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Metallic materials — Verification of the alignment of fatigue testing machines

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National foreword

This British Standard is the UK implementation of ISO 23788:2012.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Metallic materials — Verification of the alignment of fatigue testing machines

Matériaux métalliques — Vérification de l'alignement axial des machines d'essai de fatigue

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 23788 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

Introduction

Machine alignment in the context of this International Standard means the coincidence of the geometrical (loading) axes of the grips. Any departure from this ideal situation results in an angular and/or lateral offset (or misalignment) in the load train (see Annex A). Misalignment is manifested as an unwanted bending stress/strain field to exist in the test specimen or alignment measuring device (hereinafter “alignment cell”). The bending stress/strain field superimposes on the applied, presumed uniform, stress/strain field. In pure torsion testing, any misalignment results in a biaxial torsion plus bending stress/strain state.

Misalignment in the load train in axial fatigue test systems has been shown to influence significantly the fatigue test results (see References [1], [2] and [3]).

The main causes of bending due to misalignment are invariably a combination of

— poor coincidence of the centrelines of the grips, and

— inherent imperfections in the specimen or alignment cell itself.

The bending contribution due to the test machine ideally remains the same for every test specimen or alignment cell. The bending contribution due to the specimen or alignment cell varies from one device to another.

Recent research (see References [4] and [5]) has shown that no matter how carefully a specimen or an alignment cell device has been manufactured an inherent bending error always exists. Imperfections (i.e. eccentricity and angularity) arise from geometric asymmetry about the axial centreline in the device and other measurement errors relating to the chosen type, positioning and performance of the strain gauges. The device inherent bending error can be significant and sometimes even exceed that due to the machine misalignment.

In this International Standard, errors due to inherent imperfections in the alignment cell itself are eliminated. This is achieved by rotating the alignment device 180° about its longitudinal axis and subtracting its contribution from the overall maximum surface bending strain determined in the measurement. Different devices that are made of the same material and nominal dimensions should reasonably, therefore, produce the same alignment measurement results; see an example in Reference [2], Figure 10.

Metallic materials — Verification of the alignment of fatigue testing machines

1 Scope

This International Standard describes a method for verifying the alignment in a testing machine using a strain-gauged measuring device. It is applicable to dynamic uniaxial tension/compression, pure torsion and combined tension/compression plus torsion fatigue testing machines for metallic materials.

The methodology outlined in this International Standard is generic and can be applied to static testing machines and in non-metallic materials testing.

2 Normative references

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 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: tension/ compression testing machines — Verification and calibration of force-measuring system*

3 Terms and definitions

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

3.1
alignment
coincidence of the loading axes of the load train components, including the test specimen

NOTE Departure from such coincidence can introduce bending moments into the specimen.

3.2
alignment cell
carefully machined measuring device instrumented with strain gauges for use in verifying the alignment of a testing machine

3.3
alignment gauge
carefully machined mechanical device made of a split bar and a gauge for pass/fail checking of the correct alignment of the grips

3.4
average axial strain
ε_0
average longitudinal axial strain measured at the surface of the alignment cell by a set of strain gauges located in the same cross-sectional plane

NOTE The average axial strain represents the strain at the geometrical centre of the cross section.

3.5
load train
all the components between and including the crosshead and the actuator

NOTE The load train includes the specimen.

3.6
bending strain

ε_b

difference between the local strain measured by a strain gauge and the average axial strain

NOTE Bending strain is a vector characterized by a magnitude, a direction and a discrete point of application. In general, it varies from point to point on the surface of the alignment cell.

3.7
machine alignment

coincidence of the axes of the grips, which is characterized by the maximum bending strain component $\varepsilon_\mathrm{b,max,mc}$

NOTE Machine misalignment is manifested by the existence of a lateral offset and/or an angular offset between the loading axes of the upper and lower grips.

3.8
machine aspect

reference to the test machine's front, back, left and right

3.9
maximum bending strain

$\varepsilon_\mathrm{b,max}$

vector quantity with the largest bending strain magnitude in a given cross-sectional plane

NOTE Maximum bending strain vector is characterized by a magnitude, a direction and a discrete point of application.

3.10
percentage bending

β

maximum bending strain times 100 and divided by the average axial strain

3.11
measurement plane

cross-sectional plane in the alignment cell in which the transverse axes of a set of strain gauges are positioned

3.12
measurement orientations

position of the alignment cell (0°, 90°, 180° and 270°), about its longitudinal axis, which defines the location of gauge 1 or a permanent mark on the alignment cell's surface, with respect to the front of the machine

NOTE The front of the machine is the R-direction.

3.13
parallel length

L_p

parallel portion of the reduced section of the alignment cell

3.14
proportional limit

greatest stress that a material is capable of sustaining elastically, i.e. without any deviation from proportionality of stress to strain

3.15
R-direction

fixed reference direction with respect to the frame of the testing machine

NOTE Typically, it is the direction from the centre towards the front of the machine.

3.16
strain gauge axial separation

L_g

axial distance on the alignment cell between the upper and lower measurement planes

3.17
strain gauge transverse separation
W_g
transverse distance on the broad face of a thin rectangular alignment cell between the centres of the strain gauges

4 Symbols

For the purposes of this document, the following symbols apply.

Symbol	Description
$A_1 - A_4$	upper set of strain gauges
$B_1 - B_4$	lower set of strain gauges
d	minimum diameter of cylindrical alignment cell; inner diameter of alignment gauge
D	diameter at grip end of cylindrical alignment cell
e	eccentricity or lateral offset
L_p	parallel length
L_g	axial separation of strain gauges
L_z	overall length of alignment cell, alignment gauge or test specimen
r	fillet radius between the parallel length and the grip end of the alignment cell or test specimen
t	thickness of reduced section of rectangular alignment cell
w	width of reduced section of rectangular alignment cell
W	width at grip end of rectangular alignment cell
w_g	transverse separation of strain gauges
B	percentage bending
β_{ac}	percentage bending due to inherent imperfections in the alignment cell
β_{mc}	percentage bending due to machine misalignment
ε_o	average axial strain
ε_1, ε_2, etc.	readings of individual strain gauges (i.e. local strain)
ε_b	bending strain (combined value)
$\varepsilon_{b,ac}$	bending strain component due to inherent imperfections in the alignment cell
$\varepsilon_{b,mc}$	bending strain component due to machine misalignment
$\varepsilon_{b,max}$	maximum bending strain (combined value)
$\varepsilon_{b,max,ac}$	maximum bending strain component due to inherent imperfections in the alignment cell
$\varepsilon_{b,max,mc}$	maximum bending strain component due to machine misalignment
γ	angular offset

θ_{ac}	angle (clockwise where seen from above) of the location of $\varepsilon_{b,max,ac}$ with respect to gauge 1 (or a permanent mark on the alignment cell's surface)
θ_{mc}	angle (clockwise where seen from above) of the location of $\varepsilon_{b,max,mc}$ with respect to front of the machine (the R-direction)

5 Measurement requirements

5.1 Testing machine

The testing system shall have a force-measuring system comprising force transducer (load cell), conditioner and readout units. This system shall meet the requirements of ISO 7500-1.

NOTE 1 Class 1 requires that force indicated errors do not exceed ±1 % of the reading over the verification range.

It is essential that the grips enable rotating the alignment cell 180° about its longitudinal axis. It shall also adequately enable repeatable positioning and gripping of the alignment cell with minimal variation in the misalignment (see Annex B).

It is recommended, but not essential, that the machine be equipped with means for adjusting the lateral and angular offsets of one part of the load train. It is also recommended to

a) minimize the number of components of which these gripping devices are composed in order to reduce the number of mechanical interfaces, and

b) maximize the lateral stiffness of the fatigue testing machine in order to reduce the effects of any so-called reversed bending on fatigue test results in tests involving reversed tension-compression loading (see Reference [1]).

NOTE 2 See Annex C for a method for measuring machine lateral stiffness.

5.2 Alignment cell

Alignment measurement can be slightly affected by the stiffness of the alignment cell used in the measurement (see Figure 13 in Reference [2]); the lower the stiffness of the device, the higher its measurement sensitivity of machine alignment. A good alignment cell should also be sufficiently robust to last and enable successive usage over a long period of time (i.e. years). Care should be taken to ensure both requirements are adequately fulfilled.

A suitable material for an alignment cell should ideally have:

a) a sufficiently high linear elastic range;

b) a high degree of metallurgical stability;

c) freedom from appreciable residual stress to ensure dimensional stability;

d) good oxidation resistance.

Fully tempered steels, e.g. alloy steels with 0,2 % proof stress in the order of 1 000 MPa, are ideal candidate materials for alignment cells (see References [3] and [4]). High-strength aluminium alloys, such as 7075-T6, are amongst suitable alternatives.

5.3 Design and manufacturing

5.3.1 Design

The alignment cell shall have the same overall length (but not necessarily the same gauge length and cross-sectional area) as the fatigue test specimen. It shall fit into the grips in the same way the fatigue test specimen does so that use of special adaptors is avoided. For cylindrical devices, the diameter, d, shall be no more than 10 mm or the fatigue test specimen's diameter, whichever is the greater. The recommended standard diameters are 5 mm, 7,5 mm and 10 mm.

Tables 1, 2 and 3 show the recommended standard proportions. Smaller cross-section dimensions than those shown in the tables may be used subject to availability of suitable strain gauges. Figures 1 and 2 show the requirements for concentricity, straightness and parallelism (i.e. machining tolerances for surfaces which affect the alignment) for the basic alignment cell shapes.

Other geometries and profiles are permissible, provided the principal requirements of this International Standard are observed. Significant variations in dimensions can, however, preclude meaningful comparison with measurements from the recommended standard cells. For recommendations on other geometries and design of grip ends, see Reference [4].

5.3.2 Dimensions of alignment cells of circular cross-sections

See Table 1 and Figure 1.

Table 1 — Nominal dimensions for alignment cells of circular cross-sections

Dimension mm	**Recommendation**
d	5, 7,5 and 10
L_p	2,5d
r	$\geq 2d$
D	D (test specimen)
L_z	L_z (test specimen)
Surface roughness of reduced section: 0,8 µm to 1,6 µm.	

5.3.3 Dimensions of alignment cells of thick rectangular cross-sections

See Table 2 and Figure 2.

Table 2 — Nominal dimensions for alignment cells of thick rectangular cross-sections

Dimension mm	**Recommendation**
t	5, 7,5 and 10
w	$\geq t$
L_p	$\geq 2{,}5t$
r	2t to 8t
W	W (test specimen)
L_z	L_z (test specimen)
Surface roughness of reduced section: 0,8 µm to 1,6 µm.	

5.3.4 Dimensions of alignment cells of thin rectangular cross-sections

See Table 3 and Figure 2.

Table 3 — Nominal dimensions for alignment cells of thin rectangular cross-sections

Dimension mm	**Recommendation**
t	2, 3, 4
w	$\geq 5t$
L_p	$\geq 2{,}5t$
r	$2t$ to $8t$
W	W (test specimen)
L_z	L_z (test specimen)
Surface roughness of reduced section: 0,8 μm to 1,6 μm.	

5.4 Machining

Small and decreasing cuts with an adequate supply of coolant shall be used for finishing so that the metallurgical structure and properties are not affected and that undue residual stresses are not induced in the cell material. For effective bonding of the strain gauges, the optimum surface finish for the alignment cell shall be in the range 0,8 μm to 1,6 μm (see Reference [4]).

NOTE Surface roughness for fatigue test specimens are usually within 0,2 μm to 0,4 μm.

5.5 Inspection before attaching the strain gauges

The alignment cell shall be carefully inspected (with instruments, such as an optical shadowgraph or comparator) and all the critical dimensions and the associated geometrical tolerances confirmed prior to attachment of the strain gauges to ensure that all the geometrical requirements are met. After the strain gauges are applied, it is no longer possible to inspect the alignment cell with these methods.

5.6 Instrumentation with strain gauges

An array of eight strain gauges (arranged in two sets of four) shall be numbered and positioned as shown in Figure 3 (see References [4] and [5]). For cylindrical alignment cells [see Figure 3 a)], the strain gauges shall be equally spaced, 90° apart, around the circumference of the alignment cell. The configuration shown in Figure 3 b) is suitable for rectangular alignment cells with a width to thickness ratio w:$t < 3$. For higher w:t values, the gauges may be placed in pairs of back-to-back sensors and equidistant from the centreline of the alignment cell as shown in Figure 3 c). The strain gauges shall all be matched, i.e. from the same manufacturer's batch. It is recommended they have active lengths of approximately 0,1 L_p or less.

The alignment measurement parameters in this International Standard are determined from the ratios of the measured strains, and they should not, therefore, be affected by temperature changes. Use of self-temperature-compensated strain gauges matched to the alignment cell material is recommended, especially if accurate determination of the absolute axial average strain, such as in modulus measurement, is also needed.

With reference to Figure 3, Table 4 gives the locations for positioning the strain gauges on the surface of the alignment cell.

Table 4 — Locations of strain gauges

Dimension	**Requirement**
L_g	$= 0{,}75\ L_p$
w_g	$= 0{,}75\ w$

NOTE The distance $L_g = 0{,}75\ L_p$ represents the maximum feasible separation to minimize effects due to stress concentration associated with the change of section at the ends of the alignment cell's parallel length.

Care should be taken in selecting the strain gauges in accordance with the manufacturer's recommendations. It is also important to ensure that the gauges are bonded using the manufacturer's recommended procedure. The strain gauges shall be located at the specified locations to within 0,10 mm or 0,01 times the alignment cell diameter or width, whichever is the greater. Their measurement axes shall be aligned to within 2° of the longitudinal axis of the alignment cell. After installation, the alignment of the gauges shall be checked and confirmed using a suitable instrument such as an angular optical projector or a circular graticule in a low-power microscope before applying any protective coating.

The strain measuring and data acquisition system (excluding the alignment cell) shall be calibrated where appropriate. Shunt resistors and/or any other means used to calibrate the strain measuring and data acquisition systems shall be traceable to the relevant national standards. The strain measuring and data acquisition system (including the alignment cell) shall have a strain measurement uncertainty within ±5 µstrain or ±1,0 % of the indicated reading, whichever is the greater.

For three-strain gauge configuration (hereinafter the "three-gauge configuration"), see Annex D.

5.7 System checks

5.7.1 As part of ensuring the proper function of the alignment measuring system, the following checks shall be performed:

5.7.2 The following check shall be performed at least once as part of the alignment cell's commissioning procedure. Connect the alignment cell to the testing machine, apply a small force that corresponds to a nominal value of ε_0 in the alignment cell in the range 100 µstrain to 1 000 µstrain and compare the average axial strain from the top set of strain gauges to that of the lower set. If they do not agree to within 5 µstrain, the alignment cell shall be replaced.

NOTE A nominal value of ε_0 in the alignment cell is determined using the average of all the strain gauges.

5.7.3 The following check shall be performed at least once as part of the machine's loading train or the grips commissioning procedure. Evaluate the precision of gripping the specimen consistently as described in Annex B.

5.7.4 The following check shall be carried out during every alignment verification procedure. Determine the secant or Young's elastic modulus, E, of the alignment cell material (at, for example, ε_0 equals approximately 1 000 µstrain using the average of all the strain gauges). This shall be consistent from test to test and throughout the lifetime of the alignment cell within ±3 % of the mean (or known value). If not, the reason shall be investigated and appropriate action taken.

6 Alignment measurement calculations

6.1 General

The machine contribution to any bending in the alignment cell is evaluated by measuring the bending strain components (under the same applied force) in two opposite orientations, such as 0° and 180° in Figure 4 (see Reference [5]). By rotating the alignment cell, its bending components rotate relative to the machine while the machine's bending components remain unchanged. The difference between the bending strains for any single gauge at two diametrically opposite positions gives the machine's bending contribution.

6.2 Cylindrical alignment cell

For a set of four gauges, in the same cross-sectional plane under a given applied axial force, the average axial strain is given by Formula (1):

$$\varepsilon_\mathrm{o} = \left(\varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4\right)/4 \qquad (1)$$

NOTE 1 Under zero axial force and in pure torsion, the average axial strain is zero.

The local bending strains are:

$$\varepsilon_{b1} = \varepsilon_1 - \varepsilon_o \tag{2}$$

$$\varepsilon_{b2} = \varepsilon_2 - \varepsilon_o \tag{3}$$

$$\varepsilon_{b3} = \varepsilon_3 - \varepsilon_o \tag{4}$$

$$\varepsilon_{b4} = \varepsilon_4 - \varepsilon_o \tag{5}$$

Note that strain gauge readings are in units of strain and compressive strains are negative. Theoretically, $\varepsilon_1 + \varepsilon_3$ should equal $\varepsilon_2 + \varepsilon_4$.

At the front of the machine where gauge 1 is initially located, the local bending strain component due to misalignment in the machine is given by Formula (6):

$$\varepsilon_{b1,mc} = \frac{\varepsilon_{b1,0^o} - \varepsilon_{b1,180^o}}{2} \tag{6}$$

where $\varepsilon_{b1,0°}$ and $\varepsilon_{b1,180°}$ are the local bending strains measured by gauge 1 where located in orientation 0° and orientation 180°, respectively. Formula (6) is applicable to the other gauge positions to determine $\varepsilon_{b2,mc}$, $\varepsilon_{b3,mc}$ and $\varepsilon_{b4,mc}$.

The maximum bending strain due to misalignment in the machine is as given by Formula (7):

$$\varepsilon_{b,max,mc} = 1/2\sqrt{(\varepsilon_{b1,mc} - \varepsilon_{b3,mc})^2 + (\varepsilon_{b2,mc} - \varepsilon_{b4,mc})^2} \tag{7}$$

Figure 5 shows an example of variation of $\varepsilon_{b,max,mc}$ with applied average axial strain, ε_o, for a uniaxial testing machine.

For axial tests, the maximum bending strain may be expressed as a percentage. Percentage bending due to machine misalignment, β_{mc}, is:

$$\beta_{mc} = \left|\frac{\varepsilon_{b,max,mc}}{\varepsilon_o}\right| \times 100 \tag{8}$$

The angular position of the maximum bending strain is determined as follows:

For measurements in orientations 0° and 180°:

$$\theta_{mc} = \frac{(\varepsilon_{b2,mc} - \varepsilon_{b4,mc})}{|\varepsilon_{b2,mc} - \varepsilon_{b4,mc}|} \times a\cos\left(\frac{\varepsilon_{b1,mc} - \varepsilon_{b3,mc}}{2\varepsilon_{b,max,mc}}\right) \tag{9}$$

where θ_{mc} is measured from the R-direction, in clockwise rotation, if positive, and anticlockwise, if negative.

NOTE 2 It is not unusual for θ_{mc} to change slightly and gradually during the measurement if the applied force or axial strain is increased or decreased. Sudden or erratic changes, however, can indicate the existence of backlash and/or other mechanical instability in the loading system.

NOTE 3 At a given applied force, $\varepsilon_{b,max,mc}$ and θ_{mc} values are normally independent from those due to inherent imperfections in the alignment cell. In other words, different alignment cells (of the same material and dimensions) are expected to produce the same nominal values of $\varepsilon_{b,max,mc}$ and θ_{mc}.

NOTE 4 Annex E describes how to calculate the bending contribution due to inherent imperfections in the alignment cell (see Reference [5]). Annex F shows the calculation results from a numerical example for a cylindrical alignment cell under axial test conditions.

6.3 Thick rectangular alignment cell

For a thick rectangular alignment cell at zero or a given applied axial force [see Figure 1 b)], the average axial strain and the local bending strains are calculated according to the above-mentioned formulae for cylindrical alignment cells. The maximum bending strain due to the machine is calculated using Formula (10) (see Reference [5]):

$$\varepsilon_{\mathrm{b,max,mc}} = \frac{\left|\varepsilon_{\mathrm{b1,mc}} - \varepsilon_{\mathrm{b3,mc}}\right|}{2} + \frac{\left|\varepsilon_{\mathrm{b2,mc}} - \varepsilon_{\mathrm{b4,mc}}\right|}{2} \tag{10}$$

Percentage bending, β_{mc}, is calculated using Formula (8).

The maximum bending strain occurs at the corner of the alignment cell between the strain gauges with the highest reading and next highest reading.

6.4 Thin rectangular alignment cell

For a thin rectangular alignment cell at zero or a given applied axial force [see Figure 1 c)], a system similar to Figure 1 b is established, where the equivalent strains are located at the centre of the alignment cell's four faces. The corresponding local bending strain values are given by Formulae (11) (12), (13) and (14) (see References [4], [5] and [6]):

$$\varepsilon_{\mathrm{1e}} = \frac{(\varepsilon_1 + \varepsilon_2)}{2} \tag{11}$$

$$\varepsilon_{\mathrm{2e}} = \varepsilon_{\mathrm{o}} + \left[\left(\frac{\varepsilon_2 + \varepsilon_3}{2}\right) - \varepsilon_{\mathrm{o}}\right] \cdot \left(\frac{w}{w_{\mathrm{g}}}\right) \tag{12}$$

$$\varepsilon_{\mathrm{3e}} = \frac{(\varepsilon_3 + \varepsilon_4)}{2} \tag{13}$$

and

$$\varepsilon_{\mathrm{4e}} = \varepsilon_{\mathrm{o}} + \left[\left(\frac{\varepsilon_1 + \varepsilon_4}{2}\right) - \varepsilon_{\mathrm{o}}\right] \cdot \left(\frac{w}{w_{\mathrm{g}}}\right) \tag{14}$$

where, ε_{o} is the average axial strain, given by Formula (1), w is the width of the broad face of the alignment cell and w_{g} is the strain-gauge transverse separation.

The forumlae/equations for determining the local bending strains, the maximum bending strains and percentage bending are the same as given above for thick rectangular alignment cells, but substituting ε_1, ε_2, ε_3 and ε_4 with $\varepsilon_{\mathrm{1e}}$, $\varepsilon_{\mathrm{2e}}$, $\varepsilon_{\mathrm{3e}}$ and $\varepsilon_{\mathrm{4e}}$.

NOTE The maximum bending strain occurs at the corner of the alignment cell nearest to the highest reading strain gauge.

6.5 Classification of machine alignment

The level of the machine alignment shall be described according to the criteria specified in Table 5 and shown graphically in Figure 6 (see Reference [5]).

Table 5 — Alignment classes

Class	$\lvert\varepsilon_0\rvert < 1\,000$ μstrain	$\lvert\varepsilon_0\rvert \geq 1\,000$ μstrain
2	$\varepsilon_{b,max,mc} \leq 20$ μstrain	$\beta_{mc} \leq 2$ %
5	$\varepsilon_{b,max,mc} \leq 50$ μstrain	$\beta_{mc} \leq 5$ %
10	$\varepsilon_{b,max,mc} \leq 100$ μstrain	$\beta_{mc} \leq 10$ %
20	$\varepsilon_{b,max,mc} \leq 200$ μstrain	$\beta_{mc} \leq 20$ %

7 Procedure for verification of machine alignment

7.1 Purpose and frequency

The purpose of this procedure is to verify the alignment of the testing machine. An ideal time for performing this procedure is following force calibration. It shall be carried out at 12-month intervals and in the following events:

a) as part of the commissioning procedure of a newly acquired testing machine;

b) after an accidental buckling of a specimen, unless it can be demonstrated that the alignment of the machine has not been changed;

c) if any adjustment (including movement of the upper or lower crosshead), alteration or replacement has been made to the load train, unless it can be demonstrated that the alignment of the machine has not been changed.

Annex G describes a simple mechanical device that may be used for performing relatively quick, qualitative checks of alignment for cylindrical testing systems. The check intervals using this device may be requested by the customer and/or as desired during the fatigue testing programme.

System checks shall be performed in accordance with 5.7.

7.2 Procedure

a) If the machine is being commissioned or re-commissioned, carry out the uncertainty evaluation procedure in Annex B.

b) For cylindrical geometry testing, carry out an initial check using the alignment gauge device described in Annex G.

NOTE 1 Some grips for cylindrical geometry testing do not enable use of the above-mentioned alignment gauge device.

c) Connect the lead wires of the strain gauges to the conditioning equipment, allow the system to stabilize under power and ensure it is stable for at least 30 min.

d) Grip one end of the alignment cell (usually the lower end) in the grip interface so that gauge 1 is facing the front of the testing machine (i.e. in orientation 0° position, Figure 4).

e) Set the strain gauges to zero.

f) Grip the other end of the alignment cell. With the machine in force control mode, set the force to zero (or a small value where required for control stability) and record the readings of the strain gauges. For pure torsion test systems, then proceed to 7.2 h).

NOTE 2 7.2 c) to 7.2 f) produce the maximum bending strain due to the action of gripping the alignment cell.

g) Apply a series of axial force (or average axial strain, ε_0) increments as required and record the force and the corresponding readings of the strain gauges. The applied forces shall be in tension and/or in compression, depending on the type of mechanical tests performed on the testing machine. Care shall be taken not to exceed 0,75 times the alignment cell's proportional limit to avoid causing permanent damage in the device. Return to zero force and record the corresponding readings of the strain gauges.

h) Release the grips to enable performing the next step.

NOTE 3 With a rectangular alignment cell, it is necessary to completely remove the alignment cell from the grips.

i) Rotate the alignment cell 180° about its longitudinal axis so that gauge 1 is now facing the back of the testing machine (i.e. in orientation 180° position, Figure 4) and grip both ends of the alignment cell. For pure torsion test systems, record the readings of the strain gauges, then proceed to 7.2 k).

j) Repeat 7.2 g), using the same nominal forces (or average axial strain values) applied in orientation 0°.

k) Take the alignment cell out of the upper grip and record the readings of the strain gauges. All the strain gauges should read within zero ±3 µstrain. If not, the reason shall be investigated and reported. Take the alignment cell out of the lower grip.

l) In pure torsion and combined tension plus torsion test systems, it is possible that the axis of rotation of the driving grip does not precisely coincide with the loading axis where the alignment cell is gripped. In tension/compression plus torsion fatigue testing, this misalignment causes a spiral, corkscrew-like motion. To account for this off-axiality, the following may be performed:

  1) carry out the above-mentioned procedure,

  2) un-grip the alignment cell from one end and with the machine exercised in the torsion sense, rotate the driving grip 180° (or the highest angle achievable, if the latter is less than 180°), and

  3) repeat steps 7.2 d) to 7.2 k).

m) If 7.2 a) is not being done, perform two more runs of 7.2 d) to 7.2 k) (i.e. a total of three repeat measurement runs are required).

n) Carry out the elastic modulus system check given in 5.7.4.

o) Calculate $\varepsilon_{\text{b,max,mc}}$ and, except for zero force, β_{mc} (see 6.2 to 6.4 or for the three-strain gauge configuration, see Annex D).

p) Determine the machine alignment class in accordance with 6.5.

8 Reporting

8.1 Basic information

The report shall include the following:

a) a statement of compliance or non-compliance with this International Standard, i.e. ISO 23788;

b) the machine alignment class;

c) the tabulated applied force and the corresponding strain gauge readings;

d) the alignment verification calculation results;

e) the estimated measurement uncertainty (i.e. $\pm U$, Annex B);

f) the alignment cell's secant or Young's elastic modulus determined in 7.2 n);

g) a graph showing the variation of $\varepsilon_{\text{b,max,mc}}$ with ε_{o};

h) the identification number, if relevant, and type of the testing system;

i) a description of the load train;

j) the identification number, a brief description of the alignment cell, including the material, main dimensions, and type, and the numbers and locations of strain gauges;

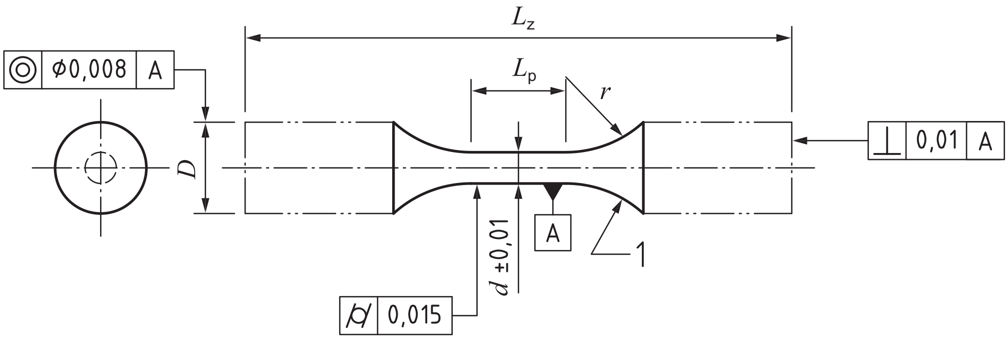
k) the type and identification number of the strain-measuring equipment, measurement uncertainty and (where applicable) the date of last calibration;

l) the values of the testing machine lateral stiffness, if known;

m) the name of operator and date of verification.

8.2 Special information

Any deviations from the procedures given in this International Standard shall be stated.



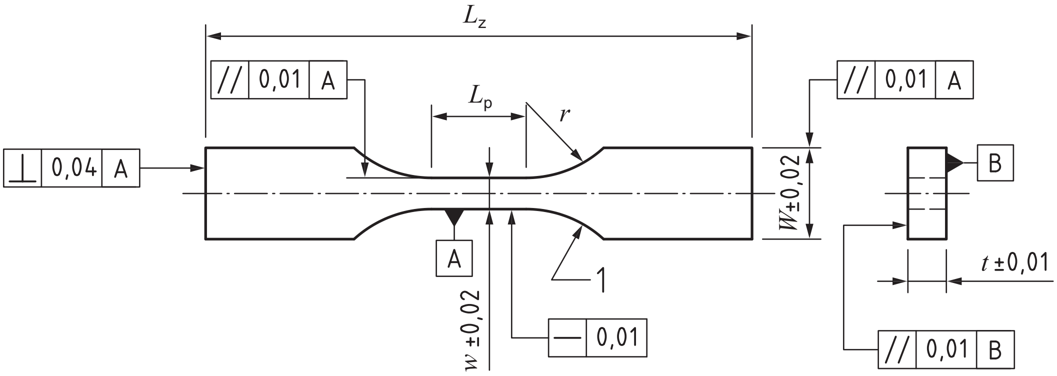
NOTE 1 All dimensions are in millimetres.

NOTE 2 For definitions of symbols for geometrical tolerances, see ISO 5459:2011 (Reference [9]).

NOTE 3 The perpendicularity requirement applies to any gripping parts used for alignment.

Figure 1 — Recommended profile for cylindrical alignment cells

(Based on Figure 2 in Reference [4])



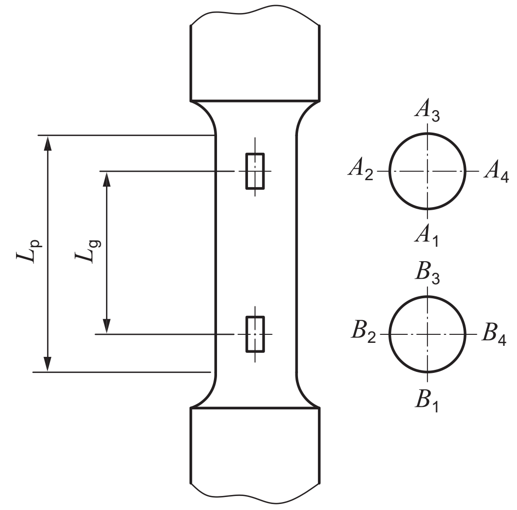
NOTE 1 All dimensions are in millimetres.

NOTE 2 For definitions of symbols for geometrical tolerances, see ISO 5459:2011 [Reference 9]

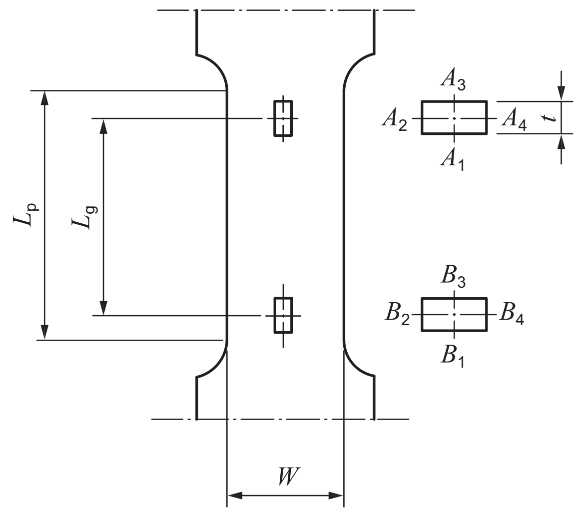
NOTE 3 The alignment cell to be symmetrical about the longitudinal centreline.

Figure 2 — Recommended profile for rectangular alignment cells

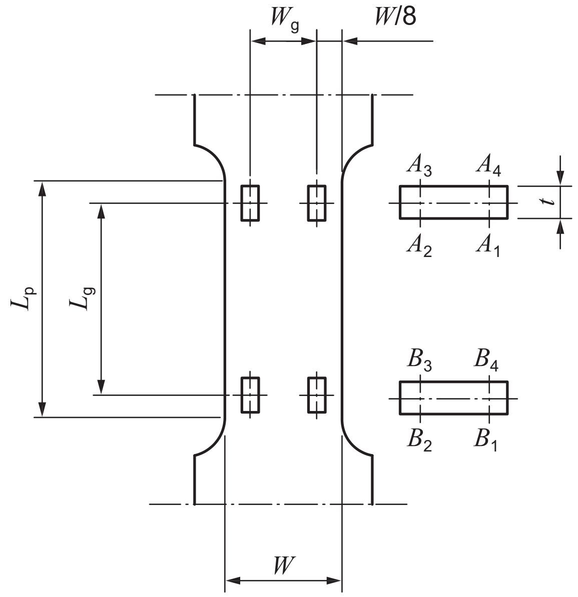
(Based on Figure 4 in Reference [4])



a) Locations on cylindrical alignment cell



b) Locations on thick rectangular alignment cell



c) **Locations on thin rectangular alignment cell**

Figure 3 — Strain gauge locations on cylindrical alignment cell, thick rectangular alignment cell and thin rectangular alignment cell

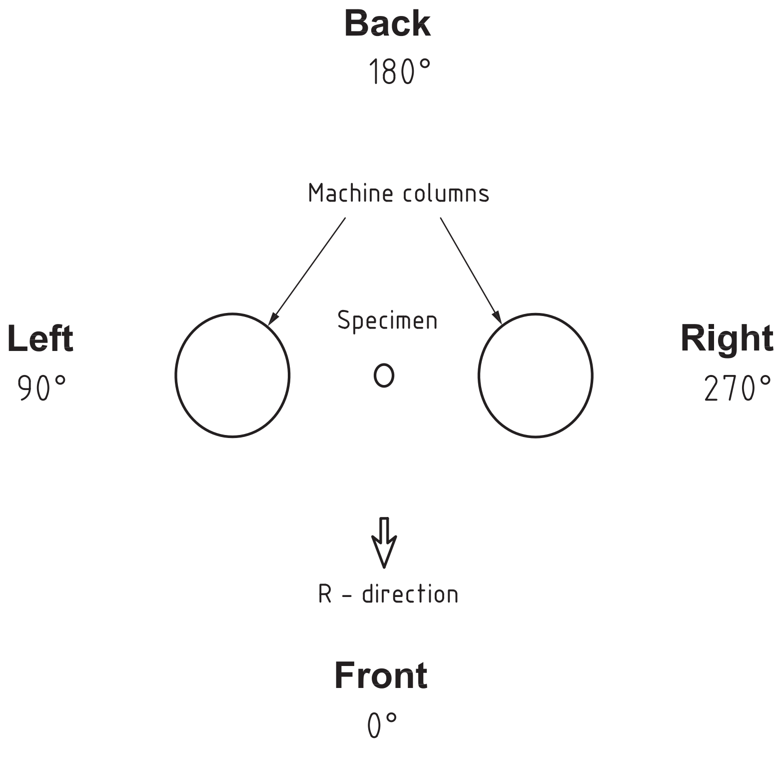
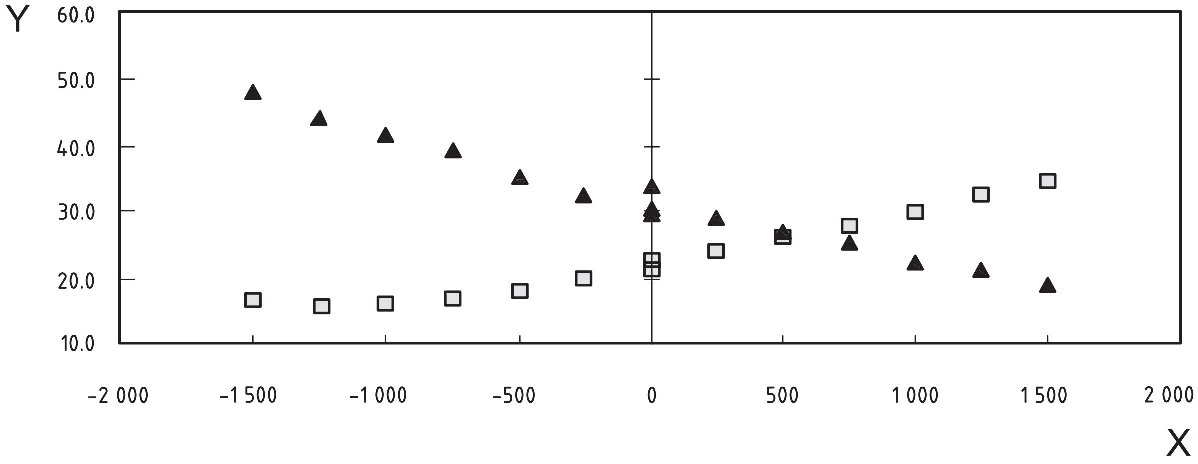


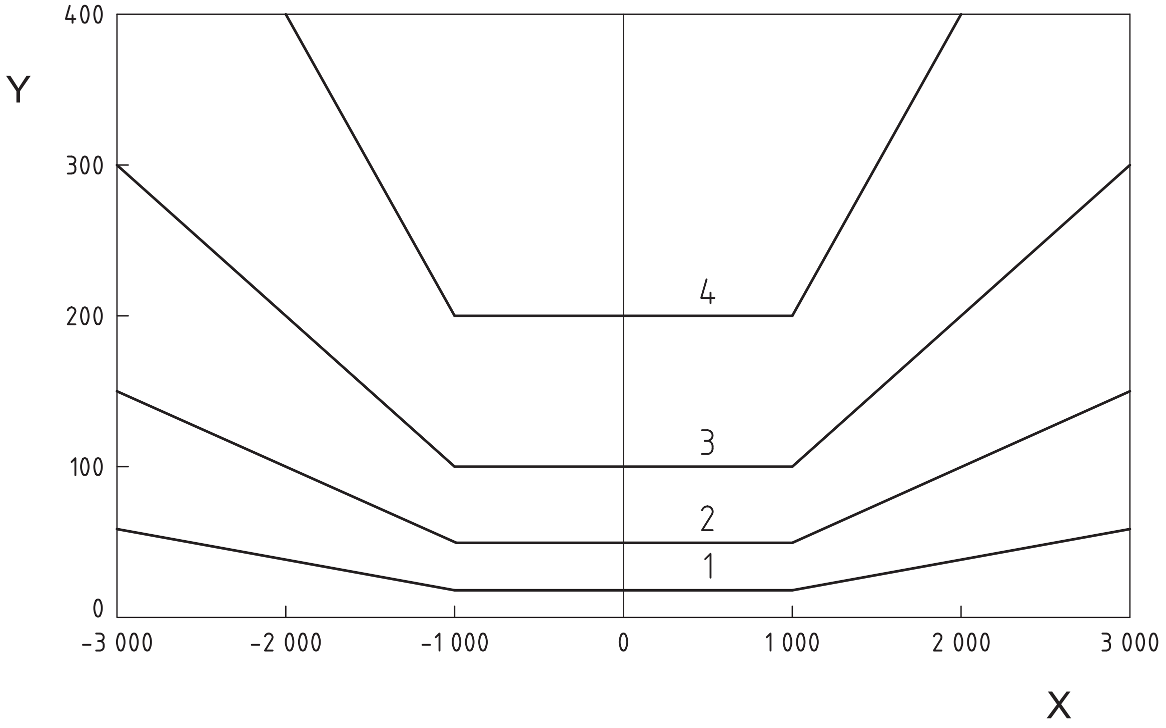
Figure 4 — Descriptions of terms used in alignment verification — The R-direction, machine aspect (front, left, back, right) and measurement orientations (0°, 90°, 180°, 270°) [Top view]



Key

X	ε_o, μstrain
Y	$\varepsilon_{b,max,mc}$, μstrain
☐	upper measurement plane
▲	lower measurement plane

Figure 5 — Graph showing an example of variation of $\varepsilon_{b,max,mc}$ with ε_o for an axial testing system



Key

X ε_o, µstrain

Y $\varepsilon_{b,max,mc}$, µstrain

1 class 2

2 class 5

3 class 10

4 class 20

Figure 6 — Criteria of alignment classes

(Source: Reference [5])

Annex A
(informative)

Causes of specimen bending and misalignment in fatigue testing machines

A.1.1 In an ideal alignment situation, the top and bottom grip centrelines are precisely in line with one another and with the centrelines of all the other components of the load-train including the specimen. Moreover, the specimen itself is absolutely symmetric about its centreline. Departures from this ideal situation are caused by

a) poor conformance of the top and bottom grip centrelines, and

b) asymmetric machining of the test specimen itself.

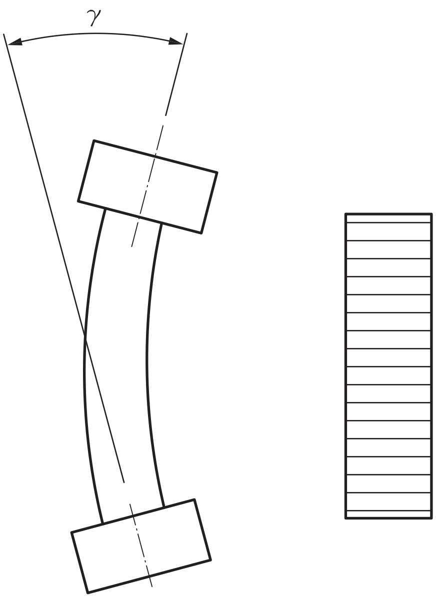
A combination of these two sources of misalignment always operates in tests under tensile or compressive forces and/or torque. In fatigue testing, any angular and/or lateral offsets in the load train can cause cyclic as well as mean bending strains superimposed on to the applied cyclic strain. In axial testing at elevated temperatures, additional bending can take place due to distortions in the load train if the specimen temperature was asymmetric (from side to side).

Specimen bending depends also on the ratio between the lateral stiffness of the specimen and the lateral stiffness of the other load train components. In reversed tension-compression low-cycle fatigue (LCF) testing, the stiffness of the specimen changes continuously during the fatigue cycle (as deformation evolves between the elastic and plastic states), throughout the test as the test material hardens or softens and as fatigue cracks develop inside the specimen. To minimize effects due to any so-called “reversed bending” (see Reference [1]) on fatigue life in reversed tension/compression (HCF as well as LCF) fatigue testing, the lateral stiffness of the load train components should be maximized.

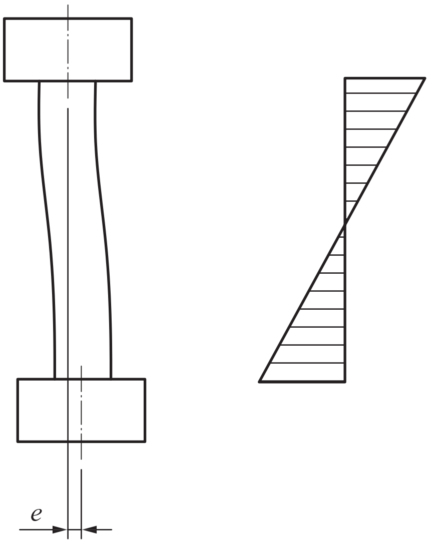
A.1.2 Figure A.1 shows the basic misalignment mechanisms encountered in axial test systems (see Reference [4]). In the simple case of an angular offset [see Figure A.1 a)], the grips’ centrelines lie in the same plane and intersect at mid-span with an angle γ. In this case, the specimen bending can be nominally uniform along the gauge length of the specimen, with tension on one side and compression on the other. This mechanism is the so-called “C-bend”.

In the simple case of a lateral offset [see Figure A.1 b)], the centrelines of the grips are parallel and axially offset with respect to each other by an amount e. Bending varies in amplitude along the gauge length of the specimen and change sign (from tension to compression on one side and compression to tension on the other). Note that the cross-section at the middle of the specimen has no bending. Sometimes this is called “S-bend”.

A.1.3 In practice, it is highly unlikely in axial testing to encounter a pure C-bend or S-bend, but is almost always a combination of the two. In non-rigid fatigue testing systems, lateral offsets of the centrelines of the grips with respect to either the machine’s crosshead or the driving actuator are more prone to cause “reversed bending” in the specimen as a result of the deformation of the load train (see References [1] and [4]).



a) C-bend due to an angular offset



b) S-bend due to a lateral offset

Figure A.1 — Basic bending mechanisms with associated bending moment distributions

Annex B
(normative)

Evaluating uncertainty in the alignment measurement

B.1 General

B.1.1 For meaningful measurements in accordance with this International Standard, it is essential to evaluate the measurement uncertainty. The following procedure is recommended to be performed at least as part of commissioning a new test system, after installing new grips or as part of a check of the system's alignment performance.

The following uncertainty evaluation procedure is in accordance with the methodology in Reference [7], which may be consulted for the uncertainty terminology used herein.

B.1.2 The measureand (i.e. the quantity being measured in this test) is $\varepsilon_{\text{b,max,mc}}$.

B.1.3 With reference to Formulae (7) and (10) and the procedure given in 7.2, the main sources of uncertainty which affect $\varepsilon_{\text{b,max,mc}}$ are the following:

a) repeatability of positioning and gripping the alignment cell consistently so that its longitudinal axis is always in the same precise position relative to the machine axis;

b) positioning the alignment cell precisely in the desired angular orientation with reference to the R-direction;

c) uncertainties relating to the strain gauges and strain measuring unit.

Experience in alignment measurement have shown that normally random sources are the most important. Systematic effects (if not already corrected) may be included in the analysis, but they are relatively insignificant and, therefore, have been excluded in the following calculations.

B.2 Procedure for estimating the standard uncertainty u

The following procedure describes how to estimate the standard uncertainty in $\varepsilon_{\text{b,max,mc.}}$ The results obtained should reflect the combined effects of all the random sources listed in B.1.3.

As with all repeatability tests, the following procedure must be performed under nominally identical testing conditions. It is important, therefore, that all the test runs are carried out on the same test system, using the same alignment cell, by the same operator, in continuous succession, in as short a period as practically possible and not be interrupted by any adjustments of the machine alignment or any other tests.

a) Carry out 7.2 c) to 7.2 k).

b) Repeat 7.2 d) to 7.2 k) as many times as practically possible.

c) Calculate the corresponding mean and standard deviation values of $\varepsilon_{\text{b,max,mc}}$.

It is important to emphasize that the alignment cell is removed completely from the grips between the test runs so that each run represents as far as practically possible a new test.

B.3 Evaluation of the expanded measurement uncertainty U

This is a type A uncertainty. Calculate the measurement uncertainty at the 95 % confidence level as given by Formula (B.1):

$$U = k_{95} u \tag{B.1}$$

where

U is the expanded uncertainty in the estimated mean;

k_{95} is a coverage factor for 95 % level of confidence (t-distribution is assumed);

u is the standard uncertainty (equals one standard deviation divided by $\surd n$);

n is the number of test runs (i.e. sample size).

Values of k_{95} may be obtained from the following Student's t-distribution table (extracted from Reference [8], Table A.2).

ν	1	2	3	4	5	6	7	8	9	10	12	14
k_{95}	12,71	4,30	3,18	2,78	2,57	2,45	2,37	2,31	2,26	2,23	2,18	2,15

ν	16	18	20	22	24	26	28	30	40	60	120	∞
k_{95}	2,12	2,10	2,09	2,07	2,06	2,06	2,05	2,04	2,02	2,00	1,98	1,96

where ν is the number of degrees of freedom equal to the sample size, n, minus one.

NOTE It is common practice in routine testing, calibration of instruments, and as recommended in ISO/IEC Guide 98-3 (see Reference [10]) and UNCERT Manual (see Reference [7]), to calculate and report the associated uncertainty for the 95 % level of confidence. For other levels, e.g. 99 %, use the appropriate coverage factor.

B.4 Reporting uncertainty estimate

The 95 % confidence interval in the above-mentioned alignment test result (the so-called "complete test result") may be expressed as:

$$\bar{\varepsilon}_{\mathrm{b,max,mc}} \pm U \tag{B.2}$$

where $\bar{\varepsilon}_{\mathrm{b,max,mc}}$ is the mean value of $\varepsilon_{\mathrm{b,max,mc}}$.

Generally, the expanded uncertainty should be reported in the same units and to the same number of significant figures as the result. The estimate should state the level of confidence associated with the coverage factor along with the means of making the estimate. Documentation is to be sufficient to allow replication of the calculation.

B.5 Measurement uncertainty requirements

B.5.1 The maximum permissible expanded uncertainty, U, shall be as follows:

Alignment class	**Requirement**
Class 2	4 µstrain or 0,4 % of the average axial strain, whichever is the greater;
Class 5	10 µstrain or 1,0 % of the average axial strain, whichever is the greater;
Class 10	20 µstrain or 2,0 % of the average axial strain, whichever is the greater;
Class 20	40 µstrain or 4,0 % of the average axial strain, whichever is the greater.

B.5.2 Uncertainty of measurement shall not be used to determine the alignment class.

Annex C
(informative)

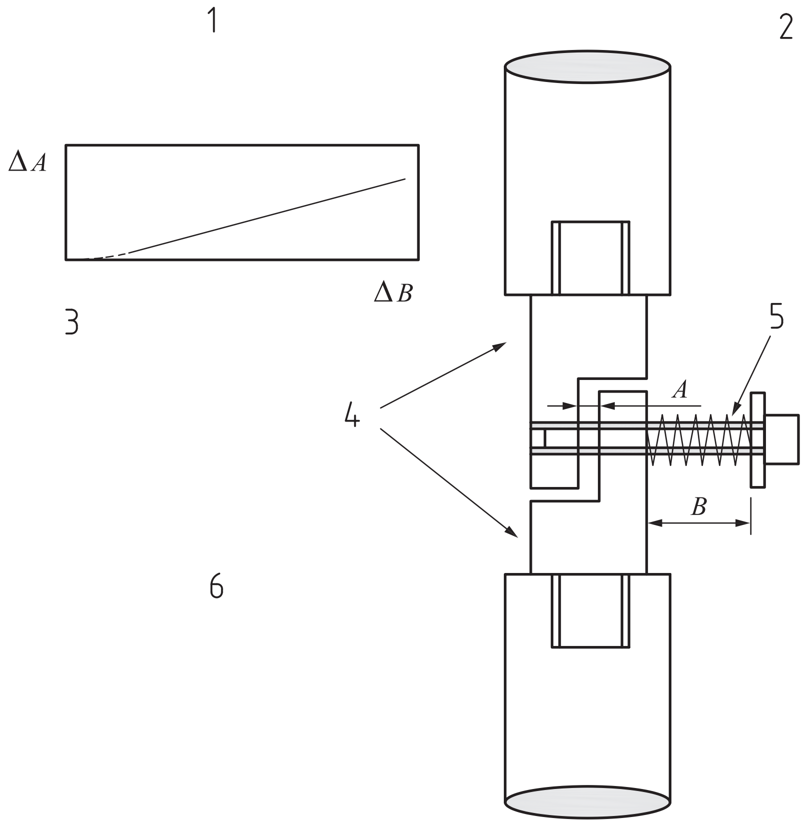
Method for measuring machine lateral stiffness

C.1 Axial and lateral stiffness of machine frame and load train are some of the parameters involved in the design and development of the testing machine. Information on lateral stiffness of the fatigue testing machine frame and load train should be provided by the machine manufacturer/supplier.

CAUTION In the following method, care should be taken not to exceed the lateral force or moment capability of the test machine load cell and other devices in the load train, such as so-called "alignment fixtures", which are used for making axial and/or angular offsets to align the testing machine. For this reason, it is recommended that this device be only designed and used by the machine's manufacturer.

Figure C.1 describes schematically a method for evaluating the lateral stiffness of testing machines. The method replaces the test specimen by two short, stiff, pull-rod extensions (PREs). A screw for applying the lateral force is threaded into the left-hand PRE and is free to slide through the right-hand PRE. Spring deflection between screw head and right-hand PRE enables the applied force to be determined. The change in separation between PREs is measured, enabling lateral stiffness of the testing machine system, including the frame, actuator and load train, to be determined.

It should be noted that the resulting machine stiffness, $k_{\mathrm{L},}$ is somewhat lower than the actual value due to a contribution to the deflection, ΔA, from the device itself.



1 Measure gaps A and B with a digital calliper for several increments of screw position and plot ΔA vs. ΔB.

2 It is better to measure A and B at the front and back and then average the readings so that the mean measurements are on the displacement axis.

3 The relationship may be nonlinear initially.

4 Testing machine lateral stiffness is equal to k_L.

5 Coil spring stiffness is equal to k_S.

6 Equating force:

$k_\mathrm{S} \times \Delta B = k_\mathrm{L} \times \Delta A$

Thus, $k_\mathrm{L} = k_\mathrm{S} \times \Delta B/\Delta A$

Since k_S is known and ΔA and ΔB measured, lateral stiffness, k_L, is readily determined.

Figure C.1 — Schematic representation of a method for measuring lateral stiffness in fatigue testing machines

Annex D
(informative)

Three-strain gauge configuration

D.1 General

The three-strain gauge configuration, where three strain gauges instead of four in each set, are used in industry for measuring bending due to misalignment in cylindrical test specimens (see Reference [6]). This method can be significantly less expensive than the four-gauge method regarding some setup elements (cost of the strain gauges and/or related conditioning and readout systems). It can be also useful for use with cylindrical alignment cells with a cross-sectional diameter of less than 5 mm. On the negative side, if one of the gauges becomes faulty, it is much more difficult, even impossible, to readily recognise this fault with the three-strain gauge configuration than with the four-gauge configuration. Faulty readings can be incorrectly taken as additional bending in the alignment cell. Furthermore, the average axial strain obtained from four-gauge configuration is expected to be more accurate than that obtained from the three-strain gauge configuration, simply because more gauges are used in determining it. It is for these reasons that the four-gauge configuration is the standard configuration adopted in this International Standard.

In the three- as well as the four-strain gauge configuration, a significant fault in one or more gauges can be mitigated by carrying out the system checks in 5.7.

D.2 Numbering and positioning of strain gauges

Clause 5.6 applies except that an array of six strain gauges (arranged in two sets of three) shall be numbered and positioned such that they are equally spaced, i.e. nominally 120° apart, around the circumference of the alignment cell (see Figure D.1).

D.3 Alignment measurement calculations

For each set of gauges, the average axial strain is:

$$\varepsilon_{\mathrm{o}} = \left(\varepsilon_1 + \varepsilon_2 + \varepsilon_3\right)/3 \tag{D.1}$$

The local bending strains are:

$$\varepsilon_{\mathrm{b1}} = \varepsilon_1 - \varepsilon_o \tag{D.2}$$

$$\varepsilon_{\mathrm{b2}} = \varepsilon_2 - \varepsilon_{\mathrm{o}} \tag{D.3}$$

$$\varepsilon_{\mathrm{b3}} = \varepsilon_3 - \varepsilon_{\mathrm{o}} \tag{D.4}$$

The maximum bending strain on the surface of the alignment cell is:

$$\varepsilon_{\mathrm{b,max}} = \varepsilon_{\mathrm{bh}} / \cos\alpha \tag{D.5}$$

$$\alpha = \arctan\left[\left(\frac{2}{\sqrt{3}}\right) . \left(\frac{\varepsilon_{\mathrm{bn}}}{\varepsilon_{\mathrm{bh}}} + \frac{1}{2}\right)\right] \tag{D.6}$$

where $\varepsilon_{\mathrm{bh}}$ and $\varepsilon_{\mathrm{bn}}$ are the local bending strains relating to the highest strain reading and the next highest strain reading, respectively, and α is the angle that defines the position of the maximum bending strain on the surface of the alignment cell and is measured from the highest reading strain gauge toward the next highest reading strain gauge.

At the front of the machine, where gauge 1 is initially located, the local bending strain component due to misalignment in the machine is:

$$\varepsilon_{\mathrm{b1,mc}} = \frac{\varepsilon_{\mathrm{b1,0^o}} - \varepsilon_{\mathrm{b1,180^o}}}{2} \tag{D.7}$$

where $\varepsilon_{\mathrm{b1,0°}}$ and $\varepsilon_{\mathrm{b1,180°}}$ are the local bending strains determined by gauge 1 where located in orientation 0° and orientation 180°, respectively. Formula (D.7) is applicable to the other gauge positions to determine $\varepsilon_{\mathrm{b2,mc}}$ and $\varepsilon_{\mathrm{b3,mc}}$.

The maximum bending strain due to misalignment in the machine is:

$$\varepsilon_{\mathrm{b,max,mc}} = \varepsilon_{\mathrm{bh,mc}} \ / \cos\alpha \tag{D.8}$$

$$\alpha = \mathrm{arctan}\left[\left(\frac{2}{\sqrt{3}}\right)\cdot\left(\frac{\varepsilon_{\mathrm{bn,mc}}}{\varepsilon_{\mathrm{bh,mc}}} + \frac{1}{2}\right)\right] \tag{D.9}$$

where $\varepsilon_{\mathrm{bh,mc}}$ and $\varepsilon_{\mathrm{bn,mc}}$ are the highest and the next highest values of $\varepsilon_{\mathrm{b1,mc}}$, $\varepsilon_{\mathrm{b2,mc}}$ and $\varepsilon_{\mathrm{b3,mc}}$, respectively and α is the angle defining the direction of the $\varepsilon_{\mathrm{b,max,mc}}$ and is measured from the highest reading strain gauge toward the next highest reading strain gauge. The angle, θ, is then determined from the knowledge of the angle, α, and the position of the highest reading strain gauge.

Percentage bending due to machine misalignment, β_{mc}, is calculated using Formula (8).

D.4 Measurement procedure

See Clause 7.

D.5 Reporting

See Clause 8.

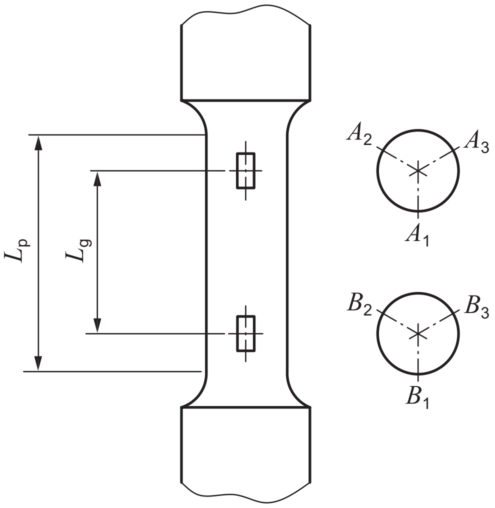


Figure D.1 — Strain gauge locations on a cylindrical alignment cell — Three-gauge configuration

Annex E
(informative)

Determination of bending contribution due to inherent imperfections in a cylindrical alignment cell device

This annex describes a determination of bending contribution due to inherent imperfections in a cylindrical alignment cell device procedure, which may be used to determine the bending component due to imperfections in a cylindrical alignment cell device. This error arises from a combination of

a) imperfections in the geometry of the device itself due to limitations in the manufacturing processes, and

b) imperfect installation of the strain gauges.

For the purposes of this annex, the following symbols apply.

Symbol	**Description**
β_{ac}	percentage bending due to inherent geometric asymmetry in the alignment cell
$\varepsilon_{\mathrm{b,ac}}$	bending strain due to inherent imperfections in the alignment cell
$\varepsilon_{\mathrm{b,max,ac}}$	maximum bending strain due to inherent imperfections in the alignment cell; it represents the bending error in the device
θ_{ac}	angle (clockwise where seen from above) of the location of $\varepsilon_{\mathrm{b,max,ac}}$ with respect to gauge 1

At the location of gauge 1, the local bending strain component due to inherent imperfections in the alignment cell is:

$$\varepsilon_{\mathrm{b1,ac}} = \frac{\varepsilon_{\mathrm{b1,0^o}} + \varepsilon_{\mathrm{b1,180^o}}}{2} \tag{E.1}$$

where $\varepsilon_{\mathrm{b1,0^o}}$ and $\varepsilon_{\mathrm{b1,180^o}}$ are the local bending strains measured by gauge 1 where located in orientation 0° and orientation 180°, respectively.

Similar formulae/equations can be developed for the other gauges and, if desired, for the measurements in Orientations 90° and 270°.

The inherent bending error in the alignment cell device is:

$$\varepsilon_{\mathrm{b,max,ac}} = 1/2\sqrt{(\varepsilon_{\mathrm{b1,ac}} - \varepsilon_{\mathrm{b3,ac}})^2 + (\varepsilon_{\mathrm{b2,ac}} - \varepsilon_{\mathrm{b4,ac}})^2} \tag{E.2}$$

The associated percentage bending due to inherent imperfections in the alignment cell, $\beta_{\mathrm{ac,}}$ is:

$$\beta_{\mathrm{ac}} = \left|\frac{\varepsilon_{\mathrm{b,max,ac}}}{\varepsilon_{\mathrm{o}}}\right| \times 100 \tag{E.3}$$

For the measurement in orientations 0° and 180°, the angular position of the maximum bending strain, $\varepsilon_{\mathrm{b,max,ac}}$, is given by Reference [5]:

$$\theta_{\mathrm{ac}} = \frac{(\varepsilon_{\mathrm{b2,ac}} - \varepsilon_{\mathrm{b4,ac}})}{|\varepsilon_{\mathrm{b2,ac}} - \varepsilon_{\mathrm{b4,ac}}|} \times a\cos\left(\frac{\varepsilon_{\mathrm{b1,ac}} - \varepsilon_{\mathrm{b3,ac}}}{2\varepsilon_{\mathrm{b,max,ac}}}\right) \tag{E.4}$$

where θ_{ac} is measured from gauge 1 in clockwise rotation, if positive, and anticlockwise, if negative.

Annex F
(informative)

Numerical example

F.1 The following numerical results are from an alignment verification measurement using a cylindrical alignment cell in accordance with 7.2 and under a compressive force.

Measurement orientation	**Strain gauge reading**				**Average strain**	**Local bending strain**			
	ε_1	ε_2	ε_3	ε_4	ε_0	ε_{b1}	ε_{b2}	ε_{b3}	ε_{b4}
Orientation 0°	−1 026,8	−924,2	−1 001,8	−1 060,2	−1 003,3	−23,6	79,1	1,5	−57,0
Orientation 180°	−998,8	−1 014,2	−1 017,1	−963,5	−998,4	−0,4	−15,8	−18,7	34,9

$\varepsilon_{b,mc}$				$\varepsilon_{b,max,mc}$	β_{mc}	θ_{mc}
Front	Left	Back	Right		%	
−11,6	47,4	10,1	−45,9	47,9	4,8	103,1

F.2 The results for the inherent bending in the alignment cell (see Annex E) are as follows:

$\varepsilon_{b,ac}$				$\varepsilon_{b,max,ac}$	β_{ac}	θ_{ac}
ε_1	ε_2	ε_3	ε_4		%	
−12,0	31,6	−8,6	−11,0	21,4	2,1	94,5

Annex G
(normative)

Alignment gauge — A method for qualitative assessment of alignment of test systems for cylindrical specimens

G.1 Figure G.1 shows schematically a non-strain-gauged pass/fail (go/no-go) device that may be suitable for checking the alignment in a test system for round specimens qualitatively and quickly (see Reference [2]). The device consists of a split bar and a gauge, both made of the same material and to tight dimensional tolerances. The material should be sufficiently hard to avoid scratching and indenting due to repeated usage.

The precision of the device in assessing the alignment satisfactorily primarily depends on the precision of machining and the amount of clearance between the gauge and the split bar. The overall length, L_Z, during the test shall be as near as possible to the overall length of the test specimen. The following are the recommended proportions and tolerances for the device which can enable the checking of moderate misalignment (i.e. class 5 to class 10). As a guide, the diameter, d, may be 8 mm to 12 mm:

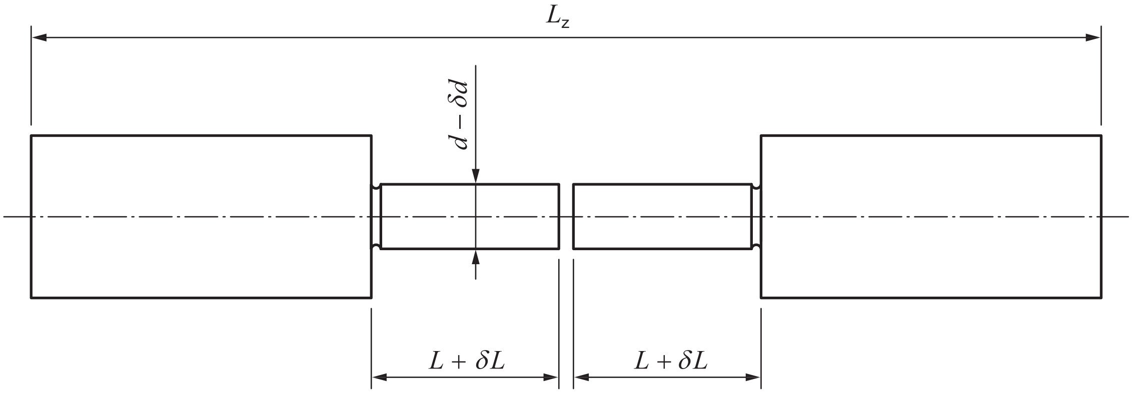
$$L = 1{,}5d - 2{,}5d$$

$$\delta d \leq 0{,}002d$$

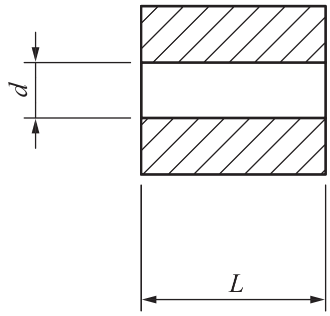
$$\delta L = 0{,}025L - 0{,}05L$$

Before splitting the bar into two parts, it shall be carefully inspected with appropriate devices, such as an optical shadowgraph or a comparator, and the critical dimensions and the associated geometrical tolerances are appropriately confirmed and certified.

During the alignment check, the two halves of the split bar should be about 0,5 mm to 1,0 mm apart, and the gauge is able to slide freely from one side of the bar to the other.



a) **Split bar**



b) Sleeve

Figure G.1 — Example of a cylindrical alignment gauge

(Source: Reference [2])

Bibliography

[1] KANDIL, F.A. AND DYSON, B.F. The influence of load misalignment during uniaxial low-cycle fatigue testing. *Fatigue & Fracture of Engineering Materials & Structures* **16**(5), 1993, pp. 509–537

[2] KANDIL, F.A. *Recent intercomparisons on low cycle fatigue and alignment measurements*. VAMAS Report No. 41, ISSN 1016-2186, National Physical Laboratory, February 2003

[3] SCHOLZ, A. Influence of bending on low cycle fatigue life of cylindrical test pieces at elevated temperature. *Materials at High Temperatures* **27**(2), 2010, pp. 127−134

[4] KANDIL, F.A. Code of practice for the measurement of bending in uniaxial low cycle fatigue testing. *Best Practice in Measurement Series*, NPL MMS 001:1995, ISBN 0 946754 10 0, National Physical Laboratory, May 1995

[5] KANDIL, F.A. *A procedure for the measurement of machine alignment in axial testing*. VAMAS Report No. 42, ISSN 1016-2186, National Physical Laboratory, February 2003

[6] ASTM E1012-05, *Standard practice for verification of test frame and specimen alignment under tensile and compressive axial force application*

[7] KANDIL, F.A. ET AL (eds.) *The UNCERT manual of codes of practice for the determination of uncertainties in mechanical tests on metallic materials.* ISBN 0-946754-41-1, Issue 1, National Physical Laboratory, September 2000. Available online (URL at the time of publication of this International Standard) at: http://www.npl.co.uk/science-technology/engineered-materials/research/mechanical/uncertainties-in-mechanical-testing-(uncert)

[8] NETER, J. AND WASSERMAN, W. *Applied linear statistical models*. ISBN 0-256-01498-1 Published by Richard D. Irwin Inc., 1974

[9] ISO 5459:2011, *Geometrical product specifications (GPS) — Geometrical tolerancing — Datums and datum systems*

[10] ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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