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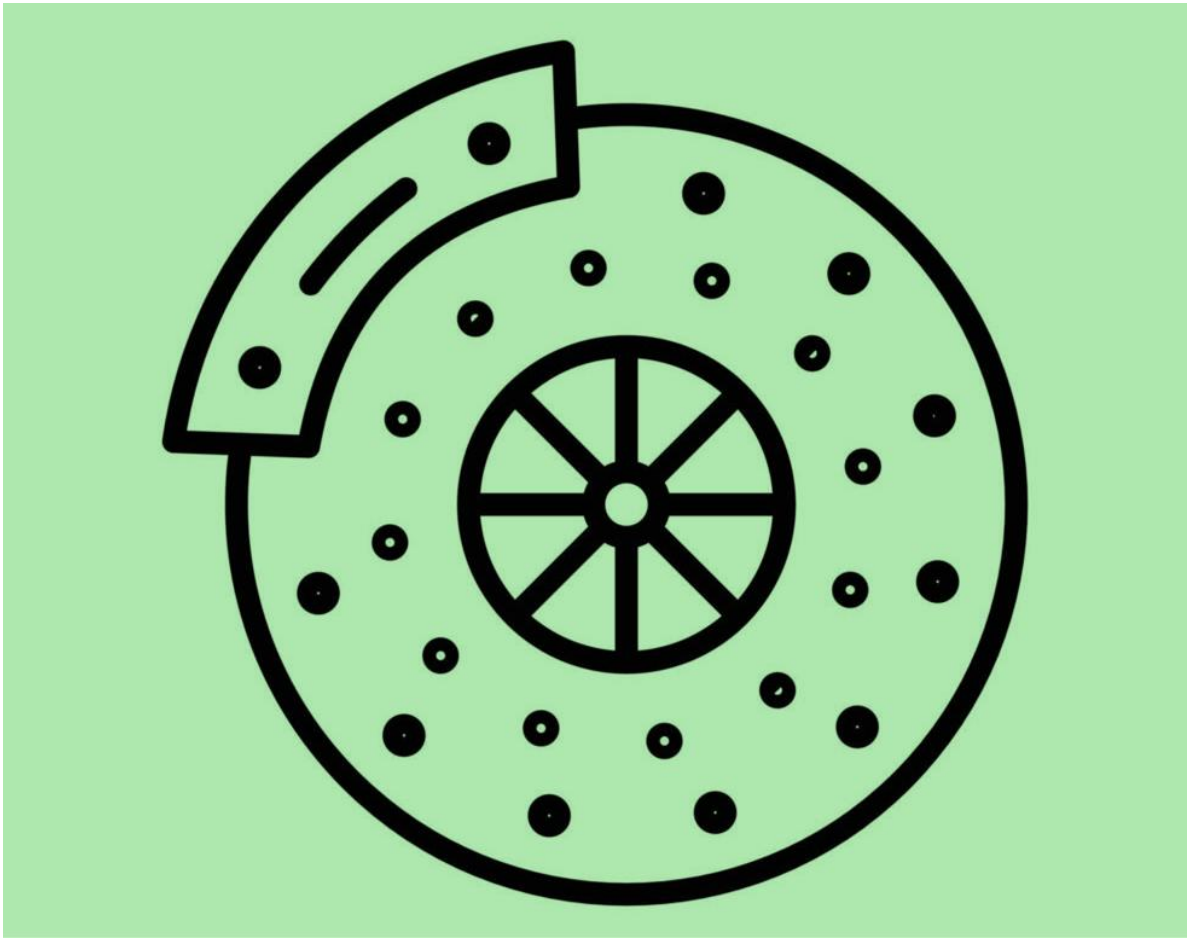
HOW TO INSPECT BRAKES OF ROAD VEHICLES



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EXECUTIVE SUMMARY

The brake efficiency test within the framework of the PTI is one of the most important tests for ensuring the road safety of vehicles. Like all tests within the PTI framework, the braking efficiency testing must also be carried out as effectively and efficiently as possible to ensure an optimal cost/benefit factor. This leads to the situation where the methods used for diverse types of braking systems or vehicle classes differ from each other. However, the most effective method is the reference value method. Only with this method can an axle-by-axle check of the braking efficiency be determined, unaffected by external influencing factors such as the current axle load.

For vehicles with air brake systems, the reference value method has been described for many years in UNECE R13, ISO 21069 and ISO 21995. However, this method can also be adapted to hydraulic brake systems and other future braking systems (e.g., electric brake systems). A further adjustment of the minimum requirements for braking efficiency would not be a problem with this method as well. Unfortunately, the reference value method cannot yet be used in many countries because the necessary data[1] is not available to the PTI organizations in such a way that it can be used directly. Effective support from EU legislation may help to overcome this problem.

BACKGROUND

Braking, along with steering, is the most relevant safety system in road vehicles, regardless of the progress of technology. The experience from periodical vehicle inspection – PTI shows the need to pay particular attention to it:

- *Three brake-related deficiencies occupy the top ten list of Belgium's most identified defects for heavy-duty vehicles. Four for trailers, being the most identified reason for rejection*[2]
- *Brake-related major defects on heavy-duty vehicles account for 21,80% of the total in Spain*[3]
- *In Slovakia, the majority (59,03%) of detected major and dangerous defects on heavy-duty vehicles*[4] *relate to the braking system*

[1] Necessary data are the vehicle-type-specific reference values (target values), as well as information needed to readout values from the vehicle's internal brake pressure sensors via the electronic vehicle diagnostic interface. This data must be supplied by the vehicle manufacturer and could be validated while type approval.
[2] Source: GOCA Vlaanderen jaarverslag (annual report) 2024
[3] Source: Open data 2023 from the Spanish Ministry of Industry and Tourism
[4] Source: Slovak information system for PTI. Data referring to 2024

THE CONTENT OF THE INSPECTION TODAY[5]

The examination of vehicles' service brakes includes a visual[6] and mechanized inspection. The challenges for visual inspection consist of having access to the different components and the appropriate reference information.

The visual inspection includes, e.g. the following execution and condition tests, among others:

- *Wear of the components.*
- *Condition of the brake system / its parts.*
- *Execution and Permissibility of the brake system / its parts.*

The mechanized inspection includes the following tests:

- *Braking performance:*
    - *Imbalance of braking forces on the same axle.*
    - *No gradual variation in brake effort.*
    - *Abnormal lag in the brake operation of any wheel.*
    - *Excessive fluctuation of brake force during each complete wheel revolution.*
- *Braking efficiency.*
- *Different Functional Tests.*

Braking efficiency is the factor that represents vehicle deceleration. It is controlled during vehicle approval on a proving ground with the vehicle fully loaded.

Indeed, this guarantees that the design of the vehicle fulfils the requirements of the approval regulations but does not ensure the braking performance throughout the vehicle's life.

[5] According to Directive 2014/45/EU and Rule 2 of the 1997 Agreement.

[6] Where a method of testing is indicated as visual, it means that, in addition to looking at the items concerned, the inspector shall also, if appropriate, handle them, evaluate their noise or use any other appropriate means of inspection not involving the use of equipment. Directive 2014/45/EU.

OPTIONS TO MEASURE BRAKING EFFICIENCY

The ideal test arrangement is to measure the deceleration of fully loaded vehicles on a road test with a high-friction road surface.

This is reasonable during the vehicle approval, but barely feasible in a vehicle inspection environment because of the required infrastructure and method.

Test track (dynamic test)

This methodology consists of driving the vehicle with the appropriate load on a test track until a given speed and braking as much as possible.

In this type of test, the test result is presented as deceleration (in $m.s^{-2}$). The required minimum service brake's efficiency criteria are defined as a percentage of braking ratio. A mathematical calculation is necessary to compare the measured value with the prescribed criteria. A very simple formula is applied in most cases, but this approach ignores the physical differences between dynamic and static tests.

The most relevant challenges are the availability of a sufficiently long, flat and even track, the assurance that it will be dry and the risk management. Anyway, the test result is heavily influenced by the friction of the road surface (e.g., it might be lowered by the weather conditions) and the initial speed of the test. Therefore, there is almost no repeatability between measured values on different days and between different test locations.

With a focus on safety, many more factors and aspects must be considered than in the usual vehicle inspection environment at indoor inspection lanes and vehicles moving at slow speeds.

The safety of all persons in or outside of the tested vehicle must be maintained along the whole vehicle's expected trajectory, including the vehicle's run-out area in the case of brake malfunction. Besides the harm to human health or lives, any potential harm to property or environment shall be minimized.

Furthermore, there are limitations to the detection of imbalance of braking forces between the left and right sides of the same axle or excessive fluctuation of brake force during wheel revolution. Using this method, only extreme cases of the service brake's imbalance or fluctuation can be clearly identified as defects. The parking brake efficiency cannot be tested at all.

In the case of trailers, the test becomes even more complex since it is necessary to remove the part of the deceleration provided by the motor vehicle.

Loaded vehicles (static test on brake tester)

The most immediate solution is to require vehicles to be inspected with a load. Because of that, some countries require vehicles to be inspected with some degree of load ranging from 40% to 75%, depending on the country and conditions.

Whereas this ensures the inspection is conducted in the worst case or near worst case, there are some practical issues to manage:

- *This puts an additional obligation on the vehicle owner/driver. In the case of heavy-duty vehicles, that could have an impact on operations.*
- *It is problematic, in some cases impossible, to ensure the loading of safety-critical vehicles like buses or those transporting of dangerous goods.*
- *There are no universal load simulator devices applicable in PTI, neither by raising axles nor by pulling down the chassis.*
- *Fully loaded vehicles may hinder other inspection points.*

Because of the above, other countries consider a different approach in which the braking forces measured by the brake testers are related to the expected forces for a given load status, as explained later.

This methodology seems to be applicable to the technical evolution of braking systems.

Estimation of the braking efficiency regardless of the load of the vehicle (static test on the brake tester)

Efficiency is calculated by comparing the braking forces and the vehicle mass. An option to do so consists of using the gross vehicle weight regardless of the load on the vehicle.

The main limitation of this methodology is the fact that maximum braking forces may be achieved before the necessary braking forces are reached because of the sliding of the tyre on the brake tester's roller.

The front axle, in particular, locks too early in the static test on a roller brake test bench because the dynamic axle load shift is missing here. In most cases, it is not possible to load the front axle. Therefore, the maximum braking efficiency that can be achieved is often too low.

That's why this methodology is not optimal, but it has some limitations that apply to the technical evolution of braking systems.

Extrapolation methods for static test on brake tester (ISO 21069)

There are different options to compare the braking forces with those theoretically expected. They all require knowledge of the actual brake pressure (or equivalent value).

The ISO 21069[7] standard is mainly used for vehicles with a pneumatic brake circuit. It considers the quite realistic assumption that braking pneumatic pressures and braking forces follow a linear correlation.

The rationale is that a braking force above a threshold pressure value, usually 2 bar, can be extrapolated to the minimum guaranteed pressure to determine the maximum braking force of each wheel.

Some loading on the vehicle may be necessary to reach the threshold pressure mentioned above. Load simulation by raising axles can also be used for vehicles with multi-axle units.

The standard allows for single-, two- and multi-point extrapolation. It must be stressed that all extrapolation methods are mathematical predictions. The precision of the calculation results is acceptable under certain conditions. These methods can not be considered to be direct proof of the braking efficiency.

Because the braking forces of the axles are added up, a very good axle may compensate for a worse one. Of course, this behaviour cannot be transferred to real braking on the road. An expert assessment of the brake force distribution to the axles must therefore always be carried out additionally.

This methodology could be adapted to the technical evolution of vehicles, i.e. electric braking, if equivalent values to the pneumatic pressure are available.

Reference braking forces method

The reference braking method evaluates the wheel braking forces generated in relation to the braking energy input. Which energy input (hydraulic, pneumatic, electric, e.g.) is used to generate the brake forces is not relevant. Reading out the relevant energy values with an OBD-II scan tool should be possible. In addition, standardized test connections must be available on the brake system with a gauge. Reading out this value via the electronic vehicle interface is advantageous, as this makes it easier to automatically combine it with the measured values of the brake tester (plate and roller brake tester) and compare it to the reference values.

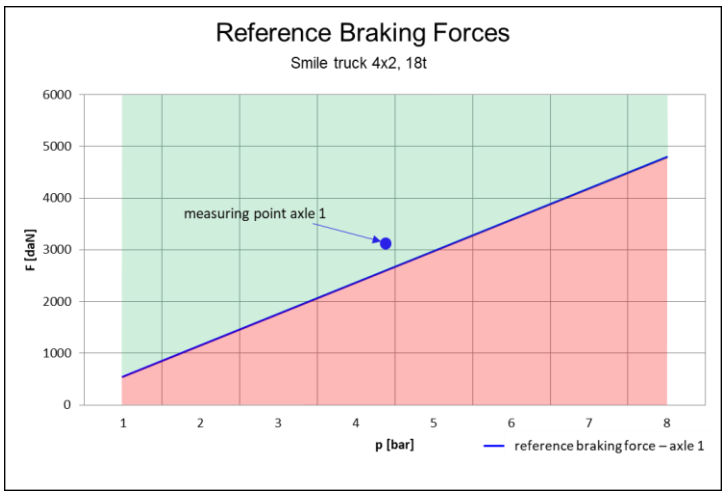
[7] Test of braking systems on vehicles with a maximum authorized total mass of over 3,5 t using a roller brake tester

This method, also based on so-called “Reference Values”, is described in UNECE R13, 5.1.4.6, and mentioned as one of the alternatives in ISO 21069, and ISO 21995[8] describes it in-depth. Minimum braking deceleration in PTI is considered verified when the measured braking force at each axle, measured in a static test on the brake tester, exceeds the corresponding reference braking force.

Further information may be required to determine the correct values for a specific vehicle (vehicle structure defined by VIN, design of the pneumatic system/availability of internal sensors on the respective axles, etc.). Of course, it must still be possible to clearly assign the brake reference values to a vehicle and its axles by using a VIN or a part of it.

Example of reference braking forces method

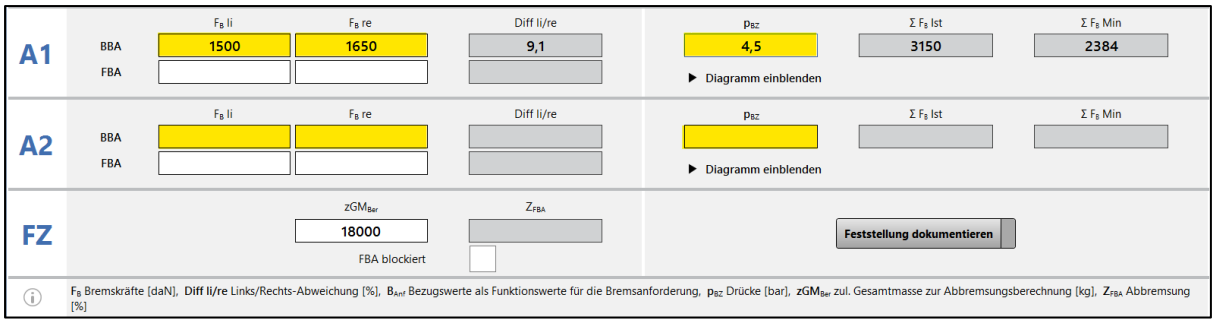
The following diagram and table show an example of a possible data structure for reference braking forces.



Minimum required date for Reference Braking Forces (Example)																
vehicle data					reference braking forces											
manufacturer	brand	type	VIN-rule	*Calculation pressure [bar]* * * not required if brake pressure 2 (p_{BZ2}) corresponds to the calculation pressure.	axle 1				axle 2				axle 3			
					p_{BZ1} [bar]	F_{b1} [daN]	p_{BZ2} [bar]	F_{b2} [daN]	p_{BZ1} [bar]	F_{b1} [daN]	p_{BZ2} [bar]	F_{b2} [daN]	p_{BZ1} [bar]	F_{b1} [daN]	p_{BZ2} [bar]	F_{b2} [daN]
FSD	Smile	truck 4x2 18t	FSD**1T5*	*8*	1,0	550	8	4800	1,0	500	8	4200	1,0	-	8	-
FSD	Smile electric	etruck 4x2 20t	FSD**1T6*	*8*	1,0	600	8	5400	1,0	550	8	4600	1,0	-	8	-
FSD	Friend 12m	citybus 4x2 2door	FSD**1B62*	*8,5*	1,0	625	8,5	4500	1,0	625	8,5	4500	1,0	-	8,5	-
FSD	Friend 12m	citybus 4x2 3door	FSD**1B63*	*8,5*	1,0	625	8,5	4500	1,0	625	8,5	4500	1,0	-	8,5	-
FSD	Friend 18m	citybus 6x2 articulated 4door	FSD**3B64*	*8,5*	1,0	650	8,5	4700	1,0	640	8,5	4600	1,0	650	8,5	4700

[8] Test of vehicle air braking systems with a permissible mass of over 3,5 t — Acquisition and use of reference values using a roller brake tester.

An example of the user interface of an application for brake test evaluation using reference braking forces is shown in the following picture.



The PTI inspector only needs to measure the brake forces and corresponding brake cylinder pressure (highlighted in yellow) and enter the values into the calculation formula. In many cases, these values are already transferred automatically from the brake test bench via the scan tool to the calculation software.

A check to see whether the axle brake forces reach or exceed the reference value required for this brake pressure is performed automatically within the software.

SUMMARY

The braking function is a critical component of road vehicle safety, and it will stay like that regardless of the evolution of technology.

Vehicle approval tests fully loaded vehicles on a proving ground, but this does not apply to inspection. Because of that, several methods have been developed over time.

This document assesses those possibilities and concludes that the best option is to use the methodology defined in the standards ISO 21069 and ISO 21995, using the Reference Values determined at the time of approval.

The benefits of this approach are:

- If the reference values are complied with, it can be assumed that the required minimum deceleration will also be achieved.
- It is applicable to new braking technologies.
- It does not require a full load.
- Best advantages of the reference value method:
    - Efficiency test of every brake of the tested vehicle without any influence of the result by the tire, road/roller/plate-surface friction, and actual load.
    - Possibility to verify the brake force distribution between the axles.

To make the use of this method universal and ensure the benefit of a proper braking test during periodic technical inspection, it is necessary to consider the following:

- Reference Values to be determined during the vehicle approval, as defined today in UNECE R13.
- Reference Values are to be available reasonably for vehicle inspection purposes.
- The vehicles' approval shall consider how to access the braking demand values in real time to be consolidated with the measurement of the braking forces.

Access to the aforementioned information shall be ensured through vehicle type-approval legislation. Unrestricted access to this data is crucial for inspectors to assess a vehicle's condition accurately.

ANNEXE – COMPARISON OF OPTIONS

Method	Linked with the "real world" deceleration on the road?	Necessary data	Additional parameters	Applicable to new braking technologies	Other pros	Other cons
Test track (dynamic test)	Direct link	• *Measured deceleration*	• *Required minimum deceleration (not part of the EU Directive yet)*	Yes	• *Actual measurement of deceleration.*	• *No proof of deceleration at maximum load.* • *Requires a safe test track.* • *Results are heavily influenced by road surface, weather conditions and test speed, almost impossible to use on wet, snowy or icy surfaces.* • *Complicated procedure for vehicle combinations (trailers).*
Loaded vehicle (static test on brake tester)	No direct link	• *GVW* • *Measured brake forces*		Yes	• *Easy for the inspection centre.*	• *It can have strong negative effects on other points of inspection.* • *Loading is not possible for some vehicles (buses, animal transporters, transport of dangerous goods).* • *In the case of passenger cars, it would be necessary to load the front axle, which is usually not possible.* • *Creates a burden to the driver or vehicle owner.*

Method	Linked with the "real world" deceleration on the road?	Necessary data	Additional parameters	Applicable to new braking technologies	Other pros	Other cons
Regardless of the load (static test on brake tester)	No direct link	• *GVW* • *Measured brake forces*		On some vehicles (if sufficient braking forces are reached)	• *Easy for the inspection centre.*	• *Vehicles may not reach the necessary braking forces because of the adherence between the tyre and the roller.* • *More cases of failed tests in comparison to the "loaded vehicle" method.*
ISO 21069 **Extrapolation method (static test on brake tester)**	No direct link, if the brake force distribution to the axles is not evaluated. Indirect link, if brake force distribution to the axles is evaluated separately	• *GVW* • *Measured brake forces* • *Measured brake pressures (or equivalent value)*	• *Maximum brake pressure (vehicle-specific or general value)*	Yes (if equivalent values to the pneumatic pressure are available)	• *Does not require a full load.*	• *It is not a direct proof of the braking efficiency; it is just a mathematical prediction.* • *Requires measurement of brake pressure (or equivalent value).* • *Some loading of the vehicle may be necessary to reach the threshold pressure.* • *Evaluation of the brake force distribution to the axles is not included in the standard.*

Method	Linked with the "real world" deceleration on the road?	Necessary data	Additional parameters	Applicable to new braking technologies	Other pros	Other cons
ISO 21069 and ISO 21995 **Reference Values method (static test on brake tester)**	Indirect link (brake force distribution to the axles is evaluated)	• *Measured brake forces* • *Measured brake pressures (or equivalent value)*	• *Reference Values (combination of brake pressure or equivalent values and required brake forces)*	Yes (if equivalent values to the pneumatic pressure are available)	• *Does not require a full load.* • *Easy for the inspection centre.*	• *Requires measurement of brake pressure (or equivalent value).* • *Reference values for the specific vehicle must be available.*

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