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Železniške naprave - Kolesne dvojice in podstavni vozički - 1. del: Metoda za načrtovanje gredi z zunanjim uležajenjem (vključuje dopolnilo A1)

Railway applications - Wheelsets and bogies - Part 1: Design method for axles with external journals

Bahnanwendungen - Radsätze und Drehgestelle - Teil 1: Konstruktionsleitfaden für außengelagerte Radsatzwellen

Applications ferroviaires - Essieux montés et bogies - Partie 1: Méthode de conception des essieux-axes avec fusées extérieures

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Railway applications - Wheelsets and bogies - Part 1: Design method for axles with external journals

Applications ferroviaires - Essieux montés et bogies - Partie 1: Méthode de conception des essieux-axes avec fusées extérieures

Bahnanwendungen - Radsätze und Drehgestelle - Teil 1: Konstruktionsleitfaden für außengelagerte Radsatzwellen

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Contents

Page

Foreword ... 4
Introduction ... 5
1 European scope ... 6
2 Normative references ... 7
3 Terms and definitions ... 7
4 Symbols and abbreviations ... 8
5 tab General ... 10
6 Forces and moments to be taken into consideration ... 10
6.1 Types of forces ... 10
6.2 Effects due to masses in motion ... 10
6.3 Effects due to braking ... 16
6.4 Effects due to curving and wheel geometry ... 20
6.5 Influence of traction ... 20
6.6 Calculation of the resultant moment ... 21
7 Determination of geometric characteristics of the various parts of the axle ... 22
7.1 Stresses in the various sections of the axle ... 22
7.2 Determination of the diameter of journals and axle bodies ... 25
7.3 Determination of the diameter of the various seats from the diameter of the axle body or from the journals ... 25
7.3.1 tab General ... 25
7.3.2 Transition between collar bearing surface and wheel seat ... 28
7.3.3 Wheel seat in the absence of an adjacent seat ... 28
7.3.4 Case of two adjacent wheel seats ... 29
7.3.5 Case of two non-adjacent wheel seats ... 30
8 Maximum permissible stresses ... 30
8.1 tab General ... 30
8.2 tab Steel grade EA1N and EA1T ... 31
8.3 tab Steel grades other than EA1N and EA1T ... 32
8.3.1 tab General ... 32
8.3.2 Steel grade EA4T ... 33
8.3.3 Other steel grades ... 35
Annex A (informative) Model of axle calculation sheet ... 36
Annex B (informative) Procedure for calculating the load coefficient for tilting vehicles ... 38
Annex C (informative) Values of forces to take into consideration for wheelsets for reduced gauge track (metric or close to a metre) ... 40
Annex D (normative) Method for determination of full-scale fatigue limits for new materials ... 41
D.1 Scope ... 41
D.2 General requirements for test pieces ... 41
D.3 General requirements for test apparatus ... 41
D.4 Axle body fatigue limit ("F1") ... 41
D.4.1 Geometry ... 41

D.4.2 Verification of the applied stress ... 42
D.4.3 End of test criterion ... 43
D.4.4 Determination of the fatigue limit ... 43
D.5 Axle bore fatigue limit ("F2") ... 43
D.5.1 Geometry ... 43
D.5.2 Verification of the applied stress ... 44
D.5.3 End of test criterion ... 44
D.5.4 Determination of the fatigue limit ... 44
D.6 Wheel seat fatigue limit ("F3 and F4") ... 44
D.6.1 Geometry ... 44
D.6.2 Verification of the applied stress ... 46
D.6.3 End of test criterion ... 46
D.6.4 Determination of the fatigue limit ... 46
D.7 Content of the test report ... 47
Bibliography ... 48

Foreword

This document (EN 13103-1:2017+A1:2022) 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, by June 2023 at the latest, and all conflicting national standards shall be withdrawn no later than June 2023.

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This document includes Amendment 1 approved by the CEN on 29 August 2022.

This document will supersede !EN 13103-1:2017".

The start and end of the text added or modified by the amendment are indicated in the text with ! and " respectively.

This document has been prepared in the context of a standardization request given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of Directive 2008/57/EC.

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

The user should address any feedback or questions regarding this document to their country's national standards organisation. A comprehensive list of these organisations can be found on the CEN website.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are required to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, the Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, the Republic of Serbia, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Railway axles were among the first train components to give rise to fatigue problems.

Many years ago, specific methods were developed in order to design these axles. They were based on a feedback process from the service behaviour of axles combined with the examination of failures and on fatigue tests conducted in the laboratory, so as to characterize and optimize the design and materials used for axles.

A European working group under the aegis of UIC[1] started to harmonize these methods at the beginning of the 1970s. This led to an ORE[2] document applicable to the design of trailer stock axles, subsequently incorporated into national standards (French, German, Italian). It was consequently converted into a UIC leaflet.

The method for this standard is based on the calculation of nominal stresses using beam theory. It was developed at a time when the calculation method per finished item had yet to be established. Fatigue limit values were obtained from tests, and the level of stress on the test pieces was calculated using beam theory. In addition, fatigue correlation coefficients were determined in the same way, using the experimental results from test pieces of different diameters and transition radii.

The following three elements:

— calculation method;

— correction coefficient values;

— fatigue limit values;

are closely linked, with the values of the two latter parameters being dependent on the calculation method.

The bibliography lists the relevant documents used for reference purposes. The method described therein is largely based on conventional loadings (now deduced from the definition of the masses declined in EN 15663). The outcome is validated by many years of operations on the various railway systems.

This standard is based largely on this method which has been improved and its scope enlarged.

In order to simplify the maintenance of axle design standardization, it was decided to merge two previous documents EN 13103 and EN 13104 into a single standard, in the form of this document.

Furthermore, this standard makes reference to mass standard EN 15663 to define the loads used in the calculations.

[1] UIC: Union Internationale des Chemins de fer.

[2] ORE: Office de Recherches et d'Essais de l'UIC.

1 European scope

This European standard:

— defines the forces and moments to be taken into account with reference to masses, traction and braking conditions;

— gives the stress calculation method for axles with outside axle journals;

— !specifies the maximum permissible stresses to be assumed in calculations for steel grades EA1N, EA1T and EA4T defined in EN 13261:2020";

— describes the method for determination of the maximum permissible stresses for other steel grades;

— determines the diameters for the various sections of the axle and recommends the preferred shapes and transitions to ensure adequate service performance.

This European Standard applies to:

— !axles defined in EN 13261:2020";

— powered and non-powered axles;

— all track gauges[3].

The design method for powered axles described in this European Standard applies to:

— solid or hollow powered axles for railway vehicles;

— solid or hollow non-powered axles for motor bogies;

— solid or hollow non-powered axles for locomotives.

The design method for non-powered axles described in this European Standard applies to solid or hollow axles for railway vehicles intended for the transportation of passengers or freight and which do not appear in the preceding list.

This European Standard is applicable to axles fitted to rolling stock intended to run under normal European conditions. Before using this European Standard, if there is any doubt as to whether the railway operating conditions are normal, it is necessary to determine whether an additional design factor has to be applied to the maximum permissible stresses. The calculation of wheelsets for special applications (e.g. tamping/lining/levelling machines) may be made according to this European Standard only for the load cases of free-running and running in train formation. This European Standard does not apply to workload cases. They are calculated separately.

This method may be used for light rail and tramway applications.

[3] If the gauge is not standard, certain formulae need to be adapted.

2 Normative references

The following documents are referenced in a normative manner, in part or in full, in this document, and are indispensable for its application. For dated references, only the cited edition applies. For undated references, the last edition of the reference document applies (including any amendments).

!EN 13260:2020", *Railway applications — Wheelsets and bogies — Wheelsets — Product requirements*

!EN 13261:2020", *Railway applications- Wheelsets and bogies - Axles - Product requirements*

!EN 15313:2016", *Railway applications - In-service wheelset operation requirements - In-service and off-vehicle wheelset maintenance*

!EN 15663:2017+A1:2018", *Railway applications - Vehicle reference masses*

3 Terms and definitions

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

3.1
Powered axle
the following axles are considered as powered axles:

— solid or hollow powered axles for railway vehicles;

— solid or hollow non-powered axles for motor bogies;

— solid or hollow non-powered axles for locomotives

3.2
non-powered axle
a solid or hollow axle used for railway vehicles intended for the transportation of passengers or freight and that is not considered as a powered axle as defined in paragraph 3.1

3.3
technical specification
a document describing the specific parameters and/or requirements of the product in addition to the requirements of this standard

3.4
Guiding axle
!axle of the first (i.e. leading) bogie of a coach used at the head of a reversible trainset. If an axle can be used in both positions (guiding or non-guiding), it is to be considered as a guiding axle"

4 Symbols and abbreviations

For the purposes of this European Standard, the symbols and abbreviations in Table 1 apply.

Table 1

Symbol	Unit	Description
m_1	kg	Mass on journals (including bearings and axle boxes)
m_2	kg	Wheelset mass and masses on the wheelset between wheel rolling circles. A definition will be included in the current revision of EN 13262 (brake disc, gear etc.)
$m_1 + m_2$	kg	For the wheelset considered, proportion of the mass of the vehicle on the rails
g	m/s²	Acceleration due to gravity
P	N	Half the vertical force per wheelset on the rail $\frac{(m_1+m_2)g}{2}$
P_0	N	Vertical static force per journal when the wheelset is loaded symmetrically $\frac{m_1 g}{2}$
P_1	N	Vertical force on the more heavily-loaded journal
P_2	N	Vertical force on the less heavily-loaded journal
P'	N	Proportion of P braked by any mechanical braking system
Y_1	N	Wheel/rail horizontal force perpendicular to the rail on the side of the more heavily- loaded journal
Y_2	N	Wheel/rail horizontal force perpendicular to the rail on the side of the less heavily-loaded journal
H	N	Force balancing forces Y_1 and Y_2
Q_1	N	Vertical reaction on the wheel situated on the side of the more heavily-loaded journal
Q_2	N	Vertical reaction on the wheel situated on the side of the less heavily-loaded journal
F_i	N	Forces exerted by the masses of the unsprung elements situated between the two wheels (brake disc(s) etc.)
F_f	N	Maximum force input of the brake shoes of the same shoeholder on one wheel or interface force of the pads on one disc
M_x	Nmm	Bending moment due to the masses in motion
M'_x, M'_z	Nmm	Bending moments due to braking
M'_y	Nmm	Torsional moment due to braking
M''_x, M''_z	Nmm	Bending moments due to traction
M''_y	Nmm	Torsional moment due to traction
MX, MZ	Nmm	Sum of bending moments
MY	Nmm	Sum of torsional moments

Symbol	Unit	Description
MR	Nmm	Resultant moment
$2b$	mm	Distance between vertical force input points on axle journals
$2s$	mm	Distance between wheel rolling circles
h_1	mm	Height above the axle centreline of vehicle centre of gravity of masses carried by the wheelset
y_i	mm	Distance between the rolling circle of one wheel and force Fi
y	mm	Abscissa for any section of the axle calculated from the section subject to force $P1$
Γ		Average friction coefficient between the wheel and the brake shoe or between the brake pads and the disc
σ	N/mm²	Stress calculated in one section
K		Fatigue stress correction factor
R	mm	Nominal wheel radius (Nominal wheel diameter / 2)
R_b	mm	Application radius of the braking force
d	mm	Diameter for one section of the axle
d'	mm	Bore diameter of a hollow axle
dm	mm	Diameter used for determining K
r	mm	Radius of transition fillet or groove used to determine K
S		Safety coefficient
G		Centre of gravity
R_{fL}	N/mm²	Fatigue limit under rotating bending up to 10^7 cycles for smooth test pieces
R_{fE}	N/mm²	Fatigue limit under rotating bending up to 10^7 cycles for notched test pieces
a_q	m/s²	Unbalanced transverse acceleration
f_q		Thrust factor

5 11.2.3.1\tab General

The major phases for the design of an axle are:

a) definition of the forces to be taken into account and calculation of the moments on the various sections of the axle;

b) selection of the diameters of the axle body and journals and - on the basis of these diameters - calculation of the diameters for the other parts of the axle;

c) the options taken are verified in the following manner:

   — stress calculation for each section;

   — comparison of these stresses with the maximum permissible stresses.

The maximum permissible stresses are mainly defined by:

— the steel grade;

— whether the axle is solid or hollow.

— the type of drive transmission.

An example of a data sheet with all these phases is given in Annex A.

6 Forces and moments to be taken into consideration

6.1 Types of forces

Three types of forces are to be taken into consideration as a function:

— of the masses in motion;

— of the braking system.

— of traction.

6.2 Effects due to masses in motion

The forces generated by masses in motion are concentrated along the vertical symmetry plane (y, z) (see Figure 1) intersecting the axle centreline.

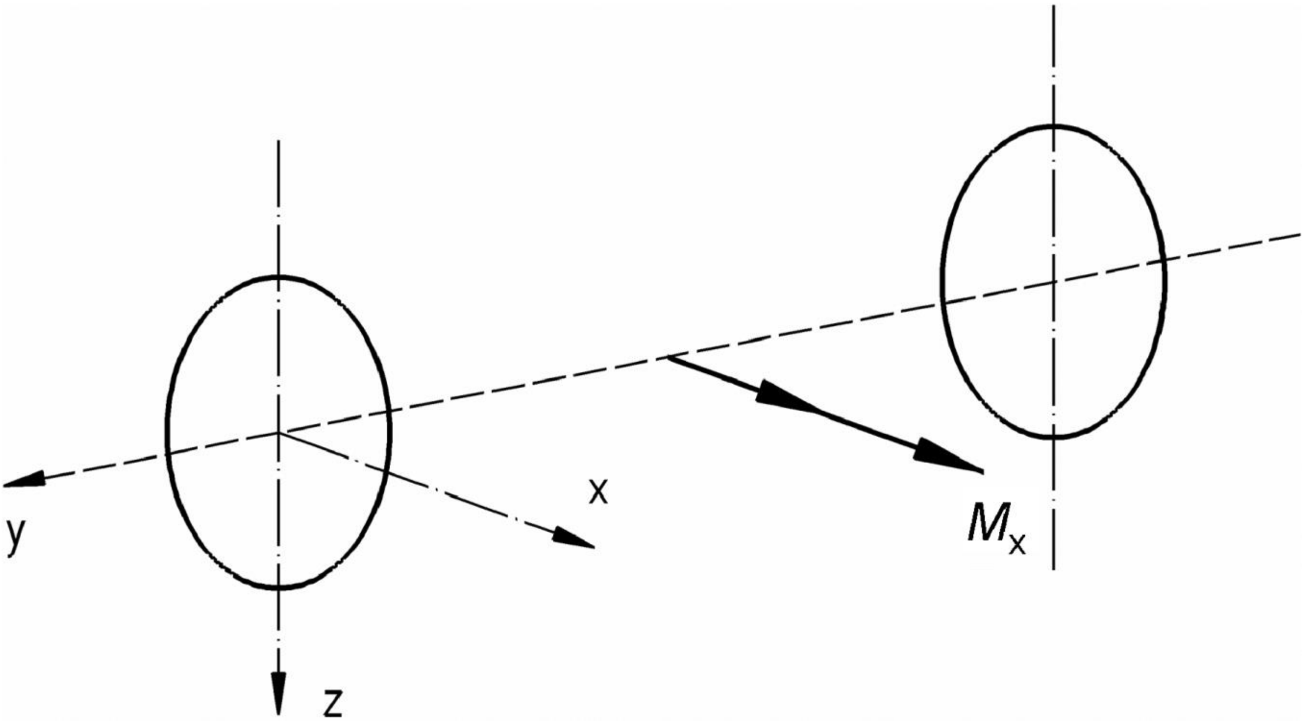


Figure 1 — Definition of axes and moments caused by masses in motion

The bending moment M_x is due to the vertical forces parallel to the Z axis.

Without any other requirement in the technical specification, Table 2 defines the masses (m_1+ m_2) to take into account for the main types of rolling stock. For certain specific applications, e.g. suburban vehicles, alternative mass definitions are required, in accordance with the specific operating conditions.

!Table 2 — Masses to take into account for the main types of rolling stock

Type of rolling stock units	Mass (m_1+ m_2)
Freight wagons Powered coaches with no accommodation for passengers, luggage or post	In-service design mass + normal design payload (maximum payload) In-service design mass and the normal design payload are defined in Standard EN 15663:2017+A1:2018
Coaches and powered coaches including accommodation for passengers, luggage or post: • High speed or long distance trains	1 – High-speed or main line vehicles In-service design mass is defined in Standard EN 15663:2017+A1:2018. The normal design payload is defined in Standard EN 15663:2017+A1:2018, where standing passengers shall be considered as: - 160 kg/m² (2 passengers per m²) in the areas accessible to standing passengers and in the restaurant compartments
Coaches and powered coaches including accommodation for passengers, luggage or post: • Passenger vehicles other than high speed or long distance	1 – High-speed or main line vehicles In-service design mass is defined in Standard EN 15663:2017+A1:2018. The normal design payload is defined in Standard EN 15663:2017+A1:2018, where standing passengers shall be considered as: - 210 kg/m² (3 passengers per m²) in the corridor areas; - 350 kg/m² (5 passengers per m²) on platforms; the value of 280 kg/m² (4 passengers per m²) may be used in specific cases (e.g. the 1st class compartment) as described in the technical specification

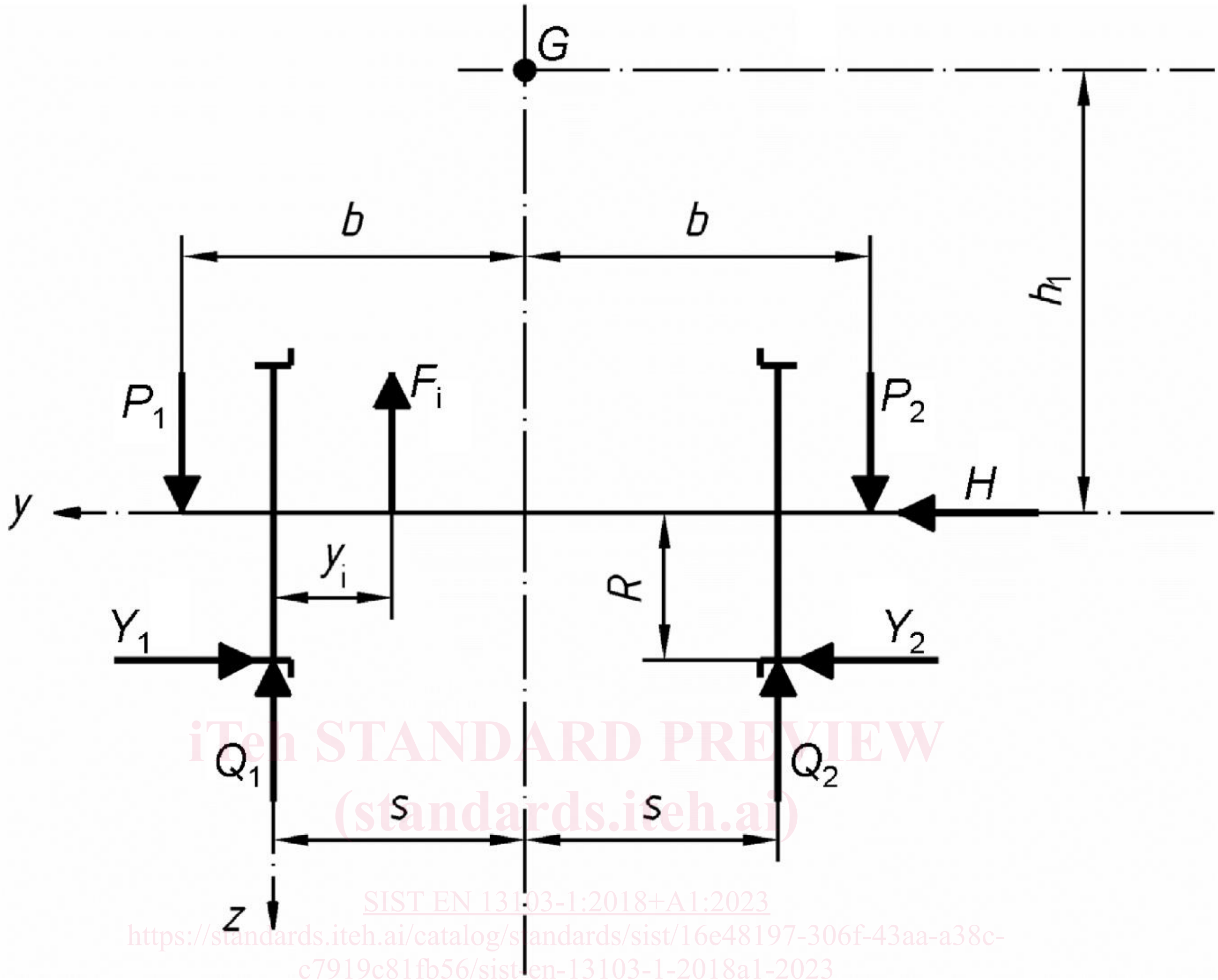
"

The bending moment *Mx* in every section is calculated from the forces *P*1, *P*2, *Q*1, *Q*2, *Y*1, *Y*2 and *Fi* indicated in Figure 2. It corresponds to the most unfavourable load case for the axle, i.e.:

— asymmetric distribution of forces;

— the direction of the forces *F*i due to the masses of the unsprung components selected in such a manner that their effect on bending is added to that due to the vertical forces;

— the value of the forces *F*i results from multiplying the mass of each unsprung component by 1 g.



Wheel rejected

G centre of gravity of vehicle

Figure — Forces to calculate the bending moment

Table 3 shows the values of the forces calculated from *m1*.

The formulae coefficient values are applicable to standard gauge axles and classical suspension. For very different gauges, a metric gauge for example, or a new system of suspension, a tilting system for example, other values shall be considered (see Annexes B and C).