

BS EN 14399-2:2015



BSI Standards Publication

High-strength structural bolting assemblies for preloading

Part 2: Suitability for preloading

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National foreword

This British Standard is the UK implementation of EN 14399-2:2015. It supersedes BS EN 14399-2:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee FME/9/-/2, Fasteners for structural bolting.

A list of organizations represented on this committee can be obtained on request to its secretary.

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la mise en précontrainte

Hochfeste vorspannbare Garnituren für
Schraubverbindungen im Metallbau - Teil 2: Eignung zum
Vorspannen

This European Standard was approved by CEN on 18 October 2014.

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Foreword

This document (EN 14399-2:2015) 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of an identical text or by endorsement, at the latest by August 2015 and conflicting national standards shall be withdrawn at the latest by November 2016.

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

This document supersedes EN 14399-2:2005.

In comparison with EN 14399-2:2005, the following modifications have been made:

- technical requirements and delivery conditions for bolting assemblies have been transferred from EN 14399-1;
- Table 1 containing the overview of the composition of bolting assemblies and component marking has been added;
- requirements for necessary information on the use of tightening methods to be stated on the label or packaging have been added;
- requirements for the test report have been revised.

EN 14399 consists of the following parts, under the general title *High-strength structural bolting assemblies for preloading*:

- **Part 1: General requirements;**
- **Part 2: Suitability for preloading;**
- **Part 3: System HR — Hexagon bolt and nut assemblies;**
- **Part 4: System HV — Hexagon bolt and nut assemblies;**
- **Part 5: Plain washers;**
- **Part 6: Plain chamfered washers;**
- **Part 7: System HR — Countersunk head bolt and nut assemblies;**
- **Part 8: System HV — Hexagon fit bolt and nut assemblies;**
- **Part 9: System HR or HV — Direct tension indicators for bolt and nut assemblies;**
- **Part 10: System HRC — Bolt and nut assemblies with calibrated preload.**

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, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This document on structural bolting reflects the situation in Europe where two technical solutions exist to achieve the necessary ductility of bolt/nut/washer(s) assemblies. These solutions consist of two different systems (HR and HV) of bolt/nut/washer assemblies (see Table 1). Both systems are well proven and it is the responsibility of the experts using 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.

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

For the same reason it is important that coating of the bolting assemblies is under the control of one manufacturer.

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

It should be pointed out that compared to ISO 272 the widths across flats (large series) for M12 and M20 have been changed to 22 mm and 32 mm respectively. These changes are justified by the following reasons.

Under the specific conditions of structural bolting, the compressive stresses under the bolt head or nut for the sizes M12 may become too large with the width across flats of 21 mm, especially if the washer is fitted eccentrically to the bolt axis.

For the size M20, the width across flats of 34 mm is very difficult to be produced. The change to 32 mm is primarily motivated by economics but it should also be pointed out that the width across flats of 32 mm was common practice in Europe.

1 Scope

This European Standard specifies the technical requirements for high-strength structural bolting assemblies in order to ensure the suitability for preloading of bolted connections in metallic structures.

A suitability test is specified to check the behaviour of the structural bolting assemblies so as to ensure that the required preload can be reliably obtained by the tightening methods specified in EN 1090-2 with sufficient margins against overtightening and against failure.

2 Normative references

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

EN 1090-2, Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures

EN 14399-1:2015, *High-strength structural bolting assemblies for preloading - Part 1: General requirements*

EN 14399-3, *High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies*

EN 14399-4, *High-strength structural bolting assemblies for preloading - Part 4: System HV - Hexagon bolt and nut assemblies*

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*

EN 14399-7, *High-strength structural bolting assemblies for preloading - Part 7: System HR - Countersunk head bolt and nut assemblies*

EN 14399-8, *High-strength structural bolting assemblies for preloading - Part 8: System HV - Hexagon fit bolt and nut assemblies*

EN 14399-9, *High-strength structural bolting assemblies for preloading - Part 9: System HR or HV - Direct tension indicators for bolt and nut assemblies*

EN 14399-10, *High-strength structural bolting assemblies for preloading - Part 10: System HRC - Bolt and nut assemblies with calibrated preload*

EN 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 898-1)*

EN 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 898-2)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 14399-1:2015 apply.

4 Symbols and units

A	elongation, (mm)
A_s	nominal stress area of the bolt, (mm^2) (see EN ISO 898-1)
d	nominal thread diameter, (mm)
F_b	bolt force during the test, (kN)
F_{bi}	individual value of the bolt force related to a given nut rotation, torque or bolt elongation, (kN)
F_{bm}	mean value of F_{bi} values, (kN)
$F_{bi,max}$	individual value of the maximum bolt force reached during the test, (kN)
$F_{p,C}$	required preload of $0,7 f_{ub} A_s$, (kN)
f_{ub}	nominal tensile strength ($R_{m,nom}$), (MPa)
k	k -factor
k_i	individual value of the k -factor
k_m	mean value of the k -factor
$l_{b,eff}$	effective preloaded bolt length given as the clamp length (Σt) plus half the nominal nut height, (mm)
M	torque applied during the test, (Nm)
M_i	individual value of the torque applied during the test, (Nm)
M_{pi}	individual value of the torque at which the bolt force has first reached the value of $F_{p,C}$, (Nm)
M_{spec}	specified value of the torque to be applied to the bolting assemblies, (Nm)
n	number of test results
s_F	estimated standard deviation of the F_{bi} values for a tightening torque M_{spec}
s_k	estimated standard deviation of the k_i -values for the preload $F_{p,C}$
V_k	coefficient of variation of the k -factor for the preload $F_{p,C}$
θ	angle of rotation of the nut relative to the bolt, ($^\circ$)
θ_{pi}	individual value of the angle θ at which the bolt force has first reached the value of $F_{p,C}$, ($^\circ$)
θ_{1i}	individual value of the angle θ at which the bolt force has reached its maximum value $F_{bi,max}$, ($^\circ$)
θ_{2i}	individual value of the angle θ , ($^\circ$)
$\Delta\theta_{1i}$	individual angle difference ($\theta_{1i} - \theta_{pi}$), ($^\circ$)
$\Delta\theta_{2i}$	individual angle difference ($\theta_{2i} - \theta_{pi}$), ($^\circ$)
$\Delta\theta_{2min}$	minimum required value of the angle difference $\Delta\theta_{2i}$ as specified in the relevant product standard ($^\circ$)
Σt	clamp length given as the total thickness of the clamped parts between the nut bearing face and the bolt head bearing face, (mm)

5 Technical requirements for structural bolting assemblies

5.1 Composition of bolting assemblies

The performance of the high-strength structural bolting assemblies as specified in Table 1 depends on the properties of their specific components. Therefore, the essential characteristics listed in EN 14399-1 are assessed through the verification of the properties of the components and/or bolting assemblies, as applicable. Other aspects dealing with marking and delivery conditions are assessed through inspection of the involved components and/or bolting assemblies, as applicable.

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

Type of bolting assembly		System HR				System HV		System HRC	
General requirements		EN 14399-1							
Suitability for preloading		EN 14399-2 and, if any, additional testing specified in the product standard							
Bolt and nut		EN 14399-3		EN 14399-7		EN 14399-4	EN 14399-8	EN 14399-10	
Marking	Bolt	HR8.8	HR10.9	HR8.8	HR10.9	HV10.9	HVP10.9	HRC10.9	
	Nut	HR8 or HR10	HR10	HR8 or HR10	HR10	HV10	HV10	HR10	HRD10
Washer(s)		EN 14399-5 ^a or EN 14399-6				EN 14399-6			EN 14399-5 ^a or EN 14399-6
Marking		H or HR ^b				H or HV ^b		H or HR ^b	H or HR ^b or HD ^c
Direct tension indicator and nut face washer or bolt face washer, if any		EN 14399-9						Not applicable	
Marking	Direct tension indicator	H8	H10	H8	H10	H10			
	Nut face washer	HN				HN			
	Bolt face washer	HB		Not applicable		HB			
^a EN 14399-5 can only be used under the nut. ^b At the choice of the manufacturer. ^c Mandatory mark for washers with enlarged outer diameter according to EN 14399-5 only.									

In order to contribute to the reduction of the risk of hydrogen embrittlement and other hydrogen related failures, the underhead radius of bolts as specified in EN 14399-3, EN 14399-4, EN 14399-8 or EN 14399-10 shall be used for any bolts of property class 10.9.

HR bolts (see EN 14399-3 or EN 14399-7) and HRC bolts (see EN 14399-10) which are too short threaded to meet the requirements for a minimum of four thread pitches under the nut in the bolting assembly according to EN 1090-2 shall be fully threaded.

5.2 Manufacturing requirements

Finish and coating shall be as specified in the relevant part of this standard. Coatings of all components of a bolting assembly shall be compatible and shall have similar corrosion resistance. Coating of each component shall be under the control of the manufacturer.

The manufacturing process for bolts of property class 10.9 shall take due care of the risk of hydrogen embrittlement, especially during the coating process. Appropriate processes shall be considered when the risk of hydrogen embrittlement cannot be avoided.

~~Bolts of property class 10.9 shall have rolled threads.~~

Hot dip galvanized nuts shall be galvanized before they are threaded. Nuts shall not be re-threaded.

5.3 Marking of the components of the bolting assemblies

All components used in assemblies for high-strength structural bolting, which are suitable for preloading, shall be marked during the manufacturing process with at least the following:

a) the identification mark of the manufacturer of the bolting assemblies,

and according to Table 1:

b) with the letter H, and

- 1) for bolts and nuts, with additional letter(s) defining the system and the symbol of the property class in accordance with EN ISO 898-1 and EN ISO 898-2, or
- 2) for direct tension indicators, with the symbol 8 or 10 corresponding to the property class of the bolt, or
- 3) for bolt face or nut face washers, with the symbol B or N respectively.

The marking of each type of component shall be assessed by visual inspection. The marking shall conform to the requirements of this subclause.

5.4 Delivery conditions for the bolting assemblies

All components shall be supplied to the purchaser either in the original unopened, single sealed package or alternatively bolts, nuts, washers and direct tension indicators, if any, in separate sealed packages of the same manufacturer of the bolting assemblies.

Bolting assemblies shall be supplied in one of the following alternatives:

a) Single bolting assembly lot: Bolts, nuts, washers and if any direct tension indicators and nut face washers or bolt face washers shall be supplied together as a set by one manufacturer. The components of the bolting assemblies shall be packed together in one package that shall be labelled with the single bolting assembly lot number and the manufacturer's identification. The suitability test shall be performed on each single bolting assembly lot by use of representative sample testing as specified in EN 14399-1. The

components of the bolting assemblies are not interchangeable within the deliveries of other single bolting assembly lots.

- b) Extended bolting assembly lot: Bolts, nuts, washers and if any direct tension indicators and nut face washers or bolt face washers shall be supplied as a set by one manufacturer. Each type of component may be packed in separate packages that shall be labelled with the manufacturing lot number of the components and the manufacturer's identification. The components of the bolting assemblies are interchangeable within the deliveries of the same manufacturer of an extended bolting assembly lot. Each extended bolting assembly lot shall be defined on the basis of one single manufacturing lot of either nuts or direct tension indicators, chosen by a documented method. The suitability test shall be performed on each extended bolting assembly lot by use of representative sample testing as specified in EN 14399-1.

Bolting assemblies shall be delivered according to one of the *k*-classes as specified in Table 2. Bolting assemblies according to *k*-class K2 shall be supplied only according alternative a) of this subclause, i.e. single bolting assembly lot.

Delivery conditions of the bolting assemblies shall be checked through the documented method according to the *k*-class declared by the manufacturer.

The composition of the bolting assemblies, labelling and packaging shall be checked by visual inspection and shall conform to the requirements of 5.1, 5.2 and this subclause.

5.5 Information to be supplied

The manufacturer of the bolting assemblies shall state the suitable methods for tightening in accordance with EN 1090-2 in relation to the declared *k*-class. The necessary information for at least one relevant tightening method as specified in Table 2 shall be stated on the label or packaging.

Table 2 — Information related to tightening methods for the required preload $F_{p,c} = 0,7 f_{ub} A_s$

Tightening method according to EN 1090-2	Minimum information to be supplied	<i>k</i> -class
Torque method	$k_m = \text{---}$ 1st step: Torque = --- Nm 2nd step: Torque = --- Nm	K2
Combined method	1st step: Torque = --- Nm 2nd step: Further rotation	K1 ^a
HRC method	—	K0 for HRD nuts K2 for HR nuts
Direct tension indicator method	—	K0 ^b
^a K2 can also be used. ^b K1 or K2 could also be used, but declared as K0.		

6 Suitability test

6.1 Principle of the test

The suitability for preloading of bolting assemblies shall be demonstrated by suitability testing in accordance with this part of the standard and any additional testing specified in the relevant product standard.

The standard test is to tighten the bolting assemblies by turning the nut and to measure, during tightening, the following parameters:

- the bolt force;
- the relative rotation between the nut and the bolt;
- the torque for both *k*-class K1 and K2;
- the bolt elongation, if required.

For special testing conditions and procedures, see Annex A.

6.2 Test apparatus

The test apparatus shall be made of steel.

The block on which the assembly is mounted shall be sufficiently rigid.

NOTE Hydraulic measuring devices normally do not meet this requirement.

It is recommended that the stiffness of the test set-up be as high as practicable.

The length of the bolt between the head and the nut shall be adjusted by the use of shims as specified in Table 3. The number of shims shall not exceed four.

Table 3 — Characteristics of shims

Dimensions in millimetres

Nominal bolt diameter	Hole diameter	Outside diameter	Thickness	Hardness for the outside shim	Parallelism
$d \leq M14$	$d + 1$	Not less than the outside assembly washer diameter and sufficient to distribute load adequately to the device	≥ 2	≥ 45 HRC through hardened	≤ 1 %
$M14 < d \leq M24$	$d + 2$				
$d > M24$	$d + 3$				

The bolt force shall be measured by a calibrated device (e.g. dynamometer) with uncertainty of ± 2 % of the actual value and a repeatability error of ± 1 %.

The rotation shall be measured to an uncertainty of $\pm 1^\circ$.

The torque shall be measured by a calibrated torque measuring device with an uncertainty of the value and a repeatability error of ± 1 %.

The bolt elongation shall be measured to an uncertainty of $\pm 1/100$ mm. The bolt shall be suitably prepared at each end to facilitate these measurements.

6.3 Test assemblies

The test shall be carried out on assemblies that include at least a washer under the nut.

Test assemblies in accordance with Table 1 shall be taken from a single assembly lot or extended assembly lot (in accordance with 5.4).

Each component of a test assembly shall be used once only.

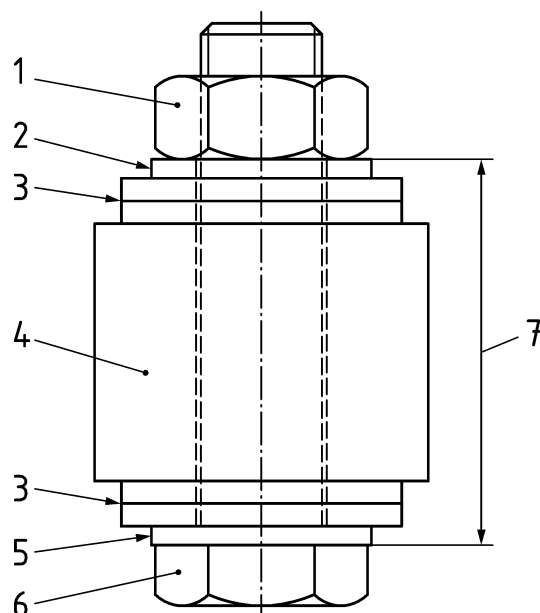
Unless otherwise agreed between the supplier and the purchaser (see Annex A), the tests shall be carried out on test assemblies in the condition of delivery without alteration of the lubrication of the components.

6.4 Test set-up

The test set-up (see Figure 1) may include shims (see Table 3) to adjust for the clamp length of the bolt to be tested.

The test assemblies and shims shall be positioned such that:

- the washer of the assembly is placed under the nut;
- the chamfered washer of the assembly or a chamfered shim is placed under the bolt head;
- the clamp length including shims and washer(s) is the minimum specified in the relevant product standard.



Key

- 1 nut: turned during tightening
- 2 washer of the assembly: prevented from rotating
- 3 shim(s)
- 4 calibrated bolt force measuring device
- 5 chamfered washer of the assembly or chamfered shim
- 6 bolt head: prevented from rotating
- 7 clamp length Σl

Figure 1 — Test set-up

6.5 Test procedure

The test shall be carried out at an ambient temperature range from 10 °C to 35 °C inclusive.

The tightening shall be carried out by rotation of the nut in a continuous manner and measurements shall be recorded throughout the test.

The speed of rotation of the test shall be from 1 min⁻¹ to 10 min⁻¹ inclusive.

Neither the bolt nor the washer under the nut shall be free to rotate during the test. If either of them rotates during tightening a new test shall be carried out to replace the test in question.

The test shall be stopped when any one of the following conditions is first satisfied:

- the angle of nut rotation exceeds $(\theta_{pi} + \Delta\theta_{2min})$;
- the bolt force drops to $F_{p,C}$;
- bolt failure by fracture occurs.

For each of the test assemblies the following curves shall be determined:

- the rotation/bolt force relationship;
- the torque/bolt force relationship, for both k -class K1 and K2;
- the elongation/bolt force relationship, if required.

The data of these relationships shall be such as to permit accurate interpretation of the results and be consistent with the accuracy of the test apparatus (see examples of curves in Figure 2 to Figure 5).

6.6 Evaluation of the test results

6.6.1 Rotation/bolt force curve

The following shall be obtained and shall be noted from each curve in accordance with Figure 2:

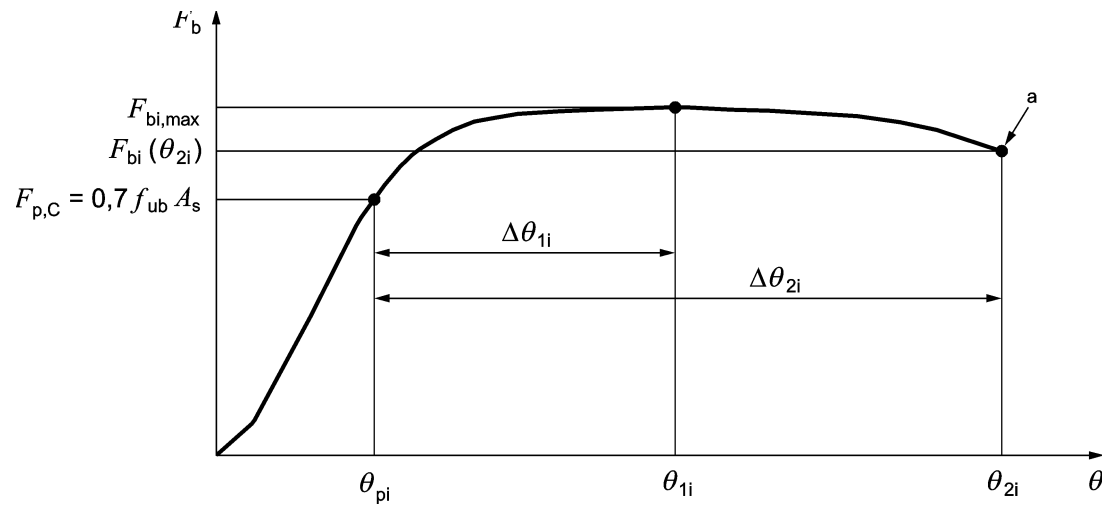
- the angle θ_{pi} at which the bolt force first reaches the value of $F_{p,C}$;
- the angle θ_{1i} at which the bolt force reaches its maximum value $F_{bi,max}$;
- the angle θ_{2i} at which the test is stopped and the corresponding value of the bolt force $F_{bi}(\theta_{2i})$.

When θ_{1i} cannot be precisely determined from the measurement data, it shall be calculated as the mean value of two angles corresponding to the two intersections of the curve with a horizontal line at 1 % below the maximum bolt force value $F_{bi,max}$ noted during the test.

Although the purpose of measuring the angle θ_{2i} is to obtain an indication of the nut rotation at which the bolt force drops back to the value $F_{p,C}$, in practice the test may be stopped when the angle difference $\Delta\theta_{2i}$ exceeds the specified required minimum value $\Delta\theta_{2min}$ according to the relevant product standard (see 6.5).

From the above angle measurements the following values are determined:

- the angle difference $\Delta\theta_{1i}$, which is defined as $(\theta_{1i} - \theta_{pi})$ and corresponds to the point at which the maximum bolt force $F_{bi,max}$ has been reached;
- the angle difference $\Delta\theta_{2i}$, which is defined as $(\theta_{2i} - \theta_{pi})$ and corresponds to the point at which the test has been stopped.



Key

a end of test

Figure 2 — Rotation/bolt force curve

6.6.2 Torque/bolt force curve for the torque at the design preload

An individual value of k (k_i) shall be obtained from each curve in accordance with Figure 3 for the torque (M_{pi}) corresponding to the bolt force ($F_{p,C}$). The value of k_i is calculated as follows:

$$k_i = \frac{M_{pi}}{d F_{p,C}}$$

The coefficient of variation (V_k) of the thus obtained k_i -values is given by the ratio of their estimated standard deviation (s_k) and their mean value (k_m).

The mean value (k_m), the estimated standard deviation (s_k) and the coefficient of variation (V_k) are calculated as follows:

$$k_m = \frac{\sum_{i=1}^n k_i}{n}$$

$$s_k = \sqrt{\frac{\sum (k_i - k_m)^2}{n - 1}}$$

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

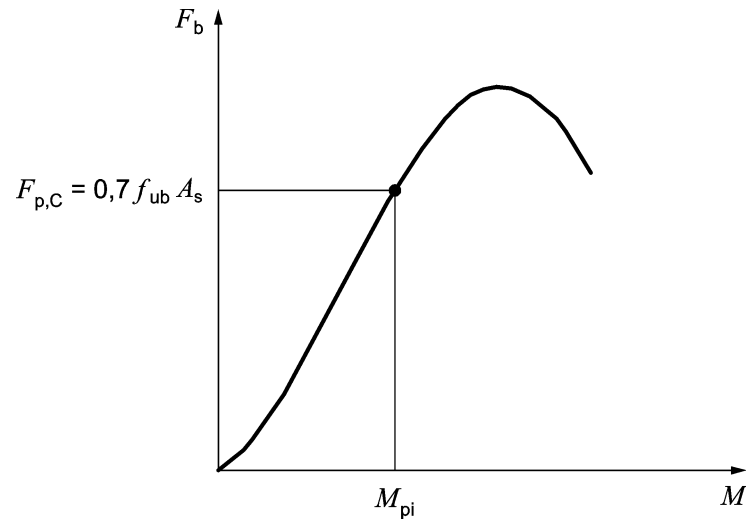
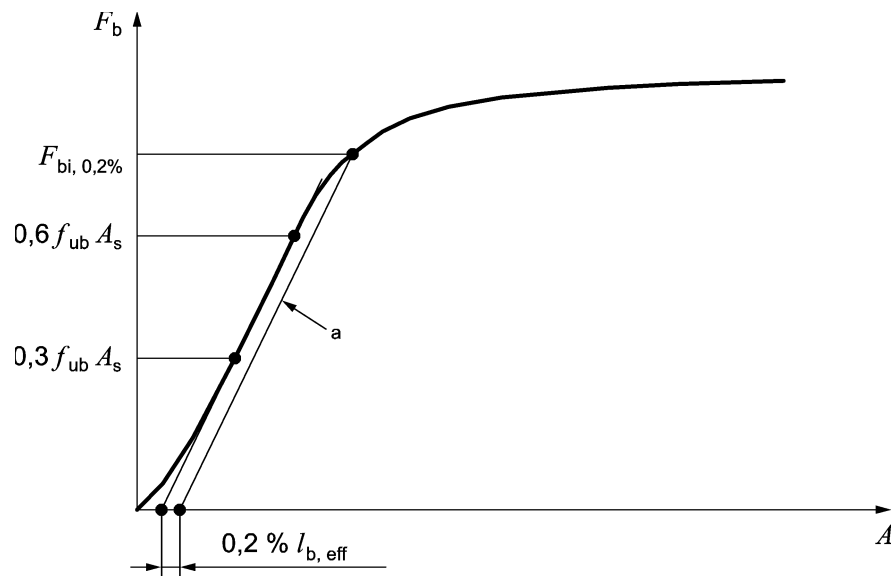


Figure 3 — Torque/bolt force curve

6.6.3 Elongation/bolt force curve

The individual bolt force value $F_{bi,0,2\%}$ corresponding to a permanent bolt elongation of 0,2 % $l_{b,eff}$, where $l_{b,eff}$ is the effective preloaded bolt length, shall be obtained from each curve in accordance with Figure 4.

The 0,2 % permanent elongation line is drawn parallel to the straight line between the two points on the curve at which the bolt force values are $0,3 f_{ub} A_s$ and $0,6 f_{ub} A_s$ respectively.



Key

a line of 0,2 % permanent elongation

Figure 4 — Elongation/bolt force curve

6.6.4 Torque/bolt force curve for the individual values of the bolt force at a specified value of the applied torque

When a specified torque value is required:

- The individual bolt force value F_{bi} at a specified torque value of M_{spec} shall be obtained from each curve in accordance with Figure 5:

$$F_{bi} = F_{bi}(M_{spec})$$

- The estimated standard deviation (s_F) and the mean value (F_{bm}) are calculated as follows:

$$s_F = \sqrt{\frac{\sum (F_{bi} - F_{bm})^2}{n - 1}}$$

with

$$F_{bm} = \frac{\sum_{i=1}^n F_{bi}}{n}$$

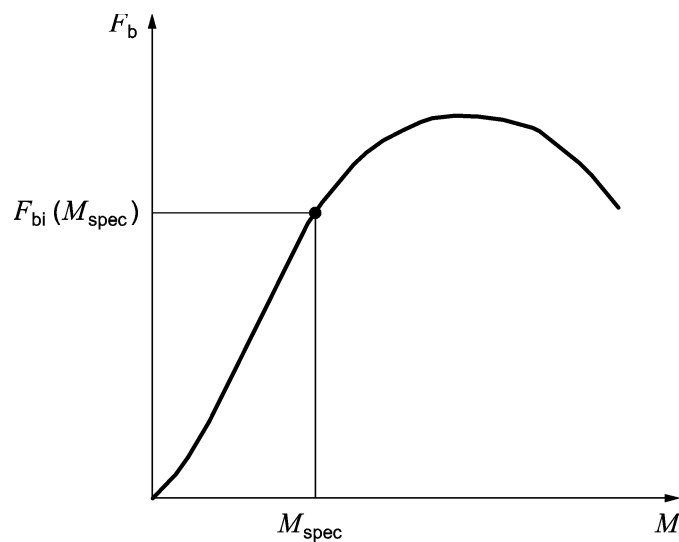


Figure 5 — Torque/bolt force curve

6.7 Test report

The following minimum information shall be included in the test documentation when tested at the bolting assemblies manufacturer:

- date of testing;
- details of the test equipment;
- the single assembly lot number, or the extended assembly lot number;
- number of bolting assemblies tested;
- designation of the bolting assemblies in accordance with EN 14399-3 to EN 14399-10 as relevant;

- test clamp length;
- speed of tightening;
- remarks concerning the execution of tests (including, if any, those on special testing conditions and procedures, see Annex A);
- tests results according to this European Standard;
- conclusions.

When the tests are not carried out by the bolting assemblies manufacturer, the following additional information shall be given:

- identification of the laboratory;
- identification of the organization ordering the test;
- date of reception of the assemblies;
- details of the test set-up including rigidity and number of shims;
- tightening conditions.

Annex A (informative)

Special testing conditions and procedures

By agreement between the supplier and the purchaser, the following special conditions can be applied. However, the test results obtained are not comparable with those for the standard test conditions:

a) Long bolts:

For the evaluation of bolts of a length greater than $10d$, the procedure in 6.6.2 for obtaining values of k is valid, but special evaluation criteria for rotation, elongation or thread deformation should be agreed.

b) Short bolts:

When the bolts are too short to meet the testing conditions defined in 6.4, one of the following possibilities can be considered:

- 1) The bolts can be tested provided that one thread length exists after tightening between the end of the bolt and the unloaded face of the nut.
- 2) Longer bolts from an otherwise similar lot can be tested using the standard test conditions. The difference in length should be as small as practicable. This applies only to extended bolting assembly lots.

c) Lubrication:

The as-delivered lubrication can be altered.

d) Tightening:

- 1) The speed of rotation can be altered.
- 2) Tightening by rotation of the head of the bolt can be carried out.

In this case, an assembly washer is required to be placed under the bolt head and both the nut and the washer under the bolt head shall be prevented from rotating. If either of them rotates during the test, a new test should be carried out to replace the test in question.

- 3) Discontinuous tightening can be carried out.

Bibliography

- [1] ISO 272, *Fasteners - Hexagon products - Widths across flats*

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