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

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

April 2024

ICS 53.020.30; 53.020.20

Will supersede EN 13001-3-5:2016+A1:2021

English Version

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

Appareils de levage à charge suspendue - Conception générale - Partie 3-5 : États limites et vérification des crochets forgés et moulés

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

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.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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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.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.



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European foreword

This document (prEN 13001-3-5:2024) 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 13001-3-5:2016+A1:2021.

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 or Annex ZB, which is an integral part of this document.

The hazards covered by this document are identified in Annex M.

This European Standard is one part of the EN 13001 series . 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 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*
- *Part 3-4: Limit states and proof of competence of machinery — Bearings¹*
- *Part 3-6: Limit states and proof of competence of machinery — Hydraulic cylinders*

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

¹ Currently at Enquiry stage.

Introduction

This document has been prepared to provide a means for the mechanical design and theoretical verification of crane hooks to conform to essential health and safety requirements. This document 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 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 machinery safety:

- 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 at 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 covers the following parts of hooks and types of hooks:

- bodies of any type of hooks made of steel forgings or steel castings, including stainless steel;
- machined shanks of hooks with a thread/nut suspension.

Plate hooks, which are those assembled of one or several parallel parts of rolled steel plates, are not covered.

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 intended to reduce or eliminate the risks associated with the following hazards:

- a) exceeding the limits of yield strength, ultimate strength, fatigue strength, brittle fracture;
- b) exceeding temperature limits of material.

This document is not applicable to hooks installed in cranes manufactured before the date of its publication and serves as a reference base for product standards for particular crane types.

This part of EN 13001 deals only with the limit state method in accordance with EN 13001-1:2015.

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 1369:2012, *Founding — Magnetic particle testing*

EN 1370:2011, *Founding — Examination of surface condition*

EN 1371-1:2011, *Founding — Liquid penetrant testing — Part 1: Sand, gravity die and low pressure die castings*

EN 1559-1:2011, *Founding — Technical conditions of delivery — Part 1: General*

EN 10025-3:2019, *Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*

EN 10213:2007+A1:2016, *Steel castings for pressure purposes*

EN 10222-4:2017+A1:2021, *Steel forgings for pressure purposes — Part 4: Weldable fine grain steels with high proof strength*

EN 10228-1:2016, *Non-destructive testing of steel forgings — Part 1: Magnetic particle inspection*

EN 10228-2:2016, *Non-destructive testing of steel forgings — Part 2: Penetrant testing*

EN 10228-3:2016, *Non-destructive testing of steel forgings — Part 3: Ultrasonic testing of ferritic or martensitic steel forgings*

EN 10250-1:2022, *Open die steel forgings for general engineering purposes — Part 1: General requirements*

EN 10250-2:2022, *Open die steel forgings for general engineering purposes — Part 2: Non-alloy quality and special steels*

EN 10250-3:2022, *Open die steel forgings for general engineering purposes — Part 3: Alloy special steels*

EN 10254:1999, *Steel closed die forgings — General technical delivery conditions*

EN 10340:2007, *Steel castings for structural uses*

EN 12680-1:2003, *Founding — Ultrasonic examination — Part 1: Steel castings for general purposes*

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 13001-3-2:2014, *Cranes — General design — Part 3-2: Limit states and proof of competence of wire ropes in reeving systems*

EN ISO 148-1:2016, *Metallic materials — Charpy pendulum impact test — Part 1: Test method (ISO 148-1:2016)*

EN ISO 642:1999, *Steel — Hardenability test by end quenching (Jominy test) (ISO 642:1999)*

EN ISO 643:2020, *Steels — Micrographic determination of the apparent grain size (ISO 643:2019, Corrected version 2023-11)*

EN ISO 683-2:2018, *Heat-treatable steels, alloy steels and free-cutting steels — Part 2: Alloy steels for quenching and tempering (ISO 683-2:2016)*

EN ISO 898-2:2022, *Fasteners — Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes (ISO 898-2:2022)*

EN ISO 21920-2:2022, *Geometrical product specifications (GPS) - Surface texture: Profile - Part 2: Terms, definitions and surface texture parameters (ISO 21920-2:2021, Corrected version 2022-06)*

EN ISO 6892-1:2019, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2019)*

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

CEN ISO/TR 15608:2017, *Welding — Guidelines for a metallic materials grouping system (ISO/TR 15608:2017)*

ISO 965-1:2013, *ISO general purpose metric screw threads — Tolerances — Part 1: Principles and basic data*

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

EN ISO 15614-1:2017, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys (ISO 15614-1:2017, Corrected version 2017-10-01)*

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 12100:2010 and ISO 4306-1:2007, 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

hook shank

upper part of the hook, from which the hook is suspended to the hoist medium 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 articulation

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

3.1.5

stand-alone hook

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

3.1.6

total deformation ratio

ratio of the area of the cast cross section to the forged cross section

Note 1 to entry: The following terms might also be used in technical literature for the same: reduction rate, reduction ratio, forging reduction.

3.2 Symbols and abbreviations

Table 1 — Symbols and abbreviations

Symbols, abbreviations	Description
A_{d1}	Cross section area of the unmachined 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 unmachined 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
$F_{Rd,s,0}$	Basic limit design forces, static
$F_{Rd,s}, F_{Rd,f}$	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_M, f_{MB}, f_{MS}	Factors of material type influence (forged/cast)
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, $g = 9,81 \text{ m/s}^2$

Symbols, abbreviations	Description
$H_{Sd,s}$	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 unmachined 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
k_Q	Load spectrum factor, in accordance with EN 13001-1:2015
k_5^*	Specific spectrum ratio factor with $m = 5$
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, $N_D = 2 \times 10^6$
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 in accordance with EN ISO 21920-2:2022
R_z	Maximum depth of surface profile in accordance with EN ISO 21920-2:2022
r_9	Relief radius of the undercut
r_{th}	Thread bottom radius
s	Length of undercut
S_h, S_s	Stress history parameters

Symbols, abbreviations	Description
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
$\beta_n, \beta_{nS}, \beta_{nT}$	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
ν_h, ν_s	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
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
$\sigma_{Tmax}, \sigma_{T1}, \sigma_{T2}$	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

4.1.1 General

The hook material shall fulfil the requirements of this clause independently of the material standard applied (see 4.1.2) and independently whether classification of the material is applied or not (see 4.1.3).

The hook material in the finished product shall have ductility to permanently deform before losing the ability to carry the load, at the temperatures specified for the use of the hook. Particularly the hook material shall fulfill the following conditions:

- the ratio of ultimate strength (f_u) to yield stress (f_y) $f_u/f_y \geq 1,1$. For the materials, which do not fulfil this condition, the design value of f_y shall be limited to $f_u/1,1$;
- the percentage elongation at fracture $A \geq 10\%$ on a gauge length $L_0 = 5,65 \times \sqrt{S_0}$ (where S_0 is the original cross-sectional area).

The hook material, after heat treatment, shall have minimum Charpy-V impact energy in accordance with EN ISO 148-1:2016 and as specified in Table 2.

Table 2 — Impact test requirement for hook material

Operation temperature	Impact test temperature	Minimum impact energy KV_2
$T \geq 0\text{ °C}$	$+20\text{ °C}$	35 J
$T \geq -20\text{ °C}$	-0 °C	35 J
$T \geq -30\text{ °C}$	-20 °C	35 J
$T \geq -40\text{ °C}$	-30 °C	35 J

To satisfy the requirements of the operating temperature, the manufacturer shall select the steel, which after suitable heat treatment, shall be consistent with achieving the chosen mechanical property grade for the selected hook form, taking into account its individual ruling thickness.

The steel shall be fully killed, stabilized against strain age embrittlement, ensured by having suitable mass content of aluminium (in general between 0,02 % and 0,05 %). The steel shall contain no more sulphur and phosphorus than the limits given in Table 3.

Table 3 — Sulphur and phosphorus content

Element	Maximum mass content as determined by	
	Cast analysis	Check analysis
Sulphur (S)	0,020 [%]	0,025 [%]
Phosphorus (P)	0,020 [%]	0,025 [%]
Sum of S + P	0,035 [%]	0,045 [%]

Where quenched and tempered steel is used, the hardenability of the steel shall fulfil the requirement of the Jominy-ratio given in Table 4. The Jominy-ratio J30/J1,5 is the ratio between J30 and J1,5, where J30 and J1,5 mean the hardness at depths 30 mm and 1,5 mm correspondingly, determined by Jominy face-quenching test in accordance with EN ISO 642:1999.

The tests shall be carried out per melt and the values be given in the technical hook information, see Annex J. For more information on hardening properties and hardness profiles, see EN ISO 683-2:2018. Where the mechanical properties of cast hooks are tested for each single hook, the hardenability may be verified by HB-testing in accordance with EN ISO 6506-1:2014 in the section of the test specimen at 1,5 mm and 30 mm depth from the surface. The hardness ratio shall fulfil the minimum requirement (Jominy-ratio) given in Table 4.

Table 4 — Hardenability of quenched and tempered materials, Jominy-ratio

Ultimate strength f_u N/mm ²	Minimum required Jominy-ratio J30/J1,5
$540 \leq f_u < 800$	65 %
$800 \leq f_u$	93 %

Hooks in the final condition shall have a grain size of

- 6 or finer for forged materials,
- 5 or finer for cast materials,

with grain size determined in accordance with EN ISO 643:2020.

4.1.2 Typical standards and grades

European Standards specify materials and their properties. Material grades and qualities for hooks given in Table 5 shall be used. For more detailed information, see the specific European Standard.

Table 5 — Suitable materials for hooks

	Material standard	Selected qualities	
Forged hooks	EN 10025-3:2019	S355N	S420N
	EN 10222-4:2017+A1:2021	P355NH P355QH	P420NH P420QH
	EN 10250-2:2022	S355J2N	
	EN ISO 683-2:2018	25CrMo4+QT	34CrNiMo6+QT
	EN 10250-3:2022	34CrMo4+QT 36CrNiMo4+QT	30CrNiMo8+QT
Cast hooks	EN 10213:2007+A1:2016	G20Mn5 + N	G20Mn5 + QT
	EN 10340:2007	G18NiMoCr3-6 + QT	GX4CrNi13-4 + QT
Grades and qualities other than those mentioned above may be used, if the requirements of 4.1.1 are fulfilled and the mechanical properties and the chemical composition are specified in the same way as in relevant European Standards.			

4.1.3 Classification of hook materials

For practical purposes, an optional classification of materials for hooks is presented in Table 6. In cases where the hook material is specified through the classification, the values of mechanical properties given in Table 6 shall be used as design values and shall be specified as minimum values by the hook manufacturer.

Table 6 — Mechanical properties for classified materials

Material class reference	Mechanical properties	
	Yield stress	Ultimate strength
	f_y N/mm ²	f_u N/mm ²
P	315	490
S	390	540
T	490	700
V	620	800
W	770	970

NOTE Acceptable strength properties of hook material are not limited to those shown in Table 6.

4.2 Workmanship

4.2.1 Forged hooks

The manufacturing process, factory tests and delivery conditions shall meet the requirements of EN 10254:1999 or EN 10250-1:2022 as relevant.

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 in the areas of the highest tensile stresses. Excess metal from the forging operation shall be removed cleanly leaving the surface free from sharp edges. The total deformation ratio shall be in accordance with the Table 7.

Table 7 — Requirement for the deformation ratio

Shank diameter d_1 [mm]	Minimum, total deformation ratio
$d_1 \leq 50$ mm	8 : 1
$50 \text{ mm} < d_1 \leq 80$ mm	6 : 1
$80 \text{ mm} < d_1 \leq 120$ mm	4 : 1
$120 \text{ mm} < d_1$	3 : 1

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

Hook forging shall be inspected for surface defects using appropriate non-destructive testing methods (NDT) in conformance to EN 10228-1:2016 or EN 10228-2:2016 and requirement of quality class 3 shall be met. Grinding may be used to reach the required surface quality. Any grinding marks shall be in circumferential direction in respect to the seat circle.

Hook forging shall be inspected for volumetric defects using appropriate NDT-methods in conformance to EN 10228-3:2016 and requirements of quality class 3 of EN 10228-3:2016 shall be met.

After heat treatment, furnace scale shall be removed and the hook shall be free from harmful defects, including cracks.

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

4.2.2 Cast hooks

The manufacturing process, in-factory tests and delivery conditions shall meet the requirements of EN 1559-1:2011 in general and the relevant material standard for the specific requirements.

The castings shall be heat-treated to meet the mechanical properties of the applicable grade. During material selection, due consideration shall be given to the material properties varying by the depth, especially in cases of large hooks.

Casting test pieces (see Clause 7) shall have representative solidification heat, mass transfer rate and microstructure distribution of the hook and the mechanical test shall demonstrate that the casting has the expected property across the section.

Prior to quenching, the ingate system is to be roughly removed. After quenching excess material from the casting system shall be removed cleanly leaving the surface free from sharp edges.

The surface roughness of the hook seat in the finished product shall be equal to or better than R_z 500 μm (corresponding to S2 in EN 1370:2011). 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 the surface of a cast hook shall be inspected for defects using appropriate NDT-methods. Requirements of severity level 2 of EN 1369:2012 or severity level 2 of EN 1371-1:2011 shall be met.

The inner quality shall be inspected by ultrasonic inspection in accordance with EN 12680-1:2003 and severity level 2 or 3 shall be met. For influence of severity level on design factors, see 5.7.1.

Weld procedures for production welding are required for all repairs during manufacturing and shall be qualified in accordance with CEN ISO/TR 15608:2017 and EN ISO 15614-1:2017. Subsequently the welded part shall be post weld heat treated. Production welds shall be made in such a manner that the values obtained for the relevant properties of the weld metal and the heat-affected zone meet the requirements of the parent material as given in this standard.

4.3 Manufacturing tolerances of forgings

In general, all dimensions of unmachined hooks shall be within [0 ; +7 %] of the nominal dimension.

For the hooks listed in Annexes A and B tolerances given in Annex C may be applied.

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

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

Heat treatment of hooks shall be done in accordance with the applicable European material standard listed in Table 5.

4.5 Cold forming by proof loading

As the last stage of the manufacturing process, a forged hook may be subjected to a “proof load test” and cold forming as a result. See guidance in Annex K.

NOTE 1 Benefits derived from the application of the proof loading in subsequent fatigue performance and to the QA Management process are not addressed in the current version of this European Standard.

NOTE 2 Cold forming by “proof load test” is outside of testing of hooks in accordance with 7.3.

4.6 Hook body geometry

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

The seat of a hook shall be of circular shape. In a single hook, the centre of curvature shall coincide with the centreline of the machined shank. In a ramshorn hook, the seat circle shall be tangential in respect to the outer edge of the unmachined shank.

A ramshorn hook shall be symmetrical in respect to the centre line of the shank.

Annexes A and B present example sets of hook body dimensions, which fulfil the requirements of this clause. The commonly used hook body and shank designs listed in Annexes A, B and F are only examples and shall not be referred to as requirements of this European Standard. Annex I give guidance for the selection of a hook size, where a hook body is in accordance with Annex A or B.

NOTE The selection of hook form is not limited to those shown in Annexes A and B.

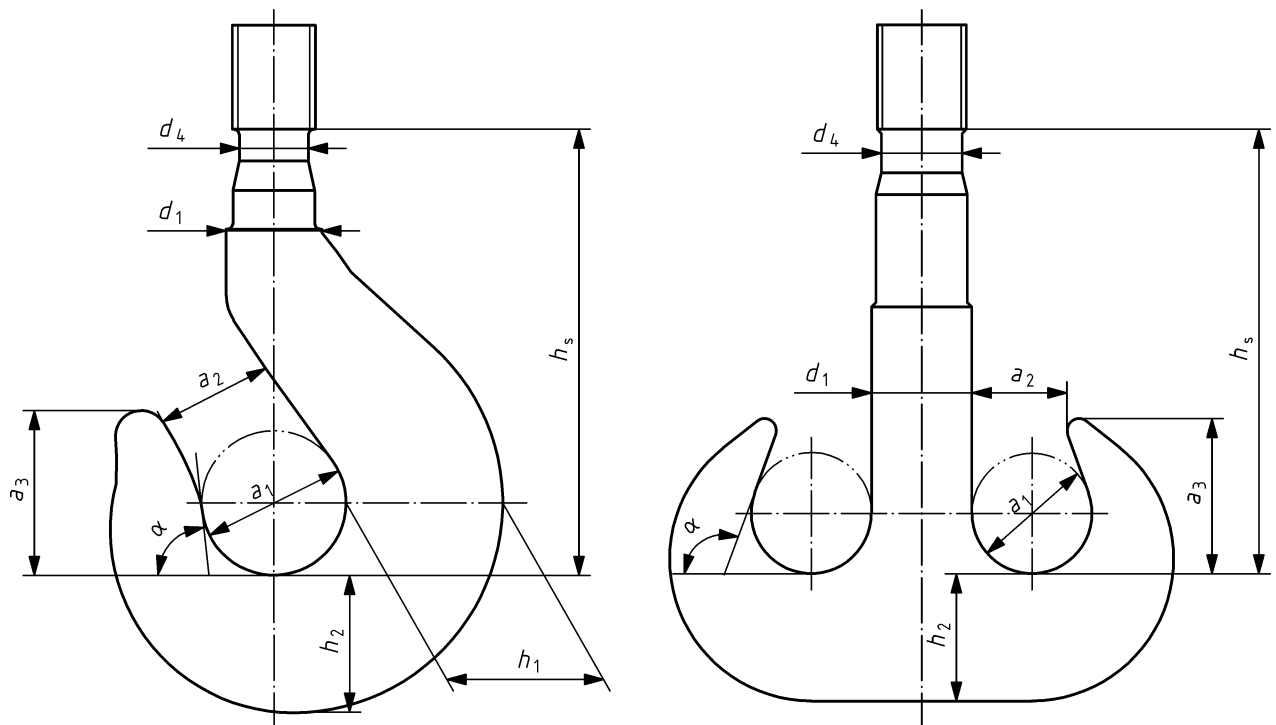


Figure 1 — Hook dimensions

The diameter of the unmachined shank (d_1) shall be proportioned to circle diameter (a_1) as follows: $d_1 \geq 0,55 a_1$.

The bifurcation point between the inner edge and the seat circle (a_1) shall be from the horizontal in minimum as follows: for a single hook $\alpha \geq 60^\circ$, for a ramshorn hook $\alpha \geq 90^\circ$.

The full throat opening (a_2), without consideration to a latch shall be proportioned to the seat circle diameter as follows: $a_2 \leq 0,85 a_1$. The effective throat opening with a latch shall be in minimum $a_0 \geq 0,7 a_1$.

The point height of a hook (a_3) shall be in minimum as follows: $a_3 \geq a_1$.

4.7 Hook shank machining

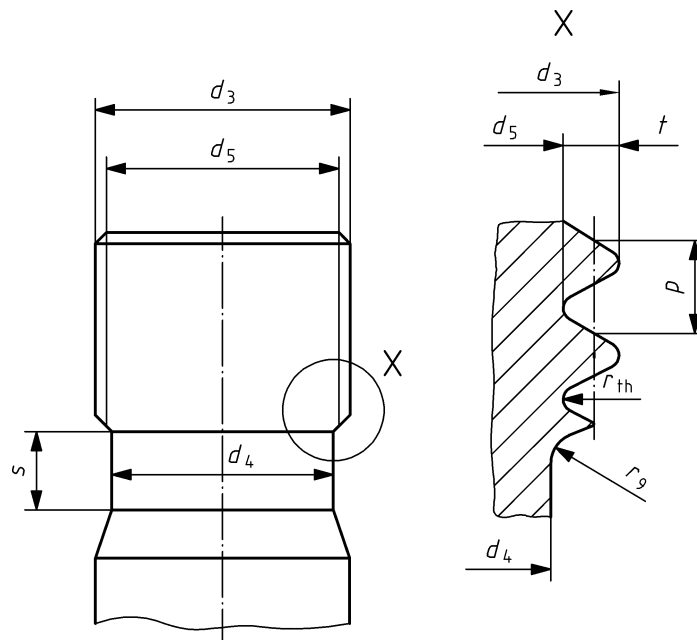


Figure 2 — Machined dimensions of shank

The length of the threaded portion of the shank shall be not less than $0,8 d_3$.

The pitch of the thread (p) shall be proportioned to the principal diameter of the thread (d_3) as follows: $0,055 d_3 \leq p \leq 0,15 d_3$.

The depth of the thread (t) shall be proportioned to the pitch of the thread (p) as follows: $0,45 p \leq t \leq 0,61 p$.

The bottom radius of the thread profile (r_{th}) shall be no less than $0,14 p$. A thread type, where the bottom radius is not specified, shall not be used.

The shank shall be undercut (with a diameter d_4) below the last threads for a length (s) proportioned to the undercut depth as follows: $s \geq 2 (d_3 - d_4)$. The undercut shall reach deeper than the core diameter of the thread profile (d_5), in minimum as follows: $d_4 \leq (d_5 - 0,3 \text{ mm})$. The undercut shall be machined with a form ground tool to a surface finish of $R_a \leq 6,3 \mu\text{m}$.

There shall be a relief radius in a transition from the threaded part to the undercut part. The relief radius (r_9) shall be proportioned to the diameter of the undercut (d_4) as follows: $r_9 \geq 0,06 d_4$. The shape of the relief transition need not be a complete quadrant of a circle.

The thinnest section of the machined shank (consequently d_4) shall fulfil the condition $d_4 \geq 0,65 d_1$, where d_1 is the diameter of the unmachined part of the shank, see Figure 1.

The whole machined section of the shank shall have a radius at each change in diameter. The machined section shall not reach the curved part of the hook body.

Screwed threads shall conform to the tolerance requirements of ISO 965-1:2013 (coarse series) and be of medium fit class 6g.

Annex F presents example sets of machined shank and thread dimensions, which fulfil the geometric requirements.

4.8 Nut

The mechanical properties of the nut material shall be equal to or better than that required for the material for hooks in accordance with 4.1. However, for standard metric nuts up to size M45 made of materials in accordance with EN ISO 898-2:2022, from the material properties of the nut at least the yield stress shall match or exceed the required yield stress of the hook material.

The height of the nut shall be such that the threaded length of the hook shank is fully engaged with the nut thread.

The nut shall be positively locked to the shank against rotation to prevent the nut from unscrewing. The locking shall not interfere with the lower two thirds of the nut/shank thread connection. The locking shall allow relative axial movement between the shank and the nut due to play in the threaded connection. Alternatively, if the nut is to be locked by a dowel or other similar fixing media, it is essential during the locking process, the nut/shank load bearing thread flanks are in contact to avoid load transmission through the locking media.

The support of the nut shall enable the hook to rotate about the vertical axis. The height position of the contact surface shall fall within the lower half of the thread connection.

Screwed threads of the nut shall comply with the tolerance requirements of ISO 965-1:2013 (coarse series) and be of medium fit class 6H. The bottom radius of the thread profile for the nut shall be not less than $0,07 p$, where p is the pitch of the thread. A thread type, where the bottom radius is not specified, shall not be used.

NOTE Distribution of the load to larger part of the thread length can be achieved by the design of the nut.

4.9 Effect of hook suspension

Effect of the hook suspension shall be taken into account in the design calculations of the hook shank, see 5.4. In cases where, by changing the crane/hook block configuration or position, the hook suspension can be brought to a rigid position, this shall be taken into account in the design calculation of the hook.

NOTE Usually the hook suspension consists of nut, cross head and bearing. For the purpose of this standard, the rope reeving is taken as part of the suspension.

5 Static strength

5.1 General

The proof of static strength for hooks shall be carried out in accordance with principles of EN 13001-1:2015 and EN 13001-2:2021. The general design limit for static strength is related to yielding of the material.

The proof shall be delivered for the specified critical sections of the hook, taking into account the most unfavourable load effects from the load combinations A, B or C in accordance with EN 13001-2:2021. The relevant partial safety factors γ_p shall be applied. The risk coefficients γ_n shall be applied where required in the specific application or as specified in the relevant European crane type standard.

5.2 Vertical design force

The vertical design force for a hook $F_{Sd,s}$ when hoisting the rated hook load, shall be calculated as follows:

$$F_{Sd,s} = \Phi \times m_{RC} \times g \times \gamma_p \times \gamma_n \quad (1)$$

with

$$\Phi = \max \left\{ \Phi_2; \left(1 + \Phi_5 \times \frac{a}{g} \right) \right\}$$

where

ϕ_2 is the dynamic factor, when hoisting an unrestrained grounded load, see EN 13001-2:2021;

ϕ_5 is the dynamic factor for loads caused by hoist acceleration, see EN 13001-2:2021;

a is the vertical acceleration or deceleration;

m_{RC} is the mass of the rated hook load;

g is the acceleration due to gravity, $g = 9,81 \text{ m/s}^2$;

γ_p is the partial safety factor, see EN 13001-2:2021;

$\gamma_p = 1,34$ for regular loads (load combinations A);

$\gamma_p = 1,22$ for occasional loads (load combinations B);

$\gamma_p = 1,10$ for exceptional loads (load combinations C);

$\gamma_p = 1,0$ for exceptional load case of 5.4.5 (load combinations C);

γ_n is the risk coefficient.

Other load actions and combinations of EN 13001-2:2021 can produce vertical forces on the hook, whose load actions shall also be analysed. The vertical design force in such cases is expressed in a general format as follows:

$$F_{Sd,s} = F_H \times \gamma_p \times \gamma_n \quad (2)$$

where

F_H is a vertical force on hook due to other load action than hoisting a rated load, e.g. a test load or a peak load in an overload condition;

γ_p is the partial safety factor as above, see EN 13001-2:2021;

γ_n is the risk coefficient.

5.3 Horizontal design force

The horizontal forces that are most significant for the strength of hooks are those caused by horizontal accelerations of the crane motions. The horizontal force shall be assumed to act at the bottom of the hook seat.

The horizontal design force of hook $H_{Sd,s}$ due to horizontal accelerations shall be calculated as follows:

$$H_{Sd,s} = \min \left\{ m_{RC} \times a \times \Phi_5 \times \gamma_p \times \gamma_n; C_t \times F_{Sd,s} / h \right\} \quad (3)$$

where

- m_{RC} is the mass of the rated hook load;
- a is the acceleration or deceleration of a horizontal motion;
- ϕ_5 is the dynamic factor for loads caused by horizontal acceleration, see EN 13001-2:2021. For hook suspensions, which are not rigidly connected in horizontal direction to the moving part of the crane, it shall be set $\phi_5 = 1$;
- γ_p is the partial safety factor as for Formula (1);
- γ_n is the risk coefficient;
- C_t is the relative tilting resistance of the hook suspension in accordance with Annex H;
- $F_{Sd,s}$ is the vertical design force in accordance with 5.2, related to the loading condition where $H_{Sd,s}$ is specified;
- h is the vertical distance from the seat bottom of the hook body to the centre of the articulation.

5.4 Bending moment of the shank

5.4.1 General

The following load actions shall be taken into consideration, when determining the total bending moment of the hook shank:

- a) horizontal forces, see 5.4.2;
- b) inclination of the hook suspension, see 5.4.3;
- c) eccentric action of vertical force in the hook seat, see 5.4.4;
- d) ramshorn hook, half of the rated load on one prong only, see 5.4.5.

The bending moments caused through these load actions shall be addressed to the same load combinations, which the primary loads or operational conditions causing the bending belong to.

5.4.2 Bending moment due to horizontal force

This clause covers the shank bending moment due to external horizontal forces. The moment M_1 shall be calculated at the critical hook shank section (see 5.6) due to the horizontal design force $H_{Sd,s}$.

$$M_1 = H_{Sd,s} \times h_s \quad (4)$$

where

- $H_{Sd,s}$ is the horizontal design force in accordance with 5.3;
- h_s is the vertical distance from the seat bottom of the hook body to the level, where the shank is supported for horizontal forces. In typical hook suspensions, h_s is as shown in Figure 1.

5.4.3 Bending moment due to inclination of hook suspension

Where the arrangement of the hoist mechanism or hook/hook block is such that the hook suspension can be brought to an inclined position in a loaded condition, the bending moment at the shank caused by this inclination shall be considered in the design calculations. Such an inclination can be caused e.g. by:

- a) differences in hoist travel distances between two separate hoist drives carrying a load beam with a hook, see Figure 3;

- b) tilting of a single rope reeving during hoisting/lowering motion, see Figure 4;
- c) tilting of a crane part, to which a hook is rigidly attached; or
- d) two-blocking of a bottom block in the uppermost hoist position with a crane part, after which this crane part is tilted.

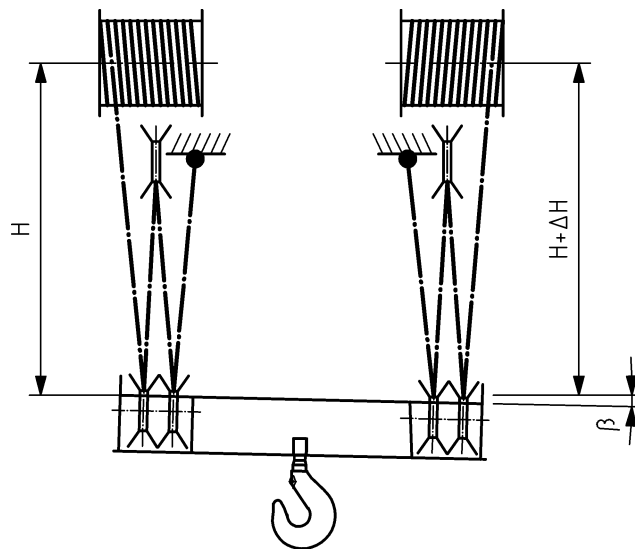


Figure 3 — Tilting of a hook in case of different distances of lifting movement

Due to an inclination, the vertical force has a force component perpendicular to the axis of the hook shank. This force shall be taken into account in the same way as the horizontal forces. The bending moment M_2 caused at the critical hook shank section is proportional to the vertical design force as follows:

$$M_2 = F_{Sd,s} \times h_s \times \sin(\beta) \quad (5)$$

where

$F_{Sd,s}$ is the vertical design force in accordance with 5.2, related to the condition with a hook inclination β ;

β is the maximum, total inclination in each relevant load combination;

h_s is the vertical distance from the seat bottom of the hook body to the upper end of the thinnest part of the hook shank.

In a rope balanced hook suspension with multiple rope falls and a single running rope coming from the drum, the hoisting/lowering movement causes the hook suspension to tilt, see Figure 4. The inclination shall be calculated as follows:

$$\beta = \arctan(C_t/h) \quad (6)$$

where

C_t is the relative tilting resistance of the hook suspension in accordance with Annex H;

h is the vertical distance from the seat bottom of the hook body to the centre of the articulation.

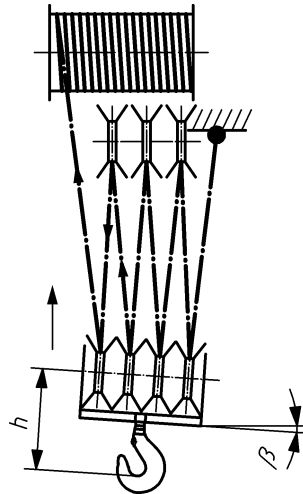


Figure 4 — Tilting of a hook suspension in a single rope reeving system

The maximum inclination, the related vertical force and the consequent moment M_2 shall be calculated separately for all relevant loading conditions of the crane.

5.4.4 Bending moment due to eccentricity of vertical force

A hoist load attachment does not always settle in the middle of the hook seat. The deviation of the vertical load action line from the centre line of the shank causes a bending moment, which shall be calculated as follows:

$$M_3 = c_e \times F_{Sd,s} \times a_1 \quad (7)$$

where

$F_{Sd,s}$ is the vertical design force in accordance with 5.2;

a_1 is the seat circle diameter of the hook body;

c_e is a coefficient for the eccentricity;

$c_e = 0,05$.

A smaller eccentricity may be used in the design calculations, if a positive, mechanical means is provided ensuring that the hoist load attachment settles closer to the hook seat centre.

5.4.5 Exceptional case for ramshorn hooks

The foreseeable misuse that a ramshorn hook is loaded on one prong only shall be taken into account as an exceptional load case. Therefore, it shall be assumed, that half of the rated load acts on one prong while the other prong is unloaded. This loading case shall be addressed in the calculations to the load combination C, with $\gamma_p = 1$, see 5.2.

For a ramshorn hook with one-sided loading, the bending moment M_4 due to eccentricity of the loading at the machined undercut section with a diameter d_4 , (see Figure 1, assumed thinnest hook shank section) shall be calculated as follows:

$$M_4 = F_{Sd,s} / 2 \times \left[e_R \times (1 - h_s / h) + h_s / h \times \min \left\{ \frac{e_R}{C_t} \right\} \right] \quad (8)$$

with

$$e_R = (a_1 + d_1) / 2$$

where

$F_{Sd,s}$ is the vertical design force in accordance with 5.2;

d_1 is the diameter of the unmachined shank;

a_1 is the seat circle diameter of the hook;

e_R is the distance from the load action point in the hook seat to the centre line of the shank;

h is the vertical distance from the seat bottom of the hook body to the centre of the articulation;

h_s is the vertical distance from the seat bottom of the hook body to the upper end of the hook undercut section, see Figure 1;

C_t is the relative tilting resistance of the hook suspension, see Annex H.

NOTE Formula (8) gives a slightly conservative method to calculate the moment at the machined section of the shank. Calculation of stresses in the unmachined shank section of ramshorn hooks in this exceptional case is given in 5.5.3 and Formula (12).

5.4.6 Design bending moment of the shank

The design bending moment at the critical shank section $M_{Sd,s}$ for the loading conditions in accordance with 5.4.2 to 5.4.4 shall be calculated separately for each relevant load combination as follows:

$$M_{Sd,s} = \min \left\{ \begin{array}{l} (M_1 + M_2 + M_3) \\ h_s / h \times C_t \times F_{Sd,s} \end{array} \right\} \quad (9)$$

where

M_1 to M_3 are the bending moments in accordance with 5.4.2 to 5.4.4;

C_t is the relative tilting resistance of the hook suspension, see Annex H;

$F_{Sd,s}$ is the vertical design force in accordance with 5.2.

Additionally to the above, the design bending moment in accordance with the exceptional case of 5.4.5 shall be taken into account in a load combination C as follows:

$$M_{Sd,s} = M_4 + H_{Sd,s} \times h_s \quad (10)$$

where

M_4 is the bending moment in accordance with 5.4.5;

$H_{Sd,s}$ is the horizontal design force in accordance with 5.3, calculated with a half of the rated load.

5.5 Hook body, design stresses

5.5.1 Loadings

The vertical design force $F_{Sd,s}$ is divided into two force components, acting in the centre of the seat circle symmetrically on the opposite sides of the vertical centre line and in an angle α in respect to vertical, see Figure 5.

As a minimum value of α , it shall be assumed that $\alpha = 45^\circ$.

For ramshorn hooks, an equal load distribution is assumed between the two prongs in load combinations A and B.

As an exceptional loading case, for ramshorn hooks it shall be assumed that half of the vertical force acts on one prong while the other prong is unloaded. This loading case shall be addressed in the calculations to the load combination C.

The horizontal forces may be neglected in the hook body calculations.

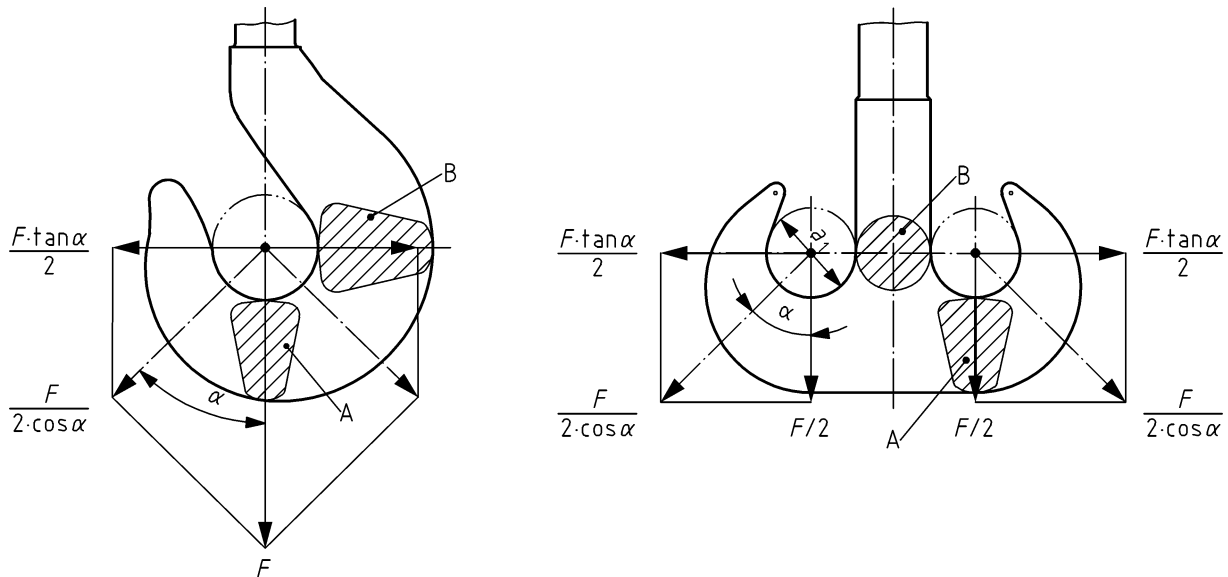


Figure 5 — Load actions on hook body and critical sections for calculation

5.5.2 Stress determination methods

Stresses in the designated sections of a hook body shall be analysed by either of the following:

- the theory of curved beam bending, an outline of which is given in Annex G;
- finite element method.

Stresses in section B of a ramshorn hook may, however, be analysed by the conventional beam bending theory.

5.5.3 Design stresses applying curved beam bending theory

The design stresses σ_{Sd} in sections A and B of single hooks and in the section A of ramshorn hooks shall be calculated as follows:

$$\sigma_{Sd,s} = \frac{\nu \times F_{Sd,s} \times R \times \eta_1}{I} \times \frac{1}{1 - \eta_1/R} \quad (11)$$

with

$$R = a_1 / 2 + \eta_1$$

and

$$\nu = 1 \quad \text{for section B of single hooks;}$$