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Incorporating corrigenda November 2012 and October 2014



BSI Standards Publication

Cranes — General design

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

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National foreword

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Users' attention is drawn to the fact that neither BS 2573-1:1983 nor BS 2573-2:1980 should be used in conjunction with the EN 13001 series as they are not complementary. The BS 2573 series will remain current until all parts of the BS EN 13001 series cited above have been published to ensure that a coherent package of standards remains available to the UK during the transition to European standards.

The publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than 3 years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of Update Standards.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international Standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

The UK participation in its preparation was entrusted by Technical Committee MHE/3, Cranes and derricks, to Subcommittee MHE/3/1, Crane design.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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

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

This Technical Specification (CEN/TS) was approved by CEN on 31 August 2009 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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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, $g = 9,81 \text{ m/s}^2$
$H_{Sd,s}$	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, $N_D = 2 \times 10^6$
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 according to EN ISO 4287:1998
R_z	Maximum depth of surface profile according to EN ISO 4287:1998
r_g	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
$\beta_R, \beta_{nS}, \beta_{nT}$	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

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
$\sigma_{Tmax}, \sigma_{T1}, \sigma_{T2}$	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

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
$T \geq -30\text{ °C}$	-20 °C	27 J
$-30\text{ °C} > T \geq -40\text{ °C}$	-30 °C	
$-40\text{ °C} > T \geq -50\text{ °C}$	-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/mm ²	Ultimate strength f_u N/mm ²
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 $[0 ; + 7 \text{ \%}]$ of the nominal dimension. The point height dimension a_3 shall be within $[- 7 \text{ \%} ; + 7 \text{ \%}]$ of the nominal dimension.

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

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 $475 \text{ }^\circ\text{C}$.

The normalizing or tempering conditions shall be at least as effective as a temperature of $475 \text{ }^\circ\text{C}$ 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 $0,25 \text{ \%}$;
- 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.

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 forged shank.

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

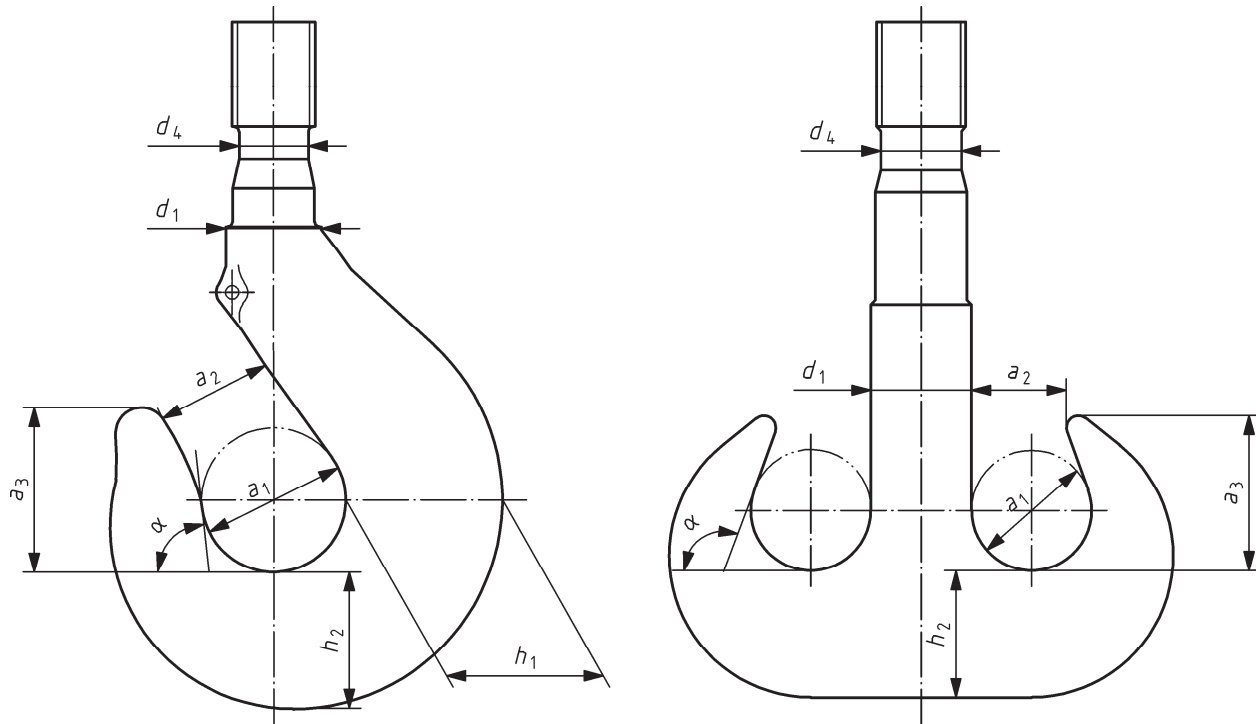


Figure 1 — Hook dimensions

The diameter of the forged 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 $a_o \geq 0,7 a_1$.

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

Annexes A and B present example sets of hook body dimensions, which fulfil the requirements of this clause.

4.7 Hook shank machining

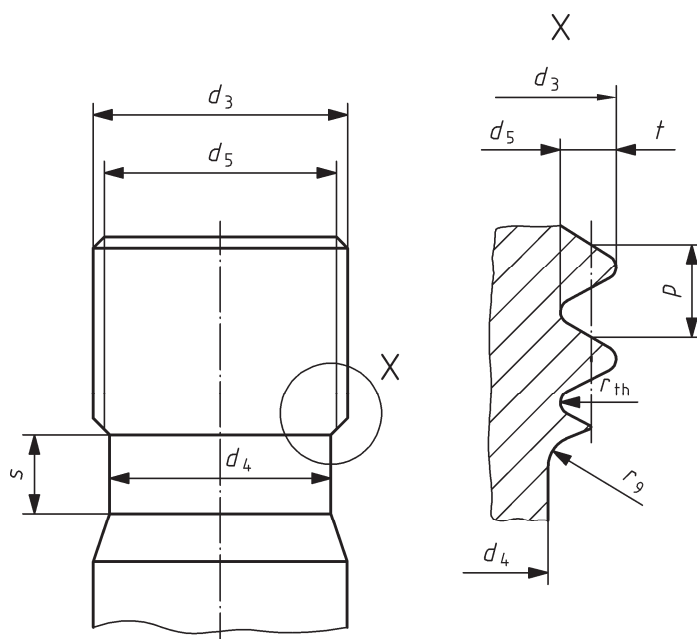


Figure 2 — Machined dimensions of shank

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 $R_a \leq 3,2 \mu\text{m}$ and shall be free from machining marks and defects.

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 forged 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 forged body.

Screwed threads shall comply with the tolerance requirements of ISO 965-1 (coarse series) and be of medium fit class 6g.

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

4.8 Nut

The material grade of the nut shall be equal to that of the hook

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 locked by a dowel or other similar fixing media, it is essential during the locking process that the nut/shank load bearing thread flanks are in direct contact to ensure resultant unimpaired load transmission.

The nut shall rest on an anti-friction bearing, enabling the hook body to rotate about the vertical axis. The contact surface of the nut resting on the bearing shall meet the requirements as stipulated by the related bearing. 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 (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.

4.9 Hook suspension

In general, and always for serially produced hook blocks, the hook suspension together with hoist rope reeving system shall be such that the system allows free tilting of the hook in any inclined direction of the load line. In cases where this articulation of the hook suspension is not provided, this shall be specially taken into consideration in the design calculations of the hook. 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.

The same load actions as specified for the hook shall be taken into account in the design of the hook suspension.

5 Static strength

5.1 General

The proof of static strength for hooks shall be carried out in accordance with principles of EN13001-1 and EN13001-2. The general design limit for static strength is 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. The relevant partial safety factors γ_p shall be applied. The risk coefficients γ_n shall be applied when required in the specific application or as specified in the relevant European crane type standard.

5.2 Vertical design load

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

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

$$\text{with } \phi = \max \left\{ \phi_2; \left(1 + \phi_5 \times \frac{a}{g} \right) \right\}$$

where

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

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

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 EN13001-2;

$\gamma_p = 1,34$ 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);

γ_n is the risk coefficient.

Other load actions and combinations of EN13001-2 may 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 EN13001-2;

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. Other horizontal forces e.g. due to wind or sideways pull actions shall be taken into account, if significant. 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:

$$H_{Sd,s} = \min \left\{ m_{RC} \times a \times \phi_5 \times \gamma_p \times \gamma_n \right. \\ \left. C_t \times F_{Sd,s} / h \right\} \quad (3)$$

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. 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 Equation (1);

γ_n is the risk coefficient;

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

$F_{Sd,s}$ 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 action 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 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 upper end of the thinnest part of the hook shank.

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 may 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 may 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.

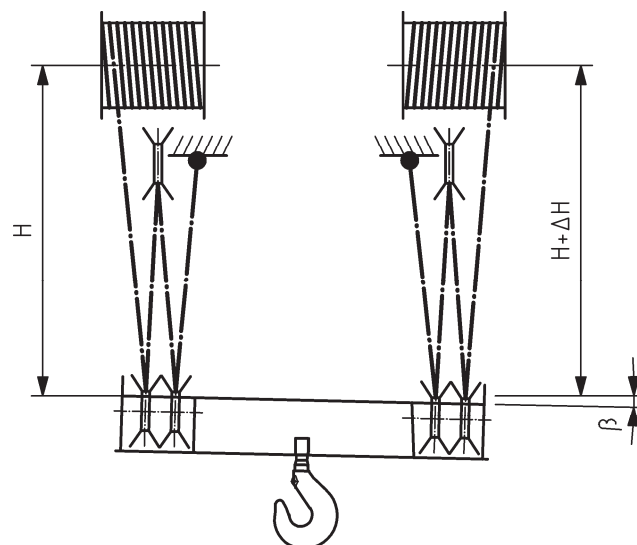


Figure 3 — Tilting of a hook in case of different hoist travel distances

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 is 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 I;

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

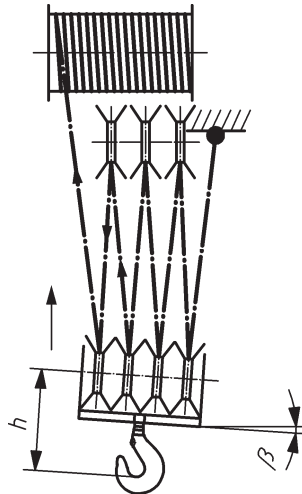


Figure 4 — Tilting of a hook suspension in a single rope reeving system

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 may 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;

$c_e = 0,05$.

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

5.4.5 Special case for a ramshorn hook

As a special 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 is addressed in the calculations to the load combination C.

For a ramshorn hook with one-sided loading, the bending moment M_4 caused at the critical hook shank section is 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 and γ_p for load combination C;

d_1 is the diameter of the forged shank;

a_1 is the seat circle diameter of the hook;

e_R is the distance of the vertical load line from 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 thinnest part of the hook shank;

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

5.4.6 Design bending moment of the shank

In general, 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:

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

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 I;

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

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

$$M_{Sd,s} = M_4 \quad (10)$$

where

M_4 is the bending moment in accordance with 5.4.5.

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 a special 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 is addressed in the calculations to the load combination C.

The horizontal forces are neglected in the hook body calculations.

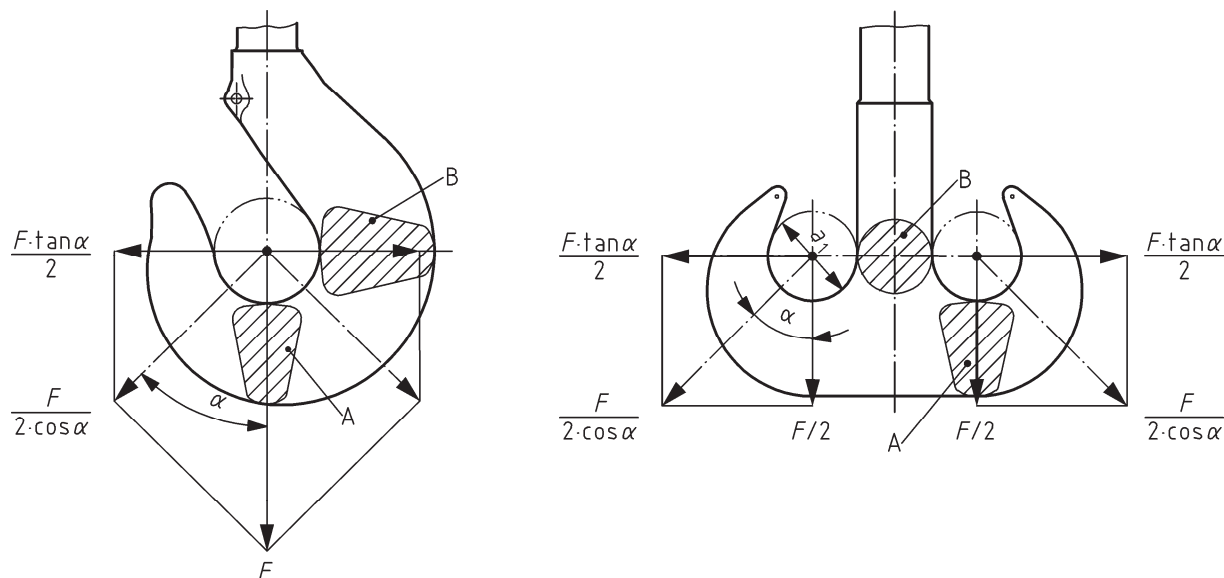


Figure 5 — Load actions on hook body and critical sections for calculation

5.5.2 Stress calculation methods

Stresses in the designated sections of a hook body shall be analysed either by the theory of curved beam bending in accordance with Annex H, by finite element methods or by full scale experiments. Stresses in section B of a ramshorn hook may, however be analysed by the conventional beam bending theory.

The following clauses are based upon the theory of curved beam bending.

5.5.3 Design stresses

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

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

$$\nu = 0,5 \times \tan \alpha \quad \text{for section A of single and ramshorn hooks, } \alpha = 45^\circ;$$

where

R is the hook curvature radius determined by the centroid of the section;

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

- I is the reference moment of inertia for curved beam;
- a_1 is the seat circle diameter of the hook;
- η_1 is the absolute value of the coordinate y at inner edge of the particular section;
- α is the angle of the load action lines in respect to vertical, see Figure 5.

The quantities η_1 and I are section specific values and shall be calculated in accordance with Annex H.

The design stress in the section B of ramshorn hook for the special case of 5.4.5 shall be calculated as follows:

$$\sigma_{Sd,s} = \frac{F}{A_{d1}} + \frac{F \times (a_1 + d_1) \times d_1 / 4}{I_{d1}} \quad (12)$$

with

$$F = F_{Sd,s} / 2$$

where

- $F_{Sd,s}$ is the vertical design force in accordance with 5.2 and γ_p for load combination C;
- A_{d1} is the cross section area of the forged shank;
- I_{d1} is the moment of inertia of the forged shank;
- d_1 is the diameter of the forged shank;
- a_1 is the seat circle diameter of the hook.

5.6 Hook shank, design stresses

The vertical design forces in accordance with 5.2 and the design bending moments in accordance with 5.4 shall be taken into account in the proof calculations of a hook shank. In general, the critical section of the shank is the undercut part immediately below the threaded section with a diameter d_4 , see Figure 1. Maximum design stress $\sigma_{Sd,s}$ is calculated as a nominal stress without stress concentration factors and using conventional beam bending theory as follows:

$$\sigma_{Sd,s} = \frac{F_{Sd,s}}{A_{d4}} + \frac{M_{Sd,s} \times d_4 / 2}{I_{d4}} \quad (13)$$

where

- $F_{Sd,s}$ is the vertical design hook force;
- $M_{Sd,s}$ is the design bending moment in the critical section, see 5.4.6;
- A_{d4} is the cross section area of the critical section of the hook shank;
- I_{d4} is the moment of inertia of the critical section of the hook shank.

5.7 Hook, proof of static strength

5.7.1 General for hook body and shank

Both for the hook body and the hook shank, it shall be proven for relevant load actions specified in 5.2 to 5.4 that

$$\sigma_{Sd,s} \leq f_{Rd} = f_1 \times \frac{f_y}{\gamma_m \times \gamma_{sm}} \quad (14)$$

where

$\sigma_{Sd,s}$ is the maximum design stress in accordance with 5.5 and 5.6 in the critical section;

f_{Rd} is the limit design stress;

f_y is the yield stress of the material in the finished product;

f_1 is the influence factor for the operation temperature;

$\gamma_m = 1,1$ is the general resistance coefficient in accordance with EN 13001-2;

γ_{sm} is the specific resistance coefficient for the section as follows:

$\gamma_{sm} = 0,75$ for the hook body section B of single hooks;

$\gamma_{sm} = 0,90$ for other sections.

In the absence of other data, the factor f_1 taking into consideration the reduction of the yield stress in high temperatures may be calculated as follows:

$$\begin{aligned} f_1 &= 1 & \text{For } -50\text{ °C} \leq T \leq 100\text{ °C} \\ f_1 &= 1 - 0,25 \times (T - 100) / 150 & \text{For } 100\text{ °C} < T \leq 250\text{ °C} \end{aligned} \quad (15)$$

where

T is the operation temperature in degrees Celsius (°C).

5.7.2 The use of static limit design force for verification of the hook body

In cases where the selected hook body is in accordance with Annexes A or B, the proof of static strength may be based on the static limit design force shown in Annex C, and it shall be proven for all relevant load actions and combinations specified in 5.2 that

$$F_{Sd,s} \leq f_1 \times F_{Rd,s} \quad (16)$$

where

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

$F_{Rd,s}$ is the static limit design force in accordance with Annex C;

f_1 is the influence factor for the operation temperature in accordance with Equation (15).

NOTE 1 Additionally, the proof of static strength for the shank is carried out in accordance with 5.7.1.