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E DIN 25201-4:2010-03 Annex B

(normative)

Test specification for demonstrating the resistance to self-loosening of secured bolted joints

B.1 Purpose and methods of testing

The purpose of the tests is to determine and facilitate a comparative assessment of the self-loosening behaviour of bolted joints subject to dynamic transverse stress under defined test conditions. The comparative assessment is made possible by comparing the results of:

- reference tests using an unsecured bolted joint.
- verification tests using a bolted joint secured with the aid of a securing element.

The purpose of the reference tests is to find the effective transverse displacement. This will serve as a reference figure for the securing effect that is to be determined through the verification test.

The test specification is based on the principle that the element must be tested in a manner that corresponds to its actual application. The minimum stressing force required for the assembly procedure is taken into account. The results of the test are not valid for elements with other sizes (diameter, surface area, materials).

B.2 Test set-up

The construction of the test set-up with which the reference and verification tests are carried out must be based in general on DIN 65151. Figure B.1 shows an example of a test block.

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Data recording and evaluation

Displacement

Item under test

Inductive displacement sensor

Four-wire strain gauges connected as a full bridge

Figure B.1 — Test block

Force or displacement excitation

Data recording and evaluation

Bolted joint under test

Figure B.2 — Relationship between the measuring points

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B.3 Test fittings

There is a set of test fittings for the:

- reference test, consisting of a bolt and nut/screw-on part, all having the standardized dimensions, and a washer.
- verification test, consisting of a bolt and nut/screw-on part, all having the standardized dimensions, the securing element under test, and a washer.

The washer substitutes for the surface that would support the component when assembled in practice. The washers used must be compliant with the DIN EN ISO 7093-1 specifications. The hardness of the washers must be:

- 200 HV for strength grades classified as up to and including 8.8.
- 300 HV for strength grades classified as above 8.8.

The surface of the washers, which are not coated, is to be ground. The plane-parallelism and flatness must comply with DIN EN ISO 4759-3 specifications, and the roughness must comply with DIN EN ISO 7093-1 specifications. The direction in which the washers are ground must match the direction of the transverse displacement of the top slide.

The washer must be securely prevented from turning.

B.4 Test conditions

B.4.1 Testing frequency

The testing frequency is 12.5 Hz. If other test frequencies are used it is necessary to ensure that the test equipment is suitable for them, and that there are no resonances in the test equipment that could affect the test result.

B.4.2 Use of parts

New parts must always be used for the fittings used in each test. It is not permitted to reuse parts that have already been stressed. This includes the washer, the bolt and nut that are mounted in the test insert when testing the bottom piece.

The dimensions and other properties of the securing elements must fully correspond to those of standard parts.

B.4.3 Surfaces

The surfaces of the parts used as the test fittings must be specified. Preferably, the surfaces are to be specified in a way that reflects the practical application for which the tests are relevant. This means typical commercial surface finishes are to be preferred.

B.4.4 Quality categories (tolerances)

The quality category of all the parts constituting the test fittings must be specified. Generally speaking, the parts should correspond to quality category A or B.

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B.4.5 Mounting position of the bolted joint

The bolted joint is to be tested as a push-through joint. Either:

- the securing bolt or the bolt with the securing element under test is held by the upper part of the test equipment, which is capable of transverse movement. The nut with which stress is applied is held by the test insert that is in the stationary lower part.

Or:

- the securing nut or the nut with the securing element under test is held by the upper part of the test equipment, which is capable of transverse movement. The bolt with which stress is applied is held by the test insert that is in the stationary lower part.

B.4.5 Clamp-length ratio of the bolted joint

The clamp-length ratio of the bolted joint under test must be 1.7:1.

B.5 Execution of the test

B.5.1 Stressing and pre-stressing force

The test fittings are tightened with a spanner until the pre-stressing force specified for the assembly of this particular type of joint is reached. The pre-stressing force can be found in Table B.1. It is 50% of the figures quoted in VDI 2230 (upper limit of the permitted coefficient of friction range μ_G = 0.14).

Table B.1 — Pre-stressing forces to be set up for the tests (lower pre-stressing force F_{vmin} for general assembly procedures)

Bolt strength category ISO 898-1, ISO 3506-1	Test pre-stressing force F_{vv} [kN] for testing elements for securing against self-loosening
8.8	*[Replaces commas with points in all figures in table]*
1.9	
A2-70	
A4-80	
Kl 100 self-locking bolts	

If the dimensions vary from this, the pre-stressing force must be adjusted accordingly.

B.5.2 Lubrication of the test fittings

The contact surfaces of the bolt head and the nut contact area, the securing element, and the washer are to be lightly oiled with a lubricant of viscosity SAE 30, e.g. HD 30 lubricating oil. A lubricant specified by the manufacturer can also be used, depending on how the part will be installed.

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In order to exclude the possibility of an illusory securing effect caused by cold-soldering of stainless steel or electro-galvanized parts, the thread and the contact surfaces of the washer are to be smeared with molybdenum sulphide paste when testing such parts.

B.5.3 Reference tests

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 must 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 must be carried out three times, using new parts each time.

B.5.4 Verification tests

The verification tests are to be performed either:

- until the pre-stressing force is fully lost.

Or:

- until 2,000 load cycles have been completed.

12 tests are to be carried out for each series of measurements.

For type approval tests, every diameter of securing element must successfully pass the verification test. The results of a verification test do not apply to other diameters than those tested.

B.5.5 Measured variables

During the reference and verification tests, the following variables are to measured and recorded:

- pre-stressing force.
- transverse displacement under load.
- number of load cycles.

B.6 Assessment

The securing effect of the securing element can be judged from a graph of pre-stressing force against the number of load cycles. The securing effect is assessed on the basis of either:

- whether full loss of pre-stressing force occurs before 2,000 load cycles have been completed.

Or:

- the percentage loss of pre-stressing force after 2,000 load cycles.

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The securing effect is considered to be adequate if the pre-stressing force remaining after 2,000 load cycles is more than 80% of the pre-stressing force before the test started, and if the curve of the pre-stressing force (its gradient) does not point to the likelihood of subsequent complete loss of pre-stressing force.

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B.7 Test report

The test report must describe:

- the test fittings that were used (number, dimensions, material designations, surface designations, quality categories, type of securing element, fitting position).
- the test parameters (test frequency, clamp-length ratio, pre-stressing force, effective transverse displacement, lubrication).
- the way the test equipment has been constructed.
- the result of the test (including the graph of remaining pre-stressing force, as per the example in figure B.3).
- the conditions under which it is permissible for the securing element to be used (all assembly methods when 50% of the pre-stressing force is applied, or only yield-point controlled assembly when based on higher pre-stressing forces; lubricated or only without lubrication; permitted surface coatings, range of diameters of the element).

Figure B.3 — Example of a graph of pre-stressing force against number of load cycles.

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Annex C

(for information only)

The theory of self-loosening

A bolted joint that has been tightened is self-locking. The friction along the thread and under the head, or against the nut, acts against the internal loosening torque of the thread.

Frictional torque in the thread without the pitch component: *[formula as per source document]*

Internal loosening torque (pitch component): *[formula as per source document]*

Frictional torque at the head: *[formula as per source document]*

Tightening torque of a joint: *[formula as per source document]*

Loosening torque of a bolted joint: *[formula as per source document]*

The joint is self-locking if: *[formula as per source document]*

(As a rule, the sum of the frictional torque at the head and the torque in the thread is something like eight or nine times larger than the pitch component (the internal loosening torque)).

Self-loosening only occurs if: *[formula as per source document]*

(e.g. as a result of reducing or removing the self-locking).

Self-loosening therefore occurs:

1) if relative movements occur between the tightened components causing the frictional bond under the head of the screw or the nut to be removed, while tilting movements in the thread lower the thread friction. This happens when the “limiting displacement” is exceeded (see Figure C.1).The loosening effect is enhanced by torques that can occur as the head of the bolt slides against its supporting surface.
2) through “breathing” of the thread of the nut when loaded axially.

Effect 1) is used for testing securing elements against loosening in comparative tests (Annex B and DIN 65151).

In particular under the influence of **extremely high** dynamic bolt forces (“impacts”), dimensioning is not always a sufficient approach for securing the bolt. In these cases, a more secure bolt should be used, and/or additional measures (Section 5) should be taken, e.g. an unsprung element in the suspension system.

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(...) is the theoretical limiting displacement

B. The limiting displacement is defined as:

F_V: Pre-stressing force (F_{v_min} is the critical figure)

μ_K: Coefficient of friction under the head (minimum value!)

L_K: Clamping length (see diagram)

E: Young's modulus of the bolt (steel: 2.1E5 N/mm^2)

I: Second moment of area of the bolt (with reference to the core diameter or clamping diameter on fully threaded bolts (d_3 or d_S), otherwise a substitute second moment of area for the deducted rod (I_{ers}) is determined conservatively through an approximation calculation with the diameter of the shaft d of the d_T)

F_Q: Transverse force *[formula as per source document]*

Figure C.1 B.— Definition of the theoretical limiting displacement

When the displacement *s* [mm] of the stressed components is equal to or greater than the limiting displacement S_{Gth}, the bulkhead will slip, and the bolt become loosened.

An element to prevent self-loosening prevents the bolt head and/or nut from slipping, but does not stop the components from sliding.

Literature

[1] BN 205031-01, Schrauben — Sechskantschrauben mit Flansch — Auflagefläche gerippt[2)] (Bolts — Flanged Hexagonal Head Bolts — Ribbed Support Surfaces)

[2] BN 205 107-02, Muttern — Sechskantmuttern mit Flansch — Auflagefläche gerippt — Form C (Nuts — Flanged Hexagonal Nuts — Ribbed Support Surfaces — Form C)

2) Rail Standard: Obtainable from DB AG, DB Systemtechnik, TZF 96, Normenmanagement, Ruschestraße 104, 10365 Berlin

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