

Railway applications — Wheelsets and bogies — Non-powered axles — Design method

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British Standard

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee RAE/3, Railway rolling stock material, which has the responsibility to:

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- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
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**Railway applications — Wheelsets and bogies —
Non-powered axles — Design method**

Applications ferroviaires — Essieux montés et bogies —
Essieux-axes porteurs — Méthode de conception

Bahnanwendungen — Radsätze und Drehgestelle —
Laufbandsatzwellen — Konstruktionsverfahren

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 256, Railway applications, the Secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2001, and conflicting national standards shall be withdrawn at the latest by October 2001.

This European Standard 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 Directives.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland 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 party under the aegis of UIC¹⁾ started to harmonize these methods at the beginning of the 1970s. This led to an ORE²⁾ 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 bibliography lists the relevant documents used for reference purposes. The method described therein is largely based on conventional loadings and applies the beam theory for the stress calculation. The shape and stress recommendations are derived from laboratory tests and the outcome is validated by many years of operations on the various railway systems.

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

1 Scope

This 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 prEN 13261:1998;
- describes how to obtain the maximum permissible stresses for other steel grades;
- determines the diameters for the various sections of the axle. The preferred shapes and transitions are identified to ensure adequate service performance.

This standard is applicable to:

- solid and hollow axles of railway rolling stock used for the carriage of passengers and freight;
- axles defined in prEN 13261:1998;
- all gauges³⁾.

This standard is applicable to non-powered axles fitted to rolling stock intended to run under normal European conditions. Before the use of this 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 standard only for the load cases of free running and running in train formation. This standard does not apply for workload cases; they are calculated separately.

For light rail and tramway applications other standards or documents, agreed between the customer and supplier, may be applied.

Non-powered axles of motor bogies and locomotives are analysed according to the requirements of EN 13104.

¹⁾ UIC: Union Internationale des Chemins de fer.

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

³⁾ If the gauge is not standard, some formulae need to be adapted.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

prEN 13260:1998 *Railway applications — Wheelsets and bogies — Wheelsets — Product requirements.*

prEN 13261:1998 *Railway applications — Wheelsets and bogies — Axles — Product requirements.*

3 Symbols and abbreviated terms

For the purposes of this European Standard, the symbols and abbreviated terms of Table 1 apply.

Table 1

Symbol	Unit	Description
m_1	kg	Mass on journals per wheelset (bearings and axle boxes masses are included)
m_2	kg	Wheelset mass and masses on the wheelset between rolling planes (brake disc, etc.)
$m_1 + m_2$	kg	For the wheelset considered, mass applied on the rails
g	m/s ²	Acceleration due to gravity
P	N	Half the vertical force per wheelset applied 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 loaded journal
P'	N	Part 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 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 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

Table 1 (continued)

Symbol	Unit	Description
M_x	N·mm	Bending moment due to the masses in motion
M'_x, M'_z	N·mm	Bending moments due to braking
M'_y	N·mm	Torsional moment due to braking
MX, MZ	N·mm	Sum of bending moments
MY	N·mm	Sum of torsional moments
MR	N·mm	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 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 on one section
K		Fatigue stress concentration factor
R	mm	Nominal radius of the rolling circle of a wheel
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 specimens
R_{fE}	N/mm ²	Fatigue limit under rotating bending up to 10^7 cycles for notched specimens
a_q	m/s ²	Unbalanced transverse acceleration
f_q		Thrust factor

4 General

The major phases for the design of an axle are the following:

- identification of the forces to be taken into account and calculation of the moments on the various sections of the axle;
- selection of the diameters for axle-body and journals - on the basis of such diameters, calculation of the diameters for the other sections;
- the options taken are verified in the following manner:
 - stress calculation for each section;
 - comparison of such stresses with the maximum permissible stresses.

The maximum permissible stresses are mainly defined by:

- the steel grade;
- whether the axle is solid or hollow.

An example data sheet is given in annex A (informative).

5 Forces and moments to be taken into consideration

5.1 Types of forces

Two types of forces are to be addressed:

- masses in motion;
- braking.

5.2 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.

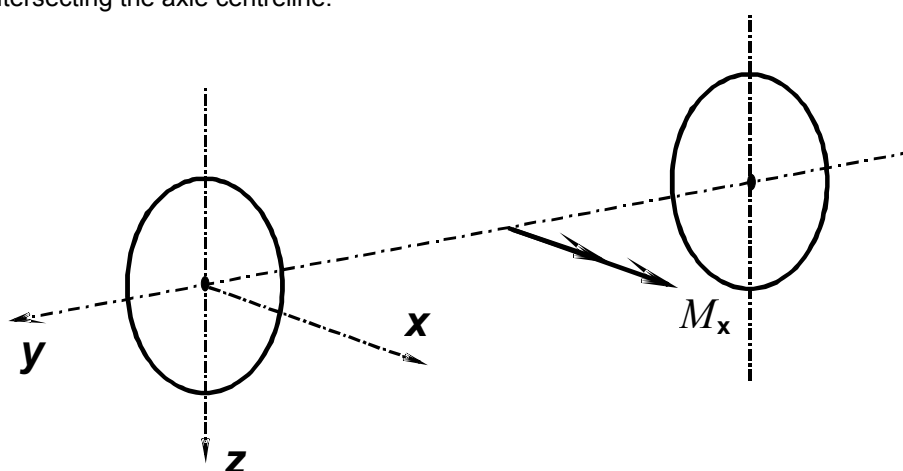


Figure 1

Unless otherwise defined by the customer, the masses ($m_1 + m_2$) to be taken into account for the main railway applications 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.