SLOVENSKI STANDARD
SIST EN 13104:2009

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Železniške naprave - Kolesne dvojice in podstavni vozički - Pogonske osi - Konstrukcijska metoda

Railway applications - Wheelsets and bogies - Powered axles - Design method

Bahnanwendungen - Radsätze und Drehgestelle - Treibradsatzwellen - Konstruktionsverfahren

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Railway applications - Wheelsets and bogies - Powered axles - Design method

Applications ferroviaires - Essieux montés et bogies - Essieux-axes moteurs - Méthode de conception

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Foreword

This document (EN 13104:2009) 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of an identical text or by endorsement, at the latest by September 2009, and conflicting national standards shall be withdrawn at the latest by September 2009

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and/or CENELEC shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13104:2001.

This European Standard 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 Directives 96/48/EC and 2001/16/EC amended by Directive 2004/50/EC.

For relationship with EU Directive(s), see informative Annexes ZA and ZB, which are integral parts of this document.

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

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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).

This method was successfully extrapolated in France for the design of powered axles and the French standard also applies to such axles. Consequently this method was 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 based largely on this method which has been improved and its scope enlarged.

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

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

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1 Scope

This standard:

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

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

3) specifies the maximum permissible stresses to be assumed in calculations for steel grade EA1N defined in EN 13261;

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

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

This standard is applicable to:

6) solid and hollow powered axles for railway rolling stock;

7) solid and hollow non-powered axles of motor bogies;

8) solid and hollow non-powered axles of locomotives[3];

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9) axles defined in EN 13261;

10) all gauges[4].

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This standard is applicable to axles fitted to rolling stock intended to run under normal European conditions. Before using this standard, if there is 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 to 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.

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 13260:2009, *Railway applications – Wheelsets and bogies – Wheelsets – Product requirements*

EN 13261:2009, *Railway applications – Wheelsets and bogies – Axles – Product requirements*

[3] In France, the interpretation of the term "locomotive" includes locomotives, locomoteurs or locotracteurs.

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

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3 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 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/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 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), gearwheel, 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	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
M''_x , M''_z	N·mm	Bending moments due to traction
M''_y	N·mm	Torsional moment due to traction
MX , MZ	N·mm	Sum of bending moments
MY	N·mm	Sum of torsional moments
MR	N·mm	Resultant moment

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Table 1 (*continued*)

Symbol	Unit	Description
$2b$	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 in 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 unnotched 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

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4 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:

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— the steel grade;

— whether the axle is solid or hollow;

— the type of transmission of motor power.

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

5 Forces and moments to be taken into consideration

5.1 Types of forces

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

— of the masses in motion;

— of the braking system;

— of the traction.

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.

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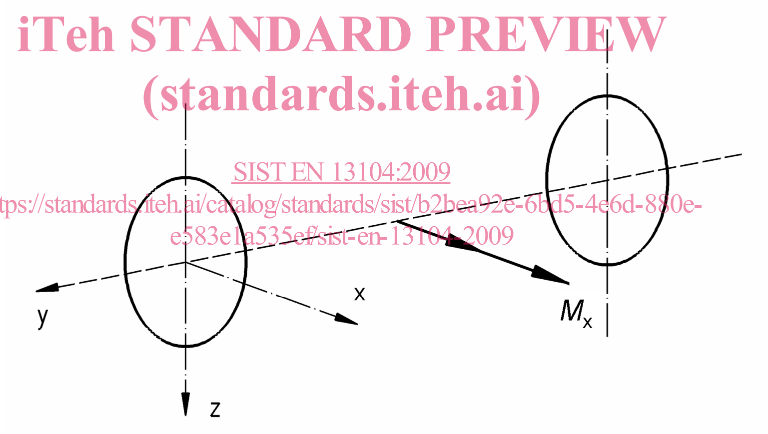

Figure 1

Unless otherwise defined by the customer, 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.

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Table 2

Type of rolling stock units	Mass $(m_1 + m_2)$
Traction units with no passenger accommodation, luggage areas and postal vans	For the axle considered, proportion of the wagon mass under maximum permissible loading in service
Traction units including passenger accommodation, luggage areas and postal vans 1 – Main line vehicles[a]	Mass in service + 1,2 × payload, "mass in service" is defined as: the vehicle mass without passengers, tanks full (of water, sand, fuel, etc.); "payload" is defined as the mass of a passenger estimated at 80 kg, including hand luggage; — 1 passenger per seat; — 2 passengers per m² in corridors and vestibules; — 2 passengers per attendant compartment; — 300 kg per m^2 in luggage compartments.
2 – Suburban vehicles[a, b]	Mass in service + 1,2 × payload, "mass in service" is defined as the vehicle mass without passengers, tanks full (of water, sand, fuel, etc.); "payload" is defined as the mass of a passenger, which is estimated at 70 kg (little or no luggage); — 1 passenger per seat; — 3 passengers per m² in corridor areas; — 4 or 5 passengers per m² in vestibule areas [b]; — 300 kg per m^2 in luggage compartments.

[a] The payloads to be taken into account to determine the mass of the mainline and suburban vehicles broadly reflect the normal operating conditions of the member railways of the International Union of Railways (UIC). If the operating conditions differ significantly, these masses may be modified, for example, by increasing or decreasing the number of passengers per m² in corridors and vestibules.

[b] These vehicles are sometimes associated with classes of passenger travel, i.e. 1st or 2nd class.

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The bending moment M_x in any section is calculated from forces P_1, P_2, Q_1, Q_2, Y_1, Y_2 and F_i as shown in Figure 2. It represents the most adverse condition 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.

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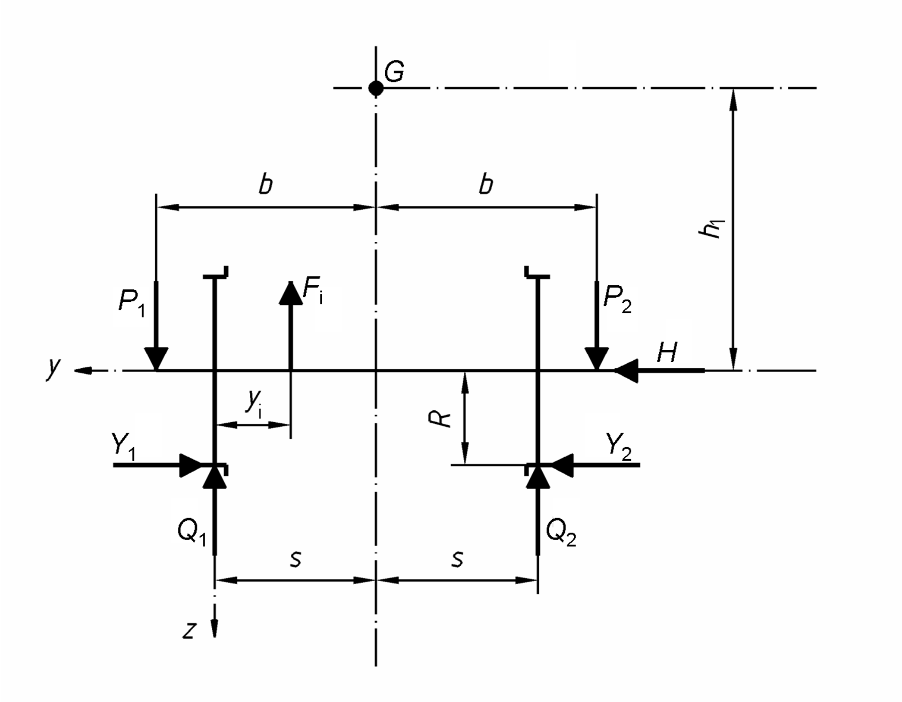

Key

G – centre of gravity of vehicle

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Figure 2

Table 3 shows the values of the forces calculated from m_1.

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

Table 3

For all wheelsets defined in the scope of this standard	$P_1 = (0{,}625 + 0{,}0875 h_1 / b) m_1 g$ $P_2 = (0{,}625 - 0{,}0875 h_1 / b) m_1 g$ $Y_1 = 0{,}35 m_1 g$ $Y_2 = 0{,}175 m_1 g$ $H = Y_1 - Y_2 = 0{,}175 m_1 g$
For all wheelsets $Q_1 = \frac{1}{2s}[P_1(b+s) - P_2(b-s) + (Y_1 - Y_2)R - \sum_i F_i(2s - y_i)]$ $Q_2 = \frac{1}{2s}[P_2(b+s) - P_1(b-s) - (Y_1 - Y_2)R - \sum_i F_i y_i]$	