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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

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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 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_o
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 $\varepsilon_{b,max,mc}$

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
$\varepsilon_{b,max}$
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	≥ 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	≥ t
L_p	≥ 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.