Evaluation of Manual and Automatic Calibration Methods for Digital Tachographs

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Abstract**—**This paper presents a quantitative analysis on the need for automotive calibration methods for digital tachographs. Digital tachographs are mandatory for vehicles used in people and goods transport and they are an important aspect for road safety and inspection. Digital tachographs need to be calibrated for workshops in order for the digital tachograph to display and record speed and odometer values correctly. Calibration of digital tachographs can be performed either manual or automatic. It is shown in this paper that manual calibration of digital tachographs is prone to errors and there can be differences between manual and automatic calibration parameters. Therefore automatic calibration methods are imperative for digital tachograph calibration. The presented experimental results and error analysis clearly support the claims of the paper by evaluating and statistically comparing manual and automatic calibration methods.

Keywords**—**Digital tachograph, road safety, tachograph calibration, tachograph workshops.

I. INTRODUCTION

DIGITAL tachographs are used to monitor vehicle and driver driving activities (such as driving times, work times, and break times) as well as events (such as overspeeding, vehicle control, and places) for goods and passenger vehicles. In Europe the digital tachograph has been mandatory for good and passenger vehicles since 01 May 2006 [1]. The digital tachograph records driver and vehicle activities of interest within the vehicle unit (tachograph) itself as well as the inserted cards, depending on data of interest.

The Digital tachograph is required to store [2]

- Date
- Vehicle registration number
- Vehicle speed (for past 24 hours of driving and overspeeding)
- Single driving or co-driver availability
- Card insertion and withdrawals
- Distance travelled
- Driver activities (driving, rest, other work, availability)
- Date and time of any activity change
- Events (overspeeding, driving without a driver card, etc.)
- Faults (internal faults, sensor faults, etc.)
- Controls by enforcement officers
- Tachograph calibration records

The digital tachograph systems consists of the vehicle unit (VU) (usually referred to as the tachograph itself) (2), motion sensor (1), and smart cards (4) used in the system as shown in Fig. 1. The VU is also used to drive the vehicle cluster (3).

Fig. 1 Components of the tachograph system

The VU receives the speed signal from the motion sensor. It then calculates the current speed (according to calibration parameters) and also updates the odometer value. The VU provides information, such as time, speed, odometer value etc. to the vehicle cluster. There are four types of tachograph cards: Driver, control, workshop and company cards. Driver cards are provided for vehicle drivers and are used to keep information related to activities of the driver. Control cards are used by control authorities to provide enforcement checks. Company cards are used by companies to isolate company related data. The insertion of a company card enables tachograph data download for companies. Workshop cards are provided to workshops and are required for the installation and calibration of the tachograph unit.

In [3], it is noted that the tachograph concept goes back to 1950, but only the recent development of Intelligent Transport System (ITS) technologies has enabled the possibility to improve the design of regulated applications to take full advantage of new technologies. In [4], it is noted that although there is no perfect way to safely retain data in the worst scenario, a way to reliably store data in the tachograph without data loss at an accident is needed.

This paper focuses on one of the most important tasks required for correct deployment of the tachograph system, namely the calibration process. The paper introduces possible calibration approaches and provides an evaluation of available methods. It is shown that manual calibration methods are prone to introduce errors in the calibration process and automatic approaches are in order to reduce inaccuracies.

II. TACHOGRAPH CALIBRATION

Calibration of a tachograph is a mandatory task that takes

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place after installation, repair or periodic maintenance and is performed by vehicle manufacturers or workshops. The tachograph is initially in the manufacturer mode, which is a pre-activation mode that enables entry of calibration parameters and vehicle related information into the VU. The calibration process is an important aspect of current first-generation tachograph systems as well as future smart tachographs [5].

There are a number of calibration parameters that are stored or updated in a VU by means of the calibration process:

- Current UTC date and time
- Current odometer value
- The effective circumference of the vehicle wheels (L-factor) and the tire size
- The overspeed limit value
- The vehicle registering country
- The vehicle registration number (VRN)
- The vehicle identification number (VIN)
- The VU constant value (**K**-factor)

The calibration parameters can be verified through the technical printout of the VU. A typical technical printout is provided in Fig. 2, in which the corresponding fields depict:

1. Date and time (UTC time).
2. Printout Type Pictogram (Technical Data Printout).
3. Surname and Name of Workshop Card Holder.
4. Card number and card expiry date.
5. Vehicle Identification Number (VIN), Vehicle Registration Number (VRN) and authorizing member state.
6. Tachograph manufacturer.
7. Tachograph part number.
8. Tachograph approval number.
9. Tachograph serial number, manufacture date, equipment type and manufacture date, equipment type and manufacture code.
10. Year of manufacture.
11. Version and installation date of the software
12. Motion sensor serial number.
13. Motion sensor approval number.
14. Date of initial installation of the motion sensor.
15. Workshop performing the calibration.
16. Address of the workshop.
17. Number and authorizing member state of the workshop card.
18. Expiry date of the workshop card.
19. Date of calibration.
20. Vehicle Identification Number (VIN).
21. Vehicle Registration Number (VRN) and authorizing member state.
22. Characteristic coefficient of the vehicle.
23. VU Constant.
24. Diameter of tire.
25. Tire size.
26. Speed setting.
27. Old and new odometer values.

The VU constant (K-factor) is important since it represents the number of pulses the tachograh receives from the motion sensor for one kilometer of distance. This value changes from vehicle to vehicle and needs to be determined during the calibration process so that the tachograph VU can accurately calculate speed and distance. In other words, the tachograph unit expects to receive K pulses from the motion sensor for each kilometer (km) of travel. The K-factor is to be determined by the workshop correctly for the tachograph to calculate, display and record driving activities appropriately. Once this value is loaded into the tachograph, the VU can accurately calculate speed and traveled distance by accumulating pulses received from the motion sensor. The accurate calculation of speed and distance is important as the tachograph is used to enforce driving legislations and any infringements are subject to penalties [6].

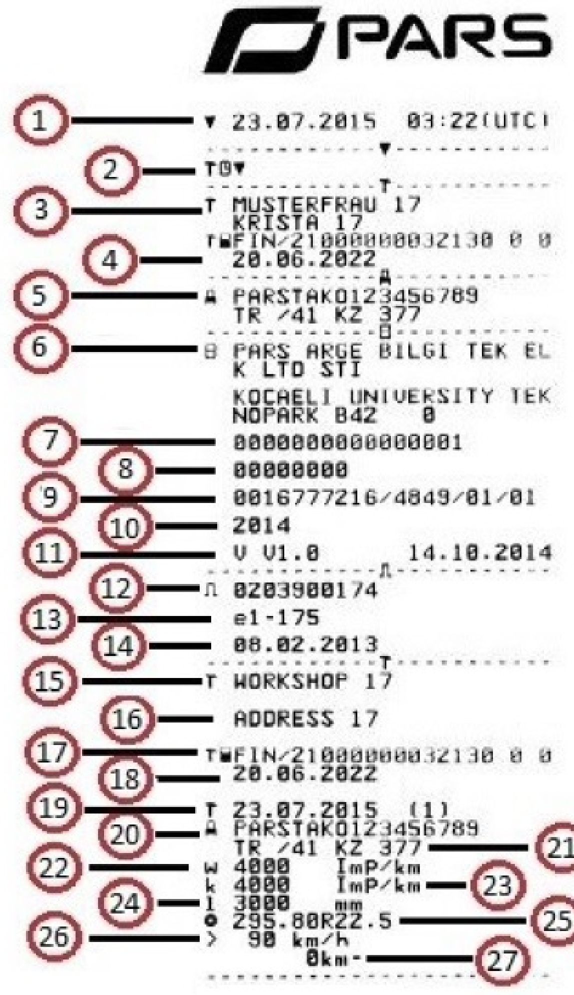

Fig. 2 Typical technical printout of VU

If the tachograph has received L pulses during a time interval of Δt then the tachograph can calculate the instantaneous speed (velocity) (v) as

$$v = (L/K)/\,\Delta t \quad (1)$$

where L/K is the travelled distance.

It is important to note that an error in the determination of the *K*-factor directly results in an error in the calculated speed and distance values. Therefore it is of upmost important to obtain the *K*-factor accurately and this is one of the most important tasks of the entire calibration process.

The Pars TT-101 calibration device is shown in Fig. 3. A tachograph calibration device is used to input parameters and values into the tachograph. This calibration device is directly connected to the VU through the front connector of the VU. This connection enables the calibration device to concurrently count pulses received by the VU (from the motion sensor) as well as enables simulation of vehicle speed so that the workshop can test if the VU displays speed and odometer information correctly and the vehicle cluster is driven successfully. Every workshop is obligated to possess a calibration device.

Fig. 3 Calibration device used to input parameters into VU

In this paper, automatic calibration is used to refer to a calibration process that involves a setup that automatically computes the *K*-factor without manual (human) intervention. Typically, a rolling road is used for this purpose in workshops, as shown in Fig. 4. In this case the calibration device can be connected to the rolling road to set speed or distance of the rolling road. The calibration device will also be connected to the tachograph so as to count the number of pulses received during the run-through. Usually either the speed of the rolling road or the overall distance is set, so as to compute the *K*-factor using the number of pulses received during the run.

Although, currently, the rolling road is accepted to be state-of-the-art for the calibration process its relatively high cost hinder its utilization in all workshops. In cases where a rolling road is not available, a manual (or physical) calibration method can be used by the workshop. In this case the workshop drives the vehicle over a certain distance (that is typically 20 meters (20 m)) and the calibration device is used to count the number of pulses received during this distance to calculate the *K*-factor. This approach has an inherent error in that over a distance of 20 m, the *K*-factor can only be obtained with a resolution of 1000/20=50 as a result of the reduced distance. Furthermore the received number of pulses can change as a result of the current position of the gearbox.

Fig. 4 Rolling road for automatic calculation of *K*-factor

In the manual calibration case, the workshop setups a track of 20 m length and the vehicle is physically driven along this track. In this case, the calculation of the pulses can be triggered either using an optical system as shown in Fig. 5, where the optical systems triggers the calibration device to start and stop counting pulses using reflector located at the beginning and end of the 20 m track that reflect the light beam send out of an optical device that is connected to the calibration device. Alternatively, the workshop personal can hit the start and stop count buttons on the calibration device while the vehicle enters the 20 m track and it arrives at the track end. In the latter case, there is an additional error source introduced, which is the response time of the workshop personal to recognize vehicle position and response time to hit the button.

Fig. 5 Manual calibration using a 20 m track

In this paper, the utilization of automatic and manual calibration methods is evaluated to determine the accuracy and introduced errors.

III. Experimental Results

In order to provide a statistical evaluation of calculation accuracy for the *K*-factor the Rolling-Road approach as well as the 20 m method using optic sensor or manual start/stop are applied to the same vehicle 10 times and the calculated *K*-factor values are recorded. The mean values and standard deviations of *K*-factor values for the different calibration methods are presented in Table I. It is clearly seen that that the standard deviation of the rolling-road approach is significantly lower than the 20 m method, while the 20 m approach with manual start/stop provides the highest standard deviation.

TABLE I
Calculated *K*-Factors for Different Calibration Methods

Method	Calculated *K*-Factor Mean Value	Calculated *K*-Factor Standard Deviation
Rolling-Road	5018,60	5,28
20m with Optic Sensor	4995,83	25,75
20m manual Start/Stop	4995,00	43,78

The maximum intra-class deviations of *K*-factor values as well as the maximum deviation from the expected *K*-factor that is taken as 5019 (mean value of rolling-road approach) for the different calibration methods are presented in Table II. It is seen that the deviation in the rolling-road method is significantly lower than the deviation of the 20 m method.

TABLE II
Calculated *K*-Factor Deviations for Calibration Methods

Method	Maximum Intra-class Deviation	Maximum Deviation from Expected Value
Rolling-Road	13	8
20m with Optic Sensor	100	69
20m manual Start/Stop	100	69

If the maximum error is calculated in terms of the ratio of the maximum deviation to the expected value, a maximum error of only 0.16% is obtained for the rolling-road method, while an error of 2.74% is obtained for the 20 m test. It is important to note that for the vehicle used in the experiments the expected *K*-factor is around 5000, while in the real-world the *K*-factor of vehicles can be as low as about 2500. Hence, in real-life the maximum error of the 20 m test is expected to be as high as about 5%. This error is too high in practical terms as it will directly affect the overspeed measurement of the tachograph and can result in a deviation of about 5km/h for a vehicle traveling at a speed of 90 km/h.

IV. Conclusion

This paper presented an evaluation of automatic and manual calibration methods for digital tachographs. It is shown that an error up to 5% can be expected for manual calibration methods. This error value is significant and therefore automatic calibration methods should be preferred or even mandated. However, the cost of automatic calibration methods is an important factor in expanding the utilization of rolling-road based calibration systems, particularly in developing countries that oblige to the digital tachograph system due to the AETR regulation [7].

Because the tachograph is used to enforce driving legislation it is important to provide accurate calibration so as to ensure reliable measurements and recordings. Therefore it is important to ensure correct calibration of the tachograph so that the objectives are satisfied.

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