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Železniške naprave - Aerodinamika - 4. del: Zahteve in preskusni postopki za aerodinamiko na odprti progi

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

Bahnanwendungen - Aerodynamik - Teil 4: Anforderungen und Prüfverfahren für Aerodynamik auf offener Strecke

Applications ferroviaires - Aérodynamique - Partie 4: Exigences et procédures d'essai pour l'aérodynamique à l'air libre

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This European Standard was approved by CEN on 21 September 2013 and includes Amendment 1 approved by CEN on 28 August 2018.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 14067-4:2013+A1:2018) 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of an identical text or by endorsement, at the latest by June 2019, and conflicting national standards shall be withdrawn at the latest by June 2019.

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

This document includes Amendment 1 approved by CEN on 2018-08-28.

This document supersedes [A1⟩ EN 14067-4:2013 ⟨A1].

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A1⟩ ⟨A1].

[A1⟩ *deleted text* ⟨A1] The results of the EU-funded research project "AeroTRAIN" (Grant Agreement No. 233985) have been used.

[A1⟩ 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. ⟨A1]

[A1⟩ *deleted text* ⟨A1]

EN 14067, *Railway applications — Aerodynamics* consists of the following parts:

— *Part 1: Symbols and units*
— *Part 2: Aerodynamics on open track* ([A1⟩ *withdrawn* ⟨A1])
— *Part 3: Aerodynamics in tunnels*
— *Part 4: Requirements and test procedures for aerodynamics on open track*
— *Part 5: Requirements and test procedures for aerodynamics in tunnels*
— *Part 6: Requirements and test procedures for cross wind assessment*

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, 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, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Trains running on open track generate aerodynamic loads on objects and persons they pass. If trains are being passed by other trains, trains are also subject to aerodynamic loading themselves. The aerodynamic loading caused by a train passing an object or a person near the track, or when two trains pass each other, is an important interface parameter between the subsystems of rolling stock, infrastructure and operation and, thus, is subject to regulation when specifying the trans-European railway system.

Trains running on open track have to overcome a resistance to motion which has a strong effect on the required engine power, achievable speed, travel time and energy consumption. Thus, resistance to motion is often subject to contractual agreements and requires standardized test and assessment methods.

1 Scope

This European Standard deals with requirements, test procedures and conformity assessment for aerodynamics on open track. Addressed within this standard are the topics of aerodynamic loadings and resistance to motion, while the topic of cross wind assessment is addressed by EN 14067-6.

This European Standard refers to rolling stock and infrastructure issues. This standard does not apply to freight wagons. It applies to railway operation on gauges GA, GB and GC according to EN 15273. The methodological approach of the presented test procedures may be adapted to different gauges.

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 1991-2, *Eurocode 1: Actions on structures — Part 2: Traffic loads on bridges*

EN 15273 (all parts), *Railway applications — Gauges*

EN 15663, *Railway applications — Definition of vehicle reference masses*

ISO 8756, *Air quality — Handling of temperature, pressure and humidity data*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
peak-to-peak pressure change
modulus of the difference between the maximum pressure and the minimum pressure for the relevant load case

3.1.2
passage of train head
passage of the front end of the leading vehicle which is responsible for the generation of the characteristic pressure rise and drop, over and beside, the train and on the track bed

3.1.3
Computational Fluid Dynamics
CFD
numerical methods of approximating and solving the equations of fluid dynamics

3.1.4
streamline shaped vehicle
vehicle with a closed and smooth front which does not cause flow separations in the mean flow field greater than 5 cm from the side of the vehicle

3.1.5
bluff shaped vehicle
vehicle that is not streamlined

3.2 Symbols

For the purposes of this document, the following symbols apply.

Table 1 — Symbols

Symbol	Unit	Significance	Explanation or remark
b	m	reference length	train width
c	m/s	speed of sound	
c_F	–	coefficient of aerodynamic force	
c_{p1}	–	aerodynamic coefficient depending on the distance from track centre Y	
c_{p2}	–	aerodynamic coefficient depending on the height above top of rail h	
c_{p3}	–	aerodynamic coefficient depending on the distance from track centre Y	
C_1	N	rolling mechanical resistance	
$C_2\, v_{tr}$	N	momentum drag due to air flow for traction and auxiliary equipment and the air conditioning systems	
$C_3\, v_{tr}^2$	N	aerodynamic drag in the resistance to motion formula	
$d\,t$	s	temporal variation	
$d\,v_{tr}$	m/s	train speed variation	
$d\,x$	m	spatial variation	
F	N	load on an object, maximum value of the force during the passage	
g	m/s^2	acceleration due to gravity	
h	m	height above top of rail	
i	‰	gradient of the track	
k	–	factor accounting for the energy stored in rotating masses	≥ 1,0
k_1	–	shape coefficient of the train	
k_2	–	shape coefficient of the train	
k_3	–	shape coefficient of the train	
L_n	m	length of the train nose	distance from front end to where the full cross section of the leading vehicle is achieved
m	kg	train mass	normal operational payload according to EN 15663

Table 1 *(2 of 4)*

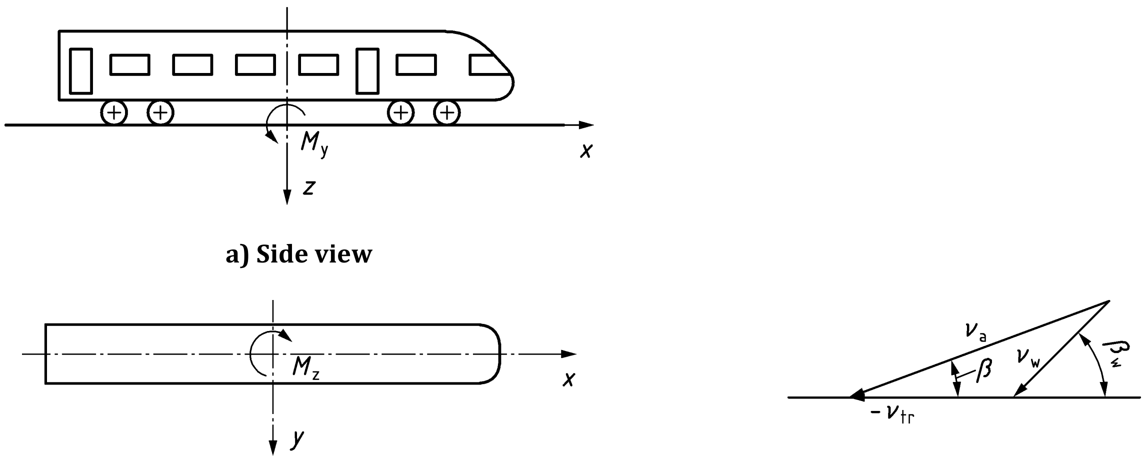
Symbol	Unit	Significance	Explanation or remark
p	Pa	pressure	
p_{max}	Pa	maximum pressure	
p_{min}	Pa	minimum pressure	
p_{1k}	Pa	characteristic value of distributed load	
p_{2k}	Pa	characteristic value of distributed load	
p_{3k}	Pa	characteristic value of distributed load	
r	m	curve radius	
Re	–	Reynolds number	based on reference length of 3,00 m at full scale
Re_{max}	–	maximum Reynolds number	
R_1	N	resistance to motion	train contribution
R_2	N	resistance to motion	infrastructure contribution
S	m²	characteristic area	
t	s	time	
u_i	m/s	resultant horizontal air speed of the i-th passage	after transformation of the time base
$u_{m,i}$	m/s	measured resultant horizontal air speed of the i-th passage	
U	m/s	induced flow speed	
$\overline{U}$	m/s	mean value over all measured maxima U_i	
U_i	m/s	maximum resultant horizontal air speed of the i-th passage after averaging and correction to the characteristic train speed	
U_{max}	m/s	maximum value of U	
$U_{2\sigma}$	m/s	upper bound of a 2 σ interval of maximum air speed	
$U_{95\%}$	m/s	maximum resultant horizontal air speed	characteristic air speed
$U_{95\%,max}$	m/s	permissible maximum resultant horizontal air speed	permissible characteristic air speed
v_{tr}	m/s	train speed	
$v_{tr,c}$	m/s	full scale train speed	
$v_{tr,i}$	m/s	train speed during the i-th passage	
$v_{tr,max}$	m/s	maximum train speed	
$v_{tr,ref}$	m/s	reference speed	
$v_{tr,test}$	m/s	nominal test speed	

Table 1 *(3 of 4)*

Symbol	Unit	Significance	Explanation or remark
$v_{w,x,i}$	m/s	wind speed component in x-direction during the i-th passage	
y^+	–	dimensionless wall distance	
Y	m	lateral distance from track centre	
Y_{min}	m	minimum lateral distance from track centre	
Y_{max}	m	maximum lateral distance from track centre	
γ	m/s^2	train acceleration measured during the coasting test	
$\Delta C_{p,2\sigma}$	–	pressure change coefficient	Upper bound of a 2 σ interval of the peak-to-peak pressure change coefficient. The peak-to-peak pressure change coefficient is defined in Formula 2.
ΔC_p	–	pressure change coefficient	
Δp	Pa	peak-to-peak pressure change	
$\overline{\Delta p}$	Pa	mean value for peak-to-peak pressure change	determined over all measurements Δp_i or by CFD
$\Delta p_{2\sigma}$	Pa	upper bound of a 2 σ interval of the peak-to-peak pressure change	
$\Delta p_{95\%}$	Pa	maximum peak-to-peak pressure change	characteristic pressure change
$\Delta p_{95\%,max}$	Pa	permissible maximum peak-to-peak pressure change	permissible characteristic pressure change
Δp_i	Pa	maximum peak-to-peak pressure value of the i-th passage	
$\Delta p_{m,i}$	Pa	maximum peak-to-peak pressure value measured during the i-th passage	
Δp_{sim}		the head pressure variation from unsteady CFD calculations	
$\overline{\Delta p_{sim}}$	Pa	the head pressure variation from steady CFD calculations	
Δt	s	characteristic time interval	passage of train head, time between pressure peaks
ε	-	relative difference	
$\sum R_i$	N	sum of all the resistances to motion	
η	Pa·s	dynamic viscosity	
ρ	kg/m^3	air density	
ρ_i	kg/m^3	air density determined during the i-th passage	
ρ_0	kg/m^3	standard air density	ρ_0 = 1,225 kg/m^3

Table1 *(4 of 4)*

Symbol	Unit	Significance	Explanation or remark
σ	–	standard deviation	can be pressure or speed
σ_{sim}	Pa	standard deviation of simulated pressure	



a) Side view

b) Top view

c) Speed vector diagram

Figure 1 – Coordinate system

4 Requirements on locomotives and passenger rolling stock

4.1 Limitation of pressure variations beside the track

4.1.1 General

A passing train generates a varying pressure field beside the track which has an effect on objects such as crossing trains, noise barriers, platform installations, etc. To define a clear interface between the subsystems of rolling stock and infrastructure, the train-induced aerodynamic pressure loads beside the track need to be known and limited.

In order to describe and to limit the train-induced aerodynamic pressure loads beside the track one reference case for rolling stock assessment is defined.

4.1.2 Requirements

4.1.2.1 Reference case

For standard GA, GB, GC gauge according to EN 15273 in the absence of embankments, cuttings and other significant trackside structures the undisturbed pressure field generated by a passing train at a position of 2,50 m distance from the centre of a straight track with standard track formation profile is referred to as the reference case. The pressure variations occurring are characterized by the upper bound of the 95 % confidence interval for the maximum peak-to-peak pressure. This maximum peak-to-peak pressure change, $\Delta p_{95\%}$, refers to the maximum pressure change which occurs during the passage of the train head.

4.1.2.2 Fixed or pre-defined train compositions

A fixed or pre-defined train composition, running at the reference speed in the reference case scenario shall not cause the maximum peak-to-peak pressure changes to exceed a value $\Delta p_{95\%,\max}$ as set out in Table 2 over the range of heights 1,50 m to 3,00 m above the top of rail during the passage of the train head. For non-identical end cars the requirement applies for each possible running direction.

Table 2 — Maximum permissible peak-to-peak pressure change $\Delta p_{95\%,\max}$ depending on maximum design speed

Maximum design speed	Permissible pressure change $\Delta p_{95\%,\max}$ at reference speed	Reference speed
$v_{tr} \leq 160$ km/h	no requirement	
160 km/h < v_{tr} < 250 km/h	$\Delta p_{95\%,\max} = 800$ Pa	maximum design speed
250 km/h ≤ v_{tr}	$\Delta p_{95\%,\max} = 800$ Pa	250 km/h

4.1.2.3 Single rolling stock units fitted with a driver's cab

Single rolling stock units fitted with a driver's cab running as the leading vehicle at the reference speed in the reference case scenario shall not cause the maximum peak-to-peak pressure changes to exceed a value $\Delta p_{95\%,\max}$ as set out in Table 2. The range of heights to be considered are 1,50 m to 3,00 m above the top of rail during the passage of the front end of this unit. For single rolling stock units capable of bidirectional operation as a leading vehicle the requirement applies for each possible running direction.

4.1.2.4 Other passenger rolling stock

For passenger rolling stock which is not covered in 4.1.2.2 or 4.1.2.3 there is no requirement.

4.1.3 Full conformity assessment

A full conformity assessment of interoperable rolling stock shall be undertaken according to Table 3.

Table 3 — Methods applicable for the full conformity assessment of rolling stock

Maximum design speed	Methods
$v_{tr} \leq 160$ km/h	No assessment needed
160 km/h < v_{tr}	Assessment by: — full-scale tests according to 6.1.2.1; or — reduced-scale moving model tests according to 6.1.2.2; or — CFD simulations according to 6.1.2.4.

4.1.4 Simplified conformity assessment

A simplified conformity assessment may be carried out for rolling stock that are subject to minor design differences in comparison to rolling stock for which a full conformity assessment already exists.

With respect to pressure variations beside the track, the only relevant design differences are differences in external geometry and differences in design speed.

This simplified conformity assessment shall take one of the following forms in accordance with Table 4:

— a statement and rationale that the design differences have no impact on the pressure variations beside the track;
— a comparative evaluation of the design differences relevant to the rolling stock for which a full conformity assessment already exists.

Table 4 — Methods and requirements applicable for simplified conformity assessment of rolling stock

Design differences	Methods and requirements
Differences in external geometry limited to — locations either downstream of the distance of the maximum cross-section from the train nose or downstream of the distance of the minimum pressure peak relative to the train nose, — the inner region of the underpart of the train (under the train and between rails), — minor differences in external geometry, — wipers and handles, — antennae with a volume smaller than 5 l, — long isolated protruding objects or gaps not being vertical or close to the front-side radius or edge smaller than 50 mm in the crosswise dimensions, — small isolated protruding objects and gaps smaller than 50 mm in each dimension.	Documentation of differences, statement of no impact and reference to an existing compliant full conformity assessment.
Other differences in external geometry (e.g. in buffers, front couplers, snow ploughs, front or side windows) keeping the basic head shape features.	Documentation of differences and reference to an existing compliant full conformity assessment AND assessment of the relative effect of differences by — reduced-scale moving model tests according to 6.1.2.2 or — CFD-simulations according to 6.1.2.4, AND evidence and documentation that (i) the difference causes changes in $\overline{\Delta p}$ less than ± 10 %, $\frac{\overline{\Delta p}(B)-\overline{\Delta p}(A)}{\overline{\Delta p}(A)}<0{,}1$ NOTE *B* refers to the new train geometry. *A* refers to the existing compliant train. and (ii) the difference does not exceed 50 % of the margin available on the compliance with 4.1.2. $(\overline{\Delta p}(B)-\overline{\Delta p}(A))<0{,}5\cdot(\Delta p_{95\%,\max}-\Delta p_{95\%}(A))$
Increase of design speed — less than 10 % for a train with original design	Documentation of differences and reference to an existing compliant full conformity assessment AND

speed < 250 km/h, — for a train with original design speed ≥ 250 km/h.	evidence and documentation based on a ΔC_p analysis that the new design under investigation still fulfils the requirements listed in 4.1.2.

4.2 Limitation of slipstream effects beside the track

4.2.1 General

A train generates a varying flow field beside the track which has an effect on persons and objects at the track side and at platforms. In order to define a clear interface between the subsystems of the rolling stock and the infrastructure, the train-induced slipstream effects need to be known and limited.

In order to describe and to limit the train-induced slipstream effects, a reference case for rolling stock assessment is defined.

NOTE Ensuring track workers' and passengers' safety at the platform involves additional issues on the operational and infrastructure side.

4.2.2 Requirements

4.2.2.1 Reference case

For standard GA, GB, GC gauges according to EN 15273, in the absence of embankments, cuttings and any significant trackside structures, the undisturbed flowfield generated by a passing train at a position of 3,00 m from the centre of a straight track with standard track formation profile is referred to as the reference case.

The air flows occurring are characterized by the upper bound of the 95 % confidence interval of maximum resultant horizontal air speeds. This maximum horizontal air speed $U_{95\%}$ refers to the whole passage of the train and its wake.

4.2.2.2 Fixed or pre-defined train compositions

A full-length, fixed or pre-defined train composition, running at reference speed in the reference case scenario shall not cause the maximum resultant horizontal air speed to exceed a value $U_{95\%,\max}$ as set out in Table 5 at a height of 0,20 m above the top of rail during the passage of the whole train and its wake. For non-symmetrical train compositions, the requirement applies for each possible running direction. For fixed or pre-defined train compositions consisting of more than one train unit, it is sufficient to assess a train composition consisting at least of two units and of a minimum length of 120 m.