SIST

SLOVENSKI STANDARD
SIST EN 4861:2021

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Aeronavtika - Postopek meteorološkega ocenjevanja kinematičnih polj, ki se merijo z digitalno slikovno korelacijo

Aerospace series - Metrological assessment procedure for kinematic fields measured by digital image correlation

Luft- und Raumfahrt - Metrologisches Messverfahren für kinematische Felder durch digitale Bildkorrelation

Série aérospatiale - Procédure d’évaluation métrologique applicable aux mesures de champs cinématiques par corrélation d’images numériques

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (EN 4861:2020) 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-STAN, 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of an identical text or by endorsement, at the latest by June 2021, and conflicting national standards shall be withdrawn at the latest by June 2021.

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1 Scope

This document specifies the monitoring of mechanical tests and inspections performed both at the material (coupon) and at the structural scale by the implementation of kinematic field measurements by digital image correlation. This document describes an in situ method for evaluating the metrological performance of an extensometer system using image correlation for the delivery of displacement fields, and by extrapolation, of deformation fields. It can be implemented prior to the actual start of the test (or inspection). It will inform of the metrological performance in testing conditions.

This document allows the metrological performance of the measuring technology to be quantified. The methodology described herein is not to be considered as a calibration step. This reference document does not exhaustively specify the constitutive elements of a generic system of Digital Image Correlation measurement. This reference does not address the measurement of 3D shapes via stereocorrelation systems.

2 Normative references

There are no normative references in this document.

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 http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
extensometer system
equipment used to measure displacement or strain fields on the surface of a tested piece

Note 1 to entry: The equipment consists of an image acquisition device and a computer system for calculating the displacement and / or strain fields from the recorded images.

Note 2 to entry: For the purposes of this document, the term "Extensometer system" applies in particular to kinematic field measurements by digital image correlation.

3.2
user
person in charge of the extensometer system implementation

3.3
2D measurement – monovision
extensometer system consisting of a single imager is a monovision system

Note 1 to entry: This system can provide full-field measurements in two (2) dimensions. The relevant plane is perpendicular to the optical axis of the imaging system.

3.4
3D surface measurement – stereocorrelation
extensometer system consisting of (at least) 2 (two) imagers is a stereovision system

Note 1 to entry: Through prior calibration following the supplier's instructions, the system provides measured displacement fields in three (3) dimensions of the monitored surface. This practice applied to image correlation is defined by the term stereocorrelation.

4 Symbols and abbreviations

Symbols used throughout this document are given in Table 1 together with their designation.

Table 1 — Symbols and designations

Symbol	Designation	Unit
l_{max}	Maximum limit of measured displacement	mm
l_{min}	Minimum limit of measured displacement	mm
l_i	Displacement indicated by extensometer system	μm
l_t	Displacement given by apparatus for assessment of metrological performance	μm
q_{rb}	Relative bias error of extensometer system	%
q_b	Absolute bias error of extensometer system	μm
r	Resolution of extensometer system	μm

5 Principle

The assessment of the metrological performance of an extensometer system involves a comparison of the readings given by the extensometer system with known variations in length provided and prescribed by a system for the assessment of the metrological performance.

NOTE 1 The user can define the displacement range(s) over which the metrological performance assessment is to be performed. In this way, the performance of the extensometer system can be optimized. The user should take special care to distinguish real displacements induced in the structure of interest motions from the experimental displacement commonly called "rigid body motions". Hence, it would be appropriate in this case to concentrate the performance assessment to the centre of the operating range.

The assessment process compares the known displacement from the calibration device with the output of the extensometer system. This output is provided in the form of data from computer files generated by the software performing the kinematic field analysis based on the acquired images. These files should contain the displacement fields that will be evaluated and the coordinate at which they are evaluated.

NOTE 2 For certain types of extensometer systems, the calibration and classification will also be dependent upon the ability of the system for the assessment of the metrological performance.

6 System for the assessment of the metrological performance

6.1 Principle

The system for the assessment of the metrological performance, which allows a known displacement l_t to be applied with respect to the object of interest, may consist of a rigid frame to which the image acquisition device is attached. The system for the assessment of the metrological performance shall comprise a mechanism for moving along the 3 (three) axes in space by translation, optionally from 1 (one) to 3 (three) rotations and a measuring device allowing to allow these displacements to be known accurately. These variations in length can be measured by, for example, by an interferometer, a linear incremental encoder or gauge blocks and a comparator, or a micrometre.

The calibration apparatus should be calibrated and should meet the performance requirements given in Table B.1.

6.2 Traceability of metrological performance assessment

The calibration apparatus and the supporting equipment (such as micrometres, callipers, and optical projection microscopes) shall be calibrated using standards that are traceable to the International System of Units (SI).

The uncertainty associated with any measurement made by the supporting equipment shall not exceed one third of the allowable error of the extensometer system being calibrated, see Table 2. The temperature measurement instrument shall have a resolution of 0,1 °C.

7 Pre-assessment inspection

7.1 Aim

Prior to the assessment, the extensometer system shall be inspected. The quality of mechanical, optical, electronic components and devices have been validated in terms of equipment such as the free motion of tables, lenses, wiring and connections, hard drive space.

The extensometer system shall be assessed in the as-found condition if at all possible. The results shall be analyzed and, if necessary, the system shall be adjusted and re-assessed. In this case, both data sets shall be reported.

7.2 Records of the inspection

Records of the pre-assessment inspection shall be kept, identifying the "as-found" condition of the extensometer system, when the inspection was performed and who performed it. These pre-assessment inspection records can take the form of either a written report or a completed "pro-forma" checklist.

7.3 Identification of extensometer system elements

The extensometer system shall be uniquely identified. Parts that may be changed by the user during normal use of the extensometer system that affects the metrological assessment of the extensometer system shall also be uniquely identified whenever possible (e.g. camera, lens, lighting). These unique identifiers are part of the records for the extensometer system. It will enable each component of the system and the adjustment parameters to be referenced (e.g. lens settings, calculation parameters of digital image correlation).

8 Measurement of physical pixel size

8.1 Case of monovision measurements – software procedure

The measurement of the physical size of the pixel is performed according to the measuring system manufacturer specifications.

8.2 Case od monovision measurements – manual procedure

The measurement of the physical size of the pixel is performed according to the internal procedure of the user. The procedure and the result of this measurement shall be documented.

8.3 Case of monovision measurements – identification during the performance assessment procedure

An alternative is to consider an identification procedure proposed in Annex E. This procedure requires the user to be able to export the displacement field measurements in pixels with the extensometer system and metric measurements for the evaluation of the metrological performance.

8.4 Case of stereovision measurements

This measurement is not applicable because it is treated during the calibration step of stereocorrelation codes.

9 Metrological assessment process

9.1 Environmental considerations

9.1.1 General

The ambient temperature during the metrological performance assessment of the extensometer system shall be recorded.

In general, the calibration of the extensometer system should be carried out at a temperature stable to within ± 2 °C, the target temperature being within the range of 18 °C to 28 °C. Temperature changes during the metrological performance assessment process may add to the uncertainty of the calibration and in some cases may affect the ability to properly assess the metrological performance of the extensometer system.

For extensometer systems used at temperatures outside the recommended range of 10 °C to 35 °C, the metrological assessment should be carried out at or near the test temperature, if facilities exist.

The extensometer system shall be placed near the system for the assessment of the metrological performance, or be mounted on it, for a sufficient duration prior to its assessment so that the parts of the extensometer system and of the system for the assessment of the metrological performance that are in contact stabilize at the metrological assessment temperature.

9.1.2 Lightning conditions

Lighting conditions for the metrological performance assessment process should be identical and consistent with those of the operational use of the Extensometer system.

NOTE A histogram of gray level distribution could prove the quality of the lighting conditions between the 2 (two) uses.

9.1.3 Case of artificial random speckle pattern

For experimental coupons or components requiring an artificial application of a random speckle pattern (e.g. paint), it should be stable and unchanged during the metrological performance evaluation process and during operational use of the extensometer system.

NOTE The measurement is performed with the same artificial random speckle pattern as for the metrological performance assessment.

9.2 Calibration increments

9.2.1 The user shall establish the range of displacements over which the extensometer system shall be assessed.

9.2.2 The number of calibration points, and the number of ranges over which the assessment is performed, shall be based upon the relationship between the minimum displacement at which a property is determined, l_{min}, and the maximum displacement at which a property is determined, l_{max} This approach shall be performed for each measurement axis, 2 (two) for monovision, and 3 (three) in stereocorrelation.

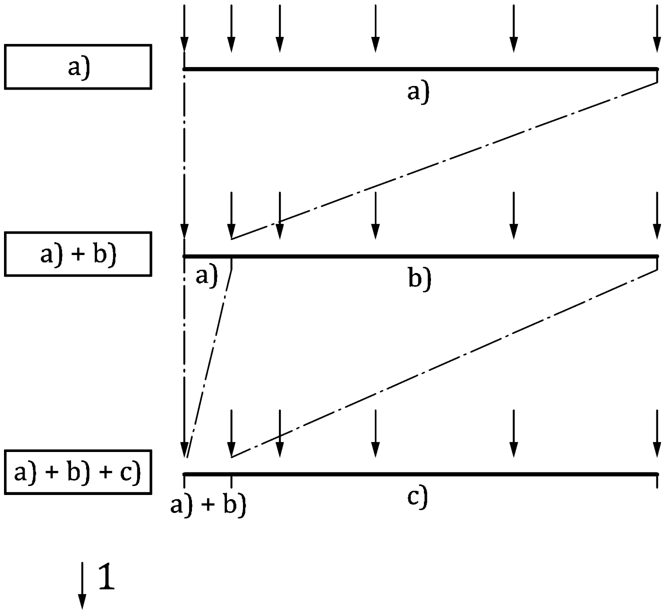
9.2.3 The following series of readings shall be made for 1 (one) measurement axis:

a) If (l_{max}/l_{min}) is less than or equal to 10, 1 (one) range of at least 5 (five) increments shall be recorded.

b) If (l_{max}/l_{min}) is greater than 10 but less than or equal to 100, 2 (two) ranges (l_{min} to 10 l_{min} and 10 l_{min} to l_{max}), or (l_{min} to 0,1l_{max} and 0,1 l_{max} to l_{max}), each of at least 5 (five) increments, shall be recorded.

c) If (l_{max}/l_{min}) is greater than 100, 3 (three) ranges (l_{min} to 10 l_{min}, 10 l_{min} to 100 l_{min}, 100 l_{min} to l_{max}), or (l_{min} to 0,01 l_{max}, 0,01 l_{max} to 0,1 l_{max}, 0,1 l_{max} to l_{max}), each of at least 5 (five) increments, shall be recorded.

For each of the 3 (three) categories [a), b), c), see above], the increment between any 2 (two) adjacent points shall not exceed one third of the range. Examples of these increments are shown in Figure 1.



Key

1 assessment points

a) series according to 9.2.3 a)

b) series according to 9.2.3 b)

c) series according to 9.2.3 c)

Figure 1 — Schematic diagram showing assessment point distribution

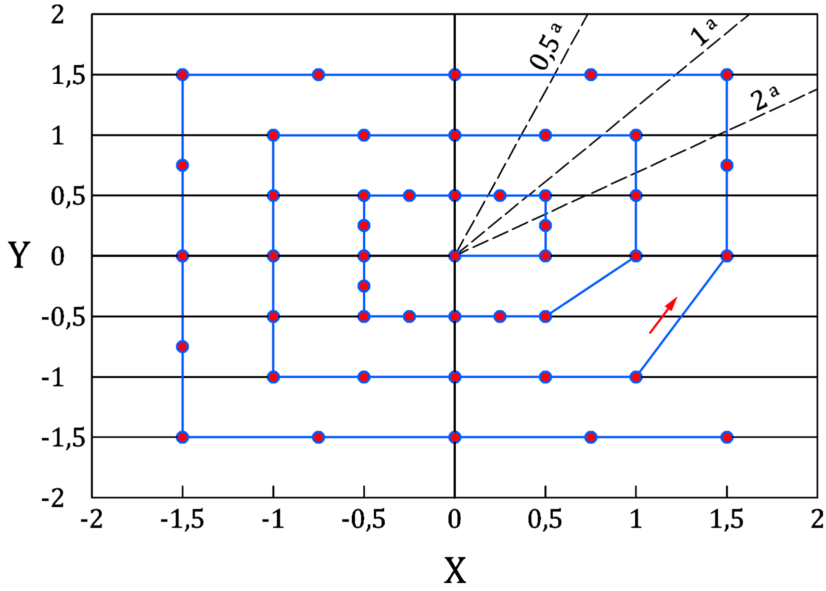
NOTE 1 A tensile test measuring, from the extensometer system, the modulus and ultimate stresses only, would fall into category a). A tensile test, establishing ultimate stresses and elongation to failure from the extensometer system, or a creep to rupture test, would fall into category b) or category c).

NOTE 2 For fatigue tests, a range of at least 5 (five) increments (with the increment ranging between any 2 (two) adjacent points not exceeding one third of the range between l_{min} and l_{max}) is used.

NOTE 3 The values derived from the above calculations can be adjusted to the nearest convenient increments to match those of the calibration apparatus.

9.2.4 When establishing l_{max} and l_{min}, operational factors such as thermal expansion of elevated temperature tests and additional displacement contingencies to cover matters such as test to test set-up variability shall be taken into account.

The implementation must mix the different measurement axes or spatial degrees of freedom satisfying 3 (three) mixing ratios: 0,5, 1 and 2, see Figure 2.



Key

a mix ratio

assessment point

Figure 2 — Mapping of an assessment point distribution for a 2D monitoring

9.3 Process for metrological performance assessment

The evaluation consists of a series of measurements, as defined in 9.2. Depending on the intended use of the extensometer system, the series is made for increasing lengths or decreasing lengths.

9.4 Determination of the extensometer system characteristics

9.4.1 General

The characteristics of the extensometer system defined below should be evaluated for each measurement axis and independently even in case of mixing of points.

9.4.2 Resolution

9.4.2.1 The resolution r is the smallest quantity which can be read on the extensometer system.

9.4.2.2 The resolution of the extensometer system is the result of a measurement performed on 11 images in a “reference” state of the measured structure. No loading, no motion shall be applied to the experimental support.

9.4.2.3 The result is the covariance matrix built from ten measured displacement fields. The resolution field is deduced from the so-called covariance matrix. Taking the square root of the diagonal terms of the covariance matrix, which corresponds to the variance of each random variable taken independently, to set the resolution field.

NOTE The use of the covariance matrix is presented in Annex C.