SLOVENSKI STANDARD
SIST EN 14067-5:2022

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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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ICS:

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93.060	Gradnja predorov	Tunnel construction

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

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Contents

Page

European foreword

This document (EN 14067-5:2021) 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of an identical text or by endorsement, at the latest by June 2022, and conflicting national standards shall be withdrawn at the latest by June 2022.

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 supersedes 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.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

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

EN 15273 series, *Railway applications — Gauges*

EN 17149-1:—,[1] *Railway applications — Strength assessment of railway vehicle structures — Part 1: General*

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.

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

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

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

3.1
compression wave
approximate step increase in pressure that travels at the speed of sound

3.2
expansion wave
approximate step decrease in pressure that travels at the speed of sound

3.3
computational fluid dynamics
CFD
numerical methods of approximating and solving the formulae of fluid dynamics

[1] Under preparation. Stage at time of publication: prEN 17149:2021.

3.4
exceptional load
infrequent load which represents the extremal load or combination of loads for the relevant operation conditions, including both steady and transient load

Note 1 to entry: Exceptional load is also described with the terms “static load”, “static design load” or “proof load”.

[SOURCE: EN 17149-1:—[1], 3.1.9; modified – “including both steady and transient load” added]

3.5
fatigue load
frequent load or combination of loads which represents the normal relevant operation conditions

[SOURCE: EN 17149-1:—[1], 3.1.11]

3.6
steady load
load that is 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 load
load that varies 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 document.

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
free cross-sectional area of a tunnel not including ballast, rail, sleepers, longitudinal piping, platform

3.11
vehicle cross-sectional area
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 document.

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: EN 17343:2020, 3.1.6.4]

3.15
load collective
pressure spectrum
table of loads and their frequency of occurrence

4 Symbols and abbreviations

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

Table 1 — Symbols

Symbol	Significance	Explanation or remark	Unit
A_S, A_T	area of integration	see Figure 12	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	see Formula (15)	
$C_{f,tu}$	tunnel friction factor or coefficient		
$C_{lifecycle}$	total load collectives in open air and in tunnels	see Formula (34)	
$C_{lifecycle,front}$	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	see Formula (C.2)	
$C_{oa,cros}$	load collective for trains meeting on the open track	see Formula (30)	

Symbol	Significance	Explanation or remark	Unit
$C_{oa,cros,i}$	load collective for trains meeting in segment *i*		
$C_{tu,cross}$	load collective for passing with crossings in tunnels	see Formula (33)	
$C_{tu,cross,j}$	load collective for passing with crossings in tunnel *j*		
$C_{tu,solo}$	load collective for solo passages in the tunnel	see Formula (31)	
$C_{tu,solo,j}$	load collective for solo passages in tunnel *j*		
CFL	Courant-Friedrich-Levy number	see 7.6.2	
c	speed of sound		m/s
D_h	hydraulic diameter	see Formula (16)	m
d_x	measurement distance	see Formulae (21), (22), (23)	m
F_{max}	maximum measured force	see Figure D.4	N
g	gravity		m/s^2
h	height	see Figure 2	m
h_l	frequency corresponding to a class of amplitudes in a rainflow matrix	see 7.7.5	
h_0	distance from top of rail to the underside of the vehicle body	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	S-N curve exponent	see 7.7.5	
k_r	vehicle structural rigidity factor	see 7.8.2	
k_1	factor	see Formula (12)	
k_2	factor	see 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	see Formula (4)	m

Symbol	Significance	Explanation or remark	Unit
$L_{virttun,j}$	virtual length of tunnel j	see Formula (37)	m
$L_{year,e}$	distance travelled per year on route section i	see 7.7.4.2	km/year
Ma	Mach number		
N_{oa}	number of sections of open track	see 7.7.4.2	1/a
N_c	number of cycles of reference value of the fatigue load	see 7.7.5	
$N_{trainsperhour}$	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	
$N_{\Delta te,j}$	calculated entry time gaps for j_{th} tunnel	see Formula (33)	
$n_{oa,cros,i}$	frequency for trains crossing on the open track in route section i	see Formula (36)	
$n_{tu,cros,j}$	frequency for trains crossing in the j_{th} double track tunnel	see Formula (38)	
$n_{tu,solo,j}$	frequency of single train passages without train encounter in the j_{th} double track tunnel	see Formula (31)	
Pe_{tr}	perimeter of train		m
Pe_{tu}	perimeter of tunnel		m
p	pressure	see Formula (40)	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	see 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 10	Pa
$p(t)_{sim}$	pressure signal in tunnel from simulation software	see 7.3.4	Pa

Symbol	Significance	Explanation or remark	Unit
$p(t)_{test}$	pressure signal in tunnel from track test	see 7.3.4	Pa
r	radius	distance between tunnel exit portal centre and the point of interest, see Figure C.3	m
r_b	corner radius of the micro-pressure wave reference vehicle	see Figure 2	m
R	tunnel radius	see Figure 1	m
R_{model}	ratio of full-scale train to its model	see 7.6.3.2	
S_{eq}	equivalent leakage area		m^2
S_{tr}	vehicle cross-sectional area	see 3.11	m^2
S_{tu}	tunnel cross-sectional area	see 3.10	m^2
t, t_A, t_B, t_S, t_T	time	see Figures 9 and 11	s
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 12	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
$v_{tr,2}$	speed of the encountering train	see 7.7.4.3	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.	km/h

Symbol	Significance	Explanation or remark	Unit
		If limited by infrastructure, maximum train speed may be lower than design speed.	
$v_{tr,ref}$	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	m^3
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
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 7	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, measured on the exterior of a train	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 7	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

Symbol	Significance	Explanation or remark	Unit
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
$\Delta p_{95\ \%,max}$	maximimum permissible pressure change	see Formulae (21), (22) and (23)	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
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	
ζ_E	loss coefficient for tunnel portal	see A.3	
ζ_h	loss coefficient of the train nose in the tunnel	see A.3	
ζ_{h0}	loss coefficient of the train nose in the open air	see A.3	
ζ_{h1}	coefficient for additional loss of the train nose in the tunnel	see A.3	
ζ_t	loss coefficient of the train tail in the tunnel	see A.3	
ζ_{t0}	loss coefficient of the train tail in the open air	see A.3	
ζ_{t1}	coefficient for additional loss of the train tail in the tunnel	see A.3	
ζ_1	loss coefficient for the train	see A.3	
ζ_N	train nose pressure loss coefficient	see A.4	
ζ_p	tunnel portal pressure loss coefficient	see A.4	
ζ_T	train tail pressure loss coefficient	see A.4	
θ_1, θ_2	temperature	see 7.3.2	° C
ρ_{amb}	ambient atmospheric air density	see Formula (12)	kg/m³