SLOVENSKI STANDARD
SIST EN 14531-1:2005

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Železniške naprave – Metode za izračune zavornih poti, poti za kontrolo hitrosti in zavarovanj stoječih vozil – 1. del: Splošni algoritmi

Railway applications - Methods for calculation of stopping distances, slowing distances and immobilization braking - Part 1: General algorithms

Bahnanwendungen - Verfahren zur Berechnung der Anhalte- und Verzögerungsbremswege und der Feststellbremsung - Teil 1: Grundlagen

Applications ferroviaires - Méthodes de calcul des distances d'arret, de ralentissement et d'immobilisation - Partie 1: Algorithmes généraux

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Railway applications - Methods for calculation of stopping distances, slowing distances and immobilization braking - Part 1: General algorithms

Applications ferroviaires - Freinage - Méthodes de calcul des distances d'arrêt et de ralentissement - Méthodes de calcul du freinage d'immobilisation - Partie 1: Algorithmes généraux

Bahnanwendungen - Bremsen - Verfahren zur Berechnung der Anhalte- und Verzögerungsbremswege - Verfahren zur Berechnung der Feststellbremsung - Teil 1: Grundlagen

This European Standard was approved by CEN on 15 March 2005.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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Contents

Foreword

This European Standard (EN 14531-1:2005) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2005, and conflicting national standards shall be withdrawn at the latest by October 2005.

This European Standard has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 96/48 and Directive 2001/16.

For relationship with EU Directives, see informative Annexes ZA and ZB, which are integral parts of this European Standard.

This European Standard is one part of the European Standard as listed below:

EN 14531, Railway applications – Methods for calculation of stopping, slowing distances and immobilization braking

— Part 1: General algorithms

— Part 2: Application to single freight wagon

— Part 3: Application to mass transit (LRV's and D- and E- MU's)

— Part 4: Application to single passengers coach

— Part 5: Application to locomotive

— Part 6: Application to high speed trains

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This European Standard is aimed at enabling the railway industries and operators to work with a common calculation method.

It describes the fundamental algorithms and calculations for the design of brake equipment for railway vehicles.

This European Standard should be considered as a technical document which gives the physical basis for the brake calculations. It will also help the user to understand the UIC 544-1 leaflet through completion of the requirements in the UIC 544-1 leaflet.

This European Standard gives examples of freight wagon applications considered as the highest priority. It is applicable for all vehicle types. If necessary, additional application examples will be added as separate parts to the European Standard.

1 Scope

This European Standard specifies a general algorithm to be used in any type of vehicle application. It enables the calculation of the various aspects of the performance: stopping or slowing distances, dissipated energy, force calculations, immobilization braking.

Typical examples of calculations for freight wagon, coach and locomotive are given in Parts 2 to 6 of this European Standard.

NOTE This European Standard does not specify the performance requirements which can be found in the different standards specified in Clause 2.

This European Standard enables the verification that the design respects the requirements according to the railway application type.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13452-1:2003, *Railway applications — Braking — Mass transit brake systems — Part 1: Performance requirements*

EN 13452-2:2004, *Railway applications — Braking — Mass transit brake systems — Part 2: Methods of test*

EN 14198:2004, *Railway applications — Braking — Requirements for the brake system of trains hauled by a locomotive*

EN 14478, *Railway applications — Braking — Generic vocabulary*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 13452-1:2004, EN 14198:2003 and EN 14478:2004 apply.

NOTE If there are inconsistencies between this European Standard and the definitions given in EN 14478, then the definitions given in EN 14478 take precedence.

3.2 Symbols and indices

For the purposes of this European Standard, the general symbols given in Table 1 and indices given in Table 2 apply.

NOTE Specific symbols are defined in the relevant clauses.

Table 1 — Symbols

Symbol	Term	Dimensions
A	area	m^2
a	deceleration	m/s^2
B	braked mass (see UIC 544-1)	kg
D	wheel diameter	m
d	diameter	m
F	force	N
F_B	braking force	N
F_g	downhill force on the train	N
f_0	available coefficient of adhesion	
g	acceleration due to gravity	m/s^2
I	rotational inertia	$kg \cdot m^2$
i	rigging ratio, calliper ratio	
m	mass	kg
n	quantity	
P	power	W
p	pressure	Pa
R	wheel radius	m
r	radius	m
s	distance	m
t	time	s
v	speed	m/s
W	energy	J
W_S	energy per square unit	J/m^2
η	efficiency	
κ	coefficient of rotating mass	
λ	brake percentage	
μ	friction coefficient	

Table 2 — General indices

Symbol	Term	Dimensions
AMG	attraction force for a magnetic brake	
a	axle	
BEC	braking force for an eddy current brake	
BED	electro-dynamic braking force	
BFR	fluid retarder	
BMG	braking force for a magnetic brake	
b	block or pad	
bog	bogie	
C	cylinder	
disc	disc	
dyn	dynamic	
e, 2	final	
eq	equivalent	
ext	external	
H	hand brake	
int	internal	
m	average, mean	
max	maximal	
min	minimal	
mot	motor	
M_unsp	unsprung mass	
MG	magnetic brake	
park	parking, immobilization	
R	reaction	
Ra	rolling resistance	
rot	rotational	
R1	return spring	
R2	regulator	
st	static	
tot	total	
tra	trailer	
veh	vehicle	

Table 2 – (*concluded*)

w	wheel	
weig	weighing	
wind	wind	
0, 1	initial	

NOTE In this European Standard, the wheelset is simply named "axle".

4 General algorithms

4.1 General algorithm to calculate stopping and slowing distances

This algorithm is presented in Annex A.

The content of each part and the corresponding calculations are explained in Clause 5.

This algorithm can be used either with mean values or with instantaneous values of, for example force or retardation which are integrated step by step.

4.2 General algorithm to calculate immobilisation brake

This algorithm is presented in Annex B.

The content of each part and the corresponding calculations are explained in Clause 6.

5 Stopping and slowing distances calculation

5.1 General

All the values which are used shall be justified, for example, by tests, calculations, or engineer's estimations, in accordance with the appropriate standards, for example EN 13452-2.

5.2 General characteristics

5.2.1 Train formation

The parameters to define train formation are:

— quantity of motor axles;

— quantity of trailer axles;

— quantity of braked axles for each brake equipment type.

In the cases of single wagon, coach or locomotive, the notion of train is restricted to the single wagon, the coach or the locomotive.

Brake equipment type shall be taken to mean a group of equipment whose purpose is to provide braking force.

For example, on a wagon or a coach, the friction brake equipment begins at the distributor and ends at the contact between the braked wheels and the rail.

Each brake equipment type shall be the subject of a specific calculation, and the quantity of braked axles shall be shared between the various types of brake equipment.

NOTE 1 When there are several brake equipment types, it is preferable to identify each type (for example by means of a number: type 1, type 2, ...).

When brake equipment is used on one part of the train under certain conditions and used on another part of the same train under other conditions, two different brake equipment types shall be considered.

NOTE 2 Other conditions can be for example, different brake cylinder pressures.

Then the two brake equipment types shall be separately described and separately calculated.

The total quantity of axles is the result of the summation of the quantity of braked and unbraked axles.

5.2.2 Vehicle and train characteristics

5.2.2.1 Static mass per axle, static mass

The static mass per axle is the mass, measured by weighing, of each axle in a stationary condition.

The static mass of the train is the summation of all the values of static mass per axle and includes all operating loads.

The static mass per axle is the static mass of the train divided by the quantity of axles only in the case where the operating load is equally shared by all axles.

It is indicated in tonnes [t].

When there are different brake equipment types, the static mass per axle shall be indicated for each brake equipment type.

NOTE If the train is equipped with different types of wheel, according to the definition of “brake equipment” it is recommended that each type of wheel is considered as being applicable to a specific brake equipment type.

5.2.2.2 Rotating mass per axle, rotating mass

5.2.2.2.1 General

The definition of the rotating mass is given in EN 14478.

It may be calculated using a theoretical approach or estimated on the basis of known typical values.

In the cases of single wagon or coach, in a first approach, designers may ignore the rotating masses if they also ignore the rolling resistance of the single wagon or the coach.

NOTE If the train is equipped with different types of wheel, according to the definition of brake equipment, it is recommended that each type of wheel is considered as being applicable to a specific brake equipment type.

5.2.2.2.2 Rough calculation example

When considering a disc, in the first instance, a disc can be considered as a single ring, the mass of which is concentrated on the mean swept diameter.

When considering a wheel, in the first instance, a wheel can be considered as a single wheel, the mass of which is concentrated on the worn wheel diameter.

5.2.2.2.3 Typical values

In some cases, the rotating masses are expressed by a coefficient of the static mass and this coefficient, κ is given by:

$$\kappa = \frac{M_{st} + M_{rot}}{M_{st}} \tag{1}$$

where

κ is the coefficient of the rotating mass;

M_{st} is the static mass, in tonnes;

M_{rot} is the rotating mass, in tonnes.

In the cases of single wagon, this coefficient is given for two conditions: in tare (about 5 t/axle or 6 t/axle) and laden (about 20 t/axle).

EXAMPLE 1 For non-powered axle with ∅920 mm wheel half worn, without disc,

— in tare condition: κ = 1,06

— in laden condition: κ = 1,02

EXAMPLE 2 For non-powered axle with ∅1 000 mm wheel half worn, without disc,

— in tare condition: κ = 1,07

— in laden condition: κ = 1,02

EXAMPLE 3 For non-powered axle with ∅850 mm wheel half worn, without disc,

— in tare condition: κ = 1,05

— in laden condition: κ = 1,02

5.2.2.3 Wheel diameters

The wheel diameter is assumed to be measured on the nominated line of contact with the running surface of the rail.

Unless otherwise specified, the wheel diameter used in the calculation shall be that of a new wheel which gives the lowest deceleration in the case of disc brakes.

NOTE If the train is equipped with different types of wheel, according to the definition of a brake equipment, it is recommended that each type of wheel is considered as being applicable to a specific brake equipment type.

5.2.2.4 Rolling resistance

The rolling resistance is the braking force provided by the structure of the train.

Unless otherwise specified the effect of wind forces is not taken into account.

The value of the rolling resistance may be by analogy to another existing vehicle, or based on a specific calculation.

When the values are the results of tests, the test conditions shall be similar to the expected operating conditions.

NOTE 1 In a first approach, with the single wagon or the coach, designers may ignore the rolling resistance if they also ignore the rotating masses.

The rolling resistance is represented by a formula which consists of:

- one term independent of vehicle speed;
- one term proportional to the speed, dealing with the mechanical components (train and track);
- a third term proportional to the square of the speed (aerodynamic resistance).

According to this formula the mathematical formulae, which shall be applied are the following:

a) Calculate the instantaneous rolling resistance as a function of the speed, F_{Ra}, in newtons (N), using the following equation:

$$F_{Ra} = A + B \times V + C \times v^2 \quad (2)$$

where

v is the instantaneous speed of the vehicle, in metres per second (m/s);

A is the characteristic coefficient of the vehicle, in newtons (N);

B is the characteristic coefficient of the vehicle, in N/(m/s);

C is the characteristic coefficient of the vehicle in $N/(m/s)^2$.

NOTE 2 The speed may be expressed in km/h and the rolling resistance in [daN] or [kN]. In this case, *A*, *B*, *C* are expressed in [daN], [daN/(km/h)], [daN/(km/h)^2] or [kN], [kN/(km/h)], [kN/(km/h)^2].

NOTE 3 Values for A, B and C may be obtained using the test method given in EN 14067-2.

b) Calculate the average rolling resistance as a function of the initial speed F_{Ra}, in newtons (N), using the following equations.

- average rolling resistance in the case of braking to a stop:

$$F_{Ra,m} = A + \frac{2}{3} \times B \times v_0 + \frac{1}{2} \times C \times v_0^2 \quad (3)$$

where

v_0 is the speed at which braking is initiated, in metres per second (m/s);

A, *B*, *C* are the coefficients in Equation (2);

NOTE 4 The speed may be expressed in km/h and the rolling resistance in [daN] or [kN]. In this case, *A*, *B*, *C* are expressed in [daN], [daN/(km/h)], [daN/(km/h)^2] or [kN], [kN/(km/h)], [kN/(km/h)^2].

- average rolling resistance in the case of slowing braking: