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Cranes - General design - Part 3-6: Limit states and proof of competence of machinery - Hydraulic cylinders

Krane - Konstruktion allgemein - Teil 3   6: Grenzzustände und Sicherheitsnachweis von Maschinenbauteilen - Hydraulikzylinder

Appareils de levage à charge suspendue - Conception générale - Partie 3-6 : États limites et vérification d'aptitude des éléments de mécanismes - Vérins hydrauliques

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European foreword

This document (EN 13001-3-6:2018) has been prepared by Technical Committee CEN/TC 147 "Cranes — Safety", the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2018, and conflicting national standards shall be withdrawn at the latest by August 2018.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

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For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

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Introduction

This European Standard has been prepared to be a harmonized standard to provide one means for the mechanical design and theoretical verification of cranes to conform with the essential health and safety requirements of the Machinery Directive, as amended. This standard 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 European Standard is a type C standard as stated in EN ISO 12100:2010.

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

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

1 Scope

This European Standard is to be used together with EN 13001-1, EN 13001-2 and EN 13001-3-1 as well as pertinent crane type product EN standards, and as such they specify general conditions, requirements and methods to, by design and theoretical verification, prevent mechanical hazards of hydraulic cylinders that are part of the load carrying structures of cranes. Hydraulic piping, hoses and connectors used with the cylinders, as well as cylinders made from other material than carbon steel, are not within the scope of this standard.

The following are significant hazardous situations and hazardous events that could result in risks to persons during intended use and reasonably foreseeable misuse. Clauses 4 to 7 of this standard are necessary to reduce or eliminate risks associated with the following hazards:

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

b) elastic instability (column buckling).

NOTE EN 13001–3–6 deals only with the limit state method in accordance with EN 13001–1.

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 10083-2:2006, *Steels for quenching and tempering — Part 2: Technical delivery conditions for non alloy steels*

EN 10210-2:2006, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

EN 10216-3:2013, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 3: Alloy fine grain steel tubes*

EN 10277-2:2008, *Bright steel products — Technical delivery conditions — Part 2: Steels for general engineering purposes*

EN 10305-1:2016, *Steel tubes for precision applications — Technical delivery conditions — Part 1: Seamless cold drawn tubes*

EN 10305-2:2016, *Steel tubes for precision applications — Technical delivery conditions — Part 2: Welded cold drawn tubes*

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

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

EN 13001-3-1, *Cranes — General Design — Part 3-1: Limit States and proof competence of steel structure*

EN 13445-2:2014, *Unfired pressure vessels — Part 2: Materials*

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

EN ISO 5817:2014, *Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections (ISO 5817:2014)*

EN ISO 8492:2013, *Metallic materials — Tube — Flattening test (ISO 8492:2013)*

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

ISO 724:1993, *ISO general-purpose metric screw threads — Basic dimensions*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 12100:2010 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Symbols an abbreviations

The essential symbols and abbreviations are given in Table 1.

Table 1 — Symbols and abbreviations

Symbols	Description
$A\%$	Percentage elongation at fracture
a	Weld throat thickness
A_i, B_i, C_i, D_i	Constants
A_s	Stress area
D	Piston diameter
d	Rod diameter
$D_{a,i}$	Diameter of axles
D_p	Pressure affected diameter
D_w	Weld diameter
E	Modulus of elasticity
F	Compressive force
F_A	Compressive force
FE	Finite Elements
f_{Rd}	Limit design stress
$f_{Rd\sigma}$	Limit design stress, normal

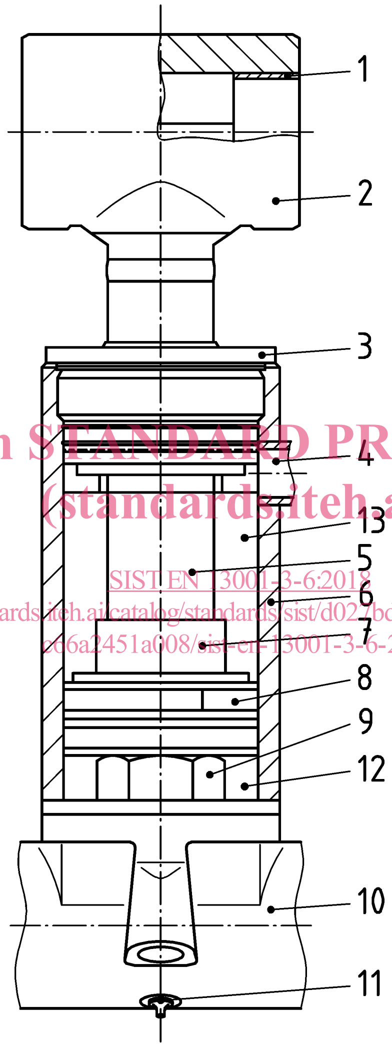
Symbols	Description
$f_{Rd\tau}$	Limit design stress, shear
F_S	Lateral force
F_{Sd}	External design force
f_u	Ultimate strength
$f_{w,Rd}$	Limit design weld stress
f_y	Yield strength
h	thickness of the cylinder bottom
I	Moment of inertia, generic
I_1	Moment of inertia of the tube
I_2	Moment of inertia of the rod
L	Overall length of the cylinder
L_1	Length of the cylinder tube
L_2	Length of the cylinder rod
m	Slope of the log $\Delta\sigma$ – log N curve
M_0	Shell section bending moment, acting at the intersection between tube and bottom
MB	Bending moment
N	Compressive force
N_k	Critical buckling load
N_{Rd}	Limit compressive design force
N_{Sd}	Compressive design force
p_{i1}	Maximum pressure in piston side chamber
p_{i2}	Maximum pressure in rod side chamber
p_o	Outer pressure
p_{Sd}	Design pressure
R	Middle radius of the tube ($R = R_i + t/2$)
r_i	Inner radius of the tube
R_i	Inner radius of the tube
r_o	Outer radius of the tube
r_r	Outer radius of the piston rod

Symbols	Description
s_3	Stress history parameter (see EN 13001–3-1)
t	Wall thickness of the tube
T_0	Shell section transverse force, acting at the intersection between tube and bottom
x, y	Longitudinal and lateral coordinates
α	Angular misalignment, radians
γ_m	General resistance factor (γ_m = 1,1, see EN 13001–2)
γ_{mf}	Fatigue strength specific resistance factor (see EN 13001–3-1)
γ_R	Total resistance factor ($\gamma_R = \gamma_m \cdot \gamma_s$)
γ_s	Specific resistance factor
$\Delta\sigma$	Stress range
$\Delta\sigma_b$	Bending stress range in the tube
$\Delta\sigma_c$	Characteristic fatigue strength
$\Delta\sigma_m$	Membrane stress range in the tube (axial)
$\Delta\sigma_{Rd}$	Limit design stress range
$\Delta\sigma_{Sd}$	Design stress range
Δp_{Sd}	Design pressure range on piston side
δ_{max}	Maximum displacement
κ	Reduction factor for buckling
λ	Slenderness
λ_i	Friction parameters
μ_i	Friction factors
ν	Poisson's ratio (ν = 0,3 for steel)
σ_a	Axial stress in the tube
σ_b	Lower extreme value of a stress range
σ_r	Radial stress in the tube
σ_{Sd}	Design stress, normal
σ_t	Tangential stress in the tube (hoop stress)
σ_u	Upper extreme value of a stress range
$\sigma_{w,Sd}$	Weld design stress, normal

Symbols	Description
τ_{Sd}	Design stress, shear
$\tau_{w,Sd}$	Weld design stress, shear

3.3 Terminology

Terms which are used in this European Standard for the main parts of hydraulic cylinder are indicated in Figure 1 to Figure 3.

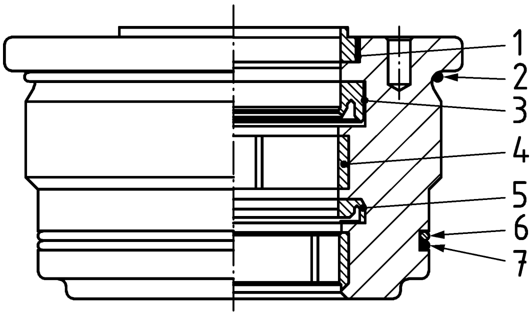


Key

1 bushing
2 rod head
3 cylinder head
4 oil connector
5 piston rod
6 cylinder tube
7 spacer
8 piston
9 nut

10 cylinder bottom
11 grease nipple
12 piston side chamber
13 rod side chamber

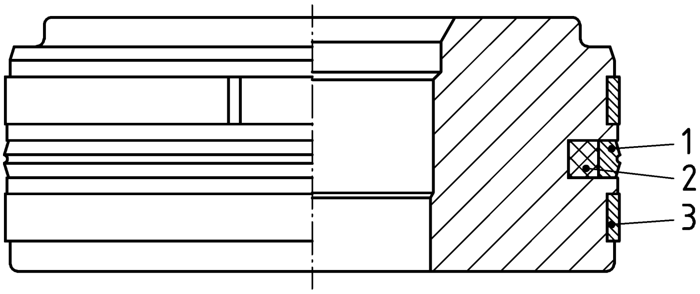
Figure 1 — Complete cylinder



Key

1 wiper
2 O-ring
3 secondary seal
4 guide ring (2 ×)
5 primary seal
6 backup ring
7 O-ring

Figure 2 — Cylinder head



Key

1 seal
2 pressure element
3 guide ring (2 ×)

Figure 3 — Piston

The figures above show some specific design features in order to exemplify the terminology. Other designs may be used.

4 General

4.1 Documentation

The documentation of the proof of competence shall include:

— design assumptions including calculation models;

— applicable loads and load combinations;

— material grades and qualities;

— weld quality levels, in accordance with EN ISO 5817:2014 and EN 13001-3-1;

— relevant limit states;

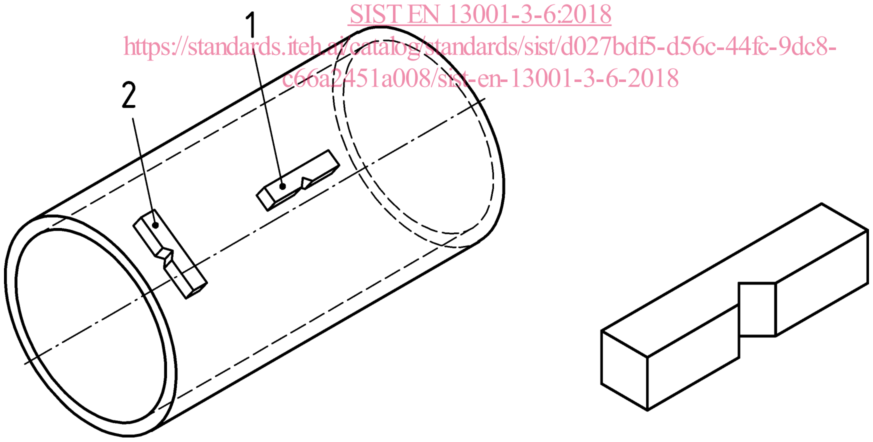
— results of the proof of competence calculation, and tests when applicable.

4.2 Materials for hydraulic cylinders

4.2.1 General requirements

The materials for tubes and rods that are subjected to internal pressure shall fulfil the following requirements:

— The impact toughness in the transversal direction shall be tested in accordance with EN ISO 148-1 and shall meet the requirements stated in EN 13001-3-1. Samples shall be cut out in the transversal direction and prepared such that the axis of the notch is perpendicular to the surface of the tube.



Key

1 sample cut out in longitudinal direction

2 sample cut out in transversal direction

Figure 4 — Sample for impact toughness testing

— If the material thickness or tube dimensions do not allow samples to be cut out, the tube material shall pass a flattening test in accordance with EN ISO 8492. For welded tubes two test are required, one with the weld aligned with the press direction and one where the weld is placed 90 degrees from the press direction. The tube section shall be flattened down to a height *H* given by:

$$H = \frac{1,07 \cdot t}{0,07 + \frac{t}{D_o}}$$

where

D_o is the outer diameter of the tube;

t is the wall thickness of the tube.

Material used in other parts shall meet the requirements stated in EN 13001-3-1.

4.2.2 Grades and qualities

European Standards specify materials and specific values. This standard gives a preferred selection. Steels in accordance with the following European Standards shall be used as tube material:

— EN 10083-2;

— EN 10210-2;

— EN 10216-3;

— EN 10277-2;

— EN 10305-1;

— EN 10305-2;

— EN 13445-2.

Alternatively, other steel grades and qualities than those listed in this clause may be used as tube material provided that they comply with the following requirements:

— the design value of f_y is limited to $f_u/1,1$ for materials with $f_u/f_y < 1,1$;

— the percentage elongation at fracture A % ≥ 14 % on a gauge length $L_0 = 5,65 \times \sqrt{S_0}$ (where S_0 is the original cross-sectional area);

Grades and qualities of materials used in other parts of cylinders or mounting interfaces of cylinders shall be selected in accordance with EN 13001-3-1.

5 Proof of static strength

5.1 General

A proof of static strength by calculation is intended to prevent excessive deformations due to yielding of the material, elastic instability and fracture of structural members or connections. Dynamic factors given in EN 13001-2 or relevant product standards are used to produce equivalent static loads to simulate dynamic effects. Also, load increasing effects due to deformation shall be considered. The use of the theory of plasticity for calculation of ultimate load bearing capacity is not considered acceptable within the terms of this standard. The proof shall be carried out for structural members and connections while taking into account the most unfavourable load effects from the load combinations A, B or C in accordance with EN 13001-2 or relevant product standards.