SLOVENSKI STANDARD
SIST EN 17149-2:2024

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Železniške naprave - Ocenjevanje odpornosti konstrukcije železniških vozil - 2. del: Ocena statične odpornosti

Railway applications - Strength assessment of rail vehicle structures - Part 2: Static strength assessment

Bahnanwendungen - Festigkeitsnachweis von Schienenfahrzeugstrukturen - Teil 2: Statischer Festigkeitsnachweis

Applications ferroviaires - Évaluation de la résistance des structures de véhicule ferroviaire - Partie 2 : Évaluation de la résistance statique

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European foreword

This document (EN 17149-2:2024) 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of an identical text or by endorsement, at the latest by October 2024, and conflicting national standards shall be withdrawn at the latest by October 2024.

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 is part of the series EN 17149 *Railway applications — Strength assessment of rail vehicle structures*, which consists of the following parts:

— *Part 1: General*

— *Part 2: Static strength assessment*

The following part is under preparation:

— *Part 3: Fatigue strength assessment based on cumulative damage*

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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Introduction

This document provides procedures and criteria for the static strength assessment based on linear analysis or nonlinear elastic plastic analysis.

It does not define load cases and does not define in which cases, for which structural components or for which kinds of rail vehicles a static strength assessment is to be undertaken.

1 Scope

This document specifies a procedure for static strength assessment of rail vehicle structures.

It is part of a series of standards that specifies procedures for strength assessments of structures of rail vehicles that are manufactured, operated and maintained according to standards valid for railway applications.

The assessment procedure of the series is restricted to ferrous materials and aluminium.

This document series does not define design load cases.

This document series is not applicable for corrosive conditions or elevated temperature operation in the creep range.

This series of standards is applicable to all kinds of rail vehicles. However, it does not define in which cases or for which kinds of rail vehicles a static strength assessment is to be undertaken.

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 12663-1:2010+A2:2023, *Railway applications — Structural requirements of railway vehicle bodies — Part 1: Locomotives and passenger rolling stock (and alternative method for freight wagons)*

EN 12663-2:2010+A1:2023, *Railway applications — Structural requirements of railway vehicle bodies — Part 2: Freight wagons*

EN 13749:2021, *Railway applications — Wheelsets and bogies — Method of specifying the structural requirements of bogie frames*

EN 15227:2020, *Railway applications — Crashworthiness requirements for rail vehicles*

EN 15827:2011, *Railway applications — Requirements for bogies and running gears*

EN 17149-1:2024, *Railway applications — Strength assessment of rail vehicle structures — Part 1: General*

EN 17343:2023, *Railway applications — General terms and definitions*

ISO/TR 25901-1:2016, *Welding and allied processes — Vocabulary — Part 1: General terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions, symbols and abbreviations given in ISO/TR 25901-1:2016, EN 17343:2023 and EN 17149-1:2024 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Stress and strain determination

4.1 General

The assessment procedure is based on stresses or strains. These can be derived from calculation or from measurement during testing.

Stresses and strains may be determined with linear elastic material behaviour or nonlinear material behaviour.

For the determination of stresses or strains for the static strength assessment of welded joints, the effects of the weld throat eccentricity e_W may be discounted.

4.2 Calculation of equivalent stress with linear elastic material behaviour

4.2.1 General

For the calculation of equivalent stress, the plane stress tensor on the surface of the component should be used as characteristic stress value for the static strength assessment. The stress components of the plane stress tensor are σ_x , σ_y , τ_{xy} with associated principal normal stresses σ_1 , σ_2.

The equivalent stress shall be determined in dependence of the ductility of the material.

NOTE Ductile material and brittle material are defined in EN 17149-1:2024.

The equivalent stress for ductile materials shall be based on the Von Mises hypothesis (see Formula (3)).

The equivalent stress for brittle materials shall be determined in accordance with the normal stress hypothesis (see Formula (4) and Formula (5)).

In case of a material with different tensile proof strength and compressive proof strength (e.g. cast material) 4.2.2 and 4.2.3 may be applied.

The compressive strength factor f_C is the ratio of the compressive proof strength over the tensile proof strength. This factor accounts for the enhanced strength of cast materials in the case of a compressive strength condition. The value of f_C shall be determined by material properties specified in standards or other validated data. In cases where those material properties are not available, the values given in Table 1 may be applied.

Table 1 — Parameter f_C

Material group	Non-cast materials	GS	GJS, ADI	GJL	GJM	Cast aluminium
f_C	1,0	1,0	1,3	2,5	1,5	1,5

As a simplified approach, the compressive strength factor for cast material f_C may be generally set to 1,0.

4.2.2 Equivalent stress for ductile materials

The equivalent stress σ_{eq} for ductile material may be determined according to the Drucker-Prager hypothesis in accordance with Formula (1).

$$\sigma_{eq} = \left[3\frac{f_C - 1}{2 f_C} \sigma_H + \frac{f_C + 1}{2 f_C} \sigma_{vM} \right] \quad (1)$$

NOTE 1 For $f_C = 1,0$ Formula (1) results in $\sigma_{eq} = \sigma_{vM}$.

σ_H is the hydrostatic stress. For the plane stress state σ_H is calculated in accordance with Formula (2).

$$\sigma_H = \frac{\sigma_1 + \sigma_2}{3} \quad (2)$$

σ_{vM} is the equivalent stress according to the Von Mises hypothesis. For the plane stress state σ_{vM} is calculated in accordance with Formula (3).

$$\sigma_{vM} = \sqrt{\sigma_1^2 - \sigma_1 \cdot \sigma_2 + \sigma_2^2} \quad (3)$$

NOTE 2 Formula (1) is also valid for the general three-dimensional stress state by taking the formulae for σ_H and σ_{vM} from the technical literature.

For a material where the compressive proof strength is lower than the tensile proof strength (e.g. in case of stainless steel in hardened condition), the above method may be applied with an appropriate factor for f_C but is limited to a plane stress state.

4.2.3 Equivalent stress for brittle materials

The equivalent stress σ_{eq} for brittle materials is determined according to the normal stress hypothesis in accordance with Formula (4) and Formula (5).

$$\sigma_{eq} = \max\left(\left|\sigma_{c1}\right|, \left|\sigma_{c2}\right|, \left|\sigma_{c3}\right|\right) \quad (4)$$

with the principal normal stress adjusted by the compressive strength factor

$$\sigma_{c1,c2,c3} = \begin{cases} \dfrac{\sigma_{1,2,3}}{f_C} & for\, \sigma_{1,2,3} < 0 \\ \sigma_{1,2,3} & for\, \sigma_{1,2,3} \geq 0 \end{cases} \quad (5)$$

NOTE For $f_C = 1,0$ Formula (4) results in $\sigma_{eq} = \max\left(\left|\sigma_1\right|, \left|\sigma_2\right|, \left|\sigma_3\right|\right)$.

4.3 Calculation with nonlinear material behaviour

4.3.1 Material models

The real material behaviour (Figure 1) may be approximated by bi-linear (Figure 2), tri-linear (Figure 3), multilinear or continuous material models. Hardening effects for strains exceeding the proof strength may be applied but also the application of an elastic ideal-plastic material law is allowed. Also, different tensile proof strength and compressive proof strength may be accounted for by an appropriate stress-strain curve.

Depending on the material model, the limit for the elastic behaviour represented by the proof strength R_p can be either the upper yield strength R_{eH} or the 0,2 % proof strength $R_{p0,2}$ as defined in EN ISO 6892-1.

NOTE [1] and [2] give hints about the definition of the material law for the nonlinear stress strain calculation.