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Železniške naprave - Aerodinamika - 4. del: Zahteve in ugotavljanje skladnosti za aerodinamiko na odprti progi

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

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

Applications ferroviaires - Aérodynamique - Partie 4: Exigences et procédures d'évaluation 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.

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European foreword

This document (prEN 14067-4:2022) 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 will supersede EN 14067-4:2013+A1:2018.

Results of the EU-funded research project “AeroTRAIN” (Grant Agreement No. 233985) are contained in this document.

In comparison with the previous edition, the following technical modifications have been made:

The scope was amended to cover track gauges other than 1 435 mm. Minor modifications and improvements were made throughout the whole document. The methods and test procedures for running resistance and train induced aerodynamic loads in the track bed were updated.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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

— Part 4: Requirements and assessment procedures for aerodynamics on open track;

— Part 5: Requirements and assessment procedures for aerodynamics in tunnels;

— Part 6: Requirements and assessment procedures for cross wind assessment;

— Part 7 (TR): Fundamentals for test procedures for train-induced ballast projection.

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. It is thus subject to regulation when specifying the trans-European railway system.

Trains running on open track have to overcome a running resistance which has a strong effect on the required engine power, achievable speed, travel time and energy consumption. Thus, running resistance is often subject to contractual agreements and requires standardized test and assessment methods. The test set-up for ballast projection was also updated.

1 Scope

This document establishes requirements, test procedures, assessment methods and acceptance criteria for operating rolling stock in open track. For pressure variations and slipstream effects beside the track, requirements and assessment methods are provided. For running resistance, assessment methods are addressed in this document. Load cases on infrastructure components due to train-induced pressure variations and slipstream effects are addressed in this document. For ballasted track test set-ups for ballast projection assessment are proposed.

The requirements only apply to rolling stock of the heavy rail system with maximum train speeds above 160 km/h and not to other rail systems. The document is applicable to all rolling stock and infrastructure in open air with nominal track gauges of 1 435 mm to 1 668 mm inclusive.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1991-2:2003,[1] *Eurocode 1: Actions on structures — Part 2: Traffic loads on bridges*

EN 15273 (all parts), *General title of the series Railway applications — Gauges*

EN 16727-2-2:2016, *Railway applications - Track - Noise barriers and related devices acting on airborne sound propagation - Non-acoustic performance - Part 2-2: Mechanical performance under dynamic loadings caused by passing trains - Calculation method*

EN 17343, *Railway applications - General terms and definitions*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 17343 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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

3.2
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

[1] Document impacted by AC:2010.

3.3
Computational Fluid Dynamics
CFD
numerical methods of approximating and solving the equations of fluid dynamics

3.4
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

3.5
bluff shaped vehicle
vehicle that is not streamlined

4 Symbols

For the purposes of this document, the symbols in Table 1 apply.

Table 1 — Symbols

Symbol	Unit	Significance	Explanation or remark
a	m/s^2	train accelerations measured during the coasting test	
a_D	m/s^2	train accelerations measured during the coasting test when the train is running downhill	
a_d	m/s^2	difference of train accelerations between two coasting tests at the same track location	
a_U	m/s^2	train accelerations measured during the coasting test when the train is running uphill	
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	
$C_{1,A}$	N	approximation of rolling mechanical resistance	see 7.4.2
$C_2\ v_{tr}$	N	momentum drag due to air flow for traction and auxiliary equipment and the air conditioning systems	

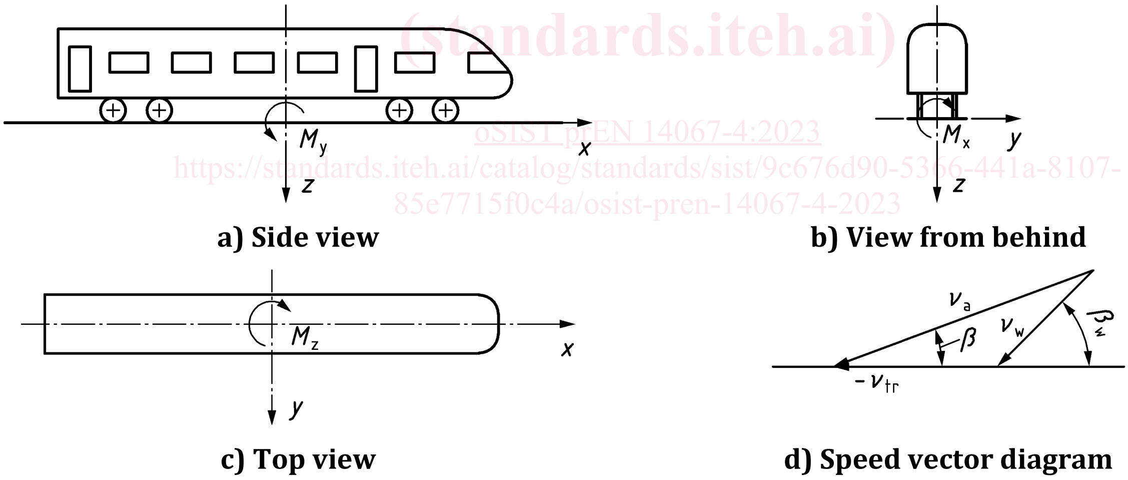
Symbol	Unit	Significance	Explanation or remark
$C_3 v_{tr}^2$	N	aerodynamic drag in the running resistance formula	
$\overline{C_3}$	N/Pa	$\overline{C_3}$ showing the density contribution	
c	m/s	speed of sound	
dt	s	temporal variation	
dv_{tr}	m/s	train speed variation	
dx	m	spatial variation	
F	N	load on an object, maximum value of the force during the passage	
F_d	N	force	see 7.4.2.2.3
g	m/s²	acceleration due to gravity	
h	m	height above top of rail	
i	–	gradient of the track	within a typical range of ± 0,03
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
L_s	m	length of test section	see 7.4.2.2
M_x	Nm	restoring moment due to the vehicles masses	see Figure 1
M_y	Nm	aerodynamic pitching moment	see Figure 1
M_z	Nm	aerodynamic yawing moment	see Figure 1
m	kg	train mass	
P_d	N	function of train speed squared between two coasting tests at the same track location	see 7.4.2.4
p	Pa	pressure	
p_{max}	Pa	maximum pressure	
p_{min}	Pa	minimum pressure	
p_{1k}	Pa	characteristic value of distributed load	

Symbol	Unit	Significance	Explanation or remark
p_{2k}	Pa	characteristic value of distributed load	
p_{3k}	Pa	characteristic value of distributed load	
Re_{max}	–	maximum Reynolds number	based on reference length of 3 m at full scale
R_1	N	running resistance	train contribution
R_2	N	running resistance	infrastructure contribution
r	m	curve radius	
S	m^2	characteristic area	
s	m	distance	see 7.4.2.2
t	s	time	
t_i	s	scaled time referring to the i-th passage	
$t_{m,i}$	s	time referring to the i-th passage	
U_i	m/s	maximum resultant horizontal air speed of the i-th passage after averaging and correction to the characteristic train speed	
$\overline{U}$	m/s	mean value over all measured maxima U_i	
U_{max}	m/s	maximum value of U	
$U_{2\sigma}$	m/s	upper bound of a 2σ interval of maximum air speed	
$U_{95\,\%}$	m/s	maximum resultant horizontal air speed	characteristic air speed from measurement
$U_{95\,\%,max}$	m/s	maximum permissible horizontal air speed	limit for characteristic air speed
$u_i(t_i)$	m/s	resultant horizontal air speed of the i-th passage	after transformation of the time base
$u_{m,i}(t_{m,i})$	m/s	measured resultant horizontal air speed of the i-th passage	
v_a	m/s	relative wind velocity	see Figure 1
v_d	m/s	difference of train speed between two coasting tests at the same track location	see 7.4.2.4
v_{d_q}	m^2/s^2	difference of train speed squared between two coasting tests at the same track location	see 7.4.2.4
v_{tr}	m/s	train speed	

Symbol	Unit	Significance	Explanation or remark
v_{trD}	m/s	instantaneous train speed coasting downhill	see 7.4.1.2
$v_{tr,i}$	m/s	train speed during the *i*-th passage	
$v_{tr,max}$	m/s	maximum train speed or design speed of a train	maximum train speed refers to train operation. if limited by infrastructure, maximum train speed may be lower than design speed.
$v_{tr,ref}$	m/s	reference speed	
$v_{tr,S1}$	m/s	measured speed at point S coasting uphill	see 7.4.1.2
$v_{tr,S2}$	m/s	measured speed at point S coasting downhill	see 7.4.1.2
$v_{tr,S1a}$	m/s	measured speed at starting point S1 coasting direction 1	see 7.4.2.2.3
$v_{tr,S1b}$	m/s	measured speed at end point coasting direction 1	see 7.4.2.2.3
$v_{tr,S2a}$	m/s	measured speed at starting point S2 coasting direction 2	see 7.4.2.2.3
$v_{tr,S2b}$	m/s	measured speed at end point coasting direction 2	see 7.4.2.2.3
$v_{tr,test}$	m/s	nominal test speed	
v_{trU}	m/s	instantaneous train speed coasting uphill	see 7.4.1.2
v_w	m/s	wind speed	wind speed measured at stationary point, see Figure 1
$v_{w,x,i}$	m/s	wind speed component in x-direction during the *i*-th passage	
$v_{w,y,i}$	m/s	wind speed component in y-direction during the *i*-th passage	
W_y	–	quotient of cross wind speed and incident air speed in track direction	see 7.1.2.1
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^+	–	dimensionless wall distance	

Symbol	Unit	Significance	Explanation or remark
β	–	yaw angle	angle between the vehicle axis and the relative wind acting on the train. In a wind tunnel with stationary train model, it is the angle between the train axis and the wind tunnel axis, see Figure 1.
β_{w}	–	wind angle to track	angle between the wind directions and the forward direction of the train, see Figure 1.
ΔC_{p}	–	pressure change coefficient	
$\Delta C_{\mathrm{p},2\sigma}$	–	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).
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
Δp_i	Pa	corrected maximum peak-to-peak pressure value of the *i*-th passage	Formula (5)
$\Delta p_{m,i}$	Pa	maximum peak-to-peak pressure value measured during the *i*-th passage	Formula (5)
Δp_{sim}	Pa	the head pressure variation from unsteady CFD calculations	
$\overline{\Delta p}_{\mathrm{sim}}$	Pa	the average of head pressure variation from CFD calculations	the average refers either to steady CFD calculations or the average of results from unsteady simulations
$\overline{\Delta p}_{\mathrm{sim,k}}$	Pa	head pressure variation from steady CFD calculations for the *k*-th height	Formula (6)
$\Delta p_{\mathrm{test},k}$	Pa	average peak-to-peak pressure value for the 6 heights *k*, taken from measurements	Formula (8)
$\Delta p_{2\sigma}$	Pa	upper bound of a 2σ interval of the peak-to-peak pressure change	
$\Delta p_{95\,\%}$	Pa	maximum peak-to-peak pressure change	characteristic pressure change

Symbol	Unit	Significance	Explanation or remark
$\Delta p_{95\,\%,\max}$	Pa	permissible maximum peak-to-peak pressure change	permissible characteristic pressure change
Δt	s	characteristic time interval	passage of train head, time between pressure peaks
ε	-	relative root mean square of the difference between a calculated pressure variation and test results	
η	Pa s	dynamic viscosity of air	
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
σ	–	standard deviation	can be pressure or speed
σ_{sim}	Pa	standard deviation of simulated pressure	



NOTE A positive β means that the apparent wind v_a is coming from the right hand side of the train.

Figure 1 — Coordinate system

5 Requirements on locomotives and passenger rolling stock

5.1 Limitation of pressure variations beside the track

5.1.1 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 reference cases for rolling stock assessment are defined for track gauges from 1 435 mm to 1 668 mm inclusive.

5.1.2 Requirements

5.1.2.1 Reference case

For track gauges from 1 435 mm to 1 668 mm inclusive the undisturbed pressure field generated by a passing train at a distance according to Table 2 from the centre of the track is referred to as the reference case. The reference case is defined for a straight track with standard track formation profile and in the absence of embankments, cuttings and other significant trackside structures. 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.

5.1.2.2 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

Track gauge mm	Maximum design speed km/h	Measurement distance from track centre m	Permissible pressure change $\Delta p_{95\,\%,max}$ at reference speed Pa	Reference speed km/h
any	$v_{tr,max} \leq 160$	2,5	no requirement	
1 435	$160 < v_{tr,max} < 250$	2,5	$\Delta p_{95\,\%,max} = 800$	$v_{tr,max}$
1 435	$250 \leq v_{tr,max}$	2,5	$\Delta p_{95\,\%,max} = 800$	250
1 524	$160 < v_{tr,max} < 250$	2,5	$\Delta p_{95\,\%,max} = 1\,600$	$v_{tr,max}$
1 668	$160 < v_{tr,max} < 250$	2,6	$\Delta p_{95\,\%,max} = 800$	$v_{tr,max}$
1 668	$250 \leq v_{tr,max}$	2,6	$\Delta p_{95\,\%,max} = 800$	250

For 1 435 mm track gauge, the requirement was derived based on rolling stock with a semi-width compliant to the reference contours GA, GB, GC, G1, G2, GB-M6, EBV 01, EBV 02, DE1 and DE3 according to EN 15273 (all parts). For 1 435 mm track gauge and if the vehicle semi-width is greater than 1 575 mm, the measurement distance from the track centre may be increased, so that the pressure probes are 0,925 m away from the train side.