SLOVENSKI STANDARD
SIST EN 14067-4:2024

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

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COMITÉ EUROPÉEN DE NORMALISATION
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European foreword

This document (EN 14067-4:2024) 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of an identical text or by endorsement, at the latest by October 2024, and conflicting national standards shall be withdrawn at the latest by October 2024.

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 14067-4:2013+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 standardization request addressed to CEN by the European Commission.

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.

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

Trains running on open track must 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 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 https://www.electropedia.org/

— ISO Online browsing platform: available at https://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

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

[1] Document impacted by AC:2010.

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 streamline shaped

3.6
unit
rolling stock that may be composed of several vehicles

3.7
fixed train composition
train formation that can only be reconfigured within a workshop environment

3.8
pre-defined train compositions
train formation of one or several units coupled together, which is defined at design stage and can be reconfigured during operation

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/s²	train accelerations measured during the coasting test	
a_{D}	m/s²	train accelerations measured during the coasting test when the train is running downhill	
a_{d}	m/s²	difference of train accelerations between two coasting tests at the same track location	
a_{U}	m/s²	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	

Symbol	Unit	Significance	Explanation or remark
C_{p3}	–	aerodynamic coefficient depending on the distance from track centre Y	
C_1	N	mechanical resistance	
$C_{1,A}$	N	approximation of mechanical resistance	see 7.4.2
$C_2\ v_{tr}$	N	momentum resistance due to air flow for traction and auxiliary equipment and the air conditioning systems	
$C_3\ v_{tr}^2$	N	aerodynamic resistance 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_{MU}	–	factor accounting for multiple units	see Formula (16)
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

Symbol	Unit	Significance	Explanation or remark
L_s	m	length of test section	see 7.4.2.2
m	kg	train mass	
N_b	–	number of additional units compared with test configuration	see 7.2.2.1
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	
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, see 7.4.1
R_2	N	running resistance	infrastructure contribution, see 7.4.1
r_C	m	reference value of curve radius	see 7.4.2.4
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	

Symbol	Unit	Significance	Explanation or remark
		correction to the characteristic train speed	
$\bar{U}$	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	
v_{trD}	m/s	instantaneous train speed coasting downhill	see 7.4.2.2
$v_{tr,i}$	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 7.4.2.2

Symbol	Unit	Significance	Explanation or remark
$v_{tr,S2}$	m/s	measured speed at point S coasting downhill	see 7.4.2.2
$v_{tr,S1a}$	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 7.4.2.2
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	
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.

Symbol	Unit	Significance	Explanation or remark
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
$\Delta p_{95\,\%,\mathrm{max}}$	Pa	permissible maximum peak-to-peak pressure change	permissible characteristic pressure change