasoline internal combustion engines, where fuel is burned, lubrication is extremely difficult due to the additional and more demanding phenomena that must be faced: high temperatures, combustion products and residues that can contaminate the lubricant, high stresses, among others [4]. Using the standards of the Ecuadorian standardization service (INEN, D445, ASTM D5185, D2896, E2412), we will verify the correct change interval of the semi-synthetic oil used in the wear, viscosity, degradation and total base number tests [5]. Sampling is the most critical aspect of oil analysis. If a representative sample is not obtained, all subsequent oil analysis efforts will be nullified. The main objectives for obtaining a representative sample are: 1. To maximize information density. To obtain as much information as possible per milliliter of oil. 2. To minimize information distortion. The concentration of information should be represented in tables of results, and graphs at different mileage where the metals present in the lubricant are visualized. It is important that the sample is not contaminated during the analysis procedure in the tests. Limits in oil analysis are sometimes referred to as alarms, which are devices created to assist in the interpretation of reports [6]. During the analysis and verification of the physicochemical degradation tests of an engine lubricating oil by means of results obtained from the sampling used in compression-ignition engines, kinematic viscosity and infrared analysis were determined establishing parameters by mileage in oxidation, nitration and sulfation.

2 Theoretical Framework

2.1 Lubricating oils

Lubricating oils are constituted by a base, which provides the primary lubrication characteristics; the base can be mineral, synthetic or vegetable. Viscosity is a factor that is affected by temperature. It is important to consider the operating temperatures to which the oil will be subjected [33]. Engine lubricants are a combination of paraffinic, naphthenic and aromatic hydrocarbons obtained by distillation of crude oil (mineral oils) or by synthesis from petrochemical products (synthetic oils). The variation in the proportion of the different types of hydrocarbons in the mixture determines the physical and chemical characteristics of the oils. A high proportion of paraffinic hydrocarbons gives the oil a higher resistance to oxidation, while a high content of aromatic hydrocarbons favors thermal stability [34].

2.2 Types of lubricating oils

Mineral oil. Base oil or lubricant base is one of the products derived from the distillation of crude oil. During petroleum refining, lubricant bases are produced, which must strictly comply with the viscosity range that characterizes them [35]. Mineral oils are derived from the distillation of petroleum and, therefore, their origin is 100% natural. Mineral base oils are made up of three types of compounds: paraffinic, naphthalenic and aromatic, the first ones being the those found in greater proportion (60 to 70%), because they have the best lubricating properties, but there are naphthalenic and aromatic compounds that provide properties that paraffins do not have, such as good behavior at low temperatures and solvent power, among others [18].

Semi-synthetic oil. They are the result of mixing or combining minerals and synthetics. No more than 30% of synthetic compounds and the remaining 30% of mineral. Thanks to this combination, excellent advantages of both are obtained, since they are more economical than synthetic compounds.

The superior characteristics of a semi-synthetic oil are:

- Higher viscosity index (withstands extreme temperatures better).
- It extends oil change intervals, because it withstands oxidation better than synthetic oils.
- Semi-synthetic lubricant improves lubrication with the help of another synthetic lubricant.
- Semi-synthetic oil is more environmentally friendly.
- Certain benefits provided by synthetic oils are obtained without having to invest in the oil [19].

Synthetic oil. It is a highly refined lubricant to prevent premature engine wear, which has outstanding flow characteristics at low temperatures. As a result, the components are lubricated avoiding frictional wear, being very effective in cold starting where a significant amount of wear can occur in the moving parts of the engine [31].

Viscosity stability.- A higher viscosity index is synonymous with a more stable viscosity over a wider temperature range produced in the engine.

Higher thermal and oxidation stability.- The higher thermal and oxidation stability of synthetic lubricants results in a lower increase in viscosity over time with respect to engine operation, thus prolonging the respective change of lubricating oil by working hours or mileage [32].

2.3 Use of lubricating oils

The lubricating oils inside the internal combustion engine of a diesel vehicle have an exclusive function with the care of the internal mobile mechanisms inside the automobile. This is how the fishing industry in the last years has prioritized to use an ideal lubricant for its diesel engines since the high cost of repairs in the short term has been a disadvantage in the last years is. For that reason, it should be clarified that the corrective maintenance of an engine is inevitable in the short or long term, but in the automotive industry it is important that a lubricating oil with excellent characteristics prolongs the useful life of the engine for a longer period of time. The study of the viscosity index at different temperatures is essential to analyze it by means of parameters with respect to its additives [10].

2.4 Synthetic oil for diesel engines

A synthetic lubricant has base oils that are highly refined in a laboratory more than those used in usual mineral engine oils, obtaining better protection and performance features in the moving and fixed parts of the engine. Synthetic lubricants are manufactured with more advanced refining processes and therefore have a special chemical treatment and have a higher purity and quality as opposed to a mineral oil. This not only removes more impurities from the crude oil, but also allows the individual molecules in the lubricant to be modified to match the demands of today's automobiles [32]. When the engine is started, the mineral lubricant takes considerable time to circulate throughout the engine system, resulting in frictional wear between moving engine parts. On the other hand, synthetic oil begins to circulate quickly, protecting every moving part within the engine. Synthetic oils can also significantly increase fuel economy. During the warm-up period of a normal truck run, mineral oils have the disadvantage of being thicker and circulating slowly throughout the engine's internal mechanism, causing wear, making the engine more fuel-intensive and less efficient. In contrast, synthetic lubricants start working faster and the engine reaches its maximum operating efficiency effectively prolonging its service life [31].

3 Method

The research paper is presented with the literature review methodology, whose purpose is to consult several authors to discuss conclusions and results. Literature review means to discover, consult and obtain references, and other materials useful for research, from which the inquiry, plus the collection of important and necessary information to pose the research problem (Hernandez et al., 2014). On the one hand, it is of the documentary type since researchers perform a second-hand information search when looking for and selecting information that is already documented: recorded, compiled and classified.

This research was conducted in a review of several articles, books, theses, projects, scientific journals and verifiable sources that ensure the credibility of the concepts and analyses presented.

3.1 Viscosity

As an example of viscosity in a diesel road transport vehicle, a quantitative and qualitative analysis of the lubricant is considered necessary, the same that complies with the operating conditions suitable for a diesel engine, with respect to its durability under progressive operating conditions. Laboratory tests in relation to the study of the lubricant is a trend of relevant importance since a baseline that represents an interpretation of the engine wear can be determined through statistical limits and if the lubricant meets the ideal characteristics through the frequency of use of the same engine, so that, through a chemical data report, it can be established by means of indicators and color codes whether the oil has a favorable engine characterization [8].

Taking as a reference a heavy equipment, it is deduced that there is one of the most relevant advantages since the lubricant allows to establish a wide durability and reduces the corrective maintenance postponing it to a longer time, therefore, the study of the ideal lubricant is reflected in the preventive maintenances having to be carried out in the established period after the pertinent oil change, and an accompaniment of the viscosity study in a specialized chemical laboratory establishing parameters of temperature, mileage, and elements that produce the oxidation phase in the moving and fixed parts of the engine, being the ideal indicator for warning tests, and establishing limit results according to the hours of operation if it is construction equipment such as backhoes, caterpillars and mechanical shovels [9].

Table 1. Lubricants according to the equipment in operation [9]

	Engine Manufacturer		
Oil Analysis	**Caterpillar**	**Cummins**	**Detroit Diesel**
	All models	**All models**	**All models**
Iron	100 ppm.	84 ppm.	150 ppm.
Copper	45 ppm.	20 ppm.	90 ppm.
Lead	100 ppm.	100 ppm.	-
Aluminum	15 ppm.	15 ppm.	-
Chromium	15 ppm.	15 ppm.	-
Spectroscopy	20 ppm.	20 ppm.	-
Sodium	40 ppm.	20 ppm.	50 ppm.
Boron	20 ppm.	25 ppm.	20 ppm.
Silicon	10 ppm.	15 ppm.	None specified
Viscosity	+20% to -10% of SAE nominal grade	+/- 1 SAE grade or 4 cSt of new oil (Visc. at 100 ˚C)	+40% to -15% of the nominal value (Visc. at 40 ˚C)
Water	0.25% max.	0.2% max.	0.3% max.
TBN	1.0 mg KOH/g min. estimate	2.0 mg KOH/g min. or half the new oil or equivalent to TAN	1.0 mg KOH/g min. estimate
Fuel dilution	5% max.	5% max.	2.5% max.
Coolant dilution	0.1% max.	0.1% max.	0.1% max.
Ferrography	In exceptions	In exceptions	In exceptions

One of the quick test alternatives to determine the degradation and wear of a diesel lubricating oil can be achieved by means of an oil spot test, establishing comparative image parameters to determine the continuous wear with respect to the oil. This basic procedure comes from an analysis with a suitable diagnostic tool to determine the scope of ideal lubrication. These images determine the wear that this oil has through color spectra. This verification can be determined as a quick test to observe the oil condition after a certain time of use. Additionally, CNG engines show a higher demand due to their high thermal and mechanical demand, exposing a high degradation after a certain time of use [11].

Table 2. Database of MAXTER MULTIGRADE CI-4 SAE 15W40 oil [11]

NAME	TBN (mgKOH)	VISCOSITY AT 100 ˚C (cSt)	SOOT FT-IR (abs/1mm)	DI	CI	WD
M01-A	9.06	14.07	0.74	94.5168	2.3854	13.0794
M02-A	9.08	12.35	0.63	90.6937	2.3664	22.0229
M03-A	9.88	13.42	0.85	94.7259	2.3766	12.5346
M04-A	6.25	13.34	0.58	93.0169	2.3832	16.6424
M05-A	9.63	14.01	0.63	88.9408	2.3585	26.0832
M06-A	8.81	13.68	0.84	95.3611	2.3826	11.0525
M07-A	6.94	13.33	0.91	93.1826	2.3687	16.1481
M08-A	8.68	13.91	1.01	95.7843	2.4104	10.1615

3.2 Engine category

Machinery manufactured by Caterpillar shown in a data sheet according to its engine characteristics is considered [14].

Table 3. Main characteristics of the Caterpillar 2014 excavator engine [14]

Engine model	**Cat• C6.6 ACERT™**
Lubrication:	Circulating pressure
Gross power: SAE J1995	111 kW
Piston diameter	105 mm
Stroke	127 mm
Displacement	6.6
Pistons:	Inline-six
Compression Ratio:	16.2 : 1

3.3 Measurement of wear elements in the lubricant

For the collection of the samples, initially the cleaning of the oil intake port that is right on the oil filter was performed as in Figure 3, then the sample was taken in a transparent plastic container of 120 ml that has an airtight lid. The label has information on the customer, unit, unit code, date of sampling, type of oil, oil hours, unit hours, so that the recommendations given regarding the condition of the oil are as accurate as possible.

In addition, the volume to be collected in each sample is 100 ml of oil and an oil sampling kit was used for this purpose. It was established to take the oil sample at intervals of 250 working hours, which corresponds to the preventive maintenance time suggested by the manufacturer [12].

Fig. 1. Oil sampling points in the engine [13]

4 Analysis of Results

4.1 SAE 15W-40 oil properties

Nomenclature of SAE 15W-40 oil, represented by the letter W, meaning Winter, referring to the degree of cold viscosity in temperature, the second numbering represents the lubricant viscosity in hot temperature. The higher the percentage of viscosity, the greater the protection to the mechanical parts. It is also emphasized that an excess of viscosity can cause internal friction and decrease the performance of the vehicle, which means a deterioration of the engine. In reference to the characteristics of the manufacturer of (2020) 15W40 Bardahl oil, it is understood that it is a multigrade oil, designed for the lubrication of 4-stroke turbocharged and naturally aspirated diesel engines. Therefore, these vehicles require a specific lubrication according to the type of engine. As an outstanding point about the 15W40 oil, it fulfills the function of protecting the engine from wear and corrosion to which it is exposed according to the activity it regularly performs, thus allowing the lubricant to adapt to the temperature diversity according to the climate to which the engine is exposed [30].

4.2 Infrared oil analysis

Over time, diesel engine oil degrades due to exposure to high temperatures and contact with combustion products. Infrared spectroscopy can detect the presence of degradation products, such as acids, resins and varnishes, which can affect the viscosity and lubricating properties of the oil. Early detection of oil degradation allows timely changes to be made and potential engine downtime to be avoided. Infrared analysis of diesel engine oil is a technique used to determine the chemical composition and quality of diesel engine lubricant by using infrared spectroscopy. This technique makes it possible to identify and quantify the different molecular components present in the oil, as well as to detect the presence of contaminants or degradation. Among those are:

- Measurement of elements in oil: Cu, Fe and Cr.
- Measurement of elements in oil: Al, Pb and Sn.
- Measurement of elements in oil: Si, Na and K.
- Measurement of elements in oil: Mo and Ni.

The measurement of elements such as aluminum Cu, Fe and Cr, Al, Pb and Sn, Si, Na and K, Mo and Ni in diesel engine oil is commonly performed through Optical Emission Spectroscopy (ICP-OES) or Atomic Absorption Spectroscopy (AA) analysis techniques. These techniques experimentally obtain the manifestation of metals in the engine lubricant and are widely used in the analysis of oils and fluids. Figure 4 shows the evolution of the acidity and alkaline reserve depletion measurements in mg KOH/g of the samples analyzed for diesel engines, respectively. It is indicated in the first instance that the intersection of the trend curves of the TAN and TBN measurements show the oil change intervals for each of the lubricating oils. As we can see, type II oil shows a clear reduction of the established period by approximately 50% (15,000 km).

Reaching the oil change intervals established by the manufacturer (30,000 km) using this type could pose serious risks of engine failure. The better performance of type I compared to type II can be attributed to its additive packages and probably to its lubricant base. It should be noted that type I has higher levels of TBN than type II, thus neutralizing the high levels of acidification of the oil at the end of the oil change interval. Diesel engines undoubtedly show a lower demand from the point of view of oil acidity, being not too much affected by this variable. Their alkaline reserve reaches without any problem the periods that have been established for these engines and can reach higher levels if we extrapolate the data obtained [29].

Table 4. Comparative Table

Characteristics	Type I	Type II	Type III
SAE Grade	10W40	15W40	15W40
Density at 15 ˚C (kg/m^3)	865	865	881
Viscosity at 40 ˚C (cSt)	91.8	112.0	108.0
Viscosity at 100 ˚C (cSt)	14.3	14.5	14.5
Viscosity Index	160	125 min.	130 min.
T.B.N. (mg KOH/g)	13.2	7.0	10
Aminic additives (Abs cm^{-1} / 0.1 mm)	17,991*	12,978*	1,275*
Antiwear additives (Abs cm^{-1} / 0.1 mm)	8,048*	10,903*	12,950*
Flash point, open cup (˚C)	>220	215	215 min.
Pour point (˚C)	<-33	-27	-27 max.
Specifications	IVECO 18-1809	API CF-4	ACEA E7/E5, API CI – 4/CH-4/SL

Table 4: Main characteristics of the lubricating oils

(*) These results correspond to measurements carried out in the laboratory using the FT-IR technique.

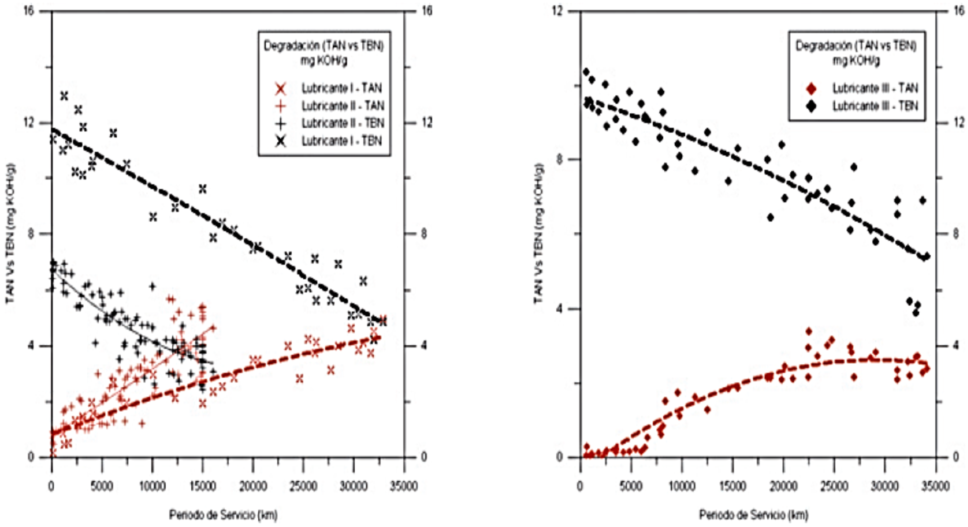

Fig. 2. Evolution of acidity measurements [29].

5 Discussion

5.1 Interpretation of the wear of new 15W40 oil

It can be seen in Table 5 that the proportion of polymer additives was similar in almost all the lubricants in the tests, and they are between 7% by weight and 8% by weight. Some irregularities were found for engine lubricants C and H, where the amount of polymer additives was above or below this range, proportionally. With reference to the absolute values of the polymeric additives, they can be somewhat overestimated due to the mechanism of size-exclusion chromatography [20].

Table 5. Chromatographic segmentation of SAE 15W- 40 lubricants [20]

	Polymer additives in oil (wt%)	**Composition of base oil+low MW additives (wt%)**				
		Saturates	**Monoaromatics**	**Diaromatics**	**Polyaromatics**	**Polar compounds**
Oil A	8.0	72.5	17.7	2.7	1.6	5.5
Oil B	8.2	71.4	15.2	2.7	2.9	7.8
Oil C	10.4	69.6	16.9	3.3	3.2	6.9

Oil D	8.1	67.3	18.3	4.2	3.4	6.8
Oil E	7.2	83.7	10.9	1.7	1.6	2.1
Oil F	7.4	84.7	7.2	1.4	0.6	6.1
Oil G	8.0	93.6	2.9	0.5	0.3	2.8
Oil H	6.4	73.1	16.4	3.3	2.3	4.8

Kinematic viscosity is relatively unaffected in all long-range automotive lubricant tests, gasoline cars identify a minor increase, diesel cars a minor decrease. Although the changes are not relevant, at least in this mileage range, it is suggested to involve these fundamentally different trends in viscosity change in engine development, particularly when considering modern extended operating ranges exceeding 20,000 km covered [21].

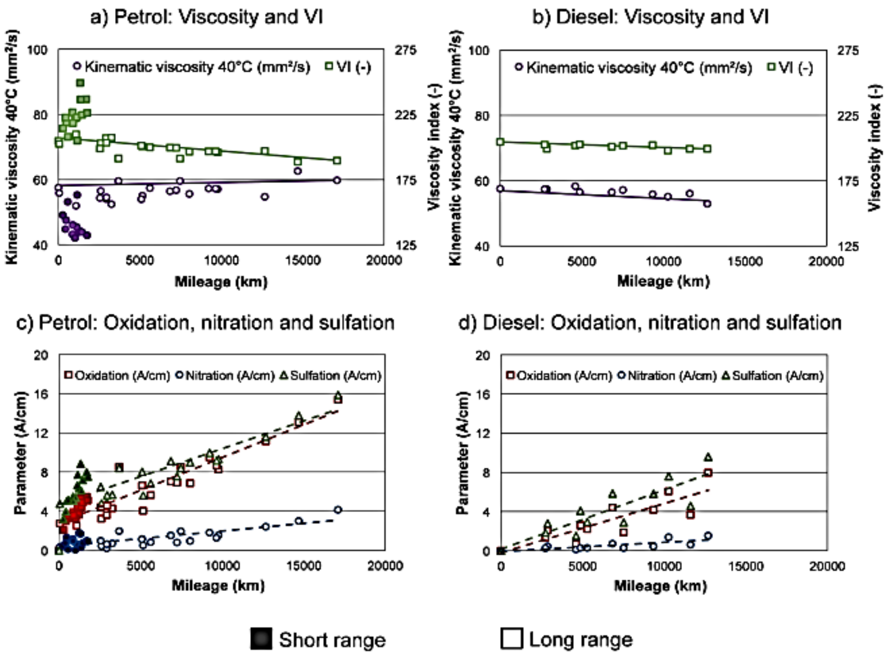

Fig. 3. Kinematic viscosity and viscosity index (VI) as a function of mileage. a) Gasoline cars, b) diesel cars. Oxidation, nitration and sulfation according to mileage. c) Gasoline cars, d) diesel cars. The lines shown only facilitate the appreciation of the results with respect to the tests carried out [21].

The 15W-40 API CI-4 and M7ADS V 15W-40 API CI-4 CH-4/SL oils show similar lubrication. The M7ADS III 15W-40 API CF-4/SG engine lubricant shows the highest surface wear, in other words, the lowest lubrication of the new engine lubricants seen in the tests. Correlation analysis of the experimental values found that the fuel content that penetrated the lubricants correlates negatively with viscosity (R = -0.87). Low water contamination in the engine oil does not cause a revealing negative effect on lubrication. A significant correlation was confirmed between the oxidation, nitration and sulfation products of chemical degradation of the lubricants used in the tests (R ≥ 0.90). These degradation products improve lubrication due to their polarity, i.e., they caused better lubrication of worn lubricants compared to new engine oils [22].

Table 6. Engine oil test assessment [22]

Oil sample No.	WS (mm^2)	$KV_{100\,°C}$ ($mm^2.S^{-1}$)	ZDDP (%)	Soot (%T)	Fuel (wt. %)	Water (wt. %)	Oxidation (A/0.1 mm)	Nitration (A/0.1 mm)	Sulfation (A/0.1 mm)
1-1	9.0	14.62	100.0	100	0.0	0.0	0.00	0.00	0.00
1-2	7.9	12.15	69.3	72	4.4	0.0	0.17	0.08	0.16
1-3	8.3	9.23	69.3	72	20.0	0.0	0.17	0.08	0.16
1-4	8.8	7.47	69.3	72	30.0	0.0	0.17	0.08	0.16
1-5	6.3	14.75	63.4	54	2.7	0.2	0.05	0.08	0.14
2-1	5.9	14.29	100.0	100	0.0	0.0	0.00	0.00	0.00
2-2	7.6	12.94	74.0	81	17.0	0.0	0.21	0.12	0.19
2-3	6.3	13.30	67.0	78	0.0	0.1	0.07	0.10	0.14
2-4	7.9	15.48	59.0	79	7.0	0.0	0.07	0.09	0.17
3-1	5.8	14.14	100.0	100	0.0	0.0	0.00	0.00	0.00
3-2	5.9	14.07	11.5	93	0.0	0.0	0.15	0.23	0.26
3-3	6.1	14.07	13.8	93	0.0	0.0	0.14	0.22	0.26
3-4	6.3	14.68	5.0	88	0.0	0.0	0.26	0.40	0.38
3-5	5.8	14.65	6.0	88	0.5	0.0	0.26	0.40	0.38
4-1	3.5	14.37	100.0	100	0.0	0.0	0.00	0.00	0.00
4-2	2.1	15.58	23.2	75	0.0	0.2	0.42	0.62	0.57

In the case of tests of used 15W-40 engine oils, those are shown in samples no. 2-2, 2-3, 2-4 (see Figure 4 and Table 6) with 12,335 km, 25,888 km and 25,900 km covered. The concentration of the ZDDP additive was inspected at the level of 74%, 67% and 59%, i.e., it did not exceed the limit amount of 30%. Based on the identification of the fuel in the oil in relation to the viscosity of the new engine lubricant [22].

The change in KV at 100 °C was less than 15.96%. The oxidative-onset temperature (OOT) of the lubricants decreased gradually with the working mileage. All OOT values of the worn lubricants are at 210 °C effectively. A general test indicated that the used engine oils retained their useful detergent and dispersant characteristics in an adequate amount. The four-ball wear scar diameters and coefficient of friction of the worn lubricants did not increase significantly after the road tests were completed. These tests are a reference for the next oil change to be performed on the automobile [23].

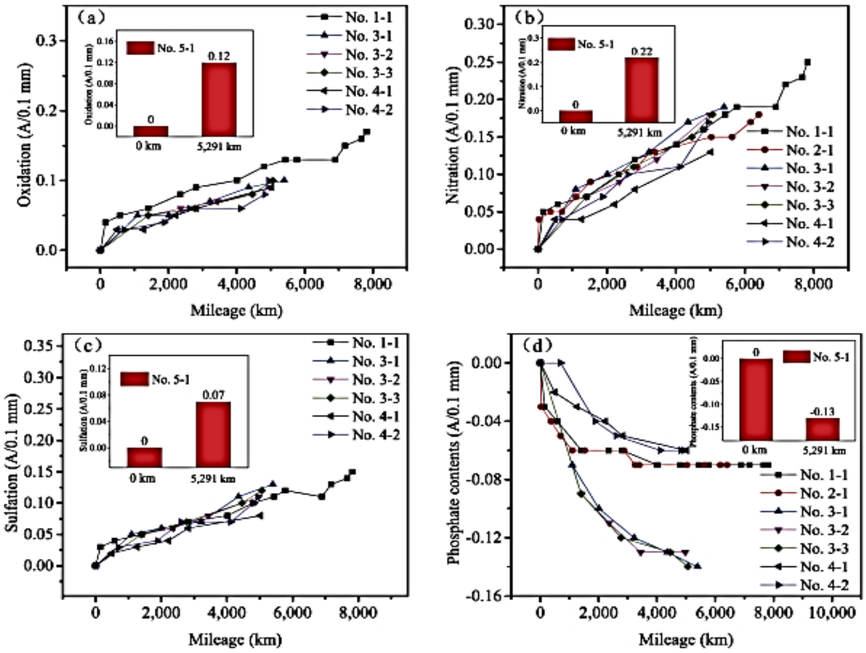

Fig. 4. Existing component test parameters of engine lubricant: (a) oxidation value, (b) nitration value, (c) sulfation value and (d) phosphate content [23].

The results of the tested lubricant components tend to be assessed by means of Fig. 2. As Figs. 2 (a) - 2 (c) show, all oxidation, nitration and sulfation values of the tested engine lubricants increased with the operating mileage, and phosphate content decreased with an amplification of the tests (Fig. 2 (d)). The oxidation, nitration and sulfation values increased rapidly, while the phosphate content declined rapidly during the primary test period. This was caused by the mix of residual lubricant and dissolution of residues of the previous lubricant. The phosphate content changed during the parallel tests with the same car model (1-1 and 2-1), the repeated test with mineral oil (3-1, 3-2 and 3-3) and the repeated test with synthetic lubricant (4-1 and 4-2). These had excellent prolongation, indicating that the consumption of antiwear components over the course of the road tests was well repeated. The experimental car 5-1 was brand new and was started with 5,291 km. The lubricant component change characteristics of car 5-1 were almost identical to those of the other road tests. The total oxidation, nitration and sulfation values of the worn lubricants were below the warning limit (1.0 A / 0.1 mm) reported in Ref. [24]. Briefly, it can be stated that the authors focused on the study of the most common form of degradation of engine lubricating oil. Oxidation occurs under mild conditions by the gradual weakening of antioxidants. Concurrently with the oxidation products, nitrates are formed. Nitration originates in the crankcase due to the occurrence of combustion gases from the explosion time in the engine. Due to the mixing of oil with air and combustion gases at high temperatures, ideal conditions are created in the crankcase for oxidation and nitration. On the same principle [25], [26], the formation of sulfates is argued, in experimental words, the formation of SOx, reactions of combustion gases with lubricant. Soot also contributes to increase the viscosity of lubricants in a diesel engine. Soot generated in the engine can cause consistent sludge, high oil viscosity or gelling of the lubricant itself [27]. Contamination of these compounds in the lubricant with soot did not cause a significant increase in viscosity due to dispersants that dispersed them in isolation [28].

5.2 Mathematical models - Tribology "Wear coefficient."

The normalization method represents an important contribution to the use of techniques in wear evaluation and failure diagnosis, since it makes the analysis independent of engine type and size, lubricant capacity and operating conditions. The normalized concentration for a metallic element in the oil sample Cn is obtained by multiplying the concentration of the wear element by coefficients that adjust this concentration according to the ratios of size (Kt), volume of lubricant in the system (Kv) and chemical composition of the engine components (Km) [15].
The correction of the concentrations measured by the spectrometer with the objective of considering the effect of particle loss in the sample taken was performed through the constant velocity model for systems with leakage and additives, developed by Espinoza [16], and which is summarized in the following equations:

$$Cm(t) = \frac{P}{Z*Vo}\left(C_{mo} - \frac{P}{Z*V_o}\right)*e^{Z.t} \quad (1)$$

Where: (2)

$$Z = \frac{Qa}{Vo}$$

With equation (1), (P) is determined. In this investigation, the effect of the filter was not considered since the tests were carried out with the engine without oil filter. The corrected concentrations, which represent the number of particles that would exist in the crankcase if there were no leaks, additives or filters at time (t), are calculated through equation (3) and (4).
If (t0) is the time of oil change, so it is equal to zero, the above equation changes to this:

$$Cc = Co + \frac{P}{V_o}(t_1 - t_0) \quad (3)$$

The normalization model showed below was developed by Espinoza [16] [17] in 990. The normalized concentration for a metallic element (i) in the oil sample Cn(i) is obtained by multiplying the concentration of the wear element measured in the oil by coefficients that adjust this concentration according to the ratios of size (Kt), volume of lubricant in the system (Kv) and chemical composition of the components of tribology (Km(i)) [16].

$$Cc = Co + \frac{P}{V_o} t \tag{4}$$

$$Cn(i) = Cd(i)\ Kt\ Kv\ Km(i) \tag{5}$$

$$Kt = Z/Zn * 1/\lambda^2 \tag{6}$$

$$Kv = V/Vn \tag{7}$$

$$Km(i) = Yn(i)/Y(i) \tag{8}$$

In equation 6, Z is the number of cylinders, λ is the similarity ratio between the analyzed engine, V is the volume of lubricant in the system. The subscript n refers to the normalized or reference engine, as expressed in equation 9.

$$D/D_n = \lambda \tag{9}$$

6 Conclusion

In the use of lubricants for vehicles, a diversity of analyses has been reported, where it is shown that lubricants, based on the components of which they are a part, can produce wear in the engine, so it is feasible to use a type of lubricant that minimizes wear through proactive maintenance.

Lubricating oils start from a general identification of category with respect to their initial manufacture, whereby mineral, semi-synthetic and synthetic oils are denoted, showing diverse physicochemical analyses in combustion engines depending on the additive that are included in the manufacture.

The diverse qualitative bibliometric analyses by description of physicochemical test methods generalize a study of kinematic viscosity considering the current viscosity trends present in synthetic oils. Additionally, the quantitative results focus on infrared analyses to determine the quantity and chemical composition of the degradation agents by concentration of metallic elements.

The analyses show that if an oil was contaminated, its hydrodynamic lubrication will lose its lubrication, which will cause severe wear in the engine, directly affecting the rings, cylinders, oil pump and in the latter producing foam, which will cause it to break, inducing cavitation. Another cause can be the content of dirt or soot in the lubricant, damaging the crankshaft, camshaft, valves and other parts. Thus, due to the above-mentioned causes, it is highly important that the oil is in perfect condition to promote the good performance of the vehicle.

In a lubricant, the presence of oxidation is observed, which is the main cause of degradation of engine oils and in general of any organic compound, therefore, synthetic oils must have agents and additives that produce a better lubricant that acts effectively in hard conditions and high working temperatures inside the engine to better preserve the moving parts of the engine.

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