

ISO9001:2015	Doc No. BS-S-7.5.3.1-5	Ver. No.: 1.0	Date Effective: 21-12-2018
Document Title: SPECIFICATION FOR HSFG BOLTING ASSEMBLIES WITH DIRECT TENSION INDICATOR WASHERS.			

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Document No. : **BS-S-7.5.3.1-5**

Document Title : **SPECIFICATION FOR HSFG BOLTING ASSEMBLIES WITH DIRECT TENSION INDICATOR WASHERS**

AMENDMENT HISTORY:

S.No.	Amendment Date	Version	Reasons for Amendments
1.	21.12.2018	1.0	New Specification for HSFG bolting assemblies with DTI washers

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SPECIFICATION FOR HSFG BOLTING ASSEMBLIES WITH DIRECT TENSION INDICATOR WASHERS

1.0 Scope:

This specification covers the norms for manufacture of HSFG bolting assemblies in friction type joints for bridges covered by IRS Steel Bridge Code, from sizes M12 to M36. This specification is intended to help better understanding of the codal provisions. For actual design/ use the relevant reference codes as given in para 2 below shall be referred to and followed. In case of any confusion, clarification or difference of opinion etc., the provisions given in the relevant reference codes as given in para 2 below shall prevail. This specification covers the use of HSFG bolting assembly in Road Over Bridges as well as Railway Bridges.

2.0 Reference Codes:

Following codes has been referred while preparation of this specification:

2.1 EN 14399 Series (High strength structural bolting assemblies for preloading):

- i) EN 14399-1:2015- General requirements.
- ii) EN 14399-2:2015- Suitability for preloading.
- iii) EN 14399-3:2015- System HR- Hexagonal bolt and nut assemblies.
- iv) EN 14399-5:2015- Plain washers.
- v) EN 14399-6:2015- Plain chamfered washers.
- vi) EN 14399-9:2009- Direct Tension Indicator for bolt and nut assembly.

2.2 EN-1090-2: 2008, Execution of Steel Structures and Aluminum Structures part 2 – Technical Requirements for Steel Structures.

3.0 Bolts:

For the purpose of HSFG connections, only high strength structural bolts confirming to the requirements for assemblies of high-strength structural bolts and nuts of system HR suitable for preloaded joints with large width across flats as specified in EN 14399-3 together with EN 14399-1 and 14399-2 shall be used. Specification for bolts and reference standards for material, general requirements, thread, mechanical properties, tolerances, finish-coatings, surface integrity, acceptability etc. has been given in Table 3 of EN 14399-3. EN 14399-3 gives two property classes: 8.8 or 10.9 for the same. The bolts have the following characteristics:

3.1 Property class: A property class has two parts separated by a decimal in the form x.y. The first part, x, indicates 1/100 of the nominal tensile strength in Newton per

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sq mm and y indicates ten times the ratio of the lower yield stress and nominal tensile strength.¹ For example, property class 8.8 means that the bolt will have nominal Ultimate Tensile strength of 800 N/mm², and lower yield stress of 80% of 800 N/mm², i.e. 640 N/mm².

3.2 Identification/Marking: High strength structural bolts manufactured according to EN 14399-3 shall be marked with: (a) Property class marking with the letters HR e.g. 8.8HR or 10.9HR (b) Identification mark of the manufacturer of bolting assembly. It is permissible for the marking to be either embossed or indented on top surface of the head.² For having better traceability, heat mark of the raw material shall be embossed on the bolt head, nut and washers. Apart from heat mark, length of bolt may also be embossed on bolt head. This will be in addition to name of manufacture and property class of bolt material.

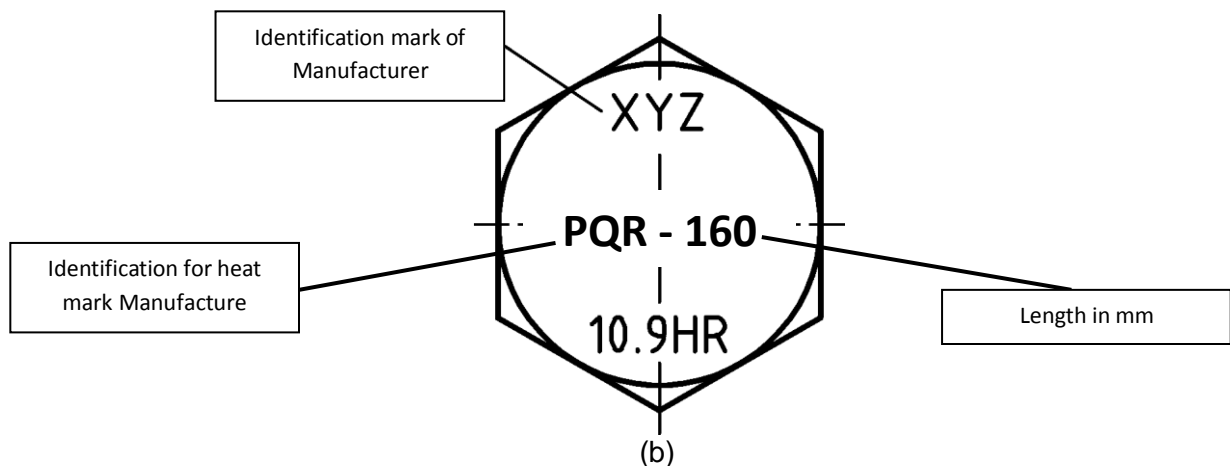


Fig. 1: Typical Marking on bolt-heads

3.3 Dimensions: Dimensions of bolts shall be as per Table 2 of EN14399-3. The bolt length shall be chosen such that after tightening the following requirements are met for bolt end protrusion beyond the nut face and the thread length: (a) The length of protrusion shall be at least the length of one thread pitch measured from outer face of the nut to the end of the bolt. (b) For preloaded bolts according to EN 14399-3 and 14399-7, at least 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.³

3.4 Surface Finish & Coatings: Wherever property class 8.8 bolts are used these shall be hot dip galvanized as per ISO: 10684 (latest version) to provide salt spray

¹ Table 3.1 of EN 1993-1-8.

² Clause 3.3 of EN 14399-3.

³ Clause 8.2.2 of EN 1090-2:2008

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resistance suitable as per site condition depending upon severity of environment. Property class 10.9 bolts shall not be hot dip galvanized since this may cause hydrogen embrittlement. So these bolts shall be coated with Zinc flakes as per ISO: 10683 (latest version), to provide salt spray resistance suitable as per site condition depending upon severity of environment. However, depending on the site conditions, locations of the bolts in the structure and corrosion proneness, use of Zinc flake spray coating as per ISO 10683 (latest version) can be adopted even for property class 8.8 bolts as well.

4.0 Nut:

For the purpose of HSFG connections, only high strength structural nuts confirming to the requirements for assemblies of high-strength structural bolts and nuts of system HR suitable for preloaded joints with large width across flats as specified in EN 14399-3 together with EN 14399-1 and 14399-2 shall be used. Specification for nuts and reference standards for material, general requirements, thread, mechanical properties, tolerances, finish-coatings, surface integrity, acceptability etc. has been given in Table 5 of EN 14399-3. Nuts shall run freely on their partnering bolt, which is easily checked during hand assembly. Any nut and bolt assembly where nut does not run freely shall be discarded. If a power tool is used, either of the following two checks may be used: (a) For each new batch of nuts or bolts their compatibility may be checked by hand assembly before installation (b) For mounted bolt assemblies but prior to tightening, sample nuts may be checked for free running by hand after initial loosening.

4.1 Property Class:⁴ Nuts are designated by property class designation, which is equal to 1/100 of the minimum tensile strength in Newton per square mm of the bolt. For HSFG bolting assemblies, the property classes to be used are 8 and 10 as specified in EN 14399-3. Property class 8 nut to be used with bolts of property class 8.8 only whereas property class 10 nuts can be used with bolts of property class 8.8 and 10.9 both. Dimensions of the nuts should be as per the table 4 of EN 14399-3.

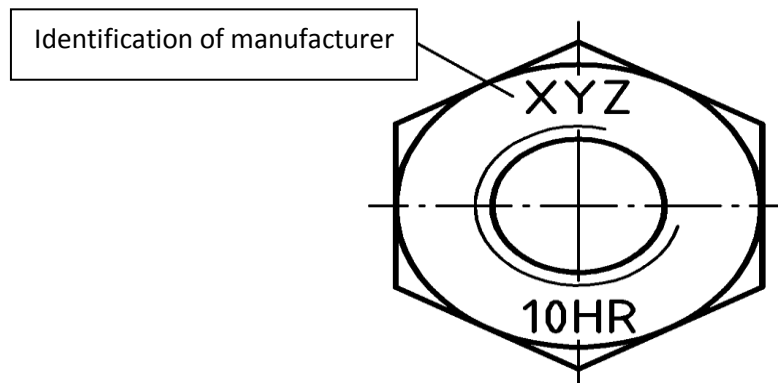


Fig. 2: Typical markings on nuts

⁴ Table-5 of EN 14399-3.

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4.2 Identification of Nut: High strength structural nuts manufactured according to EN 14399-3 shall be marked with: (a) Property class marking with the letters HR e.g. 8HR or 10HR (b) Identification mark of the manufacturer of bolting assembly. The marking shall be indented on either bearing face of chamfered nuts and shall be either indented or embossed on the non-bearing face of washer faced nuts.

4.3 Surface finish and coatings of Nut: HSFG nuts of property class 8 shall be hot dip galvanized as per ISO 10684 (latest version) to provide salt spray resistance suitable as per site condition depending upon severity of environment. Property class 10 nuts should not be hot dip galvanized since this may cause hydrogen embrittlement. So these nuts should be coated with Zinc flakes as per ISO: 10683, to provide salt spray resistance suitable as per site condition depending upon severity of environment. However, depending on the site conditions, locations of the nuts in the structure and corrosion proneness, use of Zinc flake spray coating can be adopted even for property class 8 nuts as well.

In nuts the thread type depends on the type of coating adopted for nuts. In case of hot dip galvanization of nuts, the thread in nuts should be as per tolerance class 6AZ as per ISO 261, ISO 965-5 and in other type of coatings the threads should be as per tolerance class 6H as per ISO 261, ISO 965-2, ISO 965-5.

5.0 Plain and Plain Chamfered Washer:

Washers used under heads of preloaded bolts shall be chamfered according to EN 14399-6 and positioned with the chamfer towards the bolt head. Washers according to the EN 14399-5 shall only be used under nuts. Washers according to EN 14399-5 and EN 14399-6 are not intended to be used in direct contact with oversized or slotted holes. Specification and reference standards for plain washers and plain chamfered washers regarding material, general requirements, mechanical properties, tolerances, finish-coatings, workmanship, acceptability etc. has been given in Table 3 of EN 14399-5 and EN 14399-6 respectively. Dimensions of plain and plain chamfered washers have been given in table 2 of EN 14399-5 and EN 14399-6 respectively. Plain Washers (or if necessary hardened taper washers) shall be used for HSFG bolting assemblies as follows: (a) For 8.8 bolts a washer shall be used under the bolt head or the nut, whichever is to be rotated (b) For 10.9 bolts washers shall be used under both the bolts and the nut.

Plate washers shall be used for connections with long slotted and oversized holes. One additional plate washers or up to three washers with a maximum combined thickness of 12 mm may be used in order to adjust the grip length of bolt assemblies. They shall be placed on the side that is not turned. Dimensions and steel grades of plate washers shall be specified. They shall not be thinner than 4 mm.

Taper washers shall be used if the surface of the constituent product is at an angle to a plane perpendicular to the bolt axis of more than: (a) 1/20 (3°) for bolts with $d \leq 20$ mm

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(b) 1/30 (2°) for bolts with $d > 20$ mm. Dimensions and steel grades for taper washers shall be specified.

5.1 Identification: Hardened and tempered plain washers shall be marked with at least manufacturer's identification mark and letter H. Alternatively; these may also be marked with HR in place of H when supplied as component of bolting assembly of system HR. Marking shall be indented on one of the bearing surfaces. The marking of washers with enlarged outer diameter shall be HD.

Similarly for hardened and tempered chamfered washers shall be marked with at least manufacturer's identification mark and letter H. Alternatively; these may also be marked with HR in place of H when supplied as component of bolting assembly of system HR. Marking shall be indented on non chamfered side.

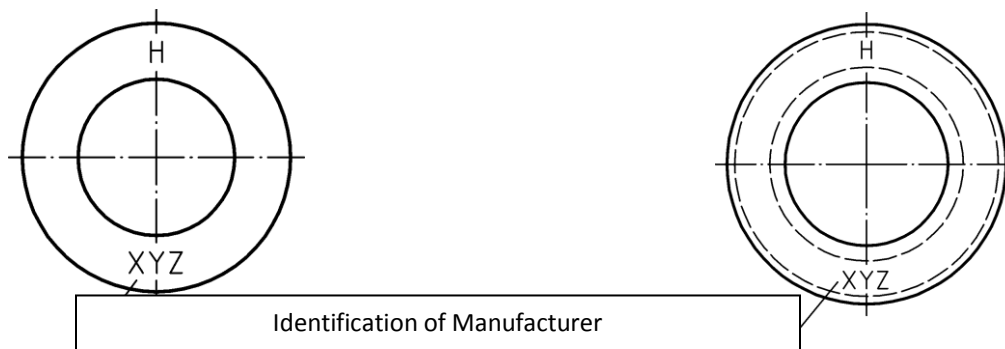


Fig. 3: Typical markings/shapes on plain and plain chamfered washers

5.2 Surface Finish and coatings: Washers as per EN 14399-5 and EN 14399-6 shall be hot dip galvanized as per ISO 10684 (latest version) to provide salt spray resistance suitable as per site condition depending upon severity of environment, however attention is drawn to the need to consider the risk of hydrogen embrittlement when selecting an appropriate surface treatment process (e.g. cleaning and coating) as per relevant coating standard. So these washers can also be coated with Zinc flakes as per ISO: 10683, to provide salt spray resistance suitable as per site condition depending upon severity of environment to avoid risk of hydrogen embrittlement.

6.0 Direct Tension Indicators (DTI) washers:

Compressible washer-type Direct Tension Indicators (DTI) as per EN 14399-9 (known formerly as load indicating washers) used in conjunction with bolt and nut face washers are a load indicating device which are placed under the bolt head or under the nut. The direct tension indicators have protrusions on one face which compress under load and thus may be used to indicate the magnitude of the preload in the assembly.

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Direct tension indicators are only to be sold as part of a complete assembly that comprises bolts and nuts and that otherwise complies with EN 14399-3. The systems of bolt/nut/washer assemblies are described in Table 1.

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 hot dip galvanizing or other surface coatings of the assembly are under the control of one manufacturer.

Beside the mechanical properties of the components, the functionality of the assembly requires that the specified preload can be achieved when the average gap remaining after tightening (compressed protrusions) is less than the specified values in this specification, if the assembly is tightened with a suitable procedure. The test method given in EN 14399-2 and EN 14399-9 has been developed to demonstrate the suitability of the components for preloading.

Table 1 — Composition of high-strength structural bolting assembly and its component marking

Type of bolting assembly		System HR	
General requirements		EN 14399-1	
Suitability for preloading		EN 14399-2 and, if any, additional testing specified in the product standard	
Bolt & Nut		EN 14399-3	
Marking	Bolt	HR8.8	HR10.9
	Nut	HR8 or HR10	HR10
Washers		EN 14399-5 ^a or EN 14399-6	
Marking		H or HR ^b	
Direct tension indicator and nut face washer or bolt face washer		EN 14399-9	
Marking	Direct Tension Indicator	H8	H10
	Nut Face Washer	HN	
	Bolt Face Washer	HB	
^a EN 14399-5 can only be used under the nut.			
^b At the choice of the manufacturer.			

Salient features of DTI as per EN 14399-9 are as below:

6.1 Dimensions of DTI: Before installation, the dimensions and tolerances of compressible washer-type direct tension indicators shall be as given in Table 2 of EN 14399-9. The size and number of protrusions on the direct tension indicator shall be

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sufficient to meet the performance requirements of clause 3.3 of EN 14399-9 and their number shall be not less than four. The protrusions on a direct tension indicator shall be spaced at equal angular intervals. The shape of the protrusions is at the discretion of the manufacturer.

6.2 Specifications and reference standards for DTI: Specifications and reference standards regarding material, general requirements, heat treatment, maximum hardness, surface finish, associated bolts and nuts, associated washers, acceptability etc. have been given in Table 3 of EN 14399-9.

6.3 Performance test of DTI: The direct tension indicators shall be tested on a calibrated load-measuring device as per description given in clause 3.4 of EN 14399-9 for the test procedure. The load requirement of Table 4 of EN 14399-9 shall be met when the direct tension indicators are compressed to the average gaps given in Table 9 of EN 14399-9. Samples of direct tension indicators shall be tested by the manufacturer after the final production process including the surface finish, if any. The minimum number of direct tension indicators tested per manufacturing lot shall be eight and all samples shall pass the test.

6.4 Marking of DTI: Direct tension indicators shall be marked with the identification mark of the manufacturer of the assembly and H8 or H10 as appropriate. The marking shall be indented into the direct tension indicator face from which the protrusions project. It is recommended to stamp lot numbers on the face of the direct tension indicator.

6.5 Nut face washers and Bolt face washers: Dimensions and tolerances of Nut face washers and Bolt face washers shall be as given in Table 6 and 7 of EN 14399-9 respectively. Specification and reference standards for Nut face washers and Bolt face washers regarding material, general requirements, heat treatment, hardness alternatives, tolerances, surface finish, associated bolts and nuts, associated washers, acceptability etc. have been given in Table 8 of EN 14399-9. Nut face washers shall be marked with the identification mark of the manufacturer of the bolting assembly and the letters HN. The marking shall indented into one face. Bolt face washers shall be marked with the identification mark of the manufacturer of the bolting assembly and the letters HB. The marking shall indented into one face.

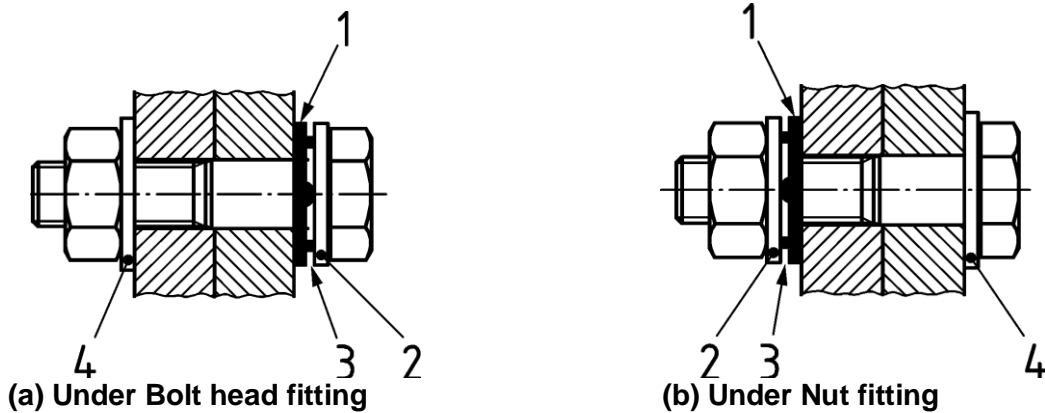
6.6 Surface finish and coatings: For corrosion protection of DTI, Nut face washers and Bolt face washers hot dip galvanization shall not be done because in case of hot dip galvanization it is difficult to accurately control the thickness of coating as well as risk of hydrogen embrittlement. Moreover excessive coating of DTI washers may lead to erroneous tensioning of HSFG bolt assembly. Hence in DTI, Nut face washer and Bolt face washer surface finish should be sherardized according to EN 13811 (latest version) or zinc flake coating as per ISO 10683 (latest version) should be done.

6.7 Type of HSFG bolting assemblies with DTI: Bolting assemblies according to this document consist of bolts and nuts which shall meet all the requirements of EN

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14399-3 (HR System). The functional characteristics of the bolting assemblies shall be achieved when tested together with direct tension indicators. The assembly may include washers according to EN 14399-6 or EN 14399-5 (under the nut only) and/or nut face or bolt face washers in accordance with Clause 4 of EN 14399-9.

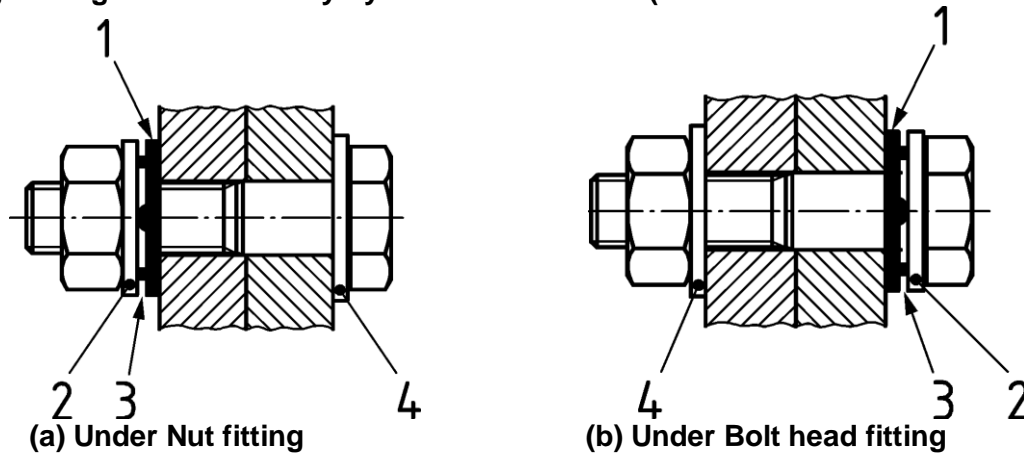


Key

1. Direct Tension Indicator
2. Bolt face washer (not required for property class 8.8)
3. Gap
4. washer according to EN 14399-5 or -6

1. Direct Tension Indicator
2. Nut face washer
3. Gap
4. washer according to EN 14399-6 (not required for property class 8.8)

Fig.4: Tightening of the assembly by rotation of the nut (Normal method of assembly)



Key

1. Direct Tension Indicator
2. Nut face washer
3. Gap
4. washer according to EN 14399-6

1. Direct Tension Indicator
2. Bolt face washer
3. Gap
4. washer according to EN 14399-5 or -6 (not required for property class 8.8)

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Fig.5: Tightening of the assembly by rotation of the bolt head (Alternative method of assembly)

Composition of high-strength structural bolting assembly (HR System) and its component marking has been given in Table 1 of this document. The assembly configurations which can be used with direct tension indicators shall be according to Figures 7 and 8 of EN 14399-9 which has been reproduced above.

6.8 Functional characteristics of DTI in bolting assembly: A specified feeler gauge as per Table 9 of EN 14399-9 which is reproduced below shall be used to determine that the required bolt preload has been achieved by the assembly after it has been tightened.

Table 2: Thickness of the feeler gauge

Direct tension indicator positions	Designation H8 and H10 Thickness of feeler gauge (mm)
Under bolt head, when nut is rotated (Figure 4a)	0.40
Under nut, when bolt is rotated (Figure 5a)	
Under nut, when nut is rotated (Figure 4b)	0.25
Under bolt head, when bolt is rotated (Figure 5b)	

Tests have shown the need for a smaller gap when the direct tension indicator is used under the rotated component. Direct tension indicators fitted as specified will result in the same loads being attained when the bolts are tightened to the specified gaps. The average specified indicator gap shall be determined using the following measurement procedure; the feeler gauge shall be used as a “no go” inspection tool. The feeler gauge shall be pointed at the centre of the bolt as per Figure 9 of EN 14399-9 and shall refuse to enter the number of refusal spaces specified in Table 10 of EN 14399-9.

Table 3: Feeler gauge requirements

Number of indicator protrusions	Minimum number of feeler gauge refusals
4	3
5	3
6	4
7	4
8	5
9	5

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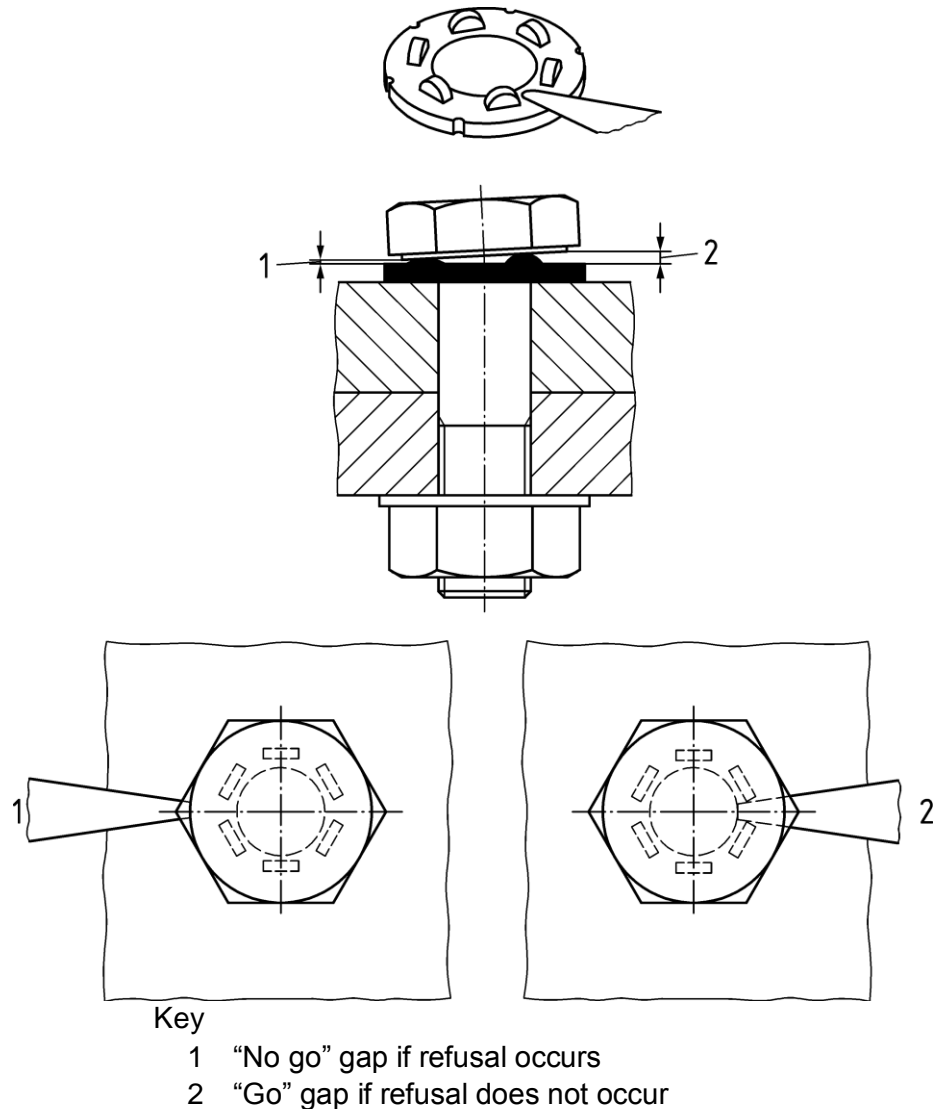


Fig.6: Checking the indicator gap (example with six protrusions)

6.9 Functional characteristics of the bolt/nut/washer(s)/DTI assembly: The functional characteristics of the bolting assembly (comprising of a bolt, a nut, a direct tension indicator and applicable washers, as required) shall be achieved when tested in accordance with the following. The principle of the test is to tighten the bolting assembly and to measure during tightening the following parameters: (a) Relative rotation between the nut and the bolt (b) Bolt force. This test procedure is based on the requirements according to EN 14399-2 and incorporates requirements applicable to assemblies which include direct tension indicators.

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6.10 Suitability test for preloading with direct tension indicator in an assembly:

Direct tension indicators conforming to EN 14399-9 are suitable according to EN 14399-2 provided they are used in an assembly comprised of matched components in accordance with Table 1 of EN 14399-9 and with EN 14399-3 (System HR) that have been tested in accordance with EN 14399-2 to determine the relative rotation between the bolt and nut. The *k*-class values shall not be determined for K1 and K2 and shall be declared as K0. Type tests shall be carried out separately for the direct tension indicator under the bolt head and under the nut. The type test shall be used to demonstrate that $\Delta\theta_2$ measured with assemblies incorporating a direct tension indicator exceeds the appropriate $\Delta\theta_{2, \min}$, by at least 10 %.

6.11 Suitability test for establishing bolt force:

The test shall be carried out in a calibrated load cell with the requirements generally as specified in EN 14399-2. If shims are required to adjust the length between bolt head and nut, these shall be used as specified in EN 14399-2. During the bolt force test the stiffness of the test equipment on which the assembly is mounted is not critical. Hydraulic measuring devices should meet this requirement. The assembly shall be assembled in accordance with Figure 7a of EN 14399-9 horizontally; the bolt force (F_{bi}) shall be determined in accordance with 5.2 of EN 14399-9 and not be less than the minimum bolt force specified in Table 4 of EN 14399-9.

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