User Manual

HV Solutions for secure connections

HV high strength bolt sets
for preloading in accordance
with EN 14399-1:2015

RAWLPLUG®
Koelner Łańcucka Fabryka Śrub

Practice, advanced technology and 60 years of experience - these three factors make Rawlplug Koelner Lancucka Fabryka Srub one of the leading manufacturers of fasteners in Europe. The history of the plant dating back to 1957 is invaluable capital, which, combined with the latest technology and the best specialists, mean that the fasteners manufactured here are of the highest quality, reliability and innovation, meeting the requirements of customers from industries where safety and confidence are the basis.

Koelner Lancucka Fabryka Srub are part of the Rawlplug Group, which brings together numerous production plants and marketing companies covering all continents. Marked with the LF trademark, the solutions are used in many industries and in the largest, most prestigious investments around the world, which is proof of the highest level of quality and service ability.

Our mission is to provide customers with products they can trust. We make this possible by continuously implementing product and production innovations. Due to the systematic reconstruction and modernization of the machine park and technological processes, we have become one of the most modern production plants in its category, employing highly qualified engineering and technical staff. Moreover we perform most of the processes on site giving us independence and absolute certainty of maintaining the highest production standards. We have our own modern research and development facilities. Our team consists of the following laboratories: Chemical, Length and Angle Measurement, Metallographic, Testing and Simulation, as well as Construction. In turn, the implemented quality management system, obtained certificates and approvals, as well as our own Quality Control Department ensure a tight and accurate control process of our fasteners and their appreciated reliability. The confirmation of our efforts is the Quality Management System implemented by the company, based on models compatible with **IATF 16949:2016, ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018**. It is the basis for maintaining the highest level of quality of products and services, minimizing the impact on the environment, as well as maintaining occupational safety.


PR 3

We have been building our product portfolio for many years based on products from the medium and higher priced segments. In addition to standard products (such as welding bolts, flange bolts with serrations, bolts with rolled washer or inch bolts) we also manufacture highly special fasteners, which constitute up to 70% of the plant's production and are made according to drawings and specifications of our customers. Special products are used in many industries, for instance, the automotive industry, where the highest quality and flawless, precise workmanship count. Bolts with the LF mark contribute to the trouble-free operation of vehicles manufactured by leading European and global automotive manufacturers, which is the best confirmation of their highest quality. Rawlplug Koelner Lancucka Fabryka Srub is also a certified manufacturer of HV high strength sets in accordance with the harmonized standard EN 14399;2015 and the guidelines of CPR Directive no. 305/2011.

In addition to technical excellence, the values we follow as a company reflect our way of thinking and determine all our actions. Every day, we strive for excellence, we are open to change and constantly ready to take on new challenges. We are constantly looking for newer, even better solutions, continuing the rich tradition of both Koelner Lancucka Fabryka Srub, as well as the Rawlplug Group - a reputable manufacturer of fasteners with a 100-year history. We focus on teamwork and motivate our employees to excel, because we are convinced that their knowledge and competences are one of the keys to our success. Our highly skilled team of specialists have developed innovative solutions which we have incorporated into our daily production processes.

As an expert in the fasteners industry, we treat our position very seriously. The needs, requirements and expectations of our customers, both internal and external, are our priority, thanks to which - as well as thanks to the partnership approach - we create long-lasting and satisfying relationships with them. We proudly continue the history of Lancucka Fabryka Srub - this valuable heritage is a challenge, inspiration and driving force for the constant search for even better, more reliable and more accurate innovations. Innovations you can trust.


RAWLPLUG

Deklaracja Właściwości Użytkowych

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TÜV NORD

CERTIFICATE

OF CONFORMITY OF THE FACTORY PRODUCTION CONTROL

9045-CPR-114502

HV HIGH-STRENGTH STRUCTURAL BOLTING ASSEMBLIES FOR PRELOADING

HV set consists of:
- bolt and nut acc to EN 14399-4
- 2 washers acc to EN 14399-6

FEATURES AND ADVANTAGES

- Property grade 10.9 (Heat treatment process according to automotive specification CQI-9)
- Suitable for preloading according to DIN EN 1090-2
- K-class: K1, 0,10 ≤ k ≤ 0,16 K-class: K2, 0,10 ≤ km≤0,23; Vk≤0,06
- Hot dip galvanization (additionally process in accordance with Deutscher Schraubenverband e.V. requirements)
- Defined and controlled friction properties
- High fatigue resistance due to lack of ferrite delta

Full product traceability

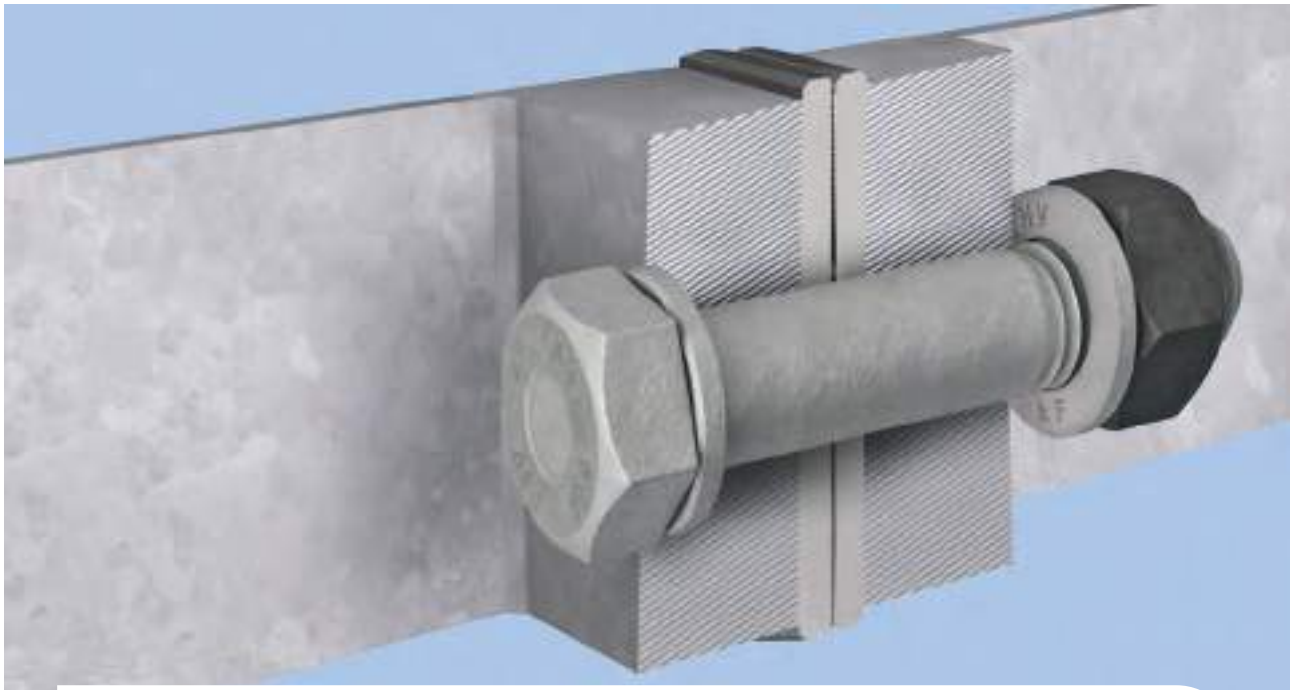
CONNECTIONS

Shear connections

- Category A: Bearing Type connections
- Category B: Slip-resistant at serviceability limit state
- Category C: Slip-resistant at ultimate limit state

Tension connections

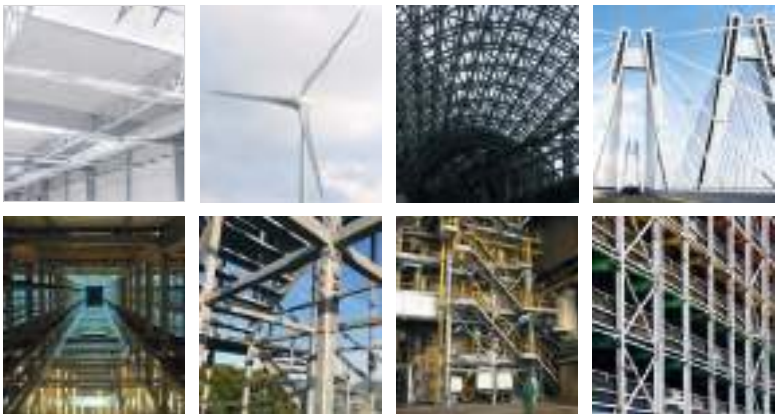
- Category D: non-preloaded
- Category E: preloaded



HV sets enable reliable, fast and simple connection of steel constructions. Simplicity of connection and safe longterm usage are main advantages.

APPLICATIONS

- Halls
- Bridges
- Trading centres
- Roof constructions
- Internal building skeletons with large lateral spread
- Multi-level parkings
- Wind turbines
- Industrial installations



HV1 LIST OF APPLICABLE STANDARDS

LIST OF APPLICABLE STANDARDS

Standard number	Year of issue*	Full name
EN 14399-1	2015	High-strength structural bolting assemblies for preloading - Par 1: General requirements
EN 14399-2	2015	High-strength structural bolting assemblies for preloading - Part 2: Suitability for preloading
EN 14399-4	2015	High-strength structural bolting assemblies for preloading - Part 4: Hexagon bolt and nut assemblies
EN 14399-6	2015	High-strength structural bolting assemblies for preloading - Part 6: Plain chamfered washers
EN 1090-2	2018	Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures
ISO 898-1		Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread
ISO 898-2		Mechanical properties of fasteners made of carbon steel and alloy steel — Part 2: Nuts with specified property classes — Coarse thread and fine pitch thread
ISO 898-3		Mechanical properties of fasteners made of carbon steel and alloy steel — Part 3: Flat washers with specified property classes
ISO 9001		Quality management systems - Requirements
IATF 16949	2016	Quality management system standard in the automotive industry
DIN 50602		Metallographic examination; microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions
ISO 148-1		Metallic materials — Charpy pendulum impact test — Part 1: Test method
ISO 6157-3		Fasteners — Surface discontinuities — Part 3: Bolts, screws and studs for special requirements
ISO 6157-2		Fasteners - Surface discontinuities - Part 2: Nuts
ISO 10684		Fasteners — Hot dip galvanized coatings
EN 1993-1-8		Eurocode 3: Design of steel structures -Part 1-8: Design of joints
EN ISO 6789		Assembly tools for screws and nuts — Hand torque tools — Requirements and test methods for design conformance testing, quality conformance testing and recalibration procedure
EN 10204	2004	Metallic Products: Types of Inspection Documents
ISO 2859-5		Sampling procedures for inspection by attributes - Part 5: System of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection

* The latest issue applies to standards for which no date of issue is given.

HV3 BOLT SETS FOR PRELOADING - GENERAL REQUIREMENTS

3.3.3.1 HOT-DIP GALVANIZATION PROCESS

3.3.3.1.1 GENERAL INFORMATION

The process should be conducted according to ISO 10684 with additional requirements and guidelines according to DASt 022 and DSV GAV, the guide for the manufacture of galvanized bolts ("Herstellung feuerverzinkter Schrauben").

Additional process requirements must be implemented due to the risk of hydrogen embrittlement and bolt cracking under stress. If hydrochloric acid used as the pickling medium before the process, use inhibitors and limit the residence time to a maximum of 15 minutes. High temperature coating 530-560 is only allowed up to a maximum diameter of M24.

Before the coating is applied, randomly check several pieces for cracks. Tests for the phenomenon of sensitization of bolts to hydrogen embrittlement should be performed in relation to the process according to ISO 15330.

Hot-dip galvanization provides efficient and durable anti-corrosion protection even in an aggressive atmosphere. Depending on the severity of adverse conditions, the zinc coating with a thickness from 50 to 70 µm, permanently bonded to the base material, guarantees full functionality of the bolt connection for many years.

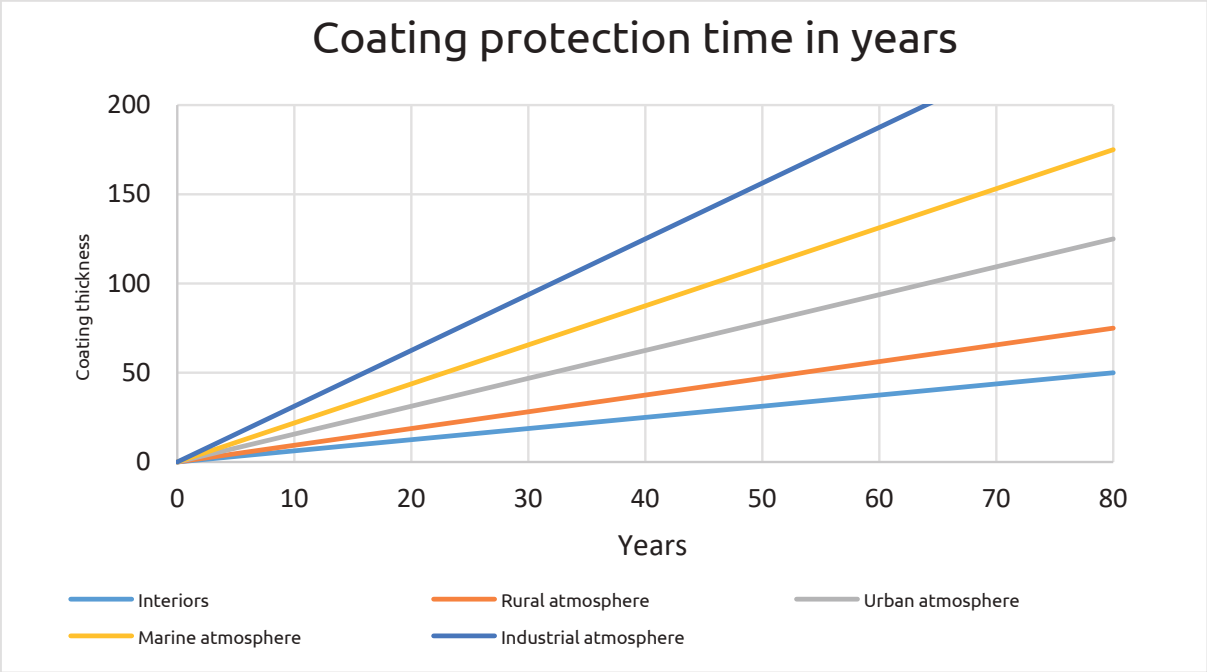


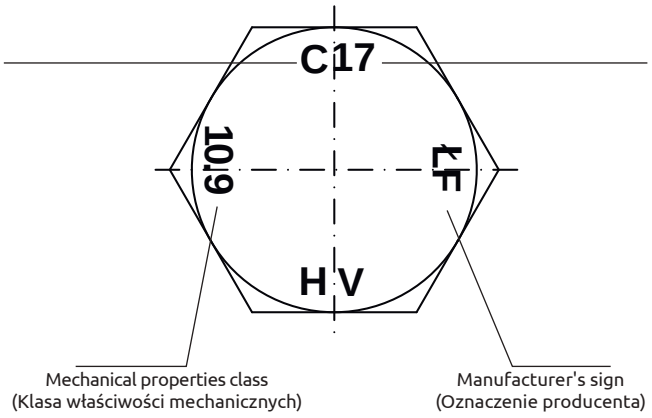
Fig. 3. Protection time of the zinc coating in years.

3.3.4 LABELING

The bolts should be labeled in accordance with PN-EN 14399-4;2015 and PN-EN 1090-2;2018 for full identification also after assembly. The bolt labeling presented in Fig. 4 consists of the mechanical property class, manufacturer identification mark, HV mark and batch identification number (e.g. month and year of production). Labeling must be placed on the upper surface of the head; concave or convex labeling is allowed.

Month of production
(Miesiąc produkcji)

Mark	Miesiąc/Month
C	styczeń/ January
D	luty/ February
E	marzec/ March
F	kwiecień/ April
H	maj/ May
I	czerwiec/ June
J	lipiec/ July
K	sierpień/ August
L	wrzesień/ September
M	październik/ October
N	listopad/ November
O	grudzień/ December



Year of production
(Rok produkcji)

Mark	Rok/Year
17	2017
18	2018
19	2019
20	2020
21	2021
22	2022
23	2023
24	2024
25	2025
26	2026
27	2027
28	2028

Fig. 4. Bolt labeling according to PN-EN 14399-4;2015, allowing full batch identification.

HV3 BOLT SETS FOR PRELOADING - GENERAL REQUIREMENTS

3.4 REQUIREMENTS FOR NUTS (EN 14399-4:2015)

3.4.1 GENERAL REQUIREMENTS

Tab. 11. Requirements for nuts and standards referenced by EN 14399-4:2005.

Material		Steel
General requirements		EN 14399-1 and EN 14399-2
Thread	Tolerance	6 H or 6 AZ
	International standards	ISO 261, ISO 965-2, ISO 965-5
Mechanical properties	Mechanical property class	10
	European standard	EN ISO 898-2
Tolerances	Accuracy class	B
	International standard	EN ISO 4759-1
Surface finish[a]	Normal	According to the process [a]
	Hot-dip galvanized	EN ISO 10684
	Other	To be agreed [b]
Surface discontinuities		Limitations concerning surface discontinuities are specified in EN 26157-1.
Acceptance		Acceptance procedure, see EN ISO 3269.

[a] According to the process" means normal finish performed by the manufacturer and light oil coverage.

[b] The recipient and the manufacturer may agree on other coatings, if they do not affect the reduction of mechanical properties or performance characteristics. Cadmium or cadmium alloy coatings are not allowed.

3.4.2 MATERIAL

Chemical composition of the material used must be in accordance with ISO 898-2.

Tab. 12. Chemical composition of steel used for the manufacture of nuts according to ISO 898-2:2012.

Thread	Strength class		Material and heat treatment of nuts	Chemical composition (% mas.)[a]			
				C	Mn	P	S
				max.	min.	max.	max.
	10[c]		Carbon steel, QT[e]	0,58	0,30	0,048	0,058

QT = Hardened and tempered nuts.

[a] In disputable matters, the product analysis applies.

[c] Alloying elements may be added, provided that the mechanical properties required in section 7 of ISO 898-2;2012 are met.

[e] In the case of materials with these property classes, the hardenability should be sufficient to provide the structure consisting of approximately 90% of martensite in the "prior-hardening" state, before tempering in the threaded area of the nut.

3.4.3 MECHANICAL AND PHYSICAL PROPERTIES

The nut should comply with PN-EN 14399-4;2015 and ISO 898-2;2012 for class 10.

Tab. 13. Hardness properties of standard threaded nuts, ISO 898-2:2012.

	Strength class 10					
Thread	Vickers hardness, HV		Brinell hardness, HB		Rockwell hardness, HR	
D	min	max	min	max	min	max
M5 ≤ D ≤ M16	272	353	259	336	26	36
M16 < D ≤M39						

Tab. 14. Test load values for nuts with the standard thread.

		Load[a], kN								
Thread	D	M12	M16	M20	M22	M24	M27	M30	M33	M36
Thread pitch	P	1,75	2	2,5	2,5	3	3	3,5	3,5	4
Strength class	10	88 500	164 900	259 700	321 200	374 200	486 500	594 700	735 600	866 000

[a] When using flat nuts, one should take into account that the shear force is less than the full-load nut test force (see Attachment A in ISO 898-2:2012).

HV3 BOLT SETS FOR PRELOADING - GENERAL REQUIREMENTS

3.4.4 NUT DIMENSIONS

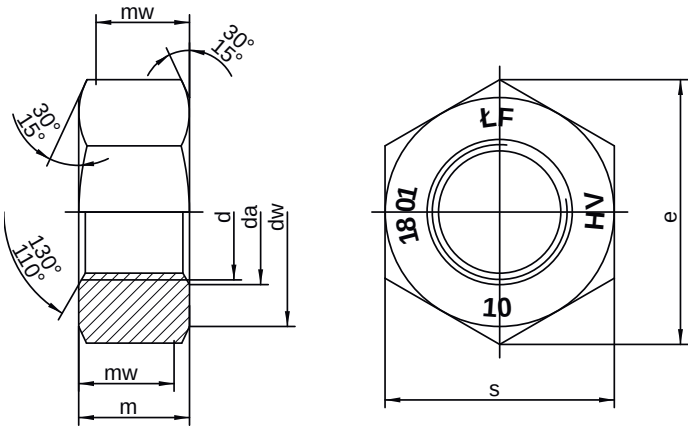


Fig. 5. Nut according to EN 14399-4;2015.

Tab. 15. Nut dimensions according to EN 14399-4;2015.

Thread (d)		M12	M16	M20	M22	M24	M27	M30	M36
Hub		1,75	2,0	2,5	2,5	3,0	3,0	3,5	4,0
da	max	13,0	17,3	21,6	23,7	25,9	29,1	32,4	38,9
	min	12	16	20	22	24	27	30	36
dw min		20,1	24,9	29,5	33,3	38,0	42,8	46,6	55,9
e min		23,91	29,56	35,03	39,55	45,20	50,85	55,37	66,44
m	nom. = max	10	13	16	18	20	22	24	29
	min	9,64	12,30	14,90	16,90	18,70	20,70	22,70	27,70
mw min		7,71	9,84	11,92	13,52	14,96	16,56	18,16	22,16
s	nom. = max	22	27	32	36	41	46	50	60
	min	21,16	26,16	31,00	35,00	40,00	45,00	49,00	58,80

Tab. 16. Nut weight according to EN 14399-4;2015.

Weight – Nuts (g/pc)								
Assortment	M12	M16	M20	M22	M24	M27	M30	M36
Weight [g]	24,76	45,45	75,4	109,12	164,04	225,14	286,01	497,63

3.4.5 NUT MARKING

The nuts should be marked in accordance with PN-EN 14399-4;2015 and PN-EN 1090-2;2018 for full identification also after assembly. The nut marking presented in Fig. 6 consists of the mechanical property class, set manufacturer identification mark, HV mark and batch number (e.g. month and year). Marking must be placed on the upper surface of the head; concave or convex marking is allowed.

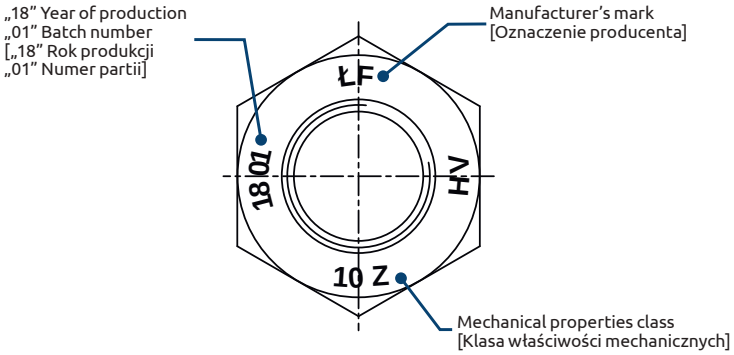


Fig. 6. Nut marking in accordance with EN 13499-4;2015, allowing full batch identification.

HV3 BOLT SETS FOR PRELOADING - GENERAL REQUIREMENTS

3.5 REQUIREMENTS FOR WASHERS (EN 14399-6;2015)

3.5.1 GENERAL REQUIREMENTS

Tab. 17. Requirements and standards referenced by EN 13499-6:2015.

Material		Steel
General requirements		EN 14399-1 and 14399-2
Mechanical properties	Hardness range	300 HV do 370 HV
Tolerances	Accuracy class	A
	International standard	EN ISO 4759-3
Finish coating[a]	Uncoated	According to the process [b]
	Hot dip galvanized	EN ISO 10684
	Others	To be agreed [c]
Workmanship		Parts shall be uniform and free of irregularities or detrimental defects. No protruding burrs shall appear on the washer
Acceptability		For acceptance procedure, see EN ISO 3269

[a] Attention is drawn to the need to take into account the risk of hydrogen embrittlement when selecting the appropriate surface treatment process (e.g. cleaning and coating), see relevant coating application standards.

[b] "According to the process" means normal finish performed by the manufacturer and light oil coverage.

[c] The recipient and the manufacturer may agree on other coatings, if they do not affect the reduction of mechanical properties or performance characteristics. Cadmium or cadmium alloy coatings are not allowed.

3.5.2 MATERIAL

Chemical composition of the washer should be in accordance with ISO 898-3;2018.

Tab.18. Chemical composition of steel used for the production of washers according to ISO 898-3:2018.

Property class	Material and process		Chemical composition (% mas.)[a,b,c]					Minimum tempering temperature [b,c] °C
	Material	Process	C		P	S	B[d]	
			min.	max.	max.	max.	max.	
300HV[f]	Alloys steel [g]	Hardening and tempering	0,17	0,80	0,035	0,035	0,003	425
	Alloys steel [h]		0,14	1,30	0,035	0,035	0,003	425

[a] In disputable matters, the product analysis applies.

[b] In the case of lock washers, see ISO 10644 or ISO 10673. Chemical composition and minimum tempering temperature should be agreed between the buyer and the supplier when placing the order.

[c] In the case of special applications (e.g. hot-dip galvanization washers), chemical composition and minimum tempering temperature should be agreed between the buyer and the supper when placing the order.

[d] The boron content should be a maximum of 0.003%, but may be up to 0.005%, provided that the boron concentration is supplemented by titanium and/or aluminum.

[f] There must be sufficient hardenability to provide the structure consisting of approximately 90% of martensite in the core area in the "post-hardening" state before tempering.

[g] Carbon steel may contain additives, e.g. chromium, manganese, nickel, etc.

[h] Alloy steel contains at least one of the following elements in the minimum amounts: 0.30% chromium, 0.20% manganese, 0.30% nickel, 0.10% vanadium, 0.08% molybdenum and 0.0008% boron. If the elements are specified in connections, the permissible value to be used to determine the steel class is 70% of the sum of the individual minimum values specified above for the given elements.

[i] To consider hydrogen embrittlement, see ISO/TR 20491.

3.5.3 MECHANICAL AND PHYSICAL PROPERTIES

Mechanical properties of the washer should be in accordance with EN 14399-6;2015 and ISO 898-3;2018.

Tab. 19. Combination of property classes of flat washers (e.g. plain washers) with property classes of bolts, screws, studs and nuts.

Threaded connections according to ISO 898-1 and ISO 898-2		Property classes for flat washers
Property class		300HV[a]
Bolts, screws and studs	Regular and high nuts	
9.8, 10.9	10	RC

RC = recommended connection

[a] Only the 200 HV or 300 HV property classes are standardized for lock washers in bolts in accordance with ISO 10644 or ISO 10674.

HV3 BOLT SETS FOR PRELOADING - GENERAL REQUIREMENTS

3.5.4 WASHER DIMENSIONS

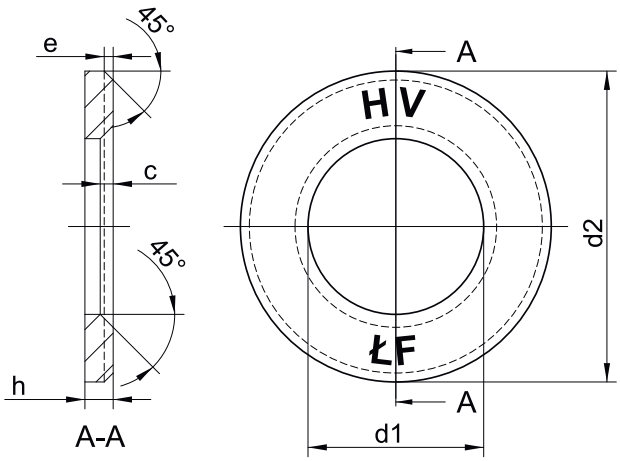


Fig. 7. Washer according to EN 14399-6;2015.

Tab. 20. Washer dimensions according to EN 13499-6;2015.

Nominal diameter of the thread of the connected bolts		12	16	20	22	24	27	30	36
d1	min	13	17	21	23	25	28	31	37
	max	13,27	17,27	21,33	23,33	25,33	28,52	31,62	37,62
d2	min	23,48	29,48	36,38	38,38	43,38	49,00	54,80	64,80
	max	24	30	37	39	44	50	56	66
h	nom.	3	4	4	4	4	5	5	6
	min	2,7	3,7	3,7	3,7	3,7	4,4	4,4	5,4
	max	3,3	4,3	4,3	4,3	4,3	5,6	5,6	6,6
e	nom. = min	0,5	0,75	0,75	0,75	0,75	1,00	1,00	1,25
	max	1,00	1,50	1,50	1,50	1,50	2,00	2,00	2,50
c	min	1,6	1,6	2,0	2,0	2,0	2,5	2,5	2,5
	max	1,9	1,9	2,5	2,5	2,5	3,0	3,0	3,0

Nut geometry should be in accordance with PN-EN 14399-6;2015, i.e. have the cut on one side.

Tab. 21. Washer weight according to EN 14399-6;2015.

Chamfered washers								
Assortment	M12	M16	M20	M22	M24	M27	M30	M36
Weight [g]	6,79	13,9	20,82	22,29	29,95	48,2	61,72	102,92

3.5.5 WASHER MARKING

Washers should be marked in accordance with PN-EN 14399-6;2015. The washer marking presented in Fig. 8 consists of the set manufacturer identification mark and HV mark. The marking should be placed on the side without cut.

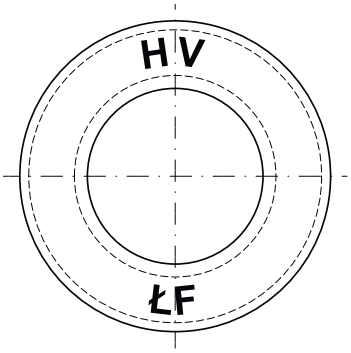


Fig. 8 Washer marking according to EN 14399-6;2015, allowing full batch identification.

GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

4.1 BOLT SETS

a) For assembly, use bolts, nuts and washers from one manufacturer.

b) HV sets for K-class K2 should only be used together with tested nuts.

c) For class 10.9 bolts, washers under the head and under the nut are required.

NOTE - The bolt set, which was tightened to the minimum tightening level and then unbolted - is not suitable for further use and should be scrapped!

d) Tightening is performed by turning the nut, unless access is insufficient, then tightening by turning the bolt requires consultation with the supplier and preparation of special sets.

NOTE - Additional lubrication of the set components is not allowed! It causes changes in the K coefficient value.

e) Tighten subsequent bolts in the first and last cycle from the most to the least rigid contact zone, as shown in Fig. 9. More than one tightening cycle may be needed to achieve even tightening.

f) Install the nuts so that their marking is visible after assembly.

g) In preloading, the protruding part of the thread, measured from the face of the nut to the end of the spindle, should have the length not less than one thread pitch.

h) Washers according to EN 14399-6 should be installed with the cut to the bolt head.

i) When using the torque control method, tightening cannot be applied after a few days (current guidelines of EN 1090-2:2018)

j) In the case of thick coatings, possible measures to compensate for the accidental drop in the tightening force should be determined in the specification.

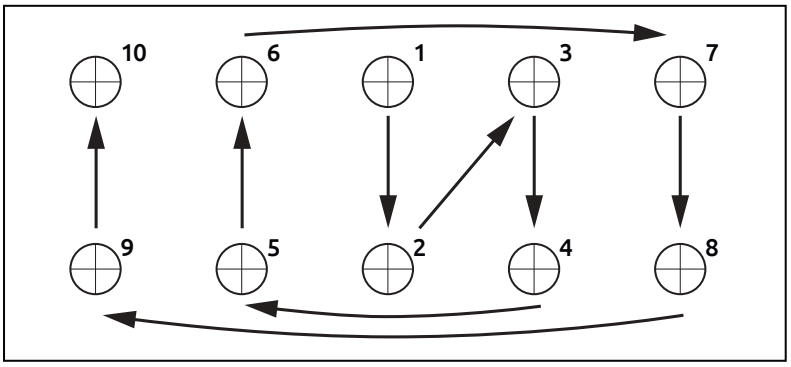


Fig. 9 Sample order of tightening bolts in the connection.

k) In the case of connections with double-sided covers (Fig. 10), the value of D should not exceed 1 [mm]. If steel seal plates are provided, ensuring non-exceedance of the aforementioned limit, their thickness should not be less than 1 [mm].

In the conditions of crevice corrosion danger, tighter contact fitting is required.

The thickness of steel plates should be selected so that the number of spacers does not exceed three.

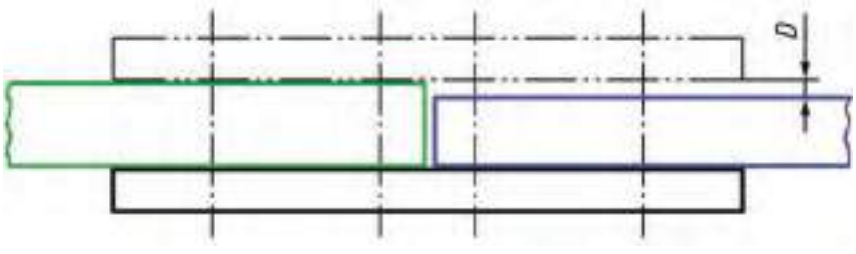


Fig. 10 Difference in the thickness of parts in the connection with double-sided covers.

HV4 GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

4.2 CONTACT SURFACES

a) Contact surfaces should be free from impurities, such as oil, dirt or paint. Burrs that could prevent close adhesion of connected surfaces should be removed.

b) Uncoated surfaces should be free from rust and other loose materials. Be careful not to disturb rough contact surfaces.

c) To adjust the clamping length, one additional sheet metal washer (not thinner than 4 mm) or at most 3 standard washers with a maximum total thickness of 12 mm can be used.

In preloading, only one washer from the side of the tightened part (nut) can be used by means of the tightening torque control method (for class K2) and possibly an additional washer made of sheet metal or standard washers from the not-tightened part (bolt).

NOTE! The use of additional washers may cause the movement of the shear plane to the threaded part of the bolt. In such cases, it is necessary to check the carrying capacity.

4.3 TORQUE WRENCHES

a) To obtain a certain tightening force, use torque wrenches that give the possibility to accurately set the required tightening torque indicated on the label of bolts obtained for preloading.

b) Hand or power wrenches can be used. Impact wrenches can be used for the first bolt tightening step. The use of the impact wrench is not recommended due to the difficulty to meet the ±4% accuracy requirement.

c) Torque wrenches should ensure decoupling when achieving the set tightening torque or have a clear reading of the torque value. In both cases, the error tolerance of ± 0.1 Mv cannot be exceeded.

d) Torque wrenches used in all phases of the torque control method and for testing should be carefully calibrated and have the accuracy of ± 4 % according to EN ISO 6789. The wrenches are kept under control in accordance with EN ISO 6789, while pneumatic wrenches are checked whenever the length of the cable changes.

e) The wrenches should be checked after each incident that occurred during their use, i.e. significant impact, fall, overload, etc., or in the case of malfunction.

f) When the result of the control is the replacement of the bolt, check the accuracy of the torque wrench.

4.4 ASSEMBLY METHOD CALCULATIONS

Tab. 22. Calculations of assembly methods of HV sets.

Tightening force $F_{p,C} = 0,7 * f_{ub} * A_s$									
		M12	M16	M20	M22	M24	M27	M30	M36
A_s	mm²	84,3	157	245	303	353	459	561	817
$F_{p,C}$	kN	59	110	172	212	247	321	393	572

K1-METHOD									
$M_{r,1} = 0,125 * d * F_{p,C}$									
First tightening step									
		M12	M16	M20	M22	M24	M27	M30	M36
0,75 $M_{r,1}$	Nm	70	170	320	440	560	820	1100	2000

* Values were rounded to facilitate the setting of the torque wrench in construction conditions.

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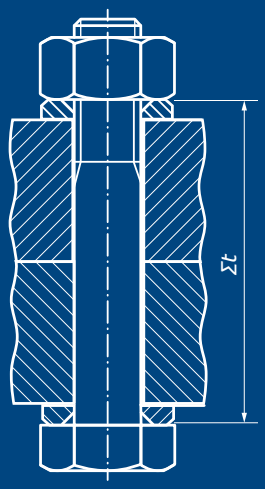
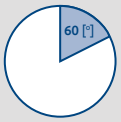
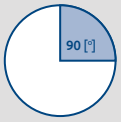
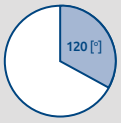
Second tightening step				
The clamp length Σt of the parts to be connected (containing all washers); d - nominal diameter of the bolt		**Additional angle/part of rotation in the second tightening**		
	Σt < 2d	Angle [°]	60	
		Part of rotation [-]	1/6	
	2d ≤ Σt ≤ 6d	Angle [°]	90	
		Part of rotation [-]	1/4	
	6d ≤ Σt ≤ 10d	Angle [°]	120	
		Part of rotation [-]	1/3	

Example of calculation of the combined method. For the M20 x 100 bolt with the value of the k coefficient of 0.12.	
First tightening step	Select from the first step table: **320 [Nm]**
Second tightening step:	For the M20 x 100 bolt, the value Σt is 73-78 [mm] from Tab. 4.
	73/20 = 3.65 and 78/20 = 3.9 hence 2d ≤ Σt ≤ 6d
	Additional angle in the second tightening step is **90 [°]**

K2-METHOD

In the K2 method, the value k_m in the connection suitability test according to EN 14399;2015 should be determined. The result of k_m must be in the range 0,10 ≤ k_m ≤0,23 and the variation of the coefficient k_m must be less or equal to 0,06 (Vk ≤ 0,06) sein. Then calculate the value $M_{r,2}$.

$M_{r,2} = k_m * d * F_{p,C}$	
First tightening step	0,75 * $M_{r,2}$ [Nm]
Second tightening step:	1,1 * $M_{r,2}$ [Nm]
	73/20 = 3,65 i 78/20 = 3,9 stąd 2d ≤ Σt ≤ 6d
Example of calculation of the torque control method. For the M20 x 100 bolt with the value of k_m 0,123 and V_k 0,048.	
	$M_{r,2}$= 0,123 * 20 * 172 = 422 [Nm]
First tightening step:	0,75 * $M_{r,2}$ = 316 [Nm]
Second tightening step:	1,1 * $M_{r,2}$ = 464 [Nm]

HV4 GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

4.5 ASSEMBLY METHOD BY COMBINED METHOD - K1

4.5.1 GENERAL ASSEMBLY GUIDELINES BY COMBINED METHOD - CLASS K1

Before assembly, the following requirements must be met:

a) Observe the recommendations from section 4.1

b) Use the torque wrench with an appropriate operating range; the wrench can be hand or mechanical.

c) Assembly with the torque that is continuous and smooth. The bolt assembly cannot be interrupted until the set-point on the wrench is obtained.

d) Perform two tightening steps.

e) Take the torque value and the angle of rotation given on the label from the manufacturer.

4.5.2 CLASS 1 LABEL

Example of the label for class K1 presented in Fig. 11 contains the following information:

a) Set assortment (e.g. M12)

b) Class 1 requirements

c) Class K1 parameter values

d) Tightening step values

4.5.3 CLASS K1 PARAMETERS

F_v – Bolt tightening value [kN]

First tightening step

a) The wrench should be set to the torque value given in "Step 1" placed on the label (e.g. for example of the label from Fig. 11 it is 70 [Nm]).

b) The first tightening step should be performed for all bolts in one connection before starting the second tightening step.

Second tightening step

a) After the first tightening step, determine the position of the bolt thread. You can use chalk or paint for marking. This will allow to easily assess the rotation of the nut after the second step.

b) The wrench should be set to the value of the angle of rotation given in "Stage 2" placed on the label (e.g. for example of the label from Fig. 11 it is 90 [°]).

c) The second tightening step should be performed for all bolts in one connection.

Fig. 11 An example of the label characterizing the bolt for class K1.

HV4 GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

4.6 TORQUE CONTROL ASSEMBLY METHOD - K2

4.6.1 GENERAL GUIDELINES FOR THE TORQUE CONTROL ASSEMBLY - CLASS K2

a) Observe the recommendations from section 4.1

b) Use the torque wrench with an appropriate operating range; the wrench can be hand or mechanical.

c) For the first step, it is recommended to use the impact wrench due to the ±4% accuracy requirement.

d) Assembly with the torque that is continuous and smooth. The bolt assembly cannot be interrupted until the set-point on the wrench is obtained.

e) Perform two tightening steps.

f) Take the torque value given on the label from the manufacturer.

4.6.2 CLASS 2 LABEL

Example of the label for class K2 presented in Fig. 12 contains the following information:

a) Set assortment (e.g. M16)

b) Class 2 requirements

c) Class K2 parameter values

d) Tightening step values

e) Note concerning the set

4.6.3 CLASS K2 PARAMETERS

F_v – Bolt tightening value [kN]

k_m – average value of the k coefficient

V_k – coefficient of variation of the k coefficient

First tightening step

a) The wrench should be set to the torque value given in "Step 1" placed on the label (e.g. for example of the label from Fig. 12 it is 165 [Nm]).

b) The first tightening step should be performed for all bolts in one connection before starting the second tightening step.

Second tightening step

a) The wrench should be set to the torque value given in "Step 2" placed on the label (e.g. for example of the label from Fig. 12 it is 245 [Nm]).

b) The second tightening step should be performed for all bolts in one connection.

Fig. 12 An example of the additional label characterizing the bolt set for class K2.

HV4 GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

4.7 CONTROL OF PRELOADED BOLT CONNECTIONS

4.7.1 FRICTION SURFACE CONTROL

a) All friction surfaces are checked visually, immediately prior to the assembly process.

b) The assessment criteria of the surface should be in accordance with section 4.1.

4.7.2 CONTROL BEFORE TIGHTENING

a) All preloading are checked visually before tightening, after initial tightening of bolts and local adjustment of the structure.

b) Acceptance criteria should be in accordance with section 4.1.

c) For EXC2, EXC3 and EXC4 class structures, check the tightening procedure.

d) Torque wrenches used to compress the connections should be verified for compliance with section 4.3 and have the calibration certificate

4.7.3 CONTROL DURING TIGHTENING AND AFTER TIGHTENING

4.7.3.1 GENERAL INFORMATION

In the case of EXC2, EXC3 and EXC4 class structures, the following control is performed during and after tightening:

a) Control locations are selected on a random sample basis, taking into account the following relevant variables: connection type, bolt group, number, type and dimensions of bolts, equipment used and its operator.

b) For control purposes, the bolt group is defined as bolt sets in similar connections, homogeneous in terms of dimension origin and class. Significant bolt groups can be divided into subgroups for control purposes;

c) The following numbers of bolt sets are controlled depending on the assembly method

- EXC2: 5% in the second step of the torque control method or combined method
- EXC3 and EXC4:
  - 5% in the first step; 10 % in the second step of the combined method,
  - 10% in the second step of the torque control method.

d) Unless the specification provides otherwise, the control is performed on a sufficient number of bolts using the sequential method **(section 4.7.3.2)**, unless the acceptance or rejection criteria for the type of sequential test (or testing of all sets) are met. The following sequence types are used:

- EXC2 and EXC3: - A sequence;
- EXC4: - B sequence;

e) At this tightening step, the connection is visually checked in terms of tight contact adhesion;

f) The final tightening control of bolt sets shall be used to detect under-tightening or, if so specified in the specification, excessive tightening of the bolts;

g) The pre-tightening control is only performed in terms of loosening the bolts;

h) The criteria defining non-compliance and correction requirements are given below for each bolt tightening method;

i) If the control indicates non-compliance, all bolt sets in a given subgroup of bolts should be checked and corrected accordingly. When negative control results are obtained using A sequence, the control can be extended using B sequence;

j) After the correction is made, the re-control is performed.

k) If the fasteners were used in accordance with the established tightening method, the entire bolt group must be replaced and confirmed.

Tab. 23. Inspection of tightening by the torque method according to EN 1090-2:2018.

Execution class	At start of tightening	After tightening
EXC2	Identification of assembly bolt lot locations	Inspection of the second tightening step
EXC3 und EXC4	Identification of assembly bolt lot locations Checking the bolt tightening procedure for each bolt group	Inspection of the second tightening step

4.7.3.2 SEQUENTIAL METHOD OF CONNECTOR CONTROL

The control of connectors using the sequential method is performed in accordance with the principles given in ISO 2859-5. The standard contains the rules referring to the progressive analysis of successively obtained control test results. The graphical method is used to control the connectors.

Two control cases are described in Fig. 13 and individual objects included in the envelope are explained:

HV4 GENERAL PROVISIONS FOR THE ASSEMBLY OF BOLT SETS

Key:	Example:	
X - number of controlled connectors,	**Dashed line:** 2, 6 and 12 connectors are defective. The control curve, crossing the envelopes in the 12th sample (R point) is in the rejection zone.	**Dotted line:** 4 and 8 connectors are defective. The control was continued until the control curve was crossed with the vertical envelope section in the 16th sample I (A point) and reached the acceptance zone.
Y - number of defective connectors,		
1 - rejection zone		
2 - continuation one (no conclusions)		
3 - acceptance zone		

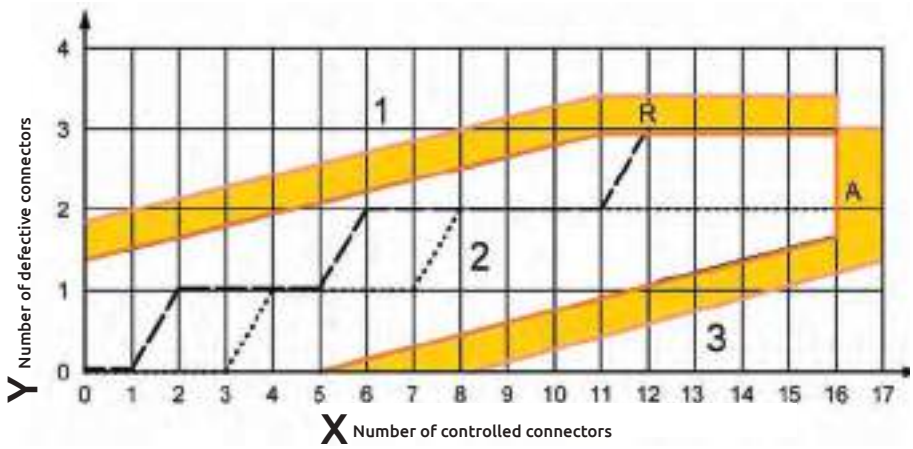


Fig. 13. Example of sequential inspection diagram according to EN 1090-2:2018.

4.7.3.3 TORQUE CONTROL METHOD

The bolt sets are controlled according to Tab. 23 by rotating the nut by means of the calibrated torque wrench (or the bolt head, if so determined). The purpose of the control is to check whether the torque value necessary to initiate the rotation is at least 1.05MA. The rotation should closely correspond to the minimum value. The following conditions apply:

a) The torque wrench used for control should be carefully calibrated and have an accuracy of ±4 %,

b) The control should be performed between 12h and 72h after completing the final tightening of the bolts in a given sub-group,

NOTE: When the bolt sets with different batch and control torque value are to be controlled, the location of each batch should be determined.

NOTE: When the contact surfaces have protective coatings, especially paint coatings, this may cause the decrease in the tightening force value, which makes it impossible to meet the design criteria. In such cases, it may be necessary to apply special control procedures, such as continuation of the tightening control.

c) When the result of the control is the replacement of the bolt, check the accuracy of the torque wrench.

d) The bolt set in which the nut turned more than 15° after the application of the torque is considered to be non-tightened (< 100%) and should be tightened to 100% of the required torque.

e) If checking the set in terms of exceeding the assembly torque is specified, the requirements must be determined and met.

NOTE: If during the control the tightening torques were exceeded, the sets should be replaced with new ones and the old sets should be scrapped.

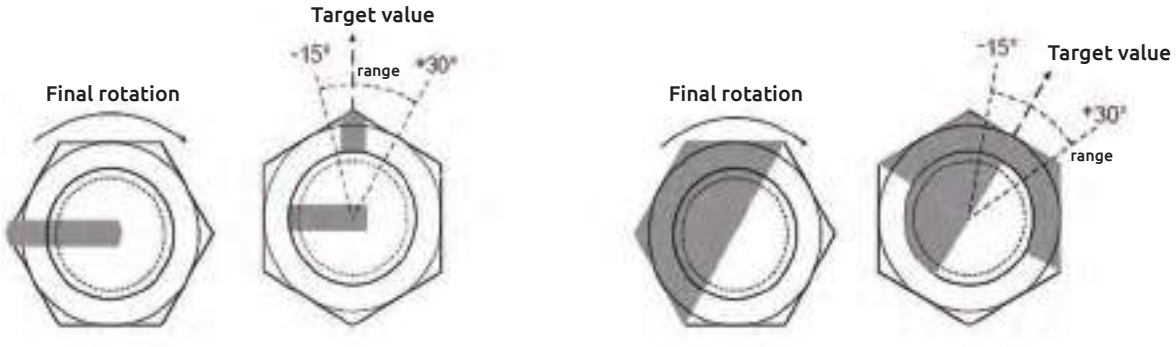


Fig. 14. Bolt marking methods before the second tightening step.

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