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Rotary tools for threaded fasteners — Performance test method

Outils rotatifs pour éléments de fixation filetés — Méthode d'essai des caractéristiques de fonctionnement

Reference number
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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 3, *Pneumatic tools and machines*.

This third edition cancels and replaces the second edition (ISO 5393:1994), which has been technically revised.

Introduction

The test method specified in this document is designed to measure the performance of power assembly tools in a laboratory environment. It is not intended as a routine in-plant inspection test.

This document is intended

— to enable the producers of power tools to offer their products under standardized technical specifications, and

— to give users of threaded fasteners a method for evaluating and specifying the performance of power assembly tools.

As with the previously published versions, this 2017 version of the document remains a fundamental test procedure, with no attempt to set acceptance criteria. Any minimum performance requirements are the responsibility of the user to meet the demands of the particular application for which the tool is intended for use.

Additional elements have been introduced with this version to address preferred test torque levels, tool performance over a defined number of operating cycles and a method to determine the precision of any torque measurement system which may be included as part of the assembly tool.

As with the previously published versions, this document is applicable to tightening tools of any power source within its scope. This version more clearly addresses electric powered tools which have become more commonly used in the workplace.

This version includes some changes to the specifications for the test joints and for the test method. These changes reflect the practical experience gained through the use of the document and are intended to improve the reproducibility of the test method. Results obtained using this version is not expected to be significantly different than results obtained using the previous version.

Information regarding rated torque, test torque and torque adjustment range: The scope (see last paragraph) allows a test to be performed at any test torque level (see 3.18). A manufacturer defines a tool's rated torque (see 3.11) and its torque adjustment range (see 3.21). Clause 6 describes a method to identify torque scatter over a defined range of torque adjustment. In theory, a manufacturer could offer a tool with a defined rated torque of 100 Nm, and may choose to identify the performance over a defined torque adjustment range of 60 Nm to 80 Nm (perhaps to satisfy a customer or market requirement). In that case, as specified in Clause 6, performance tests will be carried out at 60 Nm and 80 Nm, and should the manufacturer want to identify the tool's performance over a defined number of operating cycles, the operating cycle test would be performed at 80 Nm (the upper limit of the defined range of torque adjustment, as specified in 7.2.2). Results of the performance tests would then be valid only for that defined range of torque adjustment.

Rotary tools for threaded fasteners — Performance test method

1 Scope

This document specifies a laboratory performance test method for power assembly tools (referred throughout the document as “tool”) for installing threaded fasteners.

It provides a method for the measurement of torque repeatability (scatter)

— over a range of torque rates as specified in this document,

— over a range of torque adjustment as defined by the manufacturer, and

— over a number of operating cycles as defined by the manufacturer.

It provides a method for the measurement of the precision of the built-in torque measurement system for tools incorporating such a feature. See Annex E.

It gives instructions on equipment parameters, what to test for and how to evaluate and present the test data.

It is applicable to tools

— of any power source, e.g. pneumatic, hydraulic, and electric, including battery-powered,

— which apply torque in a generally continuous manner, and

— within the torque range 0,5 Nm to 2 000 Nm. Outside this range, it is acceptable to modify the test method providing that the modification is documented in the test report.

It is not applicable to

— impact or impulse wrenches,

— ratchet wrenches or wrenches with ratcheting clutches, and

— other tools which advance fasteners in discontinuous increments, overcoming static friction at each increment.

It allows a test to be performed at any test torque level; however, in order to minimize the number of test joints necessary for a wide range of test torque levels, a list of preferred test torque levels is provided in Annex A.

2 Normative references

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.

EURAMET/cg-14/v.2.0: March–2011, *Guidelines on the Calibration of Static Torque Measuring Devices*

3 Terms and definitions

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

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

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

— IEC Electropedia: available at http://www.electropedia.org/

3.1
angle
measure of the angular displacement through which a fastener is turned

Note 1 to entry: Expressed in degrees (°).

3.2
built-in torque measurement system
torque measurement system incorporated within a power assembly tool for tightening threaded fasteners with which the torque delivered at the output drive is measured within the tool for display, storage or control purposes

3.3
combined mean torque
$\bar{T}_{\text{comb}}$
midpoint of the *combined torque scatter* (3.5) of a tool between the lowest and highest predictable torque readings, encompassing 99,73 % or more of all possible readings

3.4
combined precision of the indicated torque
predicted range of deviation of the value indicated by the *built-in torque measurement system* (3.2)

Note 1 to entry: From the value indicated by the in-line measuring instrument.

Note 2 to entry: Encompassing 99,73 % or more of all possible torque deviations of indicated torque, taken on a range of joints of varying torque rate, from a defined high torque rate through and beyond a defined low torque rate.

Note 3 to entry: Characterized both by the mean shift of indication and the scatter of the torque difference.

3.5
combined torque scatter
ΔT_{comb}
predictable range of torque values delivered by a tool on a range of joints having a specified high *torque rate* (3.23) and a specified low torque rate at the same setting of the tool torque adjustment

Note 1 to entry: The indicated values encompassing 99,73 % or more of all possible torque readings.

Note 2 to entry: For practical purposes, combined torque scatter of a tool is the total probable range of torque of a tool run on all joints used in practice at the same setting of the tool torque adjustment.

3.6
combined torque scatter as a percentage of the combined mean torque
single numerical value designating the predictable range of torque values as delivered by a tool on a range of joints, having a specified high *torque rate* (3.23) and a specified low torque rate at the same setting of the tool torque adjustment

3.7
indicated torque
T_{Ind}
torque indicated by the power tool's *built-in torque measurement system* (3.2)

3.8
mean shift
difference in *mean torque* (3.9) of a tool run on threaded joints of two different *torque rates* (3.23) at the same setting of the tool torque adjustment

3.9
mean torque
$\bar{T}$
arithmetic average of several torque readings on a specific joint under stated conditions, calculated by dividing the sum of the readings by the number of readings

3.10
non-shut-off tool
power assembly tool for tightening threaded fasteners, which delivers an output torque as long as power is applied to the motor

Note 1 to entry: A stall tool is an example of a non-shut-off tool.

3.11
rated torque
highest *mean torque* (3.9), as defined by the manufacturer, attainable by a tool tested on a low torque-rate joint (L)

Note 1 to entry: In accordance with 5.2.4.

3.12
run-down
period of angular rotation without corresponding torque increase

Note 1 to entry: This allows the tool to reach operating speed.

3.13
automatic shut-off tool
power assembly tool for tightening threaded fasteners, which is provided with a torque control mechanism which shuts off or disconnects the power to the tool when predetermined set output torque level is attained

3.14
standard deviation
s
measure of the scatter based on the mean-squared deviation from the arithmetic mean derived from a sample of a statistical population

3.15
6*s*
range of probability, plus and minus three *standard deviations* (3.14) from the mean, derived from a sample of a statistical population

Note 1 to entry: For a normally distributed statistical population, 99,73 % of all members of that population are encompassed.

3.16
6*s* torque scatter
predictable range of torque over which a tool performs using a single torque-rate joint under controlled conditions

Note 1 to entry: For the practical purposes of this document, 6*s* torque scatter is the total probable range of torque of a tool run on a single joint at the same setting of the tool torque adjustment.

3.17
6*s* torque scatter as a percentage of the mean torque
single numerical value designating the predictable range of torque over which a tool performs on a single torque-rate joint under controlled conditions

3.18
test torque level
mean torque (3.9) level to which a test tool is adjusted on a low torque-rate joint (L)

Note 1 to entry: In accordance with 5.2.4.

3.19
tightening time
time required for the tool to complete the tightening process, beginning at 10 % of the *test torque level* (3.18) and ending at the peak dynamic torque

3.20
torque
T
product of the force turning the fastener and the perpendicular distance between the line of force and the centre of the fastener

Note 1 to entry: Expressed in newton metre (N·m).

Note 2 to entry: For the purposes of this document, peak measured torque during a tightening cycle, measured with the in-line measuring instrument as specified in 5.2.3.

3.21
torque adjustment range
range over which a power tool can be adjusted from the rated torque to the lowest *mean torque* (3.9) recommended by the manufacturer

3.22
torque difference
D
difference between the torque indicated by the power tool's *built-in torque measurement system* (3.2) and the in-line torque measurement system

Note 1 to entry: The calculation of torque difference is specified in Annex E.

Note 2 to entry: The in-line torque measurement system is specified in 5.2.3.

3.23
torque rate
increase in torque with angular displacement while advancing a fastener in a threaded joint

Note 1 to entry: Expressed in newton metre per revolution (N·m/r).

4 Symbols

Symbol	Description	Subscript	Description
D	torque difference	comb	combined over H and L joints
$\bar{D}$	mean torque difference	D	torque difference
ΔD	6s difference scatter	H[a]	on the H joint
n	number of readings	i	ith reading
s	standard deviation	Ind	indicated
T	torque	L[a]	on the L joint
$\bar{T}$	mean torque		
ΔT	6s torque scatter		

[a] As specified in 5.2.

5 Determination of torque scatter

5.1 General rules for performance tests

5.1.1 Measurements

All measurements carried out in conformity with this document shall be performed by personnel trained in the use of the equipment utilizing instrumentation, which is calibrated against existing standard methods.

5.1.2 Ambient conditions

Unless otherwise noted, the ambient conditions shall, during the test, be kept within the following limits:

— ambient temperature: 22 °C ± 5 °C;

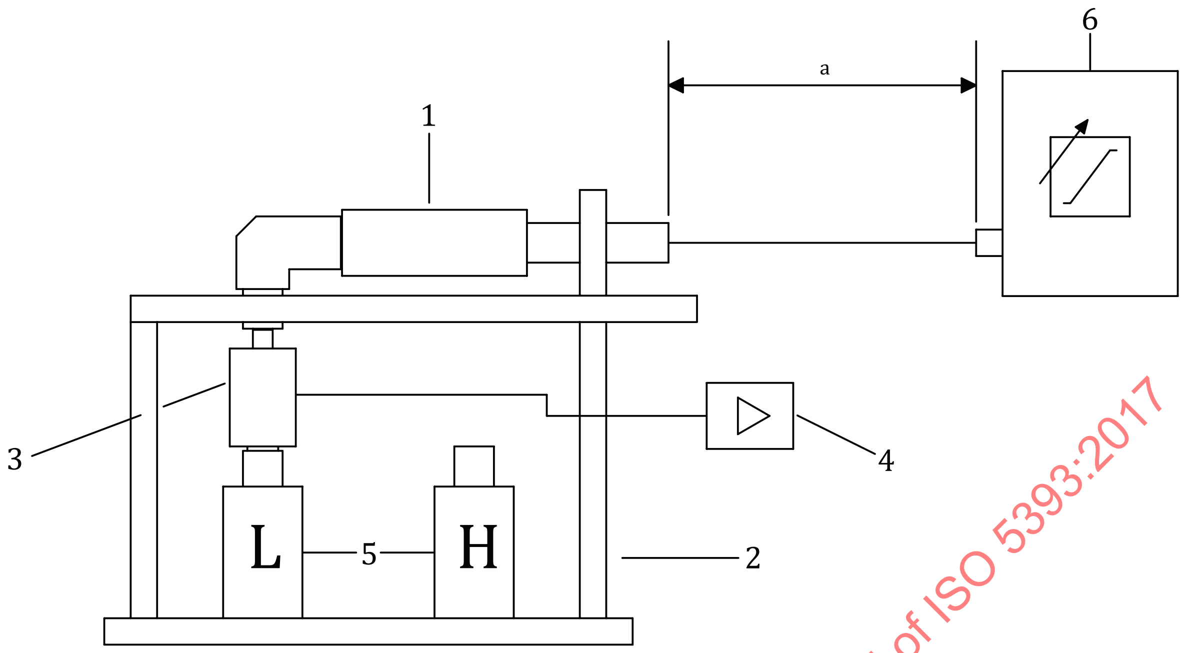
— relative humidity: below 90 %.

5.1.3 Test installation

The tool shall be connected to the test joint through the measuring instrument. The alignment of these three elements is important to reduce the influences on measured peak torque.

The tool shall be rigidly fixed in the test stand to prevent any influence by the operator.

Diagrams of typical test installations are shown in Figure 1, Figure 2 and Figure 3.



Key

1 test power tool

2 test power tool support fixture

3 torque/angle transducer

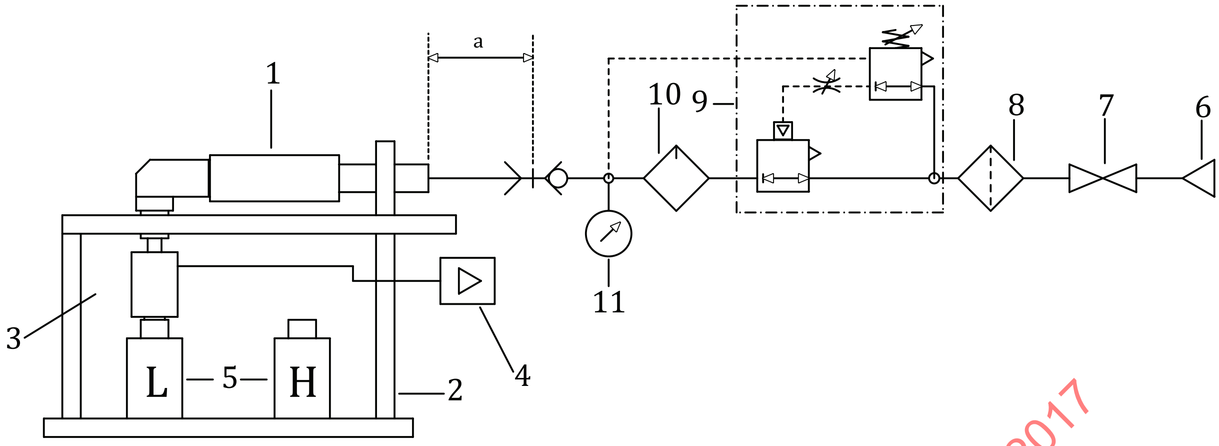
4 amplifier with peak detection and visual display or print-out capability

5 test fixture (L joint or H Joint)

6 power tool control electronics

a Cable length should not exceed 10 m.

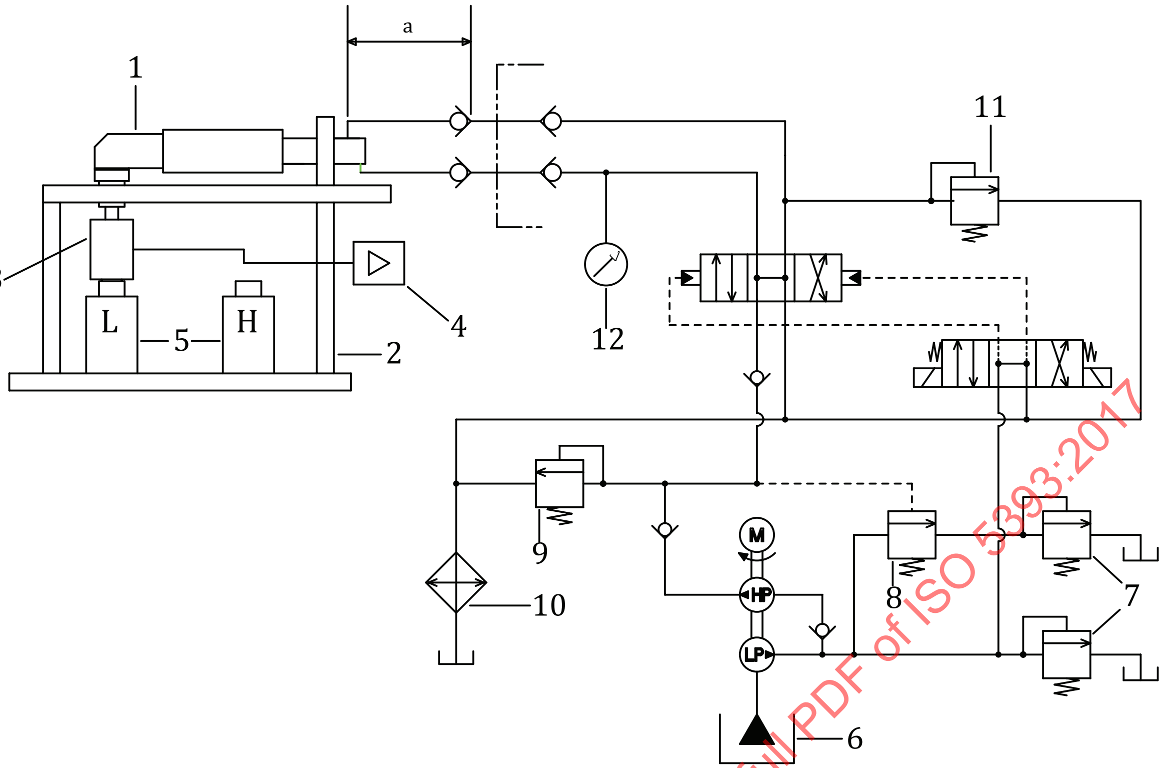
Figure 1 — Typical test installation for electric tool



Key

1 test power tool
2 test power tool support fixture
3 torque/angle transducer
4 amplifier with peak detection and visual display or print-out capability
5 test fixture (L joint or H Joint)
6 compressed air supply
7 shut-off valve
8 filter
9 pressure control [feedback pilot regulator and pilot operated regulator (with optional flow control)]
10 lubricator
11 pressure gauge
a 3-m hose length.

Figure 2 — Typical test installation for pneumatic tool



Key

1 test power tool
2 test power tool support fixture
3 torque/angle transducer
4 amplifier with peak detection and visual display or print-out capability
5 test fixture(L joint or H joint)
6 hydraulic reservoir
7 low pressure relief valve
8 unload valve
9 high pressure relief valve
10 cooler
11 relief valve
12 pressure gauge
a Hose length should not exceed 10 m.

Figure 3 — Typical test installation for hydraulic tool

5.1.4 Test tool

The test tool shall be adjusted to within 5 % of the test torque level on the low torque-rate joint (L) in accordance with the manufacturer’s instructions. The torque adjustment shall be constant throughout the test. In the case of an automatic shut-off tool, the adjustment shall be such that the shut-off mechanism operates each time.

Once the control settings have been adjusted for the test torque level, all control settings shall be constant throughout the test.

A list of preferred test torque levels is provided in Annex A. Adjusting the torque to a preferred test torque level is recommended in order to minimize the number of test joints necessary for testing.

5.1.5 Test tool condition

The test tool shall be in good working condition and lubricated in accordance with the manufacturer's specification. Before the start of the test, it shall be ensured that the tool under test is at ambient temperature.

The tool shall be tested under the manufacturer's specified input conditions and used in accordance with the manufacturer's instructions.

5.1.6 Power media

5.1.6.1 Pneumatic power

The air pressure shall be documented in the test report. The air supply shall include lubrication in accordance with the manufacturer's instructions.

The performance of pneumatic tools is affected by the ambient conditions such as atmospheric pressure and temperature. For this reason, unless otherwise specified, the following conditions shall be maintained:

— atmospheric pressure: 960 ± 100 mbar;

— compressed air temperature: 20 °C ± 5 °C.

Actual values shall be recorded if they are outside of these limits.

During performance tests of pneumatic tools, it is necessary to state the inlet air pressure. If not stated, the inlet air pressure is 6,3 bar(g)[1]. The air supply shall be free from fluctuations that would influence the result.

During performance tests of pneumatic tools, a 3-m hose of the tool manufacturer's specification shall be attached to the tool inlet. The air pressure at the inlet of this hose shall be kept within the following limits:

— free-running conditions: between the static value and 2 % below;

— approaching the test torque level: ±2 % of the static value.

NOTE A lubricator with insufficient flow properties can affect these values.

No pressure adjustments shall be made to the pilot regulator during the course of a given test.

5.1.6.2 Hydraulic power

Hydraulic tools shall be tested under rated input conditions. The maximum hydraulic pressure observed during the test shall be recorded.

The supply pressure shall be free from fluctuations that would influence the result. The typical hose length should not exceed 10 m.

5.1.6.3 Electric power

5.1.6.3.1 Mains

This includes all tools requiring an external continuous supply. It includes both a.c. and d.c. motor driven tools. Mains electric tools shall be tested under rated input conditions. The supply voltage shall

1) 1 bar = 0,1 MPa = 100 kPa.

be documented in the test report. The power supply shall be free from fluctuations that would influence the result.

The typical cable length should not exceed 10 m.

5.1.6.3.2 Battery

The battery pack nominal capacity and nominal voltage shall be recorded. The battery pack used shall be in good condition. During the tests on the operating cycle test joint (see Clause 7), the battery may be replaced with a power supply with appropriate voltage and current characteristics.

5.2 Test fixtures

5.2.1 General

The torque rate of a threaded joint varies widely from application to application and can vary appreciably on a specific assembly. The following characteristics apply.

a) On a low torque-rate joint (“soft joint”), the tightening is usually accomplished with one full revolution or more of the fastener.

b) On a high torque-rate joint (“hard joint”), the tightening is accomplished in a fraction of a revolution. On a high torque-rate joint, the kinetic energy of the rotating parts of the tool may cause the torque delivered to the fastener to be higher than that on a low torque-rate joint.

Any test of torque performance of a tool shall be conducted on joints having controlled torque rates. The test shall include a joint having a low torque rate and a joint having a high torque rate (see 5.2.4). The high and low torque rates represent the upper and lower limits of the practical range of conditions which may affect the torque output of the tool.

5.2.2 Test joint

5.2.2.1 General

To satisfy the conditions specified in 5.2.1, test fixtures for use with this document shall comply with the following requirements.

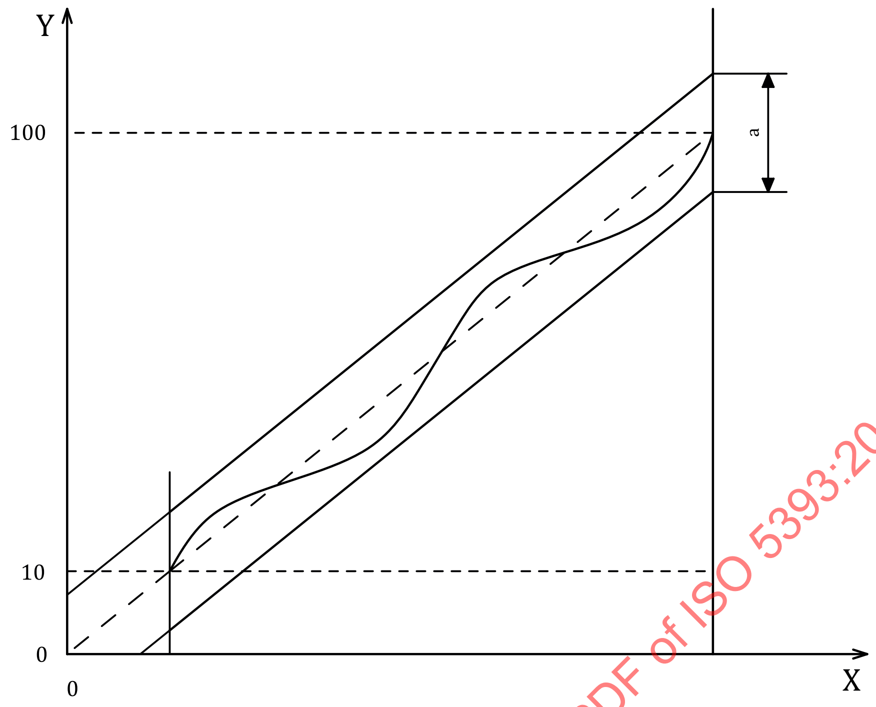
5.2.2.2 Description of the test joint torque rate and linearity

In a diagram where the required torque is plotted as a function of the angular displacement of the input drive of the test joint, the resulting curve shall be close to a straight line from 10 % to 100 % of the test torque level. The slope of this straight line is used to calculate the torque rate of the joint by regression analysis of the torque/angle measurement points from 10 % to 100 % of the test torque level.

The tightening speed may affect the frictional characteristics, and therefore the torque rate, of the test joint. When the torque rate of the test joint is measured, the joint shall be tightened through a transducer-encoder continuously at a constant speed that approximates the speed of the test tool as it approaches the test torque level. The encoder shall have a resolution of 0,25° or better. There shall be no rotational movement of the frame of reference for the angle-sensing element during the measurement.

Between 10 % and 100 % of the test torque level, the values of the high torque-rate joint curve shall not deviate from a straight line by more than 5 % of the test torque level (see Figure 4).

Between 10 % and 100 % of the test torque level, the values of the low torque-rate joint curve shall not deviate from a straight line by more than 10 % of the test torque level.



Key

X angle

Y torque level, expressed in percentage of test torque level

a ±5 % of test torque.

Figure 4 — Diagram showing torque rate linearity for the high torque-rate joint

5.2.2.3 Physical characteristics

The moment of inertia of rotating parts in the test joint should be of the same order of magnitude as the rotating parts of a screw joint for which the assembly tool is intended. This is to ensure that any torque and speed control of the power tool has realistic conditions.

The moment of inertia of rotating parts between the torque transducer (see 5.2.3) and the power tool, including any shaft or coupling used, should be of the same order of magnitude as for the socket normally used (to reduce the influence on accuracy of measured peak torque).

Torsional oscillations should be limited to reduce the influence on accuracy of measured peak torque. The stiffness and mechanical damping of rotating parts of the test joint, including any shaft or coupling used, should be high enough to limit these oscillations. For the same reason, the torque rate of the test joint shall be smooth and not show effects of quickly changing friction, e.g. from stick-slip phenomena.

Connecting shafts or couplings shall be kept to a minimum, especially between the tool and transducer. Shafts or couplings using a side loading retention shall be avoided (e.g. spring loaded socket retainer, etc.).

The graphical presentation specified in 5.3.6 shall be used to verify these requirements.

The test joints specified require high precision in order to achieve reproducibility. They reflect the common extremes of actual fastening practice, so that the tool precision revealed through tests on these specified joints can be applied to the range of fastening tasks encountered in the workplace. Examples of test joints are given in Annex B.

5.2.3 Measuring instrument

Residual torque measurements give poor correlation to joint condition (tension). Therefore, all performance measurements made in accordance with this document shall be taken dynamically during the tightening process using the measuring instruments specified below.

Torque and angle measurements shall be made by means of a rotary torque/angle transducer and an amplifier with a peak detection and visual display or print-out capability. The transducer shall be mounted in line between the tool drive and the test joint (see Figures 1, 2 and 3). The torque measurement system shall incorporate a Butterworth 3rd order low-pass filter with 500 Hz cut-off frequency.

The transducer shall be of the correct capacity for the test torque levels measured. The measurement uncertainty of the measurement chain (transducer and amplifier) shall be within the limits according to class 1 in EURAMET /cg-14/v.2.0. The resolution of the read-out shall be 0,25 % of the test torque level, or better.

The sampling rate of any analogue-to-digital converter shall be appropriately chosen to ensure that peak registration error is smaller than the resolution.

The demand of resolution of measured torque in N·m is dependent on test torque level, e.g. a test torque at 400 N·m requires a resolution of 1 N·m, a test torque at 4 N·m requires 0,01 N·m resolution. This demand is appropriate for the evaluation of a combined torque scatter value not lower than 5 %.

5.2.4 Test requirements

Each tool shall be tested on both a high (designated H) and a low (designated L) torque-rate joint, for which the following requirements are applicable.

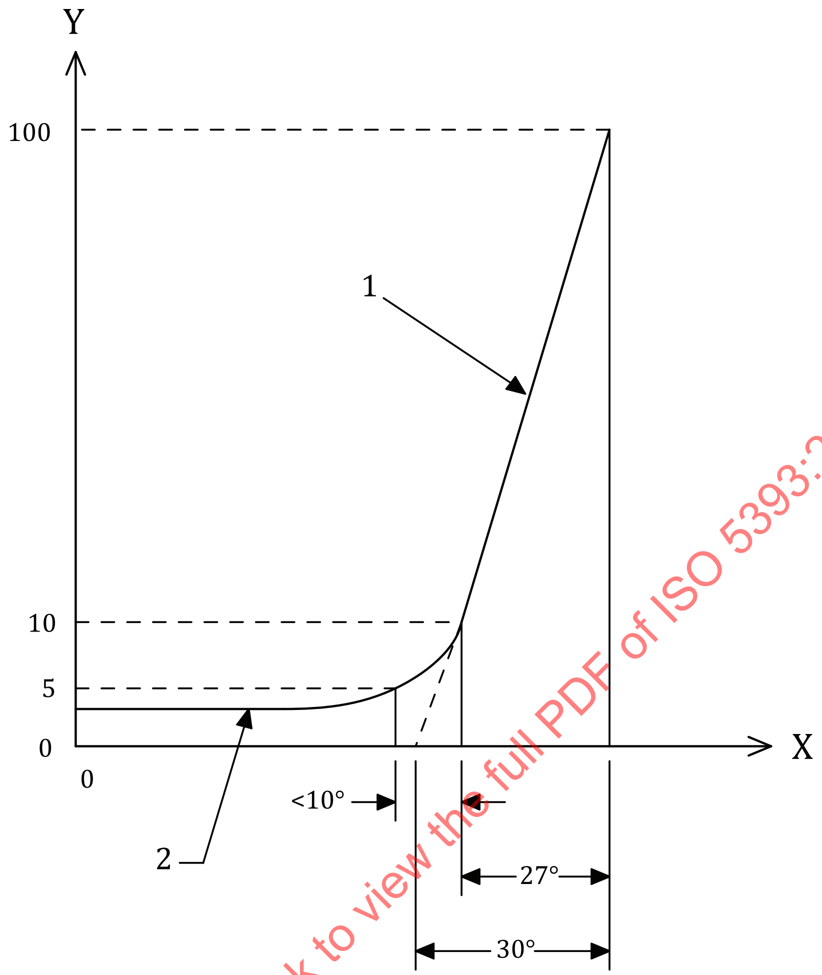
a) The test joint shall be such that the resistance to rotation during run-down shall not exceed 5 % of the test torque level.

NOTE 1 It is important that the run-down torque of the test joint is low enough that the speed of the power tool is not significantly reduced. Otherwise, the kinetic energy of its rotating parts would be reduced too much when the test torque level is reached.

b) The high torque-rate joint (H) shall be such that the torque increase from 10 % to 100 % of the test torque level corresponds to an angular displacement of 27° ± 3° (see Figure 5).

NOTE 2 An angular displacement of 27° corresponds to a total angle of 30° at a test torque level between 0 % and 100 %

c) During run-down the transition angle from the 5 % to the 10 % test torque level on the high torque-rate joint (H) shall not exceed 10° (see Figure 5).



Key

X angle

Y torque level, expressed in percentage of test torque level

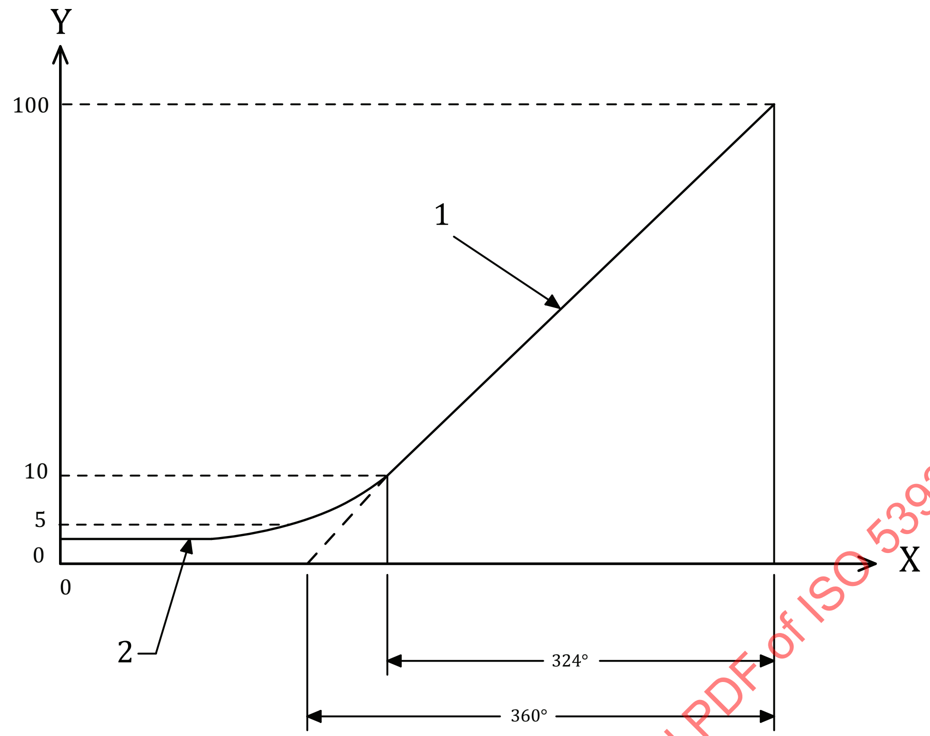
1 high torque-rate joint H

2 run-down

Figure 5 — Diagram showing the H joint

d) The low torque-rate joint (L) shall be such that the torque increase from 10 % to 100 % of the test torque level corresponds to an angular displacement of not less than 324° (see Figure 6).

NOTE 3 An angular displacement of 324° corresponds to a total angle of 360° at a test torque level between 0 and 100 %.



Key

X angle

Y torque level, expressed in percentage of test torque level

1 low torque-rate joint L

2 run-down

Figure 6 — Diagram showing L joint

NOTE 4 Additional information on test joints is given in Annex C.

5.3 Test method

5.3.1 Test cycles

A tool performance test shall consist of 50 test cycles on each of the H and L joints.

5.3.2 Run-down phase of the test cycle

The tool shall be allowed sufficient rundown time to reach stable operating conditions before reaching the torque rate of the test joint.

5.3.3 Alignment

If the test joint is such that in repeated test cycles, the relative angular orientation of the tool's output spindle with respect to the test joint is generally consistent each time the tool reaches the test torque level, then the following procedure shall be followed.

The angular orientation of the tool's output spindle with respect to the test joint shall be changed to a new unique position by rotating the drive connection by 60° to 90° (one flat of the hexagonal or square drive). This shall be repeated after every 5 test cycles or more frequently throughout the test.

NOTE Changing the angular relationship of the tool's output spindle with respect to the test joint replicates the randomness of actual production conditions and accounts for variations in the tool's gear train or spindle eccentricity.

5.3.4 Torque measurement

The peak measured torque shall be recorded for every test cycle on each of the H and L test joints.

5.3.5 Tightening time

Control settings that affect the tool performance can also affect the tightening time. The tightening time shall be recorded for at least one test cycle on each of the H and L test joints.

5.3.6 Graphical presentation

Graphs showing torque vs. time and torque vs. angle shall be recorded for at least one test cycle on each of the H and L test joints.

5.3.7 Electronically controlled tools

Electronically controlled tools often use numerous control settings which can be adjusted by the user to change the various tool performance characteristics. Adjusting these settings for minimal torque scatter may result in a longer tightening time. Conversely, adjusting the settings for minimal tightening time may result in poor torque scatter.

In order to provide the user with sufficient information regarding the test results, the control settings used for each test shall be recorded.

As specified in 5.1.4, these control settings shall be constant throughout the test on the H and L test joints at a particular test torque level.

5.4 Measurement uncertainty

The uncertainty of measurement shall be taken into account and is discussed in Annex D.

6 Tool performance over a defined range of torque adjustment

Tool torque scatter may be identified over all or part of a tool's torque adjustment range. To find a tool's torque scatter over a defined range of torque adjustment, two tool performance tests shall be carried out on both the high torque-rate joint (H) and the low torque-rate joint (L). One test at the upper limit of the defined torque adjustment range and the other test at the lower limit.

Alternately, if preferred test torque levels are used (see Annex A), one test shall be carried out at the preferred test torque level closest to, but not greater than, the upper limit of the defined torque adjustment range and the other test carried out at the preferred test torque level closest to, but not less than, the lower limit.

7 Tool performance over a defined number of operating cycles

7.1 General

Performance requirements can vary depending on the intended use of the tool. Establishing a minimum operating cycle requirement for all tools would not equally serve all needs. Tools for high production rate applications often require high operating cycle ratings, whereas tools intended for low production rate applications might benefit from lower operating cycle ratings in terms of size and cost. Therefore, the torque scatter may be identified over a defined number of operating cycles based on the standard operating cycle given in 7.2.

To identify a tool's torque scatter over a defined number of operating cycles, two tool performance tests shall be carried out. One test shall be performed on a new, unused test tool and one test shall be performed on the same test tool after completing the defined number of operating cycles.

Because of the large variety of threaded fastener joints and operating conditions in actual production environments, the user should use caution when using this method to predict the expected durability under actual conditions of use.

7.2 Operating cycle requirements

7.2.1 Tool operation

The tool shall be operated under the manufacturer's specified operating conditions.

The test tool shall be operated according to the operating cycle method as specified in 7.2.6 on a test joint that complies with the requirements of 7.2.3 for a defined number of operating cycles.

7.2.2 Torque level

The operating cycles shall be performed at a target torque level equal to the tool's rated torque. If the tool performance is to be identified over a defined range of torque adjustment, then the operating cycles shall be performed at a target torque level equal to the upper limit of the defined range of torque adjustment.

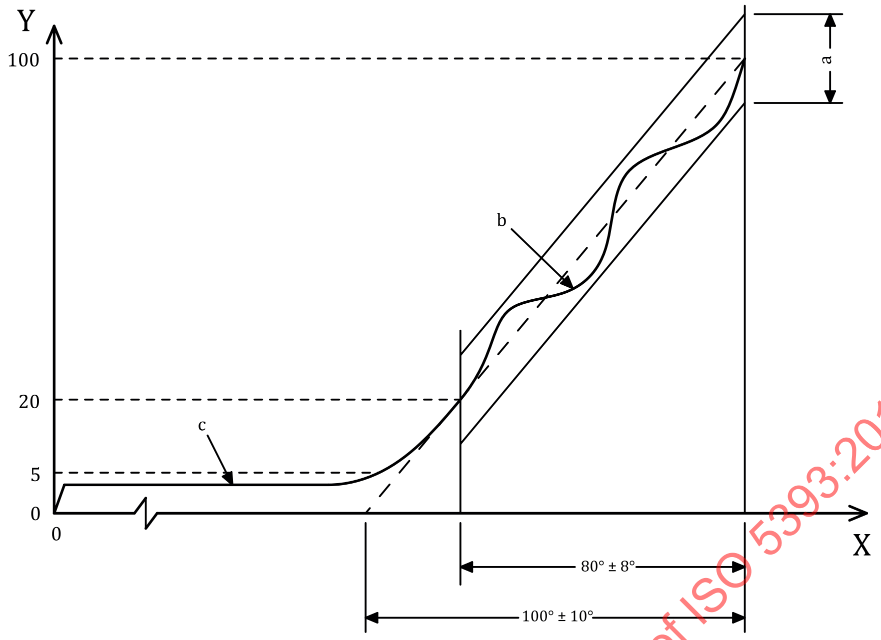
7.2.3 Operating cycle test joint

The test joint used for the operating cycles shall be such that the resistance to rotation during run-down shall not exceed 5 % of the target torque level.

The test joint shall have a torque rate such that the torque level shall increase from 20 % to 100 % of the target torque level as the joint is rotated through 80° ± 8°.

NOTE An angular displacement of 80° corresponds to a total angle of 100° at a target torque level between 0 and 100 %.

The linearity of the torque rate shall be such that between 20 % and 100 % of the target torque level, the torque rate shall not deviate from a straight line by more than 10 % of the target torque level (see Figure 7).



Key

X angle

Y torque level, expressed in percentage of the target torque level

a ±10 % of target torque level.

b Operating cycle test joint.

c Run-down.

Figure 7 — Diagram showing torque/angle curve for the operating cycle test joint

7.2.4 Ambient conditions

The performance of pneumatic tools is affected by the ambient conditions such as atmospheric pressure and temperature. For this reason, the ambient conditions shall be kept within the limits specified in 5.1.6.1.

7.2.5 Maintenance

The operating cycles may be stopped for lubrication and torque adjustment. Each such stop shall be identified as a service event.

No other maintenance shall be performed throughout the duration of the operating cycles.

7.2.5.1 Lubrication

The test tool shall be lubricated in accordance with the manufacturer's recommendation.

7.2.5.2 Torque adjustment

The torque shall be adjusted according to the manufacturer's instructions to a torque level equal to the target torque level as specified in 7.2.2. The mean torque shall be constant within ±5 % throughout the duration of the operating cycles. In the case of an automatic shut-off tool, the adjustment shall be such that the shut-off mechanism operates each time. In the case of an electronically controlled power tool, once the control settings have been adjusted, all control settings shall be constant throughout the duration of the operating cycles.

Throughout the duration of the operating cycles, mean torque should be monitored periodically on at least 10 occasions equally spaced out of the total number of cycles, e.g. for a total number of cycles of 500 k cycles monitoring shall be conducted every 50 k cycles.

Adjustments back to target torque shall be made and documented when the mean torque level differs by more than 5 % of target torque. Mean torque shall be calculated based on 10 successive cycles.

For electronically controlled tools the control settings used shall be documented.

7.2.6 Method

An operating cycle shall consist of a minimum of 8 revolutions of free run, followed by the tightening phase on the operating cycle test joint specified in 7.2.3, with the torque rising at the specified torque rate to the target torque level. The pause between each operating cycle shall be selected such that the tool remains within the manufacturer's operating limits.

Alternatively, the operating cycle rate may be accelerated by reducing the pause between each cycle. In such cases, forced heat transfer may be used to maintain the tool within operating limits.

The operating cycle test joint shall be such that in repeated operating cycles, the relative angular alignment of the tool's output spindle with respect to the test joint shall follow a generally random pattern.

The operating cycle rate shall be recorded. If forced heat transfer is used, this shall be documented.

7.2.7 Graphical presentation

Graphs showing torque vs. time and torque vs. angle shall be recorded for at least one operating cycle.

7.3 Performance test

Following the completion of the defined number of operating cycles, a performance test as specified in Clause 5 shall be performed on the sample tool at a test torque level equal to that used for the performance test performed prior to the operating cycles.

If the tool performance is to be identified over a defined range of torque adjustment, then two performance tests shall be performed following the completion of the defined number of operating cycles. One at the upper limit of the defined torque adjustment range and the other at the lower limit, as specified in Clause 6.

8 Determination of the combined precision of built-in torque measurement systems

8.1 General

Some threaded fastener tool systems, particularly electric powered tools, have built-in torque measurement systems. These systems give the user the ability to monitor the torque applied to the fastener during each tightening cycle.

The peak torque values as measured by these systems are often used in production environments as pass/fail criteria for the tightening process and may be used to control the tool. In addition, this data may be used for statistical process control or stored for future use.

Therefore, the precision of the torque readings as measured and recorded by the built-in torque measurement systems should be determined.

Information on the method to be adopted where such a determination is required is given in Annex E.

9 Evaluation of test results

9.1 Torque scatter

For evaluating tool performance on each of the H and L joints, the following shall be calculated from the test results:

— mean torque, $\bar{T}$;

— standard deviation, s;

— $6s$ torque scatter;

— $6s$ torque scatter as a percentage of the mean torque.

The mean torque $\bar{T}$ is calculated using Formula (1):

$$\bar{T} = \frac{1}{n}\sum_{i=1}^{n} T_i \qquad (1)$$

where

n is the number of readings;

T_i is the torque measured on the ith reading.

The standard deviation is calculated using Formula (2):

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(T_i - \bar{T}\right)^2} \qquad (2)$$

The $6s$ torque scatter as a percentage of the mean torque is given by Formula (3):

$$100 \times \frac{6s}{\bar{T}} \qquad (3)$$

9.2 Combined torque scatter

Since joints of uniform torque rate are very rarely used in practical applications, the tool performance on a single torque-rate joint such as H or L is of limited use in evaluating how a tool performs in actual use. However, since joints H and L represent the upper and lower limits of the practical range of torque rates found in actual applications, an analysis combining tool performance on the two test joints yields an evaluation of the tool performance on all actual applications within that range.

For evaluating tool performance over the range of practical torque rates from H through L, the following shall be calculated and listed:

— combined mean torque;

— mean shift;

— mean shift as a percentage of the combined mean torque

— combined torque scatter;

— combined torque scatter as a percentage of the combined mean torque.

For use in the calculations given below, the following values are defined:

$a = \bar{T}_H + 3s_H$

$b = \bar{T}_L + 3s_L$

$c = \bar{T}_H - 3s_H$

$d = \bar{T}_L - 3s_L$

The combined mean torque, $\bar{T}_{comb}$, is calculated as the higher of *a* and *b* plus the lower of *c* and *d;* divided by 2.

The mean shift is calculated as $\bar{T}_H - \bar{T}_L$.

The mean shift as a percentage of the combined mean torque is given by Formula (4):

$$100 \times \frac{(T_H - T_L)}{T_{comb}} \quad (4)$$

The combined torque scatter ΔT_{comb} is calculated as the higher of *a* and *b* minus the lower of *c* and *d.*

The combined torque scatter as a percentage of the combined mean torque is given by Formula (5):

$$100 \times \frac{\Delta T_{comb}}{\bar{T}_{comb}} \quad (5)$$

The combined torque scatter as a percentage of the combined mean torque shall be considered the tool's torque scatter performance at the defined test torque level.

9.3 Torque scatter over a defined range of torque adjustment

Tool performance may be identified over a defined range of torque adjustment by performing two tool performance tests as specified in Clause 6. The combined torque scatter as a percentage of the combined mean torque shall be determined for both the upper limit and the lower limit of the defined torque adjustment range.

If a single torque scatter value (combined torque scatter as a percentage of the combined mean torque) is to be presented for the defined range of torque adjustment, the larger value at either test torque level shall be chosen.

9.4 Torque scatter over a defined number of operating cycles

Tool performance may be identified over a defined number of standard operating cycles as specified in Clause 7. The combined torque scatter as a percentage of the combined mean torque shall be determined for a new, unused tool and for the same tool after completing the defined number of operating cycles.

If a single torque scatter value (combined torque scatter as a percentage of the combined mean torque) is to be presented for a defined number of operating cycles, the larger value from either performance test shall be chosen.

10 Presentation of test results

10.1 Test report

The following information shall be given in the test report:

a) reference to this document, i.e. ISO 5393:2017;

b) name of the measuring laboratory;

c) date of test and name of the person responsible for the test;

d) specification of the test tool (manufacturer, type, serial number, number of operating cycles, etc.);

e) power supply media level (air or hydraulic pressure/supply voltage, etc., as applicable);

f) ambient conditions;

g) test fixtures including connecting shafts and couplings;

h) measuring instrument (manufacturer, type, serial number, etc.);

i) operating conditions, and other quantities to be specified;

j) test torque level and defined torque adjustment range;

k) control settings for electronically controlled tools;

l) detailed results of the test, including:

— mean torque for H and L joints;

— standard deviation for H and L joints;

— $6s$ torque scatter for H and L joints;

— $6s$ torque scatter % of mean torque for H and L joints;

— tightening time for H and L joints;

— sample graphs of torque vs. time and torque vs. angle for H and L joints;

— combined mean torque;

— mean shift;

— mean shift % of combined mean torque;

— combined torque scatter;

— combined torque scatter % of combined mean torque;

m) precision of the built-in torque measurement system (where applicable), including:

— mean torque difference for H and L joints;

— standard deviation of the torque difference for H and L joints;

— combined scatter of the torque difference;

— combined scatter of the torque difference % of combined mean torque;

n) deviations from the provisions of this document (where applicable).

Annex F provides an example of a performance test form.

If tool performance is to be identified over a defined number of operating cycles, a second tool performance test shall be performed on the test tool after the defined number of operating cycles. In addition to the detailed test results given above, the following details shall be recorded:

o) operating cycle test joint details

p) sample graphs of torque vs. time and torque vs. angle for the operating cycle test joint;

q) operating cycle rate;

r) details of forced heat transfer (if applicable);

s) defined number of operating cycles;

t) torque adjustment events (if applicable);

u) maintenance service events.

10.2 Tool performance rating

Annex G defines torque scatter performance classes and provides a structured method for describing tool performance over a defined torque adjustment range and over a defined number of operating cycles. If a single tool performance rating is to be declared to describe the performance of a single power tool for tightening threaded fasteners or to describe the performance of an entire production series, the method given in Annex G may be used.

Annex A
(informative)

Preferred test torque levels

In order to minimize the number of test joints necessary for a wide range of test torque levels, the following list of preferred test torque levels is provided.

The test torque values identified in the Table A.1 are given as examples and do not restrict the user of the document from using values higher or lower than those identified.

Table A.1 — Test torque values

Test torque level N·m		
1,0	10	100
1,2	12	120
1,6	16	160
2,0	20	200
2,5	25	250
3	30	300
4	40	400
5	50	500
6	60	600
8	80	800

NOTE These preferred test torque levels are based on the R10 mathematical increment series whereby each value is approximately related to the previous value by the factor $\sqrt[10]{10}$ = 1,259.

Annex B
(informative)

Example test fixtures for rotary tools for threaded fasteners

B.1 General design

Test fixtures may be of any suitable design to meet the test joint requirements specified in 5.2.2.

The test fixtures should be durable enough to allow extended use without adversely affecting the repeatability of the test results. Preferably, a test fixture should provide for some means of adjustment to allow its use for different test torque levels.

The examples given in this annex are intended to illustrate known designs that have proven to be suitable for this purpose.

Alternative designs using other principles (e.g. hydraulic, electro-mechanical, etc.) can be equally suitable.

B.2 Test fixture with interchangeable disc

B.2.1 General

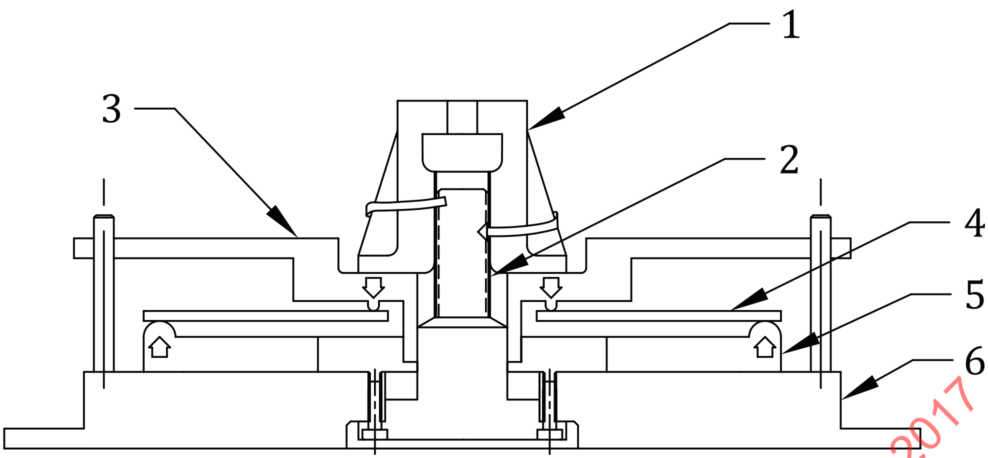
The example test fixture shown in Figure B.1 is constructed on a base. A bolt is fixed to this base. An interchangeable disc is supported on its lower side, near its outside diameter, by the outer support. The interchangeable disc is deflected by means of a nut which transmits the bolt load through the inner support.

B.2.1.1 Bolt and Nut

The bolt and nut should be hardened and the thread and friction surfaces are preferably lubricated by means of suitable grease.

B.2.1.2 Interchangeable discs and supports

Specified torque rates which comply with the requirements of this document for different test torque levels may be obtained by means of various interchangeable discs having different diameters and thicknesses. The inner and outer supports, the test bolts and the nuts may also be varied.



Key

1 nut
2 bolt
3 inner support
4 disc (interchangeable)
5 outer support
6 base

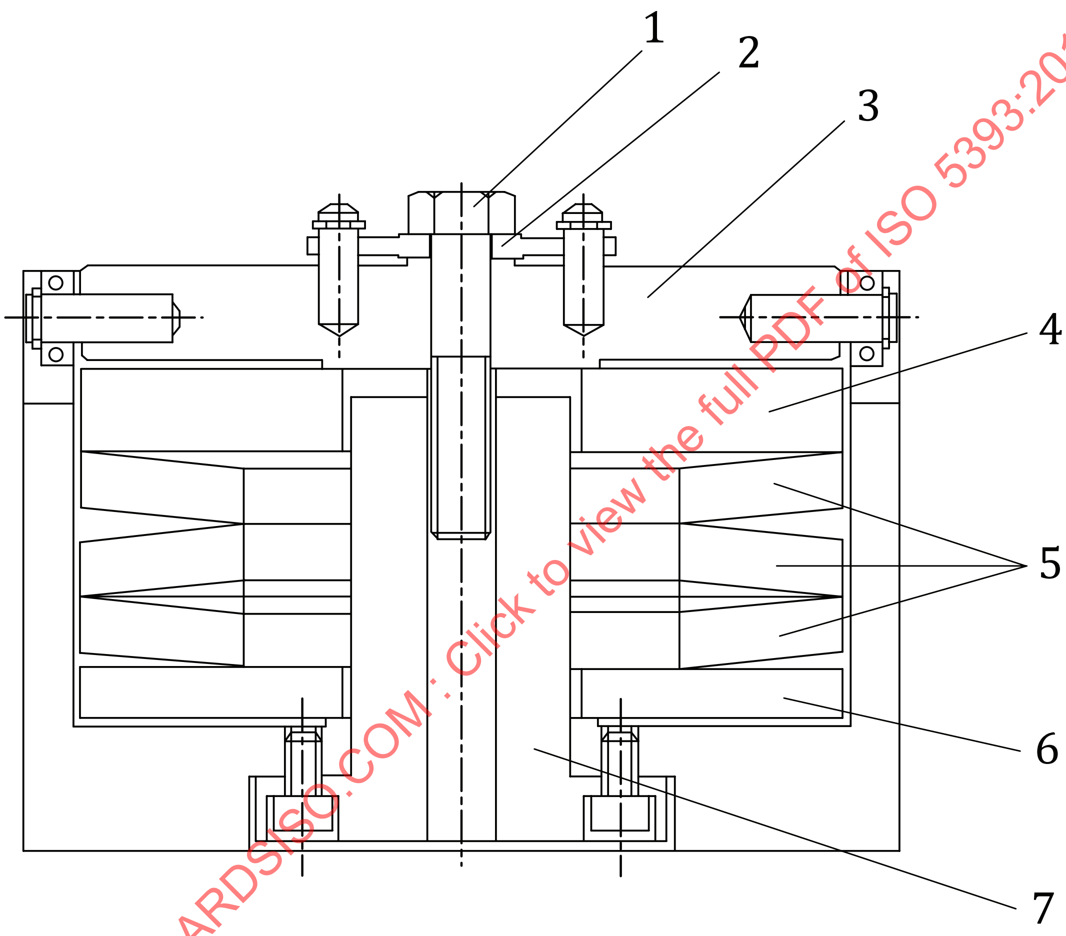
Figure B.1 — Test fixture with interchangeable disc

B.2.2 Test fixture with Belleville spring washers

B.2.3 General

The example test fixture shown in Figure B.2 is constructed within a cylindrical housing. A threaded nut is fixed to the housing. A series of Belleville spring washers are stacked within the housing. The Belleville spring washers are deflected by means of a test bolt which transmits the bolt load through an under head washer, a top plate and a spring plate.

In order to meet the requirements of this document and to obtain test results with acceptable repeatability and reproducibility, the test joint should be designed so as to have a linear torque rate.



Key

1 test bolt
2 under head washer
3 top plate
4 spring plate
5 Belleville washers (as required)
6 spacer (as required)
7 threaded nut

Figure B.2 — Test fixture with Belleville spring washers

B.2.3.1 Test bolt

In order to have good durability and to provide constant friction characteristics, the test bolt preferably has a special surface coating (NEDOX) which minimizes any stick slip effect between screw head and under-head washer as well as between the thread itself.

B.2.3.2 Under-head washer

All parts which take up torque should be hardened and the surfaces of the under-head washer should be super finished down to 0,5 µm. It should also be properly centred and tangentially fixed with two pins and minimum play in order to prevent any torque-induced displacement during the tightening process.

B.2.3.3 Top plate

The top plate supports the under-head washer and should also be properly centred and tangentially fixed with little play. Two ball bearings at the circumference minimises additional friction when the top plate is moving downwards relative to the housing during the tightening process.

B.2.3.4 Spring plate and spacer

The spring plate may be used to finely adjust the torque rate requirements. The spacer may be used to fill up the space below the Belleville springs in order to maintain a desired distance between the top plate and the threaded nut. Spring plates and washers of different thicknesses may be used to fulfil these requirements.

B.2.3.5 Belleville washer

To keep a constant torque rate, it is necessary to use as few Belleville springs and spacer layers as possible. A wide range of standard Belleville washers with equal outside diameter but with different thickness and different inside diameter are commercially available, so that a range of test bolt sizes and different torque rates can be used with one size of housing.

B.2.3.6 Threaded nut

The threaded nut should be hardened and the length of its internal thread should be at least twice the diameter. It is important that the test bolt always uses the total length of the nut. The top of the nut should be at a right angle to the thread, so that the top plate can be rested on it squarely. This case provides the highest possible torque rate for the test joint.

B.2.3.7 Condition of the test joint

To maintain the condition of the test joint, all parts should be handled with care. It is recommended to lubricate the thread and the under-head washer occasionally to improve the durability.

B.3 Test fixture with hydraulically actuated spring

B.3.1 General

The example test fixture shown in Figure B.3 is a hydraulic test joint that allows various joint rates to be selected by changing springs.

B.3.2 Operating principle

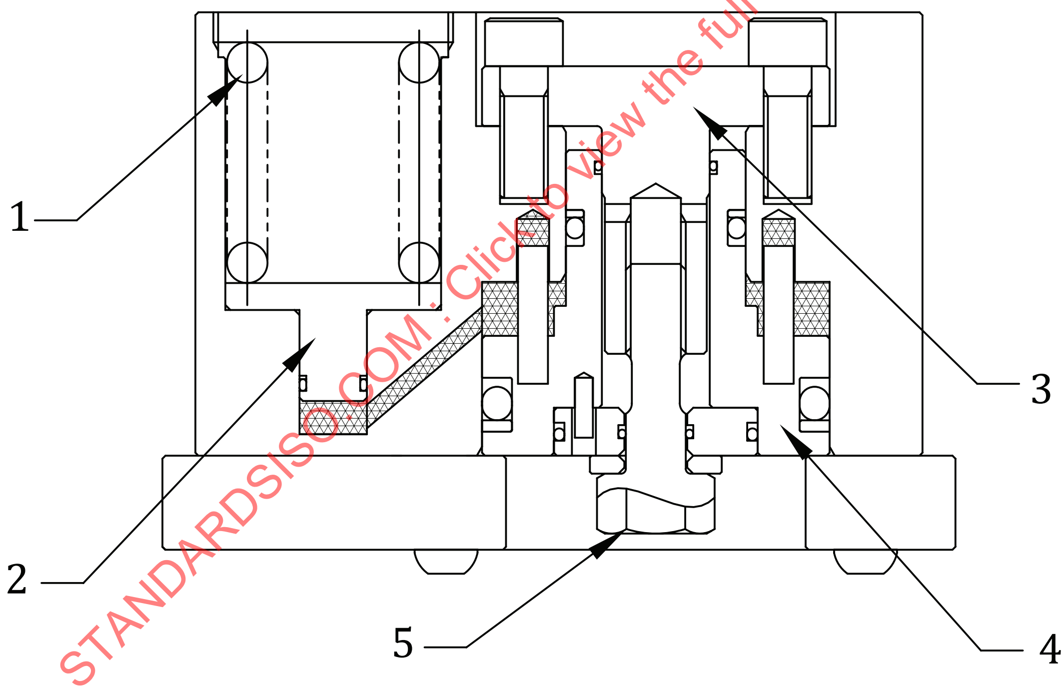
The hydraulic test joint operates on the following principle.

a) The plunger (Figure B.3, item 4) is fastened by the spindle nut (Figure B.3, item 3) and the test bolt (Figure B.3, item 5).

b) The fastening force is transferred to the piston (Figure B.3, item 2) through hydraulic fluid.

c) The movement of the piston (Figure B.3, item 2) is restricted by the compression spring (Figure B.3, item 1).

d) The joint rate is determined with the spring (Figure B.3, item 1) adjusted to the required test torque level.



Key

1 spring
2 piston
3 spindle nut
4 plunger
5 test bolt

Figure B.3 — Test fixture with spring

Annex C
(informative)

Test joint (additional information)

C.1 General

The first version of this document was published in 1981. Since that time, extensive use of this document has led to continuous improvement of the performance of the tightening tools covered within its scope.

On a specified joint, torque scatter ($6s \pm 3s$) of less than 15 % is commonly obtainable. This calls for precise specifications of the test requirements. These were reflected in the second edition, published in 1994.

The precise specifications refer to the requirements of torque rate and linearity of the high torque rate test joint and to the frequency response of the transducer and amplifier connected to the in-line torque transducer used for torque measurements. Furthermore, the high torque rate joint specified in the second edition was doubled compared to the first edition. This was because joints exist having torque rates corresponding to tightening angles of 30°.

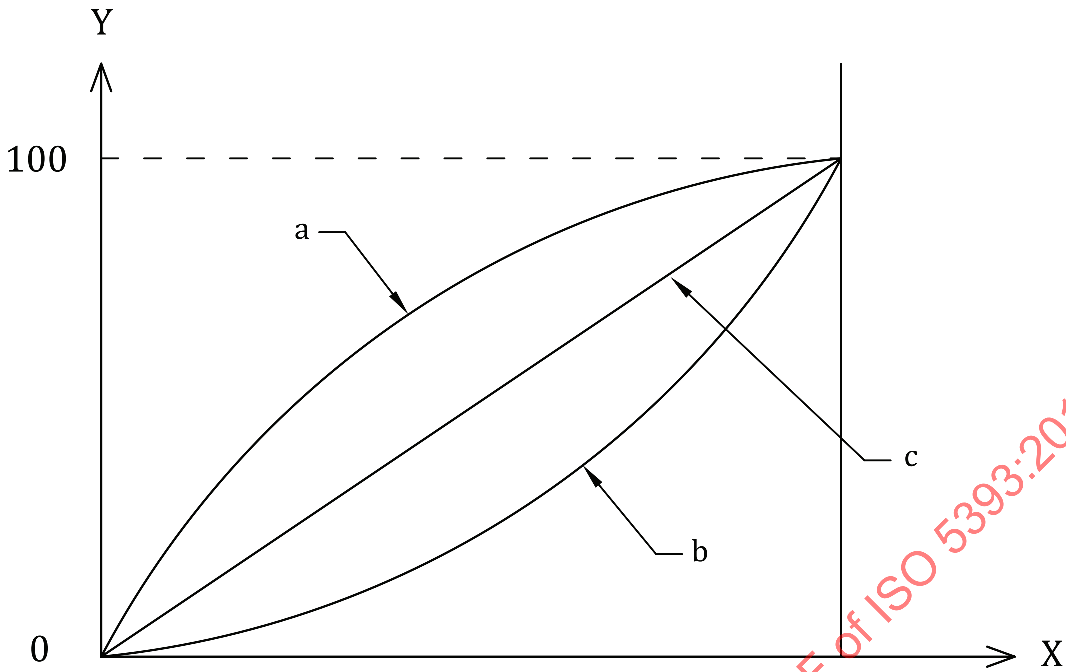
The H and L test joints specified in this document require this high precision in order to achieve reproducibility.

They reflect the common extremes of actual fastening practice, so that the tool precision revealed through tests on these specified joints can be applied to the range of fastening tasks encountered in the workplace.

Extensive use of this document has demonstrated the practicality of the method. It has been commented that the test method has become a "laboratory test method." This may be the consequence of the document, but with today's development of accurate power tools, test requirements have to be accurate to reflect the capability of the tools within its scope. A producer of power assembly tools would have this type of test equipment as part of its development laboratory.

C.2 High torque rate test joint

It is important that the test joint used is precisely specified to obtain consistent results when tools are tested on different joints with the same specification. The tightening process from the rundown to the test torque level is greatly affected by the linearity of the test joints, particularly for tools whose rotational speed is inversely related to the instantaneous torque load.



Key

X angle

Y torque level, expressed in percent

a joint with decreasing rate

b joint with increasing rate

c joint with ideal linear rate

Figure C.1 — Diagram showing joints having different rates

A process such as (a) in Figure C.1 would retard the tool at the beginning of the tightening. Thereby, the kinetic energy stored in the rotating parts is reduced when the test torque level is reached. A torque over-shoot is then not as likely to occur. A process such as (b), however, would be the opposite. The speed of the rotating parts would be high as the test torque level is reached. Thereby, the torque overshoot, i.e. the additional torque obtained due to the kinetic energy conversion, would be high.

Practical experience has demonstrated that a linearity demand of ±5 % of the test torque level above the 10 % level of the test torque is adequate (see 5.2.2.2 and Figure 3).

A linearity of this order of magnitude is obtainable with spring washer or steel torsion bar test joints. In view of the friction in the test joint, the linearity demand starts at the 10 % torque level.

C.3 Low torque rate test joint

The low torque rate joint shall be such that the rotational speeds of the moving parts are so small that torque overshoots are unlikely to occur when reaching the test torque level. In practice, this is readily achieved with tightening angles corresponding to one to three revolutions of the fastener.

C.4 Calibration and maintenance frequencies of test equipment

Test joints should have regular calibration and maintenance schedules established. These schedules at a minimum should be done on an annual basis, and adjusted according to use.

Annex D
(informative)

Determination of uncertainty of test joint measurements

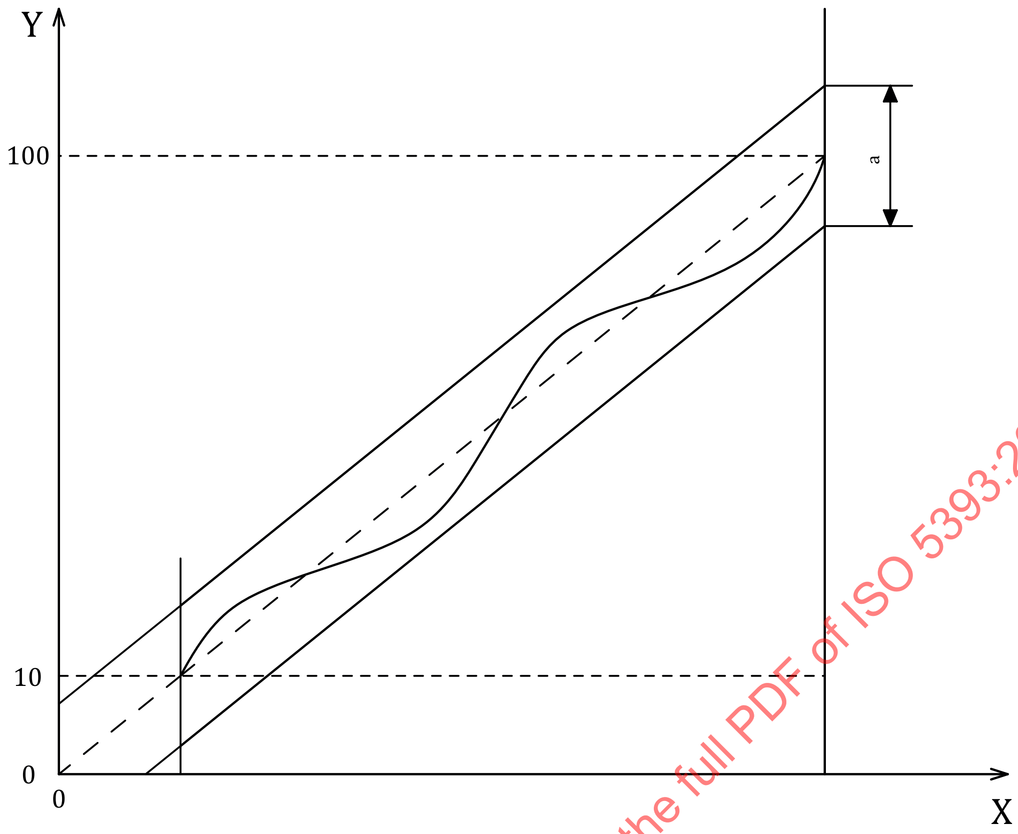
D.1 Tolerance

When the torque rate of the test joint is measured, it shall be tightened continuously (slowly and evenly) to minimize introduction of dynamic effects. The linearity of the test joints is calculated by a regression analysis of the sampled torque/angle measurement values.

The linearity requirement for the high torque rate joint specifies a 10 % tolerance for torque. This implies a tolerance of 3° regarding angle. The corresponding demand for the low torque rate joint (>360° joint) is 20 % tolerance leading to a tolerance larger than 72°. The high-torque joint requirement by that necessitates higher measurement accuracy.

From the test run under constant low speed the test joint is examined. Both angle and torque are recorded and the (angle, torque)-points are evaluated against this tolerance.

From the linear regression a tolerance band is defined, which in Figure D.1 is visualized with the two continuous lines. The criterion is that all points from the test curve shall lie within this tolerance band.



Key

X angle

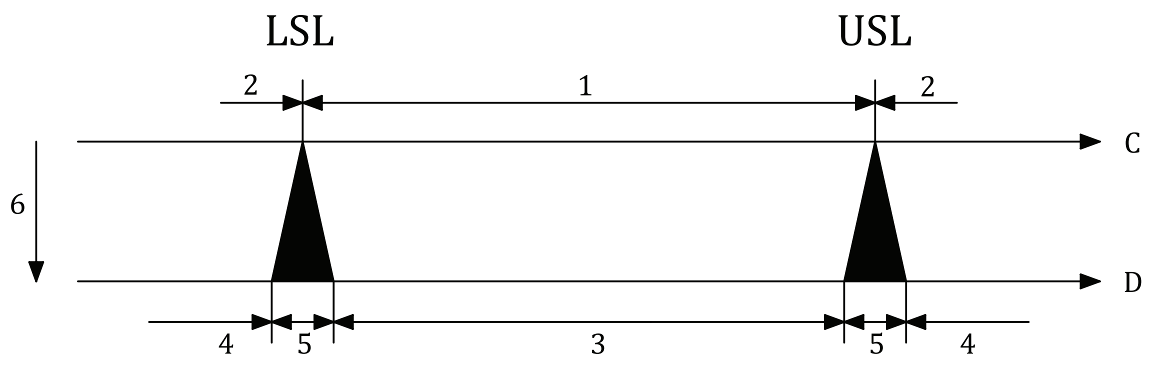
Y torque level, expressed in percentage of the test torque level

a ±5 % of test torque.

Figure D.1 — Diagram showing torque rate linearity for the high torque-rate joint

D.2 Uncertainty

As there exists an uncertainty both of measured angle and torque, the significance of this test is reduced. Testing against tolerances with consideration of measurement uncertainty is described in ISO 14253-1.



Key

C design/specification phase
D verification phase
1 specification zone (in specification)
2 out of specification
3 conformance zone
4 non-conformance zone
5 uncertainty range (gray zone)
6 increasing measurement uncertainty, U

Figure D.2 — ISO 14253 decision rules

The specification zone [1] is limited by the tolerance USL-LSL and the conformance zone [3] is reduced with the measurement uncertainty, see Figure D.2. The decrement corresponds to a grey zone [5] where it cannot with full certainty be stated if the tested equipment is conforming or non-conforming.

As sound practice, the measurement uncertainty MU and resolution are chosen as a fraction of the tolerance, T:

2*MU/T < 0,2 - 0,4 of tolerance (for double sided tolerance, e.g. VDA-5)

and;

Resolution/T < 5 % - 10 % (e.g. VDA-5 is 5 % and QS 9000 MSA is 10 %).

or rewritten, the demands for measurement uncertainty and resolution should be:

MU < 10 % - 20 % of tolerance

Resolution < 5 % - 10 % of tolerance

With the above tolerances as 10 % of test torque for torque and 3° angle:

Torque:

MU < 1 % - 2 % of test torque

Resolution < 0,5 % - 1 %.

Angle:

MU < 0,3° - 0,6°

Resolution < 0,15° - 0,3°.

These are minimum recommendations. As torque is the main performance unit there are additional needs of accuracy for torque which are all well within the limits above. The measurement uncertainty for torque transducer is in this document set as ≤1 % and resolution ≤0,25 %.

The measurement uncertainty of the angle encoder should encompass dependency of angle position, repeatability, speed, torque and resolution.

In this document, there also exists a demand of graphical documentation of torque over angle (see 5.3.7). The measurement uncertainty and resolution influences the quality of these graphs.

