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Fasteners — Torque/clamp force testing

Éléments de fixation — Essais couple/tension

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 16047 was prepared by Technical Committee ISO/TC 2, *Fasteners*, Subcommittee SC 1, *Mechanical properties of fasteners*.

Fasteners — Torque/clamp force testing

1 Scope

This International Standard specifies the conditions for carrying out torque/clamp force tests on threaded fasteners and related parts.

It is applicable, basically, to bolts, screws, studs and nuts made of carbon steel and alloy steel, whose mechanical properties are specified in ISO 898-1, ISO 898-2 or ISO 898-6, having ISO metric threads with thread sizes M3 to M39. It is also applicable to the combination of other externally and internally threaded fasteners with a triangular ISO thread according to ISO 68-1.

It is not applicable to set screws and similar threaded fasteners that are not under tensile stresses, nor to screws which form their own mating thread or threaded fasteners having additional self-locking features.

Unless otherwise agreed, the tests are carried out at room temperature. However, tests carried out under standard conditions are made at a temperature of 10 °C to 35 °C.

This method allows determination of the tightening characteristics of threaded fasteners and related parts.

2 Normative references

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

ISO 68-1, *ISO general purpose screw threads — Basic profile — Part 1: Metric screw threads*

ISO 273:1979, *Fasteners — Clearance holes for bolts and screws*

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

ISO 898-2, *Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread*

ISO 898-6, *Mechanical properties of fasteners — Part 6: Nuts with specified proof load values — Fine pitch thread*

ISO 4014, *Hexagon head bolts — Product grades A and B*

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

ISO 4032, *Hexagon nuts, style 1 — Product grades A and B*

ISO 4033, *Hexagon nuts, style 2 — Product grades A and B*

ISO 4042:1999, *Fasteners — Electroplated coatings*

ISO 4759-3:2000, *Tolerances for fasteners — Part 3: Plain washers for bolts, screws and nuts — Product grades A and C*

ISO 4762, *Hexagon socket head cap screws*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature*

ISO 7093-1, *Plain washers — Large series — Product grade A*

ISO 8673, *Hexagon nuts, style 1, with metric fine pitch thread — Product grades A and B*

ISO 8674, *Hexagon nuts, style 2, with metric fine pitch thread — Product grades A and B*

ISO 8765, *Hexagon head bolts with metric fine pitch thread — Product grades A and B*

ISO 15071, *Hexagon bolts with flange — Small series — Product grade A*

ISO 15072, *Hexagon bolts with flange with metric fine pitch thread — Small series — Product grade A*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
clamp force
F
axial tension acting on the bolt shank or compression acting on the clamped member during tightening

3.2
yield clamp force
F_y
clamp force at which the bolt shank or the engaged thread yield under combined stress condition in tightening

3.3
ultimate clamp force
F_u
maximum clamp force under combined stress condition potentially induced before bolt shank fracture

3.4
tightening torque
wrenching torque
applied torque
T
overall torque applied on nut or bolt head in tightening

3.5
yield tightening torque
T_y
tightening torque with which yield clamp force is gained

3.6
thread torque
T_{th}
torque acting on bolt shank through mating threads during tightening

3.7
bearing surface friction torque
T_b
torque acting on clamped member through bearing surfaces during tightening

3.8
ultimate tightening torque
T_u
tightening torque with which ultimate clamp force is gained

4 Symbols and their designations

See Table 1.

Table 1 — Symbols and their designations

Symbol	Designation
d	Nominal thread diameter
d_2	Basic pitch diameter of thread
d_4	Diameter of hole of test fixture
d_h	Clearance hole diameter of washer or bearing part (nominal value)
D_b	Diameter of bearing surface under nut or bolt head for friction (theoretical or measured)
D_o	Outer diameter of bearing surface, $d_{w\,min}$ or $d_{k\,min}$ (see product standards)
D_p	Diameter of plain area of bearing plate
F	Clamp force
F_p	Proof load according to ISO 898-1, ISO 898-2 or ISO 898-6, whichever is relevant
F_u	Ultimate clamp force
F_y	Yield clamp force
h	Thickness of test-bearing plate or test washer
K	Torque coefficient, $K = \frac{T}{Fd}$
L_c	Clamp length
L_t	Length of complete thread between bearing surfaces
P	Pitch of the thread
T	Tightening torque
T_b	Bearing surface friction torque
T_{th}	Thread torque
T_u	Ultimate tightening torque
T_y	Yield tightening torque
Θ	Rotation angle
μ_b	Coefficient of friction between bearing surfaces under nut or bolt head
μ_{th}	Coefficient of friction between threads
μ_{tot}	Coefficient of total friction

5 Principle of test

5.1 General

A tightening torque is steadily applied to a bolt/nut or screw/nut assembly to generate a clamp force, and to measure and/or determine one or more of the tightening characteristics, which can include torque coefficient, coefficient of total friction, coefficient of friction between threads, coefficient of friction between bearing surfaces, yield clamp force, yield tightening torque, rotation angle and ultimate clamp force. In the range of elastic deformation, a linear relationship is assumed between torque and clamp force.

NOTE For studs, only the coefficient of friction between threads is determined.

There are two different goals for testing:

a) testing of tightening characteristics of a fastener under standard conditions (see Clause 8), i.e. with test-bearing plates/test washers type HH or type HL as specified in 7.2.2 and 7.2.3 and with test nuts or test bolts as specified in 7.3 and 7.4;

b) testing of tightening characteristics of fasteners under specific conditions, see Clause 9.

The relationship between tightening characteristics which may be obtained and the parameters to be measured are shown in Table 2.

There are different methods (see 5.2 to 5.4) to describe the torque/clamp force behaviour of bolted joints with different surface and lubrication conditions.

Table 2 — Parameters to be measured to obtain respective tightening characteristics

Tightening characteristics which may be determined	Parameters to be measured					Clause
	Clamp force F	Tightening torque T	Thread torque T_{th}	Bearing surface friction torque T_b	Rotation angle Θ	
Torque coefficient, K	O	O	—	—	—	**10.1**
Coefficient of total friction, μ_{tot}	O	O	—	—	—	**10.2**
Coefficient of friction between threads, μ_{th}	O	—	O	—	—	**10.3**
Coefficient of friction between bearing surfaces, μ_b	O	—	—	O	—	**10.4**
Yield clamp force, F_y	O	—	—	—	O	**10.5**
Yield tightening torque, T_y	O	O	—	—	O	**10.6**
Ultimate clamp force, F_u	O	—	—	—	—	**10.7**
Ultimate tightening torque, T_u	O	O	—	—	—	**10.8**

5.2 Determination of coefficients of friction

To describe the most general conditions of friction without reference to the shape and dimensions of the fasteners, it is useful to determine the different coefficients of friction (see 10.2 to 10.4). The coefficient of friction is a dimensionless number, calculated from measured physical characteristics, which depends on the kind and on the geometry of the surfaces in contact. The necessary measurements are relatively expensive due to the necessity of having sensors for the clamp load and for at least two different torques, and the need to have knowledge about all relevant geometrical dimensions (d_2, P, D_b). The determined coefficients of friction can be used in torque/clamp force calculations for all dimensional ranges of fasteners with the same frictional conditions.

5.3 Determination of torque coefficient K (K-factor)

The measurement is simpler if the torque coefficient K is determined, this being calculated by the formula $K = T/(Fd)$ (see 10.1). In this case, there is a reference to the dimension d. This means that the validity of the K-factor is limited to one dimension. For the determination, it is necessary to measure the clamp force F and the tightening torque T. The K-factor can be used in torque/clamp force calculations only for fasteners with the same frictional conditions, the same dimension d and the same geometric proportion.

5.4 Determination of ratio T/F

The most simple but also most limited method is to measure the pure torque/clamp force relationship. The ratio T/F is only valid for the very special joint investigated. There is no need for knowledge of dimension or shape of the fasteners.

6 Apparatus

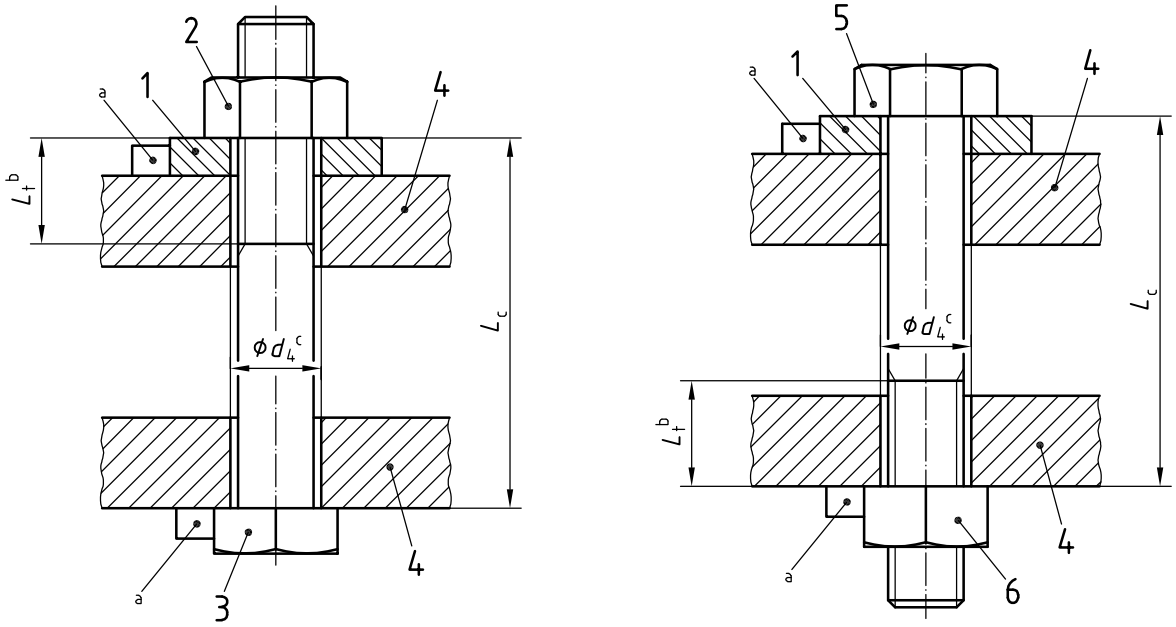
6.1 Testing machine

The testing machine shall be capable of applying tightening torque and rotation on nut, bolt head or screw head either automatically or manually, and shall be equipped with a device for measuring the items shown in Table 2 to within an accuracy of ± 2 % of the values to be measured, unless otherwise specified. The accuracy of angle measurement shall be ± 2° or ± 2 % of the measured value, whichever is the greater. For referee purposes, the tightening shall be carried out using a controlled power tool with a constant speed of rotation. The results shall be recorded electronically.

It is important that the stiffness of the testing machine, including load cells and test fixture, be constant throughout the test.

6.2 Test fixture

The test fixture shall be capable of withstanding the combination of clamp force and bearing-surface friction torque without measurable permanent deformation or displacement. Figure 1 gives basic requirements for test fixtures.



a) Testing the nut **b) Testing the bolt**

For testing studs, a fixture and setup of test specimen similar to a) is used. However, only the nut end should be tested. Before testing, the metal end of the stud shall be prevented from rotating.

Key

1 test-bearing plate, test washer or specified washer
2 nut to be tested
3 test bolt (or test screw)
4 test device (clamped member)
5 bolt (or screw) to be tested
6 test nut

a Test-bearing plate or test washer and bolt head or nut shall be fixed by suitable means to prevent rotation and shall be aligned.

b L_t should be at least $1d$ in the case of yield tightening or tightening to the ultimate clamp force.

c d_4 shall be in accordance with ISO 273:1979, fine series.

Figure 1 — Fixture and test set-up

7 Test parts

7.1 General

Test parts are mating parts for the parts to be tested.

For testing bolts, screws or nuts under standard conditions, specified test parts (test washers, test-bearing plates, test nuts, test bolts, test screws) shall be used (see Figure 1). These test parts are specified in 7.2 to 7.4.

All traces of grease, oil or other contaminations shall be removed before testing. The test parts shall be degreased by ultrasonic means and using suitable solutions in accordance with compatible practices required for health and safety. In case of dispute, the degreasing procedure shall be agreed between the contracting parties.

7.2 Test-bearing plates or test washers

7.2.1 Types

Either a test-bearing plate or a test washer of high (through-hardened, type HH) or low (type HL) hardness shall be used.

The supplier shall select the test-bearing plate or test washer and surface condition according to experience, unless otherwise specified by the purchaser at the time of order.

7.2.2 Test-bearing plate or test washer type HH

Hardness: The hardness shall be 50 HRC to 60 HRC.

Roughness: The surface shall have a roughness of Ra 0,5 ± 0,3.

Clearance hole: The clearance hole diameter d_h shall be in accordance with ISO 273:1979, medium series, and shall neither be chamfered nor have a countersink.

Thickness: The minimum thickness, h, of the test-bearing plate or test washer shall be in accordance with ISO 7093-1.

Thickness variation Δh on the same part: See Table 3; for the definition of thickness variation Δh on the same part, see ISO 4759-3.

Flatness: The flatness shall be according to the requirements of ISO 4759-3:2000, product grade A.

Surface condition:

a) plain surface uncoated and degreased;

b) zinc electroplated A1J according to ISO 4042 and degreased.

The part shall be free of burrs.

For the basic dimensions of the test-bearing plate or test washer, see Figure 2.

7.2.3 Test-bearing plate or test washer type HL

Hardness: The hardness shall be 200 HV to 300 HV

Roughness: The surface shall have a maximum roughness of Ra 1,6 for thickness $\leqslant$ 3 mm, and Ra 3,2 for thickness ($3 < h \leqslant 6$) mm, according to ISO 7093-1.

Clearance hole: The clearance hole diameter d_h shall be in accordance with ISO 273:1979, medium series, and shall neither be chamfered nor have a countersink.

Thickness: The minimum thickness h of the test-bearing plate or test washer shall be in accordance with ISO 7093-1.

Thickness variation Δh on the same part: See Table 3; for the definition of thickness variation Δh on the same part, see ISO 4759-3.

Flatness: The flatness shall be according to the requirements of ISO 4759-3:2000, product grade A.