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# SPEED MEASUREMENT UNCERTAINTY IN METROGICAL VERIFICATIONS AT IPQ

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**Abstract** – The speed measurement results of metrological verification of speedometers in the Portuguese Institute for Quality are presented. The associated measurement uncertainties are then taken into account. The measurement methodology and the results of nearly one hundred measuring instruments, with the uncertainty values are displayed and compared with the national maximum permissible errors. The results seem to suggest that the speed maximum permissible errors, for the metrological verifications, have to be changed.

**Keywords**: speedometer, uncertainty, MPE

## 1. INTRODUCTION

The Portuguese Institute for Quality (IPQ) is responsible for the Metrological Control of speedometers in Portugal [1]. At the IPQ, the Cinemometry Laboratory performs the tests of the different operations of the Metrological Verifications and the necessary tests for approving a new type of speedometer. On-the-road tests of speed measurements are performed so that the error of the measured speed be in conformity with the maximum permissible error (MPE) values published in the national Regulation for the corresponding kind of speedometers [2]. Of course, the methodology used for the measurements leading to display the measurement result, with its associated expanded uncertainty, is the same that the one the calibration of a speedometers, where the speed as the quantity of interest. The measurement result allows to decide about the conformity of the measuring instrument, regarding its MPE. In this communication, after displaying the methodology used for the speed measurements by the IPQ's Cinemometry Laboratory, measurement results of the many speedometers by Doppler's effect submitted to the metrological verifications in Portugal will allow to question the importance of the associated expanded uncertainties values with respect to its MPE. In particular, the tolerance, that is the difference between the upper and the lower MPE, of the measured speed values with the measuring instrument will be considered in the light of the published standards [3] and literature [4].

## 2. MEASUREMENT METHODOLOGY

In Portugal, the principle of working of 80 % of the speedometers used by the enforcement institutions is based on Doppler's effect. These speedometers are also well-known as radar speedometers. Almost all of these measuring instruments (MI) are of the same type. The other 20 % of the speedometers are car video systems that pursue the offender with the same speed, at constant distance from it. Therefore, our measurement methodology for the metrological operations and for the calibration too, that consists on comparing the speed measured by the MI with the one measured by a reference speedometer, has to be adapted to the kinds of MI.

Thanks to an agreement between the Portuguese Air Force (PAF) and the IPQ, the Cinemometry Laboratory is allowed to perform the speed measurements in a free airstrip of a PAF's disabled airport with a car at controlled and determined speed values. There, the MI to be verified, or to be calibrated, are located on the sides of the airstrip measuring the speed of the target car, passing many times at different controlled speeds values. According to the metrological operation, 3 or 5 speed runs are performed for the speed values of the set {50; 70; 90; 110; 130} km/h.

Two kinds of reference speedometers can then be used. Either a fixed one is located at one side of the airstrip, measuring speed values, or a mobile one is installed in the target car. The uncertainty budgets of the two reference speedometers are comparable. As it is a more versatile reference MI, for instance, also allowing the verification of the pursuing speedometers, the latter kind of reference speedometer is preferentially used.

The measurement results presented in this communication were obtained with a GPS receiver installed in the moving target car. It is a Garmin GPS76 that has speed resolution and a speed precision of 0,1 km/h. This reference MI was calibrated by the METAS' Traffic Laboratory. From the corresponding calibration certificate [5], it is possible to know that the measured speed, $v_{\mathrm{R}}$, presents the following error, $e_{v,\,\mathrm{R}} = v_{\mathrm{R}} - v_{\mathrm{V}}$, with respect to the conventional speed value, $v_{\mathrm{V}}$ and the standard uncertainty, $u_{e\ v,\ \mathrm{R}}$. During the measurement, the reference MI sends information of the date, time, position and speed, at a 1 Hz continuous update rate, to a laptop. The speed value given by the reference MI, $v_R$, is then the average of, at least, 30 values with the corresponding standard deviation, $s_{v,\,R}$, for the run of a given speed.

After the $k$ runs of any speed value, measured by the MI in verification, $v_{IM}$, its standard deviation, $s_{v,\,IM}$ and the corresponding values of the reference speedometer are calculated. It is then possible to deduce the MI measurement error, which is equal to: $e_{v,\,IM} = v_{IM} - v_V = v_{IM} - v_R + e_{v,\,R}$ and the associated uncertainty:

$$u_{e_{v,\mathrm{IM}}} = \sqrt{{u_{v_{\mathrm{IM}}}}^2 + {s_{v_{\mathrm{R}}}}^2 + {u_{e_{v,\mathrm{R}}}}^2} \qquad (1)$$

where the square of $u_{v,\,IM}$ is the quadratic sum of the MI standard deviation $s_{v,\,IM}$ and of the MI resolution standard uncertainty $u_{res.,\,IM}$.

The evaluation of the measurement result follows the propagation law of uncertainties [6], considering no correlation between the different quantities. The sensibility coefficients are easily determined and the Welch-Satterthwaite's relationship is used to deduce the effective degree of freedom, leading to the covering factor, through the inverse $t$ Student's distribution. As a matter of fact, it is always found that $k \approx 2$.

## 3. RESULTS

When considered the maximum observed errors obtained for nearly 100 different radar speedometers in verification and the associated expanded uncertainty, after their metrological verification, it is expected to deduce some tendencies. On Figure 1, are displayed the results corresponding to these data for measured speeds lower than 100 km/h (Figure 1a) and measured speeds greater than 100 km/h (Figure 1b). The corresponding average errors are also displayed and they are equal to (1,8 ± 1,2) km/h and to (2,0 ± 1,3) %, respectively, as, for speeds greater than 100 km/h, the relative speeds are displayed.

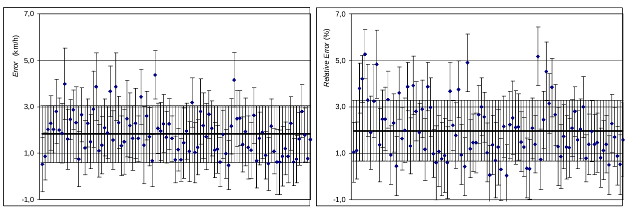


Fig. 1. Errors and uncertainties for results obtained a) at speed values lower than 100 km/h and b) greater than 100 km/h with the respective average error value (bold line).

All speeds values displayed in Figure 1 comply for the official Maximum Permissible Error (MPE) upon speed. The MPE value is equal to 5 km/h, for speed values lower than 100 km/h or 5 % of the speed value, for speed values greater than 100 km/h. However, if the value of the associated speed uncertainty is considered, instead of the mere speed value, a few results lie outside the MPE limits. Traditionally, different cases with respect to the conforming are studied [3]. Stated in the ISO 14253-1 for geometrical product specifications and also used for weighing instruments [4], they can be summarized as follows. When the sum of the error and the uncertainty lies inside the MPE, we are with a conforming case. When the error value only lies in the MPE, but its sum with the uncertainty lies outside the MPE, the case may be decided to be conforming according to the national regulation. By the same token, if the error value lies outside the MPE but its sum with the uncertainty is inside the MPE, a national regulation may also consider it to be a conforming case. Finally, when the sum of the error and the uncertainty lies outside the MPE, it is a non-conforming case. A rule of the thumb about the confirming cases is that if the measurement uncertainty is less or equal to one third of the MPE, then it should be taken into account for the conformity decision [4].

As, in Figure 1, the observed measurement uncertainty values are always lower than one third of the Portuguese regulation MPE value, the latter should be adapted in order to take into account the uncertainty values. A possibility to solve this problem would be to increase the Portuguese MPE to the measurement uncertainty value.

## 4. CONCLUSIONS

The Cinemometry Laboratory of the Portuguese Institute for Quality displayed, for the first time, the speed measurement uncertainty values of nearly all the radar speedometers in metrological verification, in Portugal. The conformance of the measured speed errors with the Portuguese regulation and an approximatively 1 km/h uncertainty value were evidenced. However, the small value of the measurement uncertainty seems to suggest that the speed measurement Portuguese MPE needs to be changed, for the metrological verifications.

For the type approval speed tests, as the MPE are smaller than for the metrological verifications, the Portuguese regulation should remain unchanged.

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