BS EN 13848-1-2019 Railwayapplications. Track. Track geomet (DP segmentation)
BS EN 13848-1:2019

BSI Standards Publication

Railway applications -Track -Track geometry quality

Part 1:Characterization of track geometry

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National foreword

This British Standard is the UK implementation of EN 13848-1:2019.It supersedes BS EN 13848-1:2003+A1:2008,which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/2,Railway Applications -Track.

A list of organizations represented on this committee can be obtained on request to its secretary.

The UK committee draws users'attention to the distinction between normative and informative elements,as defined in Clause 3 of the CEN/CENELEC Internal Regulations,Part 3.

Normative:Requirements conveying criteria to be fulfilled if compliance with the document is to be claimed and from which no deviation is permitted.

Informative:Information intended to assist the understanding or use of the document.Informative annexes do not contain requirements,except as optional requirements,and are not mandatory.For example,a test method may contain requirements,but there is no need to comply with these requirements to claim compliance with the standard.

When speeds in km/h require unit conversion for use in the UK, users are advised to use equivalent values rounded to the nearest whole number.The use of absolute values for converted units should be avoided in these cases.Please refer to the table below for agreed conversion figures:

INS,RST and ENE speed conversions

km/h

5

10

20

30

80

160
190

mph

3

5

10

20

50

100
120

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BRITISH STANDARD

BS EN 13848-1:2019

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Bahnanwendungen - Oberbau - Gleislagequalität - Teil 1:Beschreibung der Gleisgeometrie

This European Standard was approved by CEN on 23 December 2018.

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EUROPÄISCHES KOMITEE FÜRNORMUNG

CEN-CENELEC Management Centre:Rue de la Science 23,B-1040 Brussels

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European foreword

This document (EN 13848-1:2019)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 September 2019,and conflicting national standards shall be withdrawn at the latest by September 2019.

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 13848-1:2003+A1:2008.

The main changes with respect to the previous edition are listed below:

— Uncertainty and resolution values are exported to the relevant other parts (EN 13848-2,-3 and-4);

—Addition of D0 domain;

—New Annex A on decolouring;

—Improvement of Annex Bon mainly cyclic top and dip angle;

— New Annex Cand D on filtering;

—New Annex F on simulation.

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 2008/57/EC.

For relationship with EU Directive 2008/57/EC,see informative Annex ZA,which is an integral part of this document.

This European Standard is one of the EN 13848 series,Railway applications—Track—Track geometry quality,as listed below:

— Part 1:Characterization of track geometry;

— Part 2:Measuring systems—Track recording vehicles;

—Part 3:Measuring systems—Track construction and maintenance machines;

—Part 4:Measuring systems—Manual and lightweight devices;

—Part 5:Geometric quality levels—Plain line,switches and crossings;

—Part 6:Characterisation of track geometry quality.

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,Former Yugoslav Republic of Macedonia, France,Germany,Greece,Hungary,Iceland,Ireland,Italy,Latvia,Lithuania,Luxembourg,Malta,

Netherlands,Norway,Poland,Portugal,Romania,Serbia,Slovakia,Slovenia,Spain,Sweden,Switzerland, Turkey and the United Kingdom.

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1 Scope

This document gives definitions for the principal track geometry parameters and specifies minimum requirements for measurement and the analysis methods.The aim is to allow the comparability of the output of different measuring systems.

This document does not apply to Urban Rail Systems.

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 13848-2,Railway applications—Track—Track geometry quality—Part 2:Measuring systems—Track recording vehicles

EN 13848-3,Railway applications—Track—Track geometry quality—Part3:Measuring systems—Track construction and maintenance machines

EN 13848-4,Railway applications—Track—Track geometry quality—Part 4:Measuring systems — Manual and lightweight devices

EN 13848-5:2017,Railway applications—Track—Track geometry quality—Part 5:Geometric quality levels—Plain line,switches and crossings

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:

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

NOTE Refer also to the symbols and definitions described in Clause 4.

CUT p=1.00
3.1
track geometry quality
assessment of excursions in the vertical and lateral planes from the mean or design
ed geometrical
characteristics of specified parameters which give rise to safety concerns or have a corr
elation with ride
quality

CUT p=1.00
3.2
gauge face
inside face of the running rail head

CUT p=1.00
3.3
running table
upper surface of the head of the rail

Note 1 to entry: See Figure 1.

Key
1 running table

Figure 1—Running table

CUT p=1.00
3.4
running surface
curved surface defined by the longitudinal displacement of a straight line
perpendicular to the centre-
line of the track and tangential to both running tables

Note 1 to entry: See Figure 2.

Figure 2—Running surface

CUT p=1.00
3.5
uncertainty
quantity defining an interval about a result of a measurement expected to encom
pass a large fraction of
the distribution of values that could reasonably be attributed to the measurand [r
efer to ISO 21748]

Note 1 to entry: The coverage factor is equal to 2.The uncertainty as defined corre
sponds to a confidence
interval of about 95%ofa normal distribution.

Note 2 to entry: The value applicable for track recording vehicles is described in E
N 13848-2.For other
measurement devices specific values may apply according to EN 13848-3 and EN 13848-

4.

8

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EN 13848-1:2019(E)

CUT p=0.99
3.6
resolution
smallest change in the value of a quantity to be measured which produces a detectable change in the indication of the measuring instrument

Note 1 to entry: The value applicable for track recording vehicles is described in EN 13848-2.For other measurement devices specific values may apply according to EN 13848-3 and EN 13848-4.

CUT p=1.00
3.7
wavelength range
space domain taken by the parameters'components

CUT p=1.00
3.8
sampling distance
travelled distance between any two consecutive measurement points

CUT p=1.00
3.9
range of measurement
specific domain described by its limits

CUT p=1.00
3.10
isolated defect
part of the signal exceeding a given limit such as IAL,IL or AL with at least one sample for a sampling distance of 0,25m

)

Note 1 to entry: The length of the exceedance is given by the number of samples exceed ing the limit [refer to
EN 13848-5:2017].

4 Symbols and abbreviations

For the purposes of this document,symbols and abbreviated terms applied are specified in Table 1.

Unit

mm

No. Symbol

Table 1—Symbols

Designation

Track gauge

1

2

3

4

5

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7

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9

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11

12

13

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G
Zp

ZI□1

Limit of the range below the running surface within which the gauge is measured.Zp is always 14mm for a Vignole rail

mm

Deviation in the direction of consecutive running table levels on right hand rail.Used in the measurement of Longitudinal Level

mm

ZI12

Deviation in the direction of consecutive running table levels on left hand rail.Used in the measurement of Longitudinal Level

mm

Yp1

Yp2

P

D0,D1,
D2,D3

λ

V1

V2

t

Distance between point Pand a reference line on right hand rail.Used in the measurement of Alignment

mm

Distance between point Pand a reference line on left hand rail.Used in the measurement of Alignment

mm

Gauge face contact point

Wavelength ranges

Wavelength

Amplitude from the zero line.Used in the measurement of Twist

Amplitude from the mean value.Used in the measurement of Twist

Twist base-length

m

m

mm/m

mm/m

m

X,Y,Z

Axes of a track coordinate system

5 Description of the track coordinate system

The track geometry quality is described by means of a moving right-hand Cartesian coordinate system centred to the track with clockwise rotation (refer to Figure 3):

— X-axis:axis represented as an extension of the track towards the direction of running;
—Y-axis:axis parallel to the running surface;

— Z-axis:axis perpendicular to the running surface and pointing downwards.

NOTE This description is for the coordinate system of the measurement vehicle.It is up to the infrastructure manager to define a reference direction of the track.

Key
1 running direction
2 intersection between considered cross section and running surface
3 track coordinate system

Figure 3—Relationship between the axes of the track coordinate system

Rail identification (left or right rail)is not in the scope of the document,but is to be defined for the purpose of exchanging data.

6 Principal track geometric parameters

CUT p=0.91
6.1 Track gauge

CUT p=1.00
6.1.1 General

Track gauge,G,is the smallest distance between lines perpendicular to the running surface intersecting each rail head profile at point Pin a range from O to Zp below the running surfac e.In this standard Zp is always 14 mm.

In the situation of new unworn rail head the point P will be at the limit Zp below the railhead, see Figure 4.

Key
1 running surface

Figure 4—Track gauge for new rail

In the situation of worn rail head the height of point P for the left rail can be different from the right rail, see Figure 5.

Key
1 running surface

Figure 5—Track gauge for worn rail

CUT p=1.00
6.1.2 Measurement method

Track gauge can be measured using a contact system or a non-contact system.

CUT p=1.00
6.1.3 Wavelength range

Not applicable.

CUT p=1.00
6.1.4 Resolution

The values of resolution depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00
6.1.5 Measurement uncertainty

The values of uncertainty depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00
6.1.6 Range of measurement

The range shall be the nominal gauge-15 mm/+50 mm.

CUT p=1.00
6.1.7 Analysis method

Individual defects are represented by the amplitude from the nominal value to the peak value (minimum and maximum peak value).

6.2 Longitudinal level

CUT p=1.00
6.2.1 General

Longitudinal level is the deviation znin z-direction of running table levels on any rai l from the smoothed vertical position (reference line)expressed in defined wavelength ranges.The smoothing is applied over a length that covers the wavelength range of interest (minimum two times the upper limit of the wavelength range of interest).The reference line and the longitudinal level are calculated from successive measurements (refer to Figure 6).

Key
1 running table
2 reference line

CUT p=1.00
6.2.2 Measurement method

Figure 6—Longitudinal level

Longitudinal level measurements shall be made with either an inertial system or a v ersine system(that should preferably be asymmetric)or by a combination of both methods.If the versine method of measurement is used,a decolouring of the measured signals is necessary in order to eliminate the influence of the transfer function of the versine system(see Annex A).

NOTE In the case of limited analysis length,the longitudinal level can be evaluated also from geodetic measurements.

CUT p=1.00

6.2.3 Wavelength range

Three ranges expressed in wavelengths ()shall be considered:

—D1:3m<λ≤25 m;

— D2:25m<λ≤70 m;

— D3:70m<λ≤150 m,used for measuring long wavelength defects.Generally this range should only

be considered for line speeds greater than 230 km/h.

NOTE Other wavelengths longer than 70m can also be taken into consideration by the vertical curvature parameter(refer to Annex B);however,this does not give an equivalent assessment of D3 domain.

In order to detect short wavelength defects,which can generate high dynamic forces, an optional wavelength range can be considered:

D0:1m<λ≤5m (1)

When measuring in the D0 domain,the sampling distance should be reduced to 0,1m. Due to the lack of experience in this domain no additional requirements are given presently.

The filters used for calculating D0,D1,D2 and D3 shall comply with the requirements of Annex C.

CUT p=1.00

6.2.4 Resolution

The values of resolution depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00

6.2.5 Measurement uncertainty

The values of uncertainty depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00
6.2.6 Range of measurement

The requirements are specified in Table 2.

Table 2—Longitudinal level:range of measurement

Dimensions in millimetres

Wavelength range	Range of measurement
D1	±50
D2	±100
D3	±200

NOTE The high ranges of measurement stated for D2 and D3 are only required if these domains are measured on conventional lines.If D2 and D3 are only measured on high-speed lines,smaller ranges can be applied.

CUT p=1.00
6.2.7 Analysis method

Individual defects are represented by the amplitude from zero to the peak value.

6.3 Cross level

CUT p=1.00
6.3.1 General

The difference in height of the adjacent running tables computed from the angle between the running surface and a horizontal reference plane.It is expressed as the height of the vertical leg of the right-angled triangle having a hypotenuse that relates to the nominal track gauge plus the width of the rail head rounded to the nearest 10 mm(refer to Figure 7).
Cross level is also called cant or superelevation.

NOTE For nominal gauge of 1435 mm the hypotenuse is 1500 mm in length.

For nominal gauges of 1520 mm and 1524 mm the hypotenuse is 1600 mm in length.

For nominal gauge of 1668 mm the hypotenuse is 1740 mm in length.

Key
1 cross level
2 running surface
3 horizontal reference plane
4 hypotenuse

CUT p=1.00
6.3.2 Measurement method

Figure 7—Cross level

Cross level is determined by measuring either the angle between the running surface a
nd the horizontal
reference plane or the difference in height between the two running tables.
CUT p=1.00
6.3.3 Wavelength range

Not applicable.
CUT p=1.00
6.3.4 Resolution

The values of resolution depend on the type of measuring system and are given in the corresponding
parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.
CUT p=1.00
6.3.5 Measurement uncertainty

The values of uncertainty depend on the type of measuring system and are given in the corresponding
parts of the standard EN 13848-2,EN 13848-3 and EN13848-4.
CUT p=1.00
6.3.6 Range of measurement

The range of measurements shall be±225 mm.

CUT p=1.00
6.3.7 Analysis method

Individual defects are represented by the amplitude from the low pass filtered value to th
e peak value.

NOTE Usually a sliding mean over 40m is used as a low pass filter.

In addition,the measured values 〔defined as amplitude between zero and peak va
lues〕may be
compared with the design values.

6.4 Alignment

CUT p=1.00
6.4.1 General

Alignment is the deviation ypin y-direction of the position of point P(refer to 6.1.1)on an
y rail from the
smoothed lateral position (reference line)expressed in defined wavelength ranges.The
 smoothing is
applied over a length that covers the wavelength range of interest(minimum two tim
es the upper limit
of the wavelength range of interest).The reference line and the alignment are cal
culated from
successive measurements (refer to Figure 8).

Key
P point Paccording to 6.1.1
2 reference line

CUT p=1.00
6.4.2 Measurement method

Figure 8—Alignment

Alignment measurements shall be made with either an inertial system or a versine
system(that should
preferably be asymmetric)or by a combination of both methods.

If the versine method of measurement is used,a decolouring of the measured signals
 is necessary in
order to eliminate the influence of the transfer function of the versine system.

CUT p=1.00
6.4.3 Wavelength range

Three ranges expressed in wavelengths(λ)shallbe considered:
— D1:3m<λ≤25m;

—D2:25m<λ≤70m;

—D3:70m<λ≤200 m,used for measuring long wavelength defects.Generally this range
 should only

be considered for line speeds greater than 230 km/h.

In order to detect short wavelength defects,which can generate high dynamic forces,
an optional
wavelength range can be considered:

—D0:1m<λ≤5m.

When measuring in the domain D0,the sampling distance should be reduced to 0,1m.
Due to the lack of
experience in this domain no additional requirements are given presently.

The filters used for calculating D0,D1,D2 and D3 shall comply with the requirements of Annex C.

Wavelengths over 70m can also be taken in consideration by the horizontal curvature parameter (refer to Annex B).

CUT p=1.00

6.4.4 Resolution

The values of resolution depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00

6.4.5 Measurement uncertainty

The values of uncertainty depend on the type of measuring system and are given in the corresponding parts of the standard EN 13848-2,EN13848-3 and EN13848-4.

CUT p=1.00

6.4.6 Range of measurement

The requirements are specified in Table 3.

Table 3—Alignment:range of measurement

Dimensions in millimetres

Wavelength range	Range of measurement
D1	±50
D2	±100
D3	±300

NOTE The high ranges of measurement stated for D2 and D3 are only required if these domains are measured on conventional lines.If D2 and D3 are only measured on high-speed lines,smaller ranges can be applied.

CUT p=1.00

6.4.7 Analysis method

Individual defects are represented by the amplitude from zero to peak.

6.5 Twist

CUT p=1.00

6.5.1 General

The algebraic difference between two cross levels divided by their distance apart (b ase-length t),
typically expressed as mm/m.
CUT p=1.00
6.5.2 Measurement method

Twist measurements is either computed from consecutive measurements of cross lev el or taken
simultaneously at a fixed distance e.g.at a distance equivalent to the wheel-base.
CUT p=1.00
6.5.3 Wavelength range

Not applicable
CUT p=1.00
6.5.4 Resolution

The values of resolution depend on the type of measuring system and are given in the corr esponding
parts of the standard EN 13848-2,EN 13848-3 and EN13848-4.
CUT p=1.00
6.5.5 Measurement uncertainty

The values of uncertainty depend on the type of measuring system and are given in the cor responding
parts of the standard EN 13848-2,EN 13848-3 and EN 13848-4.

CUT p=1.00
6.5.6 Range of measurement

The range shall be±15 mm/m.
CUT p=1.00
6.5.7 Analysis methods

Individual defects are represented by the amplitude from the zero-line to the peak value(V).For
purposes not related to safety the mean to peak value can be used (V)(refer to Figure 9).

Key
1 low pass filtered value(mean)
2 twist
3 zero line

)

7 Measurement conditions

Figure 9—Twist-Analysis method

In order to reproduce the dynamic effects of vehicles,all of the geometric parameters should preferably
be measured on a loaded track,in which case,the applied loading at the measuring poi

nt of the rail shall
be equivalent to a minimum vertical wheel load of 25kN when considering a mean track stiffness of
90 kN/mm per rail (wheel load divided by rail deflection)and a rail profile 60E1.

There can be differences in all track geometry parameter values according to whether they are
measured in loaded or unloaded,or static or dynamic conditions.These differences should be taken into
account when comparing measurements made under different conditions.

In case of unloaded or static measurement conditions,such conditions shall be documented.

The results of measurements shall be within the specified measurement precision for different speeds
and for each direction of recording.If this is not the case,the domain of validity and/or the direction of
travel shall be specified.

All parameters shall be measured at the same location within the sampling distance specified.

All principal parameters shall be measured at the same sampling distance.For signal processing and
signal analysis reasons this sampling distance should not exceed 0,25 m.
The localization uncertainty of all discrete measurements shallbe within±10m.
The uncertainty of the sampling distance shall be within 1%o.

Annex A
(informative)

Decolouring process

A.1 Definition of decolouring

If track geometry is recorded with a chord measurement system,the measured signals (versine)of
longitudinal level and alignment are distorted in magnitude and phase.The process of compensating
these distortions of the signals is called "decolouring” ,i.e.removing the “colour"due to the chord
measurement.

For example,decolouring of a chord measurement is required if the track geometry is assessed
according to the EN 13848 series or if used for simulation purposes.

The distortion depends on the chord length and on the chord division.In the case of an asymmetric
chord division,it also depends on the running direction of the measurement car.As an example for the

distortion,Figure A.1 shows a comparison between chord measurement and the corresponding
decoloured signal along a short track section.

)

Y

Key
1 decoloured signal

2 chord measurement
X distance [m]
Y amplitude [mm]

X

100

Figure A.1—Example of distortion due to chord measurement

The distortion can be described with the help of the transfer function.The magnitud e of the transfer
function represents the amplification factor as a function of the wavelength.The mag nitude lies

between 0 and 2.As an example,Figure A.2 shows the transfer function of a 10m c

hord measurement
system with a chord division of 4m and 6m.A magnitude of zero,seen at 2m wavelength,means that
this wavelength is not recorded at all and cannot be restored.Long waves are also strongly diminished;
the maximum wavelength which can be reasonably restored in this case is about 30m to 50m.
Generally,small values of the magnitude of the transfer function mean a disadvantageous signal-to-noise ratio,where decolouring is likely to malfunction.

Y

Y

)

Key
X wavelength |m]
Y magnitude [-]and phase []

X

X

10²

10²

Figure A.2—Example of transfer function of chord measurement(chord division:4 m/6m)

A.2 Decolouring method

There are a number of methods for decolouring.A selection of references to literature is given below.

— Haigermoser A.Dynotrain Deliverable D2.6—Final report on track geometry.Tech.rep.Dynotrain

Consortium,2013

-Wolter,Klaus Ulrich:European Patent:Reconstruction of original signals from relative

measurements,EP1543439 A1,DB Netz AG,June 2005

—Aknin,Patrice;Chollet,Hugues:A new approach for the modelling of track geometry recording
vehicles and the deconvolution of versine measurements.Vehicle System Dynamics Supplement 33
(1999),pp.59-70

— Mauer,Lutz:Determination of Track Irregularities and Stiffness Parameters with Inverse Transfer
Functions of Track Recording Vehicles.Vehicle System Dynamics Supplement 24(1995),pp.117-132

A.3 Verification of a decolouring process

A.3.1 Introduction

The verification of a decolouring process can be done in two ways:

— using test signals;

— through verifications on recorded track geometry data.

The signals used in these procedures should cover the full wavelength range of interest.

A.3.2 Verification with test signals

The off-line verification as shown in Figure A.3 is possible if a test signal containing undistorted (i.e.not affected by transfer functions of chord measuring systems)track geometry with all relevant wavelengths is available.

The test signal can be either a simulated signal or a real measure coming from a measuring system (inertial or geodetic).

For example,verification of decolouring in D1 and D2 can be done through the following steps:

1)Filtering of the test signal in D1 and D2 with a filter according to the definition in Annex C;

2)Calculating the versine of the test signal considering the given chord length and division;

3)Applying the decolouring and filtering in D1 and D2 to the versine;

4)Comparing the signals obtained at point 1 and point 3.

Key
1 test signal

2   decolouring
3 decolouring error
4 bandpass filter with zero phase
5 application of versine

Figure A.3—Verification of decolouring with a test signal

The comparison of signals at point 4 can be done in the space domain and in the fr
equency domain by
computing the transfer function and coherence function between the output signals
of points 1and 3.
For other wavelength ranges a similar process can be applied.

A.3.3   Verification   with   recorded   track   geometry   data

Verification from recorded data are useful if the decolouring algorithm is not known,
or a test signal is
not available.In this case the cross check between track gauge and difference of decol
oured and filtered
alignment or between   cross level and difference of decoloured and filtered longitud
inal level is
suggested.

In order to verify the compensation of the amplitude and phase of the transfer functi
on the cross check
shall be applied in the space domain.

Cross check between the track gauge and the difference between the alignment of th
e left and the right
rail should be preferred.This is due to the higher accuracy of the track gauge meas
urement with
respect to the cross level.

The verification is done according to the following steps:

1)Filtering of track gauge with a filter according to Annex C;

2)Comparison between the filtered track gauge and the difference between the alig
nment of the left

and the right rail in the same wavelength range.Figure A.4 below gives an example for D1.

1

2

5

3

4

Key
1 left alignment D1
2 right alignment D1
3 cross check
4 zero phase
5 track gauge

Figure A.4—Verification of decolouring with recorded data

The comparison of signals at point 2 can be done in the space domain and in the frequency domain by
computing the transfer function and coherence function between the output signals of points 1 and 2.

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Annex B
(informative)

Other parameters

B.1 Introduction

The principal track geometric parameters are described in the relevant part of this standard .However, other parameters contribute to an understanding of vehicle track interaction and ride quality.These other parameters can be obtained by direct measurement or by derived measurement.Other supportive data may be necessary in order to facilitate calculation of the derived measurements.A representative list of other parameters is shown in the following.

B.2 Parameters obtained by direct measurement

The following parameters can be measured directly:

— Horizontal curvature(1/m);

— Vertical curvature(1/m);

—Gradient(mm/m);

—Acceleration (m/s²)(refer to Annex E).

B.3 Parameters obtained by derived measurement to establish in-service values

B.3.1 Cyclic irregularities

Cyclic irregularities are a derailment risk that involves a harmonic response by specific types of railway vehicles.Such vehicles are built with a suspension system that is vulnerable to this phenomenon.

A cyclic isolated defect occurs when a measured parameter (e.g.longitudinal level at D1)has a value that repeats at a set frequency along the track which induces the harmonic response to the vehicle suspension.Energy builds up in the suspension if cycles of input continue,until the vehicle wheel sets unload;leading to derailment.

The peak values of input that trigger the harmonic response can all be below Intervention Limit IL (EN 13848-5:2017).It is the combined fixed wavelength and repetitive nature of these values that trigger the harmonic reaction.

Detection is usually made by an algorithm linked to the measured parameter and can span different wavelengths to match known susceptible vehicle types.

There are several different types of cyclic irregularity some of which are listed below:

— Cyclic Longitudinal Level (or Cyclic Top);

— Cyclic Cross Fall (or Cyclic Twist).

Mitigation of the derailment risk with this type of phenomenon is usually undertaken by a combination of speed restriction to eliminate the harmonic response as well as manual/mechanical intervention.

All Alert (AL),Intervention (IL) and Immediate action limits (IAL) are derived by experimentation/experience.

Cyclic irregularities are more susceptible when combined with other isolated defects such as Twist or Alignment.

B.3.2 Dip angle

A 'Dip Angle'as defined in Figure B.1 gives pre-indication of a potential rail end break.Detection of dip angles therefore enables early intervention to such a derailment risk,especially in jointed track.

Dip angles are measured over a very short wavelength(D0)and derived from an algorithm that calculates the derivative of longitudinal level to determine the localized'gradient'and hence the 'Dip Angle' θ measured in milliradians.The higher the dip angle the more impact force the rail end will experience with passing traffic.

AL,IL and IAL values are then set,with corresponding intervention time scales and potential speed restrictions.

Rail ends are not rigid and hence the value of the measured dip angle can change dependent upon the speed,load and direction of travel of the measuring vehicle.

)

Key
1 dip angle

B.3.3 Other parameters

Figure B.1—Dip angle

The following track design parameters are defined in EN 13803[3].Deviations from the design values may be assessed by track measurements:

— Rate of change of gradient;

—Cant deficiency;

— Rate of change of cant deficiency;
—Cant deficiency variation;

— Rate of change of cant;
—Cant gradient;

— Cant variation.

Annex C
(normative)

Filter requirements

C.1 General requirements

In order to ensure a correct application of the track quality levels given in EN 13848-5
:2017,and in
order to compare data of different measuring systems(of different manufacturers),a standa
rdization of
the filters for the different wavelength domains of longitudinal level and alignment is neces
sary.

The filters are required to have linear phase and a damping of-3dB at the cut-off frequency
.Tolerance
bands for the transfer functions(magnitude responses)in the wavelength ranges D1 and D2
are given
in C.2 below.Due to the lack of experience no tolerance bands and requirements for the slo
pe are given
for D3 and D0.It is recommended that the transfer functions remain within these to
lerance bands.
However,e.g.in order to maintain data history it might be necessary to choose a tra
nsfer function
which is partly outside of the tolerance band.If the transfer function is below the lower limit
given in
the tables below,the limit values of part 5 shall be adapted accordingly (see also D.5).If th
e transfer
function is above the upper limit,the output values willbe increased.Since this is on the
safe side,no
further action is required for the safety assessment.

Diagrams ofthe filter transfer functions (including the tolerance band limits in case of D1 a
nd D2)shall
be provided together with the measurement output data.

C.2 Tolerance bands for filter transfer functions

C.2.1 Introduction

The tables in the following clauses give the tolerance bands for the transfer functions in D1
and D2,
respectively.

C.2.2 Filter for D1

D1 has the following cut-off frequencies:

— flow=0,04 m-1 (wavelength 25m)
— fhigh=0,3333m-1 (wavelength 3m)
Table C.1 defines the boundaries for the transfer function.

λ[m]

f[1/m]

≤0,62 ≥1,6026

0,68

1,4757

0,75

1,3300

0,84

1,1846

0,96

1,0395

1,12

0,8949

Table C.1—Boundaries for transfer function in D1

Lower limit
(dB)

Upper limit
(dB)

Tolerance
(upper-lower)

-Inf

-Inf

-Inf

-Inf

-Inf

-Inf

-50,0

-47,1

-43,5

-39,4

-34,8

-29,5

Inf

Inf

Inf

Inf

Inf

Inf

Remark

stopband

transition band

transition band

transition band

transition band

transition band

27

□

□

□

□

□

□

□

□

□

□

□

Y

Key

X reference filter(Butterworth,zero-phase)
Y FIR,order 200,-6dB

X

Figure D.6—Scatter plot of peak values in sections

The same kind of analysis with various realistic filters inside the tolerance band has shown very small differences with average errors not more than 1%.

In a second example,for the wavelength range D2,an FIR filter of order 400 with-6dB instead of-3dB at the cut-off wavelengths is demonstrated.The transfer function of this filter is displayed in Figure D.7, together with the transfer function of the reference filter(Butterworth,zero-phase)and of the lower limit of the tolerance band.This FIR filter is clearly below the tolerance limit in the whole D2 wavelength range.Accordingly,the scatter plot in Figure D.8 shows maximum amplitudes significantly lower than with the reference filter.The average error is 14%.

0

-2

-4

-6

-8

Y -10

-12

-14

-16

-18

-20

--1
-2
.........3

10
1 25 70
100 200

X

Key
1 reference filter(Butterworth,zero-phase)
2 FIR,order 400,-6dB

3 lower tolerance
X length [m]
Y magnitude [dB]

)

Figure D.7—Transfer functions of D2 filter example

15

10

Y

0 5 10

X

Key

X reference filter(Butterworth,zero-phase)
Y FIR,order 400,-6dB

Figure D.8—Scatter plot of peak values in sections,D2 filter example

40

Another example for wavelength range D2 demonstrates an FIR filter of order 700 using Hamming windowing(as in the previous example).The cut-off wavelengths are modified to 23,75m and 83m in order to meet-3 dB at 25m and 70m,respectively.As shown in Figure D.9,the transfer function is partly below the lower tolerance limit,in particular between 50m and 65m.On the other hand,it is clearly above the reference filter at wavelengths above 70 m.Figure D.10 shows that the resulting maximum amplitudes are in average 4%larger than with the reference filter.

Y -10

10 25 70 200

X

Key
1 reference filter(Butterworth,zero-phase)
2 FIR,order 700,-3 dB(adapted cut-off wavelength)
3 lower tolerance
X length [m]
Y magnitude [dB]

Figure D.9—Transfer functions of D2 filter example 2

Y

Key
X reference filter(Butterworth,zero-phase)
Y FIR,order 700,-3 dB

X

Figure D.10—Scatter plot of peak values in sections,D2 filter example 2

D.6 Comparison of different measurement systems

If results of different measurement systems are compared,it is recommended to use identical filters in order to exclude differences due to the filtering.If it is not possible to use identical filters,the difference due to the filtering shall be considered in the comparison.

Annex E
(informative)

Measurement of acceleration

E.1 Introduction

Acceleration measurements can be used to give an indication of track geometry quality and to detect the local track geometry deviations which have an influence on the dynamic behaviour of a vehicle.

These measurements should be used in conjunction with the main parameter measurements described in the standard.However,acceleration measurements are sensitive to the dynamic behaviour of the vehicle and other factors such as climatic conditions,actual position of the vehicle in the train and wheel rail interaction.

E.2 Measurement method

Measurements can be taken at various locations on the car body and/or bogie depending upon the particular assessment required.

—C1-vertical axle box acceleration -for the detection of rail surface defects (e.g.corrugation)and

isolated geometrical defects.

—C2-transverse bogie acceleration for the detection of short wavelength track geometry defects

(alignment or cross level).

—C3-transverse and vertical car body acceleration for the detection of defects that have an influence

on comfort.

E.3 Frequency range

— C1-vertical axle box acceleration 0 to 500 Hz
— C2-bogie acceleration 0 to 100 Hz
— C3-car body acceleration 0 to 50 Hz

E.4 Range of measurement

— C1-vertical axle box acceleration ±1000 m/s^2
— C2-bogie acceleration ±50 m/s^2
— C3-car body acceleration ±20 m/s^2

E.5 Sampling frequency

The sampling frequency should be at least 5 times the cut-off frequency applied to the signal e.g.≥2500 Hz for axle box acceleration (i.e.5×500 Hz).

E.6 Measurement conditions

—C1-(vertical axle box acceleration)the measuring speed should be adapted to the used sensors

and the analysis method.

—C2 and C3-(bogie and car body acceleration)measurement should be made at the operating speed

for the line within a tolerance of±10%.

E.7 Analysis method

—C1-(vertical axle box acceleration):

· Calculation and analysis of mean to peak and/or peak to peak values in the given frequency

range which are linked to dynamic wheel-rail forces and to isolated defects;

· Calculation of standard deviation of signal over a specified distance and a given frequency
range.This can be used for assessing corrugation and/or density of short geometric defects of
the rail;

· Double integration of the signal in a given frequency range in order to obtain a representation
of short defects of track geometry.This method can be also used for calculating longitudinal
level.

—C2 and C3-(bogie and car body acceleration)isolated defects are represented by the amplitude
from the mean value to the peak value or from zero to the peak value as defined by the
Infrastructure Manager.

E.8 Output requirements

Results should be presented in graphical form.An analogue or digital recording of raw data can also be
made to enable further analysis of measurements.It is recommended to provide the speed together
with the accelerations.

The Infrastructure Manager should define the exact output requirements.

E.9 Output presentation

— C1-(vertical axle box acceleration):

· presented as the standard deviation over a given duration or a given length for a specified

wavelength range;

· presented in a graphical format when mean/peak to peak analysis or double integration is

performed.

—C2 and C3-(bogie and car body acceleration)presented as isolated defects that exceed a

prescribed threshold.

Annex F
(informative)

Track geometry data for simulation purposes

F.1 Introduction

The dynamic behaviour of a railway vehicle and its interaction with track can be simulated with a computer software system including models for vehicle,track and wheel-rail contact.The use of measured track geometry data allows simulating the vehicle dynamics under real conditions.Important applications for the vehicles are the virtual homologation,investigation of possible designs or parameter changes.Additionally,simulations can be used for the assessment of track geometry based on vehicle responses.

This annex gives information about which data are required in order to successfully perform simulations.The required data are similar to the data used for track geometry assessment and hence can be provided by most track measurement systems.The main difference is the extended wavelength range of longitudinal level and alignment.Moreover,track layout data like curvature can be included.

F.2 Contents of track geometry data for simulation purposes

Measured track geometry data typically includes track irregularity data as well as track layout data. Both are needed in order to perform realistic simulations.

Track irregularity data of longitudinal level and alignment are used as excitation signals for the dynamic analysis of a vehicle-track system.This requires undistorted track geometry and therefore decolouring in case of chord measurement data.The required wavelength content depends on the purpose of the

simulation and on the considered speed (see F.3 for details).It differs from the D1 and D2 d
omains.

Track gauge and cross level shallbe provided in addition to longitudinal level and alignmen
t.It is not
sufficient to compute track gauge as the difference of alignment and cross level as the diff
erence of
longitudinal level,since these have a limited wavelength range and therefore do no
t contain
information about e.g.track gauge widening in curves.

Measured track layout data can include (horizontal)curvature,cant and vertical curvatu
re.It can
deviate from the nominal track layout,which is typically given in tabular form as a sequence
of track
layout elements like straight lines,transition curves,etc.In contrast,measured track layo
ut data are
sampled at the same interval as the track irregularity data,e.g.at 25cm.For simulation
s,measured
track layout data are preferred over nominal layout data,because it reflects the real
situation on the
track,and because a potential shift along the track between two different data sourc
es is avoided.
Measured (horizontal)curvature is provided by most recording systems.

All data should be synchronized along the track.

In summary,the following signals are required for simulations:

—longitudinal level of left and right rail(extended wavelength range);

—alignment of left and right rail(extended wavelength range);

—track gauge;

—cross level;

—(horizontal)curvature.

In addition,information about the line speed and the signal of vertical curvature can be req
uired.

The used sign convention shall be stated for all signals.

F.3 Extended wavelength range

For homologation purposes,vehicle dynamics is assessed for frequencies from 0,4 Hz t
o 20 Hz.The
excitation due to track irregularities shallcover this frequency range,because otherwise the
simulation
results will be incomplete.Depending on the vehicle speed,this frequency range correspond
s to various

wavelength ranges,see Table F.1.If it is not possible to provide the full wavelength range,Ta ble F.2 can
be used to identify the corresponding frequency range for a particular wavelength range.It then has to
be discussed individually about how a limited frequency range will affect the validity of simulation
results.

Table F.1—Conversions from frequencies f[Hz]to wavelengths λ[m]

Wavelength [m]

Speed

F=20 Hz F=0,4 Hz

V=80 km/h

V=120 km/h

V=160 km/h

V=230 km/h

V=300 km/h

1,1

1,7

2,2

3,2

4,2

V=360 km/h

5

56

83

111

160

208

250

)

Table F.2—Conversions from wavelengths λ[m]to frequencies [Hz]

Frequency [Hz]

Speed λ=1m λ=3m λ=25m λ=70 m λ=150m λ=200 m

V=80 km/h

22,2

7,4

V=120 km/h 33,3

11,1

V=160 km/h 44,4

14,8

V=230 km/h 63,9

21,3

V=300 km/h 83,3

27,8

V=360 km/h

100

33,3

0,9

1,3

1,8

2,6

3,3

4

0,3

0,5

0,6

0,9

1,2

1,4

0,1

0,2

0,3

0,4

0,6

0,7

0,1

0,2

0,2

0,3

0,4

0,5

In general,a wavelength range from 1m to 200 m is provided by modern track recording systems.This covers the required frequency range for most speed categories.

F.4 Numerical resolution

If track data are given with low numerical resolution,the signals can become step-like,with repeated samples of identical amplitude and jumps which are much larger than in reality.This will lead to unrealistic simulation results.It is therefore recommended to provide track data in a high numerical

resolution,e.g.with 10-3mm.This is clearly beyond the precision of the measurement system,butt prevents problems in the simulation.

F.5 Pre-processing for simulation

After the track geometry data has been provided,some pre-processing is necessary in order to make the measurement data suited for simulations.

Track measurement data typically contains both irregularity and layout data.It shall be ensured that there is no overlap and no gap of the wavelength content between the respective signals,in particular between alignment and curvature.Filtering may be used,where the cut-off wavelength depends on the line characteristics like curve radiiand transition lengths.

For simulation,depending on the software,it can be necessary or may be preferred to convert the track irregularities of the individual rails (as given by most measurement systems)to irreg

ularities at the
track centre.Figure F.1 depicts both representations.The nominal track centre Co and the nominal
tangent to to the top of both rails define the nominal position of the track and its rails.The actual track
centre C lies on the actual tangenttto the top of both rails in the middle between the track gauge points
Pl and Pr.With respect to Co,the position of C is defined by the lateral displacement y and the vertical
displacementz,andtis rotated by α with respect to to.Together with the actual track gauge g,the actual
position of both rails is defined.If the irregularities are referring to the individual rails,the left and right
vertical deviations zl and zr are the vertical distances from the top of rail points Tl and Tr to to.The left
and right lateral deviations yl and yr plus half of the nominal track gauge go give the lateral distances
from Pl and Pr to Co.The arrows in the figure indicate positive signs of the displacements and rotation.

)

Figure F.1—Track centre related and rail related irregularities

A conversion from rail related signals to track centre related signals (and vice versa)can be
accomplished by the following formulas.The lateral base b is the distance between Tl and Tr,where
typically only the nominal value is used.The angle α is assumed to be small. Differences in the
wavelength ranges of the signals are not considered in the formulas.

y=(yl+yr)/2   yl=y-(g-g0)/2

z=(zl+zr)/2   yr=y+(g-g0)/2

α=(zr-zl)/b   zl=z-α*b/2

g=yr-yl+g0   zr=z+α*b/2

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC aimed to be covered

This European Standard has been prepared under a Commission's standardization re quest M/483 to
provide one voluntary means of conforming to the essential requirements of the Directive 2008/57/EC
on the interoperability of the rail system (recast)and with the associated TSIs.

Once this standard is cited in the Official Journal of the European Union un der that
Directive 2008/57/EC,compliance with the normative clauses of this standard given in Table ZA.1
confers,within the limits of the scope of this standard,a presumption of conformity with the
corresponding Essential Requirements of that Directive and associated EFTA regulations an d with the
TSI requirements.

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□)

Table ZA.1—Correspondence between this European Standard,Commission Regulation (EU)

No 1299/2014 of 18 November 2014 on the technical specifications for interoperability rel ating
to the 'infrastructure'subsystem of the rail system in the European Union,and
Directive 2008/57/EC

Corresponding text, articles/S/annexes of the Directive 2008/57/EC	Chapter/S/annexes of the TSI	Clauses/subclauses of this European Standard	Comments

Annex II,Essential
requirements
1 General requirements

4.Description of the
Infrastructure
subsystem

1.1 Safety

Clauses 1.1.1,1.1.2(first
sentence),
CUT p=1.00
1.2.Reliability and
Availability

Clause 4.2.8.3 of the merged
TSI INF mandates
EN 13848-1:2003+A1:2008
Clause 4.for the definition of
track twist.
According to subclause 6.3.1
of the standard,cross level is
also called cant or
superelevation.

Clause 6 Principal
track geometric
parameters
6.1 Track gauge

6.2 Longitudinal level

6.3 Cross level
6.4 Alignment

CUT p=0.95
6.5 Twist

Clause 7
Measurement
conditions
Annex C(normative)
-Filter requirements

CUT p=1.00
4.2.Functional and
technical
specifications of
subsystem
CUT p=1.00
4.2.8.Immediate
action limits on track
geometry defects

CUT p=1.00
4.2.8.1.The
immediate action
limit for alignment

CUT p=1.00
4.2.8.2.The

immediate action
limit for longitudinal
level
CUT p=1.00
4.2.8.3.The
immediate action
limit for track twist
CUT p=1.00
4.2.8.4. The
immediate action
limit of track gauge as
an isolated defect
CUT p=1.00
4.2.8.5. The
immediate action
limit for cant.

WARNING1— Presumption of conformity stays valid only as long as a reference to this European Standard is maintained in the list published in the Official Journal of the European Union.Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2— Other Union legislation may be applicable to the products falling within the scope of this standard.

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