SLOVENSKI STANDARD
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Železniške naprave - Metode za izračun zavornih poti pri ustavljanju in upočasnjevanju ter zavarovanje stoječih vozil - 2. 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 2: Step by step calculations for train sets or single vehicles

Bahnanwendungen - Verfahren zur Berechnung der Anhalte- und Verzögerungsbremswege und der Feststellbremsung - Teil 2: Schrittweise Berechnungen für Zugverbände oder Einzelfahrzeuge

Applications ferroviaires - Méthodes de calcul des distances d'arrêt, de ralentissement et d'immobilisation - Partie 2: Calcul pas à pas pour des compositions de trains ou véhicules isolés

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45.060.01	Železniška vozila na splošno	Railway rolling stock in general

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English Version

Railway applications - Methods for calculation of stopping and slowing distances and immobilization braking - Part 2: Step by step calculations for train sets or single vehicles

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European foreword

This document (EN 14531-2:2015) 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of an identical text or by endorsement, at the latest by June 2016, and conflicting national standards shall be withdrawn at the latest by June 2016.

This document supersedes EN 14531-6:2009.

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.

This series of European standards EN 14531, *Railway applications — Methods for calculation of stopping and slowing distances and immobilization braking* consists of:

— *Part 1: General algorithms utilizing mean value calculation for train sets or single vehicles*;

— *Part 2: Step-by-step calculations for train sets or single vehicles.*

The two parts are interrelated and should be considered together when conducting the step-by-step calculation of stopping and slowing distances.

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.

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

Introduction

This European Standard describes a common calculation method for railway applications. It describes the general algorithms utilizing step by step calculation for use in the design and validation of brake equipment and braking performance for all types of train sets and single vehicles. In addition, the algorithms provide a means of comparing the results of other braking performance calculation methods.

The EN 14531 series was originally planned to have six parts covering the calculation methodology to be used when conducting calculations relating to the braking performance of various types of railway vehicles under the heading 'EN 14531, *Railway applications – Methods for calculation of stopping, slowing distances and immobilization braking*'. The six parts were as follows:

– Part 1: General algorithms

– Part 2: Application to single freight wagon

– Part 3: Application to mass transit (LRVs and D- and E- MUs)

– Part 4: Application to single passengers coach

– Part 5: Application to locomotive

– Part 6: Application to high speed trains

EN 14531-1 was originally published in 2005 followed by EN 14531-6 which was published in 2009.

Following the publication of these parts, it was decided that a common methodology could be used for parts 2 to 5 and this should be contained under a revised version of Part 1 and Part 6 with a title of '*Railway applications — Methods for calculation of stopping and slowing distances and immobilisation braking — Part 2: Step by step calculations for train sets or single vehicles*' .

EN 14531-1:2005 and EN 14531-6:2009 are referenced in the current TSIs (Freight wagons and Locomotive and passenger RST). The tables of the Annex ZA give the equivalence of the TSI referenced clauses of the original EN 14531 series to the clauses of this issue of EN 14531-1 and EN 14531-2.

1 Scope

This European Standard describes the step-by-step method for the calculation of brake performance utilizing time step integration which may be used for all types of train sets, units or single vehicles, including high-speed, locomotive and passenger coaches, conventional vehicles and wagons.

This European Standard does not specify the performance requirements. It enables the calculation of the various aspects of the performance: stopping or slowing distances, adhesion requirements, force calculations, etc.

This European Standard enables the verification by calculation of the stopping and slowing performance for high-speed and conventional trains operating on high-speed and conventional infrastructure. It may also be used for the detailed investigation of stopping or slowing performance at any design/verification stage.

The proposed method of this standard is based on a numerical time integration algorithm. The standard explains a simple numerical integration scheme in order to provide a useful straightforward example of the proposed method. Other numerical time integration algorithms exist, especially more accurate ones, but they are not in the scope of this standard.

When such methods are used the order of accuracy that they achieve has to be in accordance with this European Standard.

This European Standard also includes examples of distance and other dynamic calculations, see Annex B.

2 Normative references

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

EN 14067-4, *Railway applications - Aerodynamics - Part 4: Requirements and test procedures for aerodynamics on open track*

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

EN 14531-1, *Railway applications - Methods for calculation of stopping and slowing distances and immobilization braking - Part 1: General algorithms utilizing mean value calculation for train sets or single vehicles*

3 Terms, definitions, symbols and indices

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14478 and EN 14531-1 and the following apply.

3.1.1
step-by-step calculation
numerical method with finite time steps

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.

Table 1 — Symbols

Symbol	Definition	Unit
A	Area	m^2
a	Deceleration	m/s^2
D	Wheel diameter	m
F	Force	N
F_B	Braking force	N
ε	Acceptable deviation from v_{fin} used to stop the time step calculation	m/s
g_n	Standard acceleration of free fall = 9,806 65 m/s^2 (refer to ISO 80000-3)	m/s^2
i	Gradient (rising gradient is positive; e.g. for a gradient of 5 ‰, i = 0,005)	-
i_C	Cylinder/unit ratio	-
i_{rig}	Rigging ratio	-
i_{tra}	Transmission ratio	-
m	Mass	kg
n	Quantity	-
p	Pressure	Pa
P	Power of brake equipment	W
r	Radius	m
s	Distance	m
t	Time	s
W_b	Energy dissipated by brake equipment	J
τ	Coefficient of adhesion	-
μ	Coefficient of friction (brake pad or block)	-
η	Efficiency	-

Table 2 — General indices

Indices	Term
a_x	Axle
a	Available
B	Brake/braking
BED	Electro-dynamic braking force
C	Cylinder/unit
dyn	Dynamic
fin	Final
e	Equivalent
ext	External
i	brake equipment type
j	Time step
max	Maximum
n	Nominal
Ra	Train resistance to motion
req	Required
rig	Rigging
rot	Rotating
st	Static
tra	Transmission
0 or 1	Initial

4 General algorithm to conduct a step-by-step calculation

The calculation is presented in a flow chart as shown in Figure A.1.

The algorithm uses instantaneous values which are calculated step-by-step. The numerical integration shall be time-based as set out in 5.7.

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

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.

The accuracy of the input data values shall be relevant to the purpose of the calculation and shall be traceable as to how these values were established e.g. engineer´s estimation, test results, manufacturer's data. Supporting calculations or test reports (or extracts of these documents) should be attached with the performance calculation where applicable.

Representative curves of the performance of a type of brake equipment e.g. electrodynamic brake, can be determined by numerical or practical methods. The values can be given as a table.

5.2 General characteristics

5.2.1 General

Descriptions of general characteristics e.g. train formation, train mass, static and equivalent rotating mass, dynamic mass and wheel diameter are given in EN 14531-1 if not otherwise specified below.

5.2.2 Train resistance

The train resistance is a component of the train retarding force provided by the structure of the train referred as resistance to motion in EN 14067-4; this uses instantaneous values in the formula:

$$F_{\mathrm{Ra}} = A + B \cdot v + C \cdot v^2 \tag{1}$$

where:

F_{Ra} is the instantaneous value of the train resistance, in N

v is the instantaneous speed of the vehicle, in m/s

A is the characteristic coefficient of the train independent of speed considered as C_1 in EN 14067-4, in N

B is the characteristic coefficient of the train proportional to the speed considered as C_2 in EN 14067-4, in $\frac{\mathrm{N}}{(\mathrm{m/s})}$

C is the characteristic coefficient of aerodynamic train resistance considered as C_3 in EN 14067-4, in $\frac{\mathrm{N}}{(\mathrm{m/s})^2}$

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

5.3 Brake equipment type characteristics

5.3.1 General

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

See EN 14531-1 for basic descriptions of brake equipment type and entity.

5.3.2 Characteristics of friction brake equipment types

See EN 14531-1 for basic descriptions of tread and disc brake equipment types and the dynamic and static coefficients of friction of the brake block and pad, together with the calculation of tread brake and disc brake forces.

5.3.3 Characteristics of the other brake equipment types

See EN 14531-1 for basic descriptions of electrodynamic, fluid retarder, magnetic track brake and eddy current brake equipment types together with the calculation of the respective brake forces.

5.3.4 Time characteristics of each brake equipment type

5.3.4.1 Derivation of characteristics

In the step-by-step calculation, an instantaneous characteristic can be expressed by multiplication of the nominal braking force with a dimensionless factor as set out in 5.7. For example, the braking response of a brake equipment type can be considered with such dimensionless factors as a characteristic depending on time.

5.3.4.2 Creation of input data

The time characteristics, calculated as set out in 5.3.4.1 can be used directly or converted to a practical approximation, e.g. a linear description (see Annex B).

5.3.5 Blending concept

The description of a typical blending concept is described in EN 14531-1.

5.4 Initial and operating characteristics

5.4.1 Mean gradient of the track

In general, brake performance calculations are based on the assumption of a straight and level track; EN 14531-1 states the considerations and formulae when considering braking on a gradient.

5.4.2 Initial speed

For design, the calculations should as a minimum be performed from the maximum design speed.

5.4.3 Available coefficient of adhesion

If the required adhesion exceeds the available adhesion, it can lead to an increase of the stopping distance compared to a theoretical calculation as a consequence of a sliding wheelset or regulation by the wheel slide protection device.

The required adhesion of each axle, calculated as set out in 5.11.2 shall be lower than the assumed or specified available adhesion. This available coefficient of adhesion is dependent on the conditions prevalent at the time of braking e. g. sanding, speed, environmental conditions, number of axles, etc.

5.4.4 Level of the brake demand

Generally, the emergency brake demand is considered during step-by-step calculations (unless otherwise specified).

Other brake demand levels e.g. full service braking may be considered when establishing the design of each functioning brake equipment type.

5.4.5 Quantity of each brake equipment type available

Calculations shall be performed with all the brake equipment types in working order and with a specified quantity and, or location of isolated brakes.