PARTIAL MILEAGE DURABILITY OF MOTORCYCLES

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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 (NOx), 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, the European legislation, which serves as the basis for PROMOT, in particular, has several regulated methods, the main ones listed below:

- Full mileage accumulation, where the vehicle runs the entire mileage determined in the legislation;
- Partial mileage accumulation, where the vehicle runs a minimum of 50% of the mileage determined in legislation, and the emissions are extrapolated until the end;

This article aims to present a study carried out to understand and simulate the partial mileage accumulation durability for motorcycles. As this method is not yet allowed in Brazil, this article also has the objective to evaluate the feasibility of the use of partial mileage.

1. 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 require this point in the M4 phase, legislated by CONAMA Resolution 432/2011 [1]. The determination of the deterioration factors (DF) was imposed to manufacturers and importers of motorcycles and similar vehicles with forecast of annual sales higher than 10000 units. The regulation was made according to the respective minimum mileage accumulation below:

- Mopeds: 10000 km;
- Motorcycles, tricycles and quadricycles (v_{max} < 130 km/h): 18000 km;
- Motorcycles, tricycles and quadricycles ($v_{max} \geq$ 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 ($v_{max} \geq$ 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].

In EURO 5, the following procedures are established to guarantee compliance with the durability of emissions:

a) Durability with full mileage accumulation;
b) Durability with partial mileage accumulation;
c) Durability through mathematical calculation;
d) Durability through bench aging test (SBC);

The full mileage accumulation and the mathematical calculation procedure, in Brazil known as "Pre-determined Deterioration Factor - Fixed FD", items a) and c), respectively, have been carried out since PROMOT M4. However, in Europe, since EURO 4 program, partial mileage (b) and the bench aging method (d), have emerged as new possibilities.

Specifically, in the partial mileage method, the procedure is performed by running a minimum of 50% of the specified distance for the vehicle category.

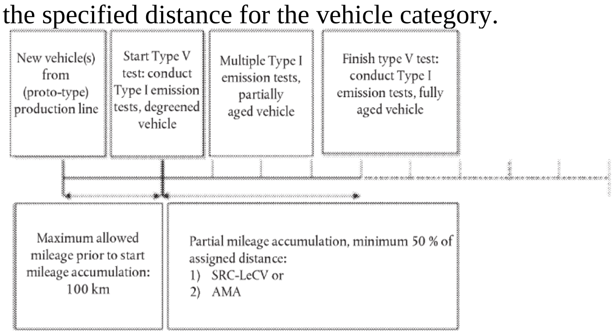

Figure 1 - Durability test procedure with partial distance accumulation (EURO 5)

As well as is done in the full mileage procedure, the manufacturer/importer must carry out several tests to verify the vehicle's emissions during the accumulation period, in order to obtain the linear regression equation representing the emission behavior of each pollutant throughout the vehicle aging.

With the equation obtained through emission values with at least 50% of the distance, it is then necessary to mathematically extrapolate up to the total distance specified by legislation.

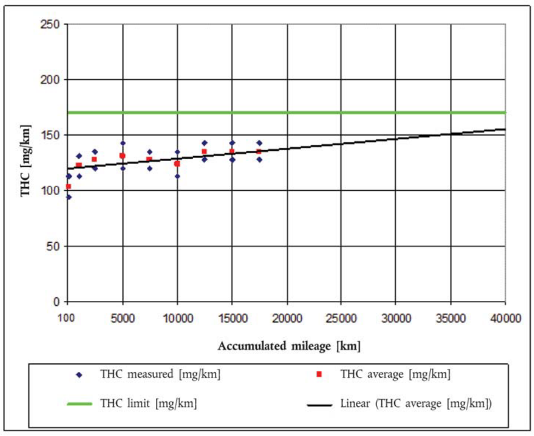

Figure 2 – Theoretical example of partial mileage (EURO 5)

In the end, it is necessary that all points of the obtained trend equation are below the current maximum emission limits for each pollutant, thus considering the completed durability.

2. STUDY

The objective of the study is to understand and evaluate the partial mileage durability. The vehicles used are described below:

-Quantity: 8 (different models);
-Brand: YAMAHA;
-Program: All PROMOT M4 homologated units;
-Fuels: 4 flex fuel models (gasoline/ethanol);
4 gasoline models;

All the models considered for the study are the vehicle families 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, being the main regulated gases in the environmental programs.

3. RESULTS

As these are official results, the emission values will be omitted so that the presentation will only be made graphically. The vehicle engine capacity will also be omitted to secure confidentiality.

To ensure a graphical visualization of the emissions behavior, a flex fuel vehicle is shown below as an example of the entire study, also to secure confidentiality. As example, the graphs below are related to model M01, showed in the compiled Table 1, where other all model results are listed.

The tested fuels in the study were:

- A22 (gasoline with 22% anhydrous ethanol);
- E100 (100% hydrous ethanol), and;
- A11H50 (mixture of 50% gasoline A22 and 50% hydrous ethanol).

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

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

-Black line: Linear regression line for full mileage accumulation.

-Red dot dash line: Linear regression line for partial mileage accumulation (50% of the full distance).

3.1 Emission deterioration results with A22 gasoline fuel

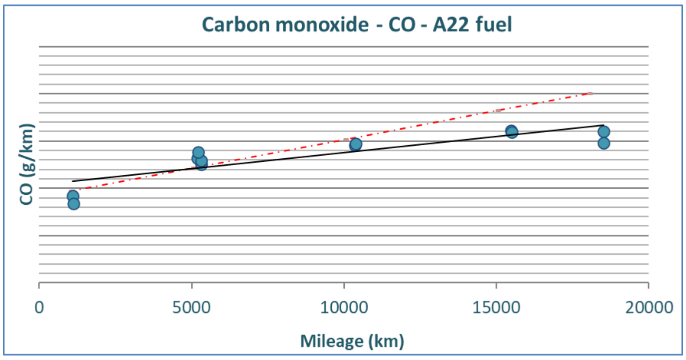

Figure 4 – Deterioration behavior of carbon monoxide with A22 fuel

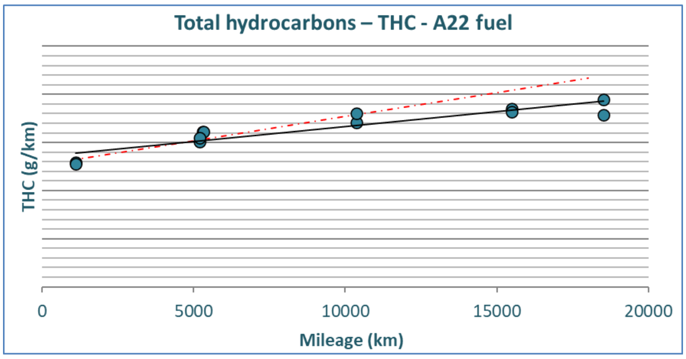

Figure 5 – Deterioration behavior of total hydrocarbons with A22 fuel

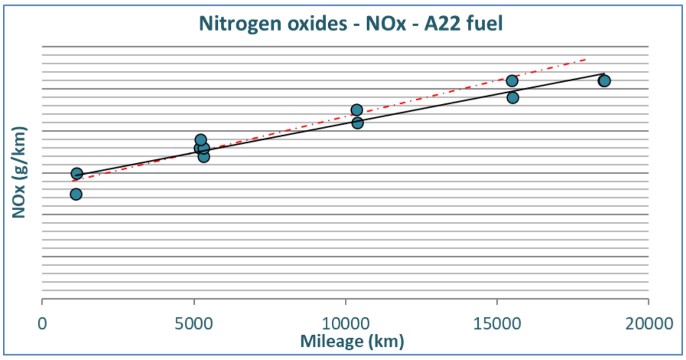

Figure 6 – Deterioration behavior of nitrogen oxides with A22 fuel

3.2 Emission deterioration results with E100 ethanol fuel

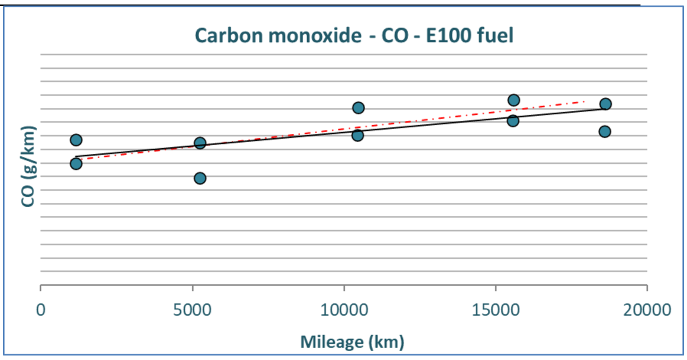

Figure 7 – Deterioration behavior of carbon monoxide with E100 fuel

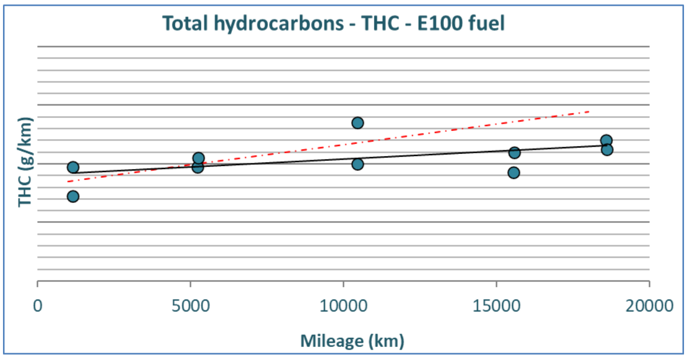

Figure 8 – Deterioration behavior of total hydrocarbons with E100 fuel

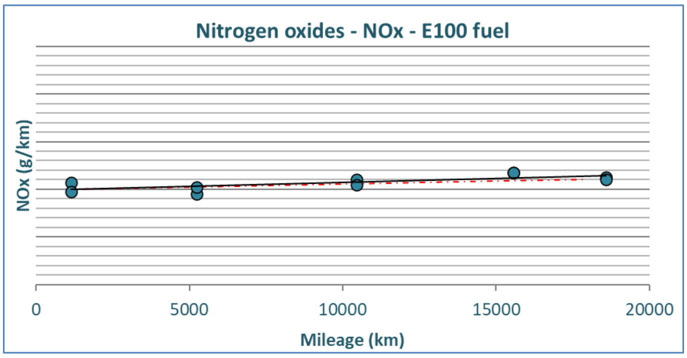

Figure 9 – Deterioration behavior of nitrogen oxides with E100 fuel

3.3 Emission deterioration results with A11H50 mixture fuel

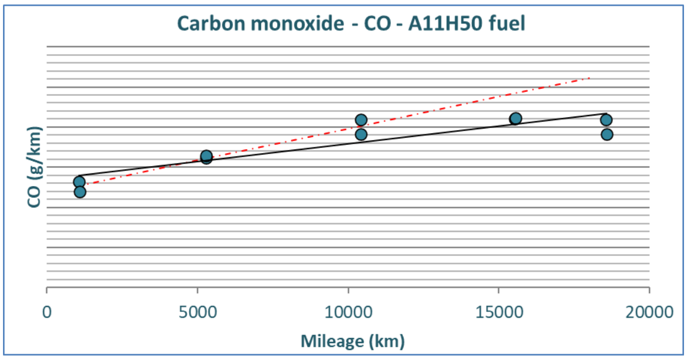

Figure 10 – Deterioration behavior of carbon monoxide with A11H50 fuel

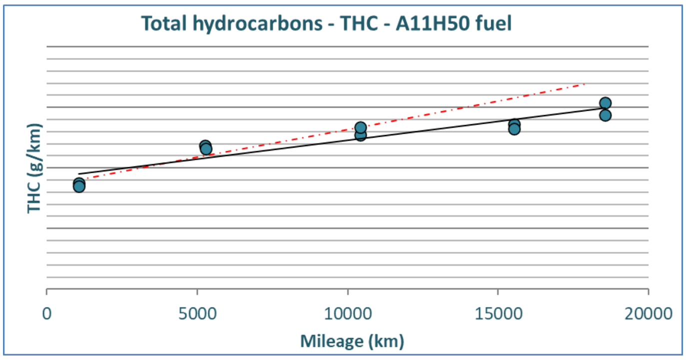

Figure 11 – Deterioration behavior of total hydrocarbons with A11H50 fuel

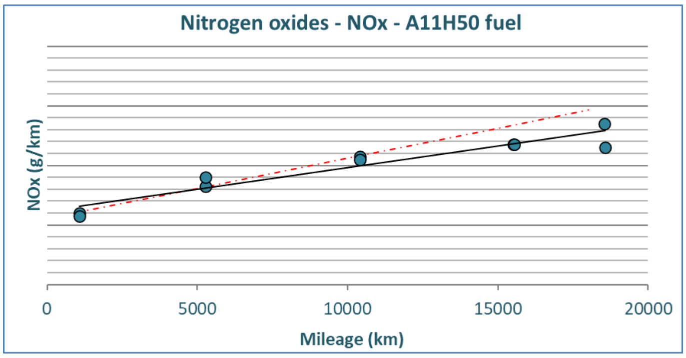

Figure 12 – Deterioration behavior of nitrogen oxides with A11H50 fuel

For purposes of comparison and data collection, the emission durability data of YAMAHA PROMOT M4 models are presented at Table 1, comparing the values of the full mileage with the simulated values if the partial calculation were performed.

Once more, to ensure confidentiality, real deterioration factors are represented as a base of 1,00. The partial 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			E100			A11H50		
		DF			DF			DF		
		REAL	PARTIAL	DIFF	REAL	PARTIAL	DIFF	REAL	PARTIAL	DIFF
M01	CO	1,00	1,302	30,2%	1,00	1,035	3,5%	1,00	1,192	19,2%
	THC	1,00	1,175	17,5%	1,00	1,071	7,1%	1,00	1,126	12,6%
	NOx	1,00	1,068	6,8%	1,00	0,964	-3,6%	1,00	1,141	14,1%
M02	CO	1,00	1,210	21,0%	1,00	0,916	-8,4%	1,00	1,003	0,3%
	THC	1,00	0,975	-2,5%	1,00	0,861	-13,9%	1,00	0,996	-0,4%
	NOx	1,00	1,035	3,5%	1,00	1,122	12,2%	1,00	1,090	9,0%
M03	CO	1,00	1,126	12,6%	1,00	0,984	-1,6%	1,00	1,002	0,2%
	THC	1,00	1,120	12,0%	1,00	0,846	-15,4%	1,00	1,071	7,1%
	NOx	1,00	1,078	7,8%	1,00	1,648	64,8%	1,00	1,134	13,4%
M04	CO	1,00	1,030	3,0%	1,00	1,024	2,4%	1,00	1,209	20,9%
	THC	1,00	0,833	-16,7%	1,00	1,000	0,0%	1,00	1,118	11,8%
	NOx	1,00	0,954	-4,6%	1,00	1,091	9,1%	1,00	1,036	3,6%
M05	CO	1,00	0,955	-4,5%	-	-	-	-	-	-
	THC	1,00	1,058	5,8%	-	-	-	-	-	-
	NOx	1,00	1,000	0,0%	-	-	-	-	-	-
M06	CO	1,00	1,388	38,8%	-	-	-	-	-	-
	THC	1,00	1,298	29,8%	-	-	-	-	-	-
	NOx	1,00	1,142	14,2%	-	-	-	-	-	-
M07	CO	1,00	1,367	36,7%	-	-	-	-	-	-
	THC	1,00	1,302	30,2%	-	-	-	-	-	-
	NOx	1,00	1,186	18,6%	-	-	-	-	-	-
M08	CO	1,00	1,031	3,1%	-	-	-	-	-	-
	THC	1,00	1,143	14,3%	-	-	-	-	-	-
	NOx	1,00	1,283	28,3%	-	-	-	-	-	-

4. ANALYSIS AND CONSIDERATIONS

It is possible to evaluate that 81.3% of the cases shown an deterioration factor (DF) of partial mileage greater than or equal to the DF of full running, that is, demonstrating that the linear regression equation considering the partial mileage leads to obtaining higher DF values.

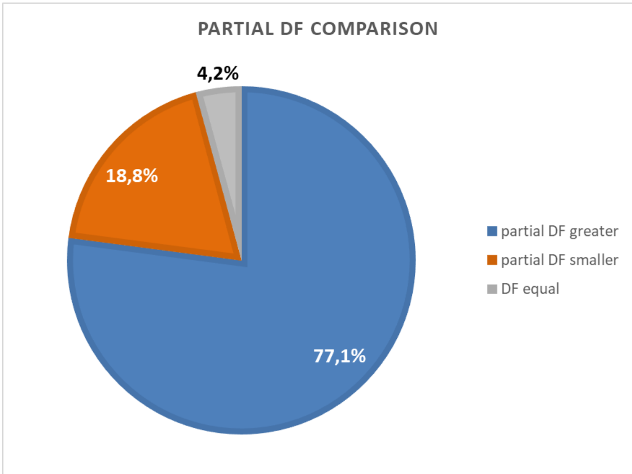

Figure 13 – Partial deterioration factor comparison

The fraction of "partial DF smaller" is the minority in this study (18%), this difference is regarded as small in the global mass of data. Note that all the models presented, without exception, had at least 1 pollutant in which the DF of partial mileage that was more critical, suggesting that all vehicles would be more difficult to comply the partial mileage accumulation DF than full mileage accumulation DF.

Considering the tested fuels, it is possible to analyze that the emission behavior has the same severity trend regardless of the fuel used. Although the partial durability was firstly regulated for European countries, whose main fuel is E5 (gasoline with 5% ethanol), the behavior with other amounts of ethanol, in this case studied with E100 and A11H50, showed that there are no objections or precautions. Higher concentrations of ethanol are a fundamental feature of the Brazilian market, which has developed amid the growth in the use of sugarcane.

It is important to note that the data collected do not show a destabilization of the emissions curve, such as, for example, a peak in emissions after the stabilized period. The motorcycle catalysts system used in the PROMOT M4 are composed of a metal substrate in the shape of a beehive, also containing precious metals such as platinum, rhodium and palladium, thus being more resistant in both vibration issue, as well as to the chemical and thermal deterioration suffered over time.

Analyzing the study, it is observed through the trend line that the deterioration behavior can be described, in general, in two main phases.

The first phase is related to the conditioning of the new catalyst and precious metals with heating to high temperatures, representing the beginning of the deterioration curve. After that, the trend is followed by a stabilization of heterogeneous catalysis reactions, resulting in catalytic conversions based on a constant deterioration equation. Summing up, there is a curve with a more accentuated behavior at the beginning, followed by a less accentuated and constant stabilization occurs, remaining until the end of the desired mileage.

The linearity of the emissions homologated according to PROMOT M4 was demonstrated in the study, and this construction of motorcycle catalysts system will be maintained for the PROMOT M5, however, the precious metals charge level will be increased in order to obtain a more efficient catalytic conversion, complying with the new emission limits.

5. CONCLUSIONS

The partial distance running tends to generate a linear regression equation with a greater slope than the slope generated by the full running method, as it considers more the emission stabilization phase.

The partial mileage has a more accentuated linear regression equation, since in its calculation the weight of the region of catalyst conditioning is significantly greater.

In general terms, according to the study, is possible to state that the DF values obtained through partial mileage are more severe than the full DF values. It is then necessary, during development, to evaluate the need for each vehicle project, the starting emission values and the lowest possible level of deterioration so that the model meets its durability.

Therefore, it is possible to perform and guarantee the total legislated distance for durability through the method of partial running produces a higher DF, that is, more severity for the manufacturer, since it will have to guarantee lower starting emission values.

It is also possible to conclude that partial mileage method should be used as an alternative to the other methods to determine the emission deterioration factors in the future. There is no technical advantage for manufacturers, as in partial mileage is harder to comply the emission limits due the higher resulting DFs. However, it brings to the manufacturers, importers and test laboratories a positive possibility of reducing the execution time of laboratory testing, as well as costs and expenses of the activity.

In terms of international harmonization, it is always important to align technical regulations, specifications, test methods and limit values in the main vehicle markets in order to have a strong and equitable product base among people around the world.

REFERENCES

[1] National Environment Council. (2011). *CONAMA Resolution 432/2011*. Brasília.

[2] National Environment Council. (2019). *CONAMA Resolution 493/2019.* Brasília.

[3] European Parliament. (2013). *Regulation (EU) 168/2013. Approval and market surveillance of two- or three-wheel vehicles and quadricycles.* Strasbourg.

[4] European Parliament. (2014). Commission Delegated Regulation (EU) 134/2014. *Environmental and propulsion unit performance requirements and amending Annex V thereof*