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High-strength structural bolting assemblies for preloading – Part 7: System HR – Countersunk head bolt and nut assemblies English version of DIN EN 14399-7:2008-03

Hochfeste planmäßig vorspannbare Schraubenverbindungen für den Metallbau –
Teil 7: System HR –
Garnituren aus Senkschrauben und Muttern
Englische Fassung DIN EN 14399-7:2008-03

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National foreword

This standard has been prepared by Technical Committee CEN/TC 185 “Fasteners” (Secretariat: DIN, Germany).

The responsible German body involved in its preparation was the *Normenausschuss Mechanische Verbindungselemente* (Fasteners Standards Committee), Technical Committee NA 067-03-04 AA *Schraubenverbindungen für den Stahlbau*.

Countersunk head bolts as in this standard have full loadability in accordance with their property class as in ISO 898-1. This means that they can withstand the minimum ultimate tensile loads specified in ISO 898-1 and that failure due to overloading during tensile loading occurs in the free threaded length.

The European Standards referred to in clause 2 of the EN have been published as the corresponding DIN EN Standards with the same number. The DIN Standards corresponding to the International Standards referred to in clause 2 of the EN are as follows:

ISO 261	DIN ISO 261
ISO 965-2	DIN ISO 965-2
ISO 965-5	DIN ISO 965-5

National Annex NA
(informative)

Bibliography

DIN ISO 261, *ISO general purpose metric screw threads — General plan*

DIN ISO 965-2, *ISO general purpose metric screw threads — Tolerances — Part 2: Limits of sizes for general purpose external and internal screw threads; medium quality*

DIN ISO 965-5, *ISO general purpose metric screw threads — Tolerances — Part 5: Limits of sizes for internal screw threads to mate with hot-dip galvanized external screw threads with maximum size of tolerance position h before galvanizing*

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 14399-7

December 2007

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English Version

High-strength structural bolting assemblies for preloading - Part 7: System HR - Countersunk head bolt and nut assemblies

Boulonnerie de construction métallique à haute résistance apte à la précontrainte - Partie 7: Système HR - Boulons à tête fraisée (vis et écrou)

Hochfeste planmäßig vorspannbare Schraubenverbindungen für den Metallbau - Teil 7: System HR - Garnituren aus Senkschrauben und Muttern

This European Standard was approved by CEN on 10 November 2007.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 14399-7:2007) has been prepared by Technical Committee CEN/TC 185 “Fasteners”, the secretariat of which is held by DIN.

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 June 2008, and conflicting national standards shall be withdrawn at the latest by June 2010.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, 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 document for structural bolting reflects the situation in Europe where two technical solutions exist to achieve the necessary ductility of bolt/nut/washer assemblies. These solutions utilize different systems (HR and HV) of bolt/nut/washer assemblies, see Table 1. Both systems are well proved and it is up to the experts responsible for structural bolting whether they use the one or the other system.

It is however important for the performance of the assembly to avoid mixing up the components of both systems. Therefore bolts and nuts for both systems are standardized in one single part of this European Standard each and the marking of the components of the same system is uniform.

Table 1 — Systems of bolt/nut/washer(s) assemblies

	Bolt/nut/washer(s) assembly System HR		**Bolt/nut/washer(s) assembly System HV**
General requirements	EN 14399-1		
Bolt/nut assemblies	EN 14399-3, EN 14399-7		EN 14399-4, EN 14399-8
Marking	HR		HV
Property classes	8.8/8 or 8.8/10	10.9/10	10.9/10
Washer(s)	EN 14399-5 or EN 14399-6		EN 14399-5 or EN 14399-6
Marking	H		H
Suitability test for preloading	EN 14399-2		EN 14399-2

Preloaded bolted assemblies are very sensitive to differences in manufacture and lubrication. Therefore it is important that the assembly is supplied by one manufacturer who is always responsible for the function of the assembly.

For the same reason it is important that the coating of the assembly is under the control of the manufacturer.

Beside the mechanical properties of the components, the functionality of the assembly requires that the specified preload can be achieved if the assembly is tightened with a suitable procedure. For this purpose a test method for the suitability of the components for preloading was created which will demonstrate whether the function of the assembly is fulfilled.

Attention is drawn to the importance of ensuring that the bolts are correctly used if satisfactory results are to be obtained. For recommendations concerning proper application, reference to prEN 1090-2 is made.

1 Scope

This document belongs to the suite of European Standards EN 14399 and is designed to be read in conjunction with EN 14399-1 for:

— general requirements;

— testing for conformity evaluation;

— evaluation of conformity;

— regulatory marking;

for assemblies of high-strength structural countersunk bolts and nuts of system HR suitable for preloaded joints with thread sizes M12 to M36 and bolt property classes 8.8 and 10.9 and EN 14399-2 for suitability testing.

This document gives requirements for:

— dimensions;

— associated washer(s) according to EN 14399-5 or to EN 14399-6;

— performance and suitability tests;

for assemblies with thread sizes M12 to M36 and bolt property classes 8.8 and 10.9.

Countersunk bolt and nut assemblies to this document have been designed to allow preloading of at least 0,7 $f_{ub} \times A_s$[1)] according to EN 1993-1-8 (Eurocode 3) and to obtain ductility predominantly by elongation of the bolt. For this purpose the components have the following characteristics:

— nut height according to style 1 (see EN ISO 4032),

— thread length of the bolt according to ISO 888.

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 1993-1-8, *Eurocode 3: Design of steel structures — Part 1-8: Design of joints*

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

EN 14399-1:2005, *High-strength structural bolting assemblies for preloading - Part 1: General requirements*

EN 14399-2:2005, *High-strength structural bolting assemblies for preloading - Part 2: Suitability test for preloading*

EN 14399-5, *High-strength structural bolting assemblies for preloading - Part 5: Plain washers*

EN 14399-6, *High-strength structural bolting assemblies for preloading - Part 6: Plain chamfered washers*

1) f_{ub} is the nominal tensile strength (R_m) and A_s is the nominal stress area of the bolt.

EN 20898-2*, Mechanical properties of fasteners - Part 2: Nuts with specified proof load values - Coarse thread (ISO 898-2:1992)*

EN 26157-1, *Fasteners - Surface discontinuities - Part 1: Bolts, screws and studs for general requirements (ISO 6157-1:1988)*

EN ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs (ISO 898-1:1999)*

EN ISO 3269, *Fasteners - Acceptance inspection (ISO 3269:2000)*

EN ISO 4032*, Hexagon nuts, style 1 - Product grades A and B (ISO 4032:1999)*

EN ISO 4759-1, *Tolerances for fasteners - Part 1: Bolts, screws, studs and nuts - Product grades A, B and C (ISO 4759-1:2000)*

EN ISO 6157-2, *Fasteners - Surface discontinuities - Part 2: Nuts (ISO 6157-2:1995)*

EN ISO 10684, *Fasteners - Hot dip galvanized coatings (ISO 10684:2004)*

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

ISO 261, *ISO general purpose metric screw threads — General plan*

ISO 888, *Bolts, screws and studs — Nominal lengths, and thread lengths for general purpose bolts*

ISO 965-2, *ISO general purpose metric screw threads - Tolerances - Part 2: Limits of sizes for general purpose external and internal screw threads - Medium quality*

ISO 965-5, *ISO general purpose metric screw threads - Tolerances - Part 5: Limits of sizes for internal screw threads to mate with hot-dip galvanized external screw threads with maximum size of tolerance position h before galvanizing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14399-1:2005 and 14399-2:2005 apply.

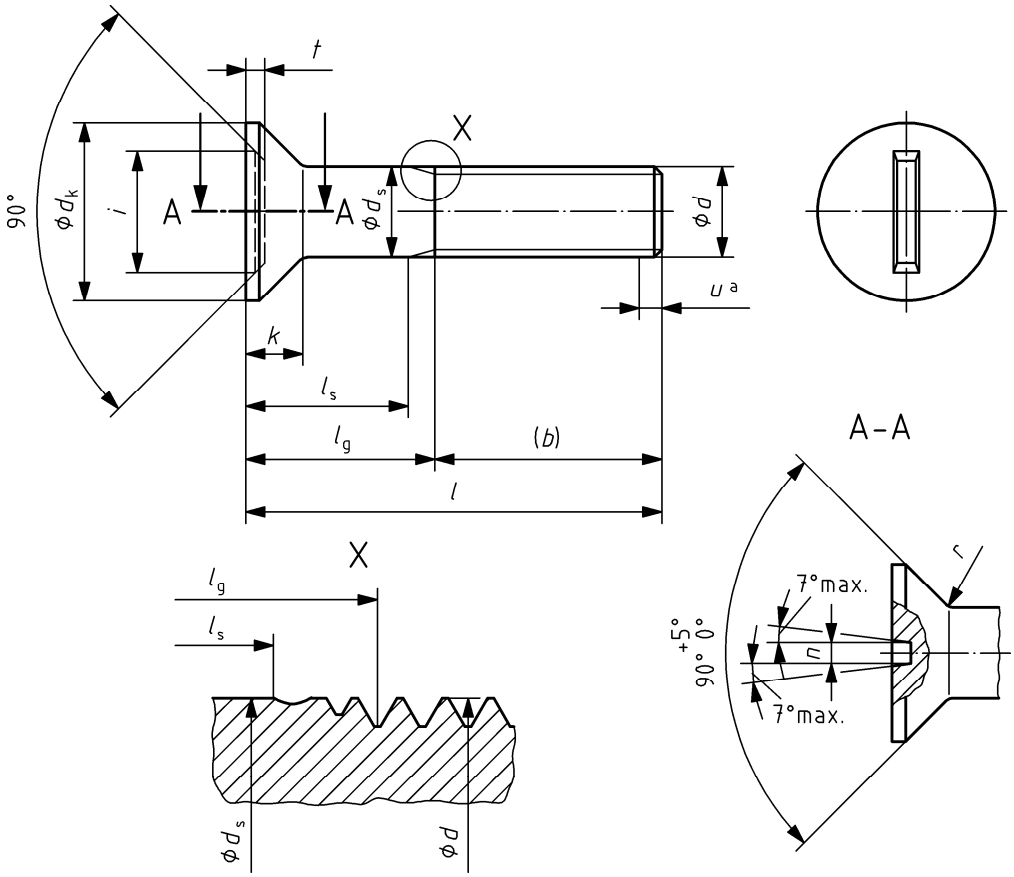
4 Bolts

4.1 General

The test method for suitability for preloading shall be as specified in EN 14399-2.

4.2 Dimensions of bolts

See Figure 1 and Table 2.



The difference between l_g and l_s shall not be less than 1,5 P.

a Incomplete thread $u \leq 2P$

Figure 1 — Dimensions of bolts

Table 2 — Dimensions of bolts [a]

Dimensions in millimetres

Thread d		M12	(M14)[b]	M16	(M18)[b]	M20
P[c]		1,75	2	2	2,5	2,5
b (ref.)	d	30	34	38	42	46
	e	—	40	44	48	52
	f	—	—	—	—	65
d_s	max.	12,70	14,70	16,70	18,70	20,84
	min.	11,30	13,30	15,30	17,30	19,16
d_k	max.	24,00	28,00	32,00	36	40
	min.	23,16	27,16	31,16	35	39
i	max.	16,5	19,5	22,5	25,5	28,5
	min.	15,5	18,5	21,5	24,5	27,5
k	nom.	8,00	9,00	10,00	12,0	13,0
	max.[i]	8,75	9,75	10,75	12,9	13,9
	min.[j]	7,25	8,25	9,25	11,1	12,1
r	max.	1,6	1,6	1,6	2	2
	min.	1,2	1,2	1,2	1,5	1,5
n	max.	3,0	3,0	3,0	3,5	3,5
	min.	2,5	2,5	2,5	3,0	3,0
t	max.	4,5	4,5	4,5	5,0	5,0
	min.	3,0	3,0	3,0	3,5	3,5

l			l_s and l_g[g, h]									
			l_s	l_g	l_s	l_g	l_s	l_g	l_s	l_g	l_s	l_g
nom.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
45	43,75	46,25	14	19,25								
50	48,75	51,25	14	19,25			18	24				
55	53,5	56,5	16,25	25			18	24				
60	58,5	61,5	21,25	30	16	22	18	24			23	30,5
65	63,5	66,5	26,25	35	21	31	18	24			23	30,5
70	68,5	71,5	31,25	40	26	36	22	32			23	30,5
75	73,5	76,5	36,25	45	31	41	27	37	21	28,5	23	30,5
80	78,5	81,5	41,25	50	36	46	32	42	25,5	38	23	30,5
85	83,25	86,75	46,25	55	41	51	37	47	30,5	43	26,5	39
90	88,25	91,75	51,25	60	46	56	42	52	35,5	48	31,5	44
95	93,25	96,75	56,25	65	51	61	47	57	40,5	53	36,5	49
100	98,25	101,75	61,25	70	56	66	52	62	45,5	58	41,5	54
110	108,25	111,75			66	76	62	72	55,5	68	51,5	64
120	118,25	121,75			76	86	72	82	65,5	78	61,5	74
130	128	132			80	90	76	86	69,5	82	65,5	78
140	138	142			90	100	86	96	79,5	92	75,5	88
150	148	152			100	110	96	106	89,5	102	85,5	98
160	156	164			110	120			99,5	112		

Table 2 *(continued)*

Dimensions in millimetres

Thread d		M22	M24	M27	M30	M36
P[c]		2,5	3	3	3,5	4
b (ref.)	d	50	54	60	66	78
	e	56	60	66	72	84
	f	69	73	79	85	97
d_s	max.	22,84	24,84	27,84	30,84	37,00
	min.	21,16	23,16	26,16	29,16	35,00
d_k	max.	44	48	54	60,0	72,0
	min.	43	47	53	58,8	70,8
i	max.	30,5	33,5	37,5	42,5	50,5
	min.	29,5	32,5	36,5	41,5	49,5
k	nom.	14,0	16,0	17,5	19,50	23,00
	max.[i]	14,9	16,9	18,4	20,55	24,05
	min.[j]	13,1	15,1	16,6	18,45	21,95
r	max.	2	2	2,5	2,5	2,5
	min.	1,5	1,5	2	2	2
n	max.	3,5	3,5	3,5	4,0	4,0
	min.	3,0	3,0	3,0	3,5	3,5
t	max.	5,0	5,0	5,0	5,5	5,5
	min.	3,5	3,5	3,5	4,0	4,0

l			l_s and l_g[g, h]									
			l_s	l_g	l_s	l_g	l_s	l_g	l_s	l_g	l_s	l_g
nom.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
65	63,5	66,5	25	32,5								
70	68,5	71,5	25	32,5	28	37						
75	73,5	76,5	25	32,5	28	37						
80	78,5	81,5	25	32,5	28	37	31	40				
85	83,25	86,75	25	32,5	28	37	31	40				
90	88,25	91,75	27,5	40	28	37	31	40	34,5	45		
95	93,25	96,75	32,5	45	28	37	31	40	34,5	45		
100	98,25	101,75	37,5	50	31	46	31	40	34,5	45		
110	108,25	111,75	47,5	60	41	56	31	40	34,5	45	41	53
120	118,25	121,75	57,5	70	51	66	45	60	34,5	45	41	53
130	128	132	61,5	74	55	70	49	64	40,5	58	41	53
140	138	142	71,5	84	65	80	59	74	50,5	68	41	53
150	148	152	81,5	94	75	90	69	84	60,5	78	46	66
160	156	164			85	100	79	94	70,5	88	56	76
170	166	174			95	110	89	104	80,5	98	66	86
180	176	184			105	120	99	114	90,5	108	76	96
190	186	194			115	130	109	124	100,5	118	86	106
200	196	204			125	140	119	134	110,5	128	96	116

NOTE The popular lengths are defined in terms of lengths $l_{s\,min}$ and $l_{g\,max}$.

Table 2 *(continued)*

[a] For hot-dip galvanized bolts, the dimensions apply before galvanizing.

[b] Non-preferred sizes

[c] P is the pitch of thread.

[d] For lengths $l_{nom.} \leq 125$ mm.

[e] For lengths 125 mm < $l_{nom.} \leq 200$ mm.

[f] For lengths $l_{nom.} > 200$ mm.

[g] $l_{g\ max.} = l_{nom.} - b$

$l_{s\ min.} = l_{g\ max.} - 5P$

[h] When $l_{s\ min.}$ as calculated by the equation in [g] is less than $k_{nom.} + 0{,}5d$ then its value shall be $k_{nom.} + 0{,}5d$ and $l_{g\ max} = l_{s\ min.} + 3P$. Bolts with shortened thread length are shown above the line.

[i] $k_{max.}$ includes the height of embossed marking, if any.

[j] $k_{min.}$ excludes the height of embossed marking, if any.

4.3 Specification for bolts and reference standard

Table 3 — Specifications for bolts and reference standards

Material		Steel
General requirements		EN 14399-1[a]
Thread	Tolerance	6g[b]
	International Standards	ISO 261, ISO 965-2
Mechanical properties	Property class	8.8 or 10.9
	European Standard	EN ISO 898-1
Impact strength	Value	$K_{V,min}$ = 27 J at -20 °C
	Test specimen[c]	ISO 148-1
	Test	EN 10045-1
Tolerances	Product grade	C except: dimension r. Tolerance for lengths ≥ 160 mm ± 4,0 mm
	International Standard	EN ISO 4759-1
Surface finish[d]	Normal	as processed[e]
	hot dip galvanized	EN ISO 10684
	Others	to be agreed[f]
Surface discontinuities		Limits for surface discontinuities are covered in EN 26157-1.
Acceptability		For acceptance procedure, see EN ISO 3269.

[a] For the time being EN 14399-1 refers only to EN 14399-3 and EN 14399-4 as far as dimensions and mechanical characteristics of the components and functional characteristics of the assemblies are concerned. Such references shall also apply to EN 14399-7.

[b] The tolerance class specified applies without surface finish. Hot-dip galvanized bolts are intended for assembly with oversize tapped nuts.

[c] The preparation of the test specimens with V-notch in the fastener shall be as specified in EN ISO 898-1.

[d] Attention is drawn to the need to consider the risk of hydrogen embrittlement in the case of bolts of property class 10.9, when selecting an appropriate surface treatment process (e.g. cleaning and coating), see the relevant coating standards.

[e] "As processed" means the normal finish resulting from manufacture with a light coating of oil.

[f] Other coatings may be negotiated between the purchaser and the manufacturer provided they do not impair the mechanical properties or the functional characteristics. Coatings of cadmium or cadmium alloy are not permitted.

4.4 Marking of bolts

High-strength structural countersunk bolts according to this part of this European Standard shall be marked with:

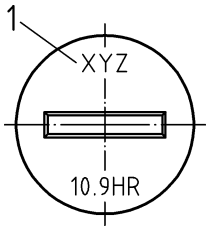
a) property class marking in accordance with EN ISO 898-1 and the letters HR.

EXAMPLE 1 10.9 HR

b) the identification mark of the manufacturer of the assembly.

It is permissible for the marking to be either embossed or indented on the top surface of the head.

EXAMPLE 2 of bolt marking (see Figure 2):



Key

1 identification mark of the manufacturer of the assembly

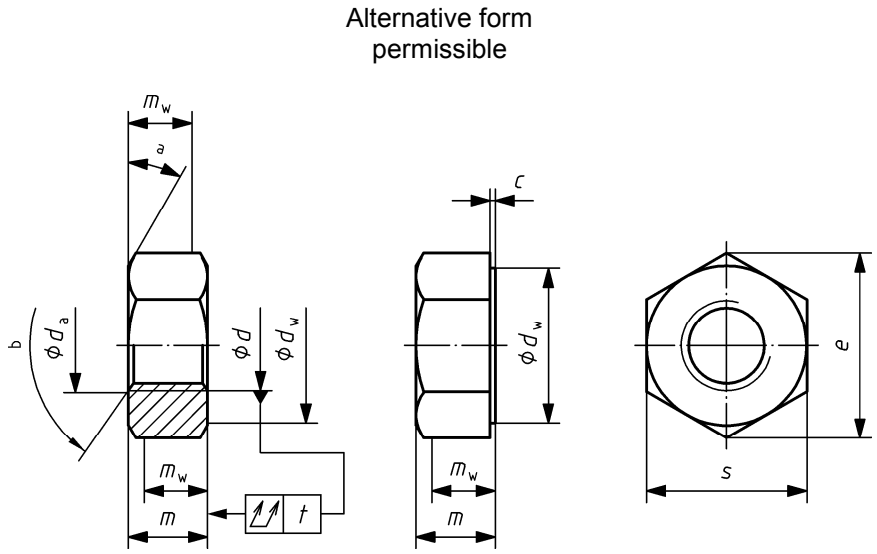
Figure 2 — Example for marking of a bolt

5 Nuts

NOTE This nut is identical with the nut specified in EN 14399-3.

5.1 Dimensions of nuts

See Figure 3 and Table 4.



a 15° to 30°
b 110° to 130°

Figure 3 — Dimensions of nuts

Table 4 — Dimensions of nuts [a]

Dimensions in millimetres

Thread d		M12	(M14)[b]	M16	(M18)[b]	M20	M22	M24	M27	M30	M36
P[c]		1,75	2	2	2,5	2,5	2,5	3	3	3,5	4
d_a	max.	13	15,1	17,3	19,5	21,6	23,7	25,9	29,1	32,4	38,9
	min.	12	14	16	18	20	22	24	27	30	36
d_w	max.	d	d	d	d	d	d	d	d	d	d
	min.	20,1	21,86	24,9	27,70	29,5	33,3	38,0	42,8	46,6	55,9
e	min.	23,91	27,12	29,56	32,95	35,03	39,55	45,20	50,85	55,37	66,44
m	max.	10,8	12,8	14,8	15,8	18	19,4	21,5	23,8	25,6	31
	min.	10,37	12,1	14,1	15,1	16,9	18,1	20,2	22,5	24,3	29,4
m_w	min.	8,3	9,7	11,3	12,1	13,5	14,5	16,2	18,1	19,5	22,4
c	max.	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8	0,8
	min.	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
s	max.	22	24	27	30	32	36	41	46	50	60
	min.	21,16	23,16	26,16	29,16	31	35	40	45	49	58,8
t		0,38	0,42	0,47	0,52	0,58	0,63	0,72	0,80	0,87	1,05

[a] For hot dip galvanized nuts the above dimensions apply before galvanizing.

[b] Non-preferred sizes.

[c] P is the pitch of thread.

[d] $d_{w\,max.} = s_{actual}$.

5.2 Specification for nuts and reference standards

Table 5 — Specifications for nuts and reference standards

Material		Steel
General requirements		EN 14399-1[a]
Thread	Tolerance	6H or 6AZ
	International Standards	ISO 261, ISO 965-2, ISO 965-5
Mechanical properties	Property class	8[b] or 10[b]
	European Standard	EN 20898-2
Tolerances	Product grade	B except dimensions m and d
	International Standard	EN ISO 4759-1[c]
Surface finish	Normal	as processed[d]
	hot dip galvanized	EN ISO 10684
	Others	to be agreed[e]
Surface discontinuities		Limits for surface discontinuities are covered in EN ISO 6157-2.
Acceptability		For acceptance procedure, see EN ISO 3269.

[a] For the time being EN 14399-1 refers only to EN 14399-3 and EN 14399-4 as dimensions and mechanical characteristics of the components and functional characteristics of the assembly are concerned. Such references shall also apply to EN 14399-7.

[b] For proof load values, see 4.3. All other mechanical properties as specified in EN 20898-2.

[c] Except tolerance of total run-out t of bearing face, see Table 4.

[d] "As processed" means the normal finish resulting from manufacture with a light coating of oil.

[e] Other coatings may be negotiated between the purchaser and the manufacturer provided they do not impair the mechanical properties or the functional characteristics. Coatings of cadmium or cadmium alloys are not permitted.

5.3 Proof load values of nuts

Table 6 — Proof load values of nuts

Thread d	Nominal stress area of standard test mandrel A_s	Property class	
		8	10
		Tolerance class 6H or 6AZ	Tolerance class 6H or 6AZ
	mm^2	Proof load ($A_s \times S_p$), N	
M12	84,3	84 300	97 800
(M14)	115	115 000	133 400
M16	157	157 000	182 100
(M18)	192	192 000	222 700
M20	245	245 000	284 200
(M22)	303	303 000	351 200
M24	353	353 000	409 500
(M27)	459	459 000	532 400
M30	561	561 000	650 800
M36	817	817 000	947 700
The proof load values are based on the following stresses under proof load: — for nuts of property class 8: 1 000 MPa — for nuts of property class 10: 1 160 MPa			

Where nuts are to be accepted on the basis of hardness values, the appropriate limits shall be those given in Table 7.

Table 7— Hardness values of nuts, if specified

Nut	Hardness limits
property class 8, tolerance class 6H	as specified in EN 20898-2 for property class 8
property class 10, tolerance class 6H or 6AZ	as specified in EN 20898-2 for property class 10
property class 8, tolerance class 6AZ, hot dip galvanized	260 HV to 353 HV (24 HRC to 36 HRC)

5.4 Decarburization of the nut thread

The decarburization of the nut thread, when measured in analogy to external threads as given in EN ISO 898-1, shall not exceed G = 0,015 mm.

5.5 Marking of nuts

High-strength structural nuts according to this part of this European Standard shall be marked with:

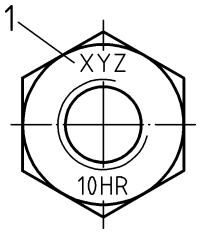
a) property class marking in accordance with EN 20898-2 and the letters HR.

EXAMPLE 1 10 HR

b) the identification mark of the manufacturer of the assembly.

The marking shall be indented on either the top or bottom face of chamfered nuts and shall be either indented or embossed on the non-bearing face of washer faced nuts.

EXAMPLE 2 of nut marking (see Figure 4):



Key
1 identification mark of the manufacturer of the assembly

Figure 4 — Example for marking of a nut

6 Designation of the countersunk head bolt/nut assembly

EXAMPLE 1 Designation of an assembly for high strength structural bolting, system HR, consisting of a countersunk head bolt with thread M16, nominal length l = 80 mm and property class 10.9 and a hexagon nut with large width across flats, with thread M16 and property class 10:

Countersunk head bolt/nut assembly EN 14399-7 — M16 x 80 — 10.9/10 — HR

If surface finishes other than "as processed" are required, the specified surface finish shall be added to the designation.

If countersunk head bolts according to this part of this European Standard are required for other purposes, they may be ordered separately and shall then be designated as follows:

EXAMPLE 2 Designation of a countersunk head bolt with thread M16, nominal length l = 80 mm and property class 10.9:

Countersunk head bolt EN 14399-7 — M16 $\times$ 80 — 10.9 — HR

7 Associated washers

Bolt/nut assemblies according to this part of this European Standard shall be assembled with washers according to EN 14399-5 or according to EN 14399-6.

8 Functional characteristics of the bolt/nut/washer(s) assembly

8.1 General

The functional characteristics of the bolt/nut/washer(s) assembly according to 8.2 to 8.5 shall be achieved when tested in accordance with EN 14399-2. For testing countersunk head bolts an adapter as shown in Table 8, Figure 5 and Figure 6 shall be used under the bolt head.

Four full threads (in addition to the thread run out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank.

NOTE For further background information as to these functional characteristics see EN 14399-2.

Table 8 — Characteristics of adapters

Nominal bolt diameter	Hole diameter	Outside diameter	Hardness for the adapters	Parallelism
M12 ≤ d ≤ M24	d + 2 mm	Not less than 3d and sufficient to distribute load adequately to the device	45 HRC to 50 HRC through hardened	≤ 1 %
d > M24	d + 3 mm			

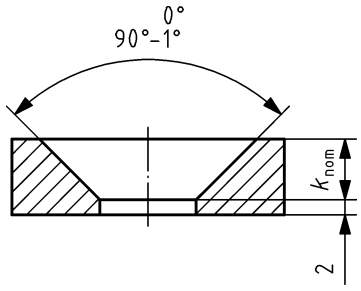
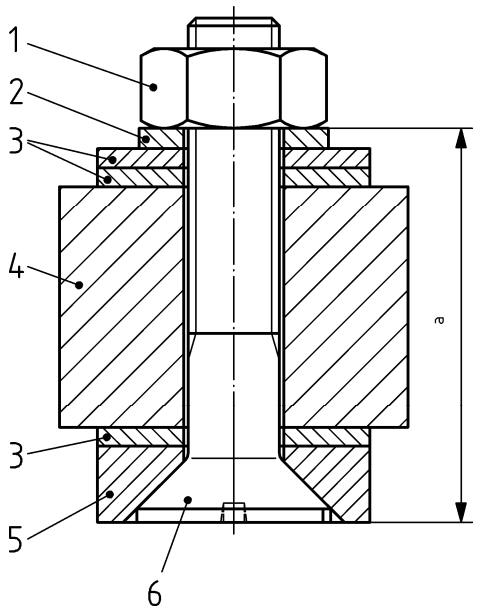


Figure 5 — Adapter

There shall be sufficient suitable lubricant on the nuts or on the bolts and washers in the as delivered conditions, to ensure that seizure will not take place on tightening the assembly and that the required preload is obtained, see Figure 6.



Key

1 nut (turned during tightening)
2 washer of the assembly (prevented from rotating)
3 shim(s)
4 calibrated bolt force measuring device
5 adapter
6 bolt head (prevented from rotating by using the screwdriver slot, if necessary)

[a] clamp length Σt

Figure 6 — Test set-up

8.2 Individual value of the maximum bolt force during the tightening test ($F_{bi\ max}$)

The following applies:

$$F_{bi\ max} \geq 0{,}9\, f_{ub} \times A_s \qquad (1)$$

where

f_{ub} is the nominal tensile strength (R_m);
A_s is the nominal stress area of the bolt;
$F_{bi\ max}$ is the individual value of the maximum bolt force reached during the tightening test.

8.3 Angle by which the nut has to be turned starting from a preload of 0,7 $f_{ub} \times A_s$ until $F_{bi\ max}$ is reached ($\Delta\Theta_1$)

The values specified in Table 9 are for information only.

Table 9 — Values for $\Delta\Theta_1$

Clamp length Σt[a]	$\Delta\Theta_1$ min.
$\Sigma t < 2{,}5\ d$	90°
$2{,}5\ d \le \Sigma t < 6\ d$	120°
$6\ d \le \Sigma t \le 10\ d$	150°

[a] The clamp length Σt is the total thickness of the clamped parts including the washer and the adapter.

8.4 Angle by which the nut has to be turned starting from a preload of 0,7 $f_{ub} \times A_s$ until F_{bi} has dropped again to 0,7 $f_{ub} \times A_s$ ($\Delta\Theta_2$)

The values for $\Delta\Theta_2$ specified in Table 10 apply.

Table 10 — Values for $\Delta\Theta_2$

Clamp length Σt[a]	$\Delta\Theta_2$ min.
$\Sigma t < 2{,}5\ d$	210°
$2{,}5\ d \le \Sigma t < 6\ d$	240°
$6\ d \le \Sigma t \le 10\ d$	270°

[a] The clamp length Σt is the total thickness of the clamped parts including the washer and the adapter.

8.5 Individual values of the k-factor (k_i), mean value of the k-factor (k_m) and coefficient of variation of the k-factor (V_k)

8.5.1 Individual values of the k-factor (k_i) for k-class K1

When k_i-values are required, they shall be in the range of $0{,}10 \le k_i \le 0{,}16$.

8.5.2 Mean value of the k-factor (k_m) and coefficient of variation of the k-factor (V_k) for k-class K2

Mean value of the k-factor is given by

$$k_m = \frac{\sum_{i=1}^{n} k_i}{n} \qquad (2)$$

with

$$k = \frac{M_i}{F_p \times d} \tag{3}$$

where

M_i is the individual value of the torque applied;
F_p is the specified preload;
d is the nominal bolt diameter.

For the coefficient of variation of the k-factor (V_k) the following applies:

$$V_k = \frac{s_k}{k_m} \tag{4}$$

where

s_k is the standard deviation $\left(s_k = \sqrt{\frac{\Sigma (k_i - k_m)^2}{n-1}} \right)$ (5)

When k_m and V_k are required, the following values apply:

$0{,}10 \leq k_m \leq 0{,}23$

$V_k \leq 0{,}10$

Bibliography

[1] prEN 1090-2, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for the execution of steel structures*