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THE USE OF PROFICIENCY TESTING SCHEMES FOR MOTORCYCLE EXHAUST EMISSIONS LABORATORY

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Abstract: In this work the Proficiency Testing Scheme (PTScheme) has been used for evaluation of the laboratories of motorcycle emissions to measure the emission levels of this kind of vehicles, supplying subsidies to the laboratories to identify and solve analytical problems and contributing for the measurement harmonization in the country. The PTScheme of automotive emissions is a type of study, provided only in Brazil and it was the first time that this procedure was carried out for motorcycles. Such proficiency test showed satisfactory results and show the importance for the industry, society and environment.

Keywords: PT Scheme, motorcycle emissions, gas analysis.

1. INTRODUCTION

The problem of the air pollution constitutes a serious problem to the human health, diminishing its quality of life. The vehicles are potential source of this pollution in everywhere. The automotive emissions of gases load diverse toxic substances that in contact with the respiratory system can produce some negative effect on the health. In the last 10 years, Brazilian automotive fleet doubled and during this period, motorcycle fleet increased four times[1]. Thus, the emission levels for this kind of vehicle must be evaluated [2] as it is already carried out for automobiles [3].

A PTScheme has the purpose to compare measurement results of different laboratories carried out under similar conditions and to have a continuous evaluation of the performance of the participating laboratories [4,5]. This evaluation is made through the results generated by interlaboratory comparisons that constitute an adjusted mechanism to evaluate and demonstrate the quality/trueness in the measurements carried out by the participants. This process is well established for automobiles with 5 accomplished rounds since 2004 [6-8], but for motorcycles it is the first time that such proficiency test is carried out. With the final report, the participant laboratories have the chance to review their analysis procedures, as well as implementing improvements in their processes.

In this work we report a proficiency test for motorcycle exhaustion emissions laboratory where the following parameters were determined: CO, CO_2, NO_x, THC, total aldehydes and autonomy. In order to verify if there was any difference in population distribution, the average results obtained by each laboratory were compared using Kruskal-Wallis test. Outliers were evaluated using box-plot. The main purpose of this first proficiency test in motorcycles was to compare the analysis results obtained by each laboratory, not to evaluate the laboratory performance.

2. METHODOLOGY

The methodology for accomplishment of the PTScheme was established in protocol [9], where the predetermined characteristics of the test motorcycles, the logistics of transportation, schedule of execution and the definition of the parameters to be analyzed are defined. Two different vehicles were used in this proficiency test: One 150 cc ethanol-fuelled motorcycle and the other one was a 250 cc gasoline-fuelled.

Seven different laboratories participated in this first round; each one received a code in order to assure the confidentiality of the test. The parameters under evaluation were carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), total hydrocarbons (THC), urban autonomy and total aldehydes. For this late parameter, the participation was optional and the participating labs received a different codification.

The laboratories carried out the tests in accordance with directive 97/24/EC, ABNT NBR 12026 for aldehyde determination and ABNT NBR 7024 for autonomy determination.

The measurement results express the amount of pollutants emitted for a light vehicle of the Otto cycle (CO, CO_2, total NO_x, THC, and Aldehydes), expressed in g/km and urban autonomy in km/L. The methodology of the testing describes situations, simulated in chassis dynamometer, of departure (in cold state), situations in urban transit and departure in hot state one. Following those situations, the functioning of a vehicle can be reproduced with description of repeatability proven in standardized situations of transit.

To compare the average results for all participants, *Kruskal-Wallis* test was carried out for each analyzed parameter. This test is based on the following hypothesis: H_0 – there is no difference on the population distribution; H_a – There is difference on the distribution. Equation 1 shows the *Kruskal- Wallis* statistics.

$$H = \frac{12}{N(N+1)}\left(\frac{R_1^2}{n_1} + \frac{R_2^2}{n_2} + \ldots + \frac{R_k^2}{n_k}\right) - 3(N+1) \quad (1)$$

Where, “n” is the number of replicates for each laboratory (in this proficiency test 3 replicates), “N” is the number of participant laboratories (N=7), “R_i” is the rank sums of each sample and “H” is *Kruskal-Wallis* value.

If any parameter shows difference on the distribution, it was identified which pair of specific means of the participants differs significantly, as shown in equation 2:

$$\left|\overline{R_j} - \overline{R_i}\right| \le Z_{\propto/k(k-1)} \sqrt{\frac{N(N+1)}{12}\left(\frac{1}{n_j} + \frac{1}{n_i}\right)} \quad (2)$$

Where “R” is the rank of j and i populations, “N” is the total results number, “n” is the replicate number for each laboratory, “k” is the number of the participants in the proficiency test and “α” is the confidence level. In this work, we used 95%.

The box plot is a useful graphical display for describing the behaviour of the data in the middle as well as at the ends of the distributions [10,11]. The box plot uses the median and the lower and upper quartiles (defined as the 25^{th} and 75^{th} percentiles). If the lower quartile is Q1 and the upper quartile is Q3, then the difference (Q3 - Q1) is called the interquartile range or IQ. A box plot is constructed by drawing a box between the upper and lower quartiles with a solid line drawn across the box to locate the median. The following quantities (called *fences*) are needed for identifying extreme values in the tails of the distribution

1. lower inner fence: Q1 - 1.5*IQ
2. upper inner fence: Q3 + 1.5*IQ
3. lower outer fence: Q1 - 3*IQ
4. upper outer fence: Q3 + 3*IQ

A point beyond an inner fence on either side is considered a **mild outlier**. A point beyond an outer fence is considered an **extreme outlier**.

For outliers detection and evaluation, box-plot was then used.

3. RESULTS

Gasoline-fueled motorcycle

Figure 1 (a-f) shows the distribution of the mean results for each studied parameter in this proficiency test. In graphs, solid lines correspond to the mean of the results and the dashed ones, the median. In all cases, for 95% confidence level, a significant difference in the data distribution was observed ($p_{calculated} < 0.05$). For Aldehydes (figure 1-f), just three participants carried out the analysis. To evaluate the difference between pairs of means among laboratories Equation 2 it was used. As significant differences among the mean results distribution were observed for all the studied parameters, it was then identified which specific mean from a certain participant differs from others. For CO determination, 21-98 and 93-98 pairs show significant differences between their means. For CO_2, the pair 81-98 showed significant difference between their mean results. Pair 93-98 showed such behaviour for THC determination, while for NO_x, pair 21-93, their means are different. For autonomy, pair 55-98 showed significant difference between their means.

For total aldehydes parameter, the mean results for laboratories AT-70 and AT-96 are statistically different.

Finally, the outliers we evaluated for all parameters, as shown in figure 2. There are no outliers for almost all studied parameters, except for autonomy (figure 2-e) where laboratory 98 showed results above calculated upper limits.

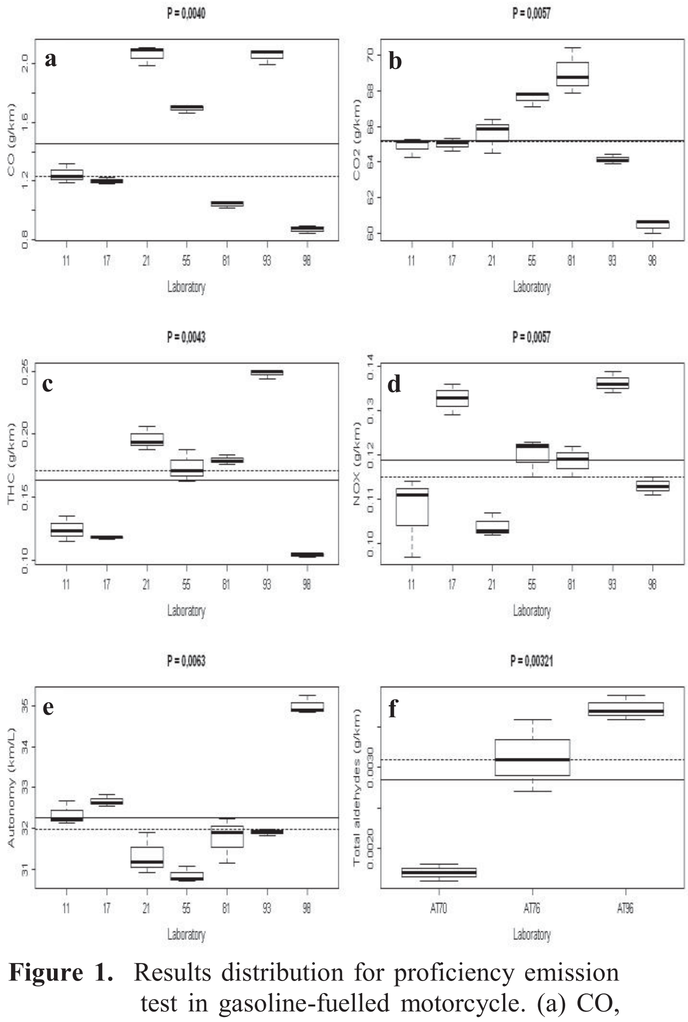

Figure 1. Results distribution for proficiency emission test in gasoline-fuelled motorcycle. (a) CO, (b) CO_2, (c) THC, (d) NO_x, (e) autonomy and (f) total aldehydes.

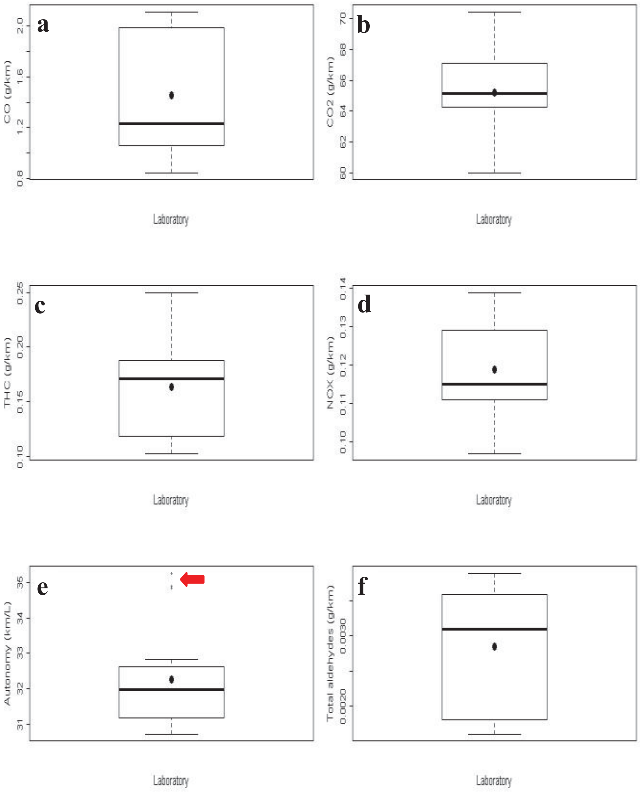

Figure 2. Box-plot for proficiency emission test in gasoline-fuelled motorcycle. a) CO, (b) CO_2, (c) THC, (d) NO_x, (e) autonomy and (f) total aldehydes.

Ethanol-fuelled motorcycle

As shown in figure 3 (a-f), for ethanol-fuelled based motorcycle, a significant difference in the population distribution was also observed. For CO determination, laboratories 11-21 and 11-81 show significant statistical differences between their means. For CO_2, the pair 81-98 showed significant difference between their mean results. Pair 21-55 showed such behaviour for THC determination, while for NO_x, pair 17-81, their means are statistically different. For autonomy, laboratories 11-81 and 81-93 showed significant difference between their means. For aldehydes, the mean results for laboratories AT-76 and AT96 significantly differ.

Laboratory 81 showed outlier results for two parameters, as shown in figure 4: CO_2 (figure 4-b) and autonomy (figure 4-e). For the first one, the values were above the upper calculated limits while for autonomy parameter, results showed the opposite behaviour.

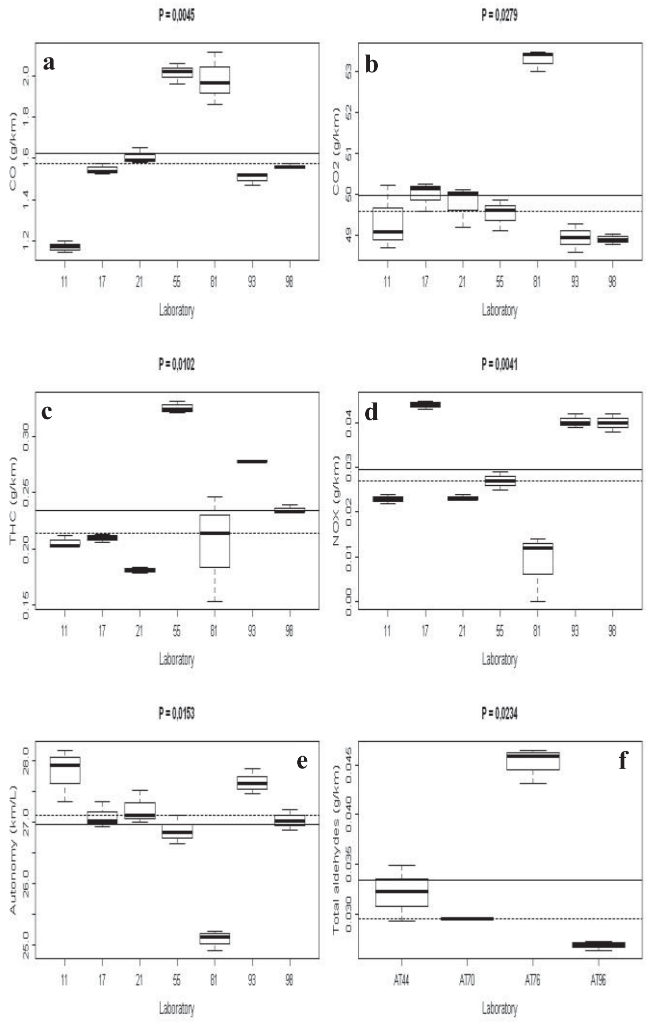

Figure 3. Results distribution for proficiency emission test in ethanol-fuelled motorcycle. a) CO, (b) CO_2, (c) THC, (d) NO_x, (e) autonomy and (f) total aldehydes.

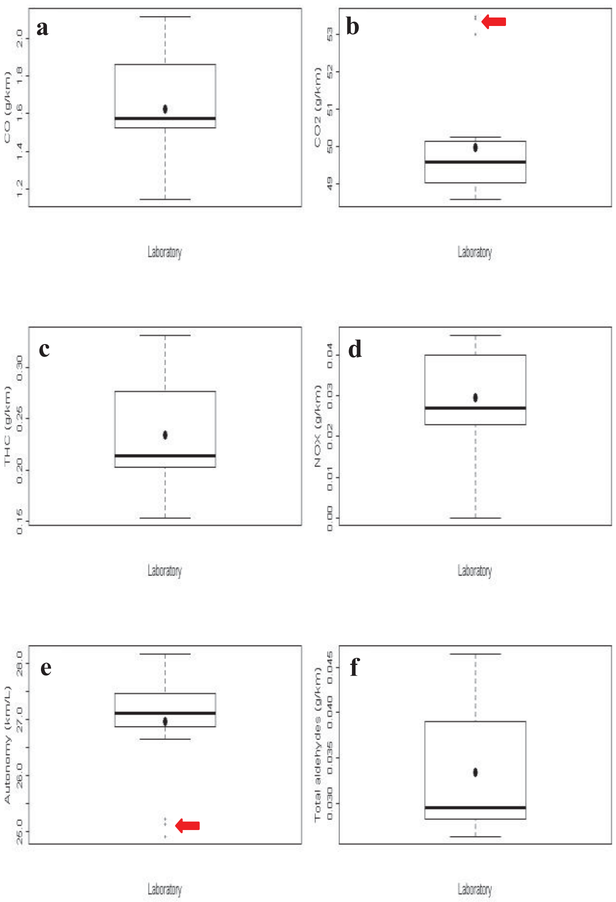

Figure 4. Box-plot for proficiency emission test in ethanol-fuelled motorcycle.

4. CONCLUSIONS

Proficiency tests in vehicle emissions is a study carried out in Brazil and as it is the first one carried out for motorcycles, the results can be considered satisfactory and it must be continued in order to improve emissions laboratory processes. The continuity of this program is very important for all players involved in the process: emission labs, automobile industry, government regulating agencies and the society.

The coefficient of variation for gasoline-fuelled motorcycle ranged from 4.2% for CO_2 determination to 36.6 % for aldehyde determination, while for alcohol-fuelled motorcycle this coefficient ranged from 3.3% for autonomy to 42.9% for NO_x. As the concentration levels of the analite decrease, the variation among the results clearly rises.

The proficiency emission test has a large variable numbers that have direct impact on the obtained results and even if in this first round the lab performances weren´t evaluated, it is necessary that each participant make a critical analysis concerning the measurement processes. A second round of this proficiency test is in progress in 2013.

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