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中国钢结构协会标准

CSCS

T/CSCSxxx-2025

钢结构建造质量控制标准  
第 6 部分：螺栓连接

Steel structures — Execution of structural  
steelwork  
Part 6: *Bolting*

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# 前 言

本标准参照GB/T 1.2—2020 给出的规则起草。

本标准参考了ISO 17607:2023 Execution of Structural Steelworks 的技术内容。

T/CSCS xxx—2025《钢结构建造质量控制标准》分为如下七个部分：

——第1部分：基本要求和术语；

——第2部分：钢材；

——第3部分：制造；

——第4部分：安装；

——第5部分：焊接；

——第6部分：螺栓连接；

——第7部分：涂装。

本部分为T/CSCS xxx—2025的第6部分。

在采用ISO 17607:2023时，本部分做了一些修改。有关技术性差异已编入正文中并在它们所涉及的条款的页边空白处用垂直单线标识。在附录B 中给出了这些技术性差异及其原因的一览表，以供参考。

对应于ISO 17607:2023，本部分还做了下列编辑性修改：

——“ISO 17607的本部分”修改为“T/CSCS xxx的本部分”；

——用小数点“.”代替作为小数点的逗号“,”；

——删除国际标准的前言和引言。

本部分的附录N、附录Q为资料性附录。

本标准由中国钢结构协会管理。

本部分起草单位：

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## **1 范围**

## **1 Scope**

本规程适用于钢结构或装配式钢结构施工中螺栓连接的设计和施工，并结合规范 ISO 17607-1 执行。

This document defines the general requirements for structural bolting in the execution of structural steelwork as structures or as fabricated components, in conjunction with ISO 17607-1.

钢结构或装配式钢结构施工中的其他要求，可参考规范 ISO 17607 的其他部分。

Additional requirements to be addressed in the execution of structural steelwork, as structures or as fabricated components, can be found in other parts of ISO 17607.

## 2 引用标准

### 2 Normative references

本文引用以下文件中的部分或全部内容。对于有标注日期的引用文件，仅采用所引用的版本。对于未标注日期的引用文件，采用引用文件的最新版本（包括修订版本）。

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

EN 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

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

EN ISO 898-3, Mechanical properties of fasteners made of carbon steel and alloy steel — Part 3: Flat washers with specified property classes

EN 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

EN ISO 3506-1, Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs

EN ISO 3506-2, Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 2: Nuts

EN ISO 4014, Hexagon head bolts - Product grades A and B

EN ISO 4017, Fasteners — Hexagon head screws — Product grades A and B

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

EN ISO 4033, Hexagon nuts, (style 2) - Product grades A and B

EN ISO 4042, Fasteners — Electroplated coating systems



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 ISO 7089, Plain washers — Normal series — Product grade A

EN ISO 7090, Plain washers, chamfered — Normal series — Product grade A

EN ISO 7091, Plain washers — Normal series — Product grade C

EN ISO 7092, Plain washers — Small series — Product grade A

EN ISO 7093-1, Plain washers — Large series — Part 1: Product grade A

EN ISO 7093-2, Plain washers — Large series — Part 2: Product grade C

EN ISO 7094, Plain washers — Extra large series — Product grade C

EN ISO 10683, Fasteners — Non-electrolytically applied zinc flake coating systems

EN ISO 10684, Fasteners — Hot dip galvanized coatings

EN ISO 14713-3, Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures — Part 3: Sherardizing

EN ISO 16228, Fasteners — Types of inspection documents

EN ISO 17607-11, Steel structures — Execution of structural steelwork— Part 1: General requirements and vocabulary

EN ISO 17607-22, Steel structures — Execution of structural steelwork— Part 2: Steels

EN ISO 17607-33, Steel structures — Execution of structural steelwork— Part 3: Fabrication

EN ISO 17607-44, Steel structures — Execution of structural steelwork— Part 4: Erection

EN ISO 17607-55, Steel structures — Execution of structural steelwork— Part 5: Welding

### 3 术语和符号

本规范采用规范 ISO 17607-1 中给出的术语和符号。

For the purposes of this document, the terms and definitions given in ISO 17607-1 apply.

规范 ISO 和 IEC 中的标准术语和符号在以下数据库进行查询：

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

—规范 ISO 在线查询平台：<https://www.iso.org/obp>

— ISO Online browsing platform: available at <https://www.iso.org/obp>

—规范 IEC 在线查询平台：

— IEC Electropedia: available at

## 4 施工技术规格说明和质量要求

### 4 Execution specification and quality requirements

#### 4.1 一般规定

##### 4.1 General

实施等级、标识、溯源和质量要求参考规范 ISO 17607-1。

See ISO 17607-1 for execution levels, identification, traceability, and quality requirements.

#### 4.2 施工技术规格说明

##### 4.2 Execution specification

全部或部分应用于同一级别的欧洲国家标准和文件，以替代现行的 ISO 标准（见第 2 条）。在特殊情况下以及本规范要求以外的情况，应在本规范中参考同一级别的欧洲国家标准和文件。

National standards and documents that provide technically equivalent conditions may be used, in whole or in part, in place of referenced ISO standards (see Clause 2) or requirements of this document. In these cases, the technically equivalent national standards and documents, and deviations from the requirements of this document shall be referenced in the execution specification.

应在施工前提供结构紧固件施工所需的信息和技术要求。

The necessary information and technical requirements for execution of structural bolting shall be agreed on and complete before commencement.

施工技术规格包括以下相关条款：

The execution specification shall include the following items as are relevant:

1 规范阶段 ISO 17607-1 的发行正在准备中。

1 Under preparation. Stage at the time of publication: ISO 17607-1.

2 规范阶段 ISO 17607-2 的发行正在准备中。

2 Under preparation. Stage at the time of publication: ISO 17607-2.

3 规范阶段 ISO 17607-3 的发行正在准备中。

3 Under preparation. Stage at the time of publication: ISO 17607-3.

4 规范阶段 ISO 17607-4 的发行正在准备中。

4 Under preparation. Stage at the time of publication: ISO 17607-4.

5 规范阶段 ISO 17607-5 的发行正在准备中。

5 Under preparation. Stage at the time of publication: ISO 17607-5.

a) 所需的其他信息，见 A.1；

a) required additional information, see A.1;

b) 指定的选项，见 A.2；

b) options that may be specified, see A.2;

c) 与施工技术规格相关的质量要求，见 A.3。

c) quality requirements related to execution levels, see A.3.

对已有施工技术规格条款进行更改时，应制定相应的修改程序。

There shall be procedures for making alterations to a previously agreed execution specification.

## 5 组成产品

### 5 Constituent products

#### 5.1 一般规定

#### 5.1 General

##### 5.1.1 组成产品选择

##### 5.1.1 Selection of constituent products

参考规范 ISO 17607-1 进行内容的选择

See ISO 17607-1 for selection of constituent products.

##### 5.1.2 合理性验证

##### 5.1.2 Verification of conformance

相关内容与相关标准或特定要求（或两者）的合理性验证，请参考规范 ISO 17607-1。

See ISO 17607-1 for verification of conformance with the order and either relevant standards or specified requirements, or both.

应根据规范 ISO 22688 提供验证性文件，并附上表 1 或表 2 中列出的信息。

Inspection documents in accordance with ISO 22688 shall be supplied with the information in Table 1 or as listed in Table 2.

表 1-按需求提供结构用螺栓产品的检验报告

Table 1—Inspection reporting for structural bolting products, by requirement

需求类型 Type of requirement 控制方法 Method of control	所需限制表示 为: Required limit expressed as:	报告 Reported
化学成分 Chemical composition	适用最小值和最大 值 Min & max, as applicable	测量值 Measured value
力学性能 (屈服强度、抗拉强度、硬度) Mechanical properties (yield strength, tensile strength, hardness)	最小值 Min	测量的最小值 Minimum value measured
	适用最大值 Max if applicable	测量的最大值 Maximum value

		measured
	最小值和最大值 Min & max	测量的最小值和最大值 Minimum and maximum value measured
力学性能 (验证载荷) Mechanical property (proof load)	达标/不达标 Pass/Fail	符合规范 Conform
表面状况 (渗碳/脱碳) Surface condition (carburization/decarburization)	达标/不达标 Pass/Fail	符合规范 Conform
测量 (几何形状、偏差) Measurement (Geometry, tolerances)	最小值 Min	测量的最小值 Minimum value measured
	最大值 Max	测量的最大值 Maximum value measured
	最小值和最大值 Min & max	测量的最小值和最大值 Minimum and maximum value measured
尺寸属性 (测量仪器) Dimensional attribute (gauge)	达标 Go	符合规范 Conform
	不达标 No-Go	
	达标/不达标 Go/No-Go	
螺栓预拉力施加 (k 值或 COV, 或必要时两者都采用) Bolting assemblies for preloading (k-value or COV, or both, if required)	适用 k 级 k-class, if applicable	k 级 k-class
检验 (目视检验 VT、磁粉检验 MT) Inspection (VT, MT)	达标/不达标 Pass/Fail	符合规范 Conform

表 2-根据 ISO 16228 的结构螺栓构件进行质量检验

Table 2 — Inspection documents for structural bolting products according to ISO 16228

组成产品 Constituent product	检验规定 Inspection documents
适用于具有预紧力的结构螺栓施加 Structural bolting assemblies suitable for	F3.1 <sup>a, b</sup>

pretensioning	
结构螺栓的安装 Structural bolting assemblies	F2.1
螺栓 <sup>c</sup> 、螺母 <sup>c</sup> 或垫圈 <sup>c</sup> Boltsc, nutsc, or washersc	F2.1
<p>a. 如果构件上标有生产批号，且制造商能够根据此批号从内部（工厂）生产控制记录中追踪到测量的特定值，则可以省略 F3.1 检验规定。 a If assemblies are marked with a manufacturing lot number and the manufacturer can trace the measured characteristic values from the internal (factory) production control records on the basis of this number, the F3.1 inspection certificate may be omitted.</p> <p>b. 如果需要，检验规定应包括适用性试验的结果。 b The inspection documents shall include the results of the suitability tests, if required.</p> <p>c. 适用于螺栓、螺母或垫圈在非预紧应用中使用，或者不作为螺栓构件的组成部分时的情况。 c Applicable if bolts, nuts or washers are supplied for use in non-pretensioned applications, or not as a component of a bolting assembly.</p>	

## 5.2 结构螺栓连接件

## 5.2 Structural bolting products

### 5.2.1 性能等级

### 5.2.1 Property classes

螺栓和螺母的性能等级以及（如适用）涂层应在产品标准中明确指定，并包括所有适用的选项。

Property classes of bolts and nuts and, if appropriate, coatings shall be specified together with any required options within the product standard.

结构螺栓连接构件和安装规范应从附录 B 中选择。

Structural bolting components and assemblies shall be selected from Annex B.

力学性能应符合以下的规定：

The mechanical properties shall be specified for:

a) 直径大于 ISO 898-1、ISO 898-2 和 ISO 898-3 标准中规定的碳钢和合金钢螺栓构件；

a) carbon and alloy steel bolting assemblies with larger diameters than those specified in ISO 898-1, ISO 898-2 and ISO 898-3;

b) 直径大于 ISO 3506-1 和 ISO 3506-2 标准中规定的或其他相关欧洲国家标准中规定的奥氏体或奥氏体-铁素体不锈钢螺栓构件;

b) austenitic or austenitic-ferritic stainless steel bolting assemblies with larger diameters than those specified in ISO 3506-1 and ISO 3506-2, or those specified in other relevant national standards;

c) 耐候的螺栓构件。

c) atmospheric corrosion-resistant bolting assemblies.

### **5.2.2 施加预拉力连接的结构螺栓和非施加预拉力的结构螺栓连接组件**

#### **5.2.2 Structural bolting assemblies for non - pretensioned applications**

符合表 B.1 至表 B.5 中给出的适用性产品标准的螺栓、螺母、垫圈和紧固件可用于非预拉应用。

Bolts, nuts, washers, and bolting assemblies that conform to the appropriate product standards as given in Table B.1 through Table B.5 may be used for non-pretensioned applications.

注：非预拉应用包括非预拉连接和一些承压型连接。

NOTE Non-pretensioned applications include non-pretensioned joints and some bearing-type joints.

### **5.2.3 预紧应用中的结构螺栓连接组件**

#### **5.2.3 Structural bolting assemblies for pretensioned applications**

符合表 B.1 至表 B.3 中给出的适用性产品标准的高强度结构螺栓、螺母、垫圈和紧固件可用于预拉应用。

High-strength structural bolts, nuts, washers and bolting assemblies that conform to the appropriate product standards as given in Table B.1 through Table B.3 may be used for pretensioned applications



除在施工规范中有规定外，不应在预拉应用中使用不锈钢螺栓。如果在预拉应用中使用，应将其视为特殊紧固件。

Unless specified in the execution specification, stainless steel bolts shall not be used in pretensioned applications. If used in pretensioned applications, they shall be treated as special fasteners.

注：预拉应用包括预拉连接和防滑连接。

NOTE Pretensioned applications include pretensioned joints and slip-resistant joints.

## **5.2.4 垫圈**

### **5.2.4 Washers**

#### **5.2.4.1 一般规定**

##### **5.2.4.1 General**

符合表 B.3 中给出的适用性产品标准的垫圈，或作为表 B.1 或表 B.2 中给出的紧固件的垫圈，可用于预紧应用。

Washers that conform to the appropriate product standards as given in Table B.3, or are included as a part of bolting assemblies as given in Table B.1 or Table B.2, may be used for pretensioned applications.

符合表 B.3 或表 B.5 中给出的适用性产品标准的垫圈，或作为表 B.1、表 B.2 或表 B.4 中给出的紧固件的垫圈，可用于非预拉连接应用。

Washers that conform to the appropriate product standards as given in Table B.3 or Table B.5, or are included as a part of bolting assemblies as given in Table B.1, Table B.2, or Table B.4, may be used for nonpretensioned applications.

#### **5.2.4.2 锥形垫圈**

##### **5.2.4.2 Taper washers**

锥形垫圈应符合平面垫圈的相关标准，但其几何尺寸应单独规定。

Taper washers shall conform with the relevant product standard for flat washers, except for dimensions applicable to shape, which shall be specified.

注：锥形垫圈也称为斜垫圈。

NOTE Taper washers are also known as bevelled washers.

#### **5.2.4.3 板式垫圈**

#### **5.2.4.3 Plate washers**

平垫圈的尺寸应根据附录 C 中的名义间隙来确定，并且其尺寸应确保垫圈与连接部件的重叠量至少与标准平垫圈与标准圆孔共同使用时相同。

Plate washers shall be dimensioned with nominal clearances according to Annex C and have dimensions that ensure that the washer overlaps the connected component by at least as much as a standard plain washer would when used with standard round holes.

#### **5.2.5 直接压力指示垫圈**

#### **5.2.5 Direct tension indicators**

符合表 B.6 中给出的产品标准的直接压力指示垫圈以及相关的与螺母面和螺栓面接触的垫圈可以使用。

Direct tension indicators and associated hardened nut face and bolt face washers that conform to the appropriate product standards as given in Table B.6 may be used.

当使用直接压力指示垫圈与承受轴向拉力的螺栓共同使用时，应考虑预拉力的损失[90]。

When direct tension indicators are used with bolts loaded in axial tension, the potential loss of pretension should be considered[90].

不应将直接压力指示垫圈与不锈钢螺栓一起使用。

Direct tension indicators shall not be used with stainless steel bolts.

如果在耐候螺栓上使用直接压力指示垫圈，则直接压力指示垫圈也应具有耐候性。

If direct tension indicators are used with atmospheric corrosion-resistant bolts, the direct tension indicators shall also be atmospheric corrosion resistant.

注：根据 ASTM F959/F959M 标准的 3 型直接压力指示垫圈可能适合作为耐候材料。

NOTE Type 3 direct tension indicators in accordance with ASTM F959/F959M can be suitable as atmospheric corrosion resistant.

### 5.2.6 替代性直接压力指示垫圈

#### 5.2.6 Alternative direct tension indicators

如果施工规范允许，可以使用表 B.6 中未列出的其他替代直接压力指示垫圈。

Alternative direct tension indicators other than those listed in Table B.6 may be used if permitted by the execution specification.

a) 应在补充规范中提供详细的安装说明，该规范应包括以下内容：

a) Detailed installation instructions shall be available in a supplemental specification that shall provide, as a minimum, for the:

- 1) 安装前验证所需替代性直接压力指示垫圈的特征和频率；  
1) required character and frequency of pre-installation verification;
- 2) 螺栓孔的对准，确保插入螺栓时不会对螺纹造成过度损坏；  
2) alignment of bolt holes to permit insertion of the bolt without undue damage to the threads;
- 3) 各种类型和尺寸的孔中紧固件的放置，包括直接压力指示垫圈和其他垫圈的放置和定位；  
3) placement of bolting assemblies in all types and sizes of holes, including placement and orientation of the direct tension indicator and other washers;
- 4) 连接的系统性组装，从连接的最坚固部分开始，直到连接层紧密接触；  
4) systematic assembly of the joint, progressing from the most rigid part of the joint until the connected plies are in firm contact; and,
- 5) 随后对连接中所有螺栓进行系统性的预紧，从连接的最坚固部分开始，以最大限度地减少先前预拉螺栓的松弛。

5) subsequent systematic pretensioning of all bolts in the joint, progressing from the most rigid part of the joint in a manner that will minimize relaxation of previously pretensioned bolts.

b) 在补充规范中应提供详细的检查说明，该说明应至少包括以下内容：

b) Detailed inspection instructions shall be available in a supplemental specification that shall provide, as a minimum, for:

1)检查所要求的安装前验证试验；

1) observation of the required pre-installation verification testing; and,

2)随后的常规检查，以确保替代直接压力指示垫圈的正确使用。

2) subsequent routine observation to ensure the proper use of alternative direct tension indicators.

#### **5.2.7 结构螺栓连接组件的涂层**

#### **5.2.7 Coated structural bolting components**

结构螺栓连接组件的涂层耐候性应与连接构件的耐候性相当。

The corrosion resistance of coated structural bolting components shall be comparable to that specified for the connected components.

可以使用热浸镀锌涂层、非电解施加的锌片涂层、电镀涂层或表 B.9 中给出的产品标准所适用的其他结构螺栓连接组件涂层，或者在没有此类标准的情况下可以根据螺栓连接组件制造商的建议进行涂层处理。

Hot-dip galvanized coatings, non-electrolytically applied zinc flake coatings, electroplated coatings, or other coatings of structural bolting components appropriate with the product standards given in Table B.9 may be used, or, in the absence thereof, with the bolting component manufacturer's recommendation.

结构螺栓连接组件的防护涂层应符合相关产品标准的要求，或者在没有相关标准的情况下，应遵从制造商的建议。

Protective coatings of structural bolting components shall conform with the

requirements of the relevant product standard or, in the absence thereof, with the manufacturer's recommendation.

对于性能等级为 10.9 或等效抗拉强度更高或以上的螺栓，不应使用电镀涂层。

For bolts of property class 10.9 or equivalent tensile strength or higher, electroplated coatings shall not be used.

注：应注意性能等级为 10.9 级等效抗拉强度或以上的电镀或热浸镀锌螺栓存在氢脆的风险。

NOTE Attention is drawn to the risk of hydrogen embrittlement of electroplated or hot dip galvanized bolts of property class 10.9 or equivalent tensile strength or higher.

#### **5.2.8 耐候结构螺栓连接组件**

##### **5.2.8 Atmospheric corrosion - resistant structural bolting components**

耐候结构螺栓连接组件的材料化学成分应明确说明。

The chemical composition of the material of atmospheric corrosion-resistant structural bolting components shall be specified.

#### **5.2.9 锁紧装置**

##### **5.2.9 Locking devices**

如果需要，应指定可有效防止在受到冲击、显著振动或循环载荷时，组件松动或预拉力损失的装置。

If required, devices shall be specified that effectively prevent loosening or loss of pretension of the assembly if subjected to impact, significant vibration, or cyclic loading.

注 1：使用楔形锁紧垫圈和使用适当的紧固技术紧固双螺母，可以最大程度地减少因松动而导致的螺栓预拉力损失。锁紧装置不能防止因松弛或蠕变而导致的预拉力损失。

NOTE 1 The use of wedge-locking washers, and the use of double-nutting with proper tightening techniques, have been shown to minimize loss of bolt pretension from self-

loosening. Locking devices cannot prevent loss of pretension from relaxation or creep.

无特殊说明，可以使用 ISO 7719、ISO 10511 以及 ISO 2320 标准中给出的性能要求。

To prevent nuts from becoming disengaged from bolts, prevailing torque nuts from ISO 7040, ISO 7042, ISO 7719, and ISO 10511, and the performance requirements given in ISO 2320, can be used unless otherwise specified.

注 2：标准 ISO 2320 包括试验用于确定预拉扭矩型螺母的性能特性或扭矩/预拉力特性。

NOTE 2 ISO 2320 includes a test to determine either the performance properties or the torque/clamp force properties, or both, for prevailing torque type steel nuts.

#### **5.2.10 特殊结构紧固件**

#### **5.2.10 Special structural fasteners**

在符合施工规范的情况下，可使用特殊结构紧固件：

When permitted by the execution specification, special structural fasteners may be used:

- 如果性能等级不超过 10.9 级（或等效抗拉强度）；
- if the property class does not exceed grade 10.9 (or equivalent tensile strength); and
- 如果性能等级不超过 10.9 级（或等效抗拉强度）；
- if the bolting component type is subjected to initial testing representative of the product type to demonstrate that its performance is suitable.

初步试验参数应包括附录 B 中列出的同类产品的相关试验要求。

Initial testing parameters should include relevant testing requirements for comparable products listed in Annex B.

应按照 7.9 条的规定，在补充规范中提供详细的安装说明。

Detailed installation instructions shall be available in a supplemental specification in accordance with 7.9.

注 1：7.9 条中提到了特殊紧固件的使用。

NOTE 1 The use of special fasteners is addressed in 7.9.

注 2：树脂注入螺栓被归类为特殊紧固件，并在规范 EN 1090-2 中进行了说明。

NOTE 2 Resin injection bolts are classified as special fasteners, and are addressed in EN 1090-2.

#### **5.2.11 包装方法**

##### **5.2.11 Packaging**

结构紧固件应妥善包装以便运输，并根据相关产品标准进行标识。所有包装的内容应清晰显示。

Structural bolting components shall be suitably packed for transportation and shall be identified in accordance with the relevant product standard. The contents of all packages shall be clearly displayed.

注：包装的适用性需考虑搬运需求、耐用性、防水性、防穿刺性以及相关问题。

NOTE Consideration for packaging suitability can include needs for handling, durability, water resistance, puncture resistance, and related concerns.

#### **5.2.12 试验报告**

##### **5.2.12 Test reports**

必要时制造商或供应商应提供试验报告，证明所有用于结构螺栓连接的部件均符合现行规范，并在结构钢构件交付、组装或安装之前提供这些报告。

If required, the manufacturer or supplier test reports documenting conformance to the applicable specifications for all components used in structural bolting shall be available on delivery and before assembly or erection of structural steel.

### 5.2.13 交付和标识

#### 5.2.13 Delivery and identification

结构螺栓连接件应以未开封且完整的包装交付。

Structural bolting components and bolting assemblies shall be delivered in unopened and complete packages.

根据 5.2.2 至 5.2.5 条的结构螺栓连接组件应按照相关产品标准的要求进行标记、交付和识别。

Structural bolting components and bolting assemblies according to 5.2.2 to 5.2.5 shall be marked, delivered and identified in accordance with the requirements of the relevant product standard.

耐候紧固件、地脚锚栓、锁定装置、平垫圈和特殊紧固件（如适用）应按照产品标准进行标记，以适当的包装交付，并按以下方式识别：

Atmospheric corrosion resistant bolting assemblies, foundation bolts, locking devices, plate washers, and special fasteners shall be marked in accordance with the product standard, if applicable, delivered in suitable packaging, and identified as follows:

a) 贴上标签，以便识别；

a) labelled such that the content is readily identifiable; and

b) 按照相关产品标准以清晰且耐用的形式贴上标签或记录以下信息：

b) labelled or documented in accordance with the relevant product standard with the following information in a legible and durable form:

— 制造商标识，如有必要还应包括批次号；

— manufacturer's identification and, if relevant, lot numbers;

— 结构紧固件的类型和材料，以及（如果适用）其组件名称；

— type of structural bolting component and material and, if appropriate, its assembly;



—保护涂层（如适用）。

— protective coating, if applicable.

#### **5.2.14 结构螺栓连接组件和部件的储存**

##### **5.2.14 Storage of structural bolting components and assemblies**

应存放在安装现场受保护的遮蔽物内的封闭容器中，以防止灰尘和湿气影响。

Structural bolting components and assemblies shall be divided by grade, size, length, and lot number. They shall be protected from dirt and moisture in closed containers in a protected shelter at the site of installation.

堆叠存放时应遵循制造商的说明。

The manufacturer's instructions shall be followed when stacking packages.

从保护储存区域中取出预计在工作班次期间安装的紧固件。未使用的组件应在工作班次结束时放回保护储存区域。组件不得从交付时的状态进行清洁或修改。

Only as many bolting components anticipated to be installed during the work shift shall be taken from protected storage. Components that are not incorporated into the work shall be returned to protected storage at the end of the work shift. Components shall not be cleaned or modified from the as-delivered condition.

应小心处理高强度螺栓，以防止螺纹损坏。除了螺纹损坏外，还应防止用以紧固螺栓的梅花头损坏。

High-strength bolts shall be handled carefully to prevent thread damage. In addition to thread damage, spline-drive assemblies shall be handled carefully to prevent spline damage.

#### **5.2.15 结构紧固件和部件的修复**

##### **5.2.15 Reconditioning of structural bolting components and assemblies**

使用扭矩控制方法（包括扭矩扳手）安装的紧固件，如果有锈迹、污垢或湿气，则不能使用，除非它们已通过试验重新达到合格标准。

Bolting components to be installed using torque control methods, including spline-drive assemblies, that accumulate rust, dirt, or moisture, shall not be incorporated into the work unless they are requalified through testing.

未能通过重新试验的扭矩扳手以及使用扭矩控制方法安装的紧固件应退还给制造商或供应商进行重新加工，包括清洁、重新润滑和重新试验，除非施工技术规格说明允许其他人进行这些操作。此类重新加工应遵循书面程序，该程序包含对润滑产品、批次控制、过程控制、抽样和适当的试验方法的要求，以验证重新加工的组件（如果有的话）在允许范围内提供所需的预拉力。

Spline-drive assemblies and those bolting components to be installed using torque control methods that fail requalification testing shall be returned to the manufacturer or supplier for reconditioning, including cleaning, relubrication, and retesting, unless these operations are permitted by the execution specification to be performed by others. Such reconditioning shall follow written procedures with requirements for lubrication products, batch control, process control, sampling, and a suitable test method to verify that the reconditioned assemblies provide the required pretension within the permitted range, if any.

### **5.3 螺柱和抗剪连接组件**

#### **5.3 Studs and shear connectors**

电弧点焊用螺纹应符合 ISO 17607-5 标准。

Threaded studs for arc stud welding shall be in accordance with ISO 17607-5.

其他类型螺栓连接用于抗剪连接件的要求应归类为特殊紧固件。

Requirements for other types of shear connectors for bolted connections shall be classified as special fasteners.

### **5.4 锚固件**

#### **5.4 Anchorages**

##### **5.4.1 基础锚栓**

##### **5.4.1 Foundation bolts**

用作基础锚栓的力学性能应符合 ISO 898-1、ISO 3506-1 标准，或由热轧碳钢、低合金钢或不锈钢制成。施工技术规格说明规定的性能。

The mechanical properties of rods used as foundation bolts shall be in accordance with ISO 898-1, ISO 3506-1 or fabricated from hot-rolled carbon, low-alloy, or stainless steel. The execution specification shall specify the required properties.

除施工技术规格说明中另有规定外，不得使用钢筋。当施工技术规格说明中允许使用钢筋时，钢筋应为可焊等级，且等级应在施工技术规格说明中明确。

Unless otherwise specified in the execution specification, steel reinforcing bars shall not be used. When permitted in the execution specification, steel reinforcing bars shall be of a weldable grade, and the grade shall be specified in the execution specification.

#### **5.4.2 其他锚固构件**

#### **5.4.2 Other anchorage systems**

施工技术规格说明应明确是否应使用专有产品。

The execution specification shall specify if proprietary products shall be used.

## 6 准备与组装

### 6 Preparation and assembly

#### 6.1 一般规定

##### 6.1 General

本条款适用于机械紧固件和销轴连接孔的加工制作。

This clause applies to holes for connections with bolts, pins, and foundation bolts.

#### 6.2 结构螺栓孔

##### 6.2 Holes for structural bolting

##### 6.2.1 一般规定

###### 6.2.1 General

应从附录 C 中选择名义间隙。除施工技术规格说明中另有规定，螺栓孔的名义间隙应按表 C.1 中的规定执行。

The nominal clearance shall be selected from Annex C. Unless specified in the execution specification, the nominal clearance for bolt holes shall be as specified in Table C.1.

应在施工技术规格说明中指定螺栓和不在规定范围内的销钉的名义间隙。名义间隙为：

The nominal clearances for bolts and for pins not intended to act in fitted conditions shall be specified in the execution specification. The nominal clearance is:

—对于圆孔，是名义孔径与名义螺栓直径之差；

— for round holes, the difference between the nominal hole diameter and the nominal bolt diameter;

—对于长圆孔，是孔的长度或宽度与名义螺栓直径之差。

— for slotted holes, the difference between the length or the width of the hole and the nominal bolt diameter.

**注 1：**附录 C 提供了几个欧洲国家标准中所述的名义间隙。

NOTE 1 Annex C provides information on nominal clearances as stated in several national standards.

**注 2：**名义孔径与拟用于孔中的螺栓的名义直径相结合，决定了孔是标准圆孔和大圆孔。短槽孔和长槽孔这两个术语应用于槽形孔，指的是用于预拉力螺栓结构设计（并在一定程度上也用于非预拉力螺栓）的两种孔类型。这些术语也用于指定非预拉力螺栓的间隙。

NOTE 2 The nominal hole diameter combined with the nominal diameter of the bolt to be used in the hole determines whether the hole is standard or oversize. The terms "short" and "long" applied to slotted holes refer to two types of holes used for the structural design of pretensioned bolts, and with limitation, non-pretensioned bolts. These terms are also used to designate clearances for non-pretensioned bolts.

施工技术规格说明应规定运动连接的特殊尺寸。

The execution specification shall specify special dimensions for movement joints.

## **6.2.2 孔的尺寸**

### **6.2.2 Dimensions of holes**

#### **6.2.2.1 一般规定**

##### **6.2.2.1 General**

除了施工技术规格说明中另有规定外，孔的尺寸应按照第 6.2.1 条中定义的名义间隙。

Unless otherwise specified in the execution specification, the dimensions of holes shall provide the nominal clearance defined in 6.2.1.

#### **6.2.2.2 长圆孔**

##### **6.2.2.2 Slotted holes**

当施工技术规格说明允许时：

When permitted by the execution specification:

— 短长圆孔可用于非预拉力连接和预拉力承载连接的任何一层或多层，前提是所有施加的载荷大致垂直于孔长轴线（在 80°至 100°之间）；

- short-slotted holes can be used in any or all plies of non-pretensioned joints and pretensioned bearing joints, provided the applied load is approximately perpendicular (between 80° and 100°) to the axis along the length of the slot;
- 短长圆孔可用于防滑连接的任何一层或多层，而不考虑所施加载荷的方向；
- short-slotted holes can be used in any or all plies of slip-resistant joints without regard for the direction of the applied load;
- 长长圆孔仅可用于非预拉力连接和预拉力承载连接的承压面的任意一层，前提是所施加的载荷大致垂直于孔长轴线（在 80°至 100°之间）；
- long-slotted holes can be used in only one ply at any individual faying surface of non-pretensioned joints and pretensioned bearing joints, provided the applied load is approximately perpendicular (between 80 ° and 100 °) to the axis along the length of the slot;
- 长长圆孔仅可用于防滑连接的承压面的任意一层，而不考虑所施加载荷的方向。
- long-slotted holes can be used in one ply only at any individual faying surface of slip-resistant joints without regard for the direction of the applied load.

**注：**螺栓连接传力元件承压面之间完全插入的垫圈不视为连接的长长圆孔组件，也不被视为承压面的任何一层。有关垫圈和填料的承压面要求，请参见第 6.3 条和第 6.4.2 条。

NOTE Fully inserted shims between the faying surfaces of load-transmitting elements of bolted joints are not considered a long-slotted element of a joint; nor are they considered to be a ply at any individual faying surface. See 6.3 and 6.4.2 for requirements for faying surfaces of shims and packing.

#### **6.2.2.3 适配螺栓孔**

#### **6.2.2.3 Holes for fit bolts**

对于适配螺栓，名义孔径应等于螺栓的杆径。

For fit bolts, the nominal hole diameter shall be equal to the shank diameter of the bolt.

**注：**对于符合规范 EN 14399-8 中的适配螺栓，杆的名义直径比螺纹部分的名义直径大 1mm。

NOTE For fit bolts conforming to EN 14399-8, the nominal diameter of the shank is 1 mm larger than nominal diameter of the threaded portion.

#### **6.2.2.4 沉头螺栓孔**

##### **6.2.2.4 Holes for countersunk bolts**

对于沉头螺栓，应确保在安装后沉孔的名义尺寸及其误差，螺栓与最外层板件的外表面平齐。因此，应根据需要指定沉孔的尺寸。

For countersunk bolts, nominal dimensions of the countersinking and tolerances on those shall be such that, after installation, the bolt shall be flush with the outer face of the outer ply. The dimensions of the countersinking shall be specified accordingly.

如果沉头螺栓被指定用于承受拉力或再施加预拉力的连接中使用，则沉孔的名义深度应至少比最外层板件的名义厚度小 2mm。

If countersunk bolts are identified as being for use in tension or in pretensioned applications, the nominal depth of countersinking shall be at least 2 mm less than the nominal thickness of the outer ply.

**注：**2mm 是允许的负公差。

NOTE The 2 mm is to allow for adverse tolerances.

#### **6.2.2.5 基础板上的基础螺栓孔**

##### **6.2.2.5 Holes in base plates for foundation bolts**

如果底板孔的名义间隙为 3mm 或更大，但不超过 8mm，则应在螺母下方使用厚度不小于 4mm 的圆形或方形垫板。

If the nominal clearance of the base plate hole is 3 mm or larger, but not more than 8 mm, a round or square plate washer of thickness not less than 4 mm shall be used under the nut.

此外，对于直径  $d$  大于 20mm、最小规定屈服强度为 400MPa 或更低的基础锚栓：  
In addition, for foundation bolts above 20 mm in diameter  $d$  with a minimum specified

yield strength of 400 MPa or less:

- 底板孔的最大直径为  $1.5d$ ;
- the maximum base plate hole diameter is  $1,5 \times d$ ;
- 垫板的最小外径为  $1.75d+20\text{mm}$ ;
- the minimum outside diameter of the plate washer plate is  $1,75 \times d + 20 \text{ mm}$ ; and
- 垫板的最小厚度为  $0.4d$ 。
- the minimum plate washer thickness is  $0,4 \times d$ .

对于最小规定屈服强度大于 400MPa 的基础螺栓，可能需要更厚的垫板。

For foundation bolts with a minimum specified yield strength greater than 400 MPa, thicker plate washers can be required.

注：上述尺寸可视为仅适用于承受重力荷载的柱子和柱基力矩较低的柱子。

NOTE The above dimensions can be considered suitable for columns supporting gravity loads only, and for columns with low levels of moment at the column base.

### 6.3 承压型连接的承压面

#### 6.3 Faying surfaces for bearing - type joints

承压型连接的承压面，无论采用非预拉力螺栓还是预拉力螺栓，都应保持清洁，无污物和其他杂质。承压面可以按照施工技术规格说明的要求不涂覆任何材料，或者涂覆任何形式的防护涂层，或者镀锌。此外，与螺栓头、螺母或垫圈（如果使用）相邻的表面也应保持清洁，无污物和其他杂质。

The faying surfaces of bearing connections, whether with non-pretensioned or pretensioned bolts, shall be free of dirt and other foreign material, and are permitted to be uncoated, coated with protective coatings of any formulation, or galvanized, as specified in the execution specification. In addition, surfaces adjacent to the bolt head and nut, or washer(s), if used, shall be free of dirt and other foreign material.

表面处理和防护涂层的要求也适用于垫板和垫圈。



Surface preparation and protective coating requirements also apply to packing plates and shims.

#### **6.4 摩擦型连接摩擦面的制备**

#### **6.4 Preparation of friction surfaces in slip - resistant joints**

##### **6.4.1 一般规定**

##### **6.4.1 General**

除了不涉及腐蚀防护，还有不适用于不锈钢材料。

This clause does not address corrosion protection of the structural steel.

##### **6.4.2 表面处理**

##### **6.4.2 Surface preparation**

应在施工规范中明确摩擦型连接的抗滑移系数。

The slip factor for slip-resistant joints shall be specified in the execution specification.

应根据特定的欧洲国家标准，从表 D.1 中选择具有指定最小抗滑移系数的表面处理和防护涂层。

Surface preparation and protective coatings that provide a designated minimum slip factor in accordance with specific national standards shall be selected from Table D.1.

没有涂层的接触面（包括与垫圈接触的表面部分）应无锈皮（紧密轧制氧化皮除外），且在 1 倍螺栓直径（但距离任何孔边缘不小于 25mm）以内的区域以及螺栓排列区域内的所有区域中，均不得有疏松锈迹、灰尘、油污、焊渣、油漆、清漆或其他涂层（包括飞溅涂层），但施工规范中另有规定的除外。如果无法满足该条件，则应对接触面进行喷砂清理。见图 1。

Uncoated faying surfaces, including parts of surfaces in contact with washers, shall be free of scale, except tight mill scale, and free of loose rust, dust, oil, welding spatter, paint, lacquer or other coatings, including overspray, other than those specified in the execution specification, in areas closer than one bolt diameter but not less than 25 mm from the edge of any hole and in all areas within the bolt pattern. If this condition cannot be achieved, the faying surface shall be blast cleaned. See Figure 1.

涂层接触面应首先进行喷砂清理，然后涂上符合或超过所需防滑要求的涂层，该涂层应满足附录 P 中的要求或列于表 D.1 中。

Coated faying surfaces shall first be blast cleaned and subsequently coated with a coating that meets or exceeds the required slip resistance that is either qualified in accordance with the requirements in Annex P or listed in Table D.1.

垫板和垫圈应具有与连接材料相同或更好的抗滑移系数表面处理。见 7.2.3 节。

Packing plates and shims shall have a surface preparation that provides the same or better slip coefficient as the connected material. See 7.2.3.

### 6.4.3 装配前的注意事项

#### 6.4.3 Precautions prior to assembly

在装配前应采取以下预防措施：

The following precautions shall be taken prior to assembly:

- a) 钻孔应在喷砂处理前完成；
- a) drilling of holes shall be completed prior to blasting;
- b) 摩擦表面应无油污、灰尘或除指定用于摩擦表面的涂层以外的其他污染物；
- b) the friction surfaces shall be free from all contaminants, such as oil, dirt, or coatings other than those specified for the friction surface;
- c) 未涂层的表面应无疏松锈迹和其他松散物质；
- c) uncoated surfaces shall be free from loose rust and other loose material;
- d) 应注意不要损坏或磨光粗糙表面；
- d) care shall be taken not to damage or smooth the roughened surface;
- e) 当拼接板临时固定到构件上时，可使用临时螺栓；
- e) when splice plates are temporarily fixed to a member, temporary bolts may be used;
- f) 在涂层固化之前，不得组装具有涂层接触面的连接层。
- f) the plies of joints with coated faying surfaces shall not be assembled before the coating has cured.

如果在喷砂处理后使用磨光机去除螺栓孔周围的毛刺，则：

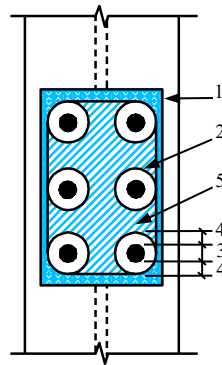
When a grinder is used on the periphery of bolt holes for the removal of burrs after blasting, either:

g) 孔附近的打磨区域应重新喷砂处理，

g) the ground area adjacent to the hole(s) shall be re-blasted, or

h) 打磨后的表面应暴露至产生红锈为止。

h) the as-ground surface shall be exposed until red rust generation has occurred.



注：

4 螺栓直径的 4 倍或 25mm，以较大者为准

Key

1 接触面的接触区域周长

4 bolt diameter or 25 mm, whichever is greater

1 perimeter of contact area of faying surfaces

2 螺栓周围的圆形区域（典型）

5 螺栓图案内的区域

5 area within the bolt pattern

2 circular area around bolt (typical)

3 螺栓直径

3 bolt diameter

图 1-摩擦型连接涂覆的贴合面

Figure 1 – Coated faying surface for slip-resistant joints

## 6.5 装配

### 6.5 Assembly

在装配之前，应清除连接部件表面的杂质。

Loose material that would prevent solid seating of the connecting parts shall be

removed before assembly.

对于摩擦型连接，除了在施工规范中另有批准，应评估可能导致螺栓预紧力大幅下降的涂层过厚情况。

For pretensioned and slip-resistant joints, excessive coating thickness that can cause substantial loss of bolt pretension shall be evaluated, unless otherwise approved in the execution specification.

预紧力的损失可通过附录 Q 中所述的试验进行评估。

Loss of pretension can be evaluated by testing as described in Annex Q.

组装时，连接部件应紧密接触，不得有自由空间或可压缩材料隔开。

When assembled, connections shall be in close contact and shall not be separated by free spaces or compressible materials.

部件的组装应在标准 ISO 17607-3 或 ISO 17607-4（视情况而定）规定的误差范围内进行。

Assembly of components shall be carried out within the tolerances specified in ISO 17607-3 or ISO 17607-4, as applicable.

应采取措施防止不同金属材料接触产生的电腐蚀。

Precautions shall be taken to prevent galvanic corrosion produced by contact between different metallic materials.

对于不允许通过铰削或切割来扩大的孔（例如适配螺栓孔），应予以识别，并且不得用作定位孔。

Holes (e.g. for fit bolts) for which enlargement by reaming or cutting is not permitted shall be identified and not be used for alignment.

**注意：**如果连接孔不能对齐，则可以提供专门对齐的附加孔。

NOTE Additional holes specifically meant for alignment can be provided where connection holes cannot be used for alignment.

## 7 结构螺栓连接

### 7 Structural bolting

#### 7.1 一般规定

##### 7.1 General

本条款涵盖了使用结构紧固件和组件在工厂和现场对钢部件连接进行螺栓紧固的要求。

This clause covers requirements for shop and site bolting of steel-to-steel connections using structural bolting components and assemblies.

#### 7.2 连接类型和装配

##### 7.2 Joint types and assembly

###### 7.2.1 连接类型

###### 7.2.1 Joint type

施工技术规格说明应确定连接类型为无预拉力连接、预拉力连接或摩擦型连接。

The execution specification shall identify the joint type as a non-pretensioned joint, pretensioned joint, or slip-resistant joint.

###### 7.2.2 连接和垫圈的组合

###### 7.2.2 Fit of joint and shims

连接部件在组装时应组装在一起以实现牢固接触，且不应被显著的空间或可压缩材料隔开。

The connected components shall be drawn together to achieve firm contact when assembled and shall not be separated by significant free spaces or compressible materials.

可以使用垫板来调整连接的适配度和结构的对中性。如果结构螺栓连接处连接部件之间的间隙为 1mm 或更小，则无需垫板。如果结构螺栓连接处连接部件之间的间隙超过 1mm，则应使用垫板将间隙缩小到 1mm 或更小。

Shims may be used to adjust the fit in connections and the alignment of the structure.

If the gap between the connected parts at the structural bolts is 1 mm or less, no

shimming is required. If the gap between the connected parts at the structural bolts exceeds 1 mm, shims shall be used to reduce the gap to 1 mm or less.

对于板厚  $t > 4\text{mm}$  和截面厚度  $t > 8\text{mm}$  的部件，除非另有说明要求全接触承压，否则在连接的中心部位达到接触承压的条件下，边缘处可留有最大 4mm 的间隙。

For constituent products with  $t > 4\text{ mm}$  for plates and  $t > 8\text{ mm}$  for sections, unless full contact bearing is specified, residual gaps of up to 4 mm may be left at the edges when contact bearing is achieved at the central part of a connection.

除施工规范中另有规定外，垫板应由扁钢制成。

Shims shall be made of flat steel unless otherwise permitted in the execution specification.

垫板应具有与结构相似的耐久性。如果垫板用于对齐由涂层材料制成的结构，则应以类似的方式对垫板进行保护，以提供规定的耐久性，除垫板需要满足特定的摩擦抗滑移系数。

Shims shall have similar durability to that of the structure. If shims are used to align structures composed of coated material, the shims shall be protected in a similar manner to provide the specified durability, unless the shims are required to meet a specified friction slip factor.

如果垫板有松动的风险，则应将其固定。对于执行等级为 EXL3 和 EXL4（执行等级为 EXL3 和 EXL4 见附录 O.3 中表 O.1: [ISO 17607-6.pdf](#)），如果使用焊接来固定垫板，则应按照规定 ISO 17607-5 的规定进行焊接。

Shims shall be secured where they are at risk of coming loose. For execution levels EXL3 and EXL4, if welding is used to secure shims, the welding shall be in accordance with ISO 17607-5.

对于防滑连接，焊接、焊接飞溅、钻孔产生的毛刺等引起连接、拼接板或连接

部件的扭曲、翘曲或弯曲，应仔细进行校正和修复，以免损坏摩擦面。

For slip-resistant joints, distortion, warping, or bending of the joint, splice plates or the connected members caused by welding, weld spatter, and burrs resulting from drilling, etc., shall be corrected and repaired with care not to damage the friction surfaces.

如果已安装部件之间的配合不良无法通过垫板进行校正，则应按照 ISO 17607-4 中指定的方法对结构部件进行局部修改。这些修改不应影响结构在临时或永久状态下的性能。这项工作可以在现场进行。对于由焊接格子部件和空间框架结构建造的结构，应小心谨慎，以确保它们不会因试图强行配合其固有刚性而承受过大的力。

If lack-of-fit between erected components cannot be corrected by the use of shims, components of the structure shall be locally modified in accordance with the methods specified in ISO 17607-4. The modifications shall not compromise the performance of the structure in the temporary or permanent state. This work may be executed on site. Care shall be taken with structures built of welded latticed components and space-frame structures to ensure that they are not subjected to excessive forces in an attempt to force a fit against their inherent rigidity.

在结构对齐、找平、找正并临时连接，以确保在后续安装或对齐结构的其余部分时部件不会移位之前，不得在部件之间建立永久连接。

Permanent connections shall not be made between components until the structure has been aligned, levelled, plumbed and temporarily connected to ensure that components will not be displaced during subsequent erection or alignment of the remainder of the structure.

### **7.2.3 垫板**

### **7.2.3 Packing plates**

在连接紧固至紧密贴合状态时，应在所有必要位置提供垫板，以确保承压面牢固接触。所有垫板均应为钢材，其表面状况应与相邻层相似。

Packing plates shall be provided wherever necessary to ensure that the load-transmitting

plies are in firm contact when the connection is tightened to the snug-tight condition. All packing plates shall be steel with a surface condition similar to that of the adjacent plies.

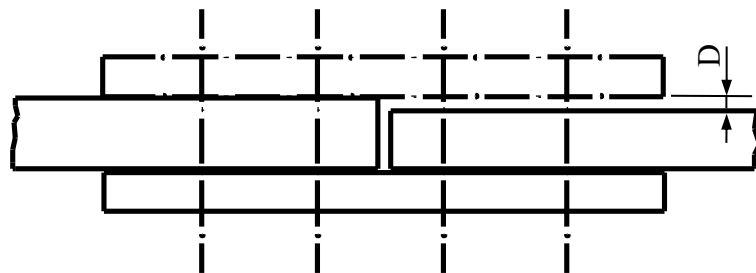
注：当垫板较厚时，也被称为填充板；当垫板较薄时，也被称为填板。

NOTE Packing plates are also referred to as filler plates when thick, or as shim plates when thin.

构成共同层一部分的单独部件的厚度差不应超过  $D$ ， $D$  通常为 2mm，见图 2。

如果提供钢垫板以确保厚度差不超过上述限制，则其厚度不得小于 1mm。

Separate components forming part of a common ply shall not differ in thickness by more than  $D$ , where  $D$  is 1 mm, see Figure 2. If steel packing plates are provided to ensure that the difference in thickness does not exceed the above limit, their thickness shall not be less than 1 mm.



注： $D$  指厚度差

Key  $D$  difference in thickness

图 2-同层部件之间的厚度差

**Figure 2 — Difference of thickness between components of a common ply**

在严重暴露的情况下，为避免间隙腐蚀，连接板件之间可能需要更紧密的接触。可能需要更紧密的接触。

In case of severe exposure, avoiding cavity corrosion can require closer contact.

应选择板厚控制垫板的数量限制在不超过三块。



Plate thickness shall be chosen to limit the number of packing plates to a maximum of three.

垫板应与连接处的相邻板部件具有相同的耐候性和力学强度。应充分考虑不同金属接触引起的电化学腐蚀风险和影响。

Packing plates shall have compatible corrosion behaviour and mechanical strength with the adjacent plate components of the connection. Full consideration shall be given to the risk and implication of galvanic corrosion resulting from dissimilar metals being in contact.

#### **7.2.4 连接的紧固**

##### **7.2.4 Snugging of joint**

每个结构紧固件应至少达到紧密贴合状态。应特别注意避免过度紧固，特别是对于短螺栓和直径 M12 或更小的螺栓。

Each structural bolt assembly shall be brought at least to a snug-tight condition. Special care shall be given to avoid over-tightening, especially for short bolts and bolts of diameter M12 or smaller.

#### **7.2.5 紧固顺序**

##### **7.2.5 Sequence of tightening**

紧固过程应从螺栓组的一个结构螺栓到另一个结构螺栓进行，从连接的刚度最大部位开始，逐渐向刚度较小的部位进行，以最大程度地减少先前预紧螺栓的松弛。为了达到均匀的施加预拉力，可能需要进行多次反复紧固。

The tightening process shall be carried out from structural bolt to structural bolt of the bolt group, starting from the most rigid part of the connection and moving progressively towards the least rigid part in a manner that will minimize relaxation of previously pretensioned bolts. To achieve a uniform snuggest condition, more than one cycle of tightening can be necessary.

**注 1：** H 型盖板连接的最坚固部分通常位于连接螺栓组的中间。H 型端板连接的最坚固部分通常位于梁或横梁翼缘旁边。

NOTE 1 The most rigid part of a cover plate connection of an H section is commonly in the middle of the connection bolt group. The most rigid parts of end plate connections of H sections are usually beside the beam or girder flanges.

对于包含高强度结构螺栓和焊接的组合连接，通常应先紧固高强度结构螺栓，然后进行焊接。

For combined joints comprising both high-strength structural bolts and welding, in general, highstrength structural bolts shall be fastened first, followed by welding.

**注：**一般而言，对于组合连接（如梁腹板由高强度结构螺栓连接且翼缘由焊接连接的梁），应先紧固高强度结构螺栓，然后进行焊接。

NOTE In general, for combined connections such as beams where the webs are connected by highstrength structural bolts and the flanges connected by welding, the high-strength structural bolts are tightened first, followed by welding.

在组合连接中，如果梁的高度或梁翼缘的厚度较大，如果先进行螺栓紧固然后进行焊接，则应考虑先进行部分螺栓紧固，然后进行焊接，最后进行最终螺栓紧固。

In combined connections, when the depth of a beam or the thickness of a beam flange is large, when bolt tightening is done first followed by welding, it should be considered that partial bolt tightening is done first, followed by welding, and then final bolt tightening.

**注 2：**在上述组合连接中，可能会出现焊接缺陷，如裂纹等。

NOTE 2 In combined connections as described above, there is a possibility that defects such as cracks, of welds can occur.

## **7.2.6 结构螺栓**

### **7.2.6 Structural bolts**

#### **7.2.6.1 螺栓直径**

##### **7.2.6.1 Bolt diameter**

除了在施工技术规格说明中以及与相关要求一起明确指定外，其他用于结构螺栓连接的名义螺栓直径应至少为 M12。

The nominal bolt diameter used for structural bolting shall be at least M12 unless specified in the execution specification together with the associated requirements.

#### **7.2.6.2 剪切面外的螺纹**

##### **7.2.6.2 Threads outside shear plane**

如果要考虑利用螺栓的五螺纹螺杆的抗剪能力，则应指定结构螺栓的尺寸，以允许螺栓长度和无螺纹部分的公差。对于厚度不等的连接部件，必要时还应指定螺栓的方向。

If it is intended that a connection utilises the shear capacity of the unthreaded shank of structural bolts, then the dimensions of the structural bolts shall be specified to allow for the tolerances on the length of the bolt and the unthreaded portion. For connected parts of unequal thicknesses, if required, the orientation of the bolt shall also be specified.

#### **7.2.6.3 夹具内的螺纹**

##### **7.2.6.3 Threads in grip**

对于非预紧结构螺栓，除在施工技术规格说明中另有说明外，在螺母的承压面和螺栓杆无螺纹部分之间，应至少保留一个完整的螺纹（除螺纹末端外）。

For non-pretensioned structural bolts, at least one full thread (in addition to the thread run-out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank, unless otherwise stated in the execution specification.

对于预紧结构螺栓，除在施工技术规格说明中另有说明外，在螺母的承压面和螺栓杆无螺纹部分之间，应至少有两道完整的螺纹。

For pretensioned structural bolts, at least two threads shall be between the bearing surface of the nut and the unthreaded part of the shank, unless otherwise stated in the

execution specification.

当使用地区或国家标准时，夹具部分内的螺纹应符合附录 F 的要求。

When regional or national standards are used, threads in the grip shall meet the requirements of Annex F.

#### **7.2.6.4 螺纹伸出部分**

#### **7.2.6.4 Thread protrusion**

紧固后，除在施工技术规格说明中另有说明外，在安装时至少应有一丝螺纹部分伸出螺母的外表面。

After tightening, at least one thread protrusion shall extend beyond the outer face of the nut when installed, unless otherwise stated in the execution specification.

当使用欧洲地区或欧洲国家标准时，螺纹伸出部分应符合附录 F 的要求。

When regional or national standards are used, thread protrusion shall meet the requirements of Annex F.

#### **7.2.7 螺母**

#### **7.2.7 Nuts**

螺母应在其配套的结构螺栓上自由旋转，这一情况在手动装配过程中可进行检查。任何螺母不能自由旋转的未涂覆螺栓连接副均不得使用。如果螺母在使用手工工具时不能轻松旋转，则涂覆组件不得用于预紧使用。

Nuts shall run freely on their partnering structural bolt, which is checked during hand assembly. Any uncoated bolting assembly where the nut does not run freely shall not be used. Coated assemblies shall not be used for pretensioned applications where the nut does not run with low resistance to rotation when using hand tools.

注：热浸镀锌螺栓的螺栓或螺母螺纹上可能有锌过量导致螺母旋转受阻的区域。

NOTE Hot dip galvanized bolts can have areas in the bolt or nut threads where excess zinc creates resistance to rotation of the nut.

如果使用电动工具，则可使用以下两种检查中的任一种：

If a power tool is used, either of the following two checks may be used:

- a) 对于每批新螺母或结构螺栓，在安装前可通过手动装配检查其兼容性；  
a) for each new batch of nuts or structural bolts, their compatibility may be checked by hand assembly before installation;
- b) 对于已安装的螺栓连接副但在尚未紧固的螺栓连接件，可在初步松开后通过手工检查螺母的自由旋转情况。  
b) for mounted bolt assemblies but prior to tightening, sample nuts may be checked for free-running by hand after initial loosening.

螺母的安装应确保在安装后能够清晰地看到所需的标识标记以供检查。

Nuts shall be installed so that their required identification markings are visible for inspection after installation.

### **7.2.8 垫圈**

### **7.2.8 Washers**

#### **7.2.8.1 一般规定**

#### **7.2.8.1 General**

如果需要垫圈，应指定垫圈是放在螺母下方还是螺栓头下方，即旋转的部件下方，或者两者下方都需要。

If washers are required, it shall be specified whether washers are to be placed under the nut or under the bolt head, whichever is to be rotated, or both.

对于只有一排螺栓的单面搭接连接，应在螺栓头和螺母下方都使用垫圈，以减少连接部件的弯曲。

For lap (shingle) joints between thin plate or sheet with only one row of bolts perpendicular to the direction of stress, washers should be used under both bolt head

and nut to reduce bending of the connected parts.

注 1：一般来说，对于非预紧结构螺栓，在标准圆孔中不需要垫圈。

**NOTE 1** In general, for non-pretensioned structural bolts, washers are not necessary with standard round holes

注 2：垫圈的使用可以减少对钢材上保护涂层的局部损坏，特别是对这些涂层较厚的地方。

**NOTE 2** The use of washers can reduce local damage to protective coatings on steel, particularly where these are thick coatings.

#### **7.2.8.2 预紧螺栓的垫圈要求**

#### **7.2.8.2 Washer requirements for pretensioned bolts**

对于预紧结构螺栓，除非另有规定，否则应按以下要求使用硬化垫圈（或必要时使用硬化锥形垫圈）：

For pretensioned structural bolts, unless otherwise specified, hardened washers (or if necessary, hardened taper washers) shall be used as follows:

a) 对于 8.8 级或等效抗拉强度的结构螺栓，应在旋转的螺栓头或螺母下方使用垫圈；

a) for grade 8.8 or equivalent tensile strength structural bolts, a washer shall be used under the bolt head or the nut, whichever is to be rotated;

b) 对于安装在屈服强度为 300MPa 或更低的钢材中的 10.9 级或等效抗拉强度的结构螺栓，应在螺栓头和螺母下方设置强度等级为 S235 的垫圈。

b) for grade 10.9 or equivalent tensile strength structural bolts installed in steel with yield strength of 300 MPa or lower, washers shall be used under both the bolt head and the nut.

c) 对于安装在屈服强度最低为 300MPa 以上的连接材料中的 10.9 级或等效抗拉强度的结构螺栓，设置强度等级高于 S235 的垫圈，除非规定在旋转的螺栓头或螺母下方使用硬化处理后的平垫圈。

c) for grade 10.9 or equivalent tensile strength structural bolts installed in connected material of specified minimum yield strength above 300 MPa, a hardened flat washer shall be used under the bolt head or nut, whichever is to be rotated.

当外层钢板出现槽形孔和大圆孔时，垫圈要求应符合表 3 的规定。所使用的垫圈应足够大，以完全覆盖该孔。

When an oversized or slotted hole occurs in an outer ply, the washer requirements shall be as prescribed in Table 3. The washer used shall be of sufficient size to completely cover the hole.

表 3-槽形孔和大圆垫圈和板式垫圈要求

**Table 3 — Washer and plate washer requirements for oversized and slotted holes**

螺栓等级 Bolt grade	结构螺栓名义直径 Nominal structural bolt diameter	外层板中的孔类型 Hole type in outer ply		
		槽形孔 Oversized	大圆孔 Short-slotted	长槽孔 Long-slotted
8.8 级或等效 强度 8.8 or equivalent strength	M12 – M36 1/2 inch – 1-1/2 inch M12-M36 152.4mm~457.2mm	标准厚度硬化垫圈 <sup>a</sup> Standard thickness hardened washer <sup>a</sup>		8mm 厚或连续杆 <sup>b,c</sup> mm thick plate washer or continuous bar <sup>b, c</sup>
10.9 级或等效 强度 10.9 or equivalent strength	M12 – M24 ½ inch – 1 inch M12-M24 152.4mm~304.8mm			
	M27 – M36 1-1/8 inch – 1-1/2 inch	8mm 厚硬化垫圈 <sup>a,b,d</sup> 8 mm thick hardened washer <sup>a, b, d</sup>		带有 10mm 厚板式垫圈或连续杆的硬化标准厚度垫圈 <sup>b,c</sup>

	M27-M36 342.9mm~457.2mm		Hardened standard thickness washer with either a 10 mm thick plate washer or continuous bar b, c
<p>a 此要求不适用于提供符合适用装配标准要求轴承圆直径的圆头的抗扭键驱动螺栓连接副头部。</p> <p>a This requirement shall not apply to heads of round head spline-drive bolt assemblies that provide a bearing circle diameter that meets the requirements of the applicable assembly standard.</p> <p>b 多个垫圈的总厚度达到 8mm 或更大时，不满足此要求。</p> <p>b Multiple washers with a combined thickness of 8 mm or larger do not satisfy this requirement.</p> <p>c 板式垫圈或条垫圈应为结构级钢材，但无需硬化处理。</p> <p>c The plate washer or bar shall be of structural-grade steel material, but need not be hardened.</p> <p>d 或者可以使用 10mm 厚的板式垫圈和普通厚度的硬化垫圈。板式垫圈无需硬化处理。</p> <p>d Alternatively, a 10 mm thick plate washer and an ordinary thickness hardened washer may be used. The plate washer need not be hardened.</p>			

当使用扭矩控制或预紧组合方法时，应在旋转元件下使用随组件提供或试验过的硬化垫圈。

When the torque control or combined method of pretensioning is used, the hardened washer as supplied or tested with the assembly shall be used under the turned element.

当使用扭矩扳手扭断螺栓预紧方法时，应在螺母下使用随组件提供的硬化片。

When the spline-drive twist-off bolt method of pretensioning is used, the hardened washer supplied with the assembly shall be used under the nut.

当使用直接压力指示垫圈紧方法时，应使用硬化垫圈，如下所示：

When the direct tension indicator method of pretensioning is used, a hardened washer shall be used as follows:

— 当旋转螺母且直接压力指示垫圈位于螺母下方时，应在螺母和直接压力指示



垫圈之间使用硬化垫圈（见图 3b）；

— when the nut is turned and the direct tension indicator is located under the nut, a hardened washer shall be used between the nut and the direct tension indicator - see Figure 3b);

— 当旋转螺栓头且直接压力指示垫圈位于螺栓头下方时，应在螺栓头和直接压力指示垫圈之间使用硬化垫圈（见图 3c）。

— when the bolt head is turned and the direct tension indicator is located under the bolt head, a hardened washer shall be used between the bolt head and the direct tension indicator -see Figure 3c).

当使用直接压力指示垫圈预紧方法时，在以下情况下不需要硬化垫圈：

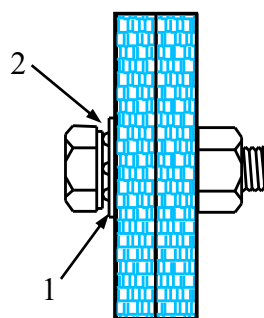
When the direct tension indicator method of pretensioning is used, a hardened washer is not required where:

— 旋转螺母且直接压力指示垫圈位于螺栓头下方（见图 3a）；

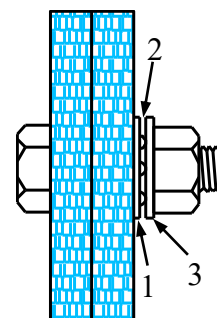
the nut is turned and the DTI is under the bolt head - see Figure 3a);

— 旋转螺栓头且直接压力指示垫圈位于螺母下方（见图 3d）。

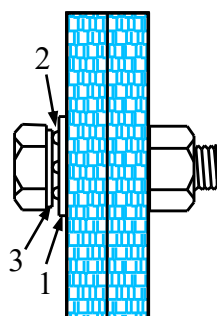
the bolt head is turned and the DTI is under the nut - see Figure 3d)



a) 螺栓头下方的 DTI，螺母转动  
a) DTI under bolt head, nut turned

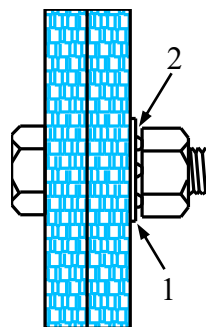


b) 螺母下方的 DTI，螺母转动  
b) DTI under nut, nut turned



c) 螺栓头下方的 DTI，螺栓头转动

c)DTI under bolt head,bolt head turned



d) 螺母下方的 DTI，螺栓头转动

d)DTI under bolt head,bolt head turned

注：

Key

1 直接压力指示垫圈（DTI）

3 硬化处理的钢垫圈

1 direct tension indicator (DTI)

3 Hardened steel washer

2 直接压力指示垫圈间隙测量位置 2 direct  
tension indicator gap measurement location

图 3—带有直接压力指示垫圈的垫圈位置

Figure 3 – Washer placement with direct tension indicators

### 7.2.8.3 倒角垫圈

### 7.2.8.3 Chamfered washers

当产品规格有要求时，用于预紧结构螺栓头下的垫圈应为倒角垫圈，且倒角朝向螺栓头。螺母下的垫圈可以是非倒角垫圈或倒角垫圈。

When required by the product specification, the washers used under heads of pretensioned structural bolts shall be chamfered and positioned with the chamfer towards the bolt head. Washers used under nuts may be non-chamfered or chamfered.

### 7.2.8.4 板式垫圈

### 7.2.8.4 Plate washers

对于表 3 中规定的带槽形孔和大圆孔的连接，应使用板式垫圈。为了调整指定为预紧的结构螺栓连接副的夹紧长度，可以使用以下方法：

Plate washers shall be used for connections with slotted and oversized holes as prescribed in Table 3. To adjust the grip length of structural bolting assemblies that are specified to be pretensioned, the following may be used:

— 一个任意厚度的板式垫圈；

— One plate washer of any thickness;

— 或最多三个板式垫圈，最大总厚度为 12mm。

— Up to three plate washers, with a maximum combined thickness of 12 mm.

为了调整指定为预紧结构螺栓连接副的夹紧长度，最多可以使用两个板式垫圈。

To adjust the grip length of structural bolting assemblies that are specified to be pretensioned, up to two plate washers may be used.

对于非预紧的结构螺栓连接副，板式垫圈或额外的板式垫圈可以放置在旋转侧或非旋转侧。

For non-pretensioned structural bolting assemblies, the plate washer or additional plate washers may be placed either on the side that is turned or on the side that is not turned.

对于使用除扭矩控制方法以外的任何方法安装的预紧结构螺栓连接副，板式垫圈或额外的板式垫圈可以放置在旋转侧或非旋转侧。

For pretensioned structural bolting assemblies installed using any method except the torque control method, the plate washer or additional plate washers may be placed either on the side that is turned or on the side that is not turned.

对于通过扭矩控制方法紧固的预紧结构螺栓连接副，只能在旋转侧使用一个板式垫圈。或者，板式垫圈或额外的板式垫圈可以放置于非旋转侧。

For pretensioned structural bolt assemblies tightened by the torque control method, only one plate washer may be used on the side that is turned. Alternatively, the plate washer or additional plate washers may be placed on the side that is not turned.

应检查详细规定螺纹不在剪切平面上的螺栓的符合性。

Bolts detailed to have the threads excluded from the shear plane should be checked for conformance.

**注 1：** 如果使用其他的垫圈或板式垫圈，或者如果使用的板式垫圈厚度与规定不同，则可能需要对剪切平面进行重新定位。

NOTE 1 Any use of additional washers or plate washers, or if plate washers of different thickness than specified are used, can result in the relocation of the shear plane.

板式垫圈的尺寸和钢材等级应在执行规范中指定。它们不应薄于 4mm。

Dimensions and steel grades of plate washers shall be specified in the execution specification. They shall not be thinner than 4 mm.

**注 2：** 对于地脚锚栓，请参见 6.2.2.4 节内容。

NOTE 2 For foundation bolts, see 6.2.2.4.

#### **7.2.8.5 锥形垫圈**

#### **7.2.8.5 Taper washers**

如果构件产品的表面与垂直于螺栓轴线的平面的夹角大于表 F.5 中规定的角度，则应使用锥形垫圈。

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 that prescribed in Table F.5.

锥形垫圈的尺寸和钢材等级应在执行规范中指定。

Dimensions and steel grades of taper washers shall be specified in the execution specification.

当使用地区或国家标准时，锥形垫圈的使用应符合表 F.5 的要求。

When regional or national standards are used, the use of taper washers shall meet the requirements of Table F.5.

### **7.2.9 锁紧方法**

#### **7.2.9 Locking methods**

除非执行规范有要求，否则不得在预紧组件上使用锁紧装置。

Locking devices shall not be used with pretensioned assemblies unless required by the execution specification.

除紧固外，如果还指定了锁紧装置，则应通过锁紧螺母、防松螺母、双螺母、螺纹滚花或其他执行规范允许的方法，防止螺母松动。

When locking devices are specified in addition to tightening, nuts shall be prevented from working loose by the use of locknuts, jam nuts, double nuts, thread burring, or other methods permitted by the execution specification.

如果非预紧连接受到冲击或振动，应考虑所选锁紧装置的有效性。参见 5.2.9 节。

Where a non-pretensioned joint is subject to impact or vibration, the effectiveness of the selected locking devices should be considered. See 5.2.9.

还应考虑用焊接连接代替螺栓连接。不得对结构螺栓和螺母进行焊接。

Welded joints should also be considered in lieu of bolted joints. Structural bolts and nuts shall not be welded.

禁止对螺母进行焊接的规定不适用于符合例如 ISO 21670 标准的特殊焊接螺母或焊接螺柱。

The prohibition on welding of nuts does not apply to special weld nuts in accordance with, e.g. ISO 21670 or to weld studs.

### 7.3 非预紧螺栓的紧固

#### 7.3 Tightening of non - pretensioned bolts

非预紧螺栓应至少达到适合的紧固状态。

Non-pretensioned bolts shall be brought to the snug tight condition, as a minimum.

将结构螺栓紧固至松紧适度状态以上不应成为拒收的理由。

Tightening structural bolts beyond the snug-tight condition shall not be cause for rejection.

注：松紧适度状态在 ISO 17607-1 标准中有定义。

NOTE The snug-tight condition is defined in ISO 17607-1.

### 7.4 预拉螺栓的紧固

#### 7.4 Tightening of pretensioned bolts

##### 7.4.1 预拉螺栓的连接程序

##### 7.4.1 Bolting procedure for pretensioned bolts

在安装和紧固预拉高强度结构螺栓之前，应准备安装和紧固的螺栓连接程序，并应至少标明结构螺栓的类型和紧固方法。

Prior to installation and tightening of pretensioned high-strength structural bolts, a bolting procedure for installation and tightening shall be prepared and shall indicate, as a minimum, the type of structural bolts and the tightening method.

螺栓紧固工作的执行和监督应按照螺栓连接程序进行。

Execution and supervision of bolt tightening work shall be carried out in accordance with the bolting procedure.

除非采用直接张力指示法、螺母旋转法或根据附录 N 制定的程序，否则预拉用

高强度结构螺栓应使用出厂时的润滑剂，不得更改。

High-strength structural bolts for pretensioning shall be used without alteration to the as-delivered lubrication unless the direct tension indicator method, the turn-of-nut method, or a procedure developed using Annex N is adopted.

如果预拉紧固过程使螺栓暴露时间较长，导致润滑剂降解，并且使用扭矩扳手施加法或螺母旋转法，则应检查润滑剂的性能合格后再进行。

If the pretensioning process is delayed under uncontrolled exposure conditions such that the lubrication has degraded, and the direct tension indicator method or the turn-of-nut method is used, the performance of the lubrication should be checked and can be improved.

在开始预拉紧固之前，应将连接部件装配在一起，并按照 7.2 节的规定紧固螺栓组中的结构螺栓，但连接部件之间的残余间隙不得超过 1mm，并对钢部件采取必要的纠正措施。

Before commencement of pretensioning, the connected components shall be fitted together and the structural bolts in a bolt group shall be tightened in accordance with 7.2, but the residual gap between connected components shall not exceed 1 mm with the necessary corrective action on steel components.

**注：**通常用于实现初步装配的结构螺栓连接副无需紧固至最小预紧力或松开，因此在最终螺栓连接过程中仍可在该位置使用。参见 7.8 节内容。

NOTE Generally, structural bolting assemblies used for achieving initial fit up need not be tightened to the minimum pretension or un-tightened and would therefore still be usable in the location in the final bolting up process. See 7.8.

除执行规范有限制外，其余可以使用 7.4.7 至 7.4.11 节中给出的任何预拉紧固方法。

Any of the pretensioning methods given in 7.4.7 through 7.4.11 may be used, unless

restricted by the execution specification.

应从连接的最大刚度部分到最小刚性部分逐步进行松紧适度状态的紧固和所有预紧步骤。为了达到均匀的预紧力，可能需要多次紧固循环。

Tightening to the snug-tight condition and all steps of pretensioning shall be carried out progressively from the most rigid part of the joint to the least rigid part. To achieve uniform pretensioning, more than one cycle of tightening may be necessary.

#### **7.4.2 施加预紧力的工具**

#### **7.4.2 Pretensioning tools**

对于扭矩法，该方法所有步骤中使用的扭矩扳手应能按照 ISO 6789 标准达到 $\pm 4\%$ 的精度。应按照 ISO 6789 标准对每把扳手进行维护，如果是气动扳手，则每次更换软管长度时都应进行检查。

For the torque method, torque wrenches used in all steps of the method shall be capable of an accuracy of  $\pm 4\%$  in accordance with ISO 6789. Each wrench shall be maintained in accordance with ISO 6789, and in case of pneumatic wrenches, checked every time the hose length is changed.

对于组合法，该方法第一步中使用的扭矩扳手应能达到 $\pm 10\%$ 的精度，并每年检查一次。

For the combined method, torque wrenches used in the first step of the method shall be capable of an accuracy of  $\pm 10\%$ , and checked yearly.

其他紧固设备（如轴向预紧用液压装置、超声波控制系统）应按照设备制造商的建议进行校准。

Other tightening equipment (e.g. hydraulic devices for axial pretensioning, ultrasonic control systems) shall be calibrated in accordance with the recommendations from the equipment manufacturer.

如果使用气动冲击扳手，则应有足够的容量和足够的空气供应，以便在大约 10



秒内完成直径达 M30（含 M30）螺栓的所需预紧，在大约 15 秒内完成更大直径螺栓的所需预紧。

Pneumatic impact wrenches, if used, shall be of adequate capacity and supplied with sufficient air to perform the required pretensioning of each bolt within approximately 10 sec for bolts up to and including M30 diameter, and within approximately 15 sec for larger diameter bolts.

在使用过程中发生任何影响扳手的事件（如重大撞击、跌落、过载）后，都应进行检查。

Checks shall be carried out after any incident affecting the wrench during use (e.g. significant impact, fall, overloading).

### 7.4.3 最小预紧力

### 7.4.3 Minimum pretension

除非执行规范中另有规定，否则名义最小预紧力  $F_p$  应按公式(1)计算：

Unless specified in the execution specification, the nominal minimum pretension  $F_p$  is calculated in accordance with Formula (1):

$$F_p = 0.7 f_{ub} \times A_s \quad (1)$$

式中：

where

$f_{ub}$  是螺栓材料的极限强度标准值；

$f_{ub}$  is the nominal tensile strength of the bolt material;

$A_s$  是螺栓的受拉应力面积。

$A_s$  is the tensile stress area of the bolt.

当使用欧洲地区或国家标准时，最小预紧力应符合附录 E 的要求。

When regional or national standards are used, the minimum pretension shall meet the requirements of Annex E.

此预紧力水平应用于所有摩擦型连接和所有其他承压型连接，除非执行规范中规定了较低的预紧力水平。在后一种情况下，还应指定结构螺栓连接副、预拉

方法、预拉参数和检验要求。

This level of pretension shall be used for all slip-resistant joints and for all other pretensioned joints unless a lower level of pretension is specified in the execution specification. In the latter case, the structural bolt assemblies, the pretensioning method, the pretensioning parameters and the inspection requirements shall also be specified.

注 2：预紧力可用于抗滑移、抗震连接、抗疲劳、执行目的或作为质量措施（例如耐久性）。

NOTE 2 Pretension can be used for slip resistance, for seismic connections, for fatigue resistance, for execution purposes, or as a quality measure (e.g. for durability).

#### **7.4.4 螺栓连接装配 K 级校准**

##### **7.4.4 Bolting assembly k - class calibration**

必要时，结构螺栓连接副的 k 级（出厂螺栓校准状态）应与所使用的方法相匹配。除了扭矩法之外的所有方法，都可以使用附录 H 进行校准作为替代方案。如果执行规范允许，也可以使用附录 H 对扭矩法的螺栓进行验证或评估。

When specified, the k-class (as-delivered bolt calibration condition) of the structural bolting assembly shall be appropriate for the method used. As an alternative for all methods except the torque method, calibration to Annex H may be used. Annex H for bolt validation or evaluation for the torque method may be used if permitted by the execution specification.

出厂校准适用于通过旋转螺母进行紧固。紧固应通过旋转螺母来完成，除非无法充分接触到组件的螺母侧。如果通过旋转螺栓头进行紧固，则应根据附录 H、通过匹配的螺栓连接副制造商的补充试验或根据适用的标准进行校准。当通过旋转结构螺栓头来紧固螺栓时，可能需要根据所采用的紧固方法采取特殊预防措施。

The as-delivered calibration is valid for tightening by rotation of the nut. Tightening shall be performed by rotation of the nut except where the access to the nut side of the assembly is inadequate. If tightening is done by rotation of the bolt head, calibration

shall be done in accordance with Annex H, by supplementary testing from the matched bolting assembly manufacturer, or in accordance with an applicable standard. Special precautions, depending on the tightening method adopted, may be necessary when bolts are tightened by rotation of the structural bolt head.

注：EN 14399-2 规范是校准适用标准的一个例子。

NOTE EN 14399-2 is an example of an applicable standard for calibration.

#### 7.4.5 $k$ 因子

#### 7.4.5 $k$ - factor

$k$  因子可按照公式 (2) 计算：

The  $k$ -factor may be calculated in accordance with Formula (2):

$$k = \frac{M}{(F \times d)} \quad (1)$$

式中：

where

$M$  是施加的紧固扭矩；

$M$  is the applied tightening torque;

$F$  是施加的预紧力；

$F$  is the achieved pretension;

$d$  是螺栓连接副的名义直径。

$d$  is the nominal diameter of the bolting assembly.

注： $k$  因子涵盖了螺母与垫圈之间承压面上的摩擦以及螺母与螺栓螺纹之间的摩擦系数。制造出的螺纹表面状况和螺母与垫圈之间承压面的变化会影响  $k$  因子，并且可以根据出厂校准条件或  $k$  级对这种变化设置限制。如果在安装前螺纹表面状况变差，这也会改变  $k$  因子的值。

NOTE The  $k$ -factor covers the friction in the bearing surface between the nut and the washer and the friction factor between the nut and bolt threads. Variability in the surface

condition of the manufactured threads and the bearing surface between nut and washer will affect the  $k$ -factor, and limits can be set for this variability in terms the as-delivered calibration condition or  $k$ -class. If there is deterioration of the surface condition of the threads before installation, this will also change the value of the  $k$ -factor.

#### 7.4.6 预安装验证试验

##### 7.4.6 Pre - installation verification testing

对于 EXL2、EXL3 或 EXL4 等级（见附录 O.3 中表 O.1: [ISO 17607-6.pdf](#)）的结构螺栓连接副，如果没有已知的  $k$  级或  $k$  级为 K0，则预安装验证试验程序应为附录 G 中提供的方法，除非执行规范中另有规定。

For structural bolting assemblies in EXL2, EXL3, or EXL4, with no known  $k$ -class or a  $k$ -class of K0, the pre-installation verification testing procedure shall be the method provided in Annex G, unless otherwise restricted by the execution specification.

对于  $k$  级为 K1 或 K2 的 EN 14399-3、EN 14399-4 和 EN 14399-10 产品规范中的结构螺栓连接副，除执行规范中另有规定外，不需要进行预安装验证试验。

For EN 14399-3, EN 14399-4, and EN 14399-10 structural bolting assemblies with a  $k$ -class of K1 or K2, pre-installation verification testing is not required, unless specified in the execution specification.

#### 7.4.7 扭矩法

##### 7.4.7 Torque method

对于使用扭矩法进行预紧的情况，除非执行规范中另有规定，否则应从附录 I 中提供的方法中选择螺栓紧固程序。

For pretensioning using the torque method, the bolting procedure shall be selected from the methods provided in Annex I, unless otherwise restricted by the execution specification.

#### 7.4.8 组合法

##### 7.4.8 Combined method

对于使用组合方法进行预紧的情况，除非执行规范中另有规定，否则应从附录 J 中提供的方法中选择螺栓紧固程序。

For pretensioning using the combined method, the bolting procedure shall be selected from the methods provided in Annex J, unless otherwise restricted by the execution specification.

注：组合方法也称为部分旋转法。

NOTE The combined method is also known as the part-turn method.

#### 7.4.9 花键驱动剪断法

##### 7.4.9 Spline - drive twist - off method

对于使用扭矩扳手扭断法进行预紧的情况，除执行规范中另有规定外，螺栓紧固程序应如附录 K 所述。

For pretensioning using the spline-drive twist-off method, the bolting procedure shall be as provided in Annex K, unless otherwise restricted by the execution specification.

注：花键驱动剪断法也称为 HRC 法、Torshear 法和扭断拉力控制螺栓法。

NOTE The spline-drive twist-off method is also known as the HRC method, Torshear method, and twist-off tension control bolt method.

#### 7.4.10 直接压力指示垫圈法

##### 7.4.10 Direct tension indicator method

对于使用直接压力指示垫圈法进行预紧的情况，除执行规范中另有规定外，螺栓紧固程序应如附录 L 所述。

For pretensioning using the direct tension indicator method, the bolting procedure shall be as provided in Annex L, unless otherwise restricted by the execution specification.

#### **7.4.11 螺母旋转法**

#### **7.4.11 Turn - of-nut method**

对于使用螺母旋转法进行预紧的情况，除非执行规范中另有规定，否则应从附录 M 中提供的方法中选择螺栓紧固程序。

For pretensioning using the turn-of-nut method, the bolting procedure shall be selected from the methods provided in Annex M, unless otherwise restricted by the execution specification.

#### **7.5 紧配合（装配）螺栓**

#### **7.5 Fit bolts**

适配螺栓可用于预紧或非预紧应用，除了以下要求外，还应根据具体情况适用 7.3 或 7.4 节。

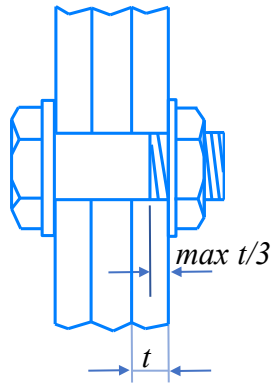
Fit bolts may be used in pretensioned or non-pretensioned applications, and 7.3 or 7.4 applies, as appropriate, in addition to the requirements below.

除在执行规范中另有规定外，适配螺栓的杆部螺纹部分（包括螺纹收尾）的长度在承压长度中所占的部分不应超过与螺母相邻的板厚的 1/3，见图 4。

The length of the threaded portion of the shank of the fit bolt (including thread run out) included in the bearing length should not exceed 1/3 of the thickness of the plate adjacent to the nut unless specified in the execution specification, see Figure 4.

配合螺栓应在不施加过大力力下进行安装，且安装方式不应损坏螺纹。

Fit bolts shall be installed without applying excessive force, and in such a way that the thread is not damaged.



注：

$t$  为板厚度

Key

$t$  Plate thickness

图 4-配合螺栓承压长度中的杆部螺纹部分

Figure 4 — Threaded portion of the shank in the bearing length for fit bolts

## 7.6 临时螺栓

### 7.6 Temporary bolts

临时螺栓用于在完全紧固或焊接之前，在架设过程中组装结构构件，以防止外部力引起的框架变形或倒塌。

Temporary bolts are used for assembly of structural members during erection prior to full fastening or welding, to prevent deformation or collapse of the framework caused by external forces.

在典型的高强度结构螺栓连接中，临时螺栓应为非预紧应用（见表 B.1 至表 B.5）或预紧应用（见表 B.1 至表 B.3）的螺栓或组件。临时螺栓的数量应约为最终连接所用螺栓总数的 1/3，且不得少于两个。临时螺栓应均衡分布，并按非预紧应用的要求紧固。

In typical high-strength structural bolted joints, temporary bolts shall be bolts or assemblies for either non-pretensioned applications (see Table B.1 through Table B.5) or pretensioned applications (see Table B.1 through Table B.3). The number of

temporary bolts shall be approximately one third of the total number of bolts used in the final joint and shall not be less than two. Temporary bolts shall be located in a balanced distribution and shall be tightened as required for a non-pretensioned application.

用于焊接连接架设件的临时螺栓应为高强度螺栓，且所有螺栓均应至少紧固至紧密贴合状态。

Temporary bolts used for erection pieces for welded joints shall be high-strength bolts, and all bolts shall be tightened to at least the snug tight condition.

在架设过程中为便于组装而临时使用的高强度结构螺栓可用于最终连接，但如果这样使用，则在连接中的所有螺栓都紧固到紧密贴合状态之前，不得进行预紧。

High-strength structural bolts used temporarily during erection to facilitate assembly may be used in the final connection, but if so used, they shall not be pretensioned until all bolts in the connection have been tightened to the snug-tight condition.

应标识出待拆除的临时螺栓。

Temporary bolts that are to be removed shall be identified.

## 7.7 预紧力损失

### 7.7 Loss of pretension

应考虑由于多种因素（如松弛、表面涂层蠕变（见附录 P 和附录 Q））导致的预紧力从其初始值开始的可能损失。对于较厚的表面涂层，应规定是否应采取的措施以抵消随后可能发生的螺栓预紧力损失。

The potential loss of pretension from its initial value due to several factors, e.g. relaxation, creep of surface coatings (see Annex P and Annex Q), should be considered. In case of thick surface coatings, it shall be specified if measures shall be taken to offset possible subsequent loss of bolt pretension.



在评估可能的预紧力损失时，应考虑使用组合法和螺母旋转法时通常达到的较高预紧力水平。

The higher levels of pretension normally achieved when using the combined method and the turn-of-nut method should be considered when evaluating the possible loss of pretension.

对于扭矩法，可以通过在几天后重新紧固来恢复所需的预紧力。

For the torque method, restoring the required pretension can be achieved by retightening after a delay of several days.

对于组合法和螺母旋转法，可以通过重新紧固来恢复所需的预紧力，但应避免预紧力过大导致螺栓连接副失效，并应考虑进行试验，以验证在不对螺栓造成过度损坏的情况下达到适当的预紧力。

For the combined method and the turn-of-nut method, restoring the required pretension can be achieved by retightening, but caution is warranted to avoid excessive levels of pretension that would cause the bolting assembly to fail, and testing should be considered to verify that suitable pretension is achieved without undue damage to the bolt.

**注意：**对于明显屈服的螺栓，通常没有公认的重新紧固步骤。需要显著增加螺母旋转的屈服螺栓可能会导致螺母与伸长的螺栓螺纹贴合并卡住。通过重新紧固来恢复所需的预紧力不被视为重复使用。

NOTE For significantly yielded bolts, there is no generally accepted procedure for retightening. Yielded bolts that require significant added nut rotation can cause the nut to engage and seize on the stretched bolt threads. Restoring the required pretension by retightening is not considered a reuse.

## 7.8 结构螺栓的重复使用

### 7.8 Reuse of structural bolts

在安装相邻螺栓时可能已松动的结构螺栓的修整或重新紧固不应被视为重复使用。除非是为了完全拆除单个螺栓连接副，否则不得松开螺栓头或螺母。

Touching up or retightening of structural bolts that may have been loosened by the installation of adjacent bolts shall not be considered to be a reuse. The bolt head or nut shall not be loosened except for the purpose of complete removal of the individual bolting assembly.

**注意：**通常用于实现初步装配的螺栓连接副不应紧固至最小预紧力或松开，因此在最终螺栓紧固过程中，它们在其位置仍可使用。

NOTE Generally, bolting assemblies used for achieving initial fit up should have not been tightened to the minimum pretension or untightened, and therefore would still be usable in their location in the final bolting up process.

如果螺栓连接副已紧固至最小预紧力并随后出现了紧固松弛现象，则应将其拆下并丢弃该组件。

If a bolting assembly has been tightened to the minimum pretension and is later untightened, it shall be removed, and the assembly shall be discarded.

如果执行规范允许，螺栓等级为 8.8 级或等效强度更低且未涂层的结构螺栓可重复使用。这种重复使用只允许一次，且仅当螺栓保持在最初预紧的同一连接中，并具有相同的锁紧时才允许。已预紧的结构螺栓不得在另一连接中重复使用。

If permitted by the execution specification, uncoated structural bolts of product class 8.8 or equivalent strength and lower may be reused. Such reuse shall only be permitted once, only where the bolt remains in the same connection in which it was originally tensioned, and with the same grip. Structural bolts that have been pretensioned shall not be reused in another connection.

以下结构螺栓不得重复使用：

The following structural bolts shall not be reused:

- a) 螺栓等级为 10.9 级或等效抗拉强度更高且未涂层的结构螺栓；
- a) uncoated structural bolts of product class 10.9 or equivalent tensile strength and higher;
- b) 任何等级的花键驱动组件；
- b) spline-drive assemblies of any product class;
- c) 任何等级的涂层结构螺栓。
- c) coated structural bolts of any product class.
- d) 已损坏或变形的螺栓。
- d) bolts that have been damaged or distorted.

**注意：** 如果螺母能够用手沿螺纹全长旋转，则螺栓等级为 8.8 级或等效强度更低且未涂层的结构螺栓适合重复使用。

NOTE As a guide, an uncoated structural bolt of product class 8.8 or equivalent strength and lower is suitable for reuse if the nut can be run up the full length of threads by hand.

## 7.9 特殊螺栓连接副的使用

### 7.9 Use of special fasteners

当指定使用特殊螺栓连接副时，应按照组件制造商的建议或说明（或两者）以及 7.1 至 7.4 的适当规定使用这些组件。

When the use of special structural bolting components is specified, they shall be used in accordance with the component manufacturer's recommendations or instructions, or both, and the appropriate provisions of 7.1 to 7.4.

**注意 1：** 特殊紧固方法是指带内螺纹的螺栓孔和带螺纹的螺柱。

NOTE 1 Examples of special structural bolting components include threaded studs, and bolts used in specially tapped holes.

可使用附录 N 来制定安装程序。

Annex N may be used to develop installation procedures.

应指定在非预紧或预紧应用中使用特殊螺栓连接副所需的任何程序试验。

Any procedure tests required for use of special bolting components in non-pretensioned or pretensioned applications shall be specified.

a) 应提供详细的安装说明，这些说明可由组件制造商、独立的试验实验室或合格的个体在补充规范中编制，并且至少应包括以下内容：

a) Detailed installation instructions shall be available and can be prepared by the component manufacturer, an independent testing laboratory, or qualified entity in a supplemental specification, and, as a minimum, shall provide for the:

1) 预紧参数（例如紧固扭矩、预紧力水平）；

pretensioning parameters (e.g. tightening torques, pretension level)

2) 所需的预安装验证的性质和频率；

required character and frequency of pre-installation verification;

3) 螺栓孔的校准，以便能够插入特殊螺栓而不会造成过度损坏；

alignment of bolt holes to permit insertion of the special bolts without undue damage;

4) 在所有孔中放置特殊螺栓，包括适当的垫圈要求；

placement of special bolts in all holes, including any washer requirements as appropriate;

连接的系统组装，从连接的最刚性部分开始，直到连接的层板牢固接触；

systematic assembly of the joint, progressing from the most rigid part of the joint until the connected plies are in firm contact;

随后对连接中所有特殊螺栓进行系统预紧，从连接的最刚性部分开始，以最大

程度地减少先前预紧螺栓的松弛。

subsequent systematic pretensioning of all special bolts in the joint, progressing from the most

rigid part of the joint in a manner that will minimize relaxation of previously pretensioned bolts.

b) 应在补充规范中提供详细的检查说明，并且至少应包括以下内容：

b) Detailed inspection instructions shall be available in a supplemental specification and, as a minimum, shall provide for:

1)提供所需的预安装验证试验；

observation of the required pre-installation verification testing; and,

2) 随后的常规观察，以确保正确使用特殊螺栓连接副。

subsequent routine observation to ensure the proper use of the special bolting components.

在预紧和非预紧组件中，只要材料、螺纹形式和螺纹公差符合各自的产品标准，并且对于预紧，可以通过验证试验制定足够的紧固参数，则可以使用特殊的带内螺纹孔和带螺纹螺柱作为螺栓连接副的等效物。

Specially tapped holes or threaded studs may be used as equivalent to the use of a bolting assembly in pretensioned and non-pretensioned assemblies provided that the materials, thread forms and thread tolerance conform with the respective product standard, and in case of pretensioning, sufficient tightening parameters can be developed by proof testing.

**注意 2：** EN 1090-2 规范提供了关于注入树脂螺栓的供应和使用的信息。

NOTE 2 EN 1090-2 provides information on the supply and use of resin injection bolts.

## **7.10 不锈钢结构螺栓的卡紧现象**

### **7.10 Galling and seizure of stainless steel structural bolts**

可以采用以下方法避免卡紧问题：

The following methods may be used to avoid galling problems:

- a) 使用防卡紧剂，例如适用于不锈钢的适当润滑剂。
- a) anti-galling agents, e.g. an appropriate lubricant suitable for stainless steel.
- b) 适用于成分、加工硬化率和硬度不同的不锈钢结构螺栓标准等级（例如，根据 ISO 3506-1 和 ISO 3506-2 标准，A2-C4、A4-C4 或 A2-A4 螺栓-螺母组合）；
- b) dissimilar standard grades of stainless steel structural bolt that vary in composition, work hardening rate and hardness (e.g. Grade A2-C4, A4-C4 or A2-A4 bolt-nut combination in accordance with ISO 3506-1 and ISO 3506-2);
- c) 在严重的情况下，使用一个组件的专有高强度不锈钢合金结构螺栓或应用硬表面涂层，例如氮化或硬铬镀层；
- c) in severe cases, a proprietary high work-hardening stainless steel alloy structural bolt for one component or hard surface coatings applied, e.g. nitriding or hard chromium plating;

如果使用不同金属或涂层，必须确保达到所需的耐腐蚀性。

If dissimilar metals or coatings are used, it is necessary to ensure that the required corrosion resistance is obtained.

**注意 1：**ISO 3506-1 标准中列出的不锈钢螺栓产品，在性能等级后应包含标识符号，可提供可控的扭矩/拉力关系。

NOTE 1 Stainless steel bolting products listed in ISO 3506-1 that include the identifier Lu immediately after the property class can provide a controlled torque/tension relationship.

**注意 2：**卡紧可能是由紧固过程中在荷载和相对运动作用下表面的局部粘附和破裂导致的。在某些情况下，可能会产生焊接贴合和卡紧。

NOTE 2 Galling can result from local adhesion and rupture of surfaces under load and in relative motion during fastening. In some cases, weld bonding and seizure can result.

**注意 3：**对螺栓进行润滑是有效的方法，但可能导致污垢的污染，并给存放带来相关问题。

NOTE 3 The greasing of bolts is beneficial but can result in contamination by dirt and can present problems for storage.

## 8 检查、试验和校正

### 8 Inspection, testing, and correction

#### 8.1 一般规定

##### 8.1 General

见国际标准 ISO17607-1。

See ISO17607-1.

#### 8.2 结构螺栓检查

##### 8.2 Structural bolting inspection

###### 8.2.1 钢结构安装前的检查

###### 8.2.1 Inspection prior to erection of steelwork

所有连接层均应符合 6.3 节的要求。

All connected plies shall meet the requirements in 6.3.

对于防滑连接，应在组装前立即对摩擦表面进行目视检查。验收标准应符合 6.4 节的规定。

For slip-resistant connections, the friction surfaces shall be visually checked immediately before assembly. Acceptance criteria shall be in accordance with 6.4.

不符合要求的情况应根据 8.3 节进行纠正。

Nonconformities shall be corrected in accordance with 8.3.

所有螺栓孔均应符合 6.2 节的要求。

All bolt holes shall meet the requirements in 6.2.

###### 8.2.2 安装螺栓前的检查

###### 8.2.2 Inspection prior to installation of bolts

在安装之前，安装人员必须对结构螺栓部件进行目视检查，查看是否存在严重的物理缺陷，包括裂缝、螺纹损坏和润滑剂流失。

Prior to installation, structural bolting components shall be visually inspected by the installer for gross physical defects, including cracks, thread damage and loss of lubrication.

对于执行等级为 EXL2、EXL3 和 EXL4 中的预紧螺栓，必须使用 7.4.6 节中规定的安装前验证试验来检查紧固程序。

For pretensioned bolts in EXL2, EXL3, and EXL4, the tightening procedure shall be checked using a pre-installation verification test prescribed in 7.4.6.

### **8.2.3 安装螺栓后的检查**

#### **8.2.3 Inspection after installation of bolts**

必须对所有螺栓进行以下检查：

All bolts shall be inspected for the following:

- a) 螺栓符合规定的等级；  
a) bolts are of the prescribed grade,
- b) 螺栓尺寸符合规定；  
b) bolts are of the prescribed size,
- c) 螺栓有足够但不过多的螺纹延伸到螺母之外；  
c) bolts have sufficient but not excessive thread extending beyond the nut, and
- d) 如果指定了锁定装置，则螺栓连接副应具有规定的锁定装置。  
d) bolting assemblies have the prescribed locking device, if a locking device has been specified.

所有连接件在用螺栓紧固后，均应进行目视检查，并将结构局部对齐，以确保连接件按照 7.2.2 节妥善包装，且连接件的各层已牢固接触。验收标准和纠正不合格的措施应符合 7.2.1 节、7.2.3 节和 7.2.4 节的规定。

All connections shall be visually checked after they are bolted up with the structure aligned locally to ensure that they are properly packed in accordance with 7.2.2, and



that the plies of the connected elements have been brought into firm contact. Acceptance criteria and action to correct nonconformity shall be in accordance with 7.2.1, 7.2.3 and 7.2.4.

如果不合格是由于不同的层厚度超过了 7.2.2 节中规定的标准，则应重新制作连接。否则，如有可能，可通过调整部件的局部对齐来纠正不合格情况。

If the nonconformity is due to differing ply thickness that exceeds the criteria specified in 7.2.2, the connection shall be remade. Otherwise, the nonconformity may be corrected, if possible, by adjusting the local alignment of the component.

必须对结构螺栓连接副进行目视检查，以确保垫圈已按要求使用。如果安装了倒角型垫圈，则必须进行目视检查，以确保装配符合 7.2.7.3 节的要求。如使用直接张力指示器，则须目视检查装配情况，以确保其符合相关产品标准或制造商的书面说明（见 7.4.10 节）。

Structural bolting assemblies shall be visually examined to ensure washers have been used as required. If chamfered washers are installed, they shall be visually checked to ensure that assembly is in accordance with 7.2.7.3. If direct tension indicators are used, the assembly shall be visually examined to ensure that it is in accordance the relevant product standard or the manufacturer's written instructions, see 7.4.10.

在检查（编制冲孔清单）过程中发现的未安装全套螺栓的连接件，应在安装完缺失的螺栓后检查其安装情况。

Connections identified during inspection (punch list preparation) that do not have a full complement of bolts shall be checked for fit up after the missing bolts have been installed.

重新完成时应再次检查已纠正的连接。

Corrected connections shall be checked again on re-completion.

## **8.2.4 检查预紧螺栓**

### **8.2.4 Inspection of pretensioned bolts**

#### **8.2.4.1 一般规定**

##### **8.2.4.1 General**

检查方法应从附录 O 提供的方法中选择，除非执行规范另有限制。

The inspection method shall be selected from the methods provided in Annex O, unless otherwise restricted by the execution specification.

在安装过程中应定期观察螺栓的预紧情况，以确保采用了适当的程序。

Pretensioning of bolts shall be periodically observed during installation to ascertain that the proper procedures are employed.

#### **8.2.4.2 预紧过程中和预紧后的检查**

##### **8.2.4.2 Inspection during and after pretensioning**

对于执行等级为 EXL2、EXL3 和 EXL4，在紧固过程中和紧固后应进行如下检查：

For EXL2, EXL3, and EXL4, inspection during and after pretensioning shall be carried out as follows:

- a) 应根据所使用的预紧方法，对已安装的螺栓连接副或安装方法进行检查，或对两者都进行检查。所选位置应随机，确保抽样涵盖以下适当的变量-连接类型、螺栓组、螺栓连接副批次、类型和尺寸，所使用的设备和安装人员；  
a) inspection of either installed bolting assemblies or installation methods, or both, shall be undertaken depending on the pretensioning method used. The locations selected shall be on a random basis, ensuring that the sampling covers the following variables as appropriate - connection type, bolt group, fastener lot, type and size; equipment used, and the installation personnel;
- b) 为了检查的目的，螺栓组的定义是相同来源的螺栓连接副在类似的连接中，具有相同尺寸和等级的螺栓连接副。为便于检查，可将大型螺栓组细分为多个子组；  
b) for the purposes of the inspection, a bolt group is defined as bolting assemblies of

the same origin in similar connections with the bolting assemblies of the same size and class. A large bolt group may be subdivided into subgroups for inspection purposes;

c) 初拧时，应对连接接头进行目视检查，以确保被连接板件完全贴紧；

c) connections shall be checked by visual inspection to ensure they have been properly packed, if required, and have achieved the snug-tight condition;

d) 如果有规定，在使用扭矩法时，应进行过度紧固；在最终检查时，应使用相同的螺栓连接副，同时检查张力不足和过度紧固；

d) for final inspection, the same bolting assembly shall be used for checking both under-tensioning, and, if specified, over-tensioning when applying the torque method;

8.2.4.3 节至 8.2.4.7 节为每种紧固法规定了不合格的定义标准和纠正措施要求。

The criteria defining a nonconformity and requirements for corrective action are specified in 8.2.4.3 to 8.2.4.7 for each pretensioning method.

如果螺栓连接副未按照规定的方法安装和预紧，则必须目睹整个螺栓组的拆除和重新安装。

If bolting assemblies are not installed and pretensioned in accordance with the defined method, the removal and re-installation of the whole bolt group shall be witnessed.

### 8.2.4.3 扭矩法检查

#### 8.2.4.3 Inspection of torque method

对螺栓连接副的检查应使用表 4，使用校准的扭矩扳手对螺母（或螺栓头，如果指定）施加扭矩。目的是检查在施加 1.05 倍扭矩值  $M_{r,i}$ （即  $M_{r,2}$  或  $M_{r,test}$ ）时螺母是否开始旋转。应注意将任何额外的旋转严格控制在最低限度。以下条件适用：

The inspection of a bolting assembly shall be carried out, using Table 4, by the application of a torque to the nut (or to the bolt head, if specified) using a calibrated torque wrench. The objective is to check that the nut does not initiate rotation when applying a torque of 1,05 times the torque value  $M_{r,i}$  (i.e.  $M_{r,2}$  or  $M_{r,test}$ ). Caution shall be taken to keep any additional rotation to a strict minimum. The following conditions apply:

a) 用于检查的扭矩扳手必须经过正确校准，精度为±4%，如校准证书所示；

a) the torque wrench used for the inspections shall be correctly calibrated and have an accuracy of  $\pm 4\%$ , as shown on the calibration certificate;

b) 检查应在相关螺栓组最终完成紧固后 12 小时至 72 小时之间进行；

b) the inspection shall be carried out between 12 h and 72 h after final completion of pretensioning in the bolt group concerned;

如果要检查的螺栓连接副来自不同的装配批次，且检查扭矩值不同，则应确定每个批次的位置。

If the bolting assemblies to be inspected are from different assembly lots, with inspection torque values that are different, the locations of each lot shall be established.

c) 如果结果为不合格，则应检查紧固所用扭矩扳手的准确性。

c) if the result is rejection, the accuracy of the torque wrench used for tightening shall be checked.

表 4 -使用扭矩紧固法时的紧固检查

Table 4 – Inspection of pretensioning by the torque method

执行类别 Execution Class	开始预紧时 At start of pretensioning	预紧后 After pretensioning
EXL2	确定装配螺栓批位置 Identification of assembly bolt lot locations	终拧检查 Inspection for under-tensioning, and, if specified, over-tensioning
EXL3 和 EXL4	确定装配螺栓批次位置 Identification of assembly bolt lot locations 检查每个螺栓组的螺栓 Checking the selection of the bolt 每螺栓组的预紧程序 pretensioning procedure for each bolt group	终拧检查 Inspection for under-tensioning, and, if specified, over-tensioning

使用检查扭矩使螺母转动超过 15°的螺栓连接副被视为紧固不足 (< 100 %), 应重新紧固至所需扭矩。

A bolting assembly for which the nut turns by more than 15° by the application of the inspecting torque is considered to be under-tensioned (<100 %) and shall be retensioned up to the required torque.

如果规定了超拧检查, 则应具体要求。超拧的螺栓连接副应拆除并丢弃。

If a check for over-tensioning is specified, the requirements shall be specified. Over-tensioned bolting assemblies shall be removed and discarded.

#### **8.2.4.4 综合方法的检查**

##### **8.2.4.4 Inspection of combined method**

对于使用组合方法安装的螺栓, 必须进行以下额外检查:

For bolts installed using a combined method, the following additional inspections shall be carried out:

- a) 必须检查扭矩扳手校准报告, 以验证其准确性符合 7.4.9 节;
- a) the torque wrench calibration reports shall be checked to verify the accuracy to 7.4.9;
- b) 应通过例行观察确保螺栓紧固人员正确地将校准扳手用于第一步的螺母紧固;
- b) it shall be ensured by routine observation that the bolting crew properly applies the calibrated wrench to the nut for the first step; and
- c) 如果连接件没有达到 7.2.1 节和 7.2.2 节规定的紧固状态, 则应通过补充试验控制扭矩扳手的校准和施加的载荷, 以达到正确的初始预紧载荷。如果仍未装配, 则应检查并调整组装连接件的厚度和倾角。
- c) if the connections do not achieve the snug-tight condition in accordance with 7.2.1 and 7.2.2, the calibrations of the torque wrenches in combination with the applied loads shall be controlled by supplementary tests to achieve the correct initial pre-tightening

load. If necessary, the initial torque application has to be repeated with the corrected torque values. If still unpacked, the thickness and sloping surfaces of the assembled connections shall be inspected and adjusted;

d) 对于执行等级为 EXL3 和 EXL4, 在对使用了相同的扭矩条件打扫了 75% 扭矩值的螺栓连接件进行标记前, 应对初拧进行检查。如果在使用检查扭矩时螺母转动超过  $15^\circ$ , 则应重新紧固, 并检查连接中的所有剩余螺栓;

d) for EXL3 and EXL4, the application of the initial torque application shall be checked before marking using the same torque conditions as used to reach the required initial bolt tension. If a nut turns by more than  $15^\circ$  by the application of the inspecting torque, it shall be retightened and all remaining bolts in the connection shall be checked;

在开始进行所需的旋转之前, 必须目测所有螺母相对于螺栓螺纹的标记;

Before the application of the required rotation starts, the markings of all the nuts relative to the bolt threads shall be visually inspected. Any mark missing shall be corrected;

应通过日常观察确保螺栓安装人员正确地将安装扳手应用于旋转部件;

It shall be ensured by routine observation that the bolting crew properly applies the installation wrench to the turned element;

终拧后, 应按照以下要求检查标记:

After the application of the required rotation, the marks shall be inspected with the following requirements:

a) 如果转角大于  $15^\circ$ , 但未达到规定数值, 则应修正该角度;

a) if the rotation angle is more than  $15^\circ$  below the specified value, this angle shall be corrected;

b) 如果转角超过规定角度  $30^\circ$ , 或螺栓或螺母失效, 则应更换新的螺栓连接副。

b) if the rotation angle is more than  $30^{\circ}$  over the specified angle, or the bolt or the nut has failed, the bolting assembly shall be replaced with a new assembly.

#### **8.2.4.5 检查花键驱动剪断法**

#### **8.2.4.5 Inspection of spline-drive twist-off bolt method**

对于使用花键驱动剪断法安装的螺栓，必须进行以下额外检查：

For bolts installed using the spline-drive twist-off bolt method, the following additional inspections shall be carried out:

a) 应通过目视检查已完成的螺栓连接副。预紧螺栓连接副是指扭矩扳手端被剪切掉的螺栓连接副。扭矩扳手端保留的螺栓连接副被视为张力不足；

a) the inspection shall be carried out on the completed bolting assemblies by visual inspection. Pretensioned bolt assemblies are identified as those with the spline end sheared off. A bolt assembly for which the spline end remains is considered to be under-tensioned;

b) 对于执行等级为 EXL3 和 EXL4，当使用定位标记（火柴标记）时，在完成紧固后，无论垫圈是否旋转，均应参照初步紧固后的标记目测螺母旋转量，对于每组螺栓，如果发现螺母旋转量存在显著差异，则应测量该组所有螺栓的螺母旋转量并计算平均旋转角，旋转角在平均旋转角 $\pm 30^{\circ}$ 范围内的螺栓应予以接受。被拒绝的螺栓应予以更换；

for EXL3 and EXL4, when location marks (matchmarks) are used, after the completion of pretensioning, regardless of any washer rotation, the nut rotation amount shall be visually inspected by making reference to marks made after the preliminary tightening. For each group of bolts, if a significant discrepancy is found in the amount of nut rotation, the nut rotation of all bolts in the group shall be measured and the average rotation angle shall be calculated. Bolts with rotation angles within  $\pm 30^{\circ}$  of the average rotation angle shall be accepted. Rejected bolts shall be replaced;

如果扭断螺栓连接副的预紧是使用另一种预紧方法完成的，则应按照该方法的规定进行检查。

If pretensioning of twist-off bolting assemblies is completed using another pretensioning method, they shall be inspected in accordance with the provisions for that method.

#### **8.2.4.6 检查直接张力指示器法**

#### **8.2.4.6 Inspection of direct tension indicator method**

对于使用直接拉力指示器方法安装的螺栓，必须进行以下额外检查：

For bolts installed using the direct tension indicator method, the following additional inspections shall be carried out:

a) 应通过例行观察确保螺栓安装人员正确地将安装扳手套在被转动的部件上；  
a) it shall be ensured by routine observation that the bolting crew properly applies the installation wrench to the turned element; and

b) 在最终预紧之前，应确保凸出部分的正确方向远离工程。应通过日常观察确保接受适当的塞尺至少在直接张力指示器凸出之间的最小允许位置，如果拒绝适当的塞尺在超过最大允许位置，则应拆除并更换螺栓连接副和直接张力指示器。

Prior to final pretensioning, it shall be ensured that the protrusions are properly oriented away from the work. It shall be ensured by routine observation that the appropriate feeler gauge would be accepted in at least the minimum permitted number of locations between the protrusions of the direct tension indicator. If the appropriate feeler gauge would be rejected in more than the maximum permitted number of locations, the bolting assembly and direct tension indicator shall be removed and replaced.

c) 在最终紧固后，必须：  
after final pretensioning, either:



1) 应使用塞尺检查直接张力指示器，以确保按照制造商的安装程序使凸出充分变形；

1) the direct tension indicators shall be inspected using a feeler gauge to ensure that adequate deformation of the protrusions has been achieved in accordance with the manufacturer's installation procedures; or

2) 应通过例行观察确保在直接张力指示器的凸出部分之间至少有最少规定数量的适当塞尺被剔除。如果直接张力指示器未紧固到规定的限度，可进一步紧固组件，直到达到该限度；

2) it shall be ensured by routine observation that the appropriate feeler gauge would be rejected in at least the minimum required number of locations between the protrusions of the direct tension indicator. If the direct tension indicator has not been tightened to the specified limit, the assembly can be further tightened until this limit is achieved; or

3) 如果直接张力指示器提供视觉指示系统，则应根据相关产品标准或制造商书面说明中的要求，对选定检查的组件进行检查，以确定系统显示已达到所要求的预紧力。

3) if the direct tension indicator provides a visual indicating system, assemblies selected for inspection shall be checked to establish that the system indicates that the required pretension has been achieved, in accordance with the requirements in the relevant product standard or manufacturer's written instructions.

如果螺栓连接副的安装不符合相关产品标准或制造商的书面安装程序、应监督不合格组件的拆除和重新安装，然后检查整个螺栓组。如果直接张力指示器的预紧力未达到规定的极限，则可进一步张紧组件，直至达到该极限。

If the bolting assemblies are not installed in accordance with the relevant product standard or in accordance with the manufacturer's written installation procedures, the removal and reinstallation of the non-conforming assembly shall be supervised, and the

whole bolt group shall then be inspected. If the direct tension indicator has not been pretensioned to the specified limit, the assembly can be further tensioned until this limit is achieved.

#### **8.2.4.7 螺母检查法**

#### **8.2.4.7 Inspection of turn - of - nut method**

对于使用螺母旋转法安装的螺栓，应进行以下附加检查：

For bolts installed using a turn-of-nut method, the following additional inspections shall be carried out:

a) 对于执行等级为 EXL3 和 EXL4，当使用定位标记时，在开始旋转之前，必须目视检查所有螺母相对于螺栓的标记。

for EXL3 and EXL4, when location marks (matchmarks) are used, before the application of the required rotation starts, the markings of all the nuts relative to the bolt shall be visually inspected. Any marks missing shall be corrected.

b) 应通过例行观察确保螺栓安装人员按表 M.1 或表 M.2 中规定的量正确旋转已转动部件和未转动部件，视情况而定可通过使用有标记的扳手套筒或定位标记来观察螺母的最终旋转。当螺栓连接副在初次安装和紧固后但在预紧前有永久位置标记时，允许在预紧后对最终位置标记进行目视检查，以代替例行观察。

it shall be ensured by routine observation that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table M.1 or Table M.2, as appropriate. Observation of the final nut rotation may be achieved by using marked wrench sockets or location marks. When bolting assemblies have permanent location marks after the initial fit-up and snugging of the joint but prior to pretensioning, visual inspection of the final location marks after pretensioning is permitted in lieu of routine observation.

## **8.2.5 特殊结构螺栓连接副的检查和特殊方法**

### **8.2.5 Inspection of special structural fasteners and special methods**

#### **8.2.5.1 一般规定**

##### **8.2.5.1 General**

应规定对使用特殊结构螺栓连接副（包括不锈钢螺栓连接副）或符合 5.2.10 节和 7.9 节的特殊方法的连接进行检查的要求。

Requirements for inspection of connections using special structural fasteners, including stainless steel fasteners, or special methods in accordance with 5.2.10 and 7.9 shall be specified.

如果在铸件材料上使用带内螺纹孔，则应在带内螺纹孔周围进行无损检测 (NDT)，以确保材料的均匀性。

If tapped holes are used in cast materials, non-destructive testing (NDT) around the tapped holes shall be carried out to ensure material homogeneity.

#### **8.2.5.2 其他螺栓结构件**

##### **8.2.5.2 Other structural bolting components**

应根据产品标准或建议、制造商建议或指定方法对与其他结构螺栓部件 (如挂钩螺栓、特殊螺栓连接副) 的连接进行检查。

Inspection of connections with other structural bolting components (e.g. hook-bolts, special fasteners) shall be applied in accordance with product standards or recommendations, manufacturers recommendations, or specified methods.

## **8.3 校正**

### **8.3 Correction**

#### **8.3.1 涂层厚度过厚**

##### **8.3.1 Excessive coating thickness**

对于预紧和防滑接头，除非在执行规范中另有批准，否则应在组装前去除或减小可能导致螺栓预紧力严重丧失的过厚涂层。

For pretensioned and slip-resistant joints, excessive coating thickness that can cause substantial loss of bolt pretension shall be removed or reduced in thickness before assembly, unless otherwise approved in the execution specification.

### 8.3.2 更换结构螺栓部件和组件

#### 8.3.2 Replacement of structural bolting components and assemblies

结构螺栓、螺母和垫圈经目视检查发现有物理缺陷时，应予以更换。

Structural bolts, nuts and washers that, on visual inspection, show evidence of physical defects shall be replaced.

在下列情况下应更换螺栓连接副：

The bolting assembly shall be replaced when:

- a) 对于花键驱动断螺栓连接副，当螺母或结构螺栓旋转时，垫圈也随之旋转；  
a) for spline-drive bolting assemblies, there is washer rotation with nut or structural bolt rotation;
- b) 当使用定位标记（匹配标记）时，发现螺母旋转量存在明显差异；  
b) when location marks (matchmarks) are used, a significant discrepancy is found in the nut rotation amount; or,
- c) 安装结构螺栓的螺栓长度或方向不正确。  
c) the bolt length or orientation of the installed structural bolt is incorrect.

一般情况下，预紧力大于规定的最小值不会导致拒收。

A pretension that is greater than the minimum value specified, in general, shall not be cause for rejection.

注意 预拉力大于规定的最小值有利于补偿预拉力损失。

NOTE A pretension that is greater than the minimum value specified is beneficial for compensating for pretension losses.

## 9 符合本文件要求所需的文件

### 9 Documents required to claim conformity to this document

#### 9.1 一般规定

#### 9.1 General

施工单位可通过以下任一方式声明自己符合本文件的要求：

Constructors may claim conformity with the requirements of this document either by:

- 采用第 2 条中提及的 ISO 标准，或
- adoption of the ISO standards referenced in Clause 2 or
  
- 采用与第 2 条中所列标准在技术上等同的其他标准，或
- adoption of other standards to those listed in Clause 2 that provide technically equivalent conditions, or
  
- 采用在技术上等同的其他文件；
- adoption of other documents that provide technically equivalent conditions;

除非执行规范中另有规定，否则施工方有责任证明所选择的标准或文件在技术上提供了与 ISO 标准同等的条件。

Unless otherwise listed in the execution specification, it is the responsibility of the constructor to demonstrate that the standards or documents selected provide technically equivalent conditions to those in the corresponding ISO standards.

在执行前，其他标准或文件的采用应由规格制定者核实和批准，并应纳入执行规格中。

Prior to execution, adoption of other standards or documents shall be verified and approved by the specifier and shall be incorporated into the execution specifications.

注 附录 B 至附录 O 的内容并不能确定所列标准或文件在技术上等同，这仍是施工方的责任。

NOTE The contents of Annex B through Annex O do not establish that the standards or documents listed are technically equivalent, which remains the responsibility of the constructor.

## **9.2 符合性声明**

### **9.2 Declaration of conformity**

声明符合这些要求的制造商应列出适用的证明标准或文件。

A constructor claiming conformity with these requirements shall list the applicable supporting standards or documents.

## 附录 A

(规范性附录)

### Annex A

(normative)

与施工等级有关的附加信息、选项清单和要求

**Additional information, list of options and requirements related to the execution levels**

#### A.1 所需附加信息清单

#### A.1 List of required additional information

Table A.1 provides the additional information that is required in the text of this document as appropriate to fully define the requirements for execution of the work to be in accordance with this document (e.g. where the wording “shall be specified” is used).

表 A.1 提供了本文件正文中需要的补充信息，以充分定义按照本文件施工等级的要求（例如，在使用“规格”字样时）。

表 A.1 - 所要求的附加信息

**Table A.1 — Additional information required**

条款 Clause	所要求的附加信息 Additional information required
4	施工技术规格说明和质量要求 Execution specification and quality requirements
4.2	技术上等同的欧洲国家标准和文件 Technically equivalent national standards and documents
4.2	与本文件要求的偏差 Deviations from the requirements of this document
5	组成产品

	<b>Constituent products</b>
5.2.1	<p>螺栓和螺母的性能等级，以及适当的涂层和产品标准中的任何必要选项</p> <p>Property classes of bolts and nuts and, if appropriate, coatings, together with any required options within the product standard</p>
5.2.2	<p>直径大于 ISO 898-1 标准、ISO 898-2 标准和 ISO 898-3 标准规定的碳钢和合金钢紧固件的力学性能</p> <p>Mechanical properties for carbon and alloy steel bolting assemblies with larger diameters than those specified in ISO 898-1, ISO 898-2 and ISO 898-3</p>
5.2.2	<p>直径大于 ISO 898-1 标准、ISO 898-2 标准和 ISO 898-3 标准中规定的奥氏体或奥氏体-铁素体不锈钢紧固件的力学性能</p> <p>Mechanical properties for austenitic or austenitic-ferritic stainless steel bolting assemblies with larger diameters than those specified in ISO 3506-1 and ISO 3506-2, or those specified in other relevant national standards</p>
5.2.2	<p>耐大气腐蚀紧固件的力学性能</p> <p>Mechanical properties for atmospheric corrosion-resistant bolting assemblies</p>
5.2.4.2	<p>对于锥形垫圈，适用于形状的尺寸（见 7.2.8.3 节）</p> <p>For taper washers, dimensions applicable to shape (see 7.2.8.3)</p>
5.2.8	<p>耐大气腐蚀结构螺栓部件材料的化学成分</p> <p>Chemical composition of the material of atmospheric corrosion-resistant structural bolting components</p>
5.4.1	<p>用作地脚螺栓的杆件属性</p> <p>Properties for rods used as foundation bolts</p>
5.4.2	<p>对于地脚螺栓以外的锚固系统，如果应使用钢筋或专有产品</p> <p>For anchorage systems other than foundation bolts, if reinforcing steels or proprietary products shall be used</p>
<b>6</b>	<b>准备和组装</b>



	<b>Preparation and assembly</b>
6.2.1	不用于安装条件下的销轴的名义间隙 Nominal clearances for pins not intended to act in fitted conditions
6.2.1	活动接头尺寸 Dimensions for movement joints
6.2.2.4	对于沉头螺栓，沉头尺寸 For countersunk bolts, dimensions of the countersinking
6.4.2	对于防滑接头，抗滑移系数 For countersunk bolts, dimensions of the countersinking
6.4.2	防滑表面允许的涂层 Coating, if permitted in the slip surface
<b>7</b>	<b>结构螺栓连接</b> <b>Structural bolting</b>
7.2.1	确定接头类型为非施加预紧力连接、预紧力连接或抗滑移连接 Identify the joint type as a non-pretensioned joint, pretensioned joint, or slip-resistant joint
7.2.2	需要完全接触承压的位置 Locations where full contact bearing is required
7.2.6.1	如果用于结构螺栓连接的螺栓名义直径小于 M12，则说明其使用要求 If a nominal bolt diameter used for structural bolting is less than M12, the requirements associated with its use
7.2.6.2	如果螺栓的螺纹必须在剪切平面外，请说明螺栓的尺寸。 Where bolts must have threads outside shear plane, the dimensions of the bolts.
7.2.6.2	如果螺栓必须在剪切平面外有螺纹，且连接部分的厚度不等。 Where bolts must have threads outside the shear plane, with connected parts of unequal thicknesses, the orientation of the bolt.
7.2.8.1	对于非预紧结构螺栓，是否需要使用标准圆孔垫圈，如果需

	<p>要，垫圈是放置在螺母下还是螺栓头下（以旋转的为准），还是两者都放置。</p> <p>For non-pretensioned structural bolts, if washers are required with standard round holes, and if so, whether washers are to be placed under the nut or under the bolt head, whichever is to be rotated, or both.</p>
7.2.8.2	<p>对于预紧结构螺栓，如果 8.8 级或同等强度的螺栓不要求使用硬化垫圈，或在以下情况下要求使用硬化垫圈</p> <p>For pretensioned structural bolts, if hardened washers are not required for Grade 8.8 or equivalent strength bolts, or are required under the unturned element.</p>
7.2.8.2	<p>对于预紧结构螺栓，如果需要或不需要 10.9 级或同等抗拉强度螺栓的硬化垫圈</p> <p>For pretensioned structural bolts, where hardened washers are required or not required for Grade 10.9 or equivalent tensile strength bolts</p>
7.2.8.4	<p>所用板式垫圈的尺寸和钢号</p> <p>Dimensions and steel grades of plate washers, where used</p>
7.2.8.5	<p>所用锥形垫圈的尺寸和钢号（见 5.2.4.1 节）</p> <p>Dimensions and steel grades of taper washers, where used (see 5.2.4.1)</p>
7.2.9	<p>预紧装配组件需要锁定装置时</p> <p>Where locking devices are required with pretensioned assemblies</p>
7.9	<p>必要时，对非预紧或预紧应用中特殊紧固件的使用进行程序试验</p> <p>When required, procedure tests for use of special bolting components in non-pretensioned or pretensioned applications</p>
8	<p><b>检查、试验和校正</b></p> <p><b>Inspection, testing, and correction</b></p>
8.2.4.1	<p>使用预紧不锈钢紧固件时，检查和试验要求</p>

	Where pretensioned stainless steel bolting assemblies are used, the requirements for inspection and testing
8.2.4.2	使用扭矩法时，最终紧固检查包括检查是否过度紧固（见 8.2.4.3 节）。 When the torque method has been used, if final tightening inspection includes checking for over-tightening (see 8.2.4.3)
8.2.4.3	如果检查是否过度紧固，要求（见 8.2.4.2 节） If checking for over-tightening, the requirements (see 8.2.4.2)
8.2.5.1	使用特殊结构紧固件或特殊方法的连接检查要求 Requirements for inspection of connections using special structural fasteners or special methods
8.2.5.2	与其他结构件连接的检查方法 Inspection method for connections with other structural bolting components, if required
9	声明符合这些要求所需的文件 <b>Documents required to claim conformity to these requirements</b>
9.1	列出所选择的标准或文件，这些标准或文件提供了与相应 ISO 标准中的条件在技术上等同的条件 List standards or documents selected that provide technically equivalent conditions to those in the corresponding ISO standards
9.1	在施工方采用时，核实并批准采用其他标准或文件，并将其纳入执行规范。 When adopted by the constructor, verify and approve adoption of other standards or documents and incorporate into the execution specifications.

## A.2 List of options

### A.2 选项清单

表 A.2 列出了可在执行规范中指定的项目，以确定本文件中给出选项的工程执行要求。

Table A.2 lists the items which may be specified in the execution specification to define requirements for the execution of the work where options are given in this document.

表 A.2-需指定的选项列表

Table A.2 — List of options to be specified

条款 Clause	要指定的选项 Option(s) to be specified
5	成分产品 Constituent products
5.2.3	如果不锈钢螺栓可用于预拉应用 If stainless steel bolts may be used in pretensioned applications
5.2.6	如果可以使用表 B.6 所列以外的其他直接张力指示器 If alternative direct tension indicators other than those listed in Table B.6 may be used
5.2.9	如果需要有效防止松动或预紧力损失的装置 If devices that effectively prevent loosening or loss of pretension required are required
5.2.9	如果可以使用现行扭矩螺母作为锁定装置 If prevailing torque nuts may be used as locking devices
5.2.10	如果可以使用特殊结构紧固件 If special structural fasteners may be used
5.2.15	如果使用扭矩法安装的扭矩扳手和紧固件的修复工作可由其他人员进行 If reconditioning of spline-drive assemblies and bolting components installed using the torque method may be performed by other than the manufacturer or supplier
5.4.1	如果地基锚栓可能使用钢筋 If reinforcing steels may be used for foundation bolts
5.4.1	如果地基锚栓使用强化钢，钢的等级 If reinforcing steels are used for foundation bolts, the grade of steel

<b>6</b>	<b>准备和装配</b> <b>Preparation and assembly</b>
6.2.1	表 C.1 以外的螺栓名义间隙 Nominal clearances for bolts if other than Table C.1
6.2.2	螺栓孔的尺寸，如果与名义间隙规定的尺寸不同 The dimensions of bolt holes if other than that provided by the nominal clearances
6.2.2.2	如果可以使用短槽孔 If short-slotted holes can be used
6.2.2.2	如果可以使用长槽孔 If long-slotted holes can be used
6.5	对于预紧和防滑接头，如果过厚的涂层会导致螺栓预紧力大幅下降，则无需在装配前去除或减薄涂层厚度 For pretensioned and slip-resistant joints, if excessive coating thickness that can cause substantial loss of bolt pretension need not be removed or reduced in thickness before assembly
<b>7</b>	<b>结构螺栓连接</b> <b>Structural bolting</b>
7.2.2	如果允许使用扁钢以外的垫圈 If shims other than those made of flat steel are permitted
7.2.2	如果需要垫圈来满足规定的摩擦抗滑移系数 If shims are required to meet a specified friction slip factor
7.2.6.3	对于非预紧结构螺栓，如果允许握柄中的螺纹少于一个全螺纹，或要求握柄中的螺纹多于一个全螺纹（见表 F.3） For non-pretensioned structural bolts, if less than one full thread in the grip is permitted, or if more than one thread in the grip is required (see Table F.3)
7.2.6.3	对于预紧结构螺栓，如果允许握柄中的螺纹少于两个，或要求

	<p>握柄中的螺纹多于两个（见表 F.1）</p> <p>For pretensioned structural bolts, if less than two threads in the grip is permitted, or if more than two threads in the grip is required (see Table F.1)</p>
7.2.6.4	<p>如果允许螺母外表面有少于一个螺纹凸出（见表 F.2 和表 F.4）</p> <p>If less than one thread protrusion beyond the outer face of the nut is permitted (see Table F.2 and Table F.4)</p>
7.2.9	<p>如果锁定装置可以使用其他方法</p> <p>If other methods can be used for locking devices</p>
7.4.1	<p>如果不允许使用 7.4.7 节至 7.4.1.1 节中的任何一种预紧方法</p> <p>If any of the pretensioning methods given in 7.4.7 through 7.4.11 are not permitted</p>
7.4.3	<p>如果使用 <math>F_p</math> 以外的名义最小预拉力</p> <p>If a nominal minimum pretension other than <math>F_p</math> is to be used</p>
7.4.3	<p>如果规定的预拉力小于 <math>F</math>，则应说明预紧方法、预紧参数和检查要求</p> <p>If a pretension less than <math>F_p</math> is specified, the pretensioning method, the pretensioning parameters and the inspection requirements</p>
7.4.4	<p>如果螺栓装配需要 k 级</p> <p>If a k-class is required for a bolting assembly</p>
7.4.4	<p>如果可以使用扭矩方法的附录 H 进行螺栓校准</p> <p>If Annex H for bolt calibration for the torque method may be used</p>
7.4.6	<p>如果从附录 G 中选择安装前验证试验程序受到限制</p> <p>If the selection of pre-installation verification testing procedure from Annex G is restricted</p>
7.4.6	<p>如果 EN 14399 规范结构紧固件的 k 级为 K1 或 K2，需要进行安装前验证试验</p> <p>If pre-installation verification testing is required for EN 14399</p>

	structural bolting assemblies with a k-class of K1 of K2
7.4.7	如果附录 I 提供的扭矩法的选择受到限制 If the selection of torque method provided from Annex I is restricted
7.4.8	如果附录 J 中提供的组合方法的选择受到限制 If the selection of combined method provided from Annex J is restricted
7.4.9	如果使用附录 K 中的扭矩扳手旋断法受到限制 If the use of the spline-drive twist-off method from Annex K is restricted
7.4.10	如果使用附录 L 中的直接张力指示器方法受到限制 If the use of the direct tension indicator method from Annex L is restricted
7.4.11	如果从附录 M 中提供的螺母旋转方法的选择受到限制 If the selection of turn-of-nut method provided from Annex M is restricted
7.5	对于配合螺栓，如果螺纹可能从螺母一侧的外表面超过板厚度的 1/3 For fit bolts, if the threads may exceed 1/3 of the thickness of the plate from the outside surface on the nut side
7.7	如果必须采取措施抵消随后可能出现的螺栓预拉力损失（见附录 Q） If measures shall be taken to offset possible subsequent loss of bolt pretension (see Annex Q)
7.8	如果产品等级为 8.8 或同等强度及更低等级的未涂层结构螺栓可以重复使用 If uncoated structural bolts of product class 8.8 or equivalent strength and lower may be reused
8	检查、试验和纠正

	<b>Inspection, testing, and correction</b>
8.2.4.1	如果附录 O 提供的检查方法的选择受到限制 If the selection of inspection method provided from Annex O is restricted
8.2.4.3	进行扭矩法检查时，如果需要对螺栓头施加扭矩 When performing inspection of the torque method, if application of a torque to the bolt head is required
<b>Annex C</b>	<b>螺栓名义孔间隙</b> <b>Nominal hole clearances for bolts</b>
Table C.1 表 C.1	用于塔柱和桅杆等应用，如果不需要减小正常圆孔的间隙 For applications such as towers and masts, if the clearance for normal round holes need not be reduced
Table C.2 表 C.2	对于直径 27 mm 或更大的螺栓，如果间隙需要从 3 mm 减小到 2 mm For bolts of diameter 27 mm or greater, if the clearance is to be reduced from 3 mm to 2 mm
<b>Annex F</b> <b>附录 F</b>	<b>握柄中的螺纹、螺纹凸出和锥形垫圈的使用</b> <b>Threads in grip, thread protrusion, and use of taper washers</b>
	见 6.7.2.6 节，7.2.6.4 节和 7.2.8.5 节 (see 6.7.2.6, 7.2.6.4, and 7.2.8.5)
<b>Annex H</b> <b>附录 H</b>	现场条件下 EN 14399 规范中预紧螺栓的校准试验 If not stated in the manufacturer's instructions, values for deformations of the direct tension indicator protrusions
	见 7.4.6 节 (see 7.4.6)
H.8	如果制造商的说明书中没有说明，直接张力指示器凸出部分的变形值 If not stated in the manufacturer's instructions, values for deformations of the direct tension indicator protrusions
<b>Annex J</b> <b>附录 J</b>	<b>预紧紧固件 -组合紧固法</b> <b>Pretensioning bolting assemblies — Combined method</b>



J1	<p>如果使用表 J.1 以外的数值</p> <p>If the use of values other than Table J.1 are to be used</p>
J3	<p>如果需要定位标记（匹配标记）</p> <p>If location marks (matchmarks) are required</p>
<p>附录 K</p> <p><b>Annex K</b></p>	<p>预紧紧固件-花键驱动剪断法</p> <p><b>Pretensioning bolting assemblies — Spline-drive twist-off method</b></p>
	<p>如果需要一个贯穿结构螺栓、螺母、垫圈和构件的标记</p> <p>If a mark running across the structural bolt, nut, washer and member is required</p>
	<p>如果允许使用其他预紧程序进行紧固</p> <p>If tightening is permitted using an alternative pretensioning procedure</p>
	<p>如果 k 级仅限于 k 级 K0、带 HRD 螺母的 K1 和 K2 或带 HR 螺母的 k 级 K2</p> <p>If the k-class is limited to k-class K0, K1 and K2 with HRD nuts, or k-class K2 with HR nuts</p>
<p>附录 M</p> <p><b>Annex M</b></p>	<p>紧固件预紧-旋转螺母法</p> <p><b>Pretensioning bolting assemblies — Turn-of-nut method</b></p>
M.1	<p>应在紧固后确定定位标记（匹配标记）</p> <p>If location marks (matchmarks) shall be established after snug tightening,</p>
<p>附录 N</p> <p><b>Annex N</b></p>	<p>螺栓紧固鉴定程序(BTQP)</p> <p><b>Bolt Tightening Qualification Procedure (BTQP)</b></p>
N3.1	<p>如果紧固必须用旋转螺母以外的方法进行</p> <p>If tightening shall be carried out by a method other than rotation of the nut</p>
N3.3	<p>如果试验组件的一个部件允许使用多次</p> <p>If a component of a test assembly is permitted to be used more than once</p>
N3.5	<p>如果必须用旋转螺母以外的方法进行紧固</p>

	If tightening shall be carried out by a method other than rotation of the nut
<b>附录 O</b> <b>Annex O</b>	<b>结构螺栓检验方法</b> <b>Method for structural bolting inspection</b>
O.2	如果需要进行执行等级为 EXL2 的车间检查 If shop inspection for EXL2 is required
<b>附录 P</b> <b>Annex P</b>	<b>确定抗滑移系数的试验</b> <b>Test to determine slip factor</b>
P3	如果需要估算螺栓预拉力随时间变化的损失 If it is required to estimate bolt pretension losses over time
P5	如果对于“位移-对数时间”曲线，结构的设计寿命不是 50 年 If, for the “displacement - log time” curve, the design life of the structure is taken as other than 50 years

### A.3 与施工等级有关的要求

#### A.3 Requirements related to the execution levels

本条款列出了本文件中提及的每个施工等级的具体要求。

This clause lists requirements specific to each of the execution levels referenced in this document

表 A.3 中以粗体字母标出的项目与一般的执行控制系统有关，可在整个钢结构工程（或钢结构工程的某一阶段）中共同选择施工等级。其他项目一般需要根据逐个构件或逐个连接细节来选择适当的施工等级。

Items identified in bold letters in Table A.3 relate to the general system of control of execution and are amenable to a common choice of execution level across the whole of the structural steelwork (or a phase of the structural steelwork). The other items generally demand the selection of the appropriate execution level on a component - by-component or a connection detail-by-detail basis.

**Table A.3 — Requirements for each execution level**

**表 A.3- 各施工等级的要求**

条款 Clauses	EXL1a	EXL2 <sup>a</sup>	EXL3	EXL4
4 - 施工技术规格和质量要求 4 - Execution specification and quality requirements				
见 ISO 17607-1 标准 See ISO 17607-1				
5 - 成分产品 5 - Constituent products				
5.1 概述 5.1 General				
检查文件 Inspection documents		见 5.1.2 节，表 1 和表 2 See 5.1.2, Table 1 and Table 2		
5.2 结构螺栓产品 5.2 Structural bolting products				
识别和标记 Identification and marking		见 5.2.13 节 See 5.2.13		
可追溯性 Traceability	—	见 ISO 17607-1 标准 See ISO 17607-1		
7 - 结构螺栓 7 - Structural bolting				
7.2.2	—	如果使用焊接固定垫圈，焊接应符合 ISO 17607-5 标准。 if welding is used to secure shims, welding in accordance with ISO 17607-5		
8 - 检查、试验和纠正 8 - Inspection, testing, and correction				
8.2.2 安装螺栓前的检查 8.2.2 Inspection prior to installation of bolts				
8.2.2	—	使用安装前验证试验检查紧固程序 tightening procedure checked using a pre-installation verification test		
8.2.4 检查预紧接头				

Inspection of pretensioned joints			
8.2.4.2	—	预张紧期间和之后的检查 inspection during and after pretensioning	
附录 O-结构螺栓连接检查方法 Annex O - Method for structural bolting inspection			
0.1 顺序检查法 0.1 Sequential inspection method			
O.1.1	—	在第一步和第二步中，整体结构中接受检 查的紧固件数量 number of bolting assemblies inspected in first	
O.1.1	—	顺序 A 型 sequential type A	顺序 B 型 sequential type B
0.2 基于施工等级的频率检查方法 0.2 Frequency inspection method based on execution level			
	见表 O.1 See Table O.1		
破折号 “-” 表示文中没有具体要求。 a dash "—" indicates no specific requirement in the text.			

## 附录 B

### Annex B

(规范性附录)

(normative)

紧固件、装配和涂层标准

#### Bolting component, assembly and coating standards

##### B.1 概述

##### B.1 General

表 B.1 至 B.9 列出了与本文件引用的 ISO 标准相对应的地区和国家标准及文件。  
下表中的破折号“-”表示不适用特定标准。

Tables B.1 to B.9 show the regional and national standards and documents corresponding to the  
ISO standard(s) referenced in this document.

注 表 B.1 至表 B.9 的内容并不确定所列标准和文件之间的任何技术等同性。

NOTE The contents of Tables B.1 to B.9 do not establish any technical equivalence between the standards and documents listed.

表 B.1 - 用于预紧和非预紧应用的结构紧固件

Table B.1 – Structural bolting assemblies for pretensioned and non -  
pretensioned applications

本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	无 None
EN	EN 14399-1 EN 14399-1 规范 EN 14399-2

	EN 14399-2 规范 EN 14399-3 EN 14399-3 规范 EN 14399-4 EN 14399-4 规范 EN 14399-7 EN 14399-7 规范 EN 14399-8 EN 14399-8 规范
AS/NZS	AS/NZS 1252.1 AS/NZS 1252.1 标准 AS/NZS 1559 AS/NZS 1559 标准
GB	GB/T 1231 GB/T 1231 规范 GB/T 16939 GB/T 16939 规范
GOST	GOST 1759.0 GOST 1759.0 标准 GOST 7796 GOST 7796 标准 GOST 7798 GOST 7798 标准 GOST 7805 GOST 7805 标准 GOST 7817 GOST 7817 标准 GOST 15589GOST 32484.1 GOST 15589GOST 32484.1 标准 GOST 32484.3 GOST 32484.3 标准 GOST 32484.4 GOST 32484.4 标准 GOST R 50791 GOST R 50791 标准

JIS/JSS	JIS B1186 JIS B1186 标准
ASTM	—

表 B.2 - 用于预拉和非预拉应用的花键驱动结构紧固件

**Table B.2 - Spline - drive structural bolting assemblies for pretensioned and non - pretensioned applications**

本文件引用的 ISO 标准和文件 <b>ISO standard(s) and documents referenced in this document</b>	无 None
EN	EN 14399-10 EN 14399-10 规范
AS/NZS	-
GB	GB/T 632 GB/T 632 规范 GB/T 633 GB/T 633 规范
GOST	GOST 32484.1 GOST 32484.1 标准 GOST 32484.4 GOST 32484.4 标准
JIS/JSS	JSS II 09 JSS II 09 标准
ASTM	ASTM F315/F3125M, grade F1852 ASTM F315/F3125M, grade F1852 规范 ASTM F315/F3125M, grade F2280 ASTM F315/F3125M, grade F2280 规范 ASTM F3148 ASTM F3148 规范

表 B.3 - 预紧力和非预紧力结构部件及相关标准

**Table B.3 - Structural components and related standards for pretensioned and non - pretensioned applications**

	Bolts 螺栓	Nuts 螺母	Washers 垫圈
本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	ISO 898-1 <sup>a</sup> 标准 ISO 898-1 <sup>a</sup>	ISO 898-2 <sup>a</sup> 标准 ISO 898-2 <sup>a</sup>	ISO 898-3 <sup>a</sup> 标准 ISO 898-3 <sup>a</sup> ISO 7089 标准 ISO 7089 ISO 7090 标准 ISO 7090 ISO 7091 标准 ISO 7091 ISO 7092 标准 ISO 7092 ISO 7093-1 标准 ISO 7093-1 ISO 7093-2 标准 ISO 7093-2 ISO 7094 标准 ISO 7094
EN	—	—	EN 14399-5 规范 EN 14399-6 规范
AS/NZS	—	—	—
GB	—	GB/T 229 规范 GB/T 229	GB/T 230 规范 GB/T 230
GOST	—	—	GOST 32484.5 标准 GOST 32484.5 GOST 32484.6 标准 GOST 32484.6
JIS/JSS	—	—	—
ASTM	ASTM F3125/F3125M	ASTM A563/A563M	ASTM F436/F436M ASTM F436/F436M



	grades A325, A325M, A490, A490M ASTM A354, grades BC, BD ASTM A449ASTM F3125/F3125M grades A325, A325M, A490, A490M ASTM A354, grades BC, BD ASTM A449 规范	Grades C3, D, DH, DH3 ASTM A563/A563M Grades C3, D, DH, DH3 规范	规范
a 不包括特性等级高于 10.9 的螺栓、螺母和垫圈。 a Bolts, nuts and washers with property class higher than 10.9 are excluded.			

**表 B.4 - 仅适用于非张拉应用的结构紧固件**

**Table B.4 - Structural bolting assemblies for non - pretensioned applications only**

本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	无 None
EN	EN 15048-1 规范 EN 15048-1 EN 15048-2 规范 EN 15048-2
AS/NZS	—
GB	—
GOST	GOST 23118 标准 GOST 23118 STO NOSTROY 2.10.76 标准 STO NOSTROY 2.10.76
JIS/JSS	—

ASTM	无 None
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**表 B.5 - 仅适用于非张拉应用的结构部件**

**Table B.5 – Structural components for non - pretensioned applications only**

	螺栓 Bolts	螺母 Nuts	垫圈 Washers
本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	ISO 4014 标准 ISO 4014 ISO 4017 标准 ISO 4017	ISO 4032 标准 ISO 4032 ISO 4033 标准 ISO 4033	—
EN	—	—	—
AS/NZS	AS 1110.1 标准 AS 1110.1 AS 1111.1 标准 AS 1111.1	AS 1112(所有部分) 标准 AS 1112 (all parts)	AS 1237 标准 AS 1237
GB	GB/T 5780 规范 GB/T 5780 GB/T 1228 规范 GB/T 1228	GB/T 41 规范 GB/T 41 GB/T 6177 规范 GB/T 6177	—
GOST	—	—	GOST 18123 标准
JIS/JSS	JIS B 1180 标准 JIS B 1180	JIS B 1181 标准 JIS B 1181	JIS B 1251 标准 JIS B 1251 JIS B 1256 标准 JIS B 1256
ASTM	ASTM A307 规范 ASTM A307	ASTM A563/A563M, grades A, B 规范 ASTM A563/A563M, grades A, B	ASTM F844 规范 ASTM F844

表 B.6 - 直接张力指示器

Table B.6 - Direct tension indicators

本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	无 None
EN	EN 14399-9 规范 EN 14399-9
AS/NZS	—
GB	—
GOST	—
JIS/JSS	—
ASTM	ASTM F959/F959M 规范 ASTM F959/F959M

表 B.7 - 不锈钢螺栓连接部件

Table B.7 - Stainless steel bolting components

	螺栓 Bolts	螺母 Nuts	垫圈 Washers
本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	ISO 3506-1 标准 ISO 3506-1	ISO 3506-2 标准 ISO 3506-2	
EN	—		
AS/NZS	—		
GB	—		
GOST	GOST 7798 标准 GOST 7798 GOST 7805 标准 GOST 7805		
JIS/JSS	—		
ASTM	ASTM A193/A193M 规	ASTM A194 规	

	范 ASTM A193/A193M ASTM A320/A320M 规范 范 ASTM A320/A320M ASTM F593 规范 ASTM F593 ASTM A1082/A1082M 规范 ASTM A1082/A1082M	范 ASTM A194 ASTM F594 规范 范 ASTM F594	
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**表 B.8 - 地脚螺栓**

**Table B.8 - Foundation bolts**

本文件引用的 ISO 标准和文件 ISO standard(s) and documents referenced in this document	无 None
EN	—
AS/NZS	—
GOST	GOST 24379.0 标准 GOST 24379.0 GOST 24379.1 标准 GOST 24379.1
GB	—
JIS/JSS	JIS B 1220 标准 JIS B 1220
ASTM	ASTM F1554 规范 ASTM F1554

**表 B.9.- 紧固件、螺栓、螺母、垫圈和直接张力指示器的涂层**

**Table B.9.— Coatings for bolting assemblies, bolts, nuts, washers, and direct tension indicators**

	热镀锌 Hot dip galvanizing	机械镀锌 Mechanical galvanizing	电镀 Electroplating	热扩散/酸化 Thermal diffusion/she rardizing	片状锌涂 层 Zinc - flake coatings
本文件引 用的 ISO 标准和文 件 ISO standard(s) and Documents referenced in this document	ISO 1461 <sup>a</sup> ISO 10684		ISO 4042	ISO 14713-3	ISO 10683
EN	—	—	—	—	—
AS/NZS	—	—	—	—	—
GB	—	—	—	—	—
GOST	GOST 9.307	—	—	GOST 28844	—
JIS/JSS	—	—	—	—	—
ASTM	ASTM F2329	ASTM B695		ASTM A1059	ASTM F1136 ASTM F2833 ASTM F3393
<p style="text-align: center;">a</p> <p>a ISO 1461 标准不适用于热镀锌产品（如紧固件），热镀锌产品有专门的标准，这些标准可能包括与 ISO 1461 标准 不同的附加要求或规定。</p> <p>ISO 1461 does not apply to hot dip galvanized products (e.g. fasteners) for which specific standards exist and which can include additional requirements or requirements which are different from those of ISO 1461.</p>					

## 附录 C

### Annex C

(规范性附录)

(normative)

#### 螺栓孔名义间隙

#### Nominal hole clearances for bolts

附录 C 提供了用于确定适当孔径的名义孔间隙。参见 6.2 节。

Annex C provides nominal hole clearances used to establish the appropriate hole size.  
See 6.2.

表 C.1 至 C.4 显示了与本文件中引用的 ISO 标准相对应的地区和国家标准及文件中的名义间隙，如各表注释中所示。

Tables C.1 to C.4 show the nominal hole clearances from regional and national standards and documents corresponding to the ISO standard(s) referenced in this document, as indicated in the NOTE to each table

表 C.1 来自于 EN 1090-2:2018 规范。

Table C.1 is based on EN 1090-2:2018.

表 C.2 和表 C.3 来自于 AISC 360-16 规范和 CSA S16-19 规范。

Table C.2 and Table C.3 are based on AISC 360-16 and CSA S16-19.

表 C.4 来自于日本建筑标准法，用于桥梁的净空除外。

Table C.4 is based on Japan Building Standard Law, except for clearances used for bridges.

表 C.5 来自于 SP 16.13330:2017 标准。

Table C.5 is based on SP 16.13330:2017.

注 表 C.1 至表 C.5 的内容并未确定所列标准和文件之间的任何技术等同性。

NOTE The contents of Tables C.1 to C.5 do not establish any technical equivalence between the standards and documents listed.

表 C.1 - 螺栓的名义间隙

Table C.1 - Nominal hole clearances for bolts

尺寸单位: mm

Dimensions in millimetres

螺栓名义直径 <i>d</i>  Nominal bolt diameter <i>d</i>	M12	M14	M16	M18	M20	M22	M24	M27 和 M36
标准圆孔 <sup>a</sup> Normal round holes <sup>a</sup>	1 <sup>b,c</sup>		2					3
大圆孔 Oversize round holes	3		4				6	8
短长圆孔 <sup>d</sup> Short-slotted holes (on the length) <sup>d</sup>	4		6				8	10
长长圆孔 <sup>d</sup> Long-slotted holes (on the length) <sup>d</sup>	1.5d							
<sup>a</sup> 对于塔柱和桅杆等应用，除非在执行规范中有明确规定，普通圆孔的名义间隙应减少 0.5 mm。 <sup>a</sup> For applications such as towers and masts the nominal clearance for normal round holes shall be reduced by 0,5 mm unless specified in the execution specification. <sup>b</sup> 对于有涂层的紧固件，可根据紧固件的涂层厚度增加 1 mm 的名义间隙。 <sup>b</sup> For coated bolting assemblies, 1 mm nominal clearance can be increased by the coating thickness of the bolting assembly.								

<p><sup>c</sup> 名义直径为 12 毫米和 14 毫米的螺栓或沉头螺栓也可用于 2 mm 间隙的孔中。</p> <p><sup>c</sup> Bolts with nominal diameter 12 mm and 14 mm, or countersunk bolts may also be used in 2 mm clearance holes</p> <p><sup>d</sup> 对于槽孔中的螺栓，宽度上的名义间隙应与标准圆孔规定的直径间隙相同。</p> <p><sup>d</sup> For bolts in slotted holes the nominal clearances across the width shall be the same as the clearances on diameter specified for normal round holes</p>
<p>注 表 C.1 来自于 EN 1090-2:2018 规范。</p> <p>NOTE Table C.1 is based on EN 1090-2:2018.</p>

表 C.2 - 螺栓名义间隙

Table C.2 — Nominal hole clearances for bolts

尺寸单位：mm

Dimensions in millimetres

螺栓名义直径 <i>d</i> Nominal bolt diameter <i>d</i>	M12	M14	M16	M18	M20	M22	M24	M27 to M36 M27 和 M36
标准圆孔 Normal round holes	2							3
大圆孔 Oversize round holes	4						6	8
短长圆孔 <sup>a</sup> Short-slotted holes (on the length) <sup>a</sup>	6						8	10
长长圆孔 <sup>a</sup> Long-slotted holes (on the length) <sup>a</sup>	1.5d							
<sup>a</sup> 对于槽孔中的螺栓，宽度上的名义间隙应与标准圆孔规定的直径间隙相同。 <sup>a</sup> For bolts in slotted holes the nominal clearances across the width shall be the same as the clearances on diameter specified for normal round holes.								



<sup>b</sup> 对于直径 27 mm 或更大的螺栓，在执行规范要求时，间隙应从 3 mm 减小到 2 mm。<sup>b</sup>  
 For bolts of diameter 27 mm or greater, the clearance shall be reduced from 3 mm to 2 mm when required by the execution specification.

注 表 C.2 来自于 AISC 360-16 规范和 CSA S16-19 规范。

NOTE Table C.2 is based on AISC 360-16 and CSA S16-19.

**表 C.3 - 螺栓名义间隙（非度量单位）**

**Table C.3 - Nominal hole clearances for bolts (non - metric units)**

尺寸单位：in

Dimension in inches

螺栓名义直径 <i>d</i>  Nominal bolt diameter <i>d</i>	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2
标准圆孔 Normal round holes	1/16					1/8			
大圆孔 Oversize round holes	1/8		3/16			1/4		5/16	
短长圆孔 <sup>a</sup> Short-slotted holes (on the length) <sup>a</sup>	3/16		1/4			5/16		3/8	
长长圆孔 <sup>a</sup> Long-slotted holes (on the length) <sup>a</sup>	1.5d								
<sup>a</sup> 对于槽孔中的螺栓，宽度上的名义间隙应与标准圆孔规定的直径间隙相同。 <sup>a</sup> For bolts in slotted holes, the nominal clearances across the width shall be the same as the clearances on diameter specified for normal round holes.									
注 表 C.3 来自于 AISC 360-16 规范和 CSA S16-19 规范。 NOTE Table C.3 is based on AISC 360-16 and CSA S16-19.									

表 C.4 - 螺栓名义间隙

Table C.4 - Nominal hole clearances for bolts

尺寸单位: mm

Dimensions in millimetres

螺栓名义直径 <i>d</i> Nominal bolt diameter <i>d</i>	M12	M14	M16	M18	M20	M22	M24	M27 to M36 M27 和 M36
带预紧螺栓的普 通圆孔 Normal round holes with pretensioned bolts	2							3
使用非预紧螺栓 的普通圆孔 Normal round holes with non pretensioned bolts	1.0				1.5			
a2.5 桥梁结构（不属于日本建筑标准法的范围）。								
a 2.5 for bridge structures (outside the scope of Japan Building Standard Law)								
注 表 C.4 来自于日本的建筑标准法。								
NOTE Table C.4 is based on Japan Building Standard Law.								

表 C.5 - 螺栓名义间隙

Table C.5 - Nominal hole clearances for bolts

尺寸单位: mm

Dimensions in millimetres

螺栓精度等级和应用条件 Bolt accuracy class and application conditions	间隙 Clearance
A 级精度螺栓 bolts of accuracy class A	0
用于架空电线杆、开放式开关设备和运输接触网的 B 级精度螺栓	1

bolts of accuracy class B in the construction of poles for overhead power lines, open switchgear and contact networks of transport	
其他情况 other cases	1,2,或 3 <sup>a</sup> 1, 2, or 3 <sup>a</sup>
<sup>a</sup> 孔的名义直径应比螺栓的名义直径大 2-3 mm。 <sup>a</sup> nominal hole diameter should be 2-3 mm larger than the nominal diameter of the bolt	
注 表 C.5 来自于 SP 53-101-98 标准。 NOTE Table C.5 is based on SP 53-101-98.	

## 附录 D

### Annex D

(规范性附录)

(normative)

#### 螺栓摩擦面抗滑移系数

#### Bolted friction surface slip factors

附录 D 提供了可用于防滑接缝摩擦面的抗滑移系数。见 6.4。

Annex D provides slip factors that may be used for friction surfaces in slip-resistant joints. See 6.4.

表 D.1 列出了地区和欧洲国家标准及文件，本附录中没有引用相应的 ISO 标准。

Table D.1 shows the regional and national standards and documents. There are no corresponding ISO standards referenced in this annex.

注 表 D.1 的内容并不确定所列标准和文件之间的任何技术等同性。

NOTE The contents of Table D.1 do not establish any technical equivalence between the standards and documents listed.

表 D.1 - 可用于摩擦表面的抗滑移系数

Table D.1 – Slip factors that may be used for friction surfaces

指定标准和摩擦面 Designated standard and friction surface	等级（指定标准） Class (for designated standard)	抗滑移系数 Slip factor
EN 1090-2:2018 规范 EN 1090-2:2018		
表面喷丸或喷砂，除去松散锈迹，无凹坑 Surfaces blasted with shot or grit with loose rust removed, not pitted	A	0.50 <sup>a</sup>

<p>表面热浸镀锌，符合 ISO 1461 标准，并进行闪光（清扫）喷砂<sup>b</sup>和碱性硅酸锌涂料，名义厚度为 60 <math>\mu\text{m}</math><sup>c</sup></p> <p>Surfaces hot dip galvanized to ISO 1461 and flash (sweep) blasted<sup>b</sup> and with alkali-zinc silicate paint with a nominal thickness of 60 <math>\mu\text{m}</math><sup>c</sup></p>	B	0.40 <sup>a</sup>
<p>表面喷丸或喷砂：</p> <p>Surfaces blasted with shot or grit:</p> <p>a) 涂有名义厚度为 60 <math>\mu\text{m}</math><sup>c</sup> 的碱性硅酸锌涂料；</p> <p>a) coated with alkali-zinc silicate paint with a nominal thickness of 60 <math>\mu\text{m}</math><sup>c</sup>;</p> <p>b) 热喷涂铝或锌或两者的组合，名义厚度不超过 80 <math>\mu\text{m}</math><sup>c</sup>。</p> <p>b) thermally sprayed with aluminium or zinc or a combination of both to a nominal thickness not exceeding 80 <math>\mu\text{m}</math><sup>c</sup>.</p>	B	0.40 <sup>a</sup>
<p>表面热浸镀锌，符合 ISO 1461 标准，并进行闪光喷砂（或同等磨损方法）<sup>b</sup></p> <p>Surfaces hot dip galvanized to ISO 1461 and flash (sweep) blasted (or equivalent abrasion method)<sup>b</sup></p>	C	0.35 <sup>a</sup>
<p>表面用钢丝刷或火焰清洗，除去松动的铁锈</p> <p>Surfaces cleaned by wire-brushing or flame cleaning, with loose rust removed</p>	C	0.30 <sup>a</sup>
<p>轧制表面</p> <p>Surfaces as-rolled</p>	D	0.20 <sup>a</sup>
<p><b>AISC 360-16, AISC 348-20 规范</b></p> <p><b>AISC 360-16, AISC 348-20</b></p>		
<p>未喷漆的喷砂清理钢表面</p> <p>Unpainted blast-cleaned steel surfaces</p>	B	0.50
<p>喷砂清理过的钢材表面有 B 级涂层</p> <p>Surfaces with Class B coatings on blast-cleaned steel</p>		
<p>未喷漆的清洁轧钢表面</p> <p>Unpainted clean mill scale steel surfaces</p>	A	0.30
<p>喷砂清理过的钢材表面有 A 级涂层</p> <p>Surfaces with Class A coatings on blast-cleaned steel</p>		

热浸镀锌表面，带或不带手工钢丝刷 Hot-dipped galvanized surfaces, with or without hand wire brushing		
CSA S16-19 规范 CSA S16-19		
未喷漆的喷砂清理钢表面 Unpainted blast-cleaned steel surfaces	B	0.52
喷砂清理过的钢材表面有 B 级涂层 Surfaces with Class B coatings on blast-cleaned steel		
金属化表面 Metallized surfaces	D	0.45
热浸镀锌表面 Hot-dip galvanized surfaces	C	0.30
未喷漆的洁净轧钢表面 Unpainted clean mill scale steel surfaces	A	0.30
喷砂清理过的钢材表面有 A 级涂层 Surfaces with Class A coatings on blast-cleaned steel		
JASS 6:2018 标准 JASS 6:2018		
通过清除整个接触界面范围内的轧制鳞片进行处理的表面，保持与空气接触，以便自发生成红锈 Surfaces treated by removing mill scale from the entire extent of the contact interface, kept open to the air so that red rust is spontaneously generated.		0.45
喷丸或喷砂表面，粗糙度值不小于 50 μm R <sub>z</sub> Surfaces shot or grit blasted, with roughness values of not less than50 μm R <sub>z</sub>		0.45
热浸镀锌表面在镀锌后轻微喷砂，表面粗糙度不小于 50 μm R <sub>z</sub> Hot-dip galvanized surfaces lightly blasted after galvanizing, with the surface roughness not less than 50 μm R <sub>z</sub>		0.40
JGJ 82-2011 标准 JGJ 82-2011		
表面喷丸或喷砂	A	0.45

Surface with shot or grit blasted		
表面喷砂并喷涂铝基或锌基金属产品 Surface with grit blasted and spray-metalized with an aluminium or zinc-based product	B	0.45
表面经过喷砂处理并喷涂锌基涂料 Surface with grit blasted and coated with zinc-based paint	C	0.40
清洁表面或用刷子除锈 Clean surface or rust cleaned with brush	D	0.30
<b>AS 4100:2020, NZS 3404 Part 1:1997 标准</b> <b>AS 4100:2020, NZS 3404 Part 1:1997</b>		
清洁轧制表面 Clean as-rolled surfaces		0.35
<b>GOST SP 16.13330.2017 规范</b> <b>GOST SP 16.13330.2017</b>		
经喷丸或喷砂处理的表面（两个表面无保护层） Surfaces treated by shot blasting or grit blasting (two surfaces without conservation)		0.58
经过火焰处理的表面（两个表面未保存） Flame treated surfaces (two surfaces without conservation)		0.42
用钢刷处理过的表面（两个表面未保存） Surfaces treated with steel brushes (two surfaces without preservation)		0.35
未经处理的表面 Surfaces without treatment		0.25
<p><sup>a</sup> 这些滑移系数值考虑了预拉力从初始值开始的潜在损失。</p> <p><sup>a</sup> The potential loss of preloading force from its initial value is considered in these slip factor values.</p> <p><sup>b</sup> 除非能证明有其他同等的磨损工艺能力，否则热浸镀锌表面的闪光（扫射）喷砂必须按照 EN 1577 3 规范中规定的程序和条件进行。热浸镀锌表面的闪光（清扫）喷砂应按照 EN 15773 规范规定的程序和条件进行。闪光（扫射）喷砂后，无光泽表面的出现表明未电镀锌的软表层已被清除。</p> <p><sup>b</sup> Unless alternative equivalent abrasion process capability can be demonstrated, flash (sweep) blasting of hot dip</p>		

galvanized surfaces shall be carried out according to the procedures and conditions set out in EN 15773. After flash

(sweep) blasting the appearance of a matt surface indicates that a soft surface layer of un-alloyed zinc has been

removed.

° 干厚度应在 40 μm 至 80 μm 范围内。

° Dry thickness to be within 40 μm to 80 μm range.



## 附录 E

### Annex E

(规范性附录)

(normative)

名义最小预紧力

**minimum bolt pretension**

附录 E 提供了可用于预紧和防滑接头的名义最小预拉力。见 7.4.3。

Annex E provides nominal minimum pretensions that may be used for pretensioned and slip-resistant joints. See 7.4.3.

表 E.1 来自于 EN 1090-2:2018 规范、JASS 6:2018 标准、AISC 360-16 规范、CSAS16-19 规范、AS/NZ 5131:2016 标准和 STO NOSTROY 2.10.76-2012 规范，如各表注释所示。

Table E.1 is based on EN 1090-2:2018, JASS 6:2018, AISC 360-16, CSA S16-19, AS/NZS 5131:2016, and STO NOSTROY 2.10.76-2012, as indicated in the NOTE to each table.

表 E.2 来自于 AISC 360-16 规范和 CSA S16-19 规范。

Table E.2 is based on AISC 360-16 and CSA S16-19.

表 E.3 依据 DAST-Richtlinie 024 标准，尺寸为 M12 至 M36 的螺纹连接的紧固 Stahlbau-Verlagsgesellschaft MbH 标准。

Table E.3 is based on DAST-Richtlinie 024, Tightening screwed connections of dimensions M12 to M36, Stahlbau-Verlagsgesellschaft MbH.

注 表 E.1 至 E.3 的内容并不确定所列标准和文件之间的任何技术等同性。

NOTE The contents of Tables E.1 through E.3 do not establish any technical equivalence between the standards and documents listed.

**表 E.1 - 公制螺栓名义最小预紧力 (kN)-公制螺栓**

**Table E.1 – Nominal minimum pretension (kN) – metric bolts**

适用标准/属	型号/螺栓直径 mm Designation/Bolt diameter
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性类别 Applicable standard/ Property class	M12	M16	M20	M22	M24	M27	M30	M36
8.8	47	88	137	170	198	257	314	458
10.9	59	110	172	212	247	321	393	572
JIS B 1186 F10T	62,6	117	182	226	262	341	417	-
ASTM F3125 grade A325M	-	91	142	176	205	267	326	475
ASTM F3125 grade A490M	-	114	179	221	257	334	408	595
AS/NZS 1252.1 Grade 8.8	-	95	145	-	210	-	335	490
AS/NZS 1252 .1 Grade 10.9	-	130	205	-	295	-	465	680
STO NOSTRO Y 2.10.76 Grade 8.8	49	91	142	-	-	-	-	-
STO NOSTRO Y 2.10.76 Grade 10.9	-	118	184	229	266	346	426	-
NOTE 上述数值来自于 EN 1090-2:2018 规范, JASS 6:2018 标准, AISC 360-16 规范, CSAS16-19 规范, AS/NZS 5131:2020 标准 与 STO NOSTROY 2.10.76-2012 规范。 NOTE Based on EN 1090-2:2018, JASS 6:2018, AISC 360-16, CSA S16-19, AS/NZS 5131:2020, and STO NOSTROY 2.10.76-2012.								

表 E.2 - 名义最小预拉力 (kN) - 非公制螺栓

Table E.2 – Nominal minimum pretension (kN) – non-metric bolts

适用标准/性能等级 Applicable standard/ Property class	螺栓直径 Inch Bolt diameter								
	1/2	5/8	3/4	7/8	1	1-1/8	1-1/4	1-3/8	1-1/2
ASTM F3125 等级 A325 和 F1852 ASTM F3125 grades A325 and F1852	54	85	125	173	227	285	361	432	523
ASTM F3125 等级 A490 和 F2280 ASTM F3125 grades A490 and F2280	67	107	156	218	285	356	454	538	658
注 上述数值来自于 AISC 360-16 规范和 CSA S16-19 规范 NOTE Based on AISC 360-16 and CSA S16-19									

表 E.3 - 名义预紧力  $F_{p,C}^*$  (kN) - 公制螺栓

Table E.3 – Nominal pretension  $F_{p,C}^*$  (kN) – metric bolts

属性类别 Property class	名称/螺栓直径 mm Designation/Bolt diameter							
	M12	M16	M20	M22	M24	M27	M30	M36
10.9	50	100	160	190	220	290	350	510
注 根据 DAST-Richtlinie 024 标准, 尺寸为 M12 至 M36 的螺纹连接的紧固, Stahlbau-Verlagsgesellschaft MbH 标准。 NOTE Based on DAST-Richtlinie 024, Tightening screwed connections of dimensions M12 to M36, Stahlbau- Verlagsgesellschaft MbH.								

## 附录 F

### Annex F

(规范性附录)

(normative)

#### 抓握螺纹、螺纹凸出和锥形垫圈的使用

##### Threads in grip, thread protrusion, and use of taper washers

附录 F 规定了抓握螺纹、螺纹凸出和锥形垫圈的使用要求。见 7.2.6.3 节、7.2.6.4 节和 7.2.8.5 节。

Annex F provides requirements for threads in grip, thread protrusion, and use of taper washers. See 7.2.6.3, 7.2.6.4 and 7.2.8.5.

表 F.1 至 F.5 列出了地区和欧洲国家标准及文件的要求。每个表中都提供了默认要求。

Tables F.1 through F.5 show the requirements of regional and national standards and documents. A default requirement is provided in each table.

注 1 表 F.1 至 F.5 的内容并未确定所列标准和文件之间的任何技术等同性。

NOTE 1 The contents of Tables F.1 through F.5 do not establish any technical equivalence between the standards and documents listed.

注 2 对于承受拉伸载荷的螺栓，可通过增加抓握螺纹数量来降低螺纹失效而非螺栓断裂的可能性。

NOTE 2 For bolts under tensile loading, the likelihood of thread failure, instead of bolt fracture, can be reduced by increasing the number of threads in the grip.

表 F.1 - 预紧螺栓夹具中的最小螺纹

Table F.1 – Minimum threads in the grip for pretensioned bolts

除非另有说明 Unless otherwise specified	2 个螺纹，除非执行规范中另有说明 2 threads unless otherwise stated in the execution specification
AS/NZS 5131:2016 标准 AS/NZS 5131:2016	一个螺纹加上紧固后的螺纹跳动量 One thread plus the thread runout after snug tightening
NZS 3404, Part 1:1997 标准	(i) 螺栓长度在 4 倍的直径以下（含 4 倍的直径）时为 5 个

NZS 3404, Part 1:1997	<p>螺纹</p> <p>(i) Five threads for a bolt length up to and including 4 diameters</p> <p>(ii) 螺栓长度超过 4 倍的直径但不超过 8 倍的直径时为 7 个螺纹</p> <p>(ii) Seven threads for a bolt length over 4 diameters but not exceeding 8 diameters</p> <p>(iii) 螺栓长度超过 8 倍的直径时为 10 个螺纹</p> <p>(iii) Ten threads for a bolt length over 8 diameters</p>
EN 1090-2:2018 规范 EN 1090-2:2018	<p>EN 14399-3 规范、EN 14399-7 规范和 EN 14399-10 规范，螺母承压面与柄的无螺纹部分之间至少应保留 4 个完整螺纹（除螺纹跳动外）。</p> <p>EN 14399-3, EN 14399-7 and EN 14399-10, 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</p> <p>EN 14399-4 规范和 EN 14399-8 规范，螺母承压面与柄的未螺纹部分之间至少应保留 2 个完整螺纹（螺纹跳动除外）。EN 14399-4 and EN 14399-8, at least two 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</p>
JASS 6:2018 标准 JASS 6:2018	<p>未说明，螺栓长度应在执行规范中规定</p> <p>Not stated, bolt length shall be specified in the execution specification</p>
JJARA 标准 ARA	<p>未说明</p> <p>None stated</p>
AISC 360-16 规范 AISC 360-16	<p>未说明</p> <p>None stated</p>
AASHTO 2017 规范 AASHTO 2017	<p>推荐三螺纹</p> <p>None stated</p>
CSA S16-19 规范 CSA S16-19	<p>未说明</p> <p>None stated</p>

**表 F.2 - 预紧螺栓的最小螺纹凸出量**

**Table F.2 – Minimum thread protrusion for pretensioned bolts**

除非另有说明 Unless otherwise specified	1 个螺纹凸出，除非执行规范中另有说明 1 thread protrusion, unless otherwise stated in the execution specification
AASHTO 2017 规范 AS/NZS 5131:2016	紧固后有 1 个螺纹凸出 1 thread protrusion after snug tightening
NZS 3404, Part 1 标准 NZS 3404, Part 1	紧固后有 1 个螺纹凸出 1 thread protrusion after snug tightening
EN 1090-2:2018 规范 EN 1090-2:2018	1 个螺纹螺距 (p) 凸出 1 thread pitch (p) protrusion
JASS 6:2018 标准 JASS 6:2018	1 螺纹 1 thread
JARA 标准 JARA	无需凸出 No protrusion required
AISC 360-16 规范 AISC 360-16	螺栓端与螺母端面平齐或凸出于螺母端面之外 Bolt end flush with or protruding beyond face of nut
CSA S16-19 规范 CSA S16-19	螺栓端与螺母端面平齐或凸出于螺母端面之外 Bolt end flush with or protruding beyond face of nut

**表 F.3 - 非预紧螺栓在夹具中的最小螺纹数**

**Table F.3 – Minimum threads in the grip for non-pretensioned bolts**

除非另有说明 Unless otherwise specified	1 个螺纹，除非执行规范中另有说明 1 thread unless otherwise stated in the execution specification
AS/NZS 5131:2016 标准 AS/NZS 5131:2016	紧固螺母后，螺母下方必须有一个清晰的螺纹跳动缺口 one clear thread run out shall be clear beneath the nut after tightening
NZS 3404, Part 1:1997 标准 NZS 3404, Part 1:1997	紧固螺母后，螺母下方必须有一个明显的螺纹跳动 one clear thread run out shall be clear beneath the nut after tightening
EN 1090-2:2018 规范 EN 1090-2:2018	紧固后，螺母下方必须有一个清晰的螺纹跳动。 one clear thread run out shall be clear beneath the nut
JASS 6:2018 标准 JASS 6:2018	未说明，螺栓长度应在执行规范中说明 Not stated, bolt length shall be specified in the execution specification

AISC 360-16 规范 AISC 360-16	未说明 None stated
AASHTO:2017 规范 AASHTO:2017	推荐三个螺纹 three threads recommended
CSA S16-19 规范 CSA S16-19	未说明 None stated

**表 F.4 – 非预紧螺栓的最小凸出量**

**Table F.4 – Minimum protrusion for non-pretensioned bolts**

除非另有说明 Unless otherwise specified	1 个螺纹凸出，除非执行规范中另有规定 1 thread protrusion, unless otherwise stated in the execution specification
AS/NZS 5131:2016 标准 AS/NZS 5131:2016	紧固后，螺母上方应至少有一条清晰的螺纹 at least one clear thread shall show above the nut after tightening
NZS 3404, Part 1:1997 标准 NZS 3404, Part 1:1997	紧固后，螺母上方应至少有一条清晰的螺纹 at least one clear thread shall show above the nut after tightening
EN 1090-2:2018 规范 EN 1090-2:2018	1 个螺纹螺距 ( $p$ ) 凸出 1 thread pitch ( $p$ ) protrusion
JASS 6:2018 标准 JASS 6:2018	3 个螺纹凸出，除非执行规范中另有规定 3 threads stickout, unless otherwise stated in the execution specification
AISC 360-16 规范 AISC 360-16	螺栓端与螺母端面齐平或凸出于螺母端面之外 Bolt end flush with or protruding beyond face of nut
AASHTO:2017 规范 AASHTO:2017	
CSA S16-19 规范 CSA S16-19	螺栓端与螺母端面齐平或凸出于螺母端面之外 Bolt end flush with or protruding beyond face of nut
CSA S6-19 规范 CSA S6-19	

**表 F.5 - 锥形垫圈的使用**

**Table F.5 – Taper washer use**

除非另有说明 Unless otherwise specified	当坡度超过 1:20 时，需要合适的锥形垫圈，非旋转部件靠在锥形垫圈上 Suitable tapered washer required when slope exceeds 1:20, non-rotating part placed against tapered washer
--------------------------------------	--

AS/NZS 5131:2016 标准 AS/NZS 5131:2016	当坡度超过 1:20 时，需要合适的锥形垫圈，非旋转部分靠锥形垫圈放置 Suitable tapered washer required when slope exceeds 1:20, non-rotating part placed against tapered washer
EN 1090-2:2018 规范 EN 1090-2:2018	1/20 (3°) 用于 $d \leq 20$ mm 的螺栓 1/20 (3°) for bolts with $d \leq 20$ mm 1/30 (2°) 用于 $d > 20$ mm 的螺栓 1/30 (2°) for bolts with $d > 20$ mm
Japan 标准 Japan	当坡度超过 1:20 时，需要合适的锥形垫圈，非旋转部件靠在锥形垫圈上 Suitable tapered washer required when slope exceeds 1:20, non-rotating part placed against tapered washer
AISC360-16 规范 AISC 360-16	ASTM F3125, 所有等级，当坡度超过 5% (1:20, 约 3°) 时，使用 1:20 锥形垫圈 ASTM F3125, all Grades, use 1:20 tapered washer for bolts when slope exceeds 5% (1:20, approx. 3°)
AASHTO:2017 规范 AASHTO:2017	
CSA S16-19 规范 CSA S16-19	ASTM F3125 等级 A325、A325、F1852，如果坡度超过 5%，则使用 1:20 锥形垫圈 (1:20, 约 3°)。 ASTM F3125 Grades A325, A325, F1852, use 1:20 tapered washer if slope exceeds 5% (1:20, approx. 3°) ASTM F3125 等级 A490、A490M、F2280，使用锥形垫圈以配合任何坡度 ASTM F3125 Grades A490, A490M, F2280, use tapered washer to match any slope
CSA S6-19 规范 CSA S6-19	



## 附录 G

### Annex G

(规范性附录)

(normative)

#### 预紧固件的安装前验证试验

##### **Pre-installation verification testing for pretensioned bolting assemblies**

本附录提供了一种试验方法，用于在安装前验证螺栓连接副和安装程序是否符合要求。

This annex provides a test method to verify, prior to installation, that the bolting assemblies and installation procedures will perform as required.

注 此安装前验证试验方法来自于 AISC 348-20 规范。

NOTE This pre-installation verification testing method is based up AISC 348-20.

试验的目的是：

The purpose of the testing is to:

- 确认整个螺栓连接副（包括润滑）是否适合预紧安装；  
— confirm the suitability of the complete bolting assembly, including lubrication, for pretensioned installation; and
- 确认所用预紧方法的程序和螺栓安装人员的正确使用。  
— confirm the procedure and proper use by the bolting crew of the pretensioning method to be used.

在施加预紧力连接和抗滑移连接中安装螺栓时，必须使用螺栓预紧力测量设备。

A bolt tension measurement device shall be used where bolts are to be installed in pretensioned joints and slip-resistant joints.

螺栓预紧力测量设备的准确性必须至少每年校准一次。

The accuracy of a bolt tension measurement device shall be confirmed through calibration at least annually.

在安装现场，应在螺栓预紧力测量设备中检查不少于三个具有代表性的完整螺栓连接副，这些组件的直径、长度、等级和批次组合应符合工程要求，以验证

预紧方法产生的预紧力至少比附录 E 中规定的预紧力大 5%。

A representative sample of not fewer than three complete bolting assemblies of each combination of diameter, length, grade and lot to be used in the work shall be checked at the site of installation in a bolt tension measurement device to verify that the pretensioning method develops a pretension that is at least 5% greater than that specified in Annex E. Washers shall be used in the pre-installation verification assemblies as required in the work.

如果任何螺栓连接副的实际预紧力小于附录 E 的规定，则应在工作中使用螺栓连接副之前确定并解决原因。在使用直接张力指示器法或螺母旋转法时，允许对螺栓连接副进行清洁、润滑和重新试验，但所有组件的处理方式必须相同。使用扭矩法、组合法、扭转螺栓法或校准扳手法时，不允许重新润滑，5.2.15 规定的情况除外。

If the actual pretension developed in any of the bolting assemblies is less than that specified in Annex E, the cause(s) shall be determined and resolved before the bolting assemblies are used in the work. Cleaning, lubrication and retesting of the bolting assemblies is permitted when the direct tension indicator method or the turn-of nut-method is used, provided that all assemblies are treated in the same manner. Relubrication is not permitted when the torque method, combined method, twist-off bolt method, or calibrated wrench method is used, except as prescribed in 5.2.15.

## 附录 H

### Annex H

(规范性附录)

(normative)

#### EN 14399 系列预紧螺栓现场条件下校准试验

##### Calibration test for the EN 14399 series pretensioned bolts under site conditions

##### H.1 总则

##### H.1 General

本附件规定了一项试验，旨在现场条件下校准用于预紧螺栓连接的高强度螺栓连接副。

This annex specifies a test intended to represent site conditions to calibrate high-strength bolting assemblies for pretensioned bolted connections.

试验的目的是确定必要的参数，以确保通过 EN 14399 系列螺栓连接副规定的预紧方法可靠地获得所需的最小预紧力。

The purpose of the test is to determine the necessary parameters to ensure that the minimum required pretension is reliably obtained by the pretensioning methods specified for the EN 14399 series bolting assemblies.

在 EN 14399-3、EN 14399-4、EN 14399-7 或 EN 14399-8 螺栓连接副中使用扭矩预紧方法时，除非在执行规范中允许，否则不得使用该试验。

This test is not to be used when the torque pretensioning method is used for EN 14399-3, EN 14399-4, EN 14399-7, or EN 14399-8 bolting assemblies, unless permitted in the execution specification.

本试验目的并非提升按照 EN 14399-1 标准声明的螺栓连接副的性能。

The purpose of this test is not to upgrade the properties of a bolting assembly declared in accordance with EN 14399-1.

## H.2 符号和单位

## H.2 Symbols and units

见表 H.1.

See Table H.1.

表 H.1-符号和单位

Table H.1 – Symbols and units

符号 Symbol	定义 Definition	单位 Units
$A_s$	螺栓名义应力面积 nominal stress area of the bolt	$\text{mm}^{2a}$
$e_M$	容许比( $e_M = (M_{\max} - M_{\min}) / M_m$ ) allowable ratio ( $e_M = (M_{\max} - M_{\min}) / M_m$ )	-
$F_b$	实验确定的螺栓受力 bolt force determined during the test	kN
$F_m$	i 个关于 $F_b$ 的试验值 $F_{b,i}$ 的平均值 mean value of the i number $F_{b,i}$ test values for $F_b$	kN
$F_{p,C}$	要求的预紧力 $0.7f_{ub}A_s$ required pretension of $0.7 f_{ub} A_s$	kN
$f_{ub}$	名义螺栓强度 ( $R_m$ ) nominal bolt strength ( $R_m$ )	MPa
$M_i$	与 $F_{p,C}$ 相关的单个扭矩值 individual value of the torque related to $F_{p,C}$	Nm
$M_m$	i 个 $M_i$ 值的平均值 mean value of the i number $M_i$ values	Nm
$M_{\max}$	i 个 $M_i$ 值的最大值 maximum value of the i number $M_i$ values	Nm
$M_{\min}$	i 个 $M_i$ 值的最小值 mean value of the i number $M_i$ values	Nm
$M_{r,\text{test}}$	扭矩参考值 torque reference value	Nm
$s_M$	i 个 $M_i$ 值的预估标准差 estimated standard deviation of the i number $M_i$ values	kN
$V_M$	i 个 $M_i$ 值的变异系数	-

$V_F$	coefficient of variation of the i number $M_i$ values $V_F$ i 个 $F_{b,i}$ 值的变异系数	-
$\theta_{pi}$	coefficient of variation of the i number $F_{b,i}$ values 螺栓受力首次达到 $F_{p,c}$ 时的单个角度值 $\theta_{at}$	°
$\theta_{1i}$	individual value of the angle $\theta_{at}$ which the bolt force has first reached the value of $F_{p,c}$ 螺栓受力首次达到其最大值 $F_{b,i,max}$ 时的单个角度值 $\theta_{at}$	°
$\theta_{2i}$	individual value of the angle $\theta_{at}$ which the bolt force has reached its maximum value $F_{b,i,max}$ 当试验停止时的单个角度值 $\theta_{at}$	°
$\Delta\theta_{1i}$	individual value of the angle $\theta_{at}$ which the test is stopped 单个角度相减 ( $\theta_{1,i}-\theta_{p,i}$ )	°
$\Delta\theta_{2i}$	the individual angle difference ( $\theta_{1,i} - \theta_{p,i}$ ) 单个角度相减 ( $\theta_{2,i}-\theta_{p,i}$ )	°
$\Delta\theta_{2,min}$	the individual angle difference ( $\theta_{2,i} - \theta_{p,i}$ ) 相关产品标准中要求的角度差 $\Delta\theta_{2,i}$ 的最小值 the minimum required value of the angle difference $\Delta\theta_{2,i}$ as specified in the relevant product standard	°
a 见 ISO 898-1 a see ISO 898-1		

### H.3 试验原理

#### H.3 Principle of the test

该试验需在螺栓紧固过程中测量以下参数：

The test has the possibility to measure the following parameters during tightening:

-螺栓荷载

— the bolt force;

-扭矩，(如果需要)；

— the torque, if required;

-螺母和螺栓的相对转角，(如果需要)。

— the relative rotation between the nut and the bolt, if required.

## H.4 试验装置

### H.4 Test apparatus

螺栓力测量装置可以遵循 EN 14399-2 标准，或者使用机械式或液压式的装置，例如载荷传感器，只要这些装置的测量精度符合 H.8 节的规定即可。螺栓力测量装置必须每年至少校准一次（或根据设备制造商的建议更频繁地校准）。

The bolt force measuring device may be in accordance with EN 14399-2, or a mechanical or hydraulic device such as a load cell, provided the accuracy of the bolt force-measuring device meets the requirements given in H.8. The bolt force measuring device shall be calibrated at least once per year (or more frequently if recommended by the equipment manufacturer) by a recognized testing authority.

用于试验的扭矩扳手应与现场使用的扳手相同。它们应具有适当的操作范围。可使用手动或电动扳手，冲击扳手除外。扳手的精度要求为：扭矩法为 $\pm 4\%$ ，组合法为 $\pm 10\%$ （视情况而定）。扭矩扳手应至少每年校准一次（或根据制造商的建议更频繁地校准）。

Torque wrenches to be used for the test shall be one of those to be used on site. They shall offer suitable operating range. Hand or power wrenches may be used, with exception of impact wrenches. The accuracy requirements for the wrenches is  $\pm 4\%$  for the torque method or  $\pm 10\%$  for the combined method as appropriate. The torque wrench shall be calibrated at least once per year (or more frequently if recommended by the manufacturer).

## H.5 试验组件

### H.5 Test assemblies

必须对每批螺栓连接副的代表性样品进行单独试验。试验组件的选择应使确保相关方面的条件相似。

Separate tests shall be carried out on representative samples from each lot of bolting assemblies concerned. Test assemblies shall be chosen so that all relevant aspects of their conditions are similar.

注意:如果螺栓连接副暴露在现场的极端环境条件下或长时间存放,则螺栓连接副的现场状况,特别是润滑性能可能会发生变化。

NOTE The site conditions of bolting assemblies, in particular the performance of the lubrication, can vary if they are left exposed to extreme environmental conditions on site or if they are stored for a long period of time.

具有代表性的螺栓连接副应包括每个检验批次的若干螺栓、螺母和垫圈。用于试验的组件不得重复用于补充试验或结构中。

Representative bolting assemblies shall consist of a number of bolts, nuts and washers of each inspection lot. The assemblies used for tests shall not be re-used for supplementary tests or in the structure.

## **H.6 试验设置**

### **H.6 Test set-up**

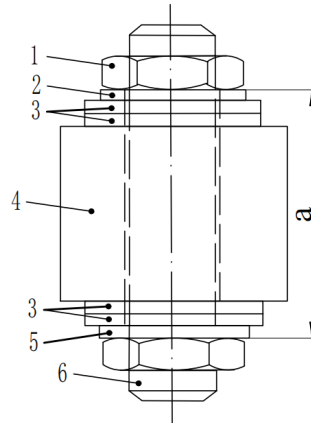
试验装置(见图 H.1)可能包括适配测量设备所需的垫圈。

The test set-up (see Figure H.1) may include shims needed to suit the measuring device.

试验组件和垫圈的位置必须符合以下要求:

The test assemblies and shims shall be positioned such that:

- 组件的构成与实际使用情况相似;
  - the composition of the assembly is similar to the utilization in practice;
- 在螺栓头下方放置一个倒角垫圈或倒垫片;
  - a chamfered washer or a chamfered shim is placed under the bolt head;
- 当螺母在紧固过程中发生转动时,应在螺母下放置垫圈;
  - a washer is placed under the nut when the nut will be turned during tightening;
- 包含垫片和垫圈在内的夹紧长度应满足相关产品标准所允许的最小值。
  - the clamp length including the shims and washer(s) is the minimum allowed in the relevant product standard.



a 夹紧长度  $\Sigma t$

a clamp length  $\Sigma t$

1 螺母

1 nut

2 在紧固过程中，当螺母转动时，螺母下的垫

圈

2 washer under the nut when nut turned during

tightening

3 垫片

3 shim(s)

4 螺栓预紧力测量设备

4 bolt tension measuring device

5 组件的倒角垫圈或倒角垫片

5 chamfered washer of the assembly or chamfered shim

6 螺栓头

图 H.1 预紧力测量设备的典型连接副

Figure H.1 – Typical assembly of the tension-measuring device

## H.7 试验步骤

### H.7 Test procedure

试验可在实验室或其他具有合适条件的地点进行。紧固方法应与现场使用的方法相同。

Tests may be carried out either in a laboratory or elsewhere under suitable conditions.

The method used for tightening shall be the same as that to be used on the site.

注：在某些情况下，由产品制造商检查螺栓连接副是否仍符合所声称的交货属性可能更方便。

NOTE In certain cases it can be more convenient to have the product manufacturer check whether bolting assemblies still meet the declared as-delivered properties.



应充分测量扭矩、相应的螺栓拉力，必要时还应测量旋转部件的相应转角，以便根据附录 H.8 对试验结果进行评估。

Sufficient measurements shall be taken of the torque, the corresponding bolt tension and, if required, the corresponding rotation of the turned part so as to permit the evaluation of the test results in accordance with H.8.

在试验过程中，固定部件和转动部件下的垫圈都不得转动。

Neither the fixed part nor the washer under the turned part shall rotate during the test. 校准的目的是记录与螺栓力  $F_{b,i}$  相关的扭矩值  $M_i$ ，并将其与螺栓的目标预紧力  $F_{p,C} = 0.7 f_{ub} A_s$  的比例相关联。

The basis of calibration is to record the torque values  $M_i$  associated with the bolt forces  $F_{b,i}$  and to relate those values to target pretension in the bolt as a proportion of  $F_{p,C} = 0.7 f_{ub} A_s$ .

对于扭矩法，当满足以下任何一个条件时，试验都将终止：

For the torque method, the test shall be terminated when any one of the following conditions is satisfied:

- 螺栓荷载超过  $1.1 F_{p,C}$ ;  
— the bolt force exceeds  $1.1 F_{p,C}$ ;
- 螺母转角超过  $(\theta_{p,i} + \Delta\theta_1)$  和/或  $(\theta_{p,i} + \Delta\theta_{2,min})$ （如需要）；  
— the angle of nut rotation exceeds  $(\theta_{p,i} + \Delta\theta_1)$  and/or  $(\theta_{p,i} + \Delta\theta_{2,min})$ , if required;
- 螺栓断裂失效  
— bolt failure by fracture occurs.

## H.8 试验结果评价

### H.8 Evaluation of test results

组合方法允许的最大扭矩值标准列于表 H.2，其中测量的扭矩值  $M_i$  是通过将一组螺栓连接副预紧至精确的  $0.75 F_{p,C}$  值来确定的。

The criteria for allowable maximum torque values for the combined method are given in Table H.2 where the measured torque values  $M_i$  are determined by preloading in one

set of bolt assemblies to the exact value of  $0,75 F_{p,C}$ .

表 H.2-组合方法的 eM 的最大值

Table H.2 – Maximum values for eM for the combined method

试验数量 Number of tests	3	4	5	6
$e_M = (M_{\max} - M_{\min})/M_m$	0.25	0.3	0.35	0.4

扭矩法的验收标准应基于八个测量扭矩值  $M_{1-8}$ 。扭矩值通过将一组八个螺栓连接副精确预加载至  $1.10 F_{p,C}$  的来确定。

The acceptance criteria for the torque method shall be based on eight measured torque values  $M_{1-8}$  determined by preloading in one set of eight bolting assemblies to the exact value of  $1,10 F_{p,C}$ .

$$M_{r,\text{test}} = (M_{\max.} + M_{\min.})/2 \quad (\text{H.1})$$

其要求：

with the requirement that

$$(M_{\max.} - M_{\min.}) \leq 0,20 M_{r,\text{test}} \quad (\text{H.2})$$

如果需要检查，则转角  $\Delta\theta_1$  和  $\Delta\theta_2$  的验收标准应与 EN 14399 中针对装配批次中螺栓连接副的相关部分中标准一致。If required to be checked, the acceptance criteria for the rotations  $\Delta\theta_1$  and  $\Delta\theta_2$  shall be those in the relevant part of EN 14399 for the bolting assemblies in the assembly lot.

注 1：转角  $\Delta\theta_1$  和  $\Delta\theta_2$  如 EN 14399-2:2015 中图 2 所示

NOTE 1 The rotations  $\Delta\theta_1$  and  $\Delta\theta_2$  are shown in Figure 2 of EN 14399-2:2015.

如果检查了转角，则应该测量螺栓的最大拉力(即转角  $\Delta\theta_1$  对应的力)。要求最大拉力应等于或大于  $0.9 f_{ub} A_s$ ，其中  $f_{ub}$  和  $A_s$  取名义值。

If the rotations are checked, then the maximum tension in the bolt shall be measured (i.e. that force corresponding to the rotation  $\Delta\theta_1$ ). The requirement is that the maximum tension shall be equal to or greater than  $0,9 f_{ub} A_s$  with  $f_{ub}$  and  $A_s$  based on nominal

values.

扭剪型螺栓法(HRC 法)的验收标准应基于扭矩扳手端开裂后八个螺栓的预紧力。

The acceptance criteria for the spline-drive twist-off bolt method (HRC method) shall be based on the pretension from eight bolts after the fracture of the spline-ends.

需要满足以下要求:

The following requirements apply:

- 单个螺栓受力  $F_b > F_{p,C}$ ;  
— individual value of  $F_b \geq F_{p,C}$ ;
- 平均螺栓受力  $F_m > 1.1 F_{p,C}$ ;  
— mean value  $F_m \geq 1.1 F_{p,C}$ ;
- $F_{b,i}$  的变异系数  $VF \leq 0.06$   
— coefficient of variation of  $F_{b,i}$   $VF \leq 0.06$ .

直接张力指示器 (DTI) 法的验收标准应基于指示器凸起变形刚好达到 EN 14399-9 规定值时对八个螺栓的预紧力测量结果。

The acceptance criteria for the direct tension indicator (DTI) method shall be based on measuring the pretension on eight bolts when the deformations of the indicator protrusions have just reached the values given in EN 14399-9.

八个试件的螺栓受力必须满足以下要求:

The following requirement applies for all eight sample values of  $F_{b,i}$ :

$$F_{p,C} \leq F_{b,i} \leq 1.2 F_{p,C}$$

注 2  $F_{p,C}$  的值见表 E.1。

NOTE 2 Values for  $F_{p,C}$  are given in Table E.1.

## H.9 试验报告

### H.9 Test report

试验报告中应包括以下最基本的信息:

The following minimum information shall be included in the test report:

- 试验日期;  
— date of testing;

- 螺栓连接副批次或扩展螺栓连接副批次的标识号；  
— identification number of the bolting assembly lot or the extended bolting assembly lot;
- 试验组件的数量；  
— number of assemblies tested;
- 连接组件的名称；  
— designation of the bolting assemblies;
- 螺栓、螺母和垫圈的标记；  
— marking of bolts, nuts and washers;
- 涂层或表面光洁度和润滑状况；如果相关，说明因现场暴露而对表面造成的改变；  
— coating or surface finish and lubrication condition; if relevant, description of alterations to the surfaces due to site exposure;
- 试验夹紧长度；  
— test clamp length;
- 用于测量拉力和扭矩的试验装置和设备的详细信息；  
— details of the test set-up and devices used to measure tension and torque;
- 有关执行试验的说明（包括特殊试验条件和流程，如转动螺栓头部）；  
— remarks concerning the execution of tests (including special testing conditions and procedures such as turning the head of the bolt);
- 根据本附件规定的试验结果；  
— tests results in accordance with this annex;
- 与检测批次相关的螺栓连接副预紧规范；  
— specifications for the pretensioning of the bolting assemblies related to the inspection lot tested;
- 扭矩扳手和校准测力装置的校准证书。  
试验报告应由授权人员签字并注明日期。  
— calibration certificates for torque wrenches and calibrated force measuring devices.  
The test report shall be signed and dated.

## 附录 I

### Annex I

(规范性附录)

(normative)

#### 预紧螺栓连接副-扭矩法

#### Pretensioning bolting assemblies — Torque method

##### I.1 总则

##### I.1 General

附件 I 提供了基于扭矩法的预紧过程，可用于施加预紧力连接和抗滑移连接。  
参见 7.4.7。

Annex I provides pretensioning procedures based on the torque method that may be used for pretensioned and slip-resistant joints. See 7.4.7.

- 扭矩方法 1 基于 EN 1090-2:2018。
- I.3, Torque method 1 is based on EN 1090-2:2018.
- 扭矩方法 2 基于 AISC 348-20。
- I.4, Torque method 2 is based on AISC 348-20.
- 扭矩方法 3 基于 DAST-Richtlinie 024:2018。
- I.5, Torque method 3 is based on DAST-Richtlinie 024:2018.

注 I.3、I.4 和 I.5 的内容并不代表所列标准和文件之间的任何技术等同性。

NOTE The contents of I.3, I.4 and I.5 do not establish any technical equivalence between the standards and documents listed.

##### I.2 扭矩法螺栓连接步骤

##### I.2 Torque method bolting procedure

螺栓紧固流程中应详细说明：

The bolting procedure shall specify:

- a) 所要使用的扭矩值，以及
- a) torque values to be used; and
- b) 为控制紧固组件所需扭矩与产生的夹紧力之间关系的可变性而采取的必要措

施。

b) measures necessary to control the variability in the relationship between the torque necessary to tighten the assembly and the resulting clamping force achieved.

结构螺栓连接副应使用具有适当工作范围的扭矩扳手进行预紧。每个螺栓的第一步紧固可使用手动、电动或冲击扳手。第二步可使用手动或电动扳手。对于扭矩方法 2，可使用可调式冲击扳手来提供所需的扭矩，然后停转。

The structural bolting assemblies shall be pretensioned using a torque wrench offering a suitable operating range. Hand, power-operated, or impact wrenches may be used for the first step of tightening for each bolt. Hand or power-operated wrenches may be used for the second step. For torque method 2, adjustable impact wrenches set to provide the required torque, then stall, may be used.

### **1.3 扭矩法 1**

#### **1.3 Torque method 1**

紧固所需的扭矩应持续平稳地施加。扭矩法预紧至少包括以下两个步骤：

The tightening torque shall be applied continuously and smoothly. Pretensioning by the torque method comprises at least the two following steps:

a)第一个紧固步骤：扳手的扭矩值应设定为约  $0.75M_{r,i}$ ， $M_{r,i} = M_{r,2}$  或  $M_{r,test}$ 。在开始第二步之前，必须对一个连接中的所有螺栓完成第一步操作；

a) a first tightening step: the wrench shall be set to a torque value of about  $0,75 M_{r,i}$  with  $M_{r,i} = M_{r,2}$  or  $M_{r,test}$ . This first step shall be completed for all bolts in one connection prior to commencement of the second step;

b)第二个紧固步骤：扳手的扭矩值为  $1.10 M_{r,i}$ ， $M_{r,i} = M_{r,2}$  或  $M_{r,test}$ 。

b) a second tightening step: the wrench shall be set to a torque value of  $1,10 M_{r,i}$  with  $M_{r,i} = M_{r,2}$  or  $M_{r,test}$ .

注 1：扭矩方法 1 基于 EN1090-2：2018。

NOTE 1 Torque method 1 is based on EN 1090-2:2018.

注 2：对于  $M_{r,2}$  使用系数 1.10，相当于  $V_k=0,06$ ，k 等级 K2 时  $(1+1,65 V_k)$ 。

NOTE 2 The use of the 1,10 coefficient with  $M_{r,2}$  is equivalent to  $(1 + 1,65 V_k)$  with

$V_k=0,06$  for k-class K2.

用于名义最小预紧力  $F_p$  的扭矩参考值  $M_{r,i}$ ，是由下列选项之一的每种螺栓和螺母组合确定的：

The torque reference values  $M_{r,i}$  to be used for a nominal minimum pretension  $F_p$  are determined for each type of bolt and nut combination used by one of the following options:

a) 基于螺栓连接副制造商应根据 EN 14399 系列相关部分定义的 k 等级值确定扭矩值：

a) values based on k-class declared by the fastener manufacturer in accordance with the relevant parts of the EN 14399 series:

$M_{r,2} = k_m d F_p$ ,  $k_m$  为 K2 等级。

$M_{r,2} = k_m d F_p$  with  $k_m$  for k-class K2;

b) 根据附录 H 确定扭矩值

b) values determined according to Annex H:

$M_{r,test} = M_m$ ,  $M_m$  根据所用紧固方法的相关步骤确定。

$M_{r,test} = M_m$ , with  $M_m$  determined according to the procedure relevant to the tightening method to be used.

## **I.4 扭矩法 2**

### **I.4 Torque method 2**

7.4.6 中规定的安装前核查流程必须每天执行，以便为每个螺栓直径、长度、等级和批次设置安装扳手。不得使用未经验证的 k 系数或根据表格或声称扭矩与预紧力相关的方程式确定的扭矩值。

The pre-installation verification procedures specified in 7.4.6 shall be performed daily for the setting of the installation wrench for each bolt diameter, length, grade and lot. k-factors or torque values determined from tables or from equations that claim to relate torque to pretension without verification shall not be used.

注 扭矩方法 2 以 AISC 348-20 为依据。

NOTE Torque method 2 is based on AISC 348-20.

螺栓连接副预安装检验应该针对连接中的所有螺母来确定安装扭矩值。在此过

程中应防止螺栓头旋转。

The installation torque determined in the pre-installation verification of the bolting assembly shall be applied to all nuts in the joint. The bolt head shall be prevented from rotating during this operation.

应用安装扭矩时，螺栓和螺母之间的相对转角应符合表 M.1 或表 M.2 中相关规定。

Application of the installation torque shall produce a relative rotation between the bolt and nut that is equal to than the rotation specified in Table M.1 or Table M.2, as applicable.

### **I.5 扭矩法 3**

#### **I.5 Torque method 3**

根据 EN 14399-4，对 K1 等级的螺栓连接副进行预紧，预紧力为  $F_{p,C*} = 0.7 f_{yb} A_s$ ，其中  $f_{yb}$  为螺栓材料的名义屈服强度， $A_s$  为螺栓的应力面积。

Pretensioning for bolting assemblies according to EN 14399-4 with k-class K1 to a pretension level of  $F_{p,C*} = 0,7 f_{yb} A_s$ , where  $f_{yb}$  is the nominal yield strength of the bolt material and  $A_s$  is the stress area of the bolt.

注 1 扭矩法 3 以 DAST Richtlinie 024:2018 为依据。

NOTE 1 Torque method 3 is based on DAST-Richtlinie 024:2018.

扭矩法紧固至少包括以下步骤：

Tightening by this torque method comprises at least the following steps:

- a) 紧固连接处的所有螺栓连接副，使其达到紧固状态；
- a) tightening of all bolting assemblies of a joint to a snug tight condition;
- b) 将连接处的所有螺栓连接副紧固到约  $0.75 M_A$  的预紧力矩值，不超过  $M_{Pre}$ ；
- b) tightening of all bolting assemblies of a joint to a pre-torque value of about  $0,75 M_A$ , not to exceed  $M_{Pre}$ ;
- c) 将连接的的所有螺栓连接副紧固到  $M_A$  扭矩值。
- c) tightening of all bolting assemblies of a joint to a torque value of  $M_A$ .



表 I.1-扭矩法 3 的预紧力  $F_{p,C^*}$  和紧固扭矩值  $M_A$

Table I.1 – Pretensioning level  $F_{p,C^*}$  and tightening torque values  $M_A$  for torque method 3

螺栓直径 Bolt diameter	M12	M16	M20	M22	M24	M27	M30	M36
预紧力 $F_{p,C^*}$ kN Pretension $F_{p,C^*}$ in kN	50	100	160	190	220	290	350	510
紧固扭矩 $M_A$ Nm Tightening torque $M_A$ in Nm	100	250	450	650	800	1250	1650	2800
最大预紧扭矩 $M_{Pre}$ Nm max. pre torque $M_{Pre}$ in Nm	75	190	340	490	600	940	1240	2100

## 附录 J

### Annex J

(规范性附录)

(normative)

#### 预紧螺栓连接副-组合法

#### Pretensioning bolting assemblies — Combined method

### J.1 总则

#### J.1 General

附件 J 提供了基于组合方法的预紧步骤，可用于预紧和抗滑移连接中。参见 7.4.8。

Annex J provides pretensioning procedures based on the combined method that may be used for pretensioned and slip-resistant joints. See 7.4.8.

- J.2, 组合方法 1 基于 EN 1090-2:2018，使用 EN 14399-3:2015 和 EN 14399-4:2015 螺栓连接副；

– J.2, Combined method 1 is based on EN 1090-2:2018 using EN 14399-3:2015 and EN 14399 4:2015 bolting assemblies;

- J.3, 组合方法 2 基于 JASS 6:2018；

– J.3, Combined method 2 is based on JASS 6:2018;

- J.4, 组合方法 3 基于 AISC 348-20，使用 ASTM F3148 螺栓连接副和 ASTM F3125 等级的 A325 和 A490 螺栓。

– J.4, Combined method 3 is based on AISC 348-20 using ASTM F3148 bolting assemblies and ASTM F3125 grade A325 and A490 bolts.

注: J.2、J.3 和 J.4 的内容并不确定所列标准和文件之间的任何技术等同性。

NOTE The contents of J.2, J.3, and J.4 do not establish any technical equivalence between the standards and documents listed.

## J.2 组合方法 1

### J.2 Combined method 1

针对 EN 14399-3 和 EN 14399-4 螺栓连接副，组合方法预紧包括两个步骤：

Pretensioning by the combined method for EN 14399-3 and EN 14399-4 bolting assemblies comprises two steps:

1) 使用具有适当工作范围的扭矩扳手，并将扳手设置为大约  $0.75 M_{r,i}$  的扭矩值， $M_{r,i}$  可以是  $M_{r,2}$ ， $M_{r,1}$  或  $M_{r,test}$ 。在开始第二步之前，一个连接中所有螺栓必须完成第一步骤；

1) Using a torque wrench offering a suitable operating range, the wrench shall be set to a torque value of about  $0,75 M_{r,i}$  with  $M_{r,i} = M_{r,2}$  or  $M_{r,1}$  or  $M_{r,test}$ . This first step shall be completed for all bolts in one connection prior to commencement of the second step;

2) 对组件的旋转部件施加规定的转角。在第一步之后，应使用记号笔或记号涂料标记螺母相对于螺栓螺纹的位置，以便在第二步中轻松确定螺母相对于螺纹的最终转角。

2) A specified part turn is applied to the turned part of the assembly. The position of the nut relative to the bolt threads shall be marked after the first step, using a marking crayon or marking paint, so that the final rotation of the nut relative to the thread in this second step can be easily determined.

该步骤应符合表 J.1 中给出的数值，除非在执行规范中另有规定。

This step shall be in accordance with the values given in Table J.1 unless specified in the execution specification.

注 组合方法 1 基于 EN 1090-2:2018，使用 EN 14399-3:2015 和 EN 14399-4:2015 螺栓连接副。

NOTE Combined method 1 is based on EN 1090-2:2018 using EN 14399-3:2015 and EN 14399-4:2015 bolting assemblies.

表 J.1-组合方法 1，附加转角(8.8 级和 10.9 级螺栓)

Table J.1 – Combined method 1, additional rotation (8.8 and 10.9 bolts)

连接部件的总名义厚度 $t$ (包括所有垫板和垫圈) Total nominal thickness $t$ of parts to be connected (including all packs and washers) $d$ =螺栓直径(mm) $d$ = bolt diameter in mm	在第二步的紧固过程中 <sup>a,b,c</sup> , 施加额外的转角 Further rotation to be applied, during the second step of tightening <sup>a,b,c</sup>	
	角度 Degrees	旋转 Turn
$t < 2d$	60	1/6
$2d \leq t < 6d$	90	1/4
$6d \leq t \leq 10d$	120	1/3
<p>a 如果转角比规定值小 15°以上，则应修正该角度。                      a If the rotation angle is more than 15° below the specified value, this angle shall be corrected.</p> <p>b 如果转角超过规定角度 30°，或螺栓或螺母失效，则应更换新的螺栓连接副。                      b If the rotation angle is more than 30° over the specified angle, or the bolt or the nut has failed, the bolt assembly shall be replaced by a new one.</p> <p>c 当螺栓头或螺母（使用锥形垫圈时）下表面与螺栓轴线不垂直时，应通过试验确定所需的转角。                      c Where the surface under the bolt head or nut (allowing for taper washers, if used) is not perpendicular to the bolt axis, the required angle of rotation should be determined by testing.</p>		

每种螺栓和螺母组合所用的名义最小预紧力  $F_p$  对应的扭矩参考值  $M_{r,i}$  是通过以下任一选项确定：

The torque reference values  $M_{r,i}$  to be used for a nominal minimum pretension  $F_p$  are determined for each type of bolt and nut combination used by one of the following options:

a ) 基于紧固件制造商根据 EN 14399 系列规范相关部分定义的  $K$  等级来确定扭矩值：

a) values based on  $k$ -class declared by the fastener manufacturer in accordance with

the relevant parts of the EN 14399 series:

1)  $M_{r,2} = k_m d F_p$ ,  $k_m$  等级为 K<sub>2</sub>;

1)  $M_{r,2} = k_m d F_p$  with  $k_m$  for k-class K2;

2)  $M_{r,1} = 0.125 d F_p$ , k 等级为 K<sub>1</sub>;

2)  $M_{r,1} = 0.125 d F_p$ , for k-class K1.

b) 根据附录 H 确定扭矩值:

b) values determined according to Annex H:

$M_{r,test} = M_m$ ,  $M_m$  根据所用紧固方法的相关步骤确定。

$M_{r,test} = M_m$  with  $M_m$  determined according to the procedure relevant to the tightening method to be used.

### J.3 组合方法 2

#### J.3 Combined method 2

对于 JIS B 1186 螺栓连接副, 组合方法预紧包括三个步骤:

Pretensioning by the combined method for JIS B 1186 bolting assemblies comprises three steps:

1) 用于紧固高强度六角螺栓的扭矩扳手必须进行校准, 一般为每日校准, 精度为 $\pm 3\%$ 。在紧固其他连接之前, 必须对本次连接进行日常校准, 以验证紧固精度。从插入螺栓到完全紧固的整个安装过程一般应在一天内完成。

1) The torque wrench used for tightening high strength hexagon bolts shall be calibrated, generally daily, to an accuracy of  $\pm 3\%$ . Daily calibration at one joint shall be conducted to verify tightening accuracy prior to tightening additional joints. The complete installation process, from inserting bolts to full tightening, shall typically be finished within one day.

2) 插入螺栓后, 应立即按照 7.2.5 对每个接头和每组螺栓进行初步紧固。必须使用预设型扭矩扳手或电动冲击扳手按照表 J.2 所示的扭矩值进行紧固。初步紧固后, 应在每个螺栓上做一个横跨螺栓、螺母、垫圈和构件的标记。

2) The preliminary tightening of every joint and every group of bolts shall be done in accordance with 7.2.5, immediately after the insertion of bolts. Tightening shall be done to the torque values shown in Table J.2 using a preset-type torque wrench or an electric

impact wrench. After preliminary tightening, a mark running across the bolt, nut, washer and member shall be made on each bolt.

3) 在完成初步紧固和标记后，应按表 J.2 所示旋转螺母进行完全紧固。当螺栓长度超过名义螺栓直径的五倍时，应根据制造商的建议在执行规范中规定螺母的旋转量。

3) Full tightening shall be done by rotating the nut as shown in Table J.2 after the completion of preliminary tightening and marking. When the bolt length exceeds five times the nominal bolt size, the amount of nut rotation shall be specified in the execution specification according to the manufacturer's recommendations.

注 组合方法二基于规范 JASS 6:2018.

NOTE Combined method 2 is based on JASS 6:2018.

**表 J.2 - 组合方法 2，初始扭矩和附加转角( 8.8 和 10.9 级螺栓)**

**Table J.2 – Combined method 2, initial torque and additional rotation (8.8 and 10.9 bolts)**

名义螺栓直径 Nominal bolt diameter	初步紧固力矩的近似值 Nm Approximate torque value for preliminary tightening Nm	
M12	50	
M16	100	
M20	150	
M22	150	
M24	200	
M27	300	
M30	400	
<b><math>L</math>=名义螺栓长度  <math>L</math> = Nominal bolt length  <math>d</math>=螺栓直径  <math>d</math> = bolt diameter</b>	<b>在第二步紧固过程中<sup>a,b</sup>，额外施加的转角 Further rotation to be applied, during the second step of tightening<sup>a,b</sup></b>	
	<b>角度 Degrees</b>	<b>旋转 Turn</b>
M12, $L \leq 5d$	60	1/6
M16-M36, $L \leq 5d$	120	1/3
$L > 5d$	在执行规范中具体说明 Specified in the execution specification	在执行规范中具体说明 Specified in the execution specification
<b>a</b> 如果转角比 120° 旋转的规定值小 30°以上（小于 90°），或者转角比 60° 旋转的规定值小		

<p>15°以上（小于 45°），则必须进行旋转校正。</p> <p>a If the rotation angle is more than 30° under the specified value of 120° rotation (less than 90°), or if the rotation angle is more than 15° under the specified value of 60° rotation (less than 45°), the rotation shall be corrected.</p> <p>b 如果转角超出规定角度 30°以上，或螺栓或螺母失效，则应更换新的螺栓连接副。</p> <p>b If the rotation angle is more than 30° above the specified angle, or the bolt or the nut has failed, the bolt assembly shall be replaced by a new one.</p>
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## J.4 组合方法 3

### J.4 Combined method 3

采用组合方法对螺栓连接副进行预紧包括三个步骤：

**Pretensioning by the combined method for bolting assemblies comprises three steps:**

注：组合方法 3 基于 AISC 348-20，使用 ASTM F3148 螺栓连接副、ASTM F3125 等级 A325 螺栓或 ASTM F3125 等级 A490 螺栓。

NOTE Combined method 3 is based on AISC 348-20 using ASTM F3148 bolting assemblies, ASTM F3125 grade A325 bolts, or ASTM F3125 grade A490 bolts.

1) 工作中应使用相关工具、螺栓连接副、装配构形和安装方法将螺栓连接副安装到螺栓预紧力测量设备中。初始扭矩应施加到螺母上。如果制造商或供应商未提供初始扭矩，则应使用表 J.3 中的扭矩或通过安装前验证试验确定的扭矩。所使用的工具必须验证或具有经认证报告，在使用过程中误差不超过  $\pm 10\%$ 。

1) The bolting assembly shall be installed in the bolt tension measurement device using the tools, bolting components, assembly configuration, and installation methods to be used in the work. The initial torque shall be applied to the nut. If the initial torque has not been provided by the manufacturer or supplier, then the torque in Table J.3 or the torque established by pre-installation verification testing shall be used. Tools used shall demonstrate or have certified output that does not vary by more than  $\pm 10\%$  during use.

**表 J.3 – 综合方法 3，如果制造商或供应商未提供，应使用的初始扭矩**

**Table J.3 – Combined method 3, initial torque to be applied, if not provided by the manufacturer or supplier**

公称螺栓直径 $d_b$ Nominal bolt diameter, db, in.	初始扭矩的扭矩值范围 lb-ft (Nm) a							
	ASTM F3125, 等级 A325 ASTM F3125, Grade A325				ASTM F3125, 等级 A490 ASTM F3148 <sup>b</sup> ASTM F3125, Grade A490 ASTM F3148 b			
	最小值 Min		最大值 Max		最小值 Min		最大值 Max	
	lb-ft	Nm	lb-ft	Nm	lb-ft	Nm	lb-ft	Nm
1/2	45	60	50	70	60	80	75	100
5/8	100	135	120	165	120	165	145	195
3/4	170	230	205	280	210	285	250	340
7/8	260	355	310	420	335	455	400	540
1	405	550	480	650	510	690	605	820
1-1/8	570	775	680	920	710	965	845	1145
1-1/4	810	1100	965	1310	1010	1370	1200	1625
1-3/8	1060	1435	1260	1710	1325	1795	1575	2135
1-1/2	1390	1885	1655	2245	1735	2350	2065	2800
<p>a 本表不能代替制造商提供的扭矩值，只能在螺栓制造商或供应商未提供紧固件扭矩时使用。</p> <p>b ASTM F3148 144 组紧固件的最大直径为 1-1/4 英寸。</p> <p>a This table shall not be used in lieu of manufacturer-provided torque values and shall only be used when torque has not been provided for a bolting assembly by the bolt manufacturer or supplier.</p> <p>b ASTM F3148 Group 144 bolting assemblies are available only up to 1-1/4-in. diameter.</p>								

2) 如果在第一步中紧固件的实际预紧力小于表 J.4 中规定的初始预紧力，则应在紧固件用于工作之前确定并解决原因。除 5.2.15 所允许的情况外，不允许对这些紧固件进行清洁、润滑和重新试验，但所有组件必须以相同方式处理。

2) If the actual tension developed in the bolting assembly during the first step is less than the initial tension specified in Table J.4, the cause(s) shall be determined and resolved before the bolting assemblies are used in the work. Cleaning, lubrication, and retesting of these bolting assemblies is not permitted, except as allowed in 5.2.15, provided that all assemblies are treated in the same manner.

**表 J.4 -组合法 3，预安装验证的最小初始拉力**

**Table J.4 - Combined method 3, minimum initial tension for pre - installation verification**



公称螺栓直径 $d_b$ Nominal bolt diameter, db, in.	预安装检验的最小初始预紧力, kips Minimum Initial tension for pre - installation verification, kips			
	ASTM F3125, 等级 A325 ASTM F3125, Grade A325		ASTM F3125, 等级 A490 ASTM F3148 a ASTM F3125, Grade A490 ASTM F3148 a	
	kips	kN	kips	kN
1/2	5	22	7	31
5/8	9	40	11	49
3/4	13	58	16	71
7/8	17	76	22	98
1	23	102	29	129
1-1/8	29	129	36	160
1-1/4	37	165	46	205
1-3/8	44	196	55	245
a ASTM F3148 144 组紧固件的最大直径为 1-1/4 英寸 a ASTM F3148 Group 144 bolting assemblies are available only up to 1-1/4-in. diameter				

3) 如果执行规范要求位置标记, 则应标记紧固件。

3) If location marks are required by the execution specification, the bolting assembly shall be marked.

4) 表 J.5 中规定的转角应适用于每个紧固件。

4) The rotation specified in Table J.5 shall be applied to each bolting assembly.

**表 J.5——组合方法 3, 施加初始扭矩后的螺母转角<sup>a,b</sup>**

**Table J.5 – Combined method 3, Nut rotation after application of initial torque<sup>a,b</sup>**

螺栓长度 <sup>c</sup> Bolt Length	转角 Rotation
不超过 $4d_b$ Not more than 4 db	90°(1/4 圈) 90° (1/4 turn)
超过 $4d_b$ , 但不超过 $8d_b$ More than 4 db but not more than 8 db	120°(1/3 圈) 120° (1/3 turn)
a 螺母的旋转是相对于螺栓的, 而与所转动的元件(螺母或螺栓)无关。对于要求的所有螺母转角, 误差为+45°(+1/8 圈)和-0°。 a Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For all required nut rotations, the tolerance is plus 45° (+1/8 turn) and minus 0°.	
b 仅适用于螺栓连接中所有材料均为钢材的情况。 b Applicable only to joints in which all material within the grip is steel.	
c 当螺栓长度超过 $8d_b$ 时, 所需的螺母转角应通过在螺栓拉力测量装置中进行试验来确定。 c When the bolt length exceeds 8 db, the required nut rotation shall be determined by actual testing in a suitable bolt tension measurement device.	

## 附录 K

### Annex K

(规范性附录)

(normative)

#### 预紧螺栓连接组件-扭矩扳手剪断法

##### **Pretensioning bolting assemblies - Spline - drive twist - off method**

用于安装的剪切扳手工作原理如下：

The shear wrench used for installation operates as follows:

- 在结构紧固件的紧固过程中，套筒转动时遇到的阻力最小。  
— during the tightening operation of a structural bolting assembly, the socket in rotation is the one that finds the least resistance to it;
- 在整个安装过程直到最后的紧固步骤，螺母的外插套顺时针旋转，而内插套固定扭矩扳手端不随之外旋，通过不断增加的扭矩使结构紧固件达到逐渐紧固的效果。  
— from the outset and right up to the last tightening step, the outer socket on the nut rotates clockwise while the inner socket holds the spline end without rotating, the result being that the structural bolting assembly is progressively tightened by the increasing torque applied to the nut;
- 在最后的紧固步骤中，也就是当达到断颈部分的最大扭矩阻力点时，内插套逆时针旋转，而螺母的外插套提供反作用力而不旋转；  
— at the last tightening step, i.e. when the torsional resistance plateau of the break-neck section is attained, the inner socket rotates anticlockwise while the outer socket on nut provides the reaction without rotating;
- 当扭矩扳手固定侧末端在颈缩部分剪断时，结构紧固件安装完成。  
— the structural bolting assembly installation is complete when the spline end shears

off at the breakneck section.

规定的预拉力由拧断结构紧固件本身通过其几何和扭转机械特性以及润滑条件来实现。安装扳手无需校准。

The specified pretension requirement is provided by the twist-off structural bolting assembly itself by means of the geometrical and torsion mechanical characteristics, together with the lubrication conditions. The installation wrench does not need calibration.

为确保连接中已完成结构紧固件的预拉力符合规定的最小预拉力要求，螺栓安装过程包括两个紧固步骤。

In order to ensure that the pretension in completed structural bolt assemblies in connections meet the specified minimum pretension requirement, the bolt installation process comprises two tightening steps.

所有扭断结构紧固件均应置于连接处。可使用剪切扳手或其他样式的扳手进行第一道紧固，使连接处达到紧固状态，使连接的各层牢固接触，而不切断扭矩扳手端。如果在此操作过程中扭矩扳手端被切断，则应卸下并更换紧固件。在开始第二步之前，必须完成连接中所有结构螺栓的第一步操作。

All twist-off structural bolting assemblies shall be placed in the connection. The first tightening step of bringing the joint to the snug-tight condition may be achieved using the shear wrench or other style wrench to bring the connected plies into firm contact, without severing the splined end. If a splined end is severed during this operation, the bolting assembly shall be removed and replaced. This first step shall be completed for all structural bolts in the connection prior to commencement of the second step.

注 1 设备制造商的指导可提供更多信息，例如说明如何识别是否发生了紧固，例如通过剪切扳手声音的变化，或其他合适的紧固方法。

NOTE 1 Guidance of the equipment manufacturer can give additional information on how to identify if snug tightening has occurred, e.g. sound of shear wrench changing, or if other methods of snug tightening are suitable.

根据执行规范的要求，在第一道紧固步骤之后，必须在每个扭断紧固件上做一个横跨结构螺栓、螺母、垫圈和构件的标记。

If required by the execution specification, after the first tightening step, a mark running across the structural bolt, nut, washer and member shall be made on each twist-off bolt assembly.

当结构螺栓的扭矩扳手端在其颈缩处被剪断时，即完成第二个紧固步骤。

The second tightening step is achieved when the spline end of the structural bolt shears off at the breakneck.

如果执行规范有要求，k 等级应仅限于带 HRD 螺母的 K0、K1 和 K2 级，或带 HR 螺母的 K2 级。

If required by the execution specification, the k-class shall be limited to k-class K0, K1 and K2 with HRD nuts, or k-class K2 with HR nuts.

注 2：k 级限制仅适用于 EN-14399-10 HRC 组件。

NOTE 2 The k-class limitations are applicable only for EN-14399-10 HRC assemblies.

如果装配条件不允许使用剪切扳手对扭断式结构紧固件进行紧固（例如由于空间不足），则应采用执行规范所允许的替代预紧方法进行紧固（例如扭矩法、组合法、直接拉力指示法、螺母转动法）。

structural bolting assembly, e.g. for lack of space, tightening shall be carried out using an alternative pretensioning procedure permitted by the execution specification (e.g. torque method, combined method, direct tension indicator method, turn-of-nut method).

## 附录 L

### Annex L

(规范性附录)

(normative)

#### 预紧螺栓连接组件-直接张力指示器法

#### Pretensioning bolting assemblies - Direct tension indicator method

直接张力指示器应通过其凸起部分的压缩变形，指示结构螺栓连接组件已达到或超过所需的最小预拉力。

Direct tension indicators shall indicate, by compression of the protrusions, that at least the required minimum pretension has been achieved in the structural bolting assembly.

注 1：本附录不适用于测量扭转的指示器。

NOTE 1 This annex does not apply to indicators that rely on torsion.

注 2：本附录不适用于使用液压仪器或超声波仪器直接测量结构螺栓预拉力。

NOTE 2 This annex does not apply to direct measurement of structural bolt pretension by use of hydraulic instruments or ultrasonic instruments.

直接拉力指示器及其相关垫圈的装配必须符合产品标准和制造商的书面说明（如适用）。参见 7.2.8.2。

The direct tension indicators and their associated washers shall be assembled in accordance with the product standard and the manufacturer's written instructions, if applicable. See 7.2.8.2.

工作检查间隙应由制造商提供，或由承包商在预安装验证试验期间设定，该间隙小于按最小所需螺栓预拉力的 1.05 倍测量的 DTI 试验间隙。

The job inspection gap shall be provided by the manufacturer, or established by the

contractor during pre-installation verification testing, as a gap less than the measured DTI test gap at  $1.05 \times$  the minimum required bolt pretension.

实现螺栓连接组件均匀初始紧密状态的第一步紧固应在直接张力指示器的凸起开始发生初始变形时进行。安装人员应检查直接张力指示器的突起部分，确保操作过程中间隙值未被压缩到小于工作检查间隙，如果出现超过情况，应卸下并更换直接张力指示器。在开始第二步之前，必须完成连接中所有结构螺栓的第一步。

The first step of tightening to reach a uniform snug-tight condition of a bolting assembly shall be when initial deformation of the direct tension indicator protrusions begins. The installer shall verify that the direct tension indicator protrusions have not been compressed to a gap that is less than the job inspection gap during this operation, and if this has occurred, the direct tension indicator shall be removed and replaced. This first step shall be completed for all structural bolts in the connection prior to commencement of the second step.

紧固的第二步是继续加力紧固，直到每个直接张力指示器的预拉力达到工作检查间隙的要求。安装人员应核实直接拉力指示器的突起已被压缩到小于工作检查间隙。直接拉力指示器上测得的间隙应该取平均值，以确保安装于结构的紧固件可被验收。

The second step of tightening shall be to apply further tightening until the job inspection gap requirements are met for each direct tension indicator. The installer shall verify that the direct tension indicator protrusions have been compressed to a gap that is less than the job inspection gap. The gaps measured on the direct tension indicator may be averaged to establish the acceptability of the structural bolting assembly.

## 附录 M

### Annex M

#### (规范性附录)

#### (normative)

#### 预紧紧固件-螺母旋转法

#### Pretensioning bolting assemblies - Turn - of - nut method

##### M.1 总则

##### M.1 General

附录 M 提供了基于螺母旋转法的预紧步骤，可用于预紧和防滑连接中。参见 7.4.11。

Annex M provides pretensioning procedures based on the turn-of-nut method that may be used for pretensioned and slip-resistant joints. See 7.4.11.

注 M.3 和 M.4 的内容并不确定所列标准和文件之间的任何技术等同性。

NOTE The contents of M.3 and M.4 do not establish any technical equivalence between the standards and documents listed.

- M.3, 螺母旋转方法 1 基于 AISC 348-20 和 AS/NZ 5131:2016;

— M.3, Turn-of-nut method 1 is based on AISC 348-20 and AS/NZ 5131:2016;

- M.4, 螺母旋转方法 2 以 CSA S16-19 为基础。

— M.4, Turn-of-nut method 2 is based on CSA S16-19.

##### M.2 螺母旋转法-总则

##### M.2 Turn - of - nut method - General

当螺母相对于螺栓充分旋转时，螺母因伸长而产生预拉力，确保螺栓至少达到所需的最小预拉力。

The turn-of-nut method provides bolt pretension through elongation of the bolt when the nut is sufficiently rotated relative to the bolt, ensuring that at least the required minimum pretension has been achieved in the bolt.

在确保有适当润滑条件的前提下，结构螺栓连接组件通过其几何和机械特性以

及变形控制来实现规定的预拉力。安装扳手无需校准。

The specified pretension requirement is provided by the structural bolting assembly itself by means of the geometrical and mechanical characteristics with deformation control, provided adequate lubrication conditions are present. The installation wrench does not need calibration.

为了确保连接中完全安装好的结构螺栓的预拉力达到规定的最小预拉力要求，螺栓安装过程包括两个紧固步骤。

In order to ensure that the pretensions in fully installed structural bolts in connections meet the specified minimum pretension requirement, the bolt installation process comprises two tightening steps.

所有结构紧固件均应置于连接处。紧固件达到均匀紧固状态，第一个紧固步骤可以使用气动冲击扳手进行少量冲击、或利用电动或液压工具施加适当扭矩（通常为达到完全预紧所需扭矩的一半）或操作人员使用标准手动紧固扳手或短柄扳钳施加全部力量来实现。在开始第二步操作之前，必须完成连接中所有结构螺栓的第一步。

All structural bolting assemblies shall be placed in the connection. The first tightening step to reach a uniform snug-tight condition of a bolting assembly may be achieved using a few impacts of a pneumatic impact wrench, an appropriate level of torque from electric or hydraulic tools, generally in the range of half the torque needed to achieve full pretension, or by the full effort of a person using a standard hand podger spanner or spud wrench. This first step shall be completed for all structural bolts in one connection prior to commencement of the second step.

如施工规范要求，在初步紧固后，应设置定位标记以标示结构螺栓与螺母的相对位置，并用于控制最终的螺母旋转量。

If required by the execution specifications, after snug tightening, location marks (matchmarks) shall be established to mark the relative position of the structural bolt and



the nut and to control the final nut rotation.

紧固的第二步是按照表 M.1 或 M.2（视情况而定）中的规定，对接头中的所有螺栓连接组件施加螺母或螺栓头的旋转。在此操作过程中，应防止扳手未旋转部分转动，除非结构螺栓和螺母上有标记，以便确定相对旋转量。可通过使用有标记的扳手套筒或使用定位标记来观察螺母的最终旋转情况。

The second tightening step is to apply nut or head rotation in accordance with Table M.1 or Table M.2, as applicable, to all bolting assemblies in the joint. The part not turned by the wrench shall be prevented from rotating during this operation, unless the structural bolt and nut are marked to enable the amount of relative rotation to be determined. Observation of the final nut rotation may be achieved by using marked wrench sockets or by using location marks.

### M.3 螺母旋转方法 1

#### M.3 Turn - of - nut method 1

注 1 螺母旋转方法 1 基于 AISC 348-20 和 AS/NZ 5131:2016。

NOTE 1 Turn-of-nut method 1 is based on AISC 348-20 and AS/NZ 5131:2016.

注 2 表 M.1 基于 ASTM F3125 的等级 A325 和 A490 螺栓以及 AS/NZS 1252 的等级 8.8 和 10.9 螺栓为基础。

NOTE 2 Table M.1 is based on the use of ASTM F3125 grades A325 and A490 and AS/NZS 1252 grades 8.8 and 10.9.

表 M.1-螺母旋转方法 1

Table M.1 - Turn - of - nut method 1

<b>L=名义螺栓长度</b>  <b>L = Nominal bolt length</b>  <b>d=螺栓直径</b>  <b>d = bolt</b>	<b>在紧固状态下进一步旋转</b>  <b>Further rotation to be applied beyond snug - tight condition</b>		
	<b>两面均垂直于螺栓轴线</b>  <b>Both faces normal to bolt axis</b>	<b>一面垂直，另一面倾斜，但与螺栓轴线的距离不超过 1:20，不使用斜面垫圈</b>  <b>One face normal, other face sloped but not more</b>	<b>两面倾斜，但与螺栓轴线的距离不超过 1:20 不使用斜面垫圈</b>  <b>Both faces sloped, but not more than 1:20 from bolt axis, bevelled washer not</b>

diameter			than 1:20 from bolt axis, bevelled washer not used		used	
	角度 Degrees	圈 Turn	角度 Degrees	圈 Turn	角度 Degrees	圈 Turn
$L \leq 4 d$	120	1/3	180	1/2	240	2/3
$4 d \leq L \leq 8 d$	180	1/2	240	2/3	300	5/6
$8d < L \leq 12 d^a$	240	2/3	300	5/6	360	1
<b>a 对于 <math>L &gt; 12d</math>, 转角将通过试验来确定</b> <b>a For <math>L &gt; 12 d</math>, rotation to be determined by testing</b>						
注 1 AISC 348 -旋转公差 $+60^\circ$ , $-0^\circ$ NOTE 1 AISC 348 — Rotation tolerance $+60^\circ$ , $-0^\circ$ 注 2 AS/NZS 5131-对于 0.5 圈或者以下的旋转, 旋转公差 $+30^\circ$ , $-0^\circ$ , 对于 2/3 圈或以上的旋转, 旋转公差为 $+45^\circ$ , $-0^\circ$ 。 NOTE 2 AS/NZS 5131— Rotation tolerance $+30^\circ$ , $-0^\circ$ for rotations of $\frac{1}{2}$ turn or less, $+45^\circ$ , $-0^\circ$ for rotations of $\frac{2}{3}$ turn or more						

#### M.4 螺母旋转方法 2

##### M.4 Turn - of - nut method 2

注 1 螺母旋转方法 2 基于 CSA S16-19。

NOTE 1 Turn-of-nut method 2 is based on CSA S16-19.

注 2 表 M.2 是基于 ASTM F3125/F3125M 的等级 A325、A325M、A490 和 A490M 螺栓的使用。

NOTE 2 Table M.2 is based on the use of ASTM F3125/F3125M grades A325, A325M, A490 and A490M.

表 M.2-螺母旋转方法 2

Table M.2 - Turn - of - nut method 2

<b><math>L</math>=名义螺栓长度  <math>L</math> = Nominal bolt length  <math>d</math>=螺栓直径  <math>d</math> = bolt diameter</b>	在紧固状态下进一步旋转 Further rotation to be applied beyond snug-tight condition		
	两面均垂直于 螺栓轴线 Both faces normal to bolt axis	一面垂直, 另一面倾斜, 但与 螺栓轴线的距离不超过 1:20, 不使用斜面垫圈 a One face normal, other face sloped but not more	两面倾斜, 但与螺栓轴线的 距离不超过 1:20 不使 用斜面垫圈 a Both faces sloped, but not more than 1:20 from bolt

			than 1:20 from bolt axis, bevelled washer not used		axis, bevelled washer not used a	
	角度 Degrees	圈 Turn	角度 Degrees	圈 Turn	角度 Degrees	圈 Turn
L≤4d	120	1/3	120	1/3	270	3/4
4d≤L≤8d,不超过 200mm 4d ≤ L ≤ 8d, not to exceed 200 mm	180	1/2	180	1/2		
8d≤L≤12d,或者螺 栓长度超过 200mm 8d < L ≤ 12, or bolt length exceeding 200 mm	240	2/3	240	2/3		
a 当使用 A490 级或 A490M 级螺栓时，倾斜面下需要斜面垫圈 a Bevelled washers required under sloping surfaces when Grade A490 or A490M bolts are used						
注：对于所有的转角，公差为±30° NOTE Tolerance ±30° for all rotations						

## 附录 N

### Annex N

(资料性附录)

(informative)

### 螺栓紧固鉴定流程 (BTQP)

#### Bolt Tightening Qualification Procedure (BTQP)

##### N.1 总则

##### N.1 General

如果缺少紧固规则和参数，例如在预紧不锈钢螺栓连接组件或通过转动螺栓头来预紧螺栓时，本附录才适用。

This annex only applies if no rules and parameters for tightening exist, e.g. for pretensioning of stainless steel bolting assemblies, or when bolts are pretensioned by turning the head.

本附件介绍了螺栓紧固鉴定流程(BTQP)，该流程为不锈钢和碳钢紧固件的预紧提供了设计和执行规则，紧固件由一个螺栓、一个螺母和垫圈组成，符合安装方法的要求。一个垫圈应安装在夹紧装置和螺栓头之间，另一个垫圈应安装在夹紧装置和螺母之间。

This annex presents a bolt tightening qualification procedure (BTQP) which provides design and execution rules for pretensioning of stainless steel and carbon steel bolting assemblies with bolting assemblies consisting of one bolt, one nut, and washers as required for the installation method. One washer should be installed between the clamping package and the bolt head and the other washer should be installed between the clamping package and the nut.

BTQP 允许确定单一配置的紧固参数。在此流程中，一种配置是：

The BTQP allows the determination of the tightening parameters for only one

configuration. In this procedure, one configuration is:

- 一个螺栓装配批次（即螺栓来自一个制造批次，螺母来自一个制造批次，垫圈来自一个制造批次，参见 ISO 17607-1）；
  - One single bolting assembly lot (i.e. bolts from one manufacturing lot, nuts from one manufacturing lot, washers from one manufacturing lot, see ISO 17607-1;
  - 一种润滑剂
  - One lubrication;
  - 一种紧固方法，并且具有明确的预拉力水平。
  - One tightening method,
- 每个新配置都应执行 BTQP。

The BTQP should be performed for each new configuration.

规定的预拉力不得超过名义预拉力水平。

The specified pretension shall not exceed the nominal pretension level.

BTQP 包括：

The BTQP includes:

- 确定适当的润滑方式，以保证螺栓的力-转角曲线有一个足够长的塑性平台期。（能否证明螺栓连接组件所需的功能特性在很大程度上取决于所使用的润滑剂类型。）
- the definition of appropriate lubrication to ensure a sufficiently long plastic plateau of the bolt force– rotation curve. (The ability to demonstrate the required functional characteristics of the bolting assembly is highly dependent on the type of lubrication used.)
- 紧固参数的评估
- the evaluation of tightening parameters.
- 进行适当的试验，以确认通过特定的紧固方法能够可靠地获取所需预拉力，并有足够的安全冗余防止过度紧固。
- a suitability test to confirm that the required pretension can be reliably obtained by a specific tightening method with a sufficient margin of safety against overtightening.

本附件仅适用于静态设计。疲劳因素可能会影响设计，也应进行评估。

This annex applies only to static design. Fatigue considerations may govern the design and should also be assessed.

图 N.1 是 BTQP 的示意图。详细参数和要求见 N.2 至 N.5。

A schematic overview of the BTQP is given in Figure N.1. The detailed parameters and requirements are given in N.2 through N.5.

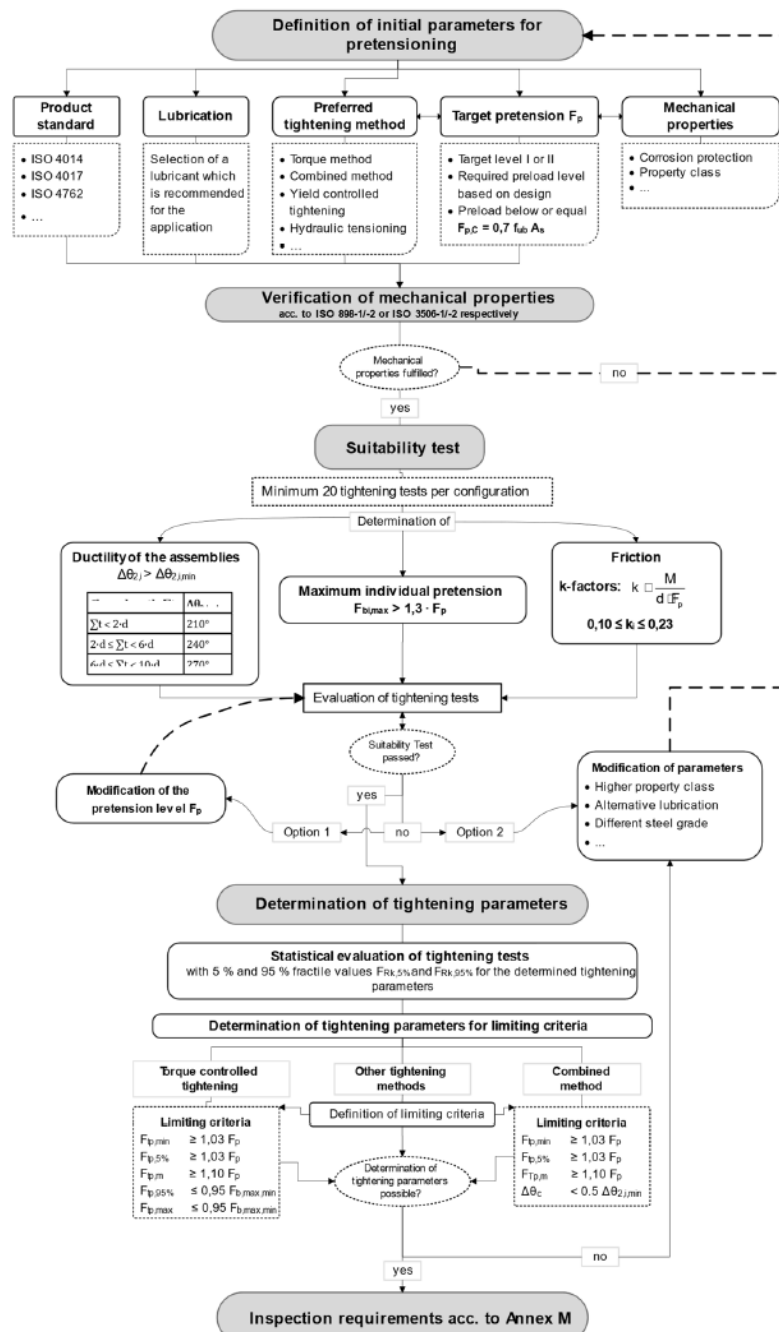


Figure N.1 – Schematic overview of the bolt tightening qualification procedure

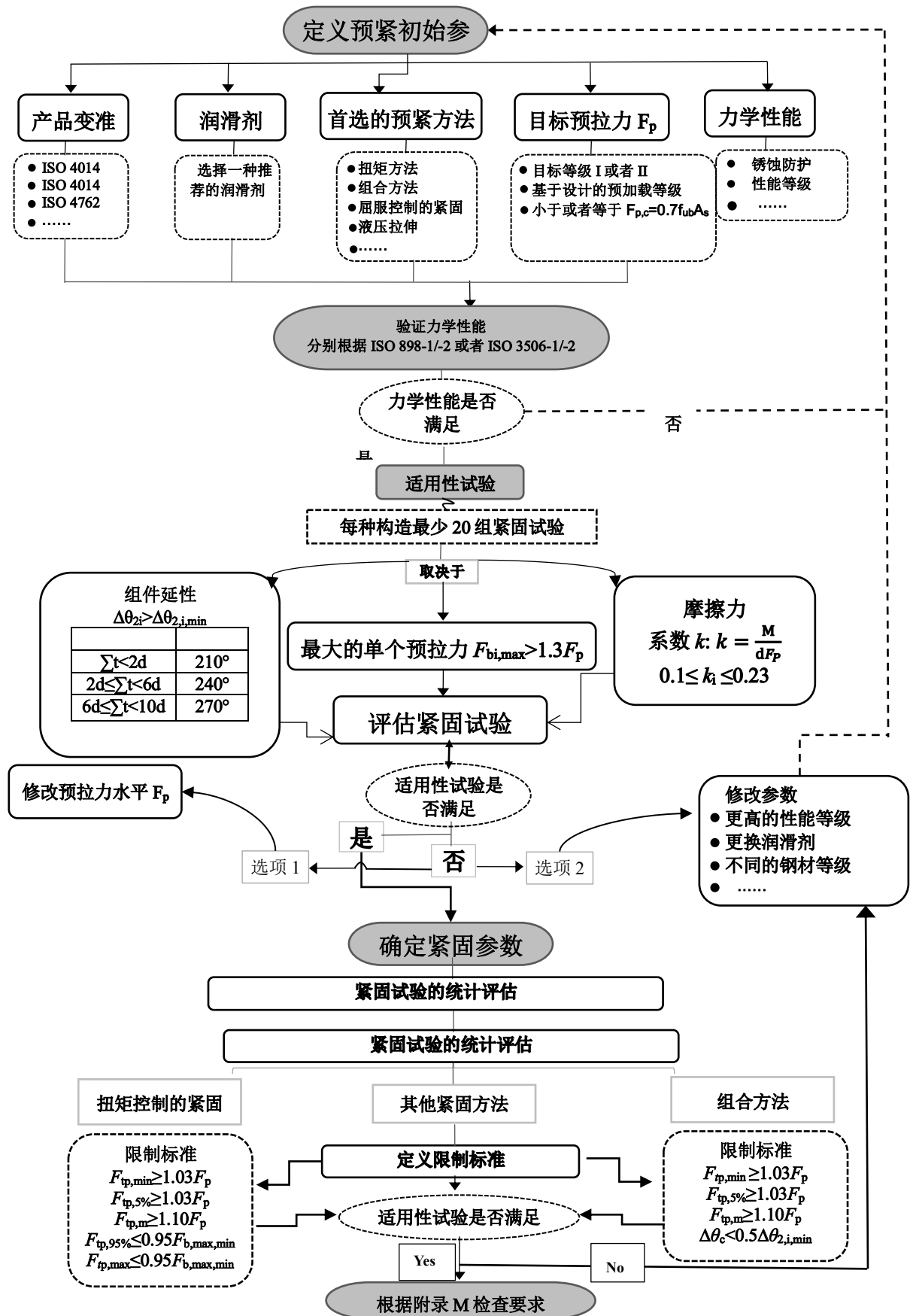


图 N.1 螺栓紧固鉴定步骤示意图概览

## **N.2 紧固件的机械性能**

### **N.2 Mechanical properties of bolting components**

紧固件应符合 ISO 3506-1 和 ISO 3506-2 对不锈钢紧固件的要求，以及 ISO 898-1 和 ISO 898-2 对碳钢紧固件的要求。

The bolting assemblies should fulfil the requirements according to ISO 3506-1 and ISO 3506-2 for stainless steel bolting assemblies, and according to ISO 898-1 and ISO 898-2 for carbon steel bolting assemblies.

## **N.3 适用性试验**

### **N.3 Suitability test**

#### **N.3.1 总则**

##### **N.3.1 General**

每种配置应至少进行 20 次紧固试验。

A minimum of 20 tightening tests shall be performed for each configuration.

除非另有规定，应通过旋转螺母进行紧固。如果通过旋转螺栓头进行紧固，则本条款中描述的试验装置和流程应作相应修改。

Unless otherwise specified, tightening shall be carried out by rotation of the nut. If tightening is carried out by rotation of the bolt head, the test set-up and the procedure described in this clause shall be modified accordingly.

试验的原理是在紧固装配过程中，持续测量以下参数：

The principle of the test is to tighten the assembly and to measure in a continuous manner, during tightening, the following parameters:

- 螺栓受力
- the bolt force;
- 螺母和螺栓之间的相对转角
- the relative rotation between the nut and the bolt;
- 扭矩
- the torque;



### N.3.2 试验装置

#### N.3.2 Test apparatus

试验装置应能够在紧固过程中连续地测定 N.3.1 节中所述的参数。

The test apparatus shall be able to determine the parameters according to N.3.1 in a continuous manner during the tightening process.

试验装置应使用钢材制造。

The test apparatus shall be made of steel.

用于装配的底座应足够刚性。

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

注： 液压测量装置通常不符合这一要求。

NOTE Hydraulic measuring devices do not normally meet this requirement.

建议试验装置的刚度越大越好。

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

应使用表 N.1 中规定的垫圈调整螺栓头和螺母之间的螺栓长度。

The length of the bolt between the head and the nut shall be adjusted by the use of shims as specified in Table N.1.

垫圈的数量不应超过 4 个。

The number of shims shall not exceed four.

应使用校准过的设备（例如测力计）连续测量螺栓力，测量不确定度为实际值的 $\pm 2\%$ ，重复性误差为 $\pm 1\%$

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

旋转测量应连续进行，精度在 $\pm 1^\circ$ 以内。

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

应使用校准过的扭矩测量装置连续测量扭矩，测量不确定度和重复性误差均为 $\pm 1\%$ 。

The torque shall be measured in a continuous manner by a calibrated torque measuring device with an uncertainty of the value and a repeatability error of  $\pm 1\%$ .

表 N.1：垫圈性能

Table N.1 – Characteristics of shims

名义螺栓直径 径 d mm Nominal bolt diameter d mm	螺栓孔直径 径 Mm Hole Diameter mm	外径 Outside diameter mm	厚度 Thickness mm	外部垫圈硬度 HRC Hardness for the outside shim HRC	平行度 Parallelism
$d \leq M14$	$d + 1$	不低于外部 装配垫圈直径，并且足以将 荷载充分分散到装置上  Not less than the outside assembly washer diameter and sufficient to distribute load adequately to the device	$\geq 2$	$\geq 45$ 完全硬化	$\leq 1\%$
$M14 < d \leq M24$	$d + 2$				
$d > M24$	$d + 3$				

### N.3.3 试验组件

### N.3.3 Test assemblies

试验应在旋转元件（螺母或螺栓头）下至少有一个垫圈的组件上进行。

The test shall be carried out on assemblies that include at least a washer under the rotated element (nut or bolt head).

试验组件应从单个组件批次中提取。

Test assemblies shall be taken from a single assembly lot.

除非特别说明，试验组件的每个部件只能使用一次。

Each component of a test assembly shall be used once only, unless otherwise specified.

应明确润滑条件，试验需在与后续使用相同的润滑条件下执行。

Lubrication conditions shall be defined. The tests shall be carried out under the lubrication conditions which will be applied in the later use.

### N.3.4 试验设置

### N.3.4 Test set - up

试验装置（见图 N.2）可能包括（见表 N.1）需要的垫圈以适配测量设备。

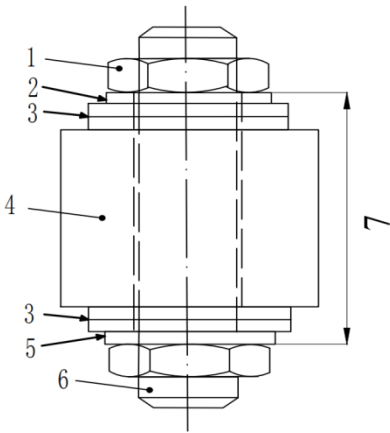
The test set-up (see Figure N.2) may include shims (see Table N.1) needed to suit the

measuring device.

试验组件和垫圈的位置必须符合以下要求：

The test assemblies and shims shall be positioned such that:

- 在旋转元件（螺母/螺栓头）下放置一个装配垫圈；
- a washer of the assembly is placed under the rotated element (nut/bolt head);
- 包括垫片和垫圈在内的夹紧长度应符合相关产品标准的最小要求。
- the clamp length including shims and washer(s) is the minimum allowed in the relevant product standard.



注

**Key**

- |   |                                      |
|---|--------------------------------------|
| 1 螺母：紧固时转动  | 5 装配垫圈或者垫片                           |
| 1 nut: turned during tightening                   | 5 washer of the assembly or shim     |
| 2 装配垫圈：禁止旋转                                       | 6 螺栓头：禁止转动                           |
| 2 washer of the assembly: prevented from rotating | 6 bolt head: prevented from rotating |
| 3 垫片  | 7 夹紧长度 $\Sigma t$                    |
| 3 shim(s)   | 7 clamp length $\Sigma t$            |
| 4 校准螺栓荷载的测量装置                                     |                                      |
| 4 calibrated bolt force measuring device          |                                      |

图 N.2：试验设置

**Figure N.2 – Test set-up**

### N.3.5 试验流程

#### N.3.5 Test procedure

试验应在环境温度为 10°C 至 35°C 的范围内进行。

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

除非另有规定，应通过旋转螺母进行紧固。原则上可以通过旋转螺栓头来紧固。本试验流程对螺母的旋转进行了说明。如果对旋转螺栓头进行紧固，则应相应修改试验装置和步骤。

Unless otherwise specified, the tightening shall be carried out by rotation of the nut. In principle, tightening by rotation of the bolt head is possible. Within this test procedure, the rotation of the nut is described. If the bolt head is to be rotated for tightening, the given test set-up and the procedure shall be modified accordingly.

连续旋转进行紧固，并在整个试验过程中记录测量结果。

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

试验的旋转速度应在 1 至 10 转/分钟之间。

The speed of rotation of the test shall be between 1 and 10 min<sup>-1</sup> (revolutions per minute).

试验过程中，螺栓和螺母下的垫圈均不得旋转。如果其中任何一个在紧固过程中转动，则应注意到这一现象，并进行新的试验以取代有问题试验。

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

当首次出现下列任何一种情况时，应停止试验：

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

- 螺母旋转的角度超过  $(\theta_{pi} + \Delta\theta_{2,i,min})$  ；
- the angle of nut rotation exceeds  $(\theta_{pi} + \Delta\theta_{2,i,min})$ ;
- 螺栓受力下降到  $F_p$
- the bolt force drops to  $F_p$ ;
- 螺栓断裂失效

— bolt failure by fracture occurs.

对于每个试验组件，应确定以下曲线：

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

— 螺栓受力与转角的关系曲线；

— the bolt force-rotation relationship;

— 螺栓受力-扭矩关系曲线

— the bolt force-torque relationship;

— 螺栓受力-伸长关系曲线（如果需要）

— the bolt force-elongation relationship, if required.

这些关系的数据应能准确解释结果且与试验装置的精度一致（参见图 N.3 和 N.4 中的曲线示例）。

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 Figures N.3 and N.4).

### N.3.6 对试验结果的评估

#### N.3.6 Evaluation of the test results

应根据图 N.3 从每个曲线中获得以下信息：

The following shall be obtained from each curve in accordance with Figure N.3:

— 记录螺栓力首先达到  $F_p$  值的角度  $\theta_{pi}$ ；

— the angle  $\theta_{pi}$  at which the bolt force first reaches the value of  $F_p$ ;  $\theta_{pi}$  is noted;

— 记录螺栓力达到其最大值  $F_{b,max}$  所对应的的角度  $\theta_{li}$ ； $F_{b,max}$  也需要被记录；

— the angle  $\theta_{li}$  at which the bolt force reaches its maximum value  $F_{b,max}$ ,  $F_{b,max}$  is also noted;

— 记录试验停止时的角度  $\theta_{2i}$ ，同时记录螺栓力  $F_b(\theta_{2i})$  的值

— the angle  $\theta_{2i}$  at which the test is stopped and at which the value of the bolt force  $F_b(\theta_{2i})$  is also noted.

同时记录所有  $F_{b,max}$  值中的最小值  $F_{b,max,min}$ 。

The minimum value of all  $F_{b,max}$  values,  $F_{b,max,min}$ , is also noted.

虽然测量角度  $\theta_{2i}$  的目的是为了得到螺栓力下降到  $F_b$  值时螺母的旋转量，但在

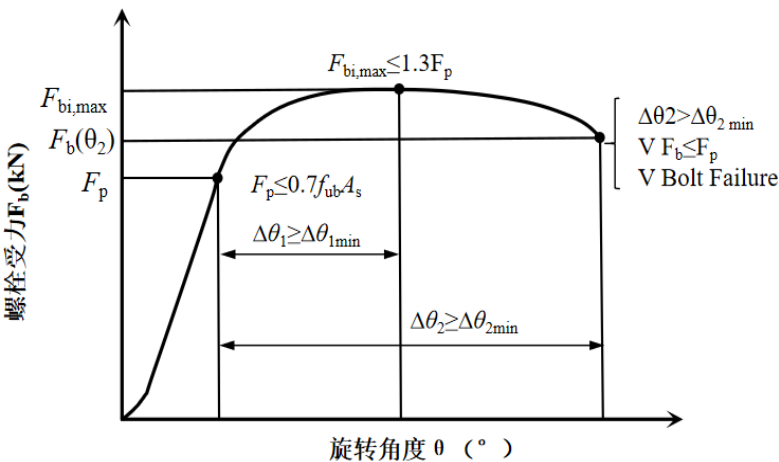
实际操作中，当角度差  $\Delta\theta_{2i}$  达到 BTQP 中规定的最小值  $\Delta\theta_{2\min}$  时，可能会停止试验。

Although the purpose of measuring the angle  $\theta_{2i}$  is to obtain an indication of the nut rotation at which the bolt force drops back to the value  $F_b$ , in practice the test may be stopped when the angle difference  $\Delta\theta_{2i}$  reaches the specified required minimum value  $\Delta\theta_{2\min}$  according to the BTQP.

根据上述角度测量结果，确定以下数值：

From the above angle measurements, the following values are determined:

- 角度差  $\Delta\theta_{1i}$ ，定义为  $(\theta_{1i} - \theta_{pi})$ ，即达到最大螺栓力  $F_{b,max}$  时的点；
- 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  $F_{b,max}$  has been reached;
- 角度差  $\Delta\theta_{2i}$ ，定义为  $(\theta_{2i} - \theta_{pi})$ ，即试验停止时的点。
- 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.



注：

**Key**

X: 转角  $\theta$ ，单位：°

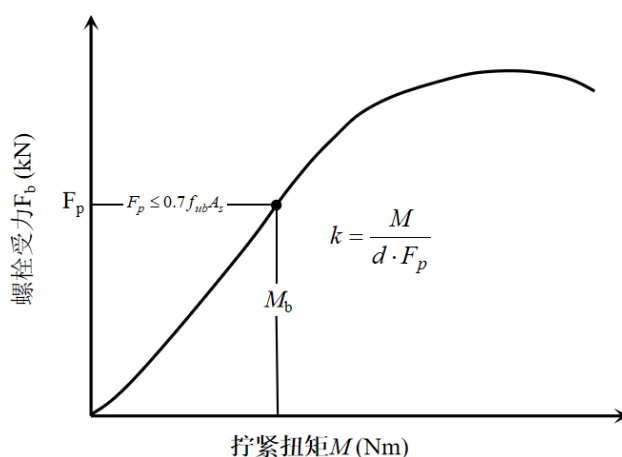
X: Angle of rotation  $\theta$  in °

Y: 螺栓受力  $F_b$ ，单位 kN

Y: Bolt force  $F_b$  in kN

图 N.3 螺栓受力-转角曲线

Figure N.3 – Bolt force-rotation curve



注:

#### Key

X: 紧固扭矩  $M$ , 单位: Nm

X: Tightening torque  $M$  in Nm

Y: 螺栓受力  $F_b$ , 单位 kN

Y: Bolt force  $F_b$  in kN

图 N.4 螺栓受力-扭矩曲线 (F/M 曲线)

Figure N.4 – Bolt force-torque curve (F/M curve)

### N.3.7 适用性要求

#### N.3.7 Requirements for suitability

##### N.3.7.1 总则

##### N.3.7.1 General

应达到本条款中规定的螺栓/螺母/垫圈) 组件的功能特性。

The functional characteristics of the bolt/nut/washer(s) assembly specified in this clause shall be achieved.

##### N.3.7.2 紧固试验中螺栓力的最大值( $F_{b,max}$ )

##### N.3.7.2 Maximum individual value of the bolt force during the tightening test ( $F_{b,max}$ )

紧固试验中单个螺栓受力的最大值应满足以下要求:

The maximum individual value of the bolt force during the tightening test should satisfy the following:

$$F_{b,max} \geq 1.3 F_p$$

(N.1)

如果不满足公式(N.1)中的条件，修改预拉力等级  $F_p$  或修改润滑等其他参数有助于满足公式要求，见图 N.1。

If the conditions in Formula (N.1) are not fulfilled, the modification of the pretension level  $F_p$  or the modification of other parameter, such as the lubrication can help satisfy the formula, see Figure N.1.

### N.3.7.3 螺母附加转角

#### N.3.7.3 Angle of additional nut rotation

该角度定义为从螺栓预拉力达到  $F_p$  时开始转动，直到螺栓受力下降到表 N.3 中规定的  $F_p$  时停止转动的角度。

The angle by which the nut should be turned starting from a pretension of  $F_p$  until the bolt force has dropped back to  $F_p$  specified in Table N.3.

表 N.3 螺母附加转角值  $\Delta\theta_{2i}$

Table N.3 – Values for angles of additional nut rotation  $\Delta\theta_{2i}$

夹紧长度 $\Sigma t^a$ Clamp length $\Sigma t^a$	$\Delta\theta_{2i,min}$
$\Sigma t < 2d$	210°
$2d \leq \Sigma t < 6d$	240°
$6d \leq \Sigma t < 10d$	270°
<sup>a</sup> $\Sigma t$ 是包括垫圈在内的夹紧部件的总厚度 <sup>a</sup> $\Sigma t$ is the total thickness of the clamped parts including washer(s).	

### N.3.7.4 K 系数的单个值

#### N.3.7.4 Individual values of the k - factor

单个  $k_i$  值必须在  $0.10 \leq k_i \leq 0.23$  的范围内， $k_i = M/(d \times F_p)$ 。

Individual  $k_i$ -values are required and shall be in the range of  $0.10 \leq k_i \leq 0.23$ , with  $k_i = M/(d \times F_p)$ .

BTQP 评估单个 k 系数以限制紧固件中的扭转。紧固参数应在 BTQP 范围内进行评估。

The BTQP evaluates individual k-factors to limit torsion in the bolting assembly. Tightening parameters shall be evaluated within the BTQP.



### **N.3.8 测试报告**

### **N.3.8 Test report**

试验文件中应包括以下最基本的信息。

The following minimum information shall be included in the test documentation.

- a) 实验室的标识;  
a) Identification of the laboratory;
- b) 检验机构的标识;  
b) Identification of the organization ordering the test;
- c) 接收试验组件的日期  
c) Date of reception of the assemblies;
- d) 试验日期  
d) Date of testing;
- e) 装配批次或扩展装配批次的标识号（由客户提供）  
e) Identification number of the assembly lot or the extended assembly lot (provided by the client);
- f) 试验组件的数量  
f) Number of assemblies tested;
- g) 紧固件名称  
g) Designation of the fasteners;
- h) 螺栓、螺母和垫圈的标记;  
h) Marking of bolts, nuts and washers;
- i) 涂层或表面处理  
i) Coating or surface finish;
- j) 润滑剂  
j) Lubrication;
- k) 试验夹紧长度  
k) Test clamp length;
- l) 包括刚度在内的试验装置详情;  
l) Details of the test set-up including rigidity;
- m) 紧固条件（紧固速度、垫圈数量）;  
m) Tightening conditions (speed of tightening, number of shims);

- n) 有关试验执行情况的说明（如果有的话，包括有关特殊试验条件和流程的说明）；
- n) Remarks concerning the execution of tests (including, if any, those on special testing conditions and procedures);
- o) 根据本文件进行的试验结果；
- o) Tests results according to this document;
- p) 根据 BTQP 的要求评估装配批次的功能特性；
- p) Evaluation of the functional characteristics of the assembly lot in relation to the requirements of the BTQP;
- q) 结论
- q) Conclusions.

## **N.4 紧固参数的确定**

### **N.4 Determination of tightening parameters**

#### **N.4.1 总则**

##### **N.4.1 General**

预紧螺栓连接件分类为：

Pretensioned bolted connections are categorised as:

- 在设计过程中使用预拉力的连接，如防滑连接或预紧拉伸连接（目标等级 I）
- Connections in which the pretension is used in the design process, e. g. slip-resistant connections or pretensioned tensile connections (target level I)
- 仅为提高可靠性而进行终拧紧固的连接件，例如，限制连接件的变形和滑移（目标等级 II）。
- Connections which are pretensioned only to enhance the serviceability, e. g. to limit the deformation and slip in the connections (target level II).

根据所选择的紧固方法，应确定紧固参数（参考扭矩、必要时的额外转角等），以满足 N.4.2 中的要求。

Based on the chosen tightening method, tightening parameters (reference torque, additional angle of rotation if needed, etc.) shall be determined to fulfil the requirements given in N.4.2.

## N.4.2 紧固参数的确定标准

### N.4.2 Criteria for the determination of the tightening parameters

为每个适用性试验确定单独的考虑相关紧固参数的螺栓力  $F_{tpi}$ 。紧固参数根据以下值确定：

The individual values of the bolt force  $F_{tpi}$  related to the considered tightening parameter are determined for each suitability test. The tightening parameters are determined by considering the following values:—

$F_{tp,min}$	所有 $F_{tpi}$ 值的最小值.
$F_{tp,min}$	the minimum value of all $F_{tpi}$ values.
$F_{tp,max}$	所有 $F_{tpi}$ 值的最大值.
$F_{tp,max}$	the maximum value of all $F_{tpi}$ values.
$F_{tp,m}$	所有 $F_{tpi}$ 值的平均值.
$F_{tp,m}$	the mean value of all $F_{tpi}$ values.
$F_{tp,5\%}$	所有 $F_{tpi}$ 值的 5 %分位数.
$F_{tp,5\%}$	the 5 % fractile of all $F_{tpi}$ values.
$F_{tp,95\%}$	所有 $F_{tpi}$ 值的 95 %分位数.
$F_{tp,95\%}$	the 95 % fractile of all $F_{tpi}$ values.

紧固参数(紧固试验中达到的螺栓预拉力)是通过考虑 5%和 95%的分位数确定的，假设试验结果呈正态分布，变异系数未知。

The tightening parameters (bolt pretension achieved in tightening tests) are determined by considering the 5 % and 95 % fractile values, assuming a normal distribution of the test results with unknown coefficients of variation.

$$F_{tp,5\%}=F_{tp,m}\times (1-k_n\times V_F) \quad (N.2)$$

$$F_{tp,95\%}=F_{tp,m}\times (1+k_n\times V_F) \quad (N.3)$$

以及

$$\text{with} \quad (N.4)$$

$$F_{tp,m} = \frac{\sum F_{tpi}}{n}$$

$$V_F = \frac{S_F}{F_{b,m}} \quad (\text{N.5})$$

$$S_F = \sqrt{\frac{1}{n-1} \times \sum (F_{tpi} - F_{tpm})^2} \quad (\text{N.6})$$

$k_n$  是根据表 N.4 确定的分位数因子,

$k_n$  is the quantile factor according to Table N.4,

$n$  是试验系列中试验结果的数量,

$n$  is the amount of test results within a test series,

$s_F$  是  $F_{bi}$  值的计算标准差,

$s_F$  is the calculated standard deviation of the  $F_{bi}$  values,

$V_F$  是  $F_{bi}$  值的计算变系数。

$V_F$  is the calculated coefficient of variation of the  $F_{bi}$  values.

**表 N.4 -  $k_n$  -假设试验结果呈正态分布且变系数未知时的统计评估值**

**Table N.4 -  $k_n$  -values for statistical evaluation, assuming a normal distribution  
of the test results with unknown coefficients of variation**

$n$	20	25	30	$\geq 40$
$k_n$	1,76	1,74	1,73	1,64

应满足表 N.5 中第 1 至 3 项的限制准则。

The limiting criteria No. 1 to 3 given in Table N.5 shall be fulfilled.

注：根据表 N.5 中给出的限制准则预估紧固系数后，对于仅需满足目标等级 II 的应用，可以放宽紧固参数。

NOTE Once the evaluation of tightening parameters in accordance with the limiting criteria given in Table N.5 has been undertaken, the tightening parameters can be relaxed for applications only required to meet target level II.

使用扭矩控制紧固法时，应满足表 N.5 中给出的限制准则 4T 和 5T。

The limiting criteria 4T and 5T given in Table N.5 shall be fulfilled if a torque controlled

tightening method is used.

使用组合紧固法时，应满足表 N.5 给出的限制准则 4C。

The limiting criterion 4C given in Table N.5 shall be fulfilled if a combined tightening method is used.

表 N.5 – 紧固系数确定准则

Table N.5 – Criteria for the determination of tightening parameters

No.	使用紧固系数预估值时应满足的限制准则 <sup>a</sup> Limiting criteria to be fulfilled, when evaluated tightening parameters are applied <sup>a</sup>	
保证预紧力最小值 $F_p$ 可靠应用准则 Criteria to ensure the minimum value of pretension $F_p$ is reliably applied		
1	同一系列试件中单个螺栓最小预紧力 $F_{tp,min}$ 应比最小预紧力 $F_p$ 高 3%。 The lowest individual pretension $F_{tp,min}$ from one test series shall exceed the required minimum pretension $F_b$ by at least 3 %	$F_{tp,min} \geq 1.03 F_p$
2	同一系列试件中单个螺栓 5%的预紧力 $F_{tp,5\%}$ 应比最小预紧力 $F_p$ 高 3%。 The 5 % fractile of the individual pretensions $F_{tp,5\%}$ from one test series shall exceed the required minimum pretension $F_b$ by at least 3 %	$F_{tp,5\%} \geq 1.03 F_p$
3	同一系列试件中单个螺栓的平均预紧力 $F_{tp,5\%}$ 应比最小预紧力 $F_p$ 高 10%。 The mean value of the individual pretension $F_{tp,min}$ from one test series shall exceed the required minimum pretension $F_b$ by at least 10 %	$F_{tp,m} \geq 1.10 F_p$
使用 <u>扭矩控制紧固法</u> 时，应避免紧固件过度紧固导致断裂 Criteria to avoid overtightening of the bolting assembly components up to fracture when evaluating parameters for a torque controlled tightening method		
4T	同一系列试件中单个螺栓 95%的预紧力 $F_{tp,95}$ 应小于或等于系列所有试件中螺栓预紧力最小值 $F_{b,min}$ 的 95%。	$F_{tp,95\%}\leq 0.95F_{b,max,min}$

	The 95 % fractile of the individual pretension $F_{tp,95\%}$ of one test series shall be less than or equal to 95 % of the minimum value of all $F_{b,max}$ values within a test series	
5T	<p>同一系列试件中单个螺栓最高预紧力 <math>F_{tp,max}</math> 应小于或等于系列所有试件中螺栓预紧力最大值 <math>F_{b,max}</math> 的 95%。</p> <p>The highest individual pretension <math>F_{tp,max}</math> of one test series shall be less than or equal to 95 % of the minimum value of all <math>F_{b,max}</math> values within a test series</p>	$F_{tp,max} \leq 0.95 F_{b,max,min}$
<p>通过组合紧固法时，应避免紧固件过度紧固导致断裂</p> <p><b>Criteria to avoid overtightening of the bolting assembly components up to fracture when evaluating parameters for a combined tightening method</b></p>		
4C	<p>在组合紧固方法第一步中使用紧固扭矩螺栓后，螺母旋转的额外转角 <math>\Delta\theta_c</math> 不应超过螺母转角差最小要求值 <math>\Delta\theta_{2i,min}</math> 的 50%</p> <p>The additional angle of nut rotation, beginning after the application of the tightening torque in the first step of the combined method, shall not exceed 50 % of the minimum required value of the angle difference <math>\Delta\theta_{2i,min}</math></p>	$\Delta\theta_c \leq 0,5 \Delta\theta_{2i,min}$
<p>a 使用紧固系数预估值施加预紧力时表中给出的限制准则应避免出现螺栓过度紧固的情况。</p> <p>a The limiting criteria given in this table shall ensure, that with evaluated tightening parameters, the desired preload is applied in the bolting assembly and overtightening is prevented</p>		

## N.5 检查要求

### N.5 Inspection requirements

检查要求根据附录 O 确定。

Inspection requirements should be defined in accordance with Annex O.

## 附录 O

### Annex O

(规范性附录)

(normative)

#### 结构螺栓连接检查方法

#### Method for structural bolting inspection

##### O.1 概述

##### O.1 General

附件O提供三种检查结构螺栓紧固情况的方法，详见8.2.4.1

Annex O provides three methods that may be used for structural bolting inspection for pretensioned bolts. See 8.2.4.1.

-方法 O.2，顺序抽样法，基于 EN 1090-2:2018。

-Method O.2, the sequential inspection method, is based on EN 1090-2:2018.

- 方法 O.3，基于施工等级的频率检查法,基于 CSA S16-19.

- Method O.3, the frequency inspection method based on execution level, is based on CSA S16-19.

-方法 O.4，基于任务的检查法, 基于 AISC 360-16.

- Method O.4, the task-based inspection method, is based on AISC 360-16.

注：O.2至O.4的内容并未在所列标准和文件之间建立任何技术等效性

NOTE The contents of O.2 through O.4 do not establish any technical equivalence between the standards and documents listed.

## **O.2 顺序抽样法**

### **O.2 Sequential inspection method**

注：以下顺序抽样法的相关内容均基于 EN1090-2:2018.

NOTE The following application of the sequential method is based on EN 1090-2:2018.

#### **O.2.1 抽样**

##### **O.2.1 Sampling**

结构中需要检查的螺栓连接副总数的百分比要求如下：

The number of bolting assemblies inspected overall in a structure shall be as follows:

a) EXL2: 扭矩法、组合紧固法、花键驱动剪断法、直接张力指示器法和旋转螺母法的第二步，比例为 5%;

a) EXL2: 5 % for the second step of the torque method, combined method, spline-drive twist-off method, DTI method, and the turn-of-nut method;

b) EXL3 和 EXL4:

b) EXL3 and EXL4:

1) 组合紧固法、花键驱动剪断法和旋转螺母法的第一步比例为 5%第二步比例为 10%;

1) 5 % for the first step and 10 % for the second step of the combined method, spline-drive twist-off method, and turn-of-nut method;

2) 扭矩法和直接张力指示器法第二步比例为 10%;

2) 10 % for the second step of the torque method and DTI method;

检查应使用顺序抽样方式，通过检查足够数量的螺栓连接副，直到满足相应的检验顺序验收标准（或者所有样本都通过检验）。序列类型如下：

The inspection shall be carried out using a sequential sampling plan for a sufficient



number of bolting assemblies until either the acceptance or the rejection conditions (or all assemblies have been tested) for the relevant sequential type are met for the relevant criteria. The sequential types shall be as follows:

- a) EXL2 和 EXL3: 方式 A (见图 O.2);
- a) EXL2 and EXL3: sequential type A (see Figure O.2);
  
- b) EXL4: 方式 B (见图 O.3).
- b) EXL4: sequential type B (see Figure O.3).

如果使用方式 A 得到的检验结果为不合格, 则可换方式 B。

If the result of inspection when using a sequential type A is rejection, the inspection may be enlarged to the sequential type B.

如果检查结果不合格, 则必须检查螺栓分组中的所有螺栓连接副, 并进行整改, 然后重新检验。

If the inspection indicates rejection, all the bolting assemblies in the bolt subgroup shall be checked, corrective actions shall be taken, and after completion re-inspection is required.

## **O.2.2 顺序检查**

### **O.2.2 Sequential inspection**

顺序抽样法应遵循 ISO 2859-5 的原则, 目的是根据检查结果逐步提出检查规则。

The sequential method for bolting assembly inspection shall be carried out in accordance with the principles in ISO 2859-5, the purpose of which being to give rules based on progressive determination of inspection results.

ISO 2859-5 提供了两种顺序抽样方法: 数值法和图解法, 图解法适用于螺栓连接副的检验。

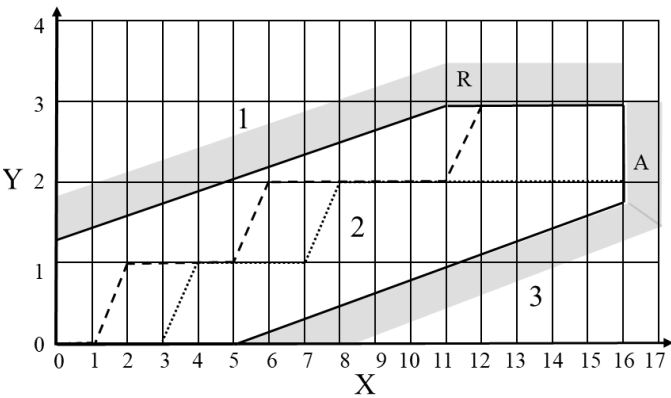
ISO 2859-5 gives two methods for establishing sequential sampling plans: the numerical method and the graphic method. The graphic method is applied for bolting assembly inspection.

在图解法中（见图 O.1），横轴代表参与检查的紧固件数量，纵轴代表有缺陷的螺栓连接副数量。

In the graphic method (see Figure O.1) the horizontal axis is the number of bolting assemblies inspected and the vertical axis the number of defective bolting assemblies.

图中直线定义三个区域：合格区、拒收区和未定区。只要检查结果处于未定区，检查继续直到检查结果处于在合格区或拒收区。进入合格区后则无需进一步抽样检查，例如：

The lines on the graph define three zones: the acceptance zone, the rejection zone and the indecision zone. As long as the inspection result is in the indecision zone the inspection is continued until the cumulative plot emerges into either the acceptance zone or the rejection zone. Acceptance means that no further sample inspection is required. Two examples are given below.



注：

Key

拒收区 (R)	X	参与检查的螺栓连接副数量
1 rejection zone (R)		number of bolting assemblies inspected
未定区	Y	有缺陷的螺栓连接副数量

2 indecision zone

number of defective bolting assemblies

合格区 (A)

3 acceptance zone (A)

举例

#### EXAMPLES

点线 第 4 和第 8 个螺栓连接副存在缺陷。检查继续直至超过垂直线，检查结果为“合格”。

Dotted line The 4th and 8th bolting assemblies were found defective. Inspection was continued until crossing the vertical curtailment line. The result is "acceptance".

虚线 第 2、第 6 和第 12 个螺栓连接副存在缺陷。退出未定区进入拒收区，检查结果是“不合格”。

Dashed line The 2nd, 6th and 12th bolting assemblies were found defective. Exit from the indecision zone is into the rejection zone. The result is "rejection".

图 O.1 – 序列类型实例

Figure O.1 – Example of sequential inspection diagram

#### O.2.3 应用

#### O.2.3 Application

序列类型 A(图 O.2)和序列类型 B(图 O.3)的应用方法如下。

Sequential type A (Figure O.2) and sequential type B (Figure O.3) apply as relevant.

a) 序列类型 A:

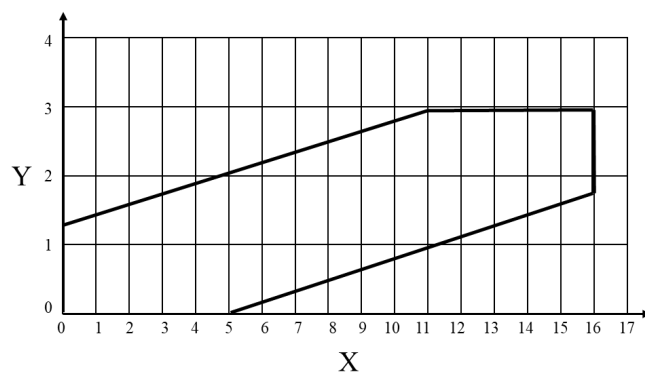
a) Sequential type A:

检查螺栓连接副的最小数量: 5;

minimum number of bolting assemblies to be inspected: 5;

检查螺栓连接副的最大数量: 16.

maximum number of bolting assemblies to be inspected: 16.



注:

**Key**

X 参与检查的螺栓连接副数量

X number of fasteners inspected

Y 有缺陷的螺栓连接副数量

Y number of defective fasteners

图O.2 – 序列类型A

Figure O.2 – Sequential type A diagram

b) 序列类型 B:

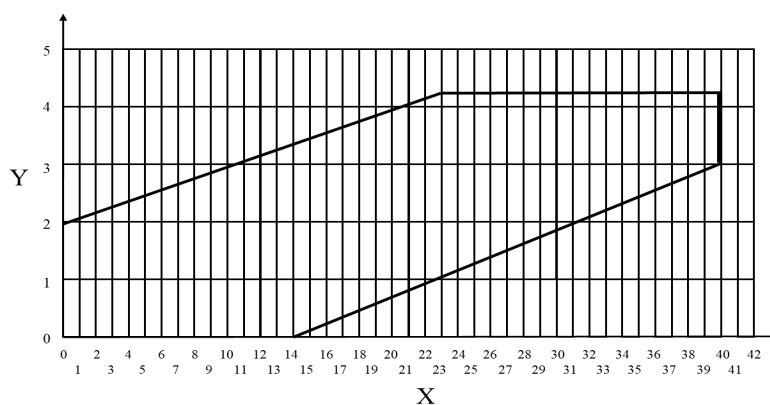
b) Sequential type B:

检查螺栓连接副的最小数量: 14;

minimum number of bolting assemblies to be inspected: 14;

检查螺栓连接副的最大数量: 40。

maximum number of bolting assemblies to be inspected: 40.



注

**Key**

X 参与检查的螺栓连接副数量

- X number of bolting assemblies inspected  
Y 有缺陷的螺栓连接副数量  
Y number of defective bolting assemblies

图 O.3 – 序列类型B

Figure O.3 – Sequential type B diagram

### O.3 基于执行级别的频率检查法

#### O.3 Frequency inspection method based on execution level

注： 以下检查方法基于CSA S16-19.

NOTE The following system is based on CSA S16-19.

第三方检查时应按表 O.1所列频率进行。

Third-party inspections should be carried out at frequencies listed in Table O.1.

表 O.1 – 基于施工等级的螺栓连接检查频次

Table O.1 – Frequency of bolting inspection based on execution level

类别 Category		施工等级 Execution level			
		EXL1	EXL2	EXL3	EXL4
工厂检查 Shop inspections		OPT	OPT <sup>a</sup>	Y	Y
S1	对于抗滑移和预紧螺栓连接，通过观察螺栓的终拧紧固组装过程，检查螺栓预拉情况 For slip-resistant and pretensioned joints, bolt inspection by witnessing installation during pretensioning of bolting assemblies	OPT	10%	20%	20%
S2	观察已完工且未列入S1的抗滑移和预紧螺栓连接，检查螺栓的安装状态 Visual bolt and connection inspection of completed slip-resistant and pretensioned joints not included in S1, in the as-installed condition	OPT	10%	50%	50%

S3	观察已完成的非预紧螺栓连接，检查螺栓的安装状态 Visual bolt and connection inspection of completed non-pretensioned joints, in the asinstalled condition	OPT	10%	50%	50%
<b>现场检查<sup>b</sup></b> <b>Site inspections<sup>b</sup></b>		<b>OPT</b>	<b>Y</b>	<b>Y</b>	<b>Y</b>
F1	对于抗滑移和预紧螺栓连接，通过观察螺栓的终拧紧固组装过程，检查螺栓预拉情况 For slip-resistant or pretensioned joints, bolt inspection by witnessing installation during pretensioning of bolting assemblies	OPT	10%	20%	20%
F2	观察已完工且未列入F1的抗滑移和预紧螺栓连接，检查螺栓的安装状态 Visual bolt and connection inspection of completed slip-resistant and pretensioned joints not included in F1, in the as-installed condition	OPT	10%	50%	50%
F3	观察已完成的非预紧螺栓连接，检查螺栓的安装状态 Visual bolt and connection inspection of completed non-pretensioned joints, in the as installed condition	OPT	10%	50%	50%
<p>OPT ⇨ 任意值 OPT ⇨ Optional Y ⇨ 建议值 Y ⇨ Yes, recommended 表中百分比为最小建议值 Where a percentage is shown, it is the minimum recommended. 。</p> <p>a EXL2的工厂检查是任意的，但是如果指定使用工厂检查，则表中列出的百分比为建议值 a Shop inspection for EXL2 is optional; however, if it is specified, then the percentages listed are recommended values.</p>					

- |   |
|---|
| <p>b 如果指定了使用工厂和现场检查，则使用指定的检查方法。</p> <p>b If both shop and site inspections are specified, inspection shall be done at either the shop or at the site.</p> |
|---|

#### **O.4 基于任务的检查法**

##### **O.4 Task-based inspection method**

注： 以下系统的检查方法基于 AISC 360-16。

NOTE The following system of inspection tasks is based on AISC 360-16.

观察螺栓连接操作是确认施工中采用的材料、程序和工艺是否符合本文件及现行规范的主要方法。

Observation of bolting operations shall be the primary method used to confirm that the materials, procedures and workmanship incorporated in construction are in conformance with this document and the execution specification.

(a) 对于非预紧连接，表 O.2 列出的观察或安装前的验证试验以及表 O.3 列出的安装过程的监控方法均不适用。在安装非预紧螺栓连接时，施工单位的螺栓检查员和其他螺栓检查员均无需在场。

(a) For non-pretensioned joints, observation or performance of pre-installation verification testing as listed in Table O.2, and monitoring of the installation procedures as listed in Table O.3, are not applicable. The constructor's bolting inspector and other bolting inspectors need not be present during the installation of fasteners in non-pretensioned joints.

(b) 对于预紧和抗滑移连接，当安装人员使用旋转螺母法或带定位标记的组合法、直接张力指示器法或花键驱动剪断法时，对螺栓预紧过程的监控应符合表 O.3 的规定。当安装人员使用这些方法安装螺栓时，施工单位的螺栓检查员和其他螺栓检查员无需在场。

(b) For pretensioned joints and slip-resistant joints, when the installer is using a turn-of-nut or combined method with location marks, the direct tension indicator method, or the spline-drive twist-off bolt method, monitoring of bolt pretensioning procedures

shall be as specified in Table O.3. The constructor's bolting inspector and other bolting inspectors need not be present during the installation of bolting assemblies when these methods are used by the installer.

(c) 对于预紧和抗滑移连接，当安装人员使用无定位标记的旋转螺母法或组合紧固法，及扭矩控制紧固法时，对螺栓预紧过程的监控应符合表 O.3 的规定。当安装人员使用这些方法时，施工单位的螺栓检查员和其他螺栓检查员应在螺栓安装期间履行规定的检查职责。

(c) For pretensioned joints and slip-resistant joints, when the installer is using a turn-of-nut or combined method without location marks, or a torque control method, monitoring of bolt pretensioning procedures shall be as specified in Table O.3. The constructor's bolting inspector and other bolting inspectors shall be engaged in their assigned inspection duties during installation of bolting assemblies when these methods are used by the installer.

螺栓连接检查任务至少应符合表 O.2、O.3 和 O.4 的要求。在这些表中，检查任务范围如下：

As a minimum, bolting inspection tasks shall be in accordance with Tables O.2, O.3 and O.4. In these tables, the inspection tasks are as follows:

- 观察(O)：检查员应随时观察这些项目，且在检验期间不需要暂停工作。
- Observe (O): The inspector shall observe these items on a random basis. Operations need not be delayed pending these inspections.
- 执行(P)：检查每个螺栓连接。
- Perform (P): These tasks shall be performed for each bolted connection.



表 O.2 – 螺栓安装前的检验任务

Table O.2 – Inspection tasks prior to bolting installation

螺栓安装前的检查工作 Inspection tasks prior to bolting installation	施工单位检查 Constructor's inspection	其他检查 Inspection by others
制造商提供的螺栓材料认证 Manufacturer's certifications available for fastener materials	O	P
包装标签应按照5.2.11中的规定标记 Packaging labelled in accordance with 5.2.11	O	O
螺栓部件应按照产品标准或规格要求标记 Bolting components marked in accordance with product standards or specified requirements	O	O
为螺栓连接组件和部件提供储存空间 Protected storage provided for bolting assemblies and bolting components	O	O
选择正确的螺栓连接形式（如等级、类型、如果螺纹不在剪切平面内，则考虑螺栓长度） Correct fasteners selected for the joint detail (e.g. grade, type, bolt length if threads are to be excluded from shear plane)	O	O
选择正确的螺栓安装顺序 Correct bolting procedure selected for joint detail	O	O
连接件需满足使用要求，包括适当的接触面和螺栓孔状况 Connecting elements, including the appropriate faying surface condition and hole preparation, meet applicable requirements	O	O
在安装前观察安装人员使用的紧固件类型和预紧方式 Pre-installation verification testing by installation personnel observed and documented for bolting assemblies and pretensioning methods used	P	O

表 O.3 – 螺栓安装时的检查工作

Table O.3 – Inspection tasks during bolting installation

螺栓安装时的检查工作 Inspection tasks during bolting installation	施工单位检查 Constructor's inspection	其他检查 Inspection by others

螺栓穿入螺栓孔后，是否按要求放置垫圈和螺母 Bolting assemblies placed in all holes and washers and nuts are positioned as required	O	O
螺栓预紧前节点应已固定 Joint brought to the snug-tight condition prior to the pretensioning operation	O	O
未使用扳手旋转的螺栓不可转动 Bolting component not turned by the wrench prevented from rotating	O	O
确保螺栓预紧从最刚性点向自由边有序进行 Bolting assemblies are pretensioned in accordance with the method specified, progressing systematically from the most rigid point toward the free edges	O	O

表 O.4 – 螺栓安装后的检查工作

Table O.4 – Inspection tasks after bolting installation

螺栓安装后的检查工作 Inspection tasks after bolting installation	施工单位检查 Constructor's inspection	其他检查 Inspection by others
记录螺栓连接是否符合标准 Document conformity or nonconformity of bolted connections	P	P

## 附录 P

### Annex P

(规范性附录)

(normative)

#### 试验确定抗滑移系数

#### Test to determine slip factor

##### P.1 一般规定

##### P.1 General

试验目的是确定特定表面处理（通常涉及表面涂层）的抗滑移系数。

The purpose of this test is to determine the slip factor for a particular surface treatment, often involving a surface coating.

试验过程旨在确保考虑到连接可能出现的蠕变变形。

The test procedure is intended to ensure that account is taken of the possibility of creep deformation of the connection.

涂层表面试验结果仅在所有重要参数均与试验试件一致时有效。

The validity of the test results for coated surfaces is limited to cases where all significant variables are similar to those of the test specimens.

##### P.2 重要变量

##### P.2 Significant variables

试验结果的重要参数如下：

The following variables shall be taken as significant on the test results:

- a) 涂层材料组成;  
a) the composition of the coating;
- b) 多层涂层表面和首层处理情况, 见 P.3;  
b) the surface treatment and treatment of primary layers in case of multi-layer systems, see P.3;
- c) 涂层最大厚度, 见 P.3;  
c) the maximum thickness of the coating, see P.3;
- d) 固化过程;  
d) the curing parameters;
- e) 螺栓性能等级, 见 P.6.  
e) the property class of the bolt, see P.6.
- f) 垫圈数量和形状;  
f) number and configuration of washers;
- g) 钢板强度。  
g) grade of steel plates
- h) 在连接接头处进行涂装与对接头施加荷载之间的最小时间间隔

### **P.3 试件**

#### **P.3 Test specimens**

试件的尺寸详图如图 P.1 所示。

The test specimens shall conform to the dimensional details shown in Figure P.1.

钢材应符合 ISO17607-2 中规定的屈服强度在 350MPa 至 700MPa 之间的任意钢

结构。

The steel material shall conform to any structural steel listed in ISO 17607-2 between 350 MPa and 700 MPa minimum specified yield strength, inclusive.

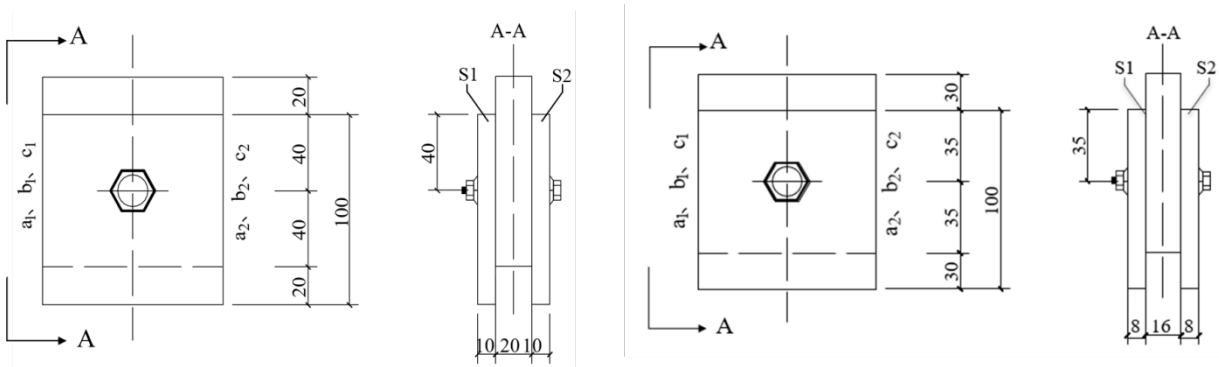
为了确保被连接的两块内层钢板的厚度相同，应从同一品种的钢材上连续切割两块内层钢板，并按相应的初始位置进行组装。

To ensure that the two inner plates have the same thickness, they shall be produced by cutting them consecutively from the same piece of material and assembled in their original relative positions.

板材边缘应精确切割，确保不影响板面之间的接触。切割板材必须平整，以确保在按 7.4 节预紧螺栓时，处理后的板面能够贴紧。

The plates shall have accurately cut edges that do not interfere with contact between the plate surfaces. They shall be sufficiently flat to permit the prepared surfaces to be in contact when the bolts have been pretensioned in accordance with 7.4.

单位：毫米



a) 孔径为 22mm 的 M20 螺栓连接副      b) 孔径为 18mm 的 M16 螺栓连接副  
a) M20 bolts in 22 mm hole diameter      b) M16 bolts in 18 mm hole diameter

注

Key

- S1 滑移面 1
- S1 Slip plane 1
- S2 滑移面 2
- S2 Slip plane 2

图P.1–抗滑移系数试验的标准试件

Figure P.1 – Compression type test specimens for static slip factor test

待试验件滑移面上的表面处理和涂层方式须符合预期结构应用。试件接触表面的平均涂层厚度至少比结构中规定的名义厚度高 25%。

The surface treatment and coating to be tested shall be applied to the contact surfaces of the test specimens in a manner consistent with the intended structural application. The mean coating thickness on the contact surface of the test specimens shall be at least 25 % thicker than the nominal thickness specified for use in the structure.

参考已公布的建议或者描述实际工序记录固化过程。

The curing procedure shall be documented, either by reference to published recommendations or by description of the actual procedure.

试件组装时，应确保螺栓受力方向与施力方向相反。

The specimens shall be assembled such that the bolts are bearing in the opposite direction to the applied tension.

应记录涂装时间和试验时间之间的间隔（以小时计）。

The time interval (in hours) between coating and testing shall be recorded.

螺栓应根据其尺寸和性能等级，预紧螺栓至规定预紧力  $F_{p,C}$  的 $\pm 5\%$ 。

The bolts shall be tightened to within  $\pm 5\%$  of the specified pretension,  $F_{p,C}$ , for the size and property class of the bolt used.

螺栓预紧力应使用精度为 $\pm 4\%$ 的设备直接测量。

The pretension in the bolts shall be directly measured with equipment that is accurate to  $\pm 4\%$ .

若需估算螺栓预紧力随时间的损失，可将试件放置一段指定时间后再次测量预紧力。

If it is required to estimate bolt pretension losses over time, the test specimens may be

left for a specified period at the end of which the pretensions may be again measured.

试验前必须测量每个试件的螺栓预紧力，必要时重新施加螺栓预紧力，精度要求 $\pm 5\%$ 。

The bolt pretensions in each test specimen shall be measured just prior to testing and, if necessary, the bolts shall be retightened to the required  $\pm 5\%$  accuracy.

注 图 P.2 中进行蠕变试验的受拉型试件是静态试验的一种替代试验装置。

NOTE The tension-type test specimen for creep test as shown in Figure P.2 is an alternative test setup for static test.

#### **P.4 抗滑移试验的过程与结果评估**

##### **P.4 Slip test procedure and evaluation of results**

首先，应以正常速度对四个试件进行加载试验（试验持续时间约为 10 至 15 分钟）。试件试验应在拉力试验机中进行，同时记录荷载-滑移曲线。

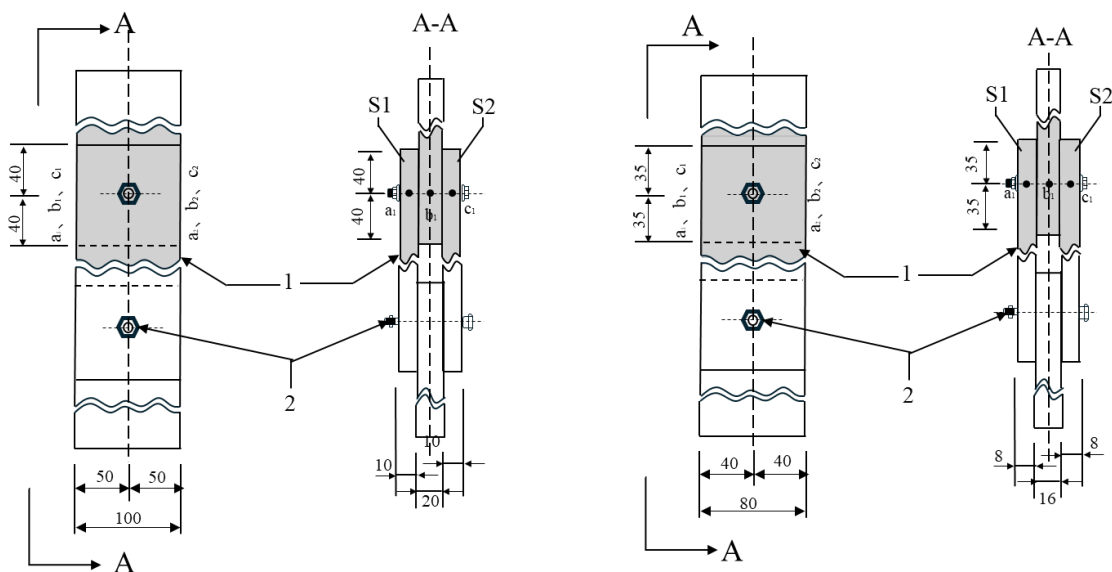
Initially, in a first step, four static tests shall be tested in compression at normal speed (duration of test approximately 10 min to 15 min). The specimens shall be tested in a universal testing machine. The loadslip relationship shall be recorded.

对比图 P.2 所示的试件，保证每个螺栓的接触面积不变，可通过拉伸试验装置替代确定荷载-滑移关系。

Initially, in a first step, four static tests shall be tested in compression at normal speed (duration of test approximately 10 min to 15 min). The specimens shall be tested in a universal testing machine. The loadslip relationship shall be recorded.

第二步中，第五个试件的蠕变试验应进行拉伸试验。

In the second step, the fifth test specimen shall be tested in tension in a creep test.



a) 孔径为22mm的M20 螺栓连接副

a) M20 bolts in 22 mm hole diameter

b) 孔径为18mm的M16 螺栓连接副

b) M16 bolts in 18 mm hole diameter

注:

Key

1 试件 (灰色部分)

specimen (in gray)

2 未紧固的螺栓滑移时的荷载

loose bolt

S1 滑移面 1

slip plane 1

S2 滑移面 2

slip plane 2

图 P.2 –蠕变试验的受拉试件

Figure P.2 – Tension-type test specimen for creep test

试件有两个滑移面：滑移面 1 和滑移面 2，如图 P.1 所示。

In a test specimen, two slip planes exist: slip planes 1 and 2 according to Figure P.1.

滑移是指内层钢板（图 P.1 位置 b）和外层盖板（图 P.1 位置 a 和 c）上相邻点在荷载作用方向上的相对位移。应对试件的两端和两个边分别进行量测。

The slip shall be taken as the relative displacement between adjacent points on an inner plate (position b, Figure P.1) and a cover plate (positions a and c, Figure P.1), in the direction of the applied load. The slip displacement shall be measured on both sides of



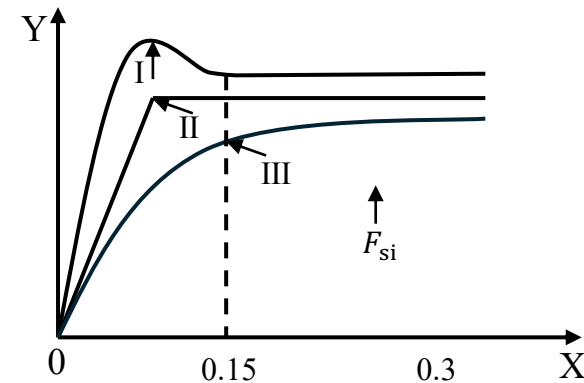
the specimen.

在滑移面 1 和 2 均产生滑移的组合滑移破坏模式中，须根据破坏模式评估试件滑移量，最终基于两次实测值确定试件平均滑移量。

Slip occurs in a failure mode of combination of slip in slip planes 1 and 2. The slip must be evaluated according to this failure mode, so that finally one mean slip value shall be determined on the basis of two measured displacements.

单个连接的抗滑移荷载  $F_{Si}$  定义为滑移达到 0.15mm 时试件的荷载，或者滑移达到 0.15mm 前试件的峰值荷载，具体见图 P.3 的荷载-位移图。

The individual slip load for a connection,  $F_{Si}$ , is defined as the load at 0,15 mm displacement or at the peak load before 0,15 mm displacement according to the load-displacement diagram as given in Figure P.3.



注：

Key

- |            |   |                                     |
|------------|---|-------------------------------------|
| <b>I</b>   | 抗滑移荷载为滑移达到 0.15mm 前的峰值荷载                          | 滑移位移 (mm)<br>slip displacement (mm) |
|            | Slip load is the peak load before slip of 0,15 mm |                                     |
| <b>II</b>  | 抗滑移荷载为滑移达到 0.15mm 前试件滑移时的荷载                       | 抗滑移荷载<br>load                       |
|            | Slip load is load at sudden slip before 0,15 mm   |                                     |
| <b>III</b> | 抗滑移荷载为滑移达到 0.15mm 时的荷载                            |                                     |
|            | Slip load is the load at slip of 0,15 mm.         |                                     |

图 P.3 – 不同荷载-滑移行为下抗滑移荷载的定义

**Figure P.3 – Definition of the slip load for different load-displacement  
behaviour**

第五个试件的抗滑移荷载应为前四个试件平均抗滑移荷载(即八个抗滑移荷载的平均值)  $F_{Sm}$  的 90%。

The fifth test specimen shall be loaded with a specific load of 90 % of the mean slip load  $F_{Sm}$  from the first four specimens (i.e. the mean of eight values).

如果第五个试件施加全部抗滑移荷载五分钟后和三小时后记录的滑移量（即延时滑移量）之差不超过 0.002 毫米，则第五个试件的抗滑移荷载应与前四个试件相同。如果延时滑移超过 0.002mm，则应根据 P.5 进行延伸蠕变试验。

If for the fifth specimen the delayed slip, i.e. difference between the recorded slip at five minutes and at three hours after the application of the full load does not exceed 0,002 mm the slip loads for the fifth test specimen shall be determined as for the first four. If the delayed slip exceeds 0,002 mm extended creep tests shall be carried out in accordance with P.5.

如果 5 个试件测得的 10 个抗滑移荷载值的标准差  $s_{Fs}$  超过平均值的 8%，则应进行附加试件的试验。试件的总数（包括前五个试样）应根据以下条件确定：

If the standard deviation  $s_{Fs}$  of the ten values (obtained from the five test specimens) for the slip load exceeds 8 % of the mean value, additional specimens shall be tested.

The total number of test specimens (including the first five) shall be determined from:

$$n > (s/3.5)^2 \quad (P.1)$$

其中：

where

$n$  试验试件数量；

$n$  is the number of test specimens;

$s$  前五个试件（十个值）抗滑移荷载的标准差  $s_{Fs}$ ，表示为平均抗滑移荷载的百分比形式。

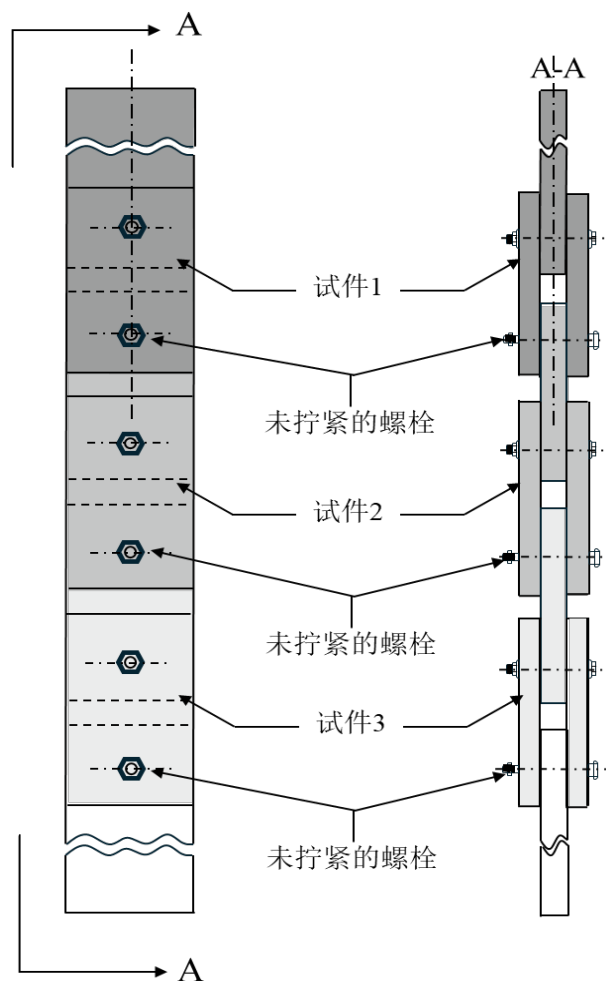
$s$  is the standard deviation  $s_{Fs}$  for the slip load from the first five specimens (ten values) expressed as a percentage of the mean slip load value.

## P.5 追加蠕变试验的流程及评估

### P.5 Extended creep test procedure and evaluation

根据 P.4 节进行追加蠕变试验时应至少试验三个试件。试验时使用拉伸型试件，并用未紧固的螺栓将多个试件连接成单链形式。试件中的螺栓应使用更高性能等级，例如 12.9 级或同等抗拉强度，连接详图见图 P.4。试件连接成单链形式时所有试件承受荷载相同。

If it is necessary to carry out extended creep tests, following P.4 at least three test specimens shall be tested. Tension-type test specimens shall be used in these tests. The specimens can be linked as a single chain-like arrangement using loose bolting assemblies, preferably with higher property class, for instance class 12.9 or equivalent tensile strength, see Figure P.4. Assembling the specimens like a chain means that the same load will be applied to all specimens.



注:

**Key**

1	未紧固的螺栓	3	试件 2
	Loose bolt		Second specimen
2	试件 1	4	试件 3
	First specimen		Third specimen

**图 P.4 –追加蠕变试验试件及试验装置**

**Figure P.4 – Test setup for extended creep tests with linked specimens**

对试件施加同时考虑 P.4 节中蠕变试验结果和追加的蠕变试验结果的特定荷载。

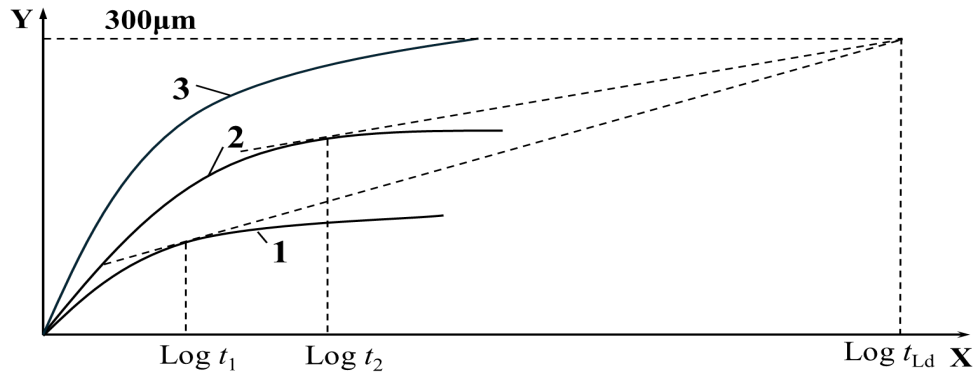
A specific load shall be applied to the test specimen whose value shall be determined to account both for the result of the creep test carried out in P.4 and for the results of all preceding extended creep tests.

施加结构应用中抗滑移系数对应的荷载，如果表面处理方式为特定类别，则根据附件 D 施加与该类别抗滑移系数对应的荷载。

A load corresponding to the slip factor proposed for use in the structural application may be adopted. If the surface treatment is to belong to a specified class, a load corresponding to the slip factor for that class may be taken in accordance with Annex D.

绘制“位移-对数时间”曲线（见图 P.5），证明根据建议的抗滑移系数确定的抗滑移荷载在结构设计寿命期间（除非现行规范特别规定，否则设计寿命默认为 50 年）产生的滑移不大于 0.3mm。“位移-对数时间”曲线可在精确确定切线的情况下进行线性外推。

A “displacement - log time” curve shall be plotted (see Figure P.5) to demonstrate that the load determined using the proposed slip factor will not cause displacements greater than 0,3 mm during the design life of the structure, taken as 50 years unless otherwise specified in the execution specification. The “displacement - log time curve” may be extrapolated linearly as soon as the tangent can be determined with sufficient accuracy.



注：

Key

1	通过追加蠕变试验 Passed extended creep test	tLd	结构设计寿命 Design life of structure
2	通过追加蠕变试验 Passed extended creep test	t1	试验1的最短持续时间 Minimum duration for test 1
3	未通过追加蠕变试验 Extended creep test is not passed	t2	试验2的最短持续时间 Minimum duration for test 2
X	对数时间轴 log (time)		
Y	滑移位移 slip displacement		

图 P.5 – 用于追加的蠕变试验的位移-对数时间曲线进行追加蠕变试验

Figure P.5 – Use of the displacement-log time curve for extended creep test

## P.6 试验结果

### P.6 Test results

单个螺栓抗滑移系数的确定方法如下：

Individual slip factor values are determined as follows:

$$\mu_i = \frac{F_{Si}}{4F_{p,C}} \quad (P.2)$$

抗滑移荷载的平均值  $F_{Sm}$  及标准差  $s_{Fs}$  计算方法如下：

The slip load mean value  $F_{Sm}$  and its standard deviation  $s_{Fs}$  are determined as follows:

$$F_{Sm} = \frac{\sum F_{Si}}{n} \quad (P.3)$$

$$s_{Fs} = \sqrt{\frac{(F_{Si} - F_{Sm})^2}{n-1}} \quad (P.4)$$

抗滑移系数的平均值  $\mu_m$  及标准差  $s_\mu$  计算方法如下：

The slip factor mean value  $\mu_m$  and its standard deviation  $s_\mu$  are determined as follows:

$$\mu_m = \sqrt{\frac{\sum \mu_i}{n}} \quad (P.5)$$

$$s_\mu = \sqrt{\frac{(\mu_i - \mu_m)^2}{n-1}} \quad (P.6)$$

抗滑移系数  $\mu$  的特征值应为置信水平 75% 时的 5% 分位数值。

The characteristic value of the slip factor shall be taken as the 5 % fractile value with a confidence level of 75 %.

对于 5 个试件所得的 5 个数值 ( $n=5$ )，特征值可取平均值减去 2.46 倍的标准差。

For five values,  $n = 5$ , from five specimens, the characteristic value may be taken as the mean value minus 2.46 times the standard deviation.

除非需要进行追加的蠕变试验，试件抗滑移系数标准值数应等于特征值。

Unless extended creep testing is required, the nominal slip factor shall be taken equal to its characteristic value.

进行追加蠕变试验时，抗滑移系数标准值即为规定的蠕变极限值，见 P.5 节。

If extended creep testing is required, the nominal slip factor may be taken as the value demonstrated to satisfy the specified creep limit, see P.5.

使用 10.9 级或同等抗拉强度螺栓确定的抗滑移系数也可用于 8.8 级或同等抗拉强度的螺栓。

Slip factors determined using bolts of property class 10.9 or equivalent tensile strength may also be used for bolts property class 8.8 or equivalent tensile strength.

或者，也可对 8.8 级或同等抗拉强度的螺栓进行单独试验。但 8.8 级或同等抗拉强度的螺栓确定的抗滑移系数不适用于 10.9 级或同等抗拉强度的螺栓。

Alternatively, separate tests may be carried out for bolts of property class 8.8 or equivalent tensile strength. Slip factors determined using bolts property class 8.8 or equivalent tensile strength shall not be assumed valid for bolts of property class 10.9 or equivalent tensile strength.



## 附件 Q

### Annex Q

(资料性附录)

(informative)

#### 螺栓预紧力损失试验

#### Test to determine loss of pretension

##### Q.1 一般规定

##### Q.1 General

预紧螺栓连接副的钢材表面须进行防腐保护，而预紧螺栓钢材的保护层或覆盖层适用性取决于紧固过程中结构的系统储备（与名义最小预紧力相关的实际预紧力）、结构服役期内的预紧力损失以及预紧目标，详见 7.7 节。

Steel surfaces of pretensioned bolted connections must generally be protected against corrosion. The suitability of the selected protective coatings or coating systems in pretensioned bolted connections depends on the extent of the possible system reserves due to the tightening procedure (the actual pretension level in relation to the nominal minimum pretensioning force), pretension losses over the service life of a structure, but also on the target of pretensioning, see 7.7.

注：若采用组合紧固法（见附件 J）或旋转螺母法（见附件 M）紧固螺栓，则系统储备应为 30%（1.3 倍名义最小预紧力）。

NOTE If tightening is carried out by the combined method (see Annex J) or turn-of-nut method (see Annex M), a system reserve of 30 % ( $1,3 \times$  nominal minimum pretension) can be expected.

对于预紧螺栓连接，如果接触面涂层厚度超过 100 $\mu$ m 或由易产生蠕变的材料组成，应检查预紧力的潜在损失，试验流程见 Q.2 节。

For pretensioned bolted connections, contact surfaces on which the coatings applied to



each surface are thicker than 100  $\mu\text{m}$  or consist of a particularly creep-prone material, the potential loss of pretension should be checked. A procedure is provided in Q.2.

本试验的目的是将预紧力损失与涂层的最大允许厚度联系起来，试验的目的不是评估涂层对滑移面上摩擦系数的影响。

The purpose of this test procedure is to relate the loss of pretension to the maximum permitted thickness of coating layers. It is not the purpose of the test to assess this effect on the friction coefficient of coatings on the faying surfaces of slip-resistant connections.

试验结果仅适用于所有重要变量均与试验试件相似的情况，对试验结果具有重要影响的变量如下：

The validity of the test results is limited to cases where all significant variables are similar to those of the test specimens. The following variables shall be taken as significant on the test results:

a) 涂层材料组成;

a) the composition of the coating;

b) 表面处理及多层涂层中基层处理情况;

b) the surface treatment and treatment of primary layers in case of multi-layer systems;

c) 涂层最大厚度;

c) the maximum thickness of the coating;

d) 涂层固化过程及涂抹涂层与紧固连接件之间的最短时间间隔;

d) the curing procedure and the minimum time interval between application of the coating and the tightening of the connection;

- e) 螺栓等级;
- e) the property class of the bolt;
- f) 垫圈数量和装配方式。
- f) number and configuration of washers.

试验试件接触面上的表面处理和涂层必须符合结构应用预期，同时记录接触面实际的粗糙度和干燥的涂层厚度。固化过程应通过已公布的建议或者描述实际固化过程的方式记录备案。

The surface treatment and coating to be tested shall be applied to the contact surfaces of the test specimens in a manner consistent with the intended structural application. The actual surface roughness and the dry coating thickness should be documented. The curing procedure shall be documented, either by reference to published recommendations or by description of the actual procedure.

## **Q.2 试验过程**

### **Q.2 Test procedure**

下述试验过程可以确定由安装影响、蠕变和螺栓松弛造成的预紧力损失：

The following test procedure can be used for determining of pretension losses due to setting effects, creep and relaxation:

a)例如，试验试件由 2 块 300 mm×150mm×8mm 和 1 块 300mm×150 mm×16 mm 的钢板组成，钢板中设置 8 个直径 18mm 的螺栓孔（见图 Q.1），试件的几何形状和接触面条件根据结构不同的预期用途改变。

a) As an example, the test specimens can consist of 2 plies 300 mm × 150 mm × 8 mm and 1 ply 300 mm × 150 mm × 16 mm with 8 holes of 18 mm diameter (see Figure Q.1). The test specimen geometries and the corresponding surface condition may differ with regard to the intended use in the structure.

b)每个试验涂层应在试件上双面涂覆;

- b) Every test ply shall be coated with the coating system on both sides;
- c) 各层钢板使用八个预紧的 M16×60mm 螺栓/螺母/垫圈组件连接在一起;
- c) The plies should be fastened together using eight preloaded M16 × 60 mm bolt/nut/washer assemblies;
- d) 各紧固件根据附录 I、J、K、L 或 M 中的方法施加预紧力;
- d) The bolting assemblies should be pretensioned according to the relevant method given in Annexes I, J, K, L or M;
- e) 螺栓的预紧力应使用精度为±4%的设备直接测量。应在至少 14 天内连续记录预紧力损失，以便绘制“预紧力损失-对数时间”曲线，并随后通过线性外推确定结构的预期使用寿命（见图 Q.2）。
- e) The pretension in the bolts shall be directly measured with equipment that is accurate to ± 4 %. The loss of pretension should be recorded continuously over a period of at least 14 days so that a "loss of pretension-log time" curve can be determined with subsequent linear extrapolation to the intended service life of the structure (see Figure Q.2).

注：螺栓紧固后，在达到最大峰值和螺栓紧固后的最初几秒（约 3 秒）时间内，螺栓预紧力曲线会出现明显下降的现象。这是由于回转螺母或者移除扳手时螺栓螺纹恢复弹性变形导致的，并非完全与紧固件的松弛有关。因此，预紧力损失中不包含这类螺栓螺纹恢复造成的损失。

NOTE After tightening of the bolts, a considerable drop in the measured pretension curve between the maximum peak and the first few seconds (about 3 seconds) after the tightening can be observed. This drop is not entirely related to relaxation behaviour of the bolted assemblies, as this phenomenon can be explained by turning back of the nut and elastic recovery of the bolt threads when the wrench is removed. For this reason, these recovery losses should not be considered as a loss of pretension.

保存并记录试验结果。

The test results should be documented.

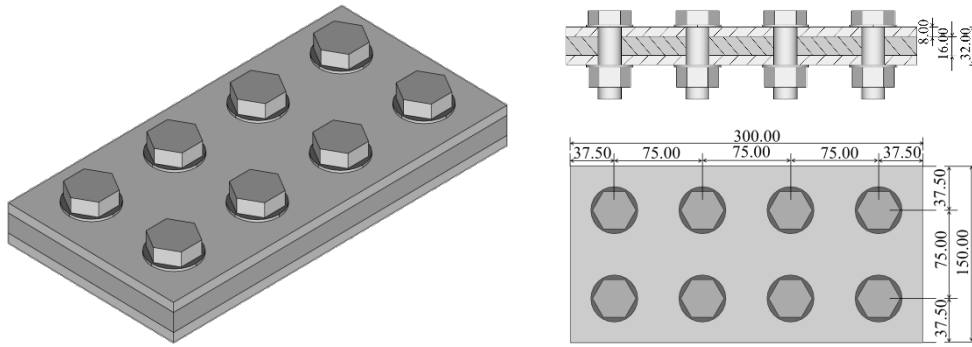
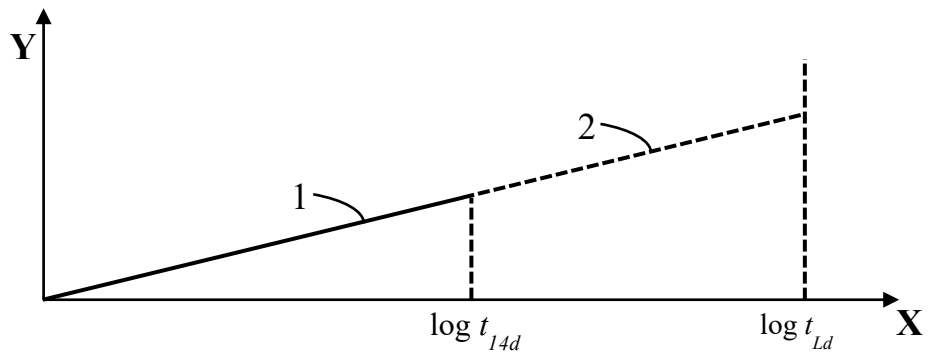


图 Q.1-试验试件举例

Figure Q.1 – Example of test specimen



注：

Key

1	实测数据 Measurement data	$t_{Ld}$	结构设计寿命 Design life of structure
2	实测数据的线性外推数据 Linear extrapolation of measurement data	$t_{14d}$	试验的最短时间 Minimum duration of the test
X	对数时间轴 time (log time)		
Y	滑移位移 loss of pretension		

图Q.2-利用预紧力损失-对数时间曲线确定预紧力损失

Figure Q.2 – Use of the loss of pretension-log time curve for determination of the loss of pretension