SLOVENSKI STANDARD
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Železniške naprave - Aerodinamika - 5. del: Zahteve in ugotavljanje skladnosti pri aerodinamiki v predorih

Railway applications - Aerodynamics - Part 5: Requirements and assessment procedures for aerodynamics in tunnels

Bahnanwendungen - Aerodynamik - Teil 5: Anforderungen und Prüfverfahren für Aerodynamik im Tunnel

Applications ferroviaires - Aérodynamique - Partie 5: Exigences et procédures d'essai pour l'aérodynamique en tunnel

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Railway applications - Aerodynamics - Part 5: Requirements and assessment procedures for aerodynamics in tunnels

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

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Contents

European foreword

This document (prEN 14067-5:2020) 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 5:2006+A1:2010.

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

— Part 1: Symbols and units;

— 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.

The results of the EU-funded research project "AeroTRAIN" (Grant Agreement No. 233985) have been used.

The contents of the previous edition of EN 14067-5 have been integrated in this document; they have been re-structured and extended to support the Technical Specifications for the Interoperability of the Trans-European rail system. Requirements on conformity assessment for rolling stock were added.

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 2016/797/EU.

For relationship with EU Directive 2016/797/EU, see informative Annex ZA, which is an integral part of this document.

1 Scope

This document establishes aerodynamic requirements, test procedures, assessment methods and acceptance criteria for operating rolling stock in tunnels. Aerodynamic pressure variations, loads, micro pressure wave generation and further aerodynamic aspects to be expected in tunnel operation are addressed in this document. Requirements for the aerodynamic design of rolling stock and tunnels of the heavy rail system are provided. The requirements apply to heavy rail systems only.

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 12663-1:2010+A1:2014,*Railway applications - Structural requirements of railway vehicle bodies - Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons)*

EN 12663-2:2010, *Railway applications - Structural requirements of railway vehicle bodies - Part 2: Freight wagons*

EN 14067-4:2013+A1:2018*Railway applications - Aerodynamics - Part 4: Requirements and test procedures for aerodynamics on open track*

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

ISO 8756:1994, *Air quality — Handling of temperature, pressure and humidity data*

prEN 17343:2019, *Railway applications — General terms and definitions*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
compression wave
approximate step change in pressure above ambient that travels at the speed of sound

3.2
expansion wave
approximate step change in pressure below ambient that travels at the speed of sound

3.3
Computational Fluid Dynamics
(CFD)
numerical methods of approximating and solving the formulae of fluid dynamics

3.4
exceptional loads
maximum loads occurring occasionally during normal operations due to both static and transient loads

3.5
fatigue loads
very large number of dynamic and aerodynamic loads of varying magnitude that the structures of rail vehicle bodies or infrastructure components are subjected to during their operational life

3.6
static loads
loads that are constant or nearly constant with time

Note 1 to entry: These loads include the dynamic pressure due to the airflow acceleration around the front of the train and pressure changes caused by strong side winds.

3.7
transient loads
loads that vary in time

Note 1 to entry: Transient loads can be divided into three kinds:

a) loads caused by trains crossing with other trains in the open air or due to the pressure field around the train;

b) loads caused by trains travelling alone or crossing with other trains in tunnels;

c) loads that arise due to the turbulent nature of the flow around trains.

Note 2 to entry: Loads a) and b) are relevant for all train structures, but loads c) may be only relevant for some high speed train components and are not considered in this standard.

3.8
tunnel
excavation or a construction around the track provided to allow the railway to pass through, for example, higher land, buildings or water

3.9
tunnel length
length of a tunnel is defined as the length of the fully enclosed section, measured centrally at rail level

3.10
tunnel cross-sectional area (for blockage ratio)
free cross-sectional area of a tunnel not including ballast, rail, sleepers, longitudinal piping, platform

3.11
vehicle cross-sectional area (for blockage ratio)
projected cross-sectional area in lengthwise direction of vehicle

3.12
critical crossing
crossing of two trains in a tunnel leading to maximum pressure changes

Note 1 to entry: The terms crossing and passing are used interchangeably in this standard.

3.13
gauge pressure
amount by which the pressure measured in a fluid, such as air, exceeds that of the atmosphere

3.14
fixed formation
group of rail vehicles which can only be coupled/uncoupled or assembled /disassembled (e.g. articulated vehicles) in a workshop environment

[SOURCE: prEN 17343:2019, 3.1.6.4]

4 Symbols and abbreviations

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

Table 1 — Symbols

Symbol	Significance	Explanation or remark	Unit
A_S, A_T	area of integration	see Figure 11	sPa
B	train/tunnel blockage ratio	$B = \frac{S_{tr}}{S_{tu}}$	
b	width of vehicle	see Figure 2	m
C	load collective	see 7.7.4.1	
$C_{f,tr}$	train friction factor or coefficient	Formula (15)	
$C_{f,tu}$	tunnel friction factor or coefficient		
$C_{lifecycle}$	total load collectives in open air and in tunnels	Formula (35)	
$C_{lifecycle,front}$	total load collectives in open air and in tunnels at front of train	see 7.7.4.2	
$C_{lifecycle,tail}$	total load collectives in open air and in tunnels at tail of train	see 7.7.4.2	
C_n	factor depending on the shape of the train nose and the shape of the tunnel portal	Formula (C.2)	
$C_{oa,cros}$	load collective for trains encountering on the open track	Formula (30)	
$C_{tu,cross}$	load collective for crossing passages in tunnels	Formula (34)	
$C_{tu,solo}$	collective for solo passages in the tunnel	Formula (31)	
CFL	Courant-Friedrich-Levy number	see 7.6.2	
c	speed of sound		m/s
D_h	hydraulic diameter	Formula (16)	m
F_{max}	maximum measured force	see Figure D.4	N
g	acceleration due to gravity		m/s2
h	height	see Figure 2	m
h_l	frequency corresponding to a class of	see 7.7.5	

Symbol	Significance	Explanation or remark	Unit
	amplitudes in a rainflow matrix		
h_0	distance from top of rail to the underside of the carbody	see Figure 2	m
h_c	height of tunnel centre above rail level	see Figure 1	m
*H, H*1, *H*2	relative humidity of air	see 7.3.2	%
k	Wöhler curve exponent	see 7.7.5	
k_r	vehicle structural rigidity factor	see 7.8.2	
k_1	factor	Formula (12)	
k_2	Factor	Formula (12)	
k_s	train roughness parameter	see 7.3.3	m
L_n	nose length of train	see Figure 2	m
$L_{n,model}$	nose length of train model	see 7.2.7	m
$L_{section,i}$	length of the route section *i*	see 7.7.4.3	km
L_{tr}	length of train	Length overall	m
L_{tu}	length of tunnel		m
$L_{tu,crit}$	critical tunnel length	see 7.7.3.6	m
$L_{tu,min}$	minimum length of a tunnel measured in full-scale tests from entry portal	Formula (4)	m
$L_{virttun,j}$	virtual length of tunnel *j*	Formula (39)	m
$L_{year,e}$	distance travelled per year on route section *i*	see 7.7.4.2	km/a
model scale	ratio of full-scale train to its model	See 7.6.3.2	
N_{oa}	number of sections of open track	see 7.7.4.2	1/a
N_c	reference cycles when calculating the damage-equivalent load amplitude	see 7.7.5	Hz
$N_{trainsperhour}$	Number of trains passing a stationary point in one direction per hour	see 7.7.5	1/h
N_{tu}	total number of tunnels on a route	see 7.7.4.2	
$N_{tu,cros}$	Number of tunnels, in which trains cross	see 7.7.4.2	
$N_{tu,solo}$	Number of tunnels, in which solo passages occur	Formula (33)	
$N_{\Delta te,j}$	calculated entry time gaps for j_{th} tunnel	Formula (34)	
$n_{oa,cros,i}$	frequency for trains crossing on the open track in route section *i*	Formula (37)	
$n_{tu,cros,j}$	frequency for trains crossing in the j_{th} double track tunnel	Formula (40)	

Symbol	Significance	Explanation or remark	Unit
$n_{tu,solo,i}$	frequency of single train passages without train encounter in the j_{th} double track tunnel	Formula (31)	
P_{etr}	perimeter of train		m
P_{etu}	perimeter of tunnel		m
p	pressure	Formula (41)	Pa
p_{eq}	damage-equivalent amplitude	see 7.7.5	Pa
p_l	classified pressure amplitude	see 7.7.5	Pa
p_L	pressure load	Formula (24)	Pa
p_{atm}	atmospheric pressure		Pa
p_d	pressure difference between external and internal pressure	see 7.1	Pa
p_e, $p_e(t)$	external pressure outside of a vehicle, or generated by a train in a tunnel	see 7.1	Pa
$p_{fullscale}$	full-scale pressures determined from $p_{modelscale}$	See Formula (19)	Pa
p_i, $p_i(t)$	internal pressure in a vehicle, or in an enclosed air volume in a tunnel	see 7.1	Pa
$p_{modelscale}$	pressures measured at model scale	See Formula (19)	Pa
p_0	reference static pressure		Pa
p_{offset}	offset pressure	see Figure 9	Pa
$p(t)_{sim}$	pressure signal in tunnel from simulation software	see 7.3.4	Pa
$p(t)_{test}$	pressure signal in tunnel from track test	see 7.3.4	Pa
r	radius	distance between tunnel exit portal centre (on the ground) and the point of interest (reception point, outside of tunnel), see Annex C	m
r_b	corner radius of the micro-pressure wave reference vehicle	see Figure 2	m
R	tunnel radius	see Figure 1	m
S_{eq}	equivalent leakage area		m2
S_{tr}	Train cross-sectional area	see 3.10	m2
S_{tu}	Tunnel cross-sectional area	see 3.9	m2
t, t_A, t_B, t_S, t_T	time	see Figures 9 and 11	s

Symbol	Significance	Explanation or remark	Unit
t_e	difference in entry time	see 7.7.3.4	s
t_{life}	Train service life	see 7.7.4.2	year
$t_{50\ \%}$	time when pressure rise is 50 % of the value at time t_T	see Figure 11	s
T	absolute temperature		K
T_f	tunnel factor	see Formula (A.26)	
U	local dominant speed (train speed or pressure wave speed)	see 7.6.2	m/s
U_0	flow velocity in tunnel relative to train before train entry	see A.4	m/s
u_0	the measured air flow in a tunnel at the moment of train entry	see 7.3.2	m/s
v_{tr}	train speed		m/s
$v_{tr,1}$	train speed	see 7.7.4.3	m/s
$v_{tr,1,rel}$	train speed relative to air flow in tunnel	see 7.3.2	m/s
$v_{tr,2}$	speed of the encountering train	see 7.7.4.3	m/s
$v_{tr,2}$	reference train speed	see 7.3.2	m/s
$v_{line,max}$	design speed of a segment of line	Maximum permitted speed in a defined track segment. The segment may be a tunnel, a line or a segment of a line.	km/h
$v_{tr,max}$	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	km/h
$v_{tr,ref}$	train reference speed		km/h
$v_{tr,test}$	train test speed	see 7.3.2	m/s
V_{int}	internal volume of the vehicle	see 7.8.3	m3
X_d, X_h, X_{fr}, X_t	dummy variables	see A.3	
X_p	distance between the entrance portal and the measuring position in the tunnel		m
x_1, x_2, x_3	longitudinal positions on the train	defined in 7.7.3.4	m

Symbol	Significance	Explanation or remark	Unit
Y_{tr}	track distance	centre to centre	m
Δh	maximum altitude difference in a tunnel	see 7.2.5	m
ΔL_1	additional length	see 7.2.2.1	m
Δp, $\Delta p(t)$	differential pressure at time t		Pa
Δp_{alt}	natural pressure variation due to altitude	see Formula (9)	Pa
$\Delta p_{d,max}$	maximum difference between internal and external pressures	see Figure D.4	Pa
Δp_{exit}	amplitude of initial compression wave at the exit portal inside the tunnel	See Formula (C.4)	Pa
Δp_{fr}	pressure change due to friction effects caused by the entry of the main part of the train into the tunnel	see Figure 6	Pa
$\Delta p_{fr,o}$	pressure change due to friction effects caused by the entry of the main part of the train into the tunnel	see 7.2.4	Pa
Δp_{HP}	pressure signature caused by the passing of the train nose at the measurement position in the tunnel	see Figure 6	Pa
$\Delta p_{i,limit}$	Pressure limit values, i = N, N+fr, N+fr+T	See Table 4	Pa
Δp_{max}	maximum peak-to-peak pressure change on outside of train		Pa
Δp_N	pressure change caused by the entry of the nose of the train into a tunnel	see Figure 6	Pa
$\Delta p_{N,o}$	pressure change caused by the entry of the nose of the train into a tunnel measured on a train on the exterior of the train	see 7.2.4	Pa
Δp_T	pressure change caused by the entry of the tail of the train into a tunnel	see Figure 6	Pa
$\Delta p_{T,o}$	pressure change caused by the entry of the tail of the train into a tunnel measured on the exterior of a train	see 7.2.4	Pa
Δp_1	pressure after train tail entrance	see A.3.2	Pa
$\overline{\Delta p}_{n}$	average nose entry pressure change	see Table 4	Pa
$\overline{\Delta p}_{fr}$	average frictional pressure rise	see Table 4	Pa
$\overline{\Delta p}_{T}$	average tail entry pressure change	see Table 4	Pa
Δt	characteristic time interval for the pressure rise	see Formula (C.2)	s

Symbol	Significance	Explanation or remark	Unit
Δt_e	time increment	see Formula (26)	s
Δx_1	additional distance to ensure a good temporal separation of individual pressure variations	see 7.2.2.2	m
$\varepsilon_{\Delta p}$	deviation between test and simulation	see 7.3.4	
ξ_E	loss coefficient for tunnel portal	see A.3	
ξ_h	loss coefficient of the train nose in the tunnel	see A.3	
ξ_{h0}	loss coefficient of the train nose in the open air	see A.3	
ξ_{h1}	coefficient for additional loss of the train nose in the tunnel	see A.3	
ξ_t	loss coefficient of the train tail in the tunnel	see A.3	
ξ_{t0}	loss coefficient of the train tail in the open air	see A.3	
ξ_{t1}	coefficient for additional loss of the train tail in the tunnel	see A.3	
ξ_1	loss coefficient for the train	see A.3	
ξ_N	train nose pressure loss coefficient	see A.4	
ξ_p	tunnel portal pressure loss coefficient	see A.4	
ξ_T	train tail pressure loss coefficient	see A.4	
θ_1, θ_2,	temperature	see 7.3.2	° C
P_{amb}	ambient atmospheric air density	See Formula (12)	kg/m3
ρ_0	Reference air density	1,225 kg/m3	kg/m3
p, p_1, p_2	air density ρ_1 in test scenario ρ_2 in reference scenario	see 7.3.2 see 7.3.2	kg/m3
τ_{dyn}	value of pressure tightness coefficient for moving rail vehicles	see 7.7.3.2	s
τ_{stat}	value of pressure tightness coefficient for static rail vehicles	see 7.8.1	s
Ω	solid angle representing the configuration around the tunnel exit portal	see C.4	
¯ , (overbar)	average of the value		