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

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Bahnanwendungen - Festigkeitsnachweis von Schienenfahrzeugstrukturen - Teil 2: Statischer Festigkeitsnachweis

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 17149-2:2022) has been prepared by Technical Committee CEN/TC 256 "'Railway applications", the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

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

— Part 1: General

— Part 2: Static strength assessment

— Part 3: Fatigue strength assessment based on cumulative damage

Introduction

This document provides procedures and criteria for the static strength assessment of exceptional load cases and ultimate load cases 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 applied.

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.

This document is applicable for exceptional load cases and ultimate load cases.

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 applied.

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+A1:2014, *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, *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*

prEN 17149-1:2021, *Railway applications — Strength assessment of railway vehicle structures — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions, symbols and abbreviations given in prEN 17149-1:2021 apply.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

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. Unless otherwise stated, the stress or the strain is determined for each individual load case separately without a corresponding load case.

Stresses and strains may be determined with linear elastic material behaviour or nonlinear material behaviour. Annex C gives guidance for the determination of plastic strains and stresses from an FEA. For welded joints, the eccentricity between the midpoint of the weld throat and the connected plate e_W needs not to be considered. This is also applicable for stress determination from strain measurements.

4.2 Calculation of equivalent stress with linear elastic material behaviour

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} .

The equivalent stress for ductile material is determined according to von-Mises-Formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 - \sigma_x \cdot \sigma_y + \sigma_y^2 + 3 \cdot \tau_{xy}^2} \qquad (1)$$

The equivalent stress for brittle material is determined according to Rankine:

$$\sigma_{eq} = \frac{1}{2}\left[\left|\sigma_x + \sigma_y\right| + \sqrt{\left(\sigma_x - \sigma_y\right)^2 + 4 \cdot \tau_{xy}^2}\right] \qquad (2)$$

For a more general approach, the derivation of the equivalent stress for the triaxial stress state may be taken from the technical literature.

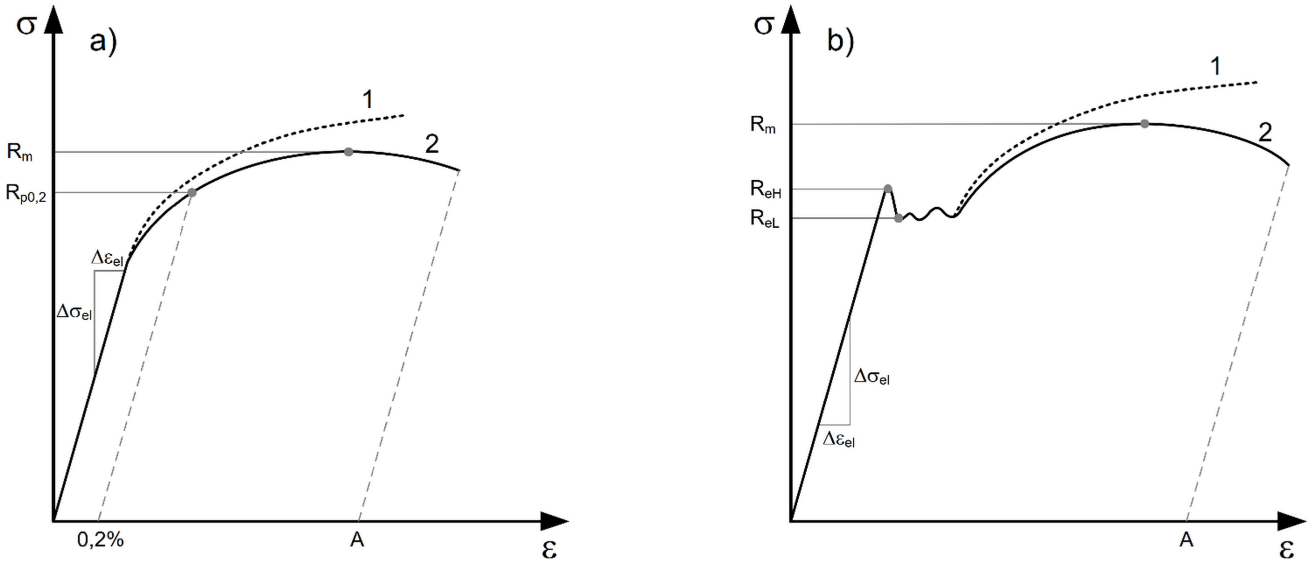
4.3 Calculation with nonlinear material behaviour

4.3.1 Material models

The real material behaviour (Figure 1) may be approximated by bi-linear (Figure 2), three-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.

Depending on the material model, the limit for the elastic behaviour represented by the proof strength R_p can be either the 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.

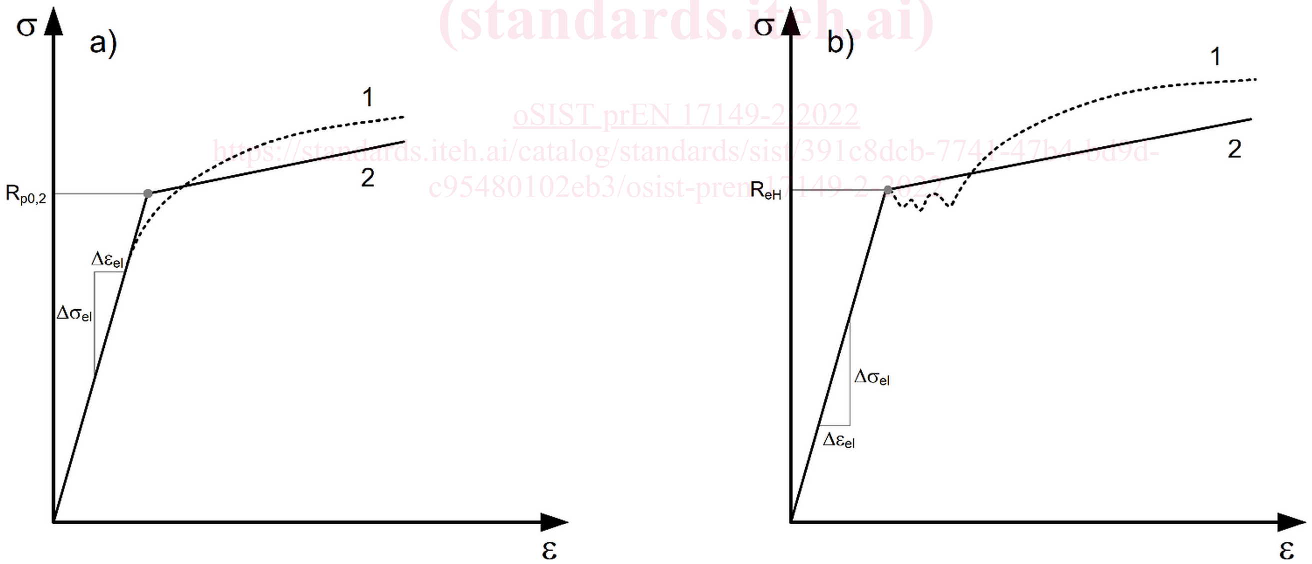


Key

1 True stress strain behaviour

2 Engineering stress strain behaviour

Figure 1 — Real material behaviour a) without distinctive yield stress b) with distinctive yield stress

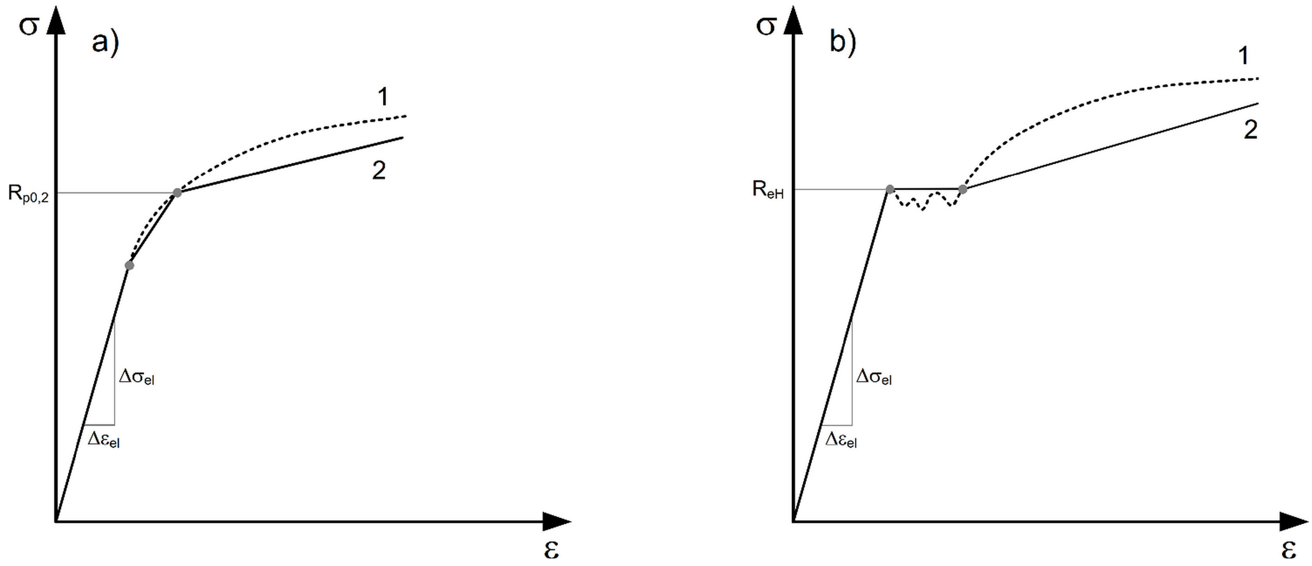


Key

1 True stress strain behaviour

2 Bi-linear approximation

Figure 2 — Bi-linear material model a) without distinctive yield stress b) with distinctive yield stress



Key

1 True stress strain behaviour

2 Three-linear approximation

Figure 3 — Three-linear material model a) without distinctive yield stress b) with distinctive yield stress

4.3.2 Equivalent stress

The calculation of equivalent stress with nonlinear material behaviour follows the procedure for linear elastic material behaviour given in 4.2.

4.3.3 Equivalent plastic strain

The equivalent plastic strain is generally calculated according to Von-Mises-Hypothesis and may be determined following the technical literature or by applying Formula (3).

$$\varepsilon_{\mathrm{p,eq}} = \sqrt{\frac{2}{3}\left(\varepsilon_{\mathrm{p,x}}{}^{2} + \varepsilon_{\mathrm{p,y}}{}^{2} + \varepsilon_{\mathrm{p,z}}{}^{2}\right) + \frac{4}{3}\left(\varepsilon_{\mathrm{p,xy}}{}^{2} + \varepsilon_{\mathrm{p,yz}}{}^{2} + \varepsilon_{\mathrm{p,xz}}{}^{2}\right)} \quad (3)$$

4.4 Determination of stresses and strains by test

In real components, residual strains due to manufacturing or preloading can occur. Measured strains during tests incorporate influences of such residual strains. The strength assessment procedure given in Clause 7 is applicable for stresses and strains derived from such measurements and sufficiently covers effects of such residual strains.

Dependent on the kind of assessment procedure (see Clause 7), the stresses shall be determined from measured strains with linear elastic material behaviour or nonlinear material models as given in 4.3.1.