COMPARATIVE STUDY OF DETERIORATION FACTOR AND THEIR TREND, BY REAL VEHICLE DURABILITY MILEAGE ON DIFFERENT DRIVING CYCLES, SRC-LECV AND AMA

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ABSTRACT

The vehicle pollutant emissions are one of the highest concerns of the society, specially thinking in the humanity future with topics like ozone layer degradation, continuity use of petrol base fuels and mainly the air quality, compromising the health and quality of population life.

In Brazil, the legislations for vehicle pollutant emissions are divided into two main environmental programs, the PROCONVE (Air Pollution Control Program by Motor Vehicles), designed for light passenger vehicles, commercial, trucks and bus, and the PROMOT (Air Pollution Control Program by Motorcycles and Similar Vehicles), designed for motorcycles, mopeds, tricycles and quadricycles.

In these legislations, the initial emissions of the vehicles are regulated with the respective emission limit, normally as a unit of emitted mass (g or mg) divided by the traveled distance unit (km). These limit values are the cutline that a vehicle can produce pollutant emissions, such as carbon monoxide (CO), total hydrocarbons (THC) and nitrogen oxides (NO_x), carbon dioxide (CO_2), among others.

The limits were previously created to control the emission with the vehicle in its first mileage, with the laboratory test being made to check the emissions with the vehicle in the production conditions. However, a concern has arisen in understanding and controlling vehicle emissions throughout their useful life. Thus, the concept of emission durability was created, where certain minimum mileage where vehicles must run and, in the end, must still comply with the pollutant maximum emission limits established by legislation.

To determine this deterioration, AMA cycle was adopted as methodology for PROMOT 4 phase. In PROMOT 5, new methodologies were introduced as SRC and SBC.

- AMA EPA cycle - Approved Mileage Accumulation Cycle.

- SRC-LeCV cycle - Standard Road Driving Cycle for L-Category Vehicles.

- SBC - Standard Bench cycle

This article has the purpose to present a comparative study by real vehicle durability performing the mileage accumulation, on a chassis dynamometer, between cycles SRC-LeCV and AMA, evaluating deterioration trend and deterioration factor based on the results of the gas emission emitted by the motorcycle engine.

INTRODUCTION

For motorcycles, mopeds and similar vehicles, the Brazilian environmental program to control pollutant emissions is the PROMOT, program that started in 2003 with the M1 phase, evolving to M2 in 2005, M3 in 2009, M4 in 2011 and the latest M5 phase in 2019.

Regarding durability of pollutant emission control systems and components, the PROMOT started to this requirement in the M4 phase, legislated by CONAMA Resolution 432/2011 [1]. The determination of the deterioration factors (DF) is mandatory to manufacturers and importers of motorcycles and similar vehicles with forecast of annual sales higher than 10000 units. The regulation stablished a minimum mileage accumulation as below:

- Mopeds: 10000 km;

- Motorcycles, tricycles and quadricycles (v_{max} < 130 km/h): 18000 km;

- Motorcycles, tricycles and quadricycles (v_{max} ≥ 130 km/h): 30000 km.

The CONAMA Resolution No. 493/2019 [2], developed to keep the program evolution, established new criteria for the PROMOT M5, especially determining new minimum distances for mileage accumulation, depending on the type of vehicle tested:

- Mopeds: 11000km;

- Motorcycles, tricycles and quadricycles (v_{max} < 130 km/h): 20000 km;

- Motorcycles, tricycles and quadricycles (v_{max} ≥ 130 km/h): 35000km.

The PROMOT M5 phase was established to promote harmonization with the latest regulations, such as technical standards, special requirements and so on. Then the normative basis for PROMOT M5 was the European environmental program EURO 5, set under the Regulation EU 168/2013 [3] and the Delegated Regulation EU 134/2014 [4].

For the newest PROMOT M5, the IBAMA Normative Instruction No. 21/2022 [5], stablished additionally to AMA cycle, other two methods to determine the deterioration factors:

1) Real vehicle durability test with total mileage accumulation by SRC-LeCV (Standard Road Cycle for L-Category Vehicle).

2) Durability test with bench aging by using SBC (Standard Bench Cycle).

All procedures are described into ABNT NBR 17008/2021 [6].

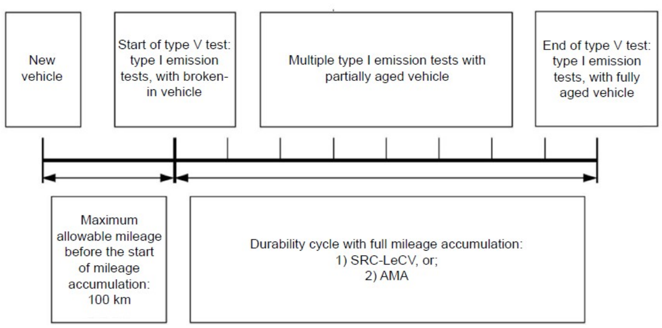

Figure 1 - Type V test, procedure for durability test with full mileage accumulation (ABNT NBR 17008/2021).

To full mileage accumulation procedure, where the vehicle runs the entire mileage determined in the legislation on method SRC-LeCV or AMA, the manufacturer/importer must carry out several measurements to verify the vehicle's emissions during the accumulation period, in order to obtain the linear regression equation representing the emission deterioration behavior of each pollutant throughout the vehicle aging.

STUDY

The objective is to present a comparative study for the real durability of the vehicle between the AMA and SRC-LeCV cycles, accumulating mileage in a chassis dynamometer,

This study is based on the 2012 report prepared by the TRL (Transport Research Laboratory) [7] from UK, a project that was the object of study to define the durability SRC-LeCV cycle to replace the AMA cycle. The objective of this TRL project was to define a mileage accumulation methodology that would adequately test the durability of components and systems relevant to gas emissions and propose associated regulatory text capable of ensuring that exhaust emissions of regulated pollutants are below the required Euro phase limits during and at the end of the normal life of the L-category vehicle. In addition, the objectives were that the defined mileage accumulation methodology resulted in an emission durability test that was:

Challenging and designed to control emissions throughout the normal life of L-category vehicles;

Practical, relatively easy to carry out and repeatable;

Representative of real traffic usage.

This TRL project proved that there was at the time no international cycle for durability mileage accumulation in Europe that met the above criteria. So that these criteria could be met, the SRC-LeCV durability cycle was developed.

The TRL compared the existing US durability cycles for motorcycles (US EPA AMA) and the cycle for cars and light vehicles (US EPA, EU and UN: SRC) and the World Harmonized Laboratory Emissions Test Cycle for Motorcycles (WMTC).

Since already in 2012 it was confirmed by this TRL project that the US EPA AMA motorcycle durability cycle proved to be outdated, as it was developed in the 1970s and no longer reflected the aging mechanisms of the emission system at the time, and that the SRC durability cycle for cars did not fully meet the characteristics and performance of the entire L-category fleet, the reason for creating the specific SRC-LeCV cycle for motorcycles was justified.

The TRL project showed that the SRC-LeCV cycle presented during the durability tests the most balanced proportions of degradation of the motorcycle mechanisms. The cycle was validated in relation to applicability with real traffic due to its correlation with the emissions data from the WMTC cycle, emphasizing that the WMTC cycle (World harmonized motorcycle test cycle) was designed using driving patterns collected from users around the world and combining them, in a way that can be used to represent real traffic use of motorcycles. This cycle is still used today for homologation tests in vehicle emissions laboratories.

METHODOLOGY

The running pattern for mileage accumulation to AMA cycle following ABNT NBR 14008/2012 and the IBAMA Normative Instruction 21/2022 where it must reach 20.000 km. For tested model, it is classified at subclass 2-1 of table 2 from ABNT NBR 16369/2022 [8] and the base speed of each lap is according to table of the Article 10 to IBAMA Normative Instruction 17/2013 [9].

AMA test cycle is a mileage accumulation cycle used to age test vehicles and their pollution control devices in a repeatable manner. AMA test cycle can be performed on the test track or on a dynamometer.

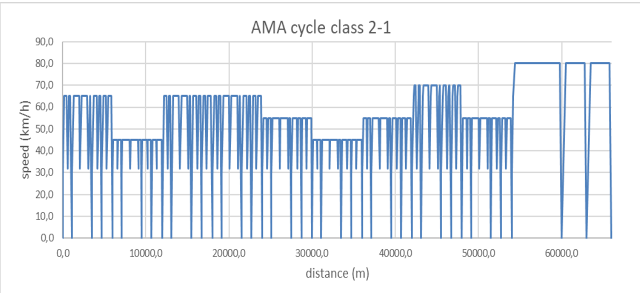

Figure 2 - AMA cycle mileage accumulation circuit (Class 2-1)

The running pattern for mileage accumulation to SRC-LeCV cycle following the ABNT NBR 17008/2021 standard and IBAMA Normative Instruction 21/2022, where it must reach 20.000 km. According to item A.3 - table A.1 for ABNT 17008/2021, tested model it is classified as 2 at SRC as base speed of each lap, based on subclass 2-1 of table 2 from ABNT NBR 16369/2022.

SRC-LeCV test cycle is a mileage accumulation cycle used to age L-category test vehicle and their pollution control devices in a repeatable manner. SRC-LeCV test cycle can be performed on the test track or on a dynamometer.

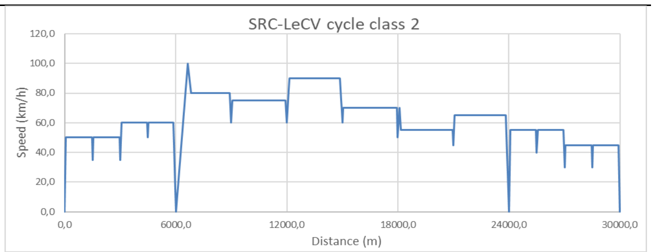

Figure 3 - SRC-LeCV cycle mileage accumulation circuit (Class 2)

Type I emission verification tests before, during and after the mileage accumulation must be conducted in accordance with the test procedure defined in ABNT NBR 16369/2022, as well for the method for determine the amount of gases carbon monoxide (CO), total hydrocarbons (THC) and nitrogen oxides (NOx) emitted by the exhaust.

The verification tests of type I emissions with reference fuels A22 and EHR, evaluating deterioration trend and deterioration factor based on the results of the emission of gases emitted by the motorcycle engine.

The tested items in the study were:

-Motorcycle quantity: 1 model (149cc), and;

-Muffler quantity: 2 mufflers (1 for SRC-LeCV cycle and the other one for AMA cycle).

The reference fuels used in the study to perform emissions tests were:

-A22 (gasoline with 22% anhydrous ethanol), and;

-EHR (100% hydrous ethanol).

The tested fuel in the study to perform mileage accumulation tests were:

-Type C Premium commercial gasoline

The model considered for the study is the vehicle family that YAMAHA homologated in Brazil for the PROMOT M4 phase.

The mass emission of carbon monoxide (CO), total hydrocarbons (THC) and nitrogen oxides (NOx), in g/km, were the analyzed pollutants. These pollutants are the main regulated gases in the environmental programs.

PRELIMINARY STUDY

Catalytic converter temperature measurement.

A catalytic converter temperature analysis test was carried out in a complete cycle of the SRC-LeCV and AMA, in order to understand the behavior of temperature in each cycle.

The measurements were performed by using a new muffler prepared with thermocouples installed before and after the catalyst.

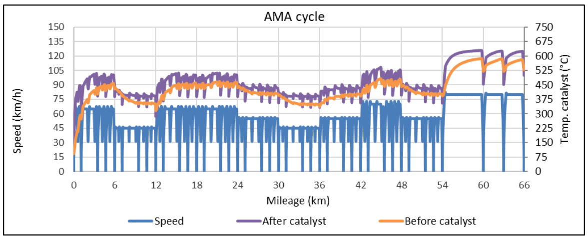

Figure 4 – Catalytic converter temperature data during the AMA cycle

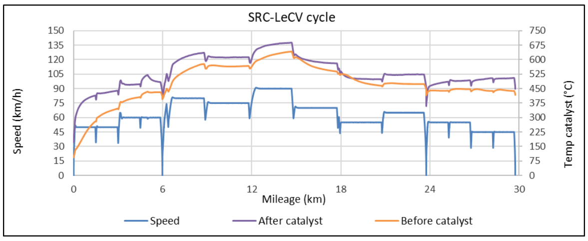

Figure 5 – Catalytic converter temperature data during the SRC-LeCV cycle

The highest temperatures were recorded at the points where the highest speeds of each cycle are reached.

The highest temperature recorded in the AMA cycle was in the final part of the test (10 and 11 lap), after 54 km driven, reaching 587°C before the catalytic converter and 628°C after the catalytic converter.

The highest temperature recorded in the SRC-LeCV cycle was in the middle of the test, in the third lap at 12 km and 18km, reaching 642°C before the catalytic converter and 688°C after the catalytic converter.

The average temperature during the AMA cycle was 417°C before the catalytic converter and 443°C after the catalytic converter, and during the SRC-LeCV cycle it was 460°C before the catalytic converter and 514°C after the catalytic converter.

Analyzing the results, it can be seen that, with a shorter distance traveled, the SRC-LeCV cycle exposed the catalytic converter around 50°C higher than AMA cycle in average.

With this information, we can conclude that for the SRC-LeCV cycle to have a degradation tendency similar to the AMA, with a shorter distance traveled, the catalytic converter must be subjected to extreme conditions.

PROCEDURE

Mileage accumulation is carried out with a riding robot following the route as determined in the methodology and always using Type C premium commercial gasoline. The end of each mileage accumulation is according to the maintenance stops foreseen in the service manual of the tested model.

As soon as the odometer reaches each maintenance mileage, the maintenance is carried out according to the service manual, checking the listed items to be evaluated.

After each maintenance, gas emissions tests are carried out, where it is evaluated with reference fuels.

RESULTS

The emission values will be omitted due to confidentiality issue. Thus the presentation will only be made graphically.

To ensure a graphical visualization of the carbon monoxide (CO), total hydrocarbon (THC) and nitrogen oxides (NO_x) emissions behavior, a flex fuel vehicle is shown below as an example of the study, hiding the values of the g/km to secure confidentiality. As an example, the graphs below refer to the comparison of trend lines of the regression curves of the carbon monoxide (CO), total hydrocarbon (THC) and nitrogen oxides (NO_x) results, of exhaustive emissions tests, performing the full mileage accumulation procedure following the SRC-LeCV and AMA cycles.

For the comprehension of the graphs to be presented below, it is important to understand what each line represents:

-Green points: real emission measurements made according to PROMOT M4 legislated distance;

-Green dot dash line: Linear regression line for full mileage accumulation on SRC-LeCV cycle.

-Red points: real emission measurements made according to PROMOT M4 legislated distance;

-Red dot dash line: Linear regression line for full mileage accumulation on AMA cycle.

Emission deterioration results with A22 gasoline fuel

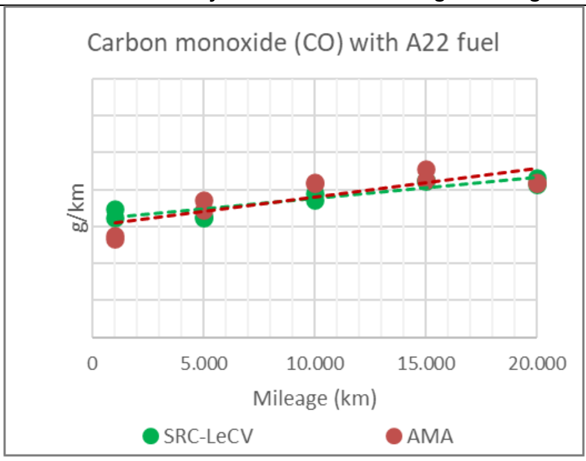

Figure 6 – Deterioration behavior of carbon monoxide with A22 fuel

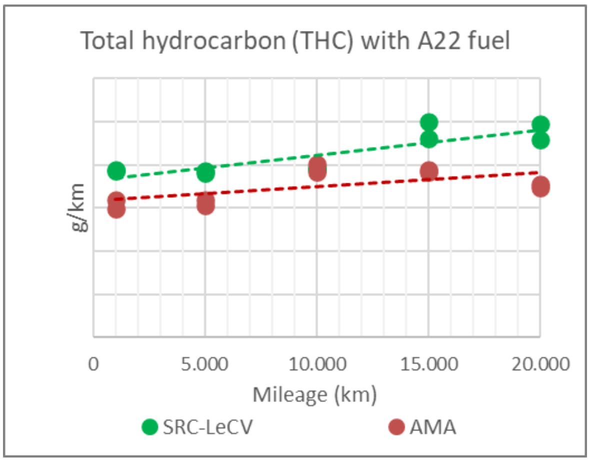

Figure 7 – Deterioration behavior of total hydrocarbon with A22 fuel

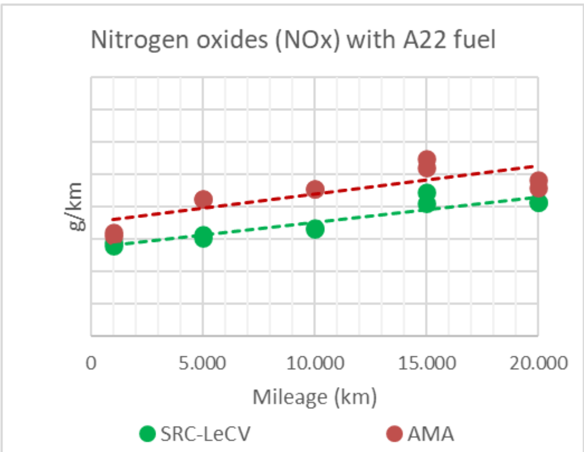

Figure 8 – Deterioration behavior of nitrogen oxides with A22 fuel

Emission deterioration results with EHR fuel

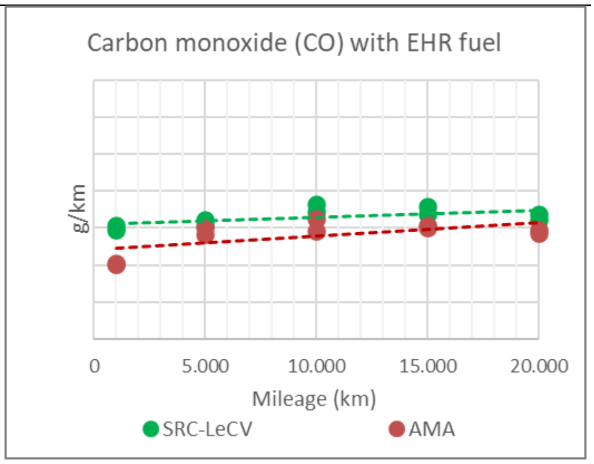

Figure 9 – Deterioration behavior of carbon monoxide with EHR fuel

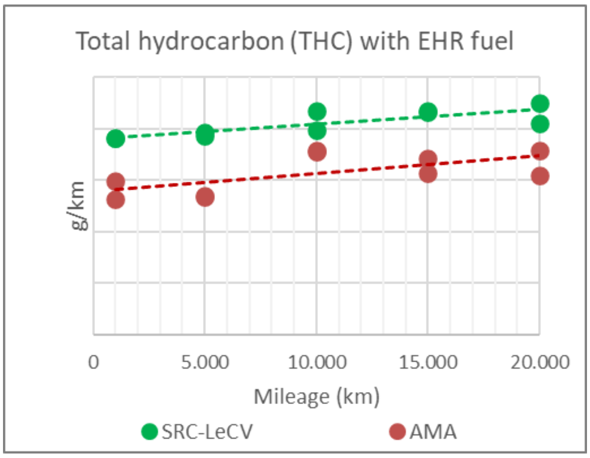

Figure 10 – Deterioration behavior of total hydrocarbon with EHR fuel

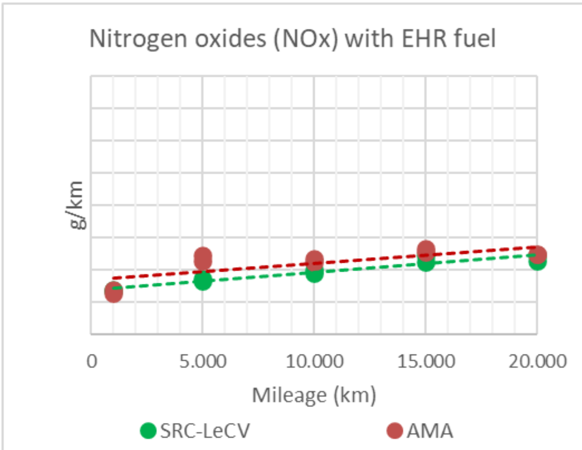

Figure 11 – Deterioration behavior of nitrogen oxides with EHR fuel

For purpose of comparison and data collection, the emission durability data of YAMAHA PROMOT M4 model are presented at Table 1, comparing the values of the full mileage accumulation procedure following the SRC-LeCV and AMA cycles.

Once more, to ensure confidentiality, AMA deterioration factors are represented as a base of 1,00. The SRC-LeCV deterioration factor is calculated as the difference over the 100% of the partial deterioration factors. The compiled results are shown in Table 1.

Table 1 – Deterioration factor results

DETERIORATION FACTOR COMPARATIVE							
MODEL	POLLUTANT	A22			EHR		
		DF			DF		
		AMA	SRC-LeCV	DIFF	AMA	SRC-LeCV	DIFF
M01	CO	1,00	0,916	-8,39%	1,00	0,873	-12,70%
	THC	1,00	1,094	9,40%	1,00	0,934	-6,56%
	NOx	1,00	1,050	4,96%	1,00	1,113	11,33%

ANALYSIS AND CONSIDERATIONS

It is possible to evaluate that comparing the deterioration factors between AMA and SRC-LeCV cycles, the carbon monoxide (CO) factor for both A22 and EHR fuels for AMA cycle were higher than SRC-LeCV cycle, the total hydrocarbons (THC) factor with A22 for AMA cycle was lower than SRC-LeCV cycle, but with EHR, THC factor for AMA cycle was higher, and for nitrogen oxide (NOx) factor, the SRC-LeCV cycle were higher than AMA cycle with both fuels.

In the graphs below, it is possible to visualize the difference in percentage of the deterioration factors for the gases: carbon monoxide (CO), total hydrocarbons (THC) and nitrogen oxide (NOx), when accumulating mileage in the AMA and SRC-LeCV cycles. Specifically, figure 12 shows this difference between the factors in both cycles for tests performed with A22, and figure 13 for tests performed with EHR.

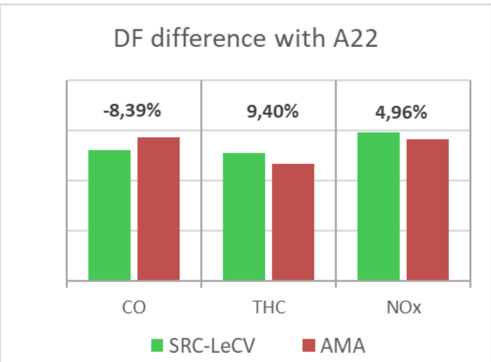

Figure 12 – Deterioration factor comparison with A22 fuel

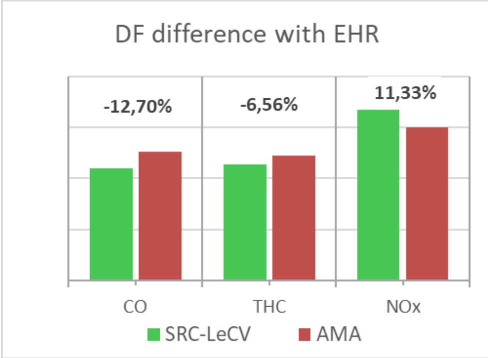

Figure 13 – Deterioration factor comparison with EHR fuel

Instead of the differences of deterioration factors between AMA and SRC-LeCV cycles for each pollutant, in case of A22 fuel, the CO DF for SRC-LeCV cycle was 8,4% lower than AMA cycle. In the other hand, the THC DF for SRC-LeCV was 9,4% higher than AMA cycle.

Once the deterioration factors of CO, THC and NOx should be analyzed as a set and not separately, it is possible to say that the deterioration factors produced by both cycles are similar.

CONCLUSIONS

This work complements and confirms the TRL study, demonstrating that the use of the SRC-LeCV cycle is applicable even for Flex-Fuel motorcycles that use both A22 and EHR fuels.

The cycle SRC-LeCV was validated in relation to applicability with real traffic due to its correlation with the emissions data from the WMTC cycle.

This study is important because it was carried out with a low displacement motorcycle, which represents the majority of the national motorcycle fleet. According to data released by ABRACICLO (Brazilian Association of Manufacturers of Motorcycles, Mopeds, Scooters, Bicycles and Similar) [10], between 2016 and 2021 there were more than 916 thousand registrations of motorcycles with a displacement between 51 cm^3 and 160 cm^3, representing around 80% of the sales in that period.

Taking account how long to complete the work and considering 8 hours worked per day, it took 81 working days to complete the mileage accumulation of 20,000 km following the AMA cycle and 60 working days to complete the mileage accumulation of 20,000 km following the SRC-LeCV cycle.

The gain in time using the SRC-LeCV cycle for accumulating mileage proved to be considerably significant and, consequently, saving resources, such as hours of laboratory use and specialized labor.

Based on these results, instead of small differences found with each deterioration factor pollutant, it is possible to affirm that the deterioration level produced by each AMA and SRC-LeCV cycle is similar.

Also, there was similarity at the deterioration trend and behavior between the AMA and SRC-LeCV cycles.

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