SLOVENSKI STANDARD
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Žerjavi - Konstrukcija, splošno - 3-3. del: Mejna stanja in dokaz varnosti stika kolo-tirnica

Cranes - General design - Part 3-3: Limit states and proof of competence of wheel/rail contacts

Krane - Konstruktion allgemein - Teil 3-3: Grenzzustände und Sicherheitsnachweis von Laufrad/Schiene-Kontakten

Appareils de levage à charge suspendue - Conception générale - Partie 3-3 : Etats limites et vérification d'aptitude des contacts galet/rail

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EUROPEAN STANDARD

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English Version

Cranes - General design - Part 3-3: Limit states and proof of competence of wheel/rail contacts

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 13001-3-3:2014) has been prepared by Technical Committee CEN/TC 147 “Cranes — Safety”, the secretariat of which is held by BSI.

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of an identical text or by endorsement, at the latest by April 2015, and conflicting national standards shall be withdrawn at the latest by April 2015.

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 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 Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This European Standard is one part of EN 13001, *Cranes — General design*. The other parts are as follows:

— *Part 1: General principles and requirements*

— *Part 2: Load actions*

— *Part 3-1: Limit states and proof of competence of steel structure*

— *Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*

— *Part 3-4: Limit states and proof of competence of machinery*

— *Part 3-5: Limit states and proof of competence of forged hooks*

For the relationship with other European Standards for cranes, see Annex D.

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, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European Standard has been prepared to provide a means for the mechanical design and theoretical verification of cranes to conform with the essential health and safety requirements. This European Standard also establishes interfaces between the user (purchaser) and the designer, as well as between the designer and the component manufacturer, in order to form a basis for selecting cranes and components.

This European Standard is a type C standard as stated in EN ISO 12100.

The machinery concerned and the extent to which hazards are covered are indicated in the Scope of this European Standard.

When provisions of this type C standard are different from those which are stated in type A or B standards, the provisions of this type C standard take precedence over the provisions of the other standards, for machines that have been designed and built according to the provisions of this type C standard.

1 Scope

This European Standard is to be used together with EN 13001-1 and EN 13001-2 and as such they specify general conditions, requirements and methods to prevent mechanical hazards of wheel/rail contacts of cranes by design and theoretical verification. This European Standard covers requirements for steel and cast iron wheels and is applicable for metallic wheel/rail contacts only.

Roller bearings are not in the scope of this European Standard.

Exceeding the limits of strength is a significant hazardous situation and hazardous event that could result in risks to persons during normal use and foreseeable misuse. Clause 5 to Clause 6 of this European Standard are necessary to reduce or eliminate the risks associated with this hazard.

This European Standard is applicable to cranes, which are manufactured after the date of approval of this European Standard by CEN, and serves as a reference base for product standards of particular crane types.

This European Standard is for design purposes only and should not be seen as a guarantee of actual performance.

EN 13001-3-3 deals only with limit state method in accordance with EN 13001-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced 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 13001-1, *Cranes - General design - Part 1: General principles and requirements*

EN 13001-2, *Crane safety - General design - Part 2: Load actions*

EN ISO 6506-1, *Metallic materials - Brinell hardness test - Part 1: Test method (ISO 6506-1)*

EN ISO 12100, *Safety of machinery - General principles for design - Risk assessment and risk reduction (ISO 12100)*

ISO 4306-1, *Cranes — Vocabulary — Part 1: General*

ISO 12488-1:2012, *Cranes — Tolerances for wheels and travel and traversing tracks — Part 1: General*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100, ISO 4306-1 and the following apply.

3.1.1
wheel
rolling component in a rolling contact enabling relative movement between two crane parts

EXAMPLE Crane travel wheels, trolley traverse wheels, guide rollers and wheels/rollers supporting slewing structures.

Note 1 to entry: Roller elements in rolling bearings are not considered as wheels.

3.1.2
unit-conform hardness
Brinell hardness HBW of the material given with the unit of the modulus of elasticity

EXAMPLE A Brinell hardness HBW of 300 results in a unit-conform hardness HB = 300 N/mm^2.

Note 1 to entry: Annex B provides a table of hardness conversion for different methods of hardness measurements.

3.2 Symbols and abbreviations

For the purposes of this document, the symbols and abbreviations given in Table 1 apply.

Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
b	Effective load-bearing width
D_{w}	Wheel diameter
E_{m}	Equivalent modulus of elasticity
E_{r}	Modulus of elasticity of the rail material
E_{w}	Modulus of elasticity of the wheel material
F	Wheel load
$F_{\mathrm{Rd,s}}$	Limit design contact force
$F_{\mathrm{Sd,s}}$	Design contact force
$F_{\mathrm{Rd,f}}$	Limit design contact force for fatigue
$F_{\mathrm{Sd,f}}$	Maximum design contact force for fatigue
$F_{\mathrm{Sd,f,i}}$	Design contact force for fatigue in contact (i)
$F_{\mathrm{Sd0,s}}$	Non-factored design contact force (calculated with partial safety factors set to 1)
F_{u}	Reference contact force
f_{f}	Factors of further influences in fatigue
f_{f1}	Decreasing factor for edge pressure in fatigue
f_{f2}	Decreasing factor for non-uniform pressure distribution in fatigue
f_{f3}	Decreasing factor for skewing in fatigue
f_{f4}	Decreasing factor for driven wheels in fatigue
f_1	Decreasing factor for edge pressure
f_2	Decreasing factor for non-uniform pressure distribution
f_{y}	Yield stress or 0,2 % proof stress of the material, prior to surface hardening when this process is applied. In the text of the standard only the term yield stress is used to denote either.
HBW	Brinell hardness
HB	Unit-conform hardness, [N/mm^2]
i	Index of a rolling contact

Symbols, abbreviations	Description
i_D	Number of rolling contacts at reference point
i_{tot}	Total number of rolling contacts during the design life of wheel or rail
m	Slope constant of log F/log N-curve for rolling contacts
k_c	Contact force spectrum factor
r_k	Radius of the crowned rail head or the second wheel radius
r_3	Radius of the wheel or rail edge
s_c	Contact force history parameter
S_c	Classes of contact force history parameter
w	Width of projecting, non-contact area
z_{ml}, z_{mp}	Depth of maximum shear stress for line and point contact case, respectively
α	Skew angle
α_g	Part of the skew angle α due to the slack of the guide
α_t	Part of the skew angle α due to tolerances
α_w	Part of the skew angle α due to wear
γ_{cf}	Contact resistance factor
γ_m	General resistance coefficient; γ_m = 1,1
γ_n	Risk coefficient
γ_p	Partial safety factors
ν	Radial strain coefficient (ν = 0,3 for steel)
ν_c	Relative total number of rolling contacts
ϕ_i	Dynamic factors (see EN 13001-2)

4 General

4.1 General principles

The proof of competence for static strength and fatigue strength shall be fulfilled for the selection of wheel and rail combination. In the proof of competence for static strength the material properties of the weaker party (wheel or rail) shall be applied, whereas the proof of competence for fatigue strength (rolling contact fatigue, RCF) shall be conducted separately to each party, applying its specific material property and number of rolling contacts.

The proof shall be applied to all arrangements in cranes, where a wheel/rail type of rolling contact occurs, e.g. crane travel wheels, trolley traverse wheels, guide rollers and wheels/rollers supporting slewing structures. The term wheel is used throughout the document for the rolling party in a contact.

NOTE For recommendations on dimensions of wheel flanges, refer to EN 13135, Annex B.

The proof of competence criteria in Clause 5 and Clause 6 are based upon Hertz pressure on the contact surface and the shear stress below the surface due to the wheel/rail contact.

Some formulae used for calculations within this document refer to a so called “unit-conform hardness” HB based on the Brinell hardness HBW given as a value without unit according to EN ISO 6506-1. The unit of HB shall match with the unit of the modulus of elasticity used in the calculation. Using SI-units, the unit-conform hardness is given by:

$$HB = HBW \cdot \frac{N}{\mathrm{mm}^2} \tag{1}$$

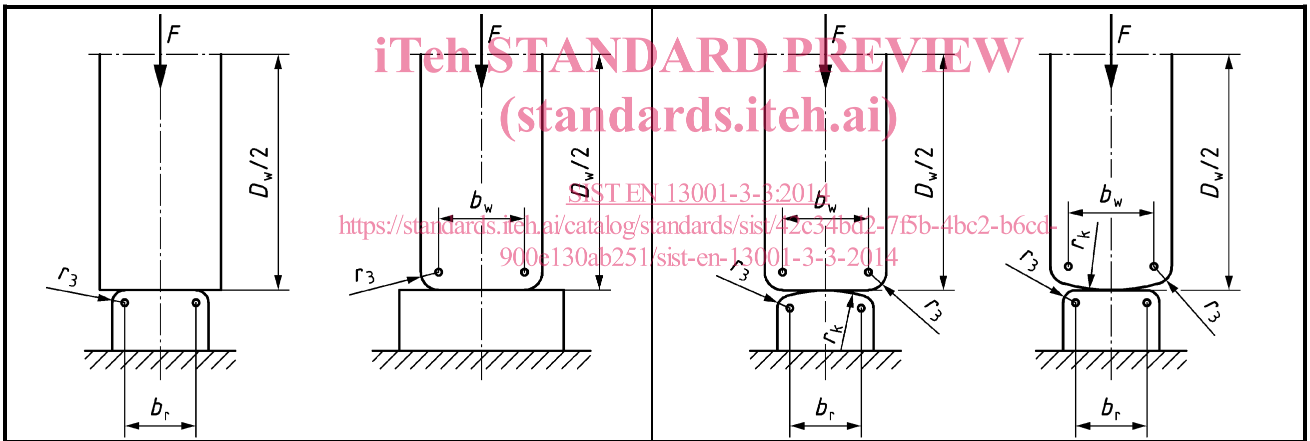
where

HB is the unit-conform hardness;

HBW is the value of the Brinell hardness.

4.2 Line and point contact cases

There are principally two different contact cases in typical designs of crane wheels and rails: a line contact and a point contact (see Figure 1). With the crown radius r_k relatively large in relation to width of the wheel and rail, as is the case for cranes, point contact even for new installations will be rapidly transformed into line contact. Figure 1 shows the conditions of the point contacts, which can be considered as line contacts, for the proof of both static and fatigue strength.



a) Line contact	**b) Point contact**
	Point contact cases, where $r_k \le 5 \times \min\left[b_r;\, b_w\right]$ are outside the scope of this standard. In cases, where $r_k > 200 \times \min\left[b_r;\, b_w\right]$, the requirements given for line contact shall be applied.

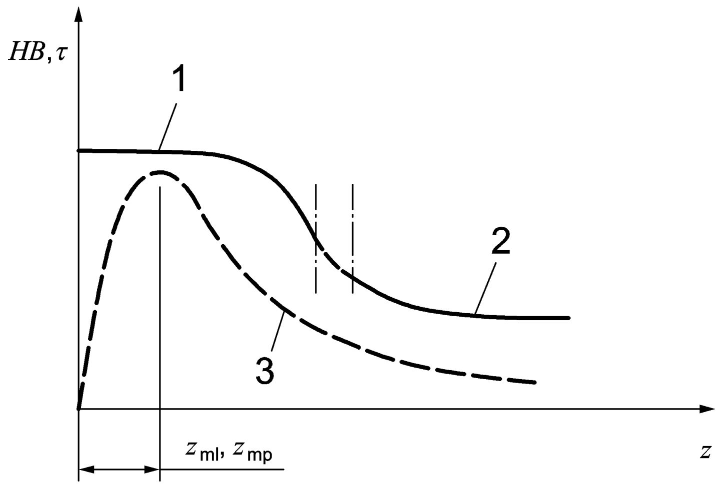
The effective contact widths (b_w, b_r) are determined by deducting from the material width of wheel/rail the effect of corner radius equal to $2 \times r_3$.

Figure 1 — Contact cases

4.3 Hardness profile below contact surface

It shall be ensured that the hardness achieved extends into the material deeper than the depth of maximum shear, preferably twice this depth. The hardness value can be obtained using the ultimate strength of the material and appropriate conversion tables. For commonly used materials, see Annex B.

Special care shall be taken with surface hardening and the depth zone, to ensure that the hardness profile does not drop below the shear profile (see Figure 2).



Key

z depth

z_{ml}, z_{mp} depths of maximum shear stress for line and point contact case respectively

HB unit-conform hardness

1 hardness, the surface hardened zone

2 hardness, the natural hardness of the material

3 shear stress τ due to contact force

Figure 2 — Hardness and shear stress versus depth

The depth of maximum shear for line contact cases shall be calculated as:

$$z_{ml} = 0{,}50 \times \sqrt{F_{Sd0,s} \times \frac{\pi \times D_w \times \left(1-\nu^2\right)}{b \times E_m}} \qquad (2)$$

and for point contact cases this shall be calculated as:

$$z_{mp} = 0{,}68 \times \sqrt[3]{\frac{F_{Sd0,s}}{E_m} \times \frac{1-\nu^2}{\left(\frac{2}{D_w}+\frac{1}{r_k}\right)}} \qquad (3)$$

where

$F_{Sd0,s}$ is the maximum, non-factored design contact force within the Load Combinations A to C in accordance with EN 13001-2;

E_m is the equivalent modulus of elasticity, see 4.4.