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INFLUENCE OF MEASUREMENT METHOD AND DATA PROCESSING ON THE RESULTS OF BRAKE PERFORMANCE TEST

Saša RADULOVIĆ [1]
Goran SIMIĆ [2]
Dragan MILKOVIĆ [3]
Vojkan LUČANIN [4]

Abstract – *In order to determine the brake weight of rail vehicles, brake perfomance test has to be perfomed. This test shall be conducted in accordance with the UIC 544-1. This regulation defines the necessary conditions and required quantities that shall be measured (speed, stopping distances, pressure etc.), but does not specify measuring method and all details about data processing. This paper presents possible influences on the results when using different speed measurement techniques or data processing details.*

Keywords – Speed, Stopping distance, Brake weight, Measurements.

1. INTRODUCTION

In accordance with European standards TSI [1], brake performance can be determined by calculation and/or experimentally - by testing. Valid standards allow assessment of the braking performance by calculation only in case of wagons fitted with cast iron brake blocks (P10) which comply also with some other limitations. In all other cases the calculations are only used for pre-determining of braking performance. The brake weight shall be finally verified by tests. The UIC 544-1 [2] prescribes the method of determining braking performance of railway vehicles and train. Braking performance is expressed through the brake mass percentage (for vehicle speeds of up to 200km/h) and deceleration (vehicle for speeds higher than 200km/h).

The regulations define needed conditions and required measuring quantities. However they do not specify way of measurement required quantities, nor details of data processing of recorded signals.

The paper presents variations in some steps during standard test of rail vehicles braking performances and different data processing procedures and potential impacts on the results.

2. DETERMINING BRAKE WEIGHT ACCORDING TO UIC 544-1

Braking performance of rail vehicles can be expressed via braked weight or via decelerations. Brake weight is the basic braking performance parameter expressed in integer numbers of tonnes.

To determine the brake weight is used the following formula:

$$B = \frac{\lambda \cdot m}{100} = \frac{\left(\frac{C}{s} - D\right) \cdot m}{100} \tag{1}$$

λ [%] – braked weight percentage
m [t] – mass of test vehicle (train)
s [m] – stopping distance
C, D [-] – constants

In accordance with UIC 544-1 braked weight is determined by testing with:

- individual vehicle or
- the train of a certain length

Tests were conducted at different speeds and load cases of vehicles with the technical characteristics of vehicles and the requirements of the regulations.

2.1. Basic testing conditions

The following conditions during tests must be met:

- atmospheric conditions - testing carried out at minimum wind and on dry rail

[1] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, sradulovic@mas.bg.ac.rs
[2] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, gsimic@mas.bg.ac.rs
[3] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, dmilkovic@mas.bg.ac.rs
[4] University of Belgrade, Faculty of Mechanical Engineering, Kraljice Marije 16, 11000 Belgrade, vlucanin@mas.bg.ac.rs

- rail gradient – mean gradient on the stopping distance should not exceed 3 ‰, a maximum gradient at the test section must be less than 5 ‰. Testing is not allowed in curve with radius of less than 1000m.
- vehicle speed - the difference between the measured and nominal speed should not exceed 4km/h,
- number of tests -it is necessary to carry out at least 4 valid tests for determining the mean stopping distance
- the condition of the wheels, brake discs and friction components - before tests, the friction components (brake pads / blocks) must be in contact with the brake disc / wheel for at least 85% of the total contact area. The temperature on any measuring point shall not exceed 100 ^{o}C and average of all measuring points should be maximum 60 ^{o}C.

2.2. Correction of individual stopping distances

After the tests it is necessary to perform correction of the measured stopping distances taking into account:

- the differences between the measured and nominal speed,
- rail gradient.

Corrections are made according to the formulas given in Appendix F.3.1 of UIC 544-1.

Corrected stopping distance must meet the requirements described in UIC 544-1.

2.3. Correction of the mean stopping distance

At the end, it is necessary to perform correction of the mean stopping distances. The correction is done according to the following criteria:

- basic correction - adjusting the existing state of the test vehicle with the general characteristics of the vehicles designed for the series,
- the brake cylinder filling time during the test.

In the basic correction the following factors are considered:

- dynamic efficiency of the brake rigging on test vehicle in relation to the mean value foreseen for operation and, in the case of disc-braked vehicles with average wheel diameter that, in relation to the diameter of the semi-worn wheel.
- in the event of the brake cylinder pressure on the test vehicle deviates from the value assumed for the design series, correction within the tolerance range of ± 0.2 bar shall be done.

3. MEASUREMENT METHODS OF REQUIRED PARAMETERS

During testing the braking performance it is necessary to measure the following parameters:

- speed,
- stopping distance (length),
- acceleration (deceleration),
- pressure in main brake pipe and in brake cylinders.

All parameters shall be measured as a function of time.

3.1. Measurement speed and stopping distance

Speed is measured to determine the initial speed of the braking for each individual measurement and it is used for the correction of individual stopping distance.

Speed can be further used to calculate the stopping distance and deceleration during braking.

The stopping distance is the basic parameter for determining the braked weight percentage. The stopping distance is distance from the moment of brake command to the vehicle stopping.

Measurement of the speed and stopping distance can be carried out using several methods, and using different types of sensors. It is possible to use sensor that directly perform measurements of speed or it can be derived from the stopping distance or from acceleration, by integration or differentiation of these signals.

Two types of sensors are commonly used for speed measurement:

• sensors independent from the wheel revolutions (radar etc.) and

• sensors which depend on the wheel rotation frequency (inductive, optical etc.)

Fig.1. Speed sensors

The bodies for conformity assessment of railway vehicles (Notify Body) usually require speed measurement sensors independent from the wheel rotation frequency (radar). Thus, the stopping distance includes the distance that vehicle eventually travel with blocked wheels. On the other hand, based on the measurement signal obtained by such a sensor it is not possible to detect appearance of wheel blocking which can cause damage of wheels(wheel flats). Blocking of wheels, can be registered on the basis of sensors signals which depend on the wheel frequency and after analysis it is possible to eliminate the causes of this and, if necessary, repeat the test.

The parameters that may affect the accuracy are:

• for the radar: the radar installation angle relative to the ground (nominal it has to be 30%)

- when using an optical sensor result depends on the wheel diameter.

These parameters can be eliminated by sensors calibration using for example laser meter of high accuracy class. Fig. 3 presents calibration of the speed sensors. Wagon was moved several time along track for some distance and measured distance indicated by the laser meter was compared with results of sensors installed on the wagon. Thus, was included correction caused by deviation of the radar installation angle and measured wheel diameter.

Fig.3. Sensors calibration

3.2. Measurement of acceleration

Measurement of acceleration (deceleration) is performed in order to determine the equivalent brake force development time. For high-speed vehicles acceleration represents the only parameter for determining the brake performance.

Also, the acceleration can be obtained by differentiating the speed signal or double differentiation of stopping distance signal.

3.3. Measurement of preassure

The pressure in the brake pipe is measured to determine the moment of brake command (moment when starts the pressure drop in the brake pipe represents the moment of brake command for single vehicle).

The values of pressure in the brake cylinders are used in the correction of stopping distance and could be used for determining the equivalent brake force development time.

4. ANALYSIS OF MEASUREMENT SIGNALS PROCESSING

4.1. Analysis of speed and stopping distance signal

Fig. 4 shows the signals of speed and stopping distance during slip test of Sdggmrss wagon [3]. Measurements were made in parallel by radar and wheel dependent optical sensor. After sensor calibration, if there is no slipping during braking process,, both types of sensors show very similar values (Fig. 4).

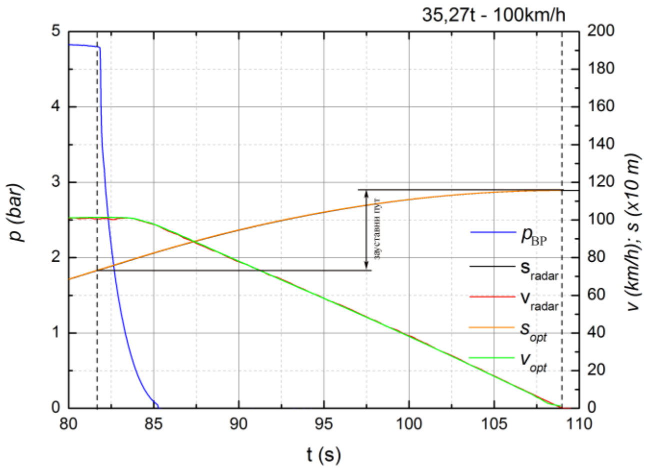

Fig.4. Sdggmrss wagon braking

Brake weight percentage determined on the basis of the results obtained by both sensors is shown in Table 1.

Tab. 1. Brake weight percentage

	Radar	Optical
initial speed (*km/h*)	100	100
corrected stopping distance (*m*	473,83	470,42
brake weight percentage (%)	101,5	100,9

4.2. Analysis of the signal processing measurements in order to obtain the equivalent brake force development time

Equivalent brake force development time t_e is illustrated in Fig. 5[2].

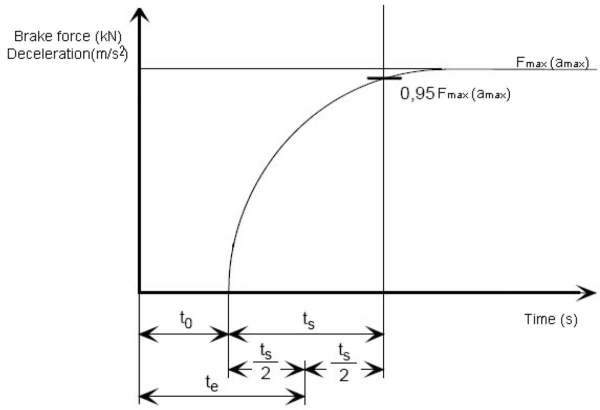

Fig.5. Equivalent brake force development time t_e

$$t_{\text{в}} = t_o + \frac{t_s}{2} \qquad (2)$$

t_e - equivalent brake force development time

t_o – time lag between brake command and start of brake force (deceleration) increase

t_s – brake development time

F_{max} (a_{max}) – fully-developed brake force (deceleration)

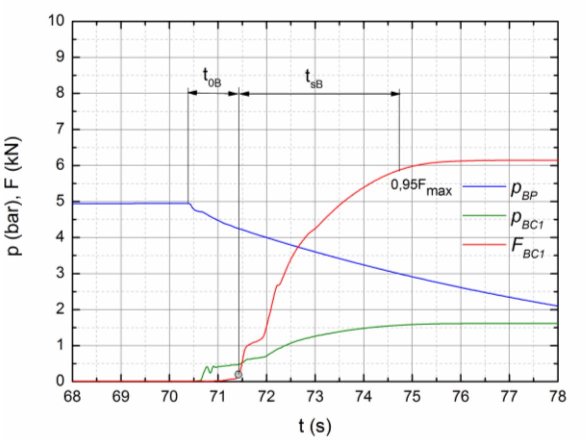

Fig.6. Determination t_e aaccording to the braking force

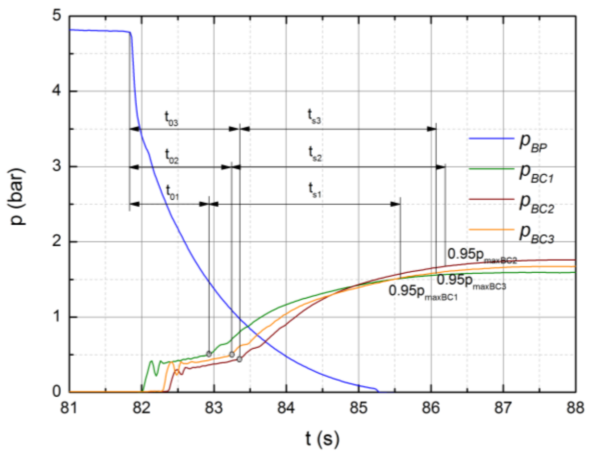

Fig.7. Determination t_e according to the pressure

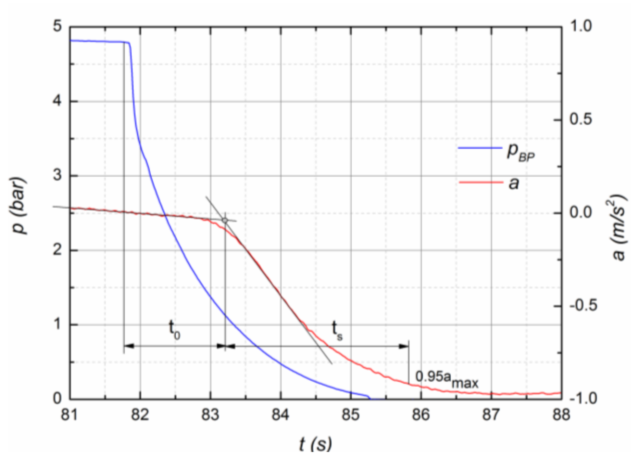

Fig.8. Determination t_e according to the deceleration

Determination of the t_e can be done in several ways:

- According to the braking force measurement signal during stationary brake tests (Fig. 6).
- According to the brake cylinder pressure measurement signal during slip tests (Fig. 7).
- According to the deceleration measurement signal during the slip tests (Fig. 8).

Tab. 2. Brake weight percentage according t_e values

Method of processing signal	t_e (s)	λ (%)
Braking force	2,83	101,6
Brake cylinder pressure	2,73	101,5
Deceleration	2,68	101,5

5. CONCLUSION

Performed analysis of brake performance test shows that the influence of variations of parameters that affect brake performance, individually cause acceptable variations in the test results.

Measured speed and stopping distance obtained by radar and optical sensor during brake testing of freight wagon showed almost identical results, i.e. difference has insignificant influence on the test results.

By analyzing the way of the signal processing in order to determine the equivalent brake force development time it appeared that the existing procedure defined in the UIC 544-1 is almost insensitive to different data processing methods. The value of equivalent brake force development time can be calculated using recorded signals from the brake cylinder pressure or deceleration.

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