SLOVENSKI STANDARD
SIST EN 14531-6:2009

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Železniške naprave - Metode za izračun zavornih poti, poti za kontrolo hitrosti in zavarovanj stoječih vozil - 6. del: Izračun za vlakovne kompozicije ali posamezna vozila s postopkom "korak za korakom"

Railway applications - Methods for calculation of stopping and slowing distances and immobilisation braking - Part 6: Step by step calculations for train sets or single vehicles

Bahnanwendungen - Verfahren zur Berechnung der Anhalte- und Verzögerungsbremswege und der Feststellbremsung - Teil 6: Schrittweise Berechnungen für Zugverbände oder Einzelfahrzeuge

Applications ferroviaires - Méthodes de calcul des distances d'arrêt, de ralentissement et d'immobilisation - Partie 6: Calculs pas à pas pour des compositions de trains ou véhicules isolés

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<u>**ICS:**</u>

45.020	Železniška tehnika na splošno	Railway engineering in general

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Railway applications - Methods for calculation of stopping and slowing distances and immobilisation braking - Part 6: Step by step calculations for train sets or single vehicles

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Foreword

This document (EN 14531-6:2009) 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of an identical text or by endorsement, at the latest by November 2009, and conflicting national standards shall be withdrawn at the latest by November 2009.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This Standard[1] is one in a series of six, under the generic title EN 14531, Railway applications — Methods for calculation of stopping distances, slowing distances and immobilization braking. The other five are:

Part 1: General algorithms;

Part 2: Application to Single Freight Wagon (in preparation)*;*

Part 3: Application to mass transit (in preparation)*;*

Part 4: Single passenger coaches (in preparation)*;*

Part 5: Locomotives (in preparation).

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part of this document.

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

[1] Although it was originally intended to prepare a series of six parts for this Standard, the intention is now to rationalize and restructure the Standard so that it comprises fewer parts.

Introduction

The objective of this European Standard is to enable the railway industries and operators to work with a common calculation method.

It describes the adapted algorithms and step-by-step calculations for the design of brake equipment for all types of train sets, electrical multiple units, diesel multiple units and single vehicles.

1 Scope

This European Standard describes a general algorithm that may be used in all types of high speed and conventional vehicle applications, including self-propelling thermal or electric trains, thermal or electric traction units; passenger carriages, mobile railway infrastructure construction and maintenance equipment and freight wagons. This standard does not specify the performance requirements. It enables the calculation of the various aspects of the performance: stopping or slowing distances, dissipated energy, force calculations and immobilization braking.

This standard enables the verification by calculation of the stopping, slowing and immobilization performance requirements for high speed and conventional trains operating on high speed and conventional infrastructure.

Other calculation methods may be used providing that the order of accuracy achieved is in accordance with this European Standard.

This standard presents:

a) example of distance and other dynamic calculations, see Annex C;

b) example of immobilisation calculations, see Annex D.

2 Normative references

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

EN 14478:2005, *Railway applications — Braking — Generic vocabulary*

EN 14531-1:2005, *Railway applications — Methods for calculation of stopping distances, slowing distances and immobilization braking — Part 1: General algorithms*

prEN 15328, *Railway applications - Braking - Brake pads* [2]

ISO 80000-3:2006, *Quantities and units — Part 3: Space and time*

ISO 80000-4:2006, *Quantities and units — Part 4: Mechanics*

3 Definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the definitions given in EN 14478:2005, EN 14531-1:2005, ISO 80000-3:2006, ISO 80000-4:2006, and the following apply.

3.1.1
static mass per axle
(1) mass, measured by weighing at the wheel-rail interface, or estimated from design evaluation of each axle in a stationary condition

2 At the time of publication, this Standard was in the process of being prepared.

(2) mass of the train divided by the quantity of axles in case where the static mass per axle is not known

3.1.2
static mass of the train
summation of all the static mass per axle values, including all operating loads

3.1.3
brake equipment type
group of equipment the purpose of which is to provide braking force

3.1.4
isolated brake equipment
status of inoperable brakes on e.g. bogie (see EN 14478)

3.1.5
active brake equipment
equipment considered during the calculation of a specific type of braking (in opposition with isolation) (see EN 14478)

3.1.6
step by step calculation
numerical method with finite time steps

NOTE Synonym for a numerical type of solving an integral.

3.2 Symbols and indices

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

NOTE Specific symbols and indices are defined in the relevant clauses.

Table 1 — Symbols

Symbol	Definition	Unit
A	area	m^2
A_s	swept area of a friction surface	m^2
a	deceleration	m/s^2
B	braked weight	t
D	wheel diameter	m
d	diameter	m
F	force	N
F_B	braking force	N
F_g	downhill force on the train	N
f	coefficient of friction	-
g_n	standard acceleration of free fall = 9,80665 m/s^2 (refer to ISO 80000-3)	m/s^2
i	gradient [a]	-
i_C	cylinder ratio	-
i_{rig}	rigging ratio	-
i_{tra}	transmission ratio	-
m	mass	kg
n	quantity	-
P	power	W
p	pressure	Pa
R	wheel radius	m
r	radius	m
s	distance	m
S	safety factor	-
t	time	s
τ	coefficient of adhesion	-
v	speed	m/s
W	energy	J
W_S	energy per square unit	J/m^2
λ	brake percentage	-
μ	coefficient of friction (brake pad or blocks)	-
η	efficiency	-

[a] Rising gradient is positive; e.g. for a gradient of 5 ‰ i = 0,005.

Table 2 — General indices

Symbol	Term
AMG	attraction force for a magnetic track brake
ax	axle
a	available
B	friction
BEC	braking force for an eddy current brake
BED	electro-dynamic braking force
BFR	fluid retarder braking force
BMG	braking force for a magnetic brake
b	block or pad
bog	bogie
C	cylinder
cha	characteristic
Bd	brake force demand
disc	disc
dyn	dynamic
e or 2	final
e	equivalent
ext	external
H	hand brake
i	brake equipment type
im	immobilization, parking, holding
int	internal
inst	instantaneous
m	average, mean
max	maximum
min	minimum
mot	motor
m_unsp	unsprung mass
MG	magnetic brake
n	normal direction
r	responsen
Ra	train resistance to motion
req	required
rig	rigging
rot	rotating
R1	return spring
R2	regulator
S	spring
st	static
t	tangential direction
tot	total
tra	transmission
wind	wind
0 or 1	initial

4 General algorithms

4.1 General algorithm to calculate stopping and slowing distances

This algorithm is presented in Figure A.1

This algorithm shall be used with instantaneous values which are calculated step by step. The numerical integration shall be time based (see 5.8). A rough estimation can be based on EN 14531-1. The rough estimation shall only be used to check the results of the numerical integration.

The content of each algorithm, the corresponding definitions of input values and different phases of calculation are given in Clause 5.

4.2 General algorithm to calculate immobilization brake

This algorithm is presented in Figure A.2.

The content of each algorithm, the corresponding definitions of input values and different phases of calculation are given in Clause 6.

5 Stopping and slowing distances calculation

5.1 Accuracy of input values

The accuracy of the calculation described here depends directly on the accuracy of the input data. All the input data shall have an appropriate order of accuracy and shall be justified by tests, further calculations or engineer's estimations, etc.

Corresponding calculations or test reports (or extracts of these documents) should be attached with the performance calculation.

5.2 General characteristics

5.2.1 Train formation

The parameters which shall be used to define train formation are:

a) quantity of motor axles;

b) quantity of trailer axles;

c) quantity of braked axles for each adhesion dependent brake equipment type;

d) quantity of non-adhesion dependent brake equipment type.

According to the braking system design, the parameters can also be defined at the level of the bogies, or of the vehicles.

Calculations shall be performed for each brake equipment type. In so doing, the brake force contributions from each of the brake equipment subtypes (e.g. disc brakes, tread brakes, electrodynamic brakes) shall be taken into consideration. All of the various types of brake equipment applied to one axle shall be identified and accounted for in the calculation.

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, etc.).

When brake equipment is used on one part of the train under certain conditions and used on another part under different conditions (for example with two different cylinder pressures for the same load level), two different brake equipment types shall be considered. In such cases, the two brake equipment types shall be identified and accounted for separately in the calculation.

NOTE 2 The total quantity of axles is the result of the sum 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

When there are different “static mass per axle”, see 3.1.1, the location in the train shall be indicated.

5.2.2.2 Equivalent rotating masses

Rotating mass (as defined in EN 14478) shall be calculated using a theoretical approach or an approved test method when applicable.

It shall be indicated the wheel size and the relevant static mass condition which is related to the mass inertias (e.g. new wheel and tare load condition).

When there are different “rotating mass per axle”, the location in the train shall be indicated.

5.2.2.3 Wheel diameters

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

The wheel diameter used in the emergency brake calculation shall be that of a wheel which gives the lowest deceleration (e.g. in the case of disc brakes, this would normally be the maximum wheel diameter).

For checking the adhesion required, τ_{req} , the wheel diameter used shall be that which gives the maximum adhesion required (e.g. in the case of disc brakes, this would normally be the minimum wheel diameter).

If the train is equipped with different sizes of wheels, each size of wheel shall be indicated to the train composition.

5.2.2.4 Train resistance

The value of train 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.

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

a) one term independent of vehicle speed;

b) one term proportional to the speed, dealing with the mechanical components (train and track);

c) a third term proportional to a power n of the speed (aerodynamic resistance).

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

To obtain the instantaneous train resistance as a function of the speed:

$$F_{Ra} = A + B \cdot v + C \cdot v^{n} \quad (1)$$

where:

F_{Ra}	is the instantaneous value of the train resistance	N
v	is the instantaneous speed of the vehicle	m/s
A	is the characteristic coefficient of the vehicle	N
B	is the characteristic coefficient of the vehicle.	N/(m/s)
C	is the characteristic coefficient of the vehicle.	$N/(m/s)^n$
n	is the exponent to be defined exactly. In case there is no exact value available, n is estimated to be 2	

For the application of more usual units, the coefficients of the formula shall be adapted.

The above units shall be used for the calculations purpose, but the speed can be expressed usually in km/h and the train resistance in N or kN. In this case, A, B, C are expressed in N, N/(km/h), $N/(km/h)^n$ or kN, kN/(km/h), $kN/(km/h)^n$.

NOTE 1 A, B, and C coefficients are function of various parameters, e.g. mass, train length. Values for A, B, and C may be obtained using the test method given in EN 14067-2.

NOTE 2 For a first calculation, the average train resistance to motion as detailed in EN 14531-1 may be used.

EXAMPLE In all these formulae, the train resistance F_{Ra} is given in N and the instantaneous speed v in m/s.

A = 4 144,9 N;

B = 100,8 N/(m/s);

C = 7,53 N/(m/s²).

For a speed of 300 km/h corresponding to 83,3 m/s, train resistance force is:

F_{Ra} = 4 144,9 + 100,8 × 83,3 + 7,53 × 83,3²;

F_{Ra} = 6 4791 N.

NOTE Other examples of values are given in Annex C.

5.3 Brake equipment characteristics

5.3.1 General

The final result of this part is the braking force generated by each brake equipment related to the top of the rail.

This clause considers the braking force generated by each brake equipment type by reference to the most common brake equipment i.e. tread and disc braking. If this equipment is not applicable, other suitable methods of brake force calculation should be adopted.

5.3.2 Friction brake equipment forces

5.3.2.1 Tread brake unit

The brake equipment of a tread brake unit acts on one shoe arrangement per cylinder as shown in Figures 1 and 2.

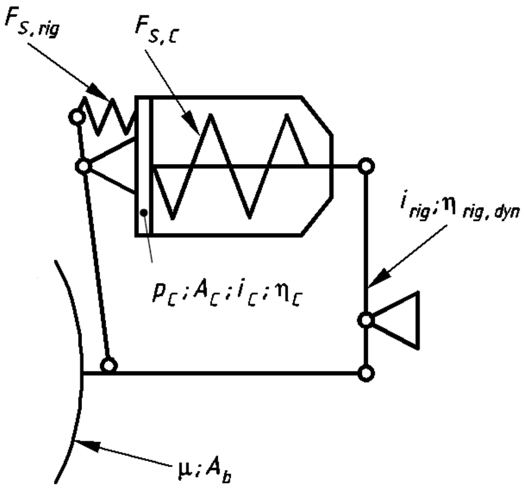

Figure 1 — Pressure applied tread brake unit

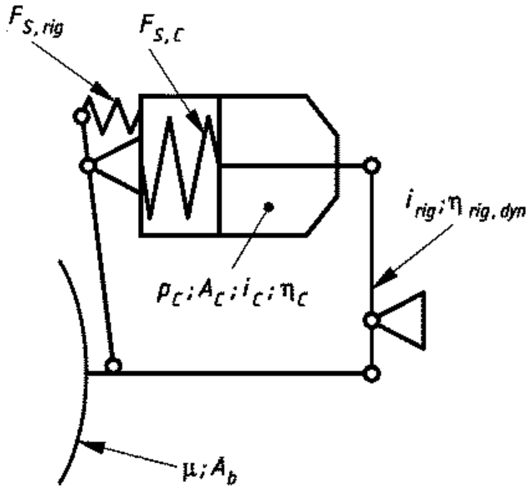

Figure 2 — Spring applied tread brake unit

The braking force characteristic of a tread brake unit can be expressed by:

Output cylinder force

$$F_c = p_c \cdot A_c \cdot i_c \cdot \eta_c + F_{s,c} \quad (2)$$

Application force on the shoe

$$F_n = F_c \cdot i_{rig} \cdot \eta_{rig,dyn} + F_{s,rig} \quad (3)$$

Braking force per unit

$$F_{B,C} = F_n \cdot \mu \quad (4)$$

where:

p_C	is the brake cylinder pressure	Pa
A_C	is the brake cylinder piston area	m^2
η_C	is the cylinder efficiency	-
i_C	is the cylinder ratio	-
	NOTE 1 For pressure applied brake equipment: **positive** value; for spring applied brake equipment: **negative** value.	
$F_{S,C}$	is the cylinder spring force	N
	NOTE 2 For braking force: **positive** value; for releasing force: **negative** value.	