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Aerospace series — Dynamic testing of the locking behaviour of bolted connections under transverse loading conditions (vibration test)

Aéronautique et espace — Essai dynamique des caractéristiques de freinage des éléments de fixation, dans des conditions de charge transversale (essai de vibration)

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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 4, *Aerospace fastener systems*.

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Aerospace series — Dynamic testing of the locking behaviour of bolted connections under transverse loading conditions (vibration test)

1 Scope

This International Standard applies to the dynamic testing of the locking behaviour of bolted connections in order to investigate the self-loosening behaviour of fasteners for aerospace applications and is mainly intended for development work.

As test apparatuses are different (e.g. stiffness distribution), testing in accordance with this International Standard, therefore, does not allow an absolute statement to be made on the locking behaviour of bolted assemblies under service loads.

Thus, the objective of this test is a comparative evaluation of locking elements under defined test conditions.

2 Normative references

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

ISO 16047, *Fasteners — Torque/clamp force testing*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16047 and the following apply.

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

[SOURCE: ISO 16047:2005, 3.1; modified — without restriction “during tightening”]

3.2
ultimate clamp force
F_u
theoretical maximum clamp force under combined stress condition potentially induced before bolt/nut failure

[SOURCE: ISO 16047:2005, 3.3, modified]

3.3
initial clamp force
F_M
clamp force after tightening of test specimen before test

3.4
relative clamp force loss
Y

$$Y = \left(1 - \frac{F}{F_M}\right) * 100\,\%$$

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3.5
number of load cycles
N
number of transverse movements of the glider plate of the apparatus

3.6
pitch diameter
D_2
d_2
diameter of the pitch cylinder or pitch cone

[SOURCE: ISO 5408:2009, 5.9, modified — without reference, without note]

3.7
minor diameter
D_1
d_1
d_3
diameter of an imaginary cylindrical or conical surface tangent to the roots of an external thread and/or to the crests of an internal thread

[SOURCE: ISO 5408:2009, 5.3, modified — without references, without notes]

3.8
tightening torque
T
overall torque applied on nut or bolt head in tightening

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[SOURCE: ISO 16047:2005, 3.4, modified — without substitutes]

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3.9
self-locking torque
prevailing torque
torque to be applied to the nut or bolt to maintain its movement of rotation in relation to the associated part, the assembly being under no axial load, and the nut-locking system being completely engaged with the bolt (two pitches minimum protrusion, including the end chamfer)

[SOURCE: ISO 5858:1999, 3.15]

3.10
transverse displacement
t_s
transverse movement of the glider plate in both directions from fastener centre line

Note 1 to entry: It is expressed in millimetres.

4 Test principle

The fasteners under test are tightened in a vibration testing machine to achieve a defined clamp force, F_M, and then subjected to dynamic transverse loading. No additional axial operating force is applied to the fasteners.

The change in clamp force during the vibration test is measured.

The test terminates after a specified number of load cycles or upon fracture of the bolt, stabilization of residual clamp force, or upon complete loss of clamp force.

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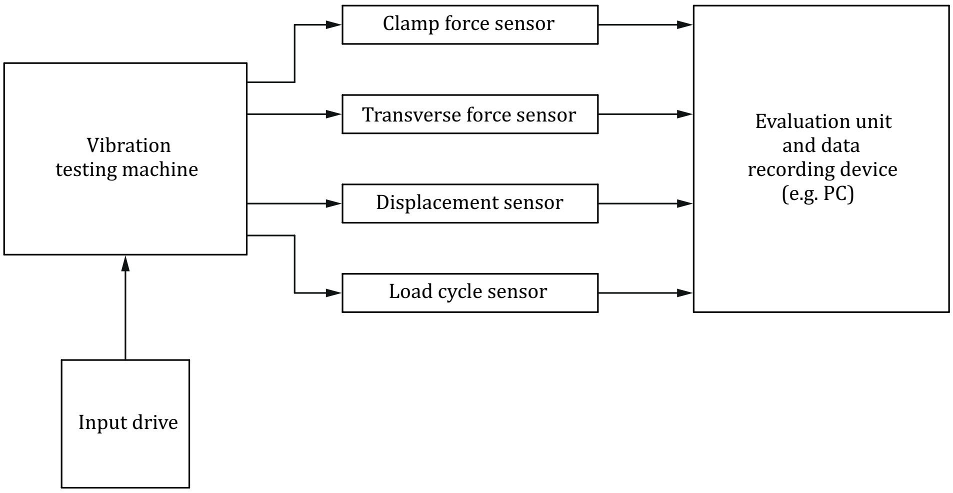
5 Apparatus

5.1 Schematic overview of components

See Figure 1.



NOTE Transverse force sensor is optional.

Figure 1 — Schematic overview of components

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5.2 Test machine description

The machine (see Figure 2 for an example of a vibration testing machine) essentially consists of e.g. a motor drive or a hydraulic drive generating a transverse displacement in the test fixture.

The test fixture consists of a stationary base and a floating glider plate which acts as clamped members in the bolted joint in which the fastener to be tested is installed. The glider plate contains a rotationally immobilized washer (test washer). The stationary base accommodates a clamp force-sensor for measuring the clamp force between the glider plate and the stationary base. In the force-sensor, a test insert is used that it is locked to prevent it from rotating. The relative movement between the stationary base and the glider plate is measured with a displacement sensor.

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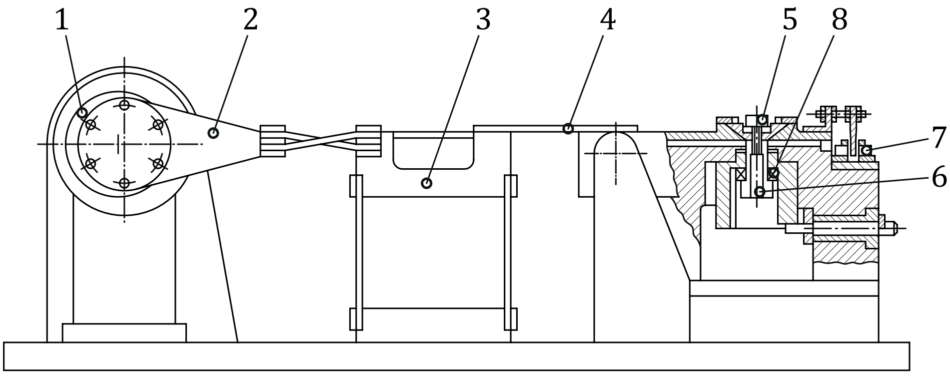

Key

1 infinitely adjustable eccentric
2 connecting rod
3 transverse force sensor (optional)
4 connecting plate
5/6 fastener test assembly
7 displacement sensor
8 clamp force sensor (axial)

Figure 2 — Example of a vibration testing machine

5.3 Apparatus requirements

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The apparatus shall meet the following requirements.

a) The relative movement (transverse displacement) between the stationary base and glider plate shall be infinitely variable, preferably during operation and adjusted through electronic control. In the thread diameter range up to 25,4 mm, the clamped-up testing facility shall permit relative movements of up to ±1,5 mm between the stationary base and the glider plate.

b) Testing frequency between 10 Hz and 15 Hz shall be possible; the frequency during the testing shall be at an accuracy of ±3 %.

c) Measurement uncertainty for the clamp force shall be within ±2 % as measured on the entire measuring chain consisting of sensor, cable, charge amplifier, and data acquisition device. The entire measuring chain shall be calibrated accordingly.

d) Measurement uncertainty for the transverse displacement shall be within ±3 % as measured on the entire measuring chain consisting of sensor, cable, charge amplifier, and data acquisition device. The entire measuring chain shall be calibrated accordingly.

e) The stationary base and the glider plate shall be concentric within ±0,1 mm at the mid-position of transverse displacement.

f) The following variables are to be measured and recorded: initial clamp force, clamp force in relation to number of load cycles, test frequency, transverse displacement plus the applied installation torque values.

g) The glider plate shall be precisely guided in the transverse direction within a tolerance of ±0,10 mm of lateral movement.

h) The stationary base and the glider plate shall be designed such that the clamp force cannot bend them. The gap between the stationary base and glider plate at fastener position shall be 1 mm ± 0,05 mm under load.

6 Test procedure

The test procedure consists of two elements; the reference test and the verification test.

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The reference tests are to be carried out on an unsecured bolted joint, assembled in the same way, and with the same parameters as specified for the verification tests that will determine the securing effect of the securing element under test.

During the reference tests, the effective transverse displacement is varied through corresponding adjustments to the drive for the test equipment (the stroke). For reasons of reproducibility, the transverse displacement at which the pre-stressing force is fully lost after 300 ± 100 load cycles shall be ascertained three times, using new parts each time. This transverse displacement provides the basis for the verification tests.

For reasons of reproducibility, a valid reference test shall be carried out three times, using new parts each time. The verification test has to be done in the same condition and settings as the reference test.

The glider plate is positioned to zero transverse displacement. The fasteners to be tested (bolt or nut) is inserted and tightened to the defined clamp force. The effective transverse displacement is verified continuously during the vibration test. The clamp force is recorded versus the number of load cycles (see Figure 3). The test is carried out at room temperature.

If locking element is not damaged after test, it can be tested multiple times to validate self-locking behaviour at multiple installation cycles, if required by test requester.

7 Test settings

Self-locking elements (e.g. nut, washer, split pin, lock wire, etc.) shall be tested typically with a transverse displacement t_s = ±0,5 mm for fastener dimensions up to and including M12/0.500” and t_s = ± 0,8 mm for fastener dimensions above M12/0,500” and at a frequency of 12,5 Hz and with the clamp force specified in Table 1 and Table 2 (representing 75 % of calculated F_u). Clamp force has to be adjusted to the weakest element of the assembly either bolt or nut strength class.

The length to diameter ratio shall be as short as possible and preferably around 2,0 to 2,5.

Different test settings could be defined by test requester.

To achieve reproducible results, the following factors need to be defined unambiguously:

a) initial clamp force (see examples Table 1 and Table 2);

b) testing frequency;

c) effective transverse displacement;

d) adjustment of the test fixture to the fastener length.

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