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Železniške naprave - Aerodinamika - 6. del: Zahteve in preskusni postopki za oceno vpliva bočnega vetra

Railway applications - Aerodynamics - Part 6: Requirements and test procedures for cross wind assessment

Bahnanwendungen - Aerodynamik - Teil 6: Anforderungen und Prüfverfahren zur Bewertung von Seitenwind

Applications ferroviaires - Aérodynamique - Partie 6 : Exigences et procédures d'essai pour l'évaluation de la stabilité vis-a-vis des vents traversiers

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Foreword

This document (EN 14067-6:2010) 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of an identical text or by endorsement, at the latest by July 2010, and conflicting national standards shall be withdrawn at the latest by July 2010.

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

This European Standard is part of the series "Railway applications – Aerodynamics" which 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

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Introduction

Trains running on open track are exposed to cross winds. The cross wind safety of railway operations depends on vehicle and infrastructure characteristics and operational conditions. Important parameters are:

— aerodynamic characteristics of the vehicle;

— vehicle dynamics (e.g. mass, suspension, bump stops);

— track gauge;

— line characteristics (radius and cant of the track, height of embankments and bridges, walls near the track);

— wind exposure of the line;

— operating speed, mode of operation (conventional, tilting, running direction).

1 Scope

This European Standard applies to the cross wind assessment of railways taking into consideration the recommendations given in Annex M on the application of the standard (migration rule). The methods presented have been applied to passenger vehicles with a maximum speed up to 360 km/h and to freight vehicles with a maximum speed up to 160 km/h. This European Standard applies to coaches, multiple units, freight wagons, locomotives and power cars.

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 14067-1:2003, *Railway applications — Aerodynamics — Part 1: Symbols and units*

EN 14067-2, *Railway applications — Aerodynamics — Part 2: Aerodynamics on open track*

EN 14363, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14067-1:2003 and the following apply.

3.1
lee rail
rail on the lee side of the track

3.2
bias
systematic error affecting an estimate

NOTE In this document, it is expressed as the ratio of a coefficient obtained during benchmark wind tunnel tests to the equivalent coefficient obtained during new wind tunnel tests.

4 Symbols and abbreviations

For the purposes of this document, the symbols given in EN 14067-1:2003 and the following apply.

Table 1 — Symbols

Symbol	Unit	Significance	Explanation or remark
$\widetilde{A}$	-	Normalized gust amplitude	
a_m	s/m	Dispersion	Dispersion determined by extreme value analysis of wind tunnel data

Table 1 *(continued)*

Symbol	Unit	Significance	Explanation or remark
a_q	m/s^2	Uncompensated lateral acceleration	
A_{xz}	m^2	Reference side area of the model vehicle	The side area of the model vehicle
A_0	m^2	Reference normalisation area	10 m^2
b_A		Lateral contact spacing	
$b_{A,min}$		Minimum lateral contact spacing	
c_{Fi}	-	Non-dimensional force coefficient based on A_0	$c_{Fi} = \frac{2 \cdot F_i}{\rho \cdot v^2 A_0}$, i = x, y, z
c_{Mi}	-	Non-dimensional moment coefficient based on A_0 and d_0	$c_{Mi} = \frac{2 \cdot M_i}{\rho \cdot v^2 A_0 d_0}$, i = x, y, z
$c_{Mx,lee}$	-	Non-dimensional rolling moment coefficient around leeward rail	
$c_{Mx,lee,bmk}$	-	Benchmark value of rolling moment coefficient around leeward rail	Rolling moment coefficient determined from the benchmark tests
d_0	m	Reference normalisation length	3 m
F	Hz	Frequency	
f_h		Function of the embankment blockage ratio, B_E	
$f_{\Delta Q}$	-	Relative windward wheel unloading factor	0,9
f_m		Method factor	To account for uncertainties in the 3 mass model.
h	m	Vehicle height	
h_{cant}	m	Cant	
h_{VEH}	m	Height of the vehicle from top of rail to roof	
h_{BL}	m	Boundary layer height	
I_i		Turbulence index for the i-wind component	$i = u, v, w$
$I_u(z)$	-	Turbulence intensity	The standard deviation of the wind tunnel velocity at height z divided by the mean velocity at that height
L	m	Vehicle length	
L_{VEH}	m	Length parameter of the vehicle car body	
^xL_i	m	Longitudinal integral length scale of the i-wind velocity component along the x direction	$i = u, v, w$

Table 1 *(continued)*

Symbol	Unit	Significance	Explanation or remark
${}^{y}L_{i}$	m	Lateral integral length scale of the i-wind velocity component along the y direction	$i = u, v, w$
${}^{x}L_{u}$	m	Turbulence length scale	Longitudinal streamwise velocity turbulence length scale in the core stream
${}^{x}L_{u\_FS}$	m	Full scale turbulence length scale	
M_{m}	Nm	Restoring moment due to the vehicles masses	
M_{la}	Nm	Moment due to uncompensated lateral acceleration	
M_{CoG}	Nm	Moment due to the lateral movement of the centre of gravity of suspended masses	
$M_{x,lee}$	Nm	Rolling moment around leeward rail	
m	kg	Vehicle mass (to be considered for cross wind assessment)	Refers to operational mass in working order according to EN 15663
m_{0}	kg	Unsprung masses	Refers to operational mass in working order according to EN 15663
m_{1}	kg	Primary suspended masses	Refers to operational mass in working order according to EN 15663
m_{2}	kg	Secondary suspended masses	Refers to operational mass in working order according to EN 15663
ΔQ	N	Wheel unloading	
Q_{0}	N	Average static wheel load	
$\Delta Q/Q_{0}$	-	Relative wheel unloading	
R_{C}	m	Radius of curve	
Re_{max}		Maximum Reynolds number	The maximum achievable Reynolds number in a wind tunnel test
S_{U}	m²/s²/Hz	Power spectral density	
S_{t}	-	Model time scale	The ratio of time at model scale to time at full scale
T_{samp}	s	Data acquisition duration	The sampling duration for acquiring data
Tu_{x}		Turbulence level	$Tu_{x} = \left(\overline{u'^{2}} / \overline{u}^{2}\right)^{0,5}$

Table 1 *(continued)*

Symbol	Unit	Significance	Explanation or remark
U_{mean}	m/s	Mean wind speed	Refers to the upwind at 4 m height above ground
U	m/s	Wind (tunnel) velocity	
$U(t)$	m/s	Instantaneous wind (tunnel) velocity	
U_{turb}	m/s	Wind velocity turbulent component along the mean wind direction	
v_a	m/s	Relative wind velocity	
v_{max}	m/s	Maximum train speed	
v_W	m/s	Wind speed	
V_x	m/s	Magnitude of wind speed vector	Refers to the upwind at 4 m height above ground
x_B	%	Blockage ratio at β = 30°	Total modelled configuration projected side area to the wind tunnel cross section
y_B	m	(Maximum) displacement of the contact point on the wheel in the wheel flange direction	
z	m	Height from the ground	
z_{CoG}	m	Height of the centre of gravity of the total vehicle	
$z_{CoG,0}$	m	Height of the centre of gravity of the unsprung masses	
$z_{CoG,1}$	m	Height of the centre of gravity of the primary suspended masses	
$z_{CoG,2}$	m	Height of the centre of gravity of the secondary suspended masses	
z_0	m	Roughness height	
β	°	Yaw angle	The 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
$\delta_{99\%}$	m	Boundary layer thickness	z coordinate at which the local velocity equals 99 % of the free stream velocity
ε_{max}		Maximum tolerance target value	
ε_{mean}		Mean tolerance target value	
ρ_0	kg/m^3	Reference air density	ρ_0 = 1,225 kg/m^3

5 Methods to assess cross wind stability of vehicles

5.1 General

This clause presents various methods to assess the cross wind stability of railway vehicles.

The basic principle is that the cross wind stability of rolling stock is given by values of characteristic wind speeds that the rolling stock can withstand before exceeding some wheel unloading limit values. When these characteristic wind speeds are listed for varying input parameters such as train speeds, uncompensated lateral accelerations or wind angles of attack, the resulting set of characteristic wind speeds is called the characteristic wind curves (CWC).

The cross wind stability of a train is given by the cross wind stability of the most cross wind sensitive vehicle in the train consist.

It has to be noted that the CWC indicate the cross wind stability of the train related to a characteristic state of the wheel vertical forces; the characteristic wind curves do not indicate an overturning threshold.

For a given train running at a range of speeds, the CWC define the maximum natural wind speed that a train can withstand before a characteristic limit for wheel unloading is exceeded. The criterion that defines the CWC is the average value of wheel unloading, ΔQ, of the most critical running gear. The term "average" means that, in case of bogies, wheel unloading is averaged over the wheel sets of the bogie. For the relative assessment of cross wind stability of vehicles the reference air density ρ_0 is fixed at 1,225 kg/m³. Further, the vehicle mass to be considered is defined as the “operational mass in working order” according to EN 15663.

The assessment of cross wind stability of vehicles separates into evaluations of the aerodynamic characteristics (i.e. the aerodynamic coefficients) and the vehicle dynamic characteristics.

Subclause 5.2 states the applicability of the various methods for the purpose of rolling stock assessment.

Subclause 5.3 provides various methods for the determination of aerodynamic coefficients of passenger and freight vehicles and locomotives.

Subclause 5.4 provides various methods for the determination of wheel unloading.

Subclause 5.5 gives information on the required presentation form of CWC of passenger and freight vehicles and locomotives.

5.2 Applicability of cross wind methodologies for rolling stock assessment purposes

Subclauses 5.3 and 5.4 provide various methods for the assessment of the aerodynamic and vehicle dynamic characteristics. In general, these methods divide into simple and complex methods. The simpler methods are easier to apply, but imply an extra uncertainty supplement because they are tuned to be conservative in comparison to the complex ones.

Table 2 specifies which method shall be applied for rolling stock assessment purposes depending on type of rolling stock and its maximum speed v_{max}.

If various methods are permitted, the choice of the method depends on the degree of accuracy necessary for the problem. As a general principle, however, it is logical to start with the simplest appropriate procedures and then to shift to more complex methods if necessary.

All vehicles shall be assessed using any of the methods in Table 2.

In case of a fixed train composition it is sufficient to prove the cross wind stability of only the most cross wind sensitive vehicle in the train consist. In other cases, it is necessary to prove the cross wind stability of each vehicle.