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Cranes - General design - Part 3-5: Limit states and proof of competence of forged hooks

Krane - Konstruktion allgemein - Teil 3-5: Grenzzustände und Sicherheitshinweise von geschmiedeten Haken

Appareils à levage à charge suspendue - Conception générale - Partie 3-5: Etats limites et vérification d'aptitude des crochets forgés

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Cranes - General design - Part 3-5: Limit states and proof of competence of forged hooks

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Foreword

This document (CEN/TS 13001-3-5:2010) has been prepared by Technical Committee CEN/TC 147 “Cranes - Safety”, the secretariat of which is held by BSI.

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 Technical Specification is one part of the EN 13001 series. The other parts are as follows:

— *Part 1: General principles and requirements*

— *Part 2: Load effects*

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

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

— *Part 3-3: Limit states and proof of competence of wheel/rail contacts*

According to the CEN/CENELEC International Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, 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.

Introduction

This Technical Specification has been prepared to provide a means for the mechanical design and theoretical verification of cranes to conform with essential health and safety requirements. This specification 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 Technical Specification is a type C standard.

The machinery concerned and the extent to which hazards are covered are indicated in the scope of this standard.

1 Scope

This Technical Specification should be used together with the other relevant parts of the standard series. As such, they specify general conditions, requirements and methods to prevent hazards in hooks as part of all types of cranes.

This Technical Specification covers the following parts of hooks and types of hooks:

— bodies of any type of point hooks made of steel forgings;

— machined shanks of hooks with a thread/nut suspension.

NOTE 1 Principles of this Technical Specification can be applied to other types of shank hooks and also where stress concentration factors relevant to that shank construction are determined and used. Plate hooks, which are those, assembled of one or several parallel parts of rolled steel plates are not covered in this Technical Specification.

This Technical Specification is applicable to hooks from materials with ultimate strength of no more than 800 N/mm^2 and yield stress of no more than 600 N/mm^2.

The following is a list of significant hazardous situations and hazardous events that could result in risks to persons during normal use and foreseeable misuse. Clauses 4 to 8 of this document are necessary to reduce or eliminate the risks associated with the following hazards:

a) Exceeding the limits of strength (yield, ultimate, fatigue);

b) Exceeding temperature limits of material;

c) Unintentional disengagement of the load from the hook.

The requirements of this Technical Specification are stated in the main body of the document and are applicable to hook designs in general. The hook body and shank designs listed in Annexes A, B and G are only examples and should not be referred to as requirements of this Technical Specification.

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

NOTE 2 This CEN/TS 13001-3-5 deals only with the limit state method in accordance with EN 13001-1.

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 10002-1, *Metallic materials — Tensile testing — Part 1: Method of test at ambient temperature*

EN 10045-1, *Metallic materials — Charpy impact test — Part 1: Test method*

EN 10025-3:2004, *Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10222-4:1998, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steels with high proof strength*

EN 10228-3:1998, *Non-destructive testing of steel forgings — Part 3: Ultrasonic testing of ferritic or martensitic steel forgings*

EN 10243-1:1999, *Steel die forgings — Tolerances on dimensions — Part 1: Drop and vertical press forgings*

EN 10250-2:1999, *Open die steel forgings for general engineering purposes — Part 2: Non-alloy quality and special steels*

EN 10250-3:1999, *Open die steel forgings for general engineering purposes — Part 3: Alloy special steels*

EN 10254, *Steel closed die forgings — General technical delivery conditions*

EN 13001-1:2004, *Cranes - General design — Part 1: General principles and requirements*

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

CEN/TS 13001-3-2, *Cranes — General design — Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*

EN ISO 4287:1998, *Geometrical product specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters (ISO 4287:1997)*

EN ISO 12100-1:2003, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology (ISO 12100-1:2003)*

ISO 965-1:1998, *ISO general purpose metric screw threads — Tolerances — Part 1: Principles and basic data*

ISO 4306-1:2007, *Cranes — Vocabulary — Part 1: General*

3 Terms and definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100-1:2003 and ISO 4306-1:2007 and the following apply.

3.1.1
hook shank
upper part of the hook, from which the hook is suspended to the hoist media of the crane

3.1.2
hook body
lower, curved part of the hook below the shank

3.1.3
hook seat
bottom part of the hook body, where the load lifting attachment is resting

3.1.4
hook suspension articulation
feature of the hook suspension, allowing the hook to tilt along the inclined load line

3.1.5
serially produced hook
hook which is designed, manufactured and released to the market as a stand alone component or as part of a hook block, without connection to a specific crane or application

3.2 Symbols and abbreviations

Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
A_{d1}	Cross section area of the forged, shank
A_{d4}	Cross section area of the critical section of hook shank
A_v	Minimum impact toughness of material
a	Acceleration
a_1	Seat circle diameter
a_2	Throat opening
a_3	Height of the hook point
b_{max}	Maximum width in the critical hook body section
b_{ref}	Reference width
C	Total number of working cycles during the design life of crane
C_t	Relative tilting resistance of the hook suspension
c_e	Coefficient for load eccentricity
D	Cumulative damage in fatigue (Palmgren-Miner hypothesis)
d_1	Diameter of the forged shank
d_3	Principal diameter of thread
d_4	Diameter of the undercut section of the shank
d_5	Thread core diameter
e_R	Distance of the vertical load line from the centre line of the shank
F	Vertical force
F_H	Vertical force on hook due to occasional or exceptional loads
$F_{Rd,s}$, $F_{Rd,f}$	Limit design forces, static / fatigue
$F_{Sd,s}$	Vertical design force for the proof of static strength
$F_{Sd,f}$	Vertical design force for the proof of fatigue strength
f_1, f_2, f_3	Factors of further influences
f_{Rd}	Limit design stress
f_y	Yield stress
f_u	Ultimate strength
g	Acceleration due to gravity, g = 9,81 m/s^2
$H_{Sd,s}$	Horizontal design force of hook
$H_{Sd,f}$	Horizontal design force for the proof of fatigue strength
h_1 , h_2	Section heights of the hook body
h	Vertical distance from the seat bottom of the hook body to the centre of the articulation
h_s	Vertical distance from the seat bottom of the hook body to critical section of hook shank
i	Index for a lifting cycle or a stress cycle
I	Reference moment of inertia for curved beam
I_{d1}	Moment of inertia of the forged shank
I_{d4}	Moment of inertia of the critical section of hook shank
k_C	Conversion factor for stress spectrum and classified duty
k_h ,k_s	Stress spectrum factors

Table 1 *(continued)*

kQ	Load spectrum factor, in accordance with EN 13001-1
k_5^* , k_6^*	Specific spectrum ratio factors, m = 5 / 6
lg	Log to the base of 10
M_1 , M_2 , M_3 , M_4	Bending moments of hook shank
$M_{1,f,i}$, $M_{2,f,i}$, $M_{3,f,i}$	Bending moments of hook shank for the proof of fatigue strength, lifting cycle i
$M_{Sd,s}$	Static design bending moment
m	Slope parameter of the characteristic fatigue design curve
m_{RC}	Mass of rated hoist load
m_i	Mass of the hook load in a lifting cycle i
N	Total number of stress cycles / lifting cycles
N_D	Reference number of stress cycles, ND =2 × 10^6
p	Pitch of thread
p_a	Average number of accelerations related to one lifting cycle
R	Radius of hook body curvature
R_a	Average depth of surface profile according to EN ISO 4287:1998
R_z	Maximum depth of surface profile according to EN ISO 4287:1998
r_9	Relief radius of the undercut
r_{th}	Thread bottom radius
s	Length of undercut
s_h , s_s	Stress history parameters
s_Q	Load history parameter
t	Depth of thread
T	Operation temperature
u_S, u_T	Depths of notches
α	Angle
α_S, α_T	Stress concentration factors
β	Angle or direction of hook inclination
β_n,β_{nS}, β_{nT}	Notch effect factors
ϕ_2	Dynamic factor for hoisting an unrestrained grounded load
ϕ_5	Dynamic factor for changes of acceleration of a movement
γ_n	Risk coefficient
γ_p	Partial safety factor
γ_m	General resistance coefficient
γ_{sm}	Specific resistance coefficient
γ_{Hf} , γ_{Sf}	Fatigue strength specific resistance factors
η_1	Edge distance of a hook body section
ν	Factor for load component
νh , νs	Relative numbers of stress cycles
μ	Factor for mean stress influence
σ_a	Shank stress due to axial force
σ_b	Shank stress due to bending moment
σ_m	Mean stress in a stress cycle
σ_A	Stress amplitude in a stress cycle
σ_{Sd}	Design stress

Table 1 *(continued)*

σ_M	Basic fatigue strength amplitude, un-notched piece
σ_p	Total stress range in a pulsating stress cycle
σ_W	Fatigue strength amplitude, notched piece
σ_{Tmax} , σ_{T1} , σ_{T2}	Transformed stress amplitudes
$\Delta\sigma_c$	Characteristic fatigue strength
$\Delta\sigma_{Rd}$	Limit fatigue design stress
$\Delta\sigma_{Sd,i}$	Stress range in a lifting cycle *i*
$\Delta\sigma_{Sd,max}$	Maximum stress range

4 General requirements

4.1 Materials

The hook material in the finished product shall have sufficient ductility to permanently deform before losing the ability to carry the load, at the temperatures specified for the use of the hook. Hook material, after forging and heat treatment, shall have minimum Charpy-V impact toughness in accordance with Table 2.

Table 2 — Impact test requirement for hook material

Operation temperature	Impact test temperature	Minimum impact toughness A_v
T ≥ - 30 °C	- 20 °C	27 J
- 30 °C > T ≥ - 40 °C	- 30 °C	
- 40 °C > T ≥ - 50 °C	- 40 °C	

European standards specify materials and their properties. This standard gives a preferred selection. For forged hooks, the material grades and qualities in accordance with Table 3 should be used. For more detailed information see the specific European Standard.

Table 3 — Preferred materials for forged hooks

Material standard	Selected qualities	
EN 10025-3	S275N S355N	S420N
EN 10222-4	P285NH P285QH P355NH P355QH	P420NH P420QH
EN 10250-2	S235J2 S355J2	
EN 10250-3	25CrMo4+QT 34CrMo4+QT 36CrNiMo4+QT	34CrNiMo6+QT 30CrNiMo8+QT

Grades and qualities other than those mentioned in the above standards and in Table 3 may be used, if the mechanical properties and the chemical composition are guaranteed by the manufacturer and conform to the qualities of the standards referenced in Table 3.

The mechanical properties (yield stress, ultimate strength) are dependent upon the thickness of the forged hook body. As a ruling thickness, either the largest width of the hook seat or the diameter of the shank shall be used, whichever is greater.

For standardisation purposes, a classification of material grades for forged hooks is specified in Table 4. In cases where the hook material is specified through the class reference, the values of mechanical properties given in Table 4 shall be used as design values and shall be guaranteed as minimum values by the hook manufacturer.

Table 4 — Material properties for classified material grades

Material class reference	Mechanical properties	
	Yield stress f_y N/mm²	Ultimate strength f_u N/mm²
M	215	340
P	315	490
S	380	540
T	500	700
V	600	800

A selection of material qualities conforming to classes of Table 4 for hook sizes in accordance with Annexes A and B is given in Annex F. Another selection of material qualities may be used, as long as the requirements of Table 4 are met and guaranteed by the hook manufacturer.

4.2 Workmanship

The manufacturing process, factory tests and delivery conditions shall meet the requirements of EN 10254.

Each hook body shall be forged hot in one piece. The macroscopic flow lines of the forging shall follow the body outline of the hook. Excess metal from the forging operation shall be removed cleanly leaving the surface free from sharp edges.

Profile cutting from a plate is not permissible for forged hooks.

The surface roughness of the hook seat in the finished product shall be equal to or better than R_z 500 µm. Grinding may be used to reach the required surface quality. Any grinding marks shall be in a circumferential direction in respect to the seat circle.

After heat treatment, furnace scale shall be removed and the hook body shall be free from harmful defects, including cracks. Hook forging shall be inspected for defects using appropriate NDT-methods according to EN 10228-3. Requirements of quality class 1 of EN 10228-3:1998 shall be met.

No welding shall be carried out at any stage of manufacture.

4.3 Manufacturing tolerances

The dimensional tolerances according to EN 10243-1 for forging grade F shall be fulfilled, except as modified herein.

The seat circle diameter and the throat opening shall be within [0 ; + 7 %] of the nominal dimension. The point height dimension a_3 shall be within [- 7 % ; + 7 %] of the nominal dimension.

The centre line of the machined shank shall not deviate from the seat centre more than ± 0,02 a_1.

The shape of the hook in its own plane shall be such that the centres of the material sections specified by the two flanks of a section shall fall between two parallel planes with a spacing of 0,05 d_1.

4.4 Heat treatment

Each forged hook shall either be hardened from a temperature above the AC_3 point and tempered, or normalized from a temperature above the AC_3 point. The tempering temperature shall be at least 475 °C.

The normalizing or tempering conditions shall be at least as effective as a temperature of 475 °C maintained for a period of 1 h.

4.5 Proof loading

As part of the manufacturing process, a hook may be proof loaded. This initial proof loading can further assist the Quality Assurance Management process as well as improve the fatigue performance of the hook in general. If proof loading is applied, the process of proof loading shall be as follows:

a) Proof loading is applied after forging, subsequent to heat treatment and shank machining;

b) The proof load force shall be applied between the hook seat and the shank suspension nut, either as a straight pull parallel to the hook shank or the load applied as in test loading in accordance with Figure 7;

c) A relative permanent set due to proof loading measured at the gap opening shall not exceed 0,25 %;

d) For batch-produced hooks the proof loading shall be applied to each hook in the batch;

e) Magnitude of proof load shall be such that the stress in the intrados exceeds the yield stress of the material;

f) In general, the magnitude of proof load should be related to the static limit design force of the hook body and be within limits between $1{,}0 \times F_{Rd,s}$ and $1{,}2 \times F_{Rd,s}$;

g) After proof loading, the hook shall be inspected for defects using appropriate NDT-methods and found free from harmful flaws, defects and cracks;

h) Proof loaded hook shall be stamped with symbol "PL" adjacent to the hook type marking.

NOTE Benefits derived from the application of the proof loading in subsequent fatigue performance and to the QA Management process are not addressed within this standard.

4.6 Hook body geometry

Proportions of hook sections shall be such that stresses do not exceed stresses in the critical sections specified in 5.5.1.