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Cranes - General design - Part 3-2: Limit states and proof of competence of steel wire ropes

Krane - Konstruktion allgemein - Teil 3-2: Grenzzustände und Sicherheitsnachweis von Stahldrahtseilen

Appareils de levage à charge suspendue - Conception générale - Partie 3-2 : Etats limites et vérification d'aptitude des câbles en acier

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Cranes - General design - Part 3-2: Limit states and proof of competence of steel wire ropes

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This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 147.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 13001-3-2:2026) has been prepared by Technical Committee CEN/TC 147 “Cranes – Safety”, the secretariat of which is held by SFS.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 13001-3-2:2014.

prEN 13001-3-2:2026 includes the following significant technical changes with respect to EN 13001-3-2:2014:

— restructuring of the document with a clear separation between provisions for running ropes and stationary ropes;

— fundamental revision of the fatigue verification concept, introducing a parameterised synthetic S-N-curve model with a defined reference point, variable slope of S-N-curves depending on D/d, and explicit consideration of probability of survival;

— introduction of a protection against low-cycle fatigue failure (Donandt-force limit), limiting the admissible fatigue design rope force;

— revision of the rope force history parameter and spectrum factor, including clarified rules for the determination of relevant bending cycles and critical rope sections;

— consolidation of rope force increasing factors (e.g. reeving efficiency, non-parallel falls, horizontal forces) into a dedicated annex;

— replacement of empirical reduction factors for multilayer drums by a separate proof of competence for multilayer spooling, differentiated by crane type, rope type and type of mechanism;

— update of normative references and Annex ZA to align with EN 13001-1:2015, EN 13001-2:2021 and Regulation (EU) 2023/1230 (Machinery Regulation).

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

For the relationship with EU Legislation, see informative Annex ZA, which is an integral part of this document.

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

Introduction

This document has been prepared to be a harmonized standard to provide one means for the mechanical design and theoretical verification of cranes to conform with the essential health and safety requirements of the Machinery Regulation, as mentioned in Annex ZA.

This document is a type-C standard as stated in EN ISO 12100:2010.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to safety of machinery:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organizations, market surveillance, etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate in the drafting process of this document.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

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

1 Scope

This document is to be used together with EN 13001-1 and EN 13001-2 and as such together they specify a proof of competence to prevent from mechanical hazards caused by failure of steel wire ropes in cranes by theoretical verification.

NOTE 1 Specific requirements for particular types of cranes are given in the appropriate European Standard for the particular crane type.

The following significant hazardous situations and hazardous events could result in risks to persons during intended use and reasonably foreseeable misuse:

— exceeding the limits of strength (yield, ultimate, fatigue).

Depending on the installation of the rope, application of Clause 5 (in case of running rope) or Clause 6 (in case of stationary rope) of this document is necessary to reduce or eliminate these risks.

This document does not apply to fibre ropes.

This document is not applicable to cranes which are manufactured before the date of its publication as EN and serves as reference for the European Standards for particular crane types.

NOTE 2 This document specifies requirements for a verification method in accordance with the limit state method according to EN 13001-1 only.

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 12385-1:2002+A1:2008, *Steel wire ropes — Safety — Part 1: General requirements*

EN 12385-2:2002+A1:2008, *Steel wire ropes — Safety — Part 2: Definitions, designation and classification*

EN 12385-4:2002+A1:2008, *Steel wire ropes — Safety — Part 4: Stranded ropes for general lifting applications*

EN 13001-1:2015, *Cranes — General design — Part 1: General principles and requirements*

EN 13001-2:2021, *Crane safety — General design — Part 2: Load actions*

EN 13411-3:2022, *Terminations for steel wire ropes — Safety — Part 3: Ferrules and ferrule-securing*

EN 13411-4:2021, *Terminations for steel wire ropes — Safety — Part 4: Metal and resin socketing*

EN 13411-6:2004+A1:2008, *Terminations for steel wire ropes — Safety — Part 6: Asymmetric wedge socket*

EN 13411-8:2011, *Terminations for steel wire ropes — Safety — Part 8: Swage Terminals and Swaging*

EN ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100:2010)*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100:2010, EN 12385-2:2002+A1:2008 and the following apply.

ISO and IEC maintain terminology 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/

3.1.1
running rope
rope which is wound on and off a drum and bent over sheaves and/or drums, therefore stressed mainly by bending and secondly by tension

3.1.2
stationary rope
rope fixed at both ends in the crane structure, primarily under tensile load, and which is not subject to winding on a drum or bending over a sheave

3.1.3
rotation-resistant rope (RR)
stranded rope designed to generate reduced levels of torque and rotation when loaded

Note 1 to entry: According to ISO 17893:2004+A1:2010 rotation resistant ropes are categorised into 3 groups regarding their rotational behaviour.

[SOURCE: EN 12385-2:2002+A1:2008, 3.6.1.3]

3.1.4
single-layer rope
stranded rope consisting of one layer of strands laid helically around a core

[SOURCE: EN 12385-2:2002+A1:2008, 3.6.1.2]

3.1.5
parallel-closed rope
stranded rope consisting of at least two layers of strands laid helically in one closing operation around a strand or fibre centre

[SOURCE: EN 12385-2:2002+A1:2008, 3.6.1.2]

3.1.6
standard rope (SR)
simplified type designation consisting of single-layer ropes and parallel closed ropes

3.1.7
design life
estimation of the intended period of use for a crane, or component based on its original design specification and taking into consideration the load spectrum expected during its intended use

Note 1 to entry: According to ISO 4301-1, a rope is considered to be a component in this document.

[SOURCE: ISO 12482:2014, 3.2, modified]

3.1.8
work cycle
operating sequence starting from hoisting a load, transferring the load, lowering and grounding the load, detaching the load and moving the unloaded load lifting attachment back to a starting position ready to hoist another load

[SOURCE: ISO 12482:2014, 3.6]

3.1.9
rope bending diameter
diameter of the axis of the rope in the state when bent over a sheave or a drum

3.2 Symbols and abbreviated terms

The main symbols used in this document are given in ISO 4301-1, EN 12385-2:2002+A1:2008, EN 13001-1, EN 13001-2 and Table 1.

Table 1 — Symbols

Symbols	Description
a	Acceleration or deceleration
C	Total number of work cycles during design life of a crane
C_r	Total number of work cycles during the design life of a rope
D	Rope bending diameter of drum or sheave
d	Nominal rope diameter
F	Rope tension force
F_h	Horizontal force acting on the hoist load
F_{min}	Minimum breaking force of the rope
$F_{Rd,f}$	Limit design rope force for the proof of fatigue strength
$F_{Rd,m}$	Limit design rope force for multilayer spooling
$F_{Rd,s}$	Limit design rope force for the proof of static strength
F_{ref}	Reference rope force value to describe the ordinate value of the reference point of the S-N-curve (Wöhler-curve) at the proof of fatigue strength
$F_{Sd,f}$	Design rope force for the proof of fatigue strength
$F_{Sd,m}$	Design rope force for multilayer spooling
$F_{Sd,s}$	Design rope force for the proof of static strength
f_F	Adjustment factor to the reference rope tension force F_{ref}

Symbols	Description
f_S	Rope force increasing factor
f_S^*	Adapted rope force increasing factor at the proof of fatigue strength
f_R	Reduction factor effecting the minimum breaking force of the rope
f_w	Adjustment factor to the reference number of bending cycles w_{ref}
g	Acceleration due to gravity
k_r	Rope force spectrum factor
l_r	Number of ropes assumed to be used during the design life of the crane
m	Exponent, slope of the S-N-curve (Wöhler-curve)
m_H	Mass of the hoist (gross) load
m_R	Mass of the portion of the suspended ropes of the hoist drive
N_{ref}	Number of tensile force cycles at reference point
N_t	Total number of tensile force cycles during the design life of a crane
n	Number of contact points passed by a part of the rope that initiates a change of curvature in the rope
n	Number of tensile force cycles
n_m	Mechanical advantage
n_s	Number of fixed sheaves between drum and moving part
$q(z)$	Normalized position density
R_r	Rope grade
r_g	Groove radius
S_r	Design load effect in particular rope
s_r	Rope force history parameter
w	Number of bending cycles
w_c	Bending count of a particular type of bending
w_{ref}	Reference number of bending cycles to describe the abscissa value of the S-N-curve (Wöhler-curve) for the proof of fatigue strength
w_{tot}	Total number of bending cycles during the design life of a rope in the rope section
z	Position coordinates
α	Deflection angle
β	Angle between falls and line of action of force
γ	Angle between direction of gravity and rope projected in plane of F_h and g
γ_m	General resistance factor
γ_n	Risk coefficient
γ_p	Partial safety factor

Symbols	Description
γ_{rb}	Resulting rope resistance factor
$\gamma_{rb,0}$	Basic rope resistance factor
γ_{ref}	Factor to adapt the minimum breaking force of the rope F_{min} to the reference rope tension force F_{ref} at the proof of fatigue strength
γ_{rf}	Rope resistance factor to be used at the proof of fatigue strength
γ_{rfD}	Rope resistance factor to prevent from exceeding the Donandt-force
γ_{s}	Specific resistance factor
δ	Fleet angle
ε	Angle between sheave planes
η_{s}	Efficiency of applied rope, sheave and bearing
η_{tot}	Total rope reeving efficiency of the rope drive
ν_{r}	Relative total number of cycles
ϕ	Dynamic factor for inertial and gravity effects
ϕ^*	Adapted dynamic factor for inertial effects at the proof of fatigue strength and multilayer spooling
ω	Groove opening angle
Index	**Description**
i, j, k	Run index
min, max	Index for indicating the minimum, maximum value of a variable

4 General

The steel wire rope shall meet the requirements specified in EN 12385-1:2002+A1:2008 and EN 12385-4:2002+A1:2008.

For the application of this document, the rope grade 2160 as specified in EN 12385-4:2002+A1:2008 shall not be exceeded.

For wire ropes made from wires with a nominal strength higher than rope grade 2160, the calculation method and parameters specified in this document shall only be applied where their applicability to the rope construction concerned has been verified. The verification shall demonstrate that the assumptions underlying the proof of competence remain valid.

NOTE 1 The selection of steel wire ropes can involve characteristics that are not part of the calculation method specified in this document, such as rope construction, material, lubrication, galvanising, etc. These characteristics can influence input values used in the proof of competence or can be subject to requirements specified in other documents, e.g. EN 12385-1, EN 12385-4 or crane-type-specific standards.

Rope terminations shall meet the requirements of one or several of the following standards: EN 13411-3:2022, EN 13411-4:2021, EN 13411-6:2004+A1:2008, EN 13411-8:2011.

Rope terminations shall be such that bending of the rope adjacent to the termination and other additional stresses on the rope are eliminated.

For non-rotation resistant ropes, the end termination shall be made in such a way that it is not possible for the rope to twist around the longitudinal axis. For rotation resistant ropes, a swivel may be integrated in the end termination to relieve any twist induced into the rope reeving system.

Running ropes are subject to considerable wear and tear and generally have a significantly shorter service life than the cranes in which they are used. The proof of competence described in this document only serves to demonstrate a sufficient level of safety to prevent spontaneous failure and short-term fatigue failure. Based on the assumptions of this proof of competence, requirements for the inspection and discarding of the wire rope shall be specified.

NOTE 2 The standard ISO 4309:2017 is no prerequisite for the application of this document, but a means of ensuring the safe operation of the crane or hoist. Rather, the assumed service life for the proof of fatigue strength is the input value for determining frequency (resp. time interval) of the periodic inspection of the rope in service.

NOTE 3 The standard ISO 4309:2017 describes the state of the art regarding the inspection of steel wire ropes and assessing their state of wear in service.

NOTE 4 The standard EN 13135:2026 provides general design requirements for wire ropes in rope drives in cranes.

5 Running ropes

5.1 General

Running ropes are used in rope drives in which specific effects can occur depending on the rope drive design. These effects can influence the rope forces acting in the rope and, consequently, the proofs of competence specified in this document. The effects relevant to the respective proof of competence are addressed in the corresponding clauses of this document.

If several independent rope drives act on the load or a structural component, the force in the respective rope drive shall be determined according to the rules of mechanics.

NOTE 1 Running ropes in cranes are stressed by tensile loads and by bending over sheaves and/or on drum. These cyclic load effects constitute a cumulative fatigue effect to the rope. In this document this effect is expressed by the rope force history parameter s_r, which is independent of time.

NOTE 2 The method of fatigue strength verification using the rope force history parameter s_r described in this document does not preclude the application of a damage accumulation calculation, e.g. Miner-Original.

NOTE 3 Unlike previous design standards for ropes, this document does not link the diameter of rope sheaves and drums to the component class (previously mechanism class) in order to allow greater flexibility in the design of rope drives. However, this does not change the fact that it is advisable to select larger sheave and drum diameters for rope drives that are used more intensively.

For the proof of fatigue strength, a suitable number of work cycles C_r shall be assumed, which are to be carried out safely with the rope. This number is usually derived from the number of work cycles of the crane C and the number of ropes l_r that are assumed to be used during the service life of the crane or hoist. When determining the number of work cycles of the rope C_r, the operating conditions and the intervals of crane inspections shall be taken into account.

NOTE 4 It is important to note that although the number of bending cycles w_{tot} is (approximately) proportional to the number of work cycles C_r, it depends significantly on the design of the rope drive, e.g. on the number and position of the rope sheaves and the range of displacements (movements). The correlation can be determined by recording data from comparable types of cranes or by simulation calculations, see B.1.

The following proofs shall be provided for running ropes:

— proof of static strength, see 5.2;

— proof of fatigue strength, see 5.3;

— proof of competence for ropes in multilayer spooling, see 5.4, if applicable.

5.2 Proof of static strength

5.2.1 General

The proof of static strength shall demonstrate compliance with the requirements specified in this clause regarding:

— a reduction of the minimum breaking force of the rope over its service life; and

— an exceedance of the yield strength of individual wires in the rope.

The proof of static strength according to Formula (1) shall be provided for all relevant load combinations according to EN 13001-2:2021, as applicable and as amended in this document.

$$F_{\mathrm{Sd,s}} \leq F_{\mathrm{Rd,s}} \tag{1}$$

where

$F_{\mathrm{Sd,s}}$ is the design rope force for the proof of static strength;

$F_{\mathrm{Rd,s}}$ is the limit design rope force for the proof of static strength.

5.2.2 Design rope force

5.2.2.1 General

The rope force considered for the proof of static strength shall be determined from the static rope force and acceleration forces, the advantage of the reeving and the efficiency of the rope drive, as well as other rope force increasing effects.

The design rope force $F_{\mathrm{Sd,s}}$ shall be calculated for all load combinations in accordance with EN 13001-2:2021, Table 13, considering the additional load actions specified in Table 2, as applicable.

5.2.2.2 Hoist rope drives

The design rope force $F_{\mathrm{Sd,s}}$ in hoist rope drives for vertical lifting of loads shall be calculated according to Formula (2):

$$F_{\mathrm{Sd,s}} = \frac{m_{\mathrm{H}} \cdot g}{n_{\mathrm{m}}} \cdot \phi_i \cdot \prod_j f_{\mathrm{S}j} \cdot \gamma_{\mathrm{p}} \cdot \gamma_{\mathrm{n}} \tag{2}$$

where

m_{H} is the mass of the hoist load including the masses of the payload, load-lifting attachments and the relevant portion of the suspended hoist ropes;

g is the acceleration due to gravity;

n_{m} is the mechanical advantage of reeving;

ϕ_i is the dynamic factor for inertial and gravity effects, see 5.2.2.4;

$f_{\mathrm{S}j}$ are the rope force increasing factors, see 5.2.2.5;

γ_{p} is the partial safety factor, see EN 13001-2:2021;

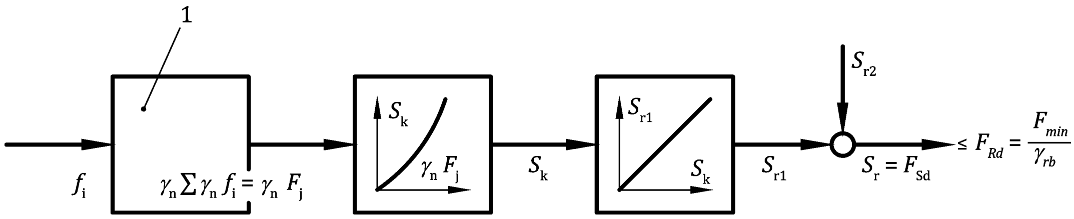
γ_{n} is the risk coefficient, as applicable, see EN 13001-2:2021;

i, j are run indices.

NOTE Formula (2) is a simplification of Formula (3) and is only intended for calculating the rope force in hoist rope drives with a freely swinging load (simple pendulum).

5.2.2.3 General rope drives

Figure 1 illustrates the general determination of the design rope force using the limit state method.



Key

1 load and load combinations according to EN 13001-2:2021, Table 13 and Table 2;

f_i characteristic load action *i* acting on the component including dynamic factors ϕ_i, see 5.2.2.4;

F_j combined load actions from load combination *j*;

S_k design load effects in rope drive *k* of ropes or rope falls, such as inner forces, resulting from load combination F_j;

S_{r1} design load effect in the particular rope as a result of load effects S_k including rope force increasing factors f_{Sj}, see 5.2.2.5;

S_{r2} design load effect in the particular rope arising from local effects, e.g. rope pre-tensioning force (in case this load effect has not been applied as load action);

$F_{Sd} = S_r$ resulting design rope force (design load effect) in particular rope;

F_{Rd} limit design rope force;

F_{min} minimum breaking force of the rope;

γ_p partial safety factors applied to individual load actions according to the load combination under consideration;

γ_n risk coefficient, where applicable;

γ_{rb} rope resistance factor;

i, j, k are run indices.

Figure 1 — Flow chart of limit state method for the proof of competence of wire ropes

NOTE A flow chart similar to Figure 1 can be found in EN 13001-1:2015, Clause 4.2.7.1, where it is used to explain the proof of competence of structural parts using the limit state method.

Step '1' in Figure 1 illustrates the creation of the relevant load combinations, which shall be applied on the mechanical model. It is important that for general rope drives additional load actions shall be considered, which are not given in EN 13001-2:2021, Table 13. These additional load actions shall be taken from Table 2. These load actions shall be multiplied with their applicable partial safety factor γ_p and added to each relevant load combination. Table 2 shall always be used in conjunction with