SLOVENSKI STANDARD

SIST EN 4859:2019

01-junij-2019

Aeronavtika - Uporaba senzorjev za ugotavljanje obremenitve objemke/vijaki z veliko natezno trdnostjo - Tehnična specifikacija

Aerospace series - Sensor based clamp load determination / high tensile bolts - Technical specification

Luft- und Raumfahrt - Sensor basierende Vorspannkraftmessung / hochfeste Schrauben - Technische Lieferbedingungen

Série aérospatiale - Détermination de la tension de serrage avec capteur / Boulons fortement contraints - Spécification technique

Ta slovenski standard je istoveten z: EN 4859:2019

ICS:

49.030.20	Sorniki, vijaki, stebelni vijaki	Bolts, screws, studs

SIST EN 4859:2019 **en,fr,de**

EUROPEAN STANDARD

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ICS 49.030.20

English Version

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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Contents

European foreword

This document (EN 4859:2019) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2019, and conflicting national standards shall be withdrawn at the latest by August 2019.

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Introduction

Aerospace and Defence Standardisation (ASD-STAN) draws attention to the fact that it is claimed that compliance with this document may involve the use of a patent concerning “Connector component with temperature-resistant sensor element” EP 2010883 B1, US 8,177,464 B2.

ASD-STAN takes no position concerning the evidence, validity and scope of this patent right.

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1 Scope

This European standard specifies the technical, qualification and quality assurance requirements for sensor based clamp load measurement systems for high tensile bolts and other clamp load sensitive elements. Primarily for aerospace applications, it is applicable to such products when referenced on the product standard or drawing.

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.

EN 2424, *Aerospace series — Marking of aerospace products*

EN 10204:2014, *Metallic products — Types of inspection documents*

3 Terms and definitions

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

3.1
thin film ultrasonic transducer
this kind of transducer applied to one of the two a bolt ends converts an electrical pulse in an ultrasonic wave travelling through the bolt body and transforms the reflected ultrasonic wave back into an electrical echo signal; the thereby used physical principles are the piezoelectric effect and its reversion

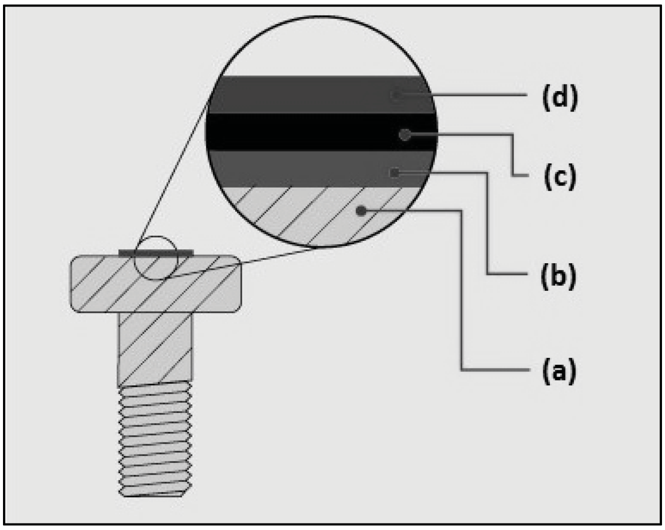
3.2
sputtering
PVD (physical vapour deposition) process to apply thin films onto a substrate; under vacuum and by means of physical methods the base material becomes transformed into the gas phase; the condensing particles form the target layer on the substrate; sputtering is used to apply thin film ultrasonic transducer on bolts

3.3
clamp load
needed axial force in a bolt to secure a save operation in a bolted joint

4 Clamp load measurements on bolts

4.1 Configuration of thin film transducer based sensor bolts

Three layers coated onto the top of the bolt (a) form an ultrasonic thin film transducer. Applied in a vacuum process the transducer becomes a permanent part of the bolt (see Figure 1). The transducer consists of a piezoelectric thin film (b), followed by a protection layer (c) and an electrode metallization (d). Figure 2 shows different sensor bolts equipped with a thin film transducer.



Key

(a) top of the bolt
(b) piezoelectric thin film
(c) protection layer
(d) electrode metallization

Figure 1 — Thin film transducer configuration

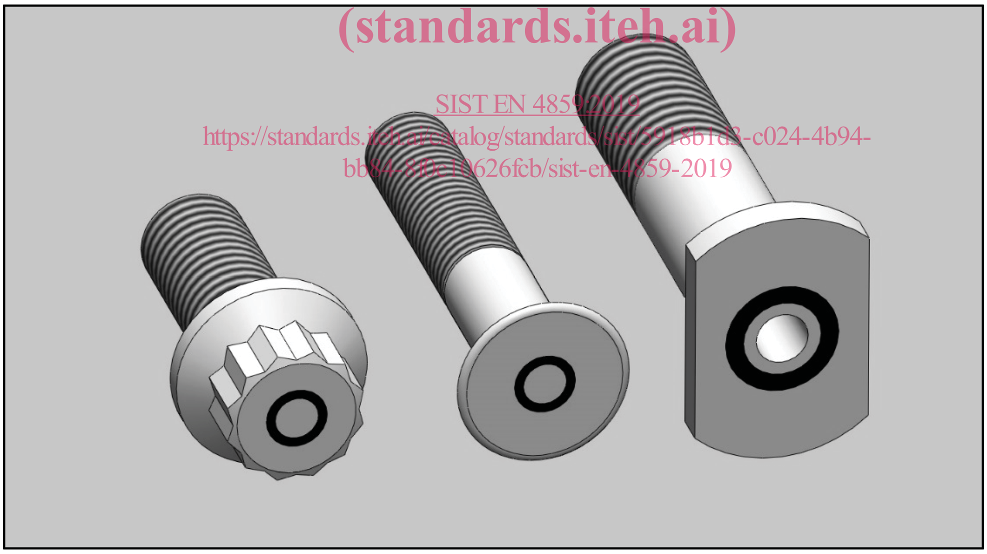


Figure 2 — Samples of sensor bolts with thin film transducer

In addition to the thin film transducer method, there are other systems to measure the clamp load in bolts. Examples are strain gages, electromagnetic acoustic transducers (EMAT) or conventional piezoelectric transducers (glued on transducer, hand held transducer).

This standard describes the requirements, test procedures etc. for thin film transducer based sensor bolts.

4.2 Determination of the clamp load on thin film transducer based sensor bolts

The ultrasonic clamp load determination in sensor bolts is based on the pulse echo method. This technique works similar to systems like sonar or ultrasonic based material testing.

The thin film transducer placed at one of the bolt ends receives an alternating current (AC) pulse. The transducer follows the change of the electrical voltage by changing its length. The coupling of the transducer with the bolts surface leads to an ultrasonic wave travelling through the bolt. The ultrasonic waves are reflected by the opposite side of the bolt and travel back in direction of the transducer (see Figure 3). There, an echo signal can be detected. The transducer works as both, as sender and receiver. Δt is the time period between pulse sending and receiving the echo.

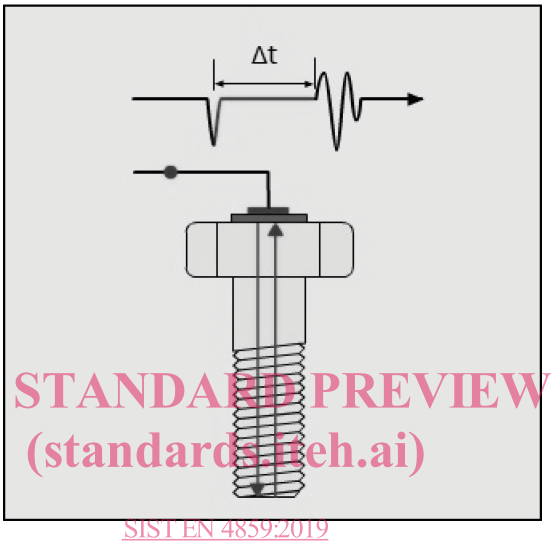


Figure 3 — Determination of the clamp load in a bolt using a thin film ultrasonic transducer

The time-of-flight (*TOF*) of an ultrasonic pulse travelling along the bolt axis shows a marked dependence on the applied tensile stress. In addition to the strain approximately given by Hook's law, there is a decrease in sound velocity, the latter of which remarkably accounts for ≈ 75 % (for steel) of the total *TOF* increase. Fortunately, both effects act in the same direction and are sufficiently linear so that the changes in *TOF* between an unloaded and a loaded state can be used as a direct measure of the applied load.

The *TOF* dependence on load can be described with low (first or second) order polynomials:

$$F = k_1 \cdot \Delta TOF = k_1 \cdot (FTOF - BTOF)$$

$$F = k_1 \cdot \Delta TOF + k_2 \cdot \Delta TOF^2$$

where

F is the load in kN;

ΔTOF is the measured *TOF* difference in ns;

$BTOF$ is the measured *TOF* under no-load conditions in ns;

$FTOF$ is the measured *TOF* under load conditions in ns;

k_1, k_2 is the material and bolt- dependent linear and quadratic load scale factors.

The desired scale factors k_1 and k_2 can be obtained by using a load cell or a tensile testing machine as reference for the applied loads and an ultrasonic measurement system to determine the *TOF* value for the different load steps.

Temperature variations affect ultrasonic *TOF* measurements by changing the length of the inspected material according to the thermal expansion law. To eliminate this influence, all *TOF* values determined and stored in the measuring device must be compensated for the current temperature. One way to do the temperature compensation is to refer all measured *TOF* values to 0 °C.

The dependence of the *TOF* on temperature can be described by a low order polynomial with sufficient accuracy. For short bolts, for materials with a highly linear thermal expansion and for small temperature ranges during *TOF* measurements, the *TOF* correction to 0 °C using a first order polynomial (straight line) is recommended. See the following formula:

$$TOF_{korr} = \frac{TOF}{(1 + C_1 \cdot TEMP)}$$

For long bolts, for materials with non-linear thermal expansion behaviour, and for large temperature ranges during *TOF* measurements, correction to 0° C using a second order polynomial (parabola) is recommended. The following formula can be used:

$$TOF_{korr} = \frac{TOF}{(1 + C_1 \cdot TEMP + C_2 \cdot TEMP^2)}$$

where

TOF	is the measured *TOF* in ns;
TOF_{korr}	is the *TOF* corrected to 0° C in ns;
Temp	is the material temperature during *TOF* measurement in °C;
C_1, C_2	is the material and bolt- dependent temperature calibration factors.

The specific material and bolt- dependent temperature calibration factors (C_1, C_2 in the formulae above) can be determined by measuring the raw (uncorrected) *TOF*s while stepping through the desired temperature range in 10 K steps.

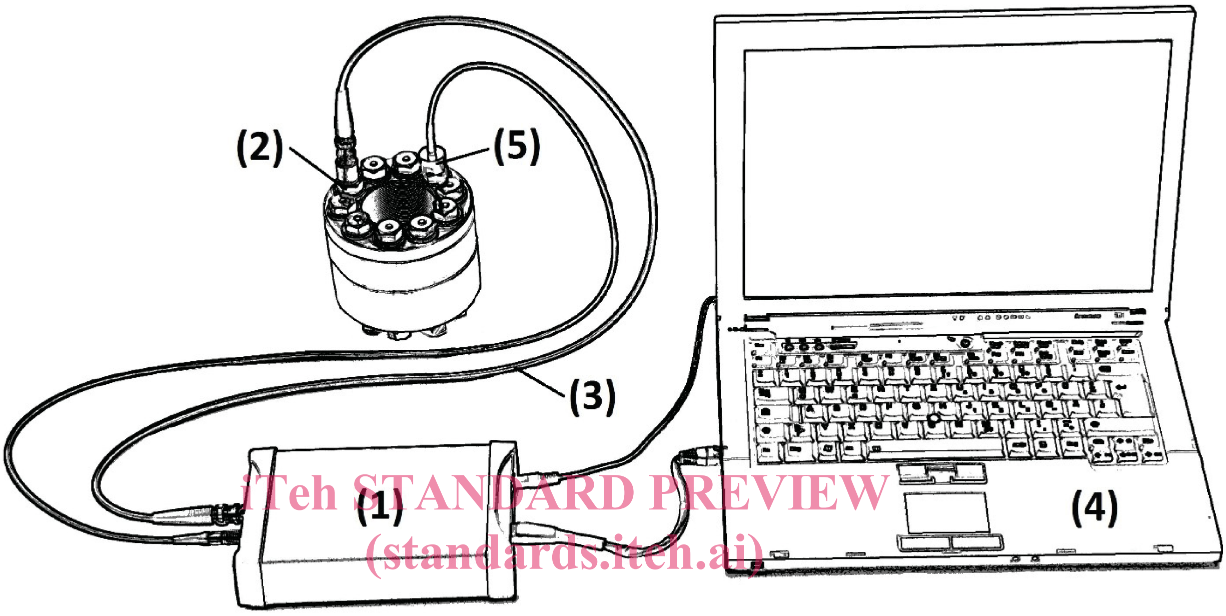
The temperature stepping requires a programmable climate chamber which allows specific (constant) temperatures to be realized for sufficiently long time spans so that the bolt definitely reaches thermal equilibrium at the given temperatures while the *TOF*s are measured with the ultrasonic measurement system. Evidence for thermal equilibrium can be gained from the constancy of the *TOF* values once the temperature level has been reached.

4.3 Basic components of an ultrasonic measurement system

The minimal configuration for an ultrasonic measurement system (see Figure 4) consists of an ultrasonic unit (1) that generates the ultrasonic pulses and receives the echoes. This unit is coaxially (3) connected with the bolt to be measured (2) and communicates with the processing unit (4). The processing unit (4) controls the ultrasonic unit (1), displays the load values, and is the interface for the user. A temperature probe (5) sitting on the joint measures the current bolt temperature. The ultrasonic unit (1) and the processing unit (4) are often combined into one device. This minimal configuration allows the permanent monitoring of one test joint.

In case that more than one bolt needs to be measured, the ultrasonic measurement system can be expanded with a multiplexor. This allows the sequential (one after another) monitoring of several test joints.

For simultaneous load determination the ultrasonic measurement system must contain several ultrasonic units (1). All units work in parallel. For this reason, this system is much faster than a system based on a multiplexor configuration. The configuration with several ultrasonic units is called a multi-channel system.



Key

(1) ultrasonic unit
(2) bolt to be measured
(3) coaxial unit
(4) processing unit
(5) temperature probe

Figure 4 — Basic components of an ultrasonic measurement system

4.4 Geometrical requirements on sensor bolts

The proper determination of the clamp load requires a sufficient echo quality. The magnitude and the form of the received echo are strongly dependent on the bolt geometry. The propagation of ultrasonic waves follows geometrical rules. Similar to the optics the angle of incidence equals the emergent angle for the reflection at any boundary surface. The transducer as integrating element collects all the different echo fractions receiving at the same time to one echo signal.

To avoid any disturbing interference during the echo formation a flat bolt reflection end is needed. The bolt head surface with the transducers on top and the bolt reflection should end parallel. This supports the ultrasonic waves to come back on a direct way from the reflection end to the transducer.