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Železniške naprave - Aerodinamika - 4. del: Zahteve in preskusni postopki pri aerodinamiki 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 draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 256.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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Foreword

This document (prEN 14067-4:2011) has been prepared by Technical Committee CEN/TC 256 “Railway Applications”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

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(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This document supersedes EN 14067-4:2005+A1:2009.

EN 14067-2 has been integrated in this document, and EN 14067-4 has been re-structured and extended to support the Technical Specifications for the Interoperability of the Trans-European rail system [2 to 4].

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

— Part 1: Symbols and units

— Part 2: Aerodynamics on open track

— 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

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 standardised test and assessment methods.

1 Scope

This European Standard deals with requirements and test procedures 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 safety is addressed by EN 14067-6.

This European standard refers to rolling stock and infrastructure issues. It applies to railway operation on standard gauge according to EN 15273. The methodological approach of the presented test procedures might be adapted to different gauge.

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

EN 1991-1-4, *Eurocode 1: Actions on structures — Part 1-4: General actions — Wind actions*

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

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

prEN 16272-2-1, *Railway applications — Track — Noise barriers — Part 2-1: Mechanical performance and stability requirements under dynamic loadings due to passing trains — Simplified calculation method*[1)]

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

3 Terms and definitions

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

3.1
peak-to-peak pressure change
modulus of difference between maximum pressure and minimum pressure for the relevant load case

3.2
passage of train head
⟨train-induced aerodynamic loads on open track⟩
passage of the front end of the leading vehicle which is responsible for the generation of the characteristic pressure rise and drop beside and in the track

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

1) Draft in preparation.

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 axis Y	
C_{p2}	–	aerodynamic coefficient depending on the distance from track axis Y	
C_{p3}	–	aerodynamic coefficient	
C_U	–	air speed coefficient	
C_1	–	rolling mechanical resistance	
$C_2\ v_{tr}$	–	air momentum drag due to cooling air for the locomotives and the air conditioning for the trailer cars	
$C_3\ v_{tr}^2$	–	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	–	accounting for the energy stored in rotating masses	
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	
m	kg	train mass	normal operational payload according to EN 15663
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	

Symbol	**Unit**	**Significance**	**Explanation or remark**
r	m	curve radius	
Re_{max}	–	maximum Reynold's number	
R_1	N	resistance to motion	train contribution
R_2	N	resistance to motion	infrastructure contribution
S	m^2	side area	
t	s	time	
U	m/s	induced flow speed	
$\overline{U}$	m/s	mean value over all measured maxima U_i	
U_i	m/s	maximum horizontal air speed of the i-th passage	
U_{max}	m/s	maximum value of U	= $U_{95\%}$
$U_{m,i}$	m/s	maximum horizontal air speed measured during the i-th passage	
$U_{2\sigma}$	m/s	upper bound of a 2 σ interval of maximum air speed	
$U_{95\%}$	m/s	maximum horizontal air speed	characteristic air speed
$U_{95\%,max}$	m/s	permissible maximum 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	
$v_{tr,m,i}$	m/s	train speed measured during the i-th passage	
$v_{w,x,i}$	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	
Y_s	m	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
ΔC_p	–	pressure change coefficient	
Δp	Pa	peak-to-peak pressure change	

Symbol	Unit	Significance	Explanation or remark
$\overline{\Delta p}$	Pa	mean value over all measurements Δp_i	
$\Delta p_{2\sigma}$	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	
Δt	s	characteristic time interval	passage of train head, time between pressure peaks
$\sum R_i$	N	sum of all the resistances to motion	
ρ	kg/m^3	air density	
ρ_0	kg/m^3	standard air density	ρ_0 = 1,225 kg/m^3
σ	–	standard deviation	

4 Requirements on interoperable 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. In order 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 any other objects 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 is to as the reference case. The vertical distance between the top of rail and the surrounding ground level shall not exceed 1,00 m.

The pressure variations occurring are characterised 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 within the relevant load cycle 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 on open track 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 3,30 m above the top of rail during the passage of the front end of the leading vehicle. For non-identical end cars the requirement applies for each possible running direction.

NOTE The wording “front end of the leading vehicle” is a precision of the wording “train head”.

Table 2 — Maximum permissible peak-to-peak pressure change $\Delta p_{95\%,\max}$ for fixed or pre-defined train compositions depending on their 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	$\Delta p_{95\%,\max}$ = 720 Pa	Maximum design speed
250 km/h ≤ v_{tr}	$\Delta p_{95\%,\max}$ = 795 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 on open track shall not cause the maximum peak-to-peak pressure changes to exceed a value $\Delta p_{95\%,\max}$ as set out in Table 3 over the range of heights 1,50 m to 3,30 m above the top of rail linked to the passage of the front end of the leading vehicle. For single rolling stock units capable of bidirectional operation as a leading vehicle the requirement applies for each possible running direction.

Table 3 — Maximum permissible peak-to-peak pressure change $\Delta p_{95\%,\max}$ for single rolling stock units fitted with a driver’s cab depending on their 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	$\Delta p_{95\%,\max}$ = 720 Pa	Maximum design speed
250 km/h ≤ v_{tr}	$\Delta p_{95\%,\max}$ = 795 Pa	250 km/h

4.1.2.4 Other passenger rolling stock

For passenger rolling stock which does not fall under 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 4.

Table 4 — 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} < 190 km/h	Assessment by – Full-scale tests according to 7.1.2.1 or – Reduced-scale moving model tests according to 7.1.2.2 or – CFD-simulations according to 7.1.2.4
190 km/h ≤ v_{tr}	Assessment by Full-scale tests according to 7.1.2.1

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 will take one of the following forms:

— a statement 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.

If a simplified conformity assessment of interoperable rolling stock is carried out, it shall be done according to Table 5.

Table 5 — Methods and requirements applicable for simplified conformity assessment of rolling stock

Design differences	Methods and requirements
Differences in external geometry limited to – locations downstream from the position where the maximum cross section is achieved – the inner region of the underpart of the train	Documentation of differences and reference to existing full conformity assessment
Other minor differences in external geometry	Documentation of differences and reference to existing full conformity assessment Assessment of relative effect of differences by – reduced-scale moving model tests according to 7.1.2.2 – CFD-simulations according to 7.1.2.4 Evidence and documentation that (i) the difference does not cause changes in $\Delta p_{95\%}$ bigger than ± 10 % and (ii) that the new design under investigation still fulfils (on the basis of original value from complete assessment and found relative difference) the requirements listed in 4.1.2
Decrease in design speed	Documentation of differences and reference to existing full conformity assessment Evidence and documentation based on a ΔC_p analysis that the new design under investigation still fulfils the requirements listed in 4.1.2
Increase of design speed – less than 10 % for a train with original design speed less than 250 km/h – for a train with original design speed equal or greater than 250 km/h	Documentation of differences and reference to existing full conformity assessment 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 passing train generates a varying flow field beside the track which has an effect on persons and objects at the track side and at platforms passed by. In order to define a clear interface between the subsystems of rolling stock and infrastructure the train-induced slipstream effects need to be known and limited.

In order to describe and to limit the train-induced slipstream effects two reference cases for rolling stock assessment are defined.

4.2.2 Requirements

4.2.2.1 Reference cases

For standard GA, GB, GC gauge according to EN 15273, the reference cases are:

— Case 1: the undisturbed flowfield generated by a passing train in the absence of any other objects at a position of 3 m distance from the centre of a straight track with standard track formation profile. The vertical distance between the top of rail and the surrounding ground level shall be within the range of 0,50 m to 1,00 m.

— Case 2: the undisturbed flowfield generated by a passing train in the absence of any other objects on a platform at a position of 3 m distance from the centre of straight track. The assessment shall either be made on a platform of height 240 mm above rail level or lower if one is available or the applicant shall select the lowest height of platform passed by the train to be used for the assessment.

The air flows occurring are characterised by the upper bound of the 95 % confidence interval of maximum 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 on a straight track with standard track formation profile on open track shall not cause the maximum horizontal air speed to exceed a value $U_{95\%,max}$ as set out in Table 6 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.

Table 6 — Maximum permissible horizontal air speed $U_{95\%,max}$ for fixed or pre-defined train compositions depending on their maximum design speed for Case 1

Maximum design speed	Permissible horizontal air speed $U_{95\%,max}$ at reference speed	Reference speed
$v_{tr} \leq$ 160 km/h	No requirement	
160 km/h < v_{tr} < 250 km/h	$U_{95\%,max}$ = 20 m/s	Maximum design speed
250 km/h ≤ v_{tr}	$U_{95\%,max}$ = 22 m/s	300 km/h or, if lower, at maximum design speed

A full-length, fixed or pre-defined train composition, running at a reference speed and passing by a platform on open track shall not cause the maximum horizontal air speed to exceed a value $U_{95\%,max}$ as set out in Table 7 at a height of 1,20 m above the platform during the passage of the whole train and its wake. For non-symmetrical train compositions, the requirement applies for each possible running direction.

Table 7 — Maximum permissible horizontal air speed $U_{95\%,max}$ for fixed or pre-defined train compositions depending on their maximum design speed for Case 2

Maximum design speed	Permissible horizontal air speed $U_{95\%,max}$ at reference speed	Reference speed
$v_{tr} \leq$ 160 km/h	No requirement	
160 km/h < v_{tr}	$U_{95\%,max}$ = 15,5m/s	200 km/h or, if lower, at maximum design speed

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

Open point on European level. / Subject to national regulations.

4.2.2.4 Other passenger rolling stock

Open point on European level. / Subject to national regulations.