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Cranes — General design — Limit states and proof of competence of forged steel hooks

Appareils de levage à charge suspendue — Conception générale — États limites et vérification d'aptitude des crochets forgés

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 96, *Cranes*, Subcommittee SC 8, *Jib cranes*.

Cranes — General design — Limit states and proof of competence of forged steel hooks

1 Scope

This International Standard is intended to be used together with the other relevant International Standards in its series. As such, they specify general conditions, requirements and methods to prevent hazards in hooks as part of all types of cranes.

This International Standard 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 The principles of this International Standard 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 from one or several parallel parts of rolled steel plates are not covered in this International Standard.

This International Standard is applicable to hooks from materials with ultimate strength of not more than 800 N/mm^2 and yield stress of not 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 International Standard 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 International Standard.

This International Standard is applicable to cranes manufactured after the date of its publication, and serves as a reference base for product standards of particular crane types.

NOTE 2 This International Standard deals only with the limit state method in accordance with ISO 8686-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines*

ISO 643, *Steels — Micrographic determination of the apparent grain size*

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

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

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

ISO 4301-1, *Cranes and lifting appliances — Classification — Part 1: General*

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

ISO 8686-1, *Cranes — Design principles for loads and load combinations — Part 1: General*

ISO 9327-1, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 1: General requirements*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 15579, *Metallic materials — Tensile testing at low temperature*

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

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

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in ISO 12100 and ISO 4306-1 and the following terms, definitions and symbols (see Table 1) apply.

3.1
hook shank
upper part of the hook, from which the hook is suspended to the hoist media of the crane

3.2
hook body
lower, curved part of the hook below the shank

3.3
hook seat
bottom part of the hook body, where the load lifting attachment is resting

3.4
hook suspension articulation
feature of the hook suspension, allowing the hook to tilt along the inclined load line

Table 1 — Symbols

Symbol	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
kQ	Load spectrum factor, in accordance with ISO 8686-1

Table 1 *(continued)*

Symbol	Description
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
$M_{1,\mathrm{f},i}$, $M_{2,\mathrm{f},i}$, $M_{3,\mathrm{f},i}$	Bending moments of hook shank for the proof of fatigue strength, lifting cycle *i*
$M_{\mathrm{Sd,s}}$	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 ISO 4287
R_{z}	Maximum depth of surface profile according to ISO 4287
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
vh, *vs*	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

Table 1 *(continued)*

Symbol	Description
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
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 avoid brittle fracture at the temperature range specified for the use of the hook. Hook material, after forging and heat treatment, shall have minimum elongation and Charpy-V impact toughness in accordance with Table 2.

Table 2 — Impact test and elongation requirements for hook material

Operation temperature	Impact test temperature	Minimum elongation, A_5	Minimum impact toughness, A_v
T ≥ - 10 °C	0 °C	15 %	35 J
T ≥ - 20 °C	− 10 °C		
− 30 °C > *T* ≥ − 40 °C	− 30 °C		
− 40 °C > *T* ≥ − 50 °C	− 40 °C		

To satisfy the requirements of the operating temperature, the manufacturer shall select an alloyed or non-alloyed steel, as appropriate, 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 produced by an electric process or by one of the oxygen processes.

The steel shall be fully killed, stabilized against strain age embrittlement and have an austenitic grain size of 6 or finer when tested in accordance with ISO 643. This shall accomplished, by ensuring that the steel contains sufficient aluminium (minimum 0,025 %) to permit the manufacture of hooks stabilized against strain-age-embrittlement during service.

The steel shall contain no more sulfur and phosphorus than the limits given in Table 3.

Table 3 — Sulfur and phosphorus content

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

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 standardization purposes, a classification of material grades for forged hooks is specified in Table 4. 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	
	Upper yield stress or 0,2 % proof 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
All materials selected shall fulfil the following requirement: $f_u/f_y \geq 1,2$		

4.2 Workmanship

The manufacturing process, factory tests and delivery conditions shall meet the requirements of ISO 9327-1.

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 rolled 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: 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 should be conducted at ambient room temperature and 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 shall be applied after the complete manufacturing process. (forging, heat treatment and machining)

b) The proof load force shall be applied between shank suspension nut and either:

   i) the base of the hook seat, for a straight line pull, parallel with the vertical axis of the shank, in the case of a single point hook.

   ii) two opposite contact points on the hook bowl surface consistent with a symmetrical 90 degree sling spread, and with load lines passing thro' the hook bowl centre(s), in the case of ramshorn hooks.

c) A relative permanent set due to proof loading measured at the gap opening shall not exceed 0,25 %; For batch-produced hooks the proof loading shall be applied to each and every hook in the batch;

d) The magnitude of the proof load ($F_{PL.}$) should reflect a 1,5f_y theoretical maximum tensile stress in the body fibres in section B for single point and section A for ramshorn hooks for the chosen material. The value of this proof load shall be determined as follows relative to either section A(ramshorn) or B(single point) as the case may be:

   Single point hook

$$F_{PL,sp} = \frac{1{,}5 f_y M_{hf.}}{1\ 000}$$

   Ramshorn hook

$$F_{PL.rh.} = \frac{1{,}5 f_y M_{hf.}}{1\ 000 v}$$

   where F_{PL} is expressed in kilonewtons (kN), f_y is the yield stress of the chosen material, and $M_{hf.}$ is a hook factor, i.e. for the hook intradoses of either section A or B, as the case may be, sample data are depicted within Annex C for individual hooks of their particular family.

$$v = 0{,}5 x \tan\alpha$$

   for section A of ramshorn hooks, α = 45° (see 5.5.3)

$M_{hf.}$ is derived from the formula

$$I\,\frac{(1-\eta_1/R)}{(R\eta_1)}$$

All definitions are as per Annex H .

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

f) Proof loaded hook shall be stamped with symbol “PL” adjacent to the hook type marking.

g) The application of proof loading will affect (beneficially) subsequent fatigue performance of the hook. Calculation methodology of an example in Annex F can be used to quantify this effect.

Steels and in particular high strength steels for hooks due to be subjected to proof loading should be selected with due attention to the need of their adequate ductility.

NOTE 1 Additional benefits derived from the application of proof loading to the QA Management process is not addressed within this standard.

NOTE 2 The maximum stressed tensile fibres under F_{PL} will of course yield and a redistribution of stress will occur, resulting in a permanent compressive stress in this tensile area when the proof load is removed

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 with respect to the centre line of the shank.

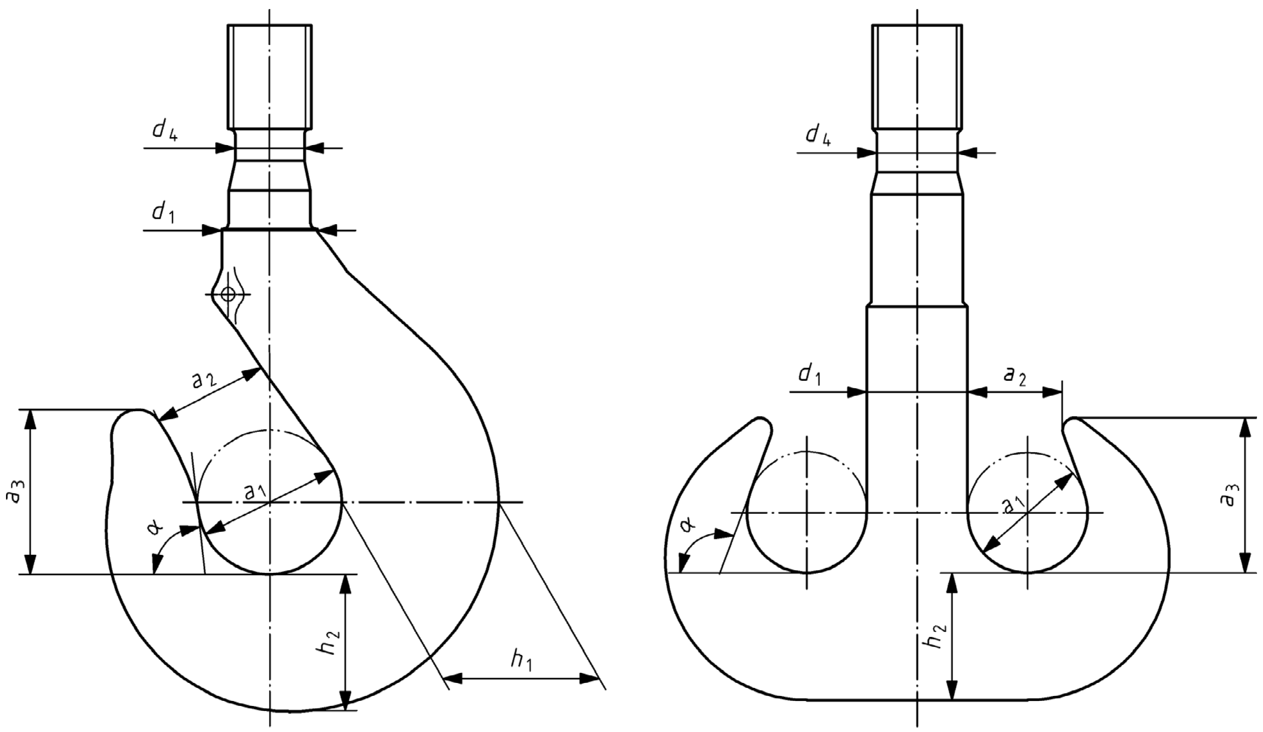

Figure 1 — Hook dimensions

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 $\alpha \geq 60°$, for a ramshorn hook $\alpha \geq 90°$

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: $a_3 \geq a_1$.

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

Other hook bodies differing from those shown within Annexes A and B can be technically assessed, either individually or as national groups to the requirements of this standard, provided dimensional characteristics shown within this clause and material requirements are fulfilled.

Furthermore, it is expected that other hook body sets in addition to those currently shown can and will be put forward for inclusion as national groups, within Annexes A and B. in the future.

4.7 Hook shank machining

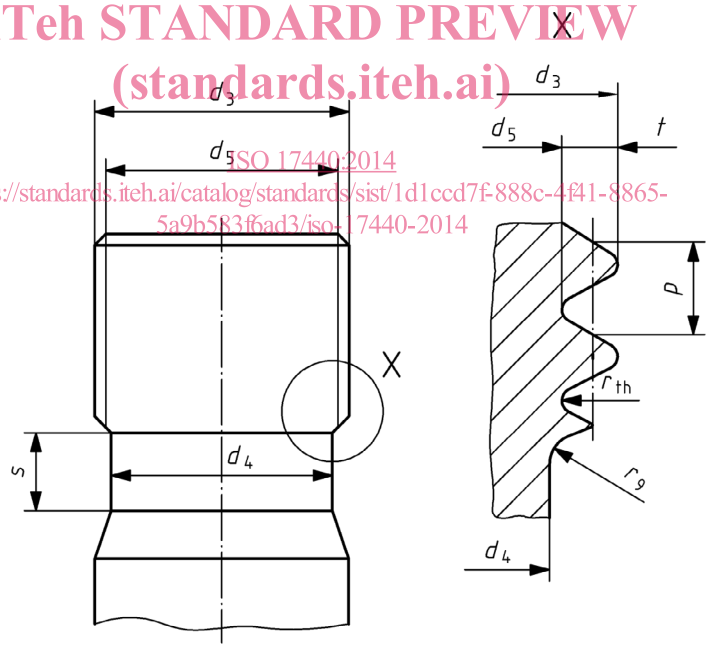

Figure 2 — Machined dimensions of shank

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