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Metallic materials — Calibration of extensometer systems used in uniaxial testing

Matériaux métalliques — Étalonnage des chaînes extensométriques utilisées lors d'essais uniaxiaux

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 9513 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*.

This third edition cancels and replaces the second edition (ISO 9513:1999), which has been technically revised. It also incorporates the Technical Corrigendum ISO 9513:1999/Cor.1:2000.

Introduction

This International Standard sets out criteria for the calibration of extensometer systems, covering general principles, the calibration equipment to be used, pre-calibration inspection and the measurement of gaugelength for various types of extensometer systems. Aspects of the calibration process are addressed, as are the assessment of the results, uncertainties, calibration intervals and reporting. Criteria for calibration apparatus, their calibration and grading are addressed, complemented by a Bibliography covering a number of important papers related to extensometer systems and their application [1] to [10]. Work is in progress to develop processes for dynamic extensometer calibration, however these have not reached, at the time of writing of this International Standard, the level of development appropriate for inclusion within this International Standard. For further information, refer to Reference [6].

Informative annexes address calculation of uncertainties of measurement for an extensometer system calibration (Annex A), calibration of calibration apparatus (Annex B) and an example of a calibration report (Annex C). Subsequent annexes address examples of extensometer system configurations (Annex D), laser extensometry (Annex E), video extensometry (Annex F), full field extensometry (Annex G) and calibration of a crosshead measurement system (Annex H).

Metallic materials — Calibration of extensometer systems used in uniaxial testing

1 Scope

This International Standard specifies a method for the static calibration of extensometer systems used in uniaxial testing, including axial and diametral extensometer systems, both contacting and non-contacting.

2 Terms and definitions

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

2.1
extensometer system
equipment used to measure displacement or strain on the surface of a test piece

NOTE For the purpose of this International Standard, the term "extensometer system" includes the indicator. Some extensometers indicate strain directly (e.g. laser extensometers or digital image correlation techniques). Other extensometers indicate the change in gauge length of a test piece; this is converted into strain by dividing by the relevant gauge length.

2.2
gauge length
portion of a test piece where extension is measured

3 Symbols and designations

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

Table 1 — Symbols and designations

Symbol	Designation	Unit
L_e	Nominal gauge length of extensometer	mm
L'_e	Measured gauge length of extensometer	mm
l_{max}	Maximum limit of calibration range	mm
l_{min}	Minimum limit of calibration range	mm
l_i	Displacement indicated by extensometer	µm
l_t	Displacement given by calibration apparatus	µm
q_{L_e}	Relative gauge length error of the extensometer system	%
q_{rb}	Relative bias error of the extensometer system	%
q_b	Absolute bias error of the extensometer system	µm
r	Resolution of the extensometer system	µm

4 Principle

The calibration of extensometer systems involves a comparison of the readings given by the extensometer with known variations in length provided by a calibration apparatus.

NOTE 1 The user can define the displacement range(s) over which the calibration is to be performed. In this way, the performance of the extensometer system can be optimized. For example, for strain-controlled low cycle fatigue, only a small portion of the operating range of the extensometer is typically used. Hence, it would be appropriate, in this case, to concentrate the calibration on the centre portion of the operating range.

The calibration process compares the known displacement from the calibration device with the output of the extensometer system. This output can range from manual readings of high precision dial gauges to the displacement indication of a transducer/electronics/data-logging system. In the latter case, the extensometer system output would include any data curve fitting applied by the electronics/data-logging system.

NOTE 2 For certain types of extensometer systems, the calibration and classification will also be dependent upon the ability of the extensometer system to define the gauge length.

5 Calibration equipment

5.1 Calibration apparatus

The calibration apparatus, which allows a known displacement l_t to be applied to the extensometer, may consist of a rigid frame with suitable coaxial spindles or other fixtures to which the extensometer can be attached. The calibration apparatus shall comprise a mechanism for moving at least one of the axial spindles together with a device for accurately measuring the change in length produced. These variations in length can be measured by, for example, an interferometer, a linear incremental encoder or gauge blocks and a comparator, or a micrometer.

NOTE Special attachments to the calibration apparatus spindles are utilized for the calibration of diametral extensometers.

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

Annex B gives a recommended calibration procedure for the calibration apparatus and details performance criteria that indicate that the apparatus is suitable for calibrating extensometer systems in accordance with this International Standard.

5.2 Calibration traceability

The calibration apparatus and the supporting equipment (such as micrometers, callipers, optical projection microscopes) shall be calibrated using standards that are traceable to the International System of Units (SI). The uncertainty associated with any measurements made by the supporting equipment shall not exceed one third of the permissible error of the extensometer system being calibrated (see Table 2). The temperature measurement instrument shall have a resolution of 0,1 °C.

6 Pre-calibration inspection

6.1 Objective

Prior to the calibration of the extensometer system it shall be inspected. This shall comprise, but not be limited to, inspection of the mechanical components for, for example, free movement, damaged parts, worn knife edges, and worn gauge length setting pins/fixtures. For extensometer systems incorporating electronic transducers, the cabling and connectors shall be examined for damage, wear, etc.

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

6.2 Records of the inspection

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

6.3 Identification of extensometer system elements

The extensometer shall be uniquely identified. Parts that may be changed by the user during normal use of the extensometer that affect the calibration of the extensometer shall also be uniquely identified where possible. However, this requirement does not extend to clamping devices used to attach the extensometer to the test piece. These unique identifications form part of the records for the extensometer system.

7 Measurement of extensometer gauge length

7.1 Fixed gauge length extensometry

7.1.1 The measured gauge length, L'_e, of a fixed gauge length extensometer shall be determined by either direct or indirect means. In both cases, the extensometer setting pin or gauge fixture is used to set the extensometer contact points to their pre-set displacement.

NOTE Variability of the measured gauge length might be experienced due to excessive play/wear in the gauge length setting mechanism.

7.1.1.1 Direct measurement of the gauge length, L'_e, is performed between the extensometer contact points, using a calibrated measuring instrument such as a caliper or a shadowgraph/projection microscope.

7.1.1.2 Indirect measurement of the gauge length, L'_e, is performed by placing the extensometer on a soft metal test piece in such a way that the blades or points of the extensometer leave their marks. Once the extensometer is removed, the distance between the marks on the test piece shall be measured, using equipment with an accuracy consistent with the required class of extensometer.

7.1.2 The relative error on the gauge length, q_{L_e}, calculated from Formula (1) shall meet the requirements given in Table 2.

$$q_{L_\mathrm{e}} = \frac{L'_\mathrm{e} - L_\mathrm{e}}{L_\mathrm{e}} \times 100 \qquad (1)$$

7.2 Variable gauge length extensometry

7.2.1 The gauge length of a variable gauge length extensometer shall be measured either directly, or indirectly.

7.2.1.1 Direct measurement of the gauge length is performed by setting the extensometer to the required gauge length using jigs, fixtures or other tools, followed by measurement between the extensometer contact points, using a calibrated measuring instrument such as a calliper or a shadowgraph/projection microscope.

7.2.1.2 Indirect measurement of the gauge length, L'_e is performed by attaching the extensometer to a soft metal test piece in such a way that the blades or points of the extensometer leave their marks. Once the extensometer is removed, the distance between the marks on the test piece is measured, using equipment with an accuracy consistent with the required class of extensometer.

7.2.2 Extensometers commonly used in creep, elevated temperature tensile or stress relaxation testing have their gauge length defined by small ridges machined on the parallel length of the test piece, to which the extensometer is clamped. The gauge length for such extensometers shall be determined directly from the test piece and shall be to an accuracy consistent with the required class of extensometer.

7.2.3 The relative error on the gauge length, q_{L_e} , calculated from Formula (1), shall meet the requirements given in Table 2.

7.2.4 Where an extensometer sets or measures the gauge length, the relative error on the gauge length shall be determined. If features on the test piece define the gauge length, the relative error on the gauge length does not need to be determined.

7.2.5 Where an extensometer automatically sets the gauge length, the maximum and minimum gauge lengths used, plus three more gauge lengths between the minimum and maximum, shall be measured. Where fewer than five gauge lengths are used, all gauge lengths shall be measured.

7.3 Non-contacting extensometry

The gauge length for non-contacting extensometry is established in accordance with the manufacturer's instructions.

7.4 Extensometer gauge lengths established using setting gauges

Where an extensometer gauge length is set using a removable gauge, the relative error on the gauge length, q_{L_e} , calculated from Formula (1) shall not exceed the values given in Table 2.

The uncertainty of measuring the gauge length shall be three times better than the allowable error in gauge length.

8 Calibration process

8.1 Environmental considerations

8.1.1 The ambient temperature during the calibration 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 18 °C to 28 °C. Temperature changes during the calibration process may add to the uncertainty of the calibration and in some cases may affect the ability to properly calibrate the extensometer.

8.1.2 For extensometers used for uniaxial testing at temperatures outside the range 10 °C to 35 °C, the calibration should be carried out at or near the test temperature, if facilities exist.

8.1.3 The extensometer shall be placed near the calibration apparatus, or be mounted on it, for a sufficient length of time prior to its calibration so that the parts of the extensometer system and of the calibration apparatus which are in contact stabilize at the calibration temperature.

8.2 Position of the extensometer

The extensometer shall be placed, wherever feasible, in the calibration apparatus in a similar orientation to that in which it will be used during uniaxial testing to avoid errors due to loss of equilibrium or to deformation of any part of the extensometer.

The extensometer shall be attached in a similar way as during uniaxial testing.

8.3 Calibration increments

8.3.1 The user shall establish the range of displacements over which the extensometer system shall be calibrated.

8.3.2 The number of calibration points, and the number of ranges over which calibration 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}.

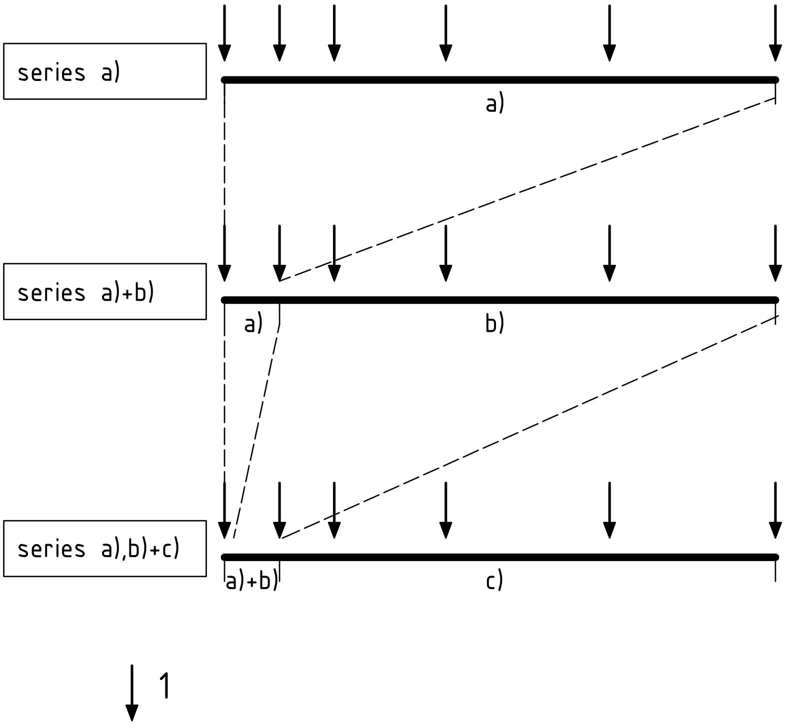
8.3.3 For monotonic tests, the following series of readings shall be made.

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

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

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

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



Key

1 calibration points

Figure 1 — Schematic diagram showing calibration point distribution

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

NOTE 2 For fatigue tests, a range of at least five increments (with the increment between any 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.

8.3.4 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.