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Railway applications - Wheelsets and bogies - Part 1: Design guide 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 guide 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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Foreword

This document (prEN 13103-1:2015) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This document is currently submitted for CEN comment.

This document is intended to replace EN 13103:2009+ A2:2012 and EN 13104:2009+A2:2012.

This document has been prepared under a mandate given to CEN/CENELEC/ETSI 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.

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) and consequently converted into a UIC leaflet.

The method 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;

— correlation 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 Scope

This European standard:

— defines the forces and moments to be taken into account with reference to masses 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 grade EA1N defined in EN 13261;

— 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;

— all gauges[3].

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

— to solid or hollow powered axles for railway vehicles;

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

— to 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 that does not appear in the previous 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 edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13260, Railway applications — Wheelsets and bogies — Wheelsets — Product requirements

EN 13261, Railway applications — Wheelsets and bogies — Axles — Product requirements

EN 15313, Railway applications – In-service wheelset operation requirements – In-service and off-vehicle wheelset maintenance

EN 15663, Railway applications- Definition of the 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 shall be 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 such 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.

4 Symbols and abbreviations

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

Table 1 — Symbols and abbreviations

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 (brake disc, etc.)
$m_1 + m_2$	kg	For the wheelset considered, proportion of the mass of the vehicle on the rails
g	m/s^2	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 the 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
MX , MZ	Nmm	Sum of bending moments
MY	Nmm	Sum of torsional moments
MR	Nmm	Resultant moment
$2b$	mm	Distance between vertical force input points on axle journals
$2s$	mm	Distance between wheel rolling circles

Table 1 (*continued*)

Symbol	Unit	Description
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 F_i
y	mm	Abscissa for any section of the axle calculated from the section subject to force P_1
Γ		Average friction coefficient between the wheel and the brake shoe or between the brake pads and the disc
σ	N/mm^2	Stress calculated in one section
K		Fatigue stress correction factor
R	mm	Nominal wheel radius (Nominal wheel diameter / 2)
R_b	mm	Brake radius
d	mm	Diameter for one section of the axle
d'	mm	Bore diameter of a hollow axle
D	mm	Diameter used for determining K
r	mm	Radius of transition fillet or groove used to determine K
S		Security coefficient
G		Centre of gravity
R_{fL}	N/mm^2	Fatigue limit under rotating bending up to 10^7 cycles for smooth test pieces
R_{fE}	N/mm^2	Fatigue limit under rotating bending up to 10^7 cycles for notched test pieces
a_q	m/s^2	Unbalanced transverse acceleration
f_q		Thrust factor

5 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.

— 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.

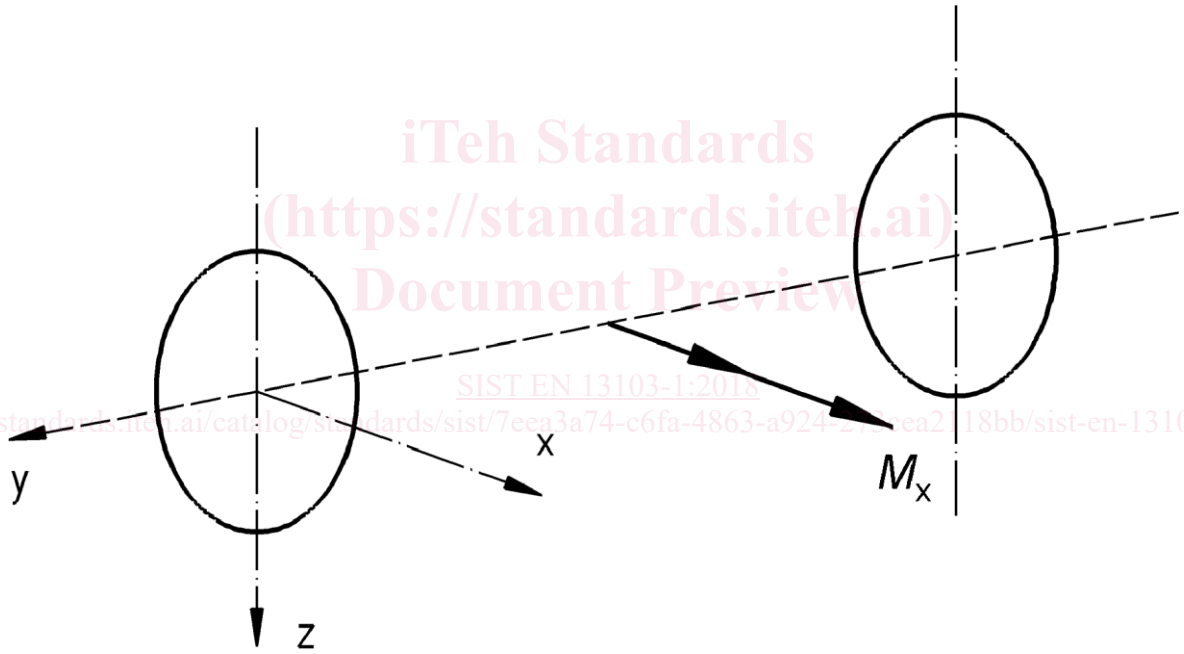

Figure 1 — Definition of centrelines

Unless otherwise defined in the technical specification, the masses $(m_1 + m_2)$ to be taken into account for the main types of rolling stock are defined in Table 2. For particular applications, e.g. suburban vehicles, other definitions for masses are necessary, in accordance with the specific operating requirements.

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