ALDEHYDES EMISSION CHARACTERIZATION OF PROMOT M4 MOTORCYCLES

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ABSTRACT

In this work, we show the characterization of aldehydes emission from exhaust muffler using various PROMOT M4 motorcycles with different engine displacements and fuel type.

The procedure used to quantify the total aldehydes was the ABNT NBR 16668, that is an standard developed specifically for 2 wheels and similar vehicles.

The motorcycles used in this work were all homologated in accordance with requirements of CONAMA Resolution No. 432 of 2011, commonly known as PROMOT 4.

The results suggest that the aldehydes emission amount tends to be higher for motorcycles with big engine displacement when compared with small engine motorcycles, which is to be expected. And the aldehydes level are very low for gasoline engines, if compared to the limit set for next gas emission phase, PROMOT M5.

Although, when we compare the results with gasoline and ethanol fuel in flex-fuel engines, it is shown that aldehydes emission with ethanol is about 7 times higher than with gasoline.

INTRODUCTION

Aldehydes are organic compounds of the carbonyl group, resulted by the oxidation of primary alcohols, dehydrogenation, or catalytic oxidation. It irritates the eyes and mucous membranes, it is toxic (carcinogenic) and it contributes to the formation of tropospheric ozone.

The control of aldehydes emission contained in the exhaust gases was first introduced for light vehicles in 1992 by CONAMA Resolution No. 03 of 1989, as PROCONVE [1] L2 phase.

Currently, the PROCONVE for light vehicles is in phase L6, in force since January 1st of 2014, which set the limit of 0,02 g/km for this pollutant.

For the motorcycles and similar vehicles, CONAMA instituted the PROMOT [2], by the CONAMA Resolution No. 297/2002. Currently, the PROMOT is at phase M4, in force since January 1st of 2014, which introduced the World-wide Motorcycle Emissions Test Cycle (WMTC), in accordance with the European Community Directive ECE/TRANS/180/Add2, and also set a new requirement and limit for evaporative emissions.

Finally, last year, CONAMA published the resolution No. 493 in June 24th of 2019. This resolution set the PROMOT M5 phase and defined the maximum limit for aldehydes emission as well as for other pollutants, according to table 1 below.

Table 1. Maximum limits of emission of pollutants in the dynamometric cycle for the PROMOT M5 phase.

Values stated in mg/km

Year	Models	CO	THC(1)	NMHC	NOx	PM(2)	Aldehydes	CO_2
01/01/2023	For the new	1,000	100	68	60	4.5	20 or 30 (3)	Inform
01/01/2025	For all	1,000	100	68	60	4.5	20	Inform

(1) Limit to be met only for vehicles using natural gas as fuel.
(2) Limit to be met only for vehicles with total or partial direct fuel injection system.
(3) Limit for motorcycles with maximum end speed higher than 130 km/h.
Source: CONAMA resolution No. 493 of 2019

Aldehydes emission for motorcycles was not introduced at PROMOT M4 phase mainly for two reasons: Lack of a specific procedure for motorcycles and lack of typical values of aldehydes emission to set a limit for motorcycles.

Thus, after the resolution of PROMOT M4 phase was published in 2013, several studies related to determine the characteristics of aldehydes emission in the motorcycles have been carried out.

In 2014, Szwarc et al. [3], using a popular 150 cc flex-fuel motorcycle, measured the aldehydes emission using E22 fuel (gasoline with 22% of anhydrous ethanol) obtaining the value of 6 mg/km with WMTC cycle and 1 mg/km with ECE R40 cycle [4]. In case of measurement using ethanol fuel, it was obtained 30 mg/km with WMTC cycle and 46 mg/km with ECE R40 cycle. The method to measure the aldehydes amount was based on the ABNT NBR 12026 [5], by using the HPLC (High Performance Liquid Chromatography) technic analysis.

Szwarc et al. concluded that aldehydes emitted by motorcycles are higher than cars and from tropospheric ozone formation point of view, it is 30% higher with ethanol when compared with gasoline and 3 times higher when compared with cars. However, the motorcycle used by Szwarc et al., was a PROMOT M3 motorcycle, which emission requirements are much less severe than PROCONVE L5 or L6 cars. The ideal is to compare the results by using a PROMOT M4 motorcycle. Current M4 phase is much more severe than M3 phase. Thus, it is important to better understand the behavior of aldehydes emission on PROMOT M4 motorcycles.

In 2016, Geraldi et al. [6] measured the aldehydes emission in various motorcycles with different engine displacements and fuel systems. All measurements were carried using the WMTC cycle and A22 fuel (Standard gasoline L6 mixed with 22% of standard anhydrous ethanol). The procedure used to determine the amount of aldehydes emission was the same procedure elaborated by the AEA's 2 wheels technical committee, based on ABNT NBR 12026, that originates the ABNT NBR 16668 [7], 2 years later.

Geraldi et al. concluded that motorcycles with big engine emit more aldehydes than motorcycles with small engine. Unless the differences of engine displacements or fuel systems, they also demonstrate that the measurement results of all the 9 motorcycles can easily meet the current limit of 20 mg/km set for passenger cars. However, it is necessary to observe that the results obtained by Geraldi et al. considered only the motorcycles with A22 fuel. It is not clear in case of flex fuel motorcycles that use ethanol fuel, if the aldehydes emission level can also meet the reference limit of 20 mg/km. Thus, it is important to better understand the behavior of aldehydes emission with ethanol fuel on PROMOT M4 flex fuel motorcycles.

1. OBJECTIVE

The objective of this work is to quantify and characterize the total aldehydes emitted by the current PROMOT M4 motorcycles. With these results, it is possible to have an overview of how much is the gap to comply with the limit set for next gas emission phase PROMOT 5.

2. METHODOLOGY AND PROCEDURES

The methodology and procedures adopted to determine the total aldehydes emission in this work followed the ABNT NBR 16668.

This standard was recently issued, and it is exclusive for 2 wheels and similar vehicles. It was elaborated by the AEA 2 wheels technical committee and the base standard was the ABNT NBR 12026, current used for light duty road vehicles. The principle of determination of aldehydes is by high performance liquid chromatograph (HPLC) and DNPH method.

The main differences of the two standards are shown at table 2:

Table 2. Differences between ABNT standards

Standard	NBR 12026	NBR 16668
Application	Light duty road vehicles	Motorcycles and similar vehicles
Drive cycle pattern	FTP75 cycle (NBR 6601 [8])	WMTC cycle (NBR 16369 [9])
Weighting factor for calculation	Cold phase: 0,43 Hot phase: 0,57	Class 1: - Part 1: 0,50 - Part 1 (hot): 0,50 Class 2: - Part 1: 0,30 - Part 2: 0,70 Class 3: - Part 1: 0,25 - Part 2: 0,50 - Part 3: 0,25

2.1. LABORATORIES AND EQUIPMENT – The measurements were carried in 3 different laboratories. Due to confidential issues, the list of used equipment will not be described here, although all 3 laboratories are accredited by IBAMA to perform motorcycle gas emission homologation. Also, the laboratories are participants of the INMETRO EP program for motorcycles emission.

2.2. TEST FUELS – The fuels used were gasohol A22 (Reference Gasoline mixed with 22% of Reference Anhydrous Ethanol) and EHR (Reference Hydrated Ethanol) as specification defined by ANP regulation.

2.3. TEST MOTORCYCLES – All motorcycles used in this work were homologated and are complying with the gas emission limits defined by PROMOT M4 regulation. They were divided by classes following the vehicle classification in terms of engine capacity and maximum vehicle speed as show at table 3.

Table 3. Vehicle classification for gas emission testing

Class	Subclass	Description
1	-	engine capacity < 150 cm^3 and Vmax < 100 km/h
2	2.1	engine capacity < 150 cm^3 and 100 km/h ≤ Vmax < 115 km/h or engine capacity ≥ 150 cm^3 and Vmax < 115 km/h
	2.2	115 km/h ≤ Vmax < 130 km/h
3	3.1	130 km/h ≤ Vmax < 140 km/h
	3.2	Vmax ≥ 140 km/h

Class 1 – In this class, there were 2 models with usual engine capacity of 125 cc and both are flex-fuel engines.

Class 2, subclass 2.1 – In this class and subclass, there were 5 models with usual engine capacity between 150 cc and 160 cc and all models are flex-fuel engines.

Class 2, subclass 2.2 – In this class and subclass, there were 5 models with usual engine capacity between 250 cc and 300 cc and all models are flex-fuel engines.

Class 3, subclass 3.1 – There were no models in this subclass.

Class 3, subclass 3.2 – In this class and subclass, there were 3 models with usual engine capacity between 600 cc and 800 cc and all models are only gasoline engines.

3. RESULTS AND ANALYSIS

The results were separated by fuel type and classes. For each class and subclass, it is shown the average, the maximum and the minimum values of the total aldehydes (formaldehydes + acetaldehydes) expressed in mg/km.

3.1 RESULTS WITH GASOOL A22 – The results of total aldehydes measurements with gasool A22 are shown at table 4 and figure 1.

The highest value of total aldehydes emission measured with gasool A22 was 5,7 mg/km, observed in a motorcycle of class 3. The class 3 motorcycles also presented the highest average of 2,8 mg/km.

This is an expected result, considering the size of engine that requires a high amount of fuel into the cylinders. Another factor that can increase the total aldehydes into the gas exhaust is the third part of drive cycle pattern in high speed that is required only for class 3 motorcycles.

Table 4. Measurement results with gasool A22

Class	Subclass	Total aldehydes (mg/km)		
		Min.	Ave	Max.
1	-	1,2	2,1	2,7
2	2.1	1,3	1,4	1,5
	2.2	0,9	1,5	1,9
3	3.2	1,1	2,8	5,7

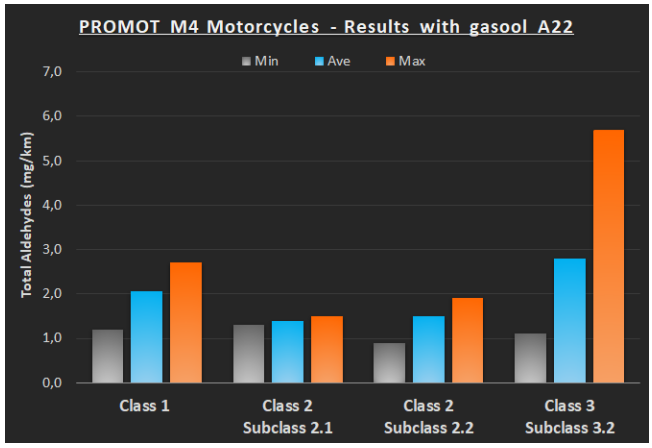

Figure 1. Aldehydes measurements with gasool A22

In general, the total aldehydes emission amount of PROMOT M4 motorcycles with gasool A22 were very low with average between of 1,5 to 2,8 mg/km. As reference, the current aldehydes emission limit set by PROCONVE L6 for light vehicles is 20 mg/km.

3.2 RESULTS WITH EHR – The results of total aldehydes measurements with EHR are shown at table 5 and figure 2.

Table 5. Measurement results with EHR

Class	Subclass	Total aldehydes (mg/km)		
		Min.	Ave	Max.
1	-	7,1	11,2	15,6
2	2.1	6,9	9,4	18,0
	2.2	8,0	14,8	31,0

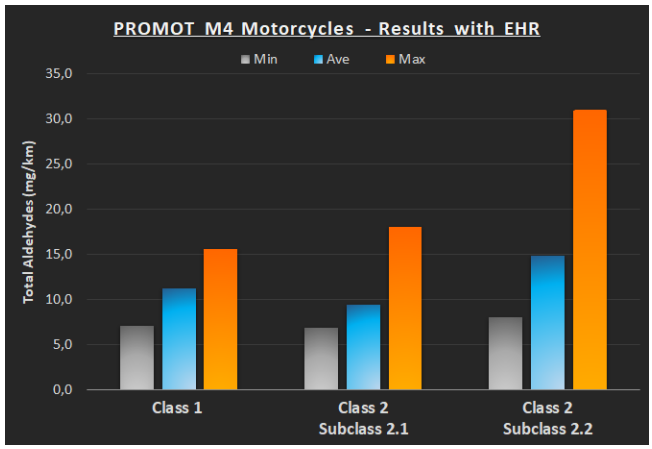

Figure 2. Aldehydes measurements with EHR

In case of EHR fuel, the highest value of total aldehydes emission measured was 31,0 mg/km, observed in a motorcycle of class 2, subclass 2.2. And the average for this subclass was 14,8 mg/km.

Measurement results for class 1 (125cc engines) and class 2, subclass 2.1 (150cc to 160 cc engines) were similar with average around 10 mg/km. The minimum value was 7,1 mg/km and the maximum value was 18,0 mg/km.

3.3 ANALYSIS – It is known that aldehydes emission amount of Otto cycle engines is direct related to the content of ethanol mixed into the gasoline.

Comparing the aldehydes emission results between gasohol A22 and EHR, by taking the average of all classes, EHR emits about 7 times more than gasool A22.

Comparing the EHR results with the limits set by PROMOT M5 phase, confirm that additional development is necessary to adapt current PROMOT M4 motorcycles, but only for those with flex-fuel engines.

CONCLUSION AND CONSIDERATIONS

Through this work developed by the AEA 2-wheels technical committee, it was possible to characterize the total aldehydes emission for a wide range of PROMOT M4 motorcycles and different fuels.

Aldehyde emissions for gasoline engines motorcycles are already in comply with the limit established by the PROMOT M5. In the case of flex-fuel engine motorcycles powered by ethanol, aldehyde emissions are close to the limit and in some cases even higher, demonstrating that they will need to be developed to adequate the current levels of aldehyde emissions.

Considering that the measurement and control of aldehyde emissions on motorcycles is an exclusive requirement to Brazil and that the limits established for PROMOT 5 will only impact flex-fuel motorcycles, this creates a burden to the development of these vehicles. Depending on the difficulty of adaptation and development cost, this new requirement may inhibit future projects and even exclude the option of using ethanol in these vehicles.

It is very important to control and continuously seek to reduce the levels of harmful gas emissions emitted by the exhaust of motorcycles, but at the same time, special care must be taken when we create or establish exclusive or very strict criteria that sometimes differ with the regulation of others countries.

Brazil's relevance within the global two-wheel market is small, so that when there are new requirements, they will not always be prioritized within the development of other markets. Thus, the lack of harmonization between regulations can create restrictions in the development of new products for the Brazilian market. This is not the case with the PROMOT M5, which is well aligned with the EURO 5 guidelines, except for aldehydes emission due to the use of ethanol in Brazil, and the acceleration noise emission.

Brazil is the exclusive market where ethanol is used as an alternative fuel and following the cars, flex-fuel motorcycles were developed. But in recent years, the Brazilian economic and political scenario has neither favored nor encouraged its use and expansion. Therefore, the maintenance of flex-fuel technology, that offer the option for using ethanol, in the motorcycles is becoming questionable in terms of cost. Comparing to cars, the impact to dilute this additional cost into the motorcycle cost is very high.

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